Population structure and reproductive biology of *Haemulopsis corvinaeformis* (Perciformes, Haemulidae) in the south coast of Pernambuco, northeastern Brazil

**ABSTRACT.** Roughneck Grunt (*Haemulopsis corvinaeformis* Steindachner, 1868) is the second most important species caught as bycatch of the shrimp fishery in Pernambuco, Northeastern Brazil. However, the population dynamic of this species is poorly known in the region. The aim of this study was to describe aspects of the population structure and reproductive biology of the *H. corvinaeformis*, providing important information for the development of sustainable management practices. Specimens were collected monthly from August 2011 to July 2012 and quarterly from October 2012 to June 2014. A total of 1,140 individuals was collected; 340 males (29.8%), 391 females (34.3%), and 409 were immature and could not be sexed (35.9%). Total length ranged from 7 to 25 cm. In general, total length of females [12.85 ± 2.49 cm (mean ± SD)] and males [12.72 ± 2.46 cm (mean ± SD)] were similar (*p* > 0.05). The proportion of males and females was similar along the year, except in March. The relationship between total length and total weight was statistically significant (*p* < 0.05), showing an isometric growth. The (GSI) coupled with the distribution of maturational stages suggests that females reproduce all year around, with a peak during October-November. The length at first maturity (L50) was estimated at 11.88 cm for females and 11 cm for males.

**KEYWORDS.** Dynamic population, gonadosomatic index, isometric growth.

**PALAVRAS-CHAVE.** Dinâmica populacional, índice gonadossomático, crescimento isométrico.
found to a depth of 50 m (Courtenay & Sahlman, 1978; Cervigón et al., 1992). The species has an important role in the food chain, either feeding on components of the system (e.g. small fishes, shrimps and copepods) (Denadaí et al., 2013) or integrating the diet of other fishes. Furthermore, this species serves as a food source for local fishers (Chaves & Corrêa, 2000; García et al., 2010).

Despite the abundance and ecological importance of this species, relatively few studies on its population dynamics have been carried out. Investigations regarding this species in Brazil are restricted to the coast of the states of Ceará (Costa & Santos, 1995), Rio Grande do Norte (Silva et al., 2012), Paraná (Costa & Santos, 1995; Chaves, 1998) and Santa Catarina (Souza & Chaves, 2007). Consequently, required information for the conservation of H. corvinaeformis is still absent in many places along the Brazilian coast. Among the essential information required for the stock management and conservation, we may mention the population structure and aspects of the reproductive biology, as the mean length of maturation and breeding season, necessary to establish minimum catch sizes, closed season or no take areas (King, 2007). However, when absent, the lack of information hampers the ability of managers to make a sustainable decision, and considering our study case, may threat the local food security.

In this context, the aim of this study was to describe the mean length of maturation, breeding season and population structure of the species H. corvinaeformis caught as shrimp-trawl bycatch in the south of Pernambuco, providing essential information for the development of sustainable management practices.

**MATERIAL AND METHODS**

The study site is in the Southern coast of Pernambuco, northeast of Brazil, in the coastal area of the city of Sirinhaém. This region has the largest and most productive motorized fishing fleet among the coastal cities of Pernambuco (Tischer & Santos, 2002). Samples were collected in the coastal zone, near
the Santo Aleixo Island (08°35’57”-08°36’57”S, 34°56’58”-35°00’48”W; Fig. 1) at a depth of 10 to 20 m (Fig. 1).

Specimens of *H. corvinaeformis* were collected from the bycatch of an artisanal shrimp outrigger trawler from the local fleet, from August 2011 to July 2012 and every three months from October 2012 to June 2014. The fishery was carried out by day at full moon using two bottom otter trawls that sampled across sectional area of water on the bottom approximately 10 m wide and 6.1 m deep. Mesh size of 30 mm guided the fish to a 25-mm mesh in the cod end. Every sample consisted of three trawling tows that were two hours long. Once collected, the specimens were immediately put on ice onboard, then transported to the laboratory and stored in a freezer (-18º C) until the analysis. The surface water temperature was measured for each sample using a multiparameter. Pluviometric data were obtained through the Agência Pernambucana de Águas e Clima (APAC). For a better characterization of the seasons, we used the historical average accumulation of rainfall per month of the years 2002 to 2012.

