Basic Biological Aspects of *Dormitator maculatus* “Naca” (Bloch, 1792) from the Alvarado Lagoon in Veracruz, Mexico

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Abstract. *D. maculatus* is an artisanal fishing resource of great economic and gastronomic importance in the area, although its annual availability is erratic due to the deterioration and contamination of its habitat, in addition to poor management of its fishery; the latter because it is easily captured during its breeding season. Basic biological aspects of *D. maculatus* were estimated, such as size composition, sex ratio, and type of growth. A total of 700 organisms, 364 males and 336 females, were collected and analyzed during 12 continuous months. As a result, sizes between 4.4 to 17.0 cm were obtained, averaging 10.2 cm. The most common length range in females was 8.1 - 9.0 cm and 9.1 - 10.0 cm in males. The annual sex ratio was 1M: 0.87F; with significant differences from July to October (2M:1F) and January (1M:2F). It was observed that the species tends to form aggregations, however, it maintains a 1M:1F ratio in the remaining period. The length-weight relationship parameters show that *D. maculatus* presents positive allometric growth ($r^2 = 0.93452$) for both sexes. Males were slightly larger and heavier than females. The minimum size of sexual maturity obtained was $L_{m50} = 8.21$ and 8.41 cm for females and males, respectively.

1. Introduction

The species *Dormitator maculatus* (Bloch) [1], belongs to the family Eleotridae. *D. maculatus* is the most abundant and representative species of the family Eleotridae in estuarine systems of the Veracruz state in Mexico [2]. It is distributed at a latitude between 37º N and 5º S, and at a temperature between 17º and 35º C, along the Atlantic slope of North Carolina to the southeast of Brazil [3]. It is also found on the coasts of the Caribbean Sea and the Gulf of Mexico, specifically on the latter in: Tamiahua, in the state of Tamaulipas; Gutiérrez Zamora, Alvarado and Sontecomapan in Veracruz; Frontera in Tabasco; Laguna de Térmidos in Campeche; and Yalkú and Bacalar wetlands in Quintana Roo [4]. The family Eleotridae is represented by the euryhaline fish. Some of its species tend to take advantage of freshwater currents as migratory routes to brackish waters. *D. maculatus* is a demersal species, found mainly in fresh waters and in brackish to marine mangrove areas, where they begin the reproduction stage. It is distributed in a salinity gradient from 0 to 21 ppm and up to 38.4 ppm. In some cases, these biotic and abiotic environmental factors determine fish growth [5]. *D. maculatus* commonly inhabits coastal marine environments and tidal river mouths [6]. Adults are found in swamps, ponds, and slow-flowing streams; where they remain partially covered with mud and sometimes in low oxygen conditions [4, 7].

The fishing season for *D. maculatus* is during the rainy season, which is from September to October, when mature individuals come to spawn in the Alvarado Lagoon [8]. Its fishery is artisanal and is considered a target species, it is one of the main fishing resources of the Alvarado Lagoon.
system considered of high commercial value [7, 9]. In recent years, its natural habitat has been deteriorated due to anthropogenic activities, which has caused some concern among fishermen. However, although the volume of catch has decreased, its fishery has not been regulated to this date [10]. This species has qualities with potential for aquaculture, yet it is vitally important to conduct research aimed at understanding the optimal conditions for inducing it into aquaculture. It is recommended that before starting to cultivate aquatic organisms, there is in-depth knowledge of the biology and physiology of the species susceptible be cultivated should be known in depth [11]. Due to the limited knowledge on the biology and ecology of *D. maculatus* from Alvarado Lagoon, the objective of this study was to analyze the size composition, sex ratio, growth type (length-weight relationship) and size at first maturity, in order to be able to describe its life cycle and contribute to a better understanding of these aspects.

2. Materials and Methods

2.1. Study Area and Sampling Sites

The study area is the Alvarado Lagoon system, which was designated a RAMSAR site on February 2, 2004 by the Commission for Natural Protected Areas (CONAP) [12] (figure 1). It is a plain formed by brackish lagoons with an area of 267,010 ha in the central coastal zone of the State of Veracruz, southwest of the Gulf of Mexico. The lagoons of Alvarado, Buen País and Camaronera stand out, which depend on fresh water contributions of the Papaloapan, Blanco, Limón and Acula rivers. Its vegetation includes mangroves, flooded forests and a wide variety of species of floating and rooted emergent aquatic vegetation (FIR, 2003). The municipalities that compose it are: Alvarado, Tlalixcoyan, Ignacio de la Llave, Acula, Tlacotalpan and Ixmatlahuacan [13, 14].

