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# COMPARISON OF MORPHOLOGY AND GROWTH ASPECTS OF TIGERTOOTH CROAKER (*Otolithes ruber* BLOCH & SCHNEIDER, 1801) IN THE PERSIAN GULF AND OMAN SEA

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## ABSTRACT

Morphological and growth aspects of Tigertooth croaker (Otolithes ruber) were examined in order to assess differences between stocks of this species in the Persian Gulf and Oman Sea. The minimum and maximum total lengths of this species were 17.78 cm and 47.99 cm in the Oman Sea and 17.05 cm and 38.64 cm in the Persian Gulf respectively. Morphological measurements of fish (total length, standard length, weight) and otolith (length, width, weight, age) were compared by analysis in R software. The One-way ANOVA for each parameter showed significant differences between morphological characteristics ($P<0.05$). PCA analysis showed that all morphometric parameters have a high value (91.23%) for regional discrimination and the MANOVA test indicated that two areas based on comparison of all morphological characteristics have a significant difference with $P \leq 0.05$. For the Oman Sea, the LWR equation was (w= 0.00523TL, 3.1844) and for the Persian Gulf, it was (w= 0.001794TL, 3.5309). KDE showed that the Oman Sea has a larger age density than the Persian Gulf and there is a significant difference between regions ($P<0.05$). Our results suggest that the O. ruber from the Persian Gulf and Oman Sea are distinct biological stocks, and should be differently managed.

**Keywords: Morphological; Otolithes ruber; Oman Sea; Persian Gulf**

## INTRODUCTION

The Tigertooth croaker (*Otolithes ruber,* Bloch and Schneider, 1801), a fish species of the family Sciaenidae, constitutes one of the most important regional fishery resources. This species is distributed from the Persian Gulf to the Oman Sea, and also occurs in tropical and subtropical waters of other countries, such as the Indian and Pacific oceans, China, and the Malay Archipelago (Rahnama *et al*., 2017).

Stock is a sub-group of one species that can also develop phenotypic and genotypic differences over time due to the separation in reproduction of each stock, different environmental condition, natural selection, or other factors (Rahnama *et al*., 2023; Vaz *et al*., 2023). The identification of species and stocks are important for biodiversity management and stock assessment that can be studied by morphological characteristics (Qiao *et al*., 2022; Mounir *et al*., 2022). Morphometric analysis is one of the most common mathematical methods to study differences between stocks and provide simplified information about population dynamics in different regions (Froese & Pauly, 2011; Marini *et al*., 2017). In theory, once we

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accurately determine the relationships between length, weight, and age, these models can be utilized to distinguish between different stocks (Mehanna & Farouk, 2021). The fish length-weight relationship is one of the most useful indexes for scientists and researchers (Li *et al*., 2023; Landa & Antolinez, 2018). Calculating the length-weight relationships is valuable for estimating fish length from weight values and understanding aspects of fish stock such as mortality, composition, reproduction, and