For all individuals, total length (TL), standard length (SL) and the total weight (TW) were recorded. Subsequently, a ventral-longitudinal incision was made and the gonads removed for macroscopic sex and maturation stage determination. Eviscerated fish and gonads were weighed to the nearest 0.01 g. The maturation stages were classified according to the scale proposed by Vazzoler (1996): stages A, immature; B, maturing; C, mature, and D, spawned or resting.

The population structure was described by considering months and sexes. To determine significant differences in TL between them, a two-way ANOVA [data log 10 (x + 1) transformed] was performed (Sokal & Rohlf, 1987) following the necessary assumptions of normality (Kolmogorov-Smirnov test) and homoscedasticity (Levene’s test). The Tukey’s post-hoc test was used to determine significant differences between months and sexes (Zar, 2009). The sex-ratios, determined totally, by month and size classes (1 cm), were statistically tested for significant deviations from the expected 1:1 ratio with a χ² test (α = 0.05) (Dagnelie, 1975).

A regression analysis was applied to estimate biometric relationships, where the total length (TL) was the independent variable and total weight (TW) was the dependent variable. These relationships were determined separately for both sexes and pooled sexes. The relation is isometric when b = 3, hypoallometric or negative allometric when b < 3, and hyperallometric or positive allometric when b > 3. The null hypothesis of the isometric growth (H0: b = 3) was tested by t – test, using the statistic: \( t = (b - 3)/S_b \), where \( S_b \) is the standard error of the slope, for α=0.05 for testing significant differences among slopes (b) between two regressions for the same species (Zar, 2009). The differences between males and females were also compared by the Student’s t-test. The fit of the model to the data was measured by the coefficient of Pearson r-squared (R²).

To analyze the mature size at first maturity (L_m) (length at which 50% of the individuals attain gonadal maturity for the first time), the percentage of adults (stages B, C and D) by length was calculated and considered as dependent variable (Y), and the total length as the independent variable (X). Next, these values were adjusted by the least-squares method to a logistic curve, which is given according to King (2007): \( P_i = 1/(1 + e^{-r(L_i-L_{50})}) \), where \( P_i \) is the proportion of adult individuals for each class i, \( L_i \) is total length at each class i, \( L_{50} \) is total length that corresponds to 0.5 (50%) proportion of adults and \( r \) is the logistic curve slope. \( L_{50} \) was obtained for males, females and pooled sexes. Also, a confidence interval of 95% was calculated for each value of \( L_{50} \).

The spawning season was evaluated considering data collected from August 2011 to June 2012, through the relative frequency of the gonadal maturation stages and by calculating the Gonadosomatic Index (GSI) bimonthly for females, based on Vazzoler (1996): GSI = (GW/TW) *100, Where GW = gonad weight and TW = total weight of the specimen. This analysis included only adult females (those at the same size or larger than the length at first sexual maturity calculated in this study). Kruskal-Wallis test (given that the assumptions of parametric tests were not met) was used (p <0.05) to compare differences of the GSI between months.

The Spearman’s rank correlation was used to measure the strength of the relation between temperature and rainfall, with GSI values and percentage of mature females (stage C).

## RESULTS

A total of 1,140 specimens of *H. corvinaeformis* was collected; 340 males (29.8%), 391 females (34.3%), and 409 immatures (35.9%), which could not be sexed. Total length ranged from 7 to 25 cm (males 7.1-19.8 cm, females 7-25 cm, TL), and the total weight oscillated from 4.2 to 117 g (males 4.5-104.6g, females 4.2-117 g, TW). The highest number of individuals for pooled sexes of TL occurred in the length class of 12-13 cm. In general, total length of females [12.85 ± 2.49 cm (mean ± SD)] and males [12.72 ± 2.46 cm (mean ± SD)] were similar (p > 0.05) (Fig. 2). Except for the month of July, individuals of *H. corvinaeformis* were found throughout the year.

