Research Article

Potential of carapeba (*Eugerres brasilianus*) for aquaculture production

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**ABSTRACT.** *Eugerres brasilianus* is an appreciated commercial species in the market of the northeastern region of Brazil. The purpose of this study was to analyze and determine the diet, reproductive period, and management of carapeba in recirculating aquaculture systems. The fishes were caught with a gillnet at two different places near the São Francisco River mouth. The stomach content was analyzed according to the frequency of occurrence method, using the index of relative importance, assessing the degsusededr of stomach repletion. The reproductive period was established by determining the gonadosomatic index and gonad maturation stages. The behavior and management of the fish were observed in captivity when subjected to artificial diets in cultivation tanks. The striped carapeba is best feed at dusk, mainly Crustacea Amphipoda, Insecta Chironomidae and Crustacea Tanaidae. The species has parcelled spawning, which occurs from February to March and from July to September. There are morphological differences between males and females, especially in the urogenital papilla, size and color. In captivity, the best fish density was between 7 and 8 fish m⁻³, showing a good rates of centesimal composition, adapting well to the supplied diet.

**Keywords:** Gerreidae, feeding, behavior, sexual maturation, reproductive period, aquaculture.

**INTRODUCTION**

The gerreids; popularly named carapeba, caratinga, carapicus or mojarras; have great importance in artisanal fishing and are greatly appreciated for human consumption. They are widely distributed from the Antilles to the south of Brazil (Bezerra *et al.*, 2001; Costa *et al.*, 2012).

The carapeba have been cited among the fish with the highest potential for marine fish farming in Brazil because it has good market value in some regions of the country, making it able to be used in polycultures and dugout ponds (Cavalli *et al.*, 2011).

*Eucinostomus melanopterus*, *Diapterus rhombeus* and *Eugerres brasilianus* are consistently captured in the vicinity of riverside towns of the lower São Francisco
River, northeastern Brazil. *E. brasilianus* sets as the most important among the species, being the sixth in landings as well as being the Gerreidae with the highest growth, reaching 40 cm (Bezerra et al., 2001; Soares et al., 2011; Paiva et al., 2013).

Despite the significant importance of this resource, data about its embryonic and larval development and reproductive cycle are rather scarce (Hernández et al., 2012). Little is known about the feeding rate and the reproductive biology of these anadromous organisms, which is considered as an obstacle to the proper managing in a farming environment (Poveda & López, 2007; Hernández et al., 2012).

Other factors, such as the behavior and the social relationships, are also essential to avoid the high degree of rejection of wild fish in captivity, normally related to stress and hierarchical behavior both to dominant as well as to dominated fish. They potentiate the aggression and cannibalism, contributing to changes in the growth rates and increased mortality in a confined environment (Sloman, 2007; Soares et al., 2007). Another important aspect to be approached refers to the studies about feeding habits, which are in extremely necessary so the ecological relations between organisms can be understood and to formulate diets capable to meet the nutritional demand in a confined environment.

Given this context, this study had as objective to understand the reproductive period, composition of the natural diet, behavior and feeding in a confined environment, from matrices of *E. brasilianus* captured from the mouth of the São Francisco River, in order to promote the viability of a cultivation form for this species.

**MATERIALS AND METHODS**

The fishing (authorized by SISBIO under the number 22211-1) and Animal Ethics Committee was done monthly between April 2013 and March 2014, in two areas near the Crôa Island and the Estuary/Fall (10°27'41.7"S, 36°26'13.5"W), comprising a distance between 2 and 10 km from the mouth of the São Francisco River (Fig. 1). The region is characterized by a sub-humid climate with an average annual temperature of 25°C and a varying precipitation of 500-1300 mm, concentrated between April and July.

The targeted fish of the whole study were mainly caught around dusk or at night, always in low tides in quadrature at a depth of 4 to 7 m, using gillnet (300x1.5 m; opening mesh of 45 mm between opposite knots). The time between the launching and the gathering of the fishing net was between 20 and 40 min.