![Figure 1. Study area and sampling sites. A. Sampling in the months of September and October 2016 (latitude 18°46' and longitude 95°45'). B. Sampling in the months of August, November and December (2016), and from January to June 2017 (latitude 95°44' and longitude 18°45').](image)

Sampling was conducted monthly from August 2016 to July 2017. An average of 60 specimens of *Dormitator maculatus* was collected, in sites A and B (figure 2). In site A, sampling was carried out in September and October, with a manual codend trawl, to ensure the capture of all possible sizes (figure 1). While in site B, organisms were collected between November and August, with the fishing net called nasa, as part of the accompanying fauna in the capture of shrimp. The specimens were transported alive in a plastic container with ice, a few drops of clove essence (*Syzygium aromaticum*)
were added as an anesthetic. The samples were transported to the Laboratory of Investigación de Recursos Acuáticos (LIRA) of the Tecnológico de Boca del Río, Veracruz (ITBOCA).

![Figure 2. Dormitator maculatus from the Alvarado lagoon system, Veracruz, Mexico.](image)

2.2. Size Composition
The biometric data of each specimen was recorded and measured with an ichthyometer (±1mm accuracy) to obtain the total length (TL) and furcal length (FL); the body weight was measured with an Adam Equipment CQT202 Core Compact Digital Balance (capacity 200g x 0.01g).

2.3. Sex Ratio (M: F)
The sex ratio of males and females was calculated monthly. The sex of each individual was determined according to the external characteristics of the genital papilla, except when the size of the organism was very small; in this case, microscopic observations were made to confirm the macroscopic morphological characteristics (external sexual dimorphism). The monthly sex ratio (M: F) was calculated by dividing the total number of females by the total number of males per month of sampling. Likewise, the Chi-Square ($\chi^2$) statistical test was used, which indicates whether there is a significant difference in the theoretical 1:1 ratio ($p \leq 0.05$) [15] (Equation 1).

$$\chi^2_c = \sum \frac{(f_i - \hat{f}_i)^2}{\hat{f}_i}$$ (1)

where: $\chi^2_c$ = Chi square calculated, $f_i$ = observed proportion of females or males, $\hat{f}_i$ = half of n, and n = total organisms.

2.4. Length-Weight Relationship (LWR)
To determine the type of growth, it was necessary to determine the monthly length-weight ratio (LWR). For this purpose, the potential model proposed by Tessier [16], the length-weight data by linearization through natural logarithms, and later, a linear regression analysis were applied. From equation (2) and its resolution by least squares, variables $a$ and $b$ were obtained. The length-weight relationship is described by the following potential model proposed by Ricker ([17] and Pauly [18], in the following equation:

$$WT = a \times L^b$$ (2)

where $WT$ = total fresh weight (g), $L$ = total length of the organism (cm), $a$ = shape coefficient (regression constant) is equal to the condition factor (K) and $b$ = allometric coefficient.

According to the following approach, isometric growth is when the increase in weight and length is equal throughout its development ($b = 3$); positive allometric growth occurs when $b > 3$, in which the weight increase is proportionally greater than increase in length for larger organisms; while negative allometric growth is when the weight increase is proportionally less than the increase in length ($b < 3$) [16, 19]. This is obtained by posing the following hypothesis: Ho: $\beta = 3$ and HA: $\beta \neq 3$ [16]. Later, to
test the hypothesis and determine the type of growth of the species, a comparison between slopes was made with the Student’s t-test ($p < 0.05$) [15].

2.5. Length-Weight Relationship (LWR)
A qualitative evaluation of the gonads was carried out to identify color, shape, size, texture, in order to determine the size at first maturity ($Lm_{50}$), that is, when 50% of the population is sexually mature. The stages of sexual maturity of males and females were defined with the scale proposed by Nikolsky [20] and Brown-Peterson et al. [21]. To estimate the $Lm_{50}$ the proportion of sexually mature organisms (by size class) was plotted, obtaining the curve parameters, and then the observed data were adjusted to a logistic model [22, 23] with the following equation (3).

$$Hp = \frac{1}{1+e^{a+(b\cdot L)}}$$

where: $Hp$ = proportion of sexually mature males and females for each class mark (stages III, IV and V), $L$ = class mark of the furcal length interval (FL), $a$ and $b$ constants of the linearized logistic model.

3. Results

3.1. Size Composition
It was observed, within the basic biological parameters, that the monthly distribution of the 700 organisms analyzed was divided into 364 males and 336 females. The overall average height was 10.12 cm, the minimum TL was 4.4 cm and the maximum TL was 17.0 cm. Descriptive statistics show that males are larger and heavier than females; the mean size in males was equal to 10.54 cm and the average weight was equal to 18.40 g, while for females the average height and weight were 9.71 cm and 14.48 g respectively; for both sexes the mode was 10 cm. It is worth mentioning that the largest sizes were obtained during the breeding season, in September and October for both sexes, the total length fluctuated between 7 and 17 cm (figure 3). In terms of size structure, for females the most common interval was 7.1 - 9.0 cm (17.0%) and 8.1 - 9 cm (17.0%), representing 34.0% of the sample. The most representative frequency of size in males was 8.1 to 9.0 cm (14.6%) and 9.1 to 10 cm (14.0%), with a representativeness of 28.6% (figure 3); however, males larger than 11.1 cm are more frequent.