The largest individuals were caught in April, with a mean TL of 15 cm (SD ± 2 cm). The smallest individuals were observed in May and June, with a mean total length of 11.9 cm (SD ± 1.2 cm) and 11.9 cm (SD ± 2.1 cm), respectively (Fig. 3). Considering the whole period, TL of males and females did not differ significantly (p < 0.05) (Fig. 3). However, females were larger than males in October, November, January, April and June (p < 0.05) (Fig. 3). Overall, there was no predominance of males over females (1.02:1) (\( \chi^2 \), p > 0.05). The same pattern was observed in all length classes and months, except in March, where males were more abundant than females (Fig. 3) (\( \chi^2 \), p < 0.05).

The regression analysis between TL and TW for females, males and pooled sexes were significant (p<0.05), showing an...
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**Fig. 2.** Absolute frequency distribution per length classes of males, females and pooled sexes for Roughneck Grunt, *Haemulopsis corvinaeformis* (Steindachner, 1868) captured from August 2011 to July 2014, off the coast of State of Pernambuco, northeastern Brazil. The vertical line represents the L50.

**Fig. 3.** Monthly average (±SD) of the total length (TL, cm) of males, females and pooled sexes of Roughneck Grunt, *Haemulopsis corvinaeformis* (Steindachner, 1868), captured from August 2011 to July 2012, off the coast of state of Pernambuco, northeastern Brazil. Different letters indicate significant size differences between months for pooled sexes (*, significant sizes differences between males and females; **, significant differences in sexual ratio).

**Tab. I.** Descriptive statistics and TW-TL relationship parameters for the Roughneck Grunt, *Haemulopsis corvinaeformis* (Steindachner, 1868), captured from August 2011 to June 2014, off the coast of State of Pernambuco, northeastern Brazil [TL, total length (cm); SD, standard deviation; min, minimum; max, maximum; SL, standard length (cm); TW, total weight]. Different superscript letters indicate significant differences between males and females. *, indicates significant allometric growth.

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Pooled sexes</th>
</tr>
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<tbody>
<tr>
<td>TL, mean±S.D.</td>
<td>12.72±2.46</td>
<td>12.85±2.49</td>
<td>12.72±2.24</td>
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<tr>
<td>(TL&lt;sub&gt;max&lt;/sub&gt; - TL&lt;sub&gt;min&lt;/sub&gt;)</td>
<td>(7.1 – 19.8)</td>
<td>(7 – 25)</td>
<td>(6.3-25)</td>
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<tr>
<td>SL, mean±S.D.</td>
<td>10.48±1.86</td>
<td>10.56±2.02</td>
<td>10.10±2.10</td>
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<tr>
<td>(SL&lt;sub&gt;max&lt;/sub&gt; - SL&lt;sub&gt;min&lt;/sub&gt;)</td>
<td>(5.9 – 16)</td>
<td>(5.6 – 17.5)</td>
<td>(5.3 – 17.5)</td>
</tr>
<tr>
<td>Weight characteristics (g)</td>
<td></td>
<td></td>
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<tr>
<td>TW, mean±S.D.</td>
<td>30.5±12.05</td>
<td>31.2±18.41</td>
<td>28±17.52</td>
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<tr>
<td>(TW&lt;sub&gt;max&lt;/sub&gt; - TW&lt;sub&gt;min&lt;/sub&gt;)</td>
<td>(4.5 – 104.6)</td>
<td>(4.2 – 117)</td>
<td>(3 – 117)</td>
</tr>
<tr>
<td>TL-TW equation</td>
<td>TW=0.019TL&lt;sup&gt;3.0469&lt;/sup&gt;</td>
<td>TW=0.0141TL&lt;sup&gt;2.9656&lt;/sup&gt;</td>
<td>TW=0.01251TL&lt;sup&gt;3.0265&lt;/sup&gt;</td>
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<tr>
<td>Determination Coefficient (r&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>0.9396</td>
<td>0.9470</td>
<td>0.9592</td>
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<tr>
<td>t-test (Coefficient b=3)</td>
<td>p &gt; 0.05</td>
<td>p &gt; 0.05</td>
<td>p &gt; 0.05</td>
</tr>
<tr>
<td>Growth Type</td>
<td>Isometric (*)</td>
<td>Isometric (*)</td>
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isometric growth \((p > 0.05)\). The \(b\) coefficients were different between males and females (\(\text{TL} \times \text{SL}\) and \(\text{TL} \times \text{TW}\)) (Tab. I).