**Study of the feeding behavior**

The fish were weighed on a scale with an accuracy of 0.01 g. Then, the digestive tract was removed and fixed in 4% formaldehyde. The biometric data of each fish (standard length-SL) were taken with the help of an analog caliper, and then weighed to get the gutted weight (GW). After 24 h, the digestive tract of each fish was removed from the formaldehyde (4%) and stored in 70% ethyl alcohol for later analysis of the stomach contents (ASC).

The ASC was conducted through qualitative and quantitative methods; the Digestion Degree (DD) analysis being the qualitative method, and the Repletion Index (RI), Frequency of Occurrence (%FO) and Numerical Frequency (%NF) corresponded to the quantitative methods. The Important Alimentary Index (IAi) proposed by Kawakami & Vazzoler (1980) was also used to identify in the lowest taxonomic category possible.

The stomach Repletion Index (RI) consists of the analysis of the amount of food in the stomach or digestive tract, being able to observe if it is full, empty or with a little amount of food, expressed in percentages, according to five categories for RI: empty, partially empty, medium, partially full, and full.

The Frequency of Occurrence (%FO) corresponded to the percentage that specific feeding item occurs in the stomach or digestive tract, being expressed by the formula: $\text{FO} = \frac{n_i}{N} \times 100$, where $n_i$ is the number of stomachs or digestive tracts in which the item "$i$" occurred and N is the total number of stomachs or digestive tracts with content analyzed.

The Numerical Frequency (% NF) was determined by counting the number of alimentary items found in each digestive tract, divided by the total number of fish, verified by the formula: $\text{%NF} = \frac{n_i}{N} \times 100$ where $n_i$ is the number of the item "$i$" and N is the total number of items shown. The alimentary items were counted, being considered only the whole organisms or parts which were possible to be identified.

The method proposed by Kawakami & Vazzoler (1980) was used for the Important Alimentary Index (IAi), given by: $\text{IAi} = \frac{\%FO \times \%NF}{100 + \sum(\%FO \times \%NF)}$ where FO is the frequency of occurrence of the item shown and FN is the numerical frequency of the item shown. The categories were classified as main (IAi ≥ 50%), secondary (25% ≥ IAi <50%), and accessory (IAi <25%).

**Study of the reproductive period**

The specimens were labeled and conditioned in isothermal coolers (Styrofoam boxes) of 20 kg with ice, and then transported to the laboratory. After the iden-
tification and photographic records, the animals were measured with the help of an ictiometer and a digital caliper, obtaining the following parameters: standard length (SL), head length (HL), interorbital distance (ID) and height (ALT). The fish were weighed on a digital scale with an accuracy of four decimals. The gonads were separated from the extracted material and were measured in for their length and diameter using a digital caliper, then weighed on an analytical scale, and last, conditioned in pots with 4% formalin, and after 24 h, in 70% alcohol for further macroscopic analysis.

The Vazzoler maturation stages were made following the Vazzoler scale (Vazzoler, 1996), being classified in five stages: Stage A (immature), Stage B (in maturity), Stage C (mature) and Stage D (emptied). Additional characteristics were computed such as length and weight of the gonad in relation to the abdominal cavity, vascularization, coloration and degree of turgidity.

**Calculation of the reproductive parameters**

In order to determine the gonadosomatic index (GSI) of a fish, the equation, \( \text{GSI} = \left( \frac{\text{GB}}{\text{BW}} \right) \times 100 \), was applied where \( \text{GW} \) is the gonad weight, and \( \text{BW} \) the body weight.

The sexual proportion between males and females was estimated from the relation of the total number of both sexes in all the months that the fish were caught, using the nonparametric chi-square \( (\chi^2) \), using the equation: \( \chi^2 = (O - E)^2 + E \), where \( O \) is the frequency percentage of males and females per month, and \( E \) is the expected sexual proportion.

Figure 1. São Francisco River basin (A: High São Francisco, B-C: Medium São Francisco; D: Lower São Francisco) (points 4 and 5-estuary, points 1 and 2- Crôa Island (10°27’41.7”S, 36°26’13.5”W). Photo: Simone Moreira.