3.2. Sex Ratio (M: F)
Of the total organisms analyzed, the result was 52% male and 48% female, which corresponds to an observed ratio of 1:0.87. In May and from July to October a greater number of males was observed, while from November to April the greatest number corresponded to females (figure 4). However, it
was only in September, October and January that significant differences in sex ratio were observed (Table 1).

**Table 1.** Male and female frequencies, Chi square values ($\chi^2$) and sex ratio per month of *D. maculatus*.

| Month          | Males | Females | Total | $\chi^2$ | Proportion M: F |
|----------------|-------|---------|-------|----------|-----------------|
| August 2016    | 28    | 18      | 26    | 2.17     | 1:0.64          |
| September      | 72    | 49      | 121   | 4.37$^a$ | 1:0.68          |
| October        | 52    | 21      | 73    | 13.16$^a$| 1:0.40          |
| November       | 27    | 32      | 59    | 0.42     | 1:1.19          |
| December       | 20    | 25      | 45    | 0.56     | 1:1.25          |
| January 2017   | 16    | 34      | 50    | 6.48$^a$ | 1:2.13          |
| February       | 21    | 29      | 50    | 1.28     | 1:1.38          |
| March          | 23    | 27      | 50    | 0.32     | 1:1.17          |
| April          | 21    | 29      | 50    | 1.28     | 1:1.38          |
| May            | 26    | 24      | 50    | 0.08     | 1:0.92          |
| June           | 28    | 28      | 56    | 0.00     | 1:1.00          |
| July           | 30    | 20      | 50    | 2.00     | 1:0.67          |
| **Total**      | 364   | 336     | 700   | 1.12     | 1:0.87          |

$^a$ Indicates significant differences between the proportion 1:1 ($p \leq 0.05$).

**Figure 4.** Sex ratio of *D. maculatus* from the Alvarado Lagoon system during an annual cycle.

### 3.3. Length-Weight Relationship (LWR) and Growth Estimation

The coefficient obtained in the regression analysis was $b > 3.1718$ ($a = -4.8, gl = 699; p < 0.05$). After obtaining evidence of the reliability of the model and the correlation between the length-weight variables ($r^2 = 0.9345$), the hypothesis test (Ho: $b = 3$ y HA: $b \neq 3$) was contrasted, in which significant differences were observed [16]. It was observed that *D. maculatus* presents a positive relative growth of allometric type for both sexes. The smaller organisms gradually increase their length; the subsequent growth stops because the weight gain is greater than the growth rate in length (figure 5). Meanwhile, in adults, the weight gain is greater than the increase in length.
3.4. First Maturity Size

In the classification of length intervals every two centimeters (TL = 4.1 a 14.0 cm), a greater number of mature fish was recorded, taking into account that the percentage of immature organisms was 40%. Of the mature organisms, 56% were male and 44% female. The minimum size of sexual maturity for females was L_{50} = 8.21 cm and for males L_{50} = 8.41 cm (figure 6).

4. Discussion

4.1. Size Composition

The frequency of length of the captured organisms was observed to have an overall mean length of 10.54 cm; with a maximum of 17.0 cm and a minimum of 4.4 cm in length. This is different from what was reported by Winemiller & Ponwith [24] in two freshwater streams in Costa Rica. Where the size of *D. maculatus* fluctuated between 1.5 and 8.96 cm in males and 1.78 - 7.00 cm in females. The males were larger, in weight and length than the females, as reported in this study for *D. maculatus* from Alvarado Lagoon in Veracruz, Mexico. According to the results obtained, the average length of males and females was 10.54 cm and 18.40 g. and the average weight was 18.40 and 9.71 cm and 14.48 g. respectively. The mean length obtained in this study was similar to that reported (TL = 10.2 cm) by Craig et al. [25] in mangrove wetlands of the Everglades Park in Florida, and also to that
reported (TL = 14.5 cm) by Hugg [26] for North American estuarine and freshwater fish. In contrast, Franco-López et al. [27, 28] observed larger sizes in females (15.9 cm), than in males (14.7 cm). While, other authors recorded shorter lengths in males (8.45 cm) and females (7.9 cm) in the organisms of the Alvarado Lagoon [29]. In Cuba, Claro [30] reported a maximum length of 70 cm; and according to Nelson [31], the members of this family reach a maximum length of approximately 60 cm.