*Haemulopsis corvinaeformis* is a gonochoristic species with no identifiable sexual dimorphism in body shape or color. Overall, 35.7\% of the female specimens collected during the study were immature, 33.4\% were maturing, 26.8\% were mature, and 4.1\% were spawned. Immature and mature individuals were always present, providing strong evidence that the species spawns all year around (Fig. 4). However, the mean gonadosomatic index was higher in October-November and then gradually decreased until June-July. Also, the bimesters of October-November and April-May were statistically similar with each other \((p<0.05)\), with both presenting higher percentages of mature and spawned or resting individuals (April-May) (Fig. 4).

The Spearman’s rank correlation presented a non-significant relationship between temperature and rainfall with GSI values and percentage of mature females (stage C) \((p > 0.05)\).

The length at first maturity \((L_{50})\) was estimated as 11.88 cm \((\text{CI} \pm 0.45)\) TL for females, 11 cm \((\text{CI} \pm 0.50)\) TL for males and 11.45 cm \((\text{CI} \pm 0.35)\) TL for pooled sexes. The smallest adult individual had a body length of 8.5 cm, whereas all those with TL above 18.5 cm were adults (Fig. 5).

The length-weight relationship (LWR) is very important for the fisheries management and for environmental...
monitoring programs (Morey et al., 2003). It has been used to estimate the weight of individual fish from its length and compare fish populations or species from different regions and environment. The relationship allows to relate the changes of body shape and weight associated with different situations as growth, reproduction and anthropogenic impacts (Le Cren, 1951; Froese, 2006). Moreover, the $b$ value of the LWR relationship may also give indications of the beginning of reproductive events (Le Cren, 1951). In the present study, an isometric growth was observed, showing that the individuals did not change form along the ontogenetic growth. Isometric growth has also been observed for H. corvinaeformis in the Southern cost of Brazil (Vianna et al., 2004). In addition, the growth pattern (male $b=3.0469$; female $b=2.9656$) found in this study was similar than those ($b=2.99$) found by Vianna et al., (2004) and smaller than those find by Chaves (1998) ($b=3.183$) in Paraná, Brazil. Differences on pattern of growth may be explained by differences on food availability, population, sex, environmental conditions or physiology among studied areas (Froese, 2006).

Sex ratio provides important information of the relationship between individuals and environment and the population situation of each species. This tool also provides basic information for assessing population structure, reproductive potential and for estimating the size of population stock (Stratoudakis et al., 2006). In the present study, the overall sex ratio was balanced between males and females ($1:1$) ($\chi^2$ test, $p<0.05$). The sex ratios were also balanced in all size classes and months, except in March, when males were more abundant than females. However, Silva et al. (2012) and Denadai et al. (2013) indicated a higher proportion of females of H. corvinaeformis in state of Rio Grande do Norte and a higher proportion of males in Caraguatatuba Bay, state of São Paulo, respectively. Although the reasons for these divergences are not clear, they might be related to differences in the ecosystems and increased fishing pressure in either one of the sexes, as they may have different growth rates, and thus, may be harvested differently (Runsdorf et al., 2010).

