Biological and Ecological Aspects of *Trichiurus lepturus* Linnaeus, 1758 (Perciformes: Trichiuridae) in Boca Del Rio, Veracruz, Mexico

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Abstract: *Trichiurus lepturus* is a coastal species of cosmopolitan distribution, with commercial importance in different regions of the world. It is ranked in the sixth place of landing volume worldwide, but in Mexico there is no formally established fishery, in addition to the limited information on aspects of its biology in this area. This work was developed in order to study the biological and ecological aspects of this species in Boca del Rio, Veracruz. The basic meristic measures (TL, LC, MH, ED and body weight and weight of gonads and hepatopancreas) and the Gonosomatic index (GSI) and Hepato-somatic index (HSI) were estimated, with which weight - length relationship, the type of growth and condition index were estimated. The sex ratio (F:M), in the windy season was 4:1, 1.86:1 in the dry season and 1.5:1 in the rainy season, with higher values for the GSI in the windy season January to March, 1.98. The growth for this species is negative allometric in rainy season and positive allometric for the rest of the year. It is a predominantly piscivorous species including cannibalism. There were no differences in body proportions between males and females, so that the estimated relations can only be considered for the differentiation of this species and not for separation of sexes.

Keywords: *Trichiurus lepturus* · GSI · HSI · Fisheries

INTRODUCTION

*Trichiurus lepturus* Linnaeus, 1758, is a benthopelagic and anphidromous species of widely distribution in warm and temperate waters of the world, with maximum depths of 350 m [1].

The Atlantic cutlassfish has been studies on its reproductive and life cycle in Asia [2,3]; and South America [4, 5]; whereas, [5-7] reported feeding data of the species; Haimovici and Martins [4] presented the age distribution groups in areas of the continental shelf of Brazil. Also it has been studied aspects of its distribution in relation to environmental conditions such [8] in South West Africa, in Japan [9,10,11,12], in Taiwan [13], in Korea [14] and in China [3]. The weight-length relationship has been reported by Dawson [15] for the northern Gulf of Mexico.

Apart from its commercial importance in some regions of the world, this species is notable for the tropic position in coastal areas, where it behaves as a carnivorous species [7].

In the western Atlantic is distributed from the Cape Cod, Massachusetts (40° N) to the Rio de la Plata (37° S), in Argentina. In southern Brazil is abundant despite being near the limit of their distribution. Their abundance in the region was associated with adaptations of feeding on a wide size range of benthic and pelagic organisms [16].

On the shores of the South Atlantic in Rio Grande do Sul, Brazil, it has been recognized that females and pre-adults of this species remain within the limits of the continental platform during the winter for feeding, while adults are located outside the continental platform [4]. Regarding this [4,7] consider that coastal areas are suited to meet the energy needs associated with growth conditions, reproduction and spawning.
In some countries it represents an exploitable fish resource, while in others it is not consumed. Commercial capture of this species is ranked in the sixth place of landing volume worldwide, with areas in the Asian Pacific, China and Japan, with the largest volumes of capture, with 85% of the global statistics [16,17].

In some areas of the Gulf of Mexico, the exploitation of this species is performed locally using small boats or fishing lines. On the shores of the United States, it is reported, since registration began in 1991 to date, a capture of 290 tonnes [18], but in Mexico, in the state of Tabasco since the year of 2000, the catching reports volumes ranging from 40 to 300 tonnes per year [19]. It should be mentioned that even when they benefit in some parts of the Gulf of Mexico, there is no formally established fishery for this species [20], besides there is no information on aspects of its biology in this area. Therefore, the present work was developed in order to study aspects such as the size distribution, length-weight relationship, sex ratio, gonosomatic and hepato-somatic indices, condition index and feeding in Boca del Río, Veracruz, Mexico.