In addition, factors about the presence of sexual dimorphism were observed between the sexes and between mature and immature fish by observing the urogenital papilla, color and other morphological characteristics.

**Maintenance of the reproducers in cultivation facilities**

The fish were captured alive and then accommodated in three 50-L coolers (styrofoam boxes) each, using a volume of 30 L of water, maintaining the average temperature of 25°C with constant and partial water exchange in order to keep the amount of oxygen above 5 mg L\(^{-1}\).

Concluding the transportation, the fish were transferred to a reception tank with dimensions of 152x71x51 cm and 5 salinity and sandblasting constant for a period of one hour. After this stage, they were conditioned in another tank of the same size containing eugenol as an anesthetic, diluted in 1/10 alcohol at a concentration of 4 mg L\(^{-1}\). Next, the specimens were weighed and measured (standard length), and then the urogenital papilla was observed and the presence or absence of ectoparasites. Finally, after the biometrics, the fish were chipped with ISO FDX-B transponder of 134.2 Khz and accommodated in pre-molded PVC canvas tanks with a necessary volume of 2000 L and salinity around 10.

The tanks, in a recirculation system, were arranged on a wooden platform of 30 cm high. They were set in a way that there would be a flow into treatment water
boxes of 0.50 m³ containing mechanical filters filled with bivalve shells, gravel, crushed stone, sand and cartridge filters with filtering capacity of 25 μ, and another biological filter with added bioballs increase and aerobic bacteria (biofilter) and two Canister model filters.

The water quality indicators in field and in laboratory pH, oxygen, oxide-reduction potential (ORP), dissolved solids and temperature were monitored with a multiparameter probe from Hanna Instruments, model 9828, Woonsocket, USA, to a depth of approximately 1.5 m below the water surface. The total ammonia (NH3-NH4+) was measured weekly and evaluated with the help of a spectrophotometer from Hanna Instruments, model HI 83203, Belgium, using the model HI93700-01 reagents. The nitrate NO₃ and phosphorus (P) of the emissions were analyzed with the same equipment, using the HI93705-01 reagents for nitrate and the HI93717-01 reagents for the phosphate.

The diet in captive carapebas corresponded to a proportion of 60% of crustacean and bivalve mollusks (freshwater shrimp, Macrobrachium acanthurus, Crustacea Amphipoda and maçum-Anomalocardia brasiliana) and a pelleted diet with 40% crude protein, containing fishmeal, soybean meal, proteinose, premix, soybean oil and wheat flour (Table 1).

### Analysis of the centesimal composition

Ten carapeba fish were evaluated aiming to obtain the body composition, assessing proteins (Kjeldhal method), humidity, with an oven at 105°C, ashes; obtained with a muffle at 550°C and total lipids by extraction with chloroform and methanol (2:1) (AOAC, 1990).

### Statistical analyzes

The analysis of morphological data, were analyzed by ANOVA (5% probability), the differences were tested with a Tukey test (5%) and the Bonferroni test for the comparison of two measurements (5%).

### RESULTS

#### Studies of the feeding behavior

The average water temperature, dissolved oxygen, pH and salinity at the places obtained maintained an average of 25.0 ± 0.7°C, 4.0 ± 1.0 mg L⁻¹, pH 4.5 ± 0.6 and salinity 6.0 ± 3.5, throughout this study period.

In studies of the feeding behavior, 141 E. brasilianus fish were caught with standard length (SL) ranging between 11.7 and 26.0 cm, though, 106 (75%) of these had some food in their digestive tract. The analysis of the digestive degree (DD) revealed that only 5.6% of the fish had the digested gastrointestinal contents unidentifiable and 25.6% were at the beginning of the digestion, making it possible to identify most of the alimentary items consumed by the fish. For E. brasilianus fish caught near the mouth of the São Francisco River, the digested organic matter (DOM) accounted for around 49% of its gastrointestinal content. The frequency of occurrence (%FO), the numerical frequency (FN%) and the IAi of ingested items by the carapeba are described in Table 2, where it was possible to identify 13 alimentary categories.

