RELATIONSHIP BETWEEN FISH LENGTH AND OTOLITH DIMENSIONS IN THE CARANGID FISH \textit{(Carangoides coeruleopinnatus (Rüppell, 1830)) COLLECTED FROM THE SEA OF OMAN}

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Abstract: The regressions between otolith size (length and width) and fish length of the carangid fish, \textit{Carangoides coeruleopinnatus} living along the coasts of the Sea of Oman were provided. ANCOVA test showed no differences in length and width of the right and left otolith of fish specimens obtained. Similarly, no significant difference was observed between regressions of fish length on width and length of otolith length, so a single linear regression was plotted against total length (TL) for otolith length (OL) and otolith width (OW).

Keywords: Otolith dimensions, Fish length, Sea of Oman, Muscat

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Introduction

The Carangidae family known popularly with their members called Jacks is among the large families of the order Perciformes and it is important in both tropical and subtropical waters.

The carangid species are large, strong swimming, open-water and carnivorous fishes (Randall 1995). In Oman, this family is composed of 48 species belonging to 24 genera (Randall 1995), and they are considered among the most important commercial commodities.

Among the three pairs of otoliths in bony fishes, sagittae have the largest pair (Harvey et al. 2000). Due to their large size and their distinct growth rings in most bony fishes, sagittae have been widely used by fisheries biologists (Boehlert 1985, Summerfelt and Hall 1987).

Paleontologists, oceanographers and marine biologists have used the species specific distinctive morphology of the sagittae and their dense structure that can resist certain degree of disintegration to determine the identity of fish species found in middens, sediments and stomach content of marine birds and mammals (Fitch 1964, 1969, Tripple and Beamish 1987, Ainley et al. 1981, Treacy and Crawford 1981). In the early years of the second half of the twentieth century the importance of the positive relationship between otolith size and fish size was demonstrated by Trout (1954) and Templemann and Squires (1956).

Researches in fish biology and population dynamics get huge usage of the otolith length-total length relationship (Echeverria 1987). Furthermore, the identity of the eaten fish species and their size can be estimated from their otolith retrieved from the digestive tract of the piscivorous fishes (Aydin et al. 2004).

The relationship between fish length and otolith length and width has not been investigated in the fish fauna of Oman. Therefore, the aim of the present study is to find out the relationship between fish length and otolith length and width in the carangid fish species C. coeruleopinnatus. These data may be used by researchers studying archaeology and food habits of piscivores to determine the size of fishes from the length of recovered otolith.

Materials and Methods

Fish specimens were collected during the period March-May 2010 from waters around Muscat City at the Oman Sea coasts using long lines. The specimens were identified according to Randall (1995). Total length (TL), most anterior point to the posterior tip of the caudal fin was considered and measured to the nearest millimeter. Sagittae were (total of 57 individuals, i.e., 114 otolith) removed through a cut in the cranium to expose them, then cleaned and stored dry in glass vials and the left and right otolith were considered separately. Specimens with obvious evidence of calcite crystallization (Strong et al. 1986) or other aberrant formations were rejected. Each sagittae, systematically placed with the sulcus acusticus oriented through the observer and its length was determined using hand-held vernier callipers and defined as the longest dimension between the rostrum and postrostrum axis (nomenclature of Smale et al. 1995) and width as the dimensions from the dorsal to ventral edge taken at right angles to the length through the focus of the otolith. The relationship between otolith size (length and width) and fish length (TL) were determined using least squares linear regression for the following parameters: otolith length (OL)-fish length (TL) and otolith width (OW)-fish length (TL). These equations were first calculated for both left and right otoliths and ANCOVA test (Fowler and Cohen 1992) was used to check any differences between regressions. Similarly, the sex-linked changes in fish length and otolith length were examined statistically with the ANCOVA test. The regression coefficients were compared and when significant differences (P<0.05) were not found, the $H_0$ hypothesis ($b_{right} = b_{left}$) was accepted. When the equations did not differ statistically, a single linear regression was reported for each parameter (OL and OW). The significance of the linear regressions was verified using the ANCOVA test.