**MATERIALS AND METHODS**

Six sampling events were done in the Boca del Río beach of Municipality, Veracruz, México, during the study period from March 2011 to March 2013. Specimens of *Trichiurus lepturus* was obtained directly from the commercial catch, which uses hooks and line early morning (6:00 to 10:00 hrs) along the coastline and the mouth of the estuary at no more than 30 m deep. The collected specimens were transported in coolers to the Laboratorio de Zoología of the FES- Iztacala, UNAM, for analysis.

In the laboratory the specimens were identified using the keys of De la Cruz -Torres, *et al.* [21] and McEachran and Flechhelm [22]. The following morphometric measurements were recorded for each individual: Total length (TL), Cephalic length (CL), maximum height (MH) and eye diameter (ED) with the help of a measuring board (precision 0.1 mm) plus the weight (W) by using a beam balance (accuracy 0.1 g).

Organisms were dissected to remove the gonads, hepatopancreas and stomach contents. Both the weight of the gonad (Gw) and hepatopancreas (Lw), were measured by using a semi-analytical balance (0.01 g of accuracy) to estimate the Gonosomatic (GSI) and hepato-somatic (HSI) indices using the expressions:

\[
\text{GSI} = \frac{Gw}{W} \times 100
\]

\[
\text{HSI} = \frac{Lw}{W} \times 100
\]

The sex ratio was estimated for season, from the number of males and females in each age recorded [23,24].

The weight-length relationship was calculated for each sex and for each season using the equation of Ricker [39], which adjusts the values through a potential relationship was used weight relative to the length of the individual, from the equation:

\[
W = aL^b
\]

where,

\[W = \text{Weight (g)}\]

\[L = \text{Length (cm)}\]

\[a = \text{Intercept}\]

\[b = \text{Slope factor (allometry)}\]

The growth rate was determined using the "t"-student test, between the value of the weight-length ratio (b) as an allometric coefficient and b=3, as an isometric growth using the following equation:

The Fulton condition index (k) was calculated according to the values obtained from the weight-length relationship, was calculated for each species and for each season, according to the following relationship:

\[
K = \frac{W}{L^b} \times 100
\]

where,

\[K = \text{Condition index}\]

\[W = \text{Average weight (g)}\]

\[L = \text{Average length (cm)}\]

\[B = \text{Slope of the weight-length relationship}\]

In order to determine whether there are differences between the morphometric measurements recorded for this species, a Student’s *t*-test (p <0.05) was performed to compare the measurements results of males and females, as well as a Fisher’s *F*-test (p <0.05) of variance of the measurements obtained between males and females.

The stomach content analysis was performed by removing the digestive tract and identifying each food item to the lowest taxonomic level using a stereoscopic microscope and using hard structures such as otoliths, bones of the jaw and skull and calcareous structures [25]. The results were processed using the relative importance index adjusting its estimate to 100%.
RESULTS

Of all individuals captured, 147 organisms were used to calculate the gonosomal and hepato-somatic indices as well as the condition index for the different seasons for females and males. The results obtained are shown in Table 3, (Fig. 2).

The weight-length relationship estimated for each sex, annual and combination demonstrate the results shown in Fig. 3, 4 and 5.

The growth rate estimated from the weight-length relationship, taking into account the Student's *t*-test, which considers isometric growth (*b* = 3, *p* < 0.05), shows that growth for this species is positive allometric, in windy and dry seasons, while in the rainy season is negative allometric, as shown in Table 4.

Finally, in the records of stomach contents was found that the main food types for this species were Engraulidae, Sciaenidae and Clupeidae fish families and cannibalism of young individuals. Crustaceans such as shrimp and juveniles of the family Portunidae were also present at varying proportions in the diet at different times of the year, according to the abundances of these species in the area.