### Studies of the reproductive behavior

One hundred thirty-four E. brasilianus fish, 98 being female and 36 being male, were analyzed to determine the reproductive period, with a predominance of female fish (proportion 1M:3F) throughout the sample period, of which 75% of the captured fish were found with their gonads in development or mature.

Regarding the seasons of the year, the number of females predominated in all the periods, moreover in the summer (January) and end of spring (November) the relation between the proportion of females and males reached the highest levels (1M:4F; χ² = 12.5 and 1M:3.4F; χ² = 9.5) (chi-square test, χ²; P < 0.05). In February and March (dry season), some fish were found with gonads in maturation and spawned; and between March and April (beginning of the rainy season), the occurrence of more than 50% (L₅₀) of the fish caught in process maturation was observed. However, in the months of July to September, the highest occurrence of mature and spawning fish was recorded (Fig. 2).

The standard length of the smallest and greatest mature female specimen was 16.3 and 25.0 cm respectively, whereas for the males this length was 14.8 and 19.2 cm (smallest and largest specimen). However, the L₅₀ or length of first sexual maturity for the carapebas at the mouth of the São Francisco River was estimated at 15.0 cm for the males and 17.0 cm for the females, while the L₁₀₀ (average standard length in which

<table>
<thead>
<tr>
<th>Items</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>36.0</td>
</tr>
<tr>
<td>Ether extract</td>
<td>4.0</td>
</tr>
<tr>
<td>Humidity</td>
<td>12.0</td>
</tr>
<tr>
<td>Mineral matter</td>
<td>8.0</td>
</tr>
<tr>
<td>Fibrous matter</td>
<td>2.0</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.6</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 1. Chemical composition of diet for carapebas in captivity.
Table 2. Alimentary items of the *E. brasilianus* with their frequency of occurrence (FO%), numerical frequency (FN%), important alimentary index (IAi%), and the category of the alimentary index (CAI).

<table>
<thead>
<tr>
<th>Items alimentary</th>
<th>FO%</th>
<th>FN%</th>
<th>IAi%</th>
<th>CAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphipoda Crustacea</td>
<td>53.77</td>
<td>44.75</td>
<td>51.00</td>
<td>Main</td>
</tr>
<tr>
<td>Chironomidae Insecta</td>
<td>45.45</td>
<td>35.00</td>
<td>35.00</td>
<td>Secondary</td>
</tr>
<tr>
<td>Tanaidacea Crustacea</td>
<td>43.40</td>
<td>15.30</td>
<td>12.26</td>
<td>Accessory</td>
</tr>
<tr>
<td>Isopoda Crustacea</td>
<td>19.81</td>
<td>0.75</td>
<td>0.25</td>
<td>Accessory</td>
</tr>
<tr>
<td>Ostracoda Crustacea</td>
<td>9.45</td>
<td>0.60</td>
<td>0.12</td>
<td>Accessory</td>
</tr>
<tr>
<td>Mollusca Gastropoda</td>
<td>17.00</td>
<td>0.96</td>
<td>0.40</td>
<td>Accessory</td>
</tr>
<tr>
<td>Mollusca Bivalvia</td>
<td>9.45</td>
<td>0.53</td>
<td>0.10</td>
<td>Accessory</td>
</tr>
<tr>
<td>Turbellaria</td>
<td>16.85</td>
<td>0.92</td>
<td>0.30</td>
<td>Accessory</td>
</tr>
<tr>
<td>Nematoda</td>
<td>11.32</td>
<td>0.59</td>
<td>0.10</td>
<td>Accessory</td>
</tr>
<tr>
<td>Insecta</td>
<td>12.26</td>
<td>0.60</td>
<td>0.12</td>
<td>Accessory</td>
</tr>
<tr>
<td>Macroalgae</td>
<td>11.23</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bivalve digested</td>
<td>32.07</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sediment</td>
<td>42.45</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Digestated organic matter</td>
<td>49.05</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Others</td>
<td>4.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The average weight of female fish (230.4 ± 35.0 g) throughout the year was significantly higher than the male fish (162.3 ± 18.2 g), (Bonferroni test, *P* < 0.05), and the females being found with the highest weight values in the month of November (296 g) and males in June (230 g).