4.2. Sex Ratio
As for the sex ratio, Potts & Wootton [32] indicate that the variation of the sexes is determined by environmental, genetic and evolutionary factors. In this study, differences in sex ratios were observed, with males significantly higher than females, from July to October. This was associated with the rainy season in the region (July to October) and the breeding season [33], since D. maculatus forms aggregations to migrate to the sea in September and October. Regarding the sex ratio, it was observed that D. maculatus forms aggregations of two males for each female (2M:1F) as a reproductive strategy during the breeding period (September and October); in January the ratio was inverse (1M:2.13F) ($X^2 = 6.48, p < 0.05$). In the remaining months (November, December, and February to July), the sex ratio remained at 1M:1F. This differs from that reported by Franco-López et al. [27, 28] who recorded a sex ratio of 1:1 for D. maculatus from the Alvarado Lagoon throughout the year.

4.3. Length-Weight Relationship (LWR) and Growth Estimation
The mean length recorded in January was 8.4 and 7.6 cm for males and females, respectively; this suggests a possible segregation of the sexes during the breeding resting period. This phenomenon coincides with the low temperatures recorded in January [34]. In studies carried out by Franco-López et al. [27, 28] a general sex ratio of 1M:1F was reported throughout the year, which differs from the results obtained in this study. The type of growth described as length-weight relationship was estimated with the allometric function, by which it was determined that D. maculatus has a positive allometric growth for both sexes ($b = 3.1718$). This indicates that, at a certain size, the growth rate in weight is greater than that of length, this growth is consistent with the robustness that characterizes the species. Unlike Franco-López et al. [27] who reported isometric growth ($b = 3.0195$) for D. maculatus of both sexes in the Alvarado Lagoon. To compare the results of this research, the data generated from the family Eleotridae or the genus Dormitator were taken as a reference. Segura-Guevara et al. [35] estimated the length-weight relationship for Gobiomorus dormitor in the Sinú River in Colombia, reporting a slight difference between males and females and between months. The annual value for males and females was $b = 3.14$ and 3.13, respectively; therefore, its growth was reported as positive allometric. This agrees with the reports by Vázquez-Calderón et al. [36] for Dormitator latifrons in Costa Chica, Oaxaca; who also documented a positive allometric growth for this species of the family Eleotridae.

Sandoval-Huerta et al. [37] reported the length-weight relationship of fourteen estuarine species in Michoacán, Mexico. Being the family Eleotridae the most represented by three species: D. latifrons, identified as positive allometric growth ($b = 3.309$); Gobiomorus maculatus and Eleotris picta with isometric type growth according to the values of $b = 3.042$ and 3.074, respectively. Thus, Peyton et al. [38] determined the growth rate for various species in Hawaiian estuaries and for Eleotris sandwincensis, reporting an allometric growth rate ($b = 3.25$). In general, the above reports agree on the growth type that characterizes organisms in the family Eleotridae. According to Ricker [39] the differences between different populations of the same species, or between the same population in different years, may be associated with their nutritional condition, in this case influenced by the season and the physicochemical conditions of the water in the place of capture. This would explain the difference in the type of growth reported for the same species in the same place of capture.

4.4. Size of First Sexual Maturity ($L_{50}$)
The size at first maturity ($L_{m50}$) observed was 8.21 cm in males and 8.41 cm in females. Schmitter-Soto [4] reported the sexual maturity of $D. maculatus$ at 10 cm on the coast of Quintana Roo, Mexico. This size difference is related to the fishing effort and fishing gear used in the Alvarado Lagoon system, when larger organisms are caught. However, the average size reported was greater than $L_{m50}$ in the breeding months (September and October), which is when mature organisms form large schools along their migration route and due to this, are easily caught with gillnets (½ inch mesh size), used as fishing gear in the Alvarado Lagoon system.

5. Conclusions
The data obtained show that the average TL of $D. maculatus$ was 10.12 cm, with males being larger than females. The monthly sex ratio shows that the species tends to form aggregations by sex and size, which are related to the season and the reproductive cycle of the species. $D. maculatus$ forms aggregations associated with the reproductive period (September and October), in which the proportion of males is greater (2M:1F), while during post-spawning (January) the ratio is inverted (1M:2F) and then, they remain 1:1 for the remainder of the year. It was determined that the growth type of $D. maculatus$ in the study area is allometric positive for both sexes. Females reach first sexual maturity before males. The size at first maturity ($L_{m50}$) for females is 8.21 cm and 8.41 cm for males. It is evident that $D. maculatus$ develops strategies to compensate for nutritional and environmental anomalies, which is reflected in the total length, size at first maturity, type of growth and sex ratio; this with the purpose of ensuring the survival of the species in the Alvarado Lagoon system in Veracruz, Mexico. Overfishing and unsustainable management of the fishery in this system are factors that alter the life cycle of the species and prevent the development of sizes, either greater than or equal to those reported in organisms of the same species in other study areas.

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