### Table 1: Values of height (cm) and weight (g) by sex and season to *Trichiurus lepturus* in Boca del Rio, Veracruz.

<table>
<thead>
<tr>
<th>SEASON</th>
<th>SIZE (cm)</th>
<th>Average</th>
<th>WEIGHT (g)</th>
<th>Average</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>WINDY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>FEMALES</td>
<td>26.8 - 88</td>
<td>71.15</td>
<td>7.8 - 521</td>
<td>259.86 ± 84.091</td>
<td></td>
</tr>
<tr>
<td>MALES</td>
<td>40.4 - 97.5</td>
<td>71.57 ± 11.34</td>
<td>35.4 - 680.3</td>
<td>287.56 ± 49.71</td>
<td></td>
</tr>
<tr>
<td>DRY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>FEMALES</td>
<td>55.6 - 85</td>
<td>67.4 ± 11.42</td>
<td>94.4 - 428.7</td>
<td>200.6 ± 55.28</td>
<td></td>
</tr>
<tr>
<td>MALES</td>
<td>52 - 78.7</td>
<td>66.07±15.27</td>
<td>83.9-318.6</td>
<td>187.8 ± 49.6</td>
<td></td>
</tr>
<tr>
<td>RAINY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>FEMALES</td>
<td>51.2 - 81</td>
<td>67.7 ± 17.4</td>
<td>21-391</td>
<td>233.63 ± 63.0</td>
<td></td>
</tr>
<tr>
<td>MALES</td>
<td>54 - 78.3</td>
<td>68.9 ± 19.5</td>
<td>101- 322.8</td>
<td>231.38 ± 40.74</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2: Morphometric relationships for *Trichiurus lepturus* in Boca del Rio, Veracruz

<table>
<thead>
<tr>
<th>Relation</th>
<th>Equation</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Length vs Cephalic Length</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>CL=0.149 TL -1.1019</td>
<td>0.901</td>
</tr>
<tr>
<td>Males</td>
<td>CL=0.154 TL -1.301</td>
<td>0.943</td>
</tr>
<tr>
<td>ALL</td>
<td>CL=0.150 TL -1.136</td>
<td>0.914</td>
</tr>
<tr>
<td><strong>Total-Length vs Maximum Height</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>MH=0.75 TL -0.483</td>
<td>0.880</td>
</tr>
<tr>
<td>Males</td>
<td>MH=0.073 TL -0.414</td>
<td>0.884</td>
</tr>
<tr>
<td>ALL</td>
<td>MH=0.0747 TL -0.4741</td>
<td>0.879</td>
</tr>
<tr>
<td><strong>Total-Length vs Diameter Eye</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>DE=0.016 TL +0.218</td>
<td>0.860</td>
</tr>
<tr>
<td>Males</td>
<td>DE=0.017 TL +0.165</td>
<td>0.934</td>
</tr>
<tr>
<td>ALL</td>
<td>DE=0.0166 TL +0.2018</td>
<td>0.864</td>
</tr>
</tbody>
</table>

where: TL = Total Length, CL = Cephalic Length, MH = Maximum Height and DE = Diameter Eye.
Table 3: Values of the gonosomatic, hepato-somatic and condition indices for *Trichiurus lepturus*

<table>
<thead>
<tr>
<th>INDEX</th>
<th>WINDY</th>
<th>DRY</th>
<th>RAINY</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>FEMALES</td>
<td>1.635367281</td>
<td>1.197726744</td>
</tr>
<tr>
<td></td>
<td>MALES</td>
<td>0.434084636</td>
<td>0.589201676</td>
</tr>
<tr>
<td>HSI</td>
<td>FEMALES</td>
<td>0.796023183</td>
<td>0.577209294</td>
</tr>
<tr>
<td></td>
<td>MALES</td>
<td>0.543341836</td>
<td>0.415066983</td>
</tr>
<tr>
<td>CI</td>
<td>FEMALES</td>
<td>0.01533221</td>
<td>0.04535187</td>
</tr>
<tr>
<td></td>
<td>MALES</td>
<td>0.01751989</td>
<td>0.02985851</td>
</tr>
</tbody>
</table>

Table 4: Values Weight-Length Relationship and Student t values by sex and season

| Trichiurus lepturus |
|---------------------|-------------------|----------------|-----------------|
|                     | b     | a     | R²   | t_cal | n  |
| WINDY               |       |       |      |       |    |
| FEMALES             | 3.3724 | 0.000134 | 0.981 | 52.894 | (2.012) | 56 |
| MALES               | 3.3513 | 0.000150 | 0.986 | 28.873 | (2.145) | 14 |
| TOTAL               | 3.3682 | 0.000137 | 0.982 | 60.559 | (1.994) | 70 |
| DRY                 |       |       |      |       |    |
| FEMALES             | 3.0870 | 0.000436 | 0.956 | 29.199 | (2.021) | 41 |
| MALES               | 3.1868 | 0.000286 | 0.958 | 21.324 | (2.074) | 22 |
| TOTAL               | 3.1246 | 0.000372 | 0.957 | 36.845 | (2.000) | 63 |
| RAINY               |       |       |      |       |    |
| FEMALES             | 3.1466 | 0.000389 | 0.973 | 25.924 | (2.080) | 21 |
| MALES               | 2.6502 | 0.003196 | 0.984 | 26.918 | (2.145) | 14 |
| TOTAL               | 2.972  | 0.000816 | 0.969 | 32.394 | (2.032) | 35 |

Fig. 1: Total Length vs. Cephalic Length (a), Total Length vs. Maximum Height (b) Total Length vs Diameter Eye (c) for *Trichiurus lepturus*
Fig. 2: Somatic indices for Trichiurus lepturus in different seasons: GSI = gonosomatic index, HSI = hepato-somatic index and CI = condition index.

Fig. 3: Weight-length relationship for females of *Trichiurus lepturus* (annual).

Fig. 4: Weight-length relationship for males of *Trichiurus lepturus* (annual).
Fig. 5: Weight-length relationship for *Trichiurus lepturus* both sexes (annual)

**DISCUSSION**

This species was found demerso-pelagic habits, pre-adult and juvenile stages in the shallow waters of the continental shelf up to sizes that allow them to migrate to deeper areas. About this, Haimovici and Ávila-da-Silva [26] both mention that this species in Brazilian coast youth organisms registered 5-30 cm, subadults 30 to 70 cm and adults over 70 cm in total length, in this study sizes ranging from 26 to 97 cm were registered, suggesting that stages are found in the area for growth and as adults who serve as opportunistic feeders, as reported by [4,7].

According to Froese and Pauly [27], the catch sizes of this species should be related to the sexual maturity size, so for Cuba it was reported a size of 75 cm of total length, while for Brazil, a size of 99 cm in total length. For Mexico there is no information on this aspect, we observed that in the different seasons of the study, the average size captured were below of the reported by the authors regarding the size of sexual maturity to other locations in the Gulf of Mexico and the Atlantic. This is considered important because the information obtained shows that the catch in this area will be done on individuals who have not been yet reproduced, which could affect fishery yield and maintaining adequate populations of this species.

The sex ratio was favorable for females at different times of the year, with values ranging from 4 to 1 in the windy to 1.5 to 1 in the rainy, this pattern is consistent with that reported by [28-31], in localities of South Florida, Oman Coasts, South China Coasts and Cuba Coasts respectively, where the sex proportion mentioned is favorable for females. This proportion relate to the fishing gear used to catch them, finding that those organisms obtained by trawl and size under 25 cm, are predominantly male, while the organisms caught with lures presented larger sizes to 80 cm, are mainly females [28].

In recent decades, the use of morphometric characters has increased to identify the various species of fish stocks [32,33]. Among the measures considered concerning the anatomy of fish, are the length of the head, body height, eye diameter, length of the upper and lower jaw, length of the fins (pectoral, pelvic, dorsal and anal), height caudal peduncle, to name a few [34]. In this regard, Volpedo and Thompson [35] mention that there may be gender and life stages morphometric differences of the species. In our case, the measurements registered at *Trichiurus lepturus*, allowed us to recognize that there are no differences in measures of cephalic length, maximum height and diameter of the eye, between the sexes, so that the estimated relationships may be considered as distinctive for this species in the area.

The behavior of the gonosomatic (GSI), hepato-somatic (HSI) and condition indices (CI) for this species has been linked to the seasonal cycle of gonadal development and reproductive stages. Accordingly, Al-Nahdi, *et al.* [29] mention that the highest values of the GSI for this species, registered in the Oman coast, was close to three, a value that set the breeding season in the months of May and June. In the present study the highest GSI values corresponded to the windy season (January to March), with 1.98, coinciding
with that reported [28] in the coast of Florida, who also registered the highest values in the months of January to March. Meanwhile HSI, showed a similar behavior, although their values ranged from 0.87 in windy to 0.43 in dry for females and 0.47 to 0.30 for males, about this Al-Nahdi, *et al.* [29] mention that the declining value of the HSI after the breeding season, may be the result of energy consumed in the spawning season, resulting in a depletion of the resources of the liver, which could explain the values of this index for this species in the study area.

Meanwhile, the condition factor in both sexes was higher in the rainy season, with 0.44 for females and 0.46 for males, decreasing towards the windy season. This behavior is in concordance with that reported by Al-Nahdi, *et al.* [29], who noticed that the decrease in the condition index for this species can be explained by the redirection of the available energy reserves from fat and muscle tissue to the gonads for their maturation. The decrease in the condition factor as the reproductive cycle proceeds is explained by the fact that the reproductive activity involves high energetic cost for the organisms [36].

The behavior of the weight-length relationship helped to identify differences between both sexes, with the highest values of the coefficient growth rate for females (3.3292), compared to that obtained for males (3.2146) and obtaining a value of (3.2904) for all individuals in the present study, a similar behavior is registered [29,37,38], in the India and Oman coasts, who attributed the high values of the coefficient "b" as related to dietary habits of individuals *Trichiurus lepturus*. Thus, to determine the rate of growth for each sex and applying the student’s *t*-test, in all three cases was allometric positive to give the value of the coefficient "b" > 3, however to implement its determination sex and season, the growth rate was positive allometric for females and males in the windy and dry seasons and only turned negative allometric for males in the rainy season.

As mentioned above, the behavior of somatic indices and the type of growth are related to reproductive and alimentary behavior, being an opportunistic predator species, their main prey being fish of the Engrauilidae Clupeidae and Sciaenidae families and young individuals of the same species. In addition they feed on crustaceans such as shrimp and young portunids that inhabit the coastal platform and are consumed in variable proportions throughout the year depending on the reproductive cycle of the prey species, as referred Haimovici and Martins [4], who suggest that the reproduction of *T. lepturus* in the southern Brazil, is related to local production processes. This behavior is consistent with that reported [5,6,7], who reported that *T. lepturus* is a predominantly piscivorous species that includes the practice of cannibalism and where penaeid crustaceans and cephalopods are part of their diet.

Several authors recognize that the behavior of piscivorous species primarily associated with the consumption of pelagic organisms may be a strategy to minimize search time, which stimulate increased energy and to meet their nutritional requirements. Of the various recognized dams for this species, in Brazil and Taiwan coasts, [4,6] mentioned that variations in the specific composition of the diet may reflect faunal composition between different geographic areas that compose the distribution of this species.

**CONCLUSIONS**

*Trichiurus lepturus* has a cosmopolitan distribution and has therefore been an accessible resource for many countries; in Mexico is not considered as a resource to be exploited in large fisheries, although it is well appreciated in various locations in Veracruz, from artisanal fisheries and local trade. Presents an allometric positive growth throughout the year and without large variation in the somatics index (GSI, HSI and CI). The GSI, in females, increases during the rainy season, suggesting a reproductive season between rainy and windy. There are no differences in body proportions between males and females so that the estimated relationships can’t be considered for sexual separation, although yes for the differentiation of this species.

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**REFERENCES**