As for the morphometric data, except for the standard length (SL) data, there were no significant differences for both sex or age, between characters; interorbital distance (ID) (cm); head length (HL) (cm) and height (ALT) (cm) (ANOVA, *P* > 0.05).

The presence of the three orifices (excretion, feces and urine) and adult females is clearly visible when they show standard lengths greater than 18.0 cm, while in mature male fish, they are seen only two orifices: of excretion and releasing of the spermatozoa (Fig. 3).

**Studies of capture, acclimatization, and behavior in captivity**

The mortality rate between the capture and transportation was 20%, due to injuries from the capture, being common in fish with longer standard lengths (above 20 cm).

As for the behavior in captivity, 34 carapebas with an average length of 18 ± 2 cm and weight of 166.0 ± 10.8 g, and by the end of three months in farming tanks had average final weight of 200.0 ± 12.2 g, being a weight gain of 45 ± 7 g and feeding conversion of 2.0 ± 0.12.

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**Figure 2.** a) Yellowish mature female gonad, vascularized and with large oocytes full of yolk, b) mature male gonad, testicles occupying part of the coelomic cavity, flowing milky sperm. Photos: Simone Moreira.
The physical and chemical parameters in a confined environment were as follows: 7.7 ± 0.3 mg L⁻¹ oxygen-O₂, 26.9 ± 1.4 temperature (°C), 7.7 ± 0.1 pH, 13.7 ± 2.5 salinity, 18.9 ± 0.1 μS cm⁻¹ conductivity, 12.3 ± 0.1 mg L⁻¹ total dissolved solids (TDS), and 70.0 ± 7.0 mg L⁻¹ oxide-reduction potential (ORP) were measured during the experiment and presented satisfactory results. The ammonia (<1 mg L⁻¹) showed low values, showing no significant changes throughout this study.

During the early phases of this study, it was observed that to reduce the density of carapebas per tank (2 to 4 fish m⁻³), promotes the development of territorial instinct, however, as more fish are added to the system (7 to 8 fish m⁻³), this aggressive behavior reduces significantly. Incidents such as chasing each other with aggression (common among darker colored males) causing injuries to the scales and/or fins, besides fights and/or competition for food and territory, is the third cause of death.

At the end of the experiment, all fishes had adapted well, feeding with greater feeding rate around dusk and a smaller scale in the early hours of dim environment. As for the centesimal composition, the carapebas which were fed the artificial diet had protein, lipid, humidity and ash content of 18.2 ± 1.1%; 2.8 ± 0.6%; 76.3 ± 2.0% and 1.2 ± 0.2% on wet matter, respectively.

**DISCUSSION**

Results with feeding behavior suggest that the feeding time of this species is possibly nocturnal, since fishing was mainly done in the evening (at dusk). In support of this hypothesis, the digestive tracts of all carapebas captured during daytime were empty (GR).

The carapeba is a fish with nocturnal habits, well-defined pace, generalist and opportunistic, which concentrates its feeding activity during the evening, but feed itself during the day in darker places (Zavala-Camin, 1996; Ramos et al., 2014).

The high amounts of DOM and high rate of sediment in the digestive tract of the Gerreidae is common. This fact is due to their "poke around" substrate feeding behavior looking for their prey. According to Blaber (2000), the highly protractile mouth is a characteristic of Gerreidae family that allows them to capture small invertebrates and explore available food resources in substrate.

In this study, Crustacea Amphipoda, Insecta Chironomidea, and Crustacea Tanaidacea were the three most important items consumed. These results suggest that the *E. brasilianus* as an opportunistic species, due to the consumption of prey available in abundance in the environment and generalist by ingest a wide variety of items throughout the year. According to Zavala-Camin (1996), these fish are considered omnivores, being able to change alimentary spectrum according to the availability of food in the environment. Ekpo et al. (2014) showed 183 food occurrences in estuarine fish in Qua Iboe River estuary, Nigeria, when crustaceans, detritus, nematodes, protozoans and insects were more found. According with study, the fishes feed on more than one type of food item, which reduced competition.

Crustacea Amphipoda represented the largest item in the IA for the carapebas, being the food most eaten during the drier season in the region of the mouth of the São Francisco River. As a food source, the amphipods are fundamental to various groups, including fish, being found in considerable quantities in the stomach contents of commercially important species (Palma & Ojeda, 2002). The alimentary items consumed by *E. brasilianus* were similar to those observed in studies of Chaves & Otto (1999), except for the occurrence of polychaete, which was not seen as a feeding item of this species during this study period at the mouth of the San Francisco River.

The macroscopic analysis of the gonads allowed to confirm that the reproductive period possibly coincided with the end of the rainy season and beginning of the dry season (July to September), and the end of the summer/drier season (February-March), classifying
the carapeba as a fish that spawns at different moments. Such a fact can also be seen in the study of Silva et al. (2005) with fish of the same family.

This hypothesis is confirmed in the studies of Bezerra et al. (2001), in which states that the GSI average of Diapterus rhombeus showed lower amplitude in the first trimester of the year and detecting higher levels in the third and fourth trimester. It is likely that the E. brasilianus may migrate for reproductive purposes from fresh water to coastal environment, having sheltered and good food supply near the mouth of a river as a transitional environment/area, thus completing their reproductive cycle. Such hypothesis is consistent with the findings of Chaves & Otto (1998) with rhombeus Diapterus species, and also with Barbanti et al. (2013) analyzing the fauna fish in the Bertioga Channel in São Paulo.

As for the predominance of females in this study, Raposo & Gurgel (2001) stated that the highest incidence of females means a response of the population to the favorable conditions provided by the environment (preserved mangrove area), such as increased alimentary supply. The most docile behavior that territorial males (agonistic behavior with death because of fights and injuries) and degree of longevity reached are also factors to be considered (Shibatta, 2006).

Both male and female fish differ in the standard medium length, dark color (dominant males), the urogenital papilla shape and bulging belly (mature females). This discussion is reinforced in the studies of Ramires et al. (2007), in which stated that most of the fish do not have external morphological characteristics that can be observed in the distinction between the sexes.

The capture point 5 and 6 adopted as more expressive mangrove areas and of higher salinity (between 10 to 15) characterized by having a higher incidence of fish caught, very likely because of the availability of food and shelter/transitional area since the carapebas spawn in coastal regions and salinity near 30 (Ayala-Perez et al., 2001; Santos et al., 2012).

The average of mortality is common during of capture and trasportation, Reyes et al. (2012) stated in their studies that the formation of a new reproducer stock takes more time due to adjustments during the capture phase and acclimatization, where the longer specimens are susceptible to the handling of the fixture due to the high stress.

The Agonistic behavior of carapeba can be attributed to territorialism. Territorialism is the behavior of defending a feeding area and factors related to the density of the fish in an area can also influence the territoriality in a population (Holbrook & Schmitt, 2002). This significantly decreased with increasing density, maintenance of homogeneous lot, increase in the number of feeders and disposal (reduction) of aggressive males (dominant). After the first two weeks of acclimation, the formation of couples was observed, even though the male normally was smaller and darker, it had a protective behavior while courting the female.

The centesimal composition of the carapebas studied, after five months in captivity, showed good parameters of humidity, ash, lipids, and especially protein content. The analysis of this study are reinforced by the information from Menezes et al. (2009), stating that the striped carapeba has good protein indicators, near 21%, low cholesterol content and lipid.

**CONCLUSIONS**

The E. brasilianus can be classified as a first order carnivorous species (CI) since its main food is Crustacea Amphipoda and Insecta Chironomidae. It can also be considered a generalist and opportu-nistic due to the change in their feeding spectrum according to the time of the year.

The reproductive period of the E. brasilianus at the mouth of the São Francisco River has two peaks: the first from February through March (drier season) and the second, which is most favorable to reproduction, from July to September, with an initial size of sexual maturity of 17 cm for females and 15 cm for males.

The carapeba adapted well to the artificial diet offered which gave them a good centesimal and organoleptic composition into its meat, being an alternative to inclusion of the species in the cultivation.

**REFERENCES**