Results and Discussion

One population of C. coeruleopinnatus was used in the analysis presented in the work at hand. The linear regressions of otolith length and width against fish length for male, female and combined sexes were calculated and are given in Figures 1&2.
Table 1. Result of regression analyses between otolith dimension on fish length of *Carangoides coeru leopinnatus*.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Intercept</th>
<th>Intercept</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>3.184</td>
<td>6.7895</td>
<td>0.4659</td>
</tr>
<tr>
<td>Width</td>
<td>6.3503</td>
<td>6.9675</td>
<td>0.5279</td>
</tr>
</tbody>
</table>

Figure 1. Total length otolith length relationship.

Figure 2. Total length otolith width relationship.
The result of the analyses has revealed no statistical significant differences (P>0.05) between; (1) the regressions of the fish length on the left and right otolith sizes; (2) the regressions of the otolith length and width of two sexes; (3) the combined (male & female) regression of the left and right otolith length.

Among the protocols of fish identification, shape of the otolith stands as one of the main tool to separate fish species due to their high interspecific variability (Battaglia et al. 2010). Therefore several reference works on the morphology of the fish otolith are in use specially in the field of identification of fish preys, to identify fish species depending on the shape of their otolith (Smale et al. 1995, Campana 2004, Lombarte et al. 2006, Tusset et al. 2008), however, only certain geographical areas are covered and the access to reference material remains requisite (Santos et al. 2001). Thus, it is essential to estimate specific equations which are useful to calculate the size and mass of the preys.

The results of the present paper address to this need, providing TL-OL and TL-OW relationships for the carangid fish *C. coeruleopinnatus*. Despite the commercial importance role of this species in the Omani waters, its biology and ecology had not been well investigated until today in Oman.

There are some limitations to the use of biomass reconstruction from otolith size. Several authors have shown that individuals of the same species inhabiting different areas or individuals of different stocks of the same species have different growth rate. Such difference in the growth rate will affect the morphology of the otolith (Campana and Casselman 1993, Reichenbacher et al. 2009). The increased or reduced otolith growth rates most often are the result of changes in water temperature, water depth and diet (e.g., Lombarte and Lleonart 1993, Katayama and Isshiki 2007, Mérigot et al. 2008), however, only certain geographical areas are covered and the access to reference material remains requisite (Santos et al. 2001). Thus, it is essential to estimate specific equations which are useful to calculate the size and mass of the preys.

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The effect of chemical and mechanical abrasion in the digestive track of predators on the otolith traits might become factor to underestimate otolith size (Jobling and Breiby 1986, Granadeiro and Silva 2000). Similar results were obtained for some otolith of the species in question retrieved from the stomach of fishes collected from Sea of Oman. In these otoliths, the ornaments usually found on the mesial side of the otolith have been severely abrassed and the anterior and posterior edges of the otolith have been deteriorated and the size of the otolith looks much smaller than that of the otolith recovered directly from the fish body of the same species (Sulaiman et al. 2007, Saad 2005, Khalid 2007).

Unlike the previous studies that focused on the relationship between fish and sagitta sizes (Wyllie 1987, Gamboa 1991, Granadeiro, Silva 2000, Harvey et al. 2000, Waeussle et al. 2003, Battaglia et al. 2010), this paper supplies additional information by considering both the otolith length (OL) and otolith width (OW). It is more suitable to calculate more than one equation (TL-OL and TL-OW) since the tip of the otolith rostrum or the dorsal or ventral edges of the otolith may be damaged, making it impossible to measure the OL or OW.

In contrast with the findings of Harvey et al. (2000) and Waessle et al. (2003) the otolith of the species in question did not show significant differences in size between left and right sagittae. This finding is in agreement with the results of Battaglia et al. (2010).

In spite of all data fitted well with the linear regressions obtained in the present study, it is advisable to use these equations within the fish size range limit reported for this species in the results section. Authors who studied wide range of fish length and include larvae in their sample, have supplied two different TL-OL regressions, one for the small sized fish and another for the adult specimens (Nishimura and Yamada 1988, Linskowski 1991). Such situation is not applicable to the results obtained in the present study as no larvae were present in the sample as the individuals of *C. coeruleopinnatus* collected in the present paper belong to the 202-313 mm TL range, the regressions TL-OL and TL-OW calculated here in can be accepted.

**Conclusions**

There are no differences in length and width of the right and left otolith of fish specimens obtained. This is also true for the regressions between fish length on the length and width of otolith, so a single linear regression was plotted against total length (TL) for otolith length (OL)
and otolith width (OW). These relationships provide a reliable tool in feeding studies and also provide support to palaeontologists in their research on fish fossils.

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