Gonadosomatic index (GSI) and proportion of maturation stages are important parameters to determine the spawning season of a species, which may be used to determine the ideal time and duration for a management action (Mian et al., 2017). In the present study, GSI coupled with the distribution of maturation stages suggest that females reproduce all year round, with a peak during October-November. The continuous reproduction observed to the species was also observed in Brazil in the states of Rio Grande do Norte (Silva et al., 2012), Santa Catarina (Souza & Chaves, 2007) and São Paulo (Denadai et al., 2013). In tropical regions, where seasonal temperature variations are low, the rainfall plays a decisive role in determining reproductive cycles (Parsons et al., 2007; Chellappa et al., 2010). Munro et al. (1973) reported that spawning of haemulids in Jamaica is related to water temperature, with a maximum spawning during the months with lowest temperatures, though some spawning occurs all months. In our case, no relationship of temperature or rainfall to spawning was observed for this species. However, several other factors may be influencing the reproduction, such as differentiation in genetic combination, day light, turbidity, depth of water and availability of food (Jasmine & Molina, 2016).

The constant occurrence of mature individuals throughout the year, mainly during October-November, suggests that H. corvinaeformis use the area during their reproductive period. In addition, the presence of immature individuals during all months indicates that the recruitment of the studied species also occurs throughout the year in the region. Thus, this information characterizes the study area as a place of considerable ecological importance for the species. Besides the ecological relevance for H. corvinaeformis, at least ten other species of Sciaenidae family use the area as reproduction site or transition zone for reproduction (Silva et al., 2015a).

In reproduction studies, the definition of size at first gonadal maturity has a fundamental importance for the development of sustainable fishery management practices, given this parameter is widely used as the minimum threshold for the harvesting of stocks (Fontes-Filho, 2011). In the present study, mean size at first maturity was 11.45 cm for pooled sexes, with similar values for females (11.88 cm) and males (11 cm); which is slightly higher than the observed to Rio Grande do Norte (10.3 cm for males and 10.4 cm for females) (Silva et al., 2012). Size at sexual maturity between populations of the same species can vary due to growth rates, fishing removals, fishing gears, food availability, and hydrologic conditions (Chapman et al., 1996; Hood & Johnson, 2000; Potts & Manooch, 2001). Although the sampled specimens are certainly related to the selectivity of the fishing gear, considering the size at first maturity found in this study, less than 30% of individual are juveniles. It means that most of harvest individuals might have been able to reproduce and contribute for population renewal, representing a good indicator for the sustainability of the H. corvinaeformis stock.

Haemulopsis corvinaeformis is the second most important species caught as bycatch of the shrimp fishery in Pernambuco, with considerable ecological and social functions. However, most of bycatch organisms in Pernambuco, including H. corvinaeformis, have no fishing regulations or any control of the landings by the Brazilian authorities. Although successful strategies for managing these resources depend on interactions among highly heterogenous social, political and economic factors, the results of the present study, combined with other studies in the region, can be used to guide adequate management policies. A main step towards ensuring the long-term conservation of many species would be the use of bycatch reduction devices, which are tools designed to improve the selectivity of fishing gear and reduce bycatch in shrimp trawlers up to 40% (Garcia-Caudillo et al., 2000; Brewer et al., 2006). In addition, as shrimp trawlers off the coast of Pernambuco accidentally catch many species along with at least three shrimps Penaeidae target species, a regulation for this area should be drawn up considering
the main species involved. One option is a regulation based on the Ecosystem Approach to Fisheries (EAF), associated with a permanent monitoring of changes on populational parameters, as sexual proportion, biometric relationships and size. Previous studies in the region have shown that most of the catch (bycatch and target) of the shrimp fishery in Pernambuco occurs in the same area and share the same reproduction season, i.e. between October and March (Lopes et al., 2014, 2017; Silva et al., 2015a,b, 2016). Hence, the establishment of Marine Protect Areas (MPA) or a fishery-closing period should improve the conservation of the species and marine habitats exploited by this fishery in Pernambuco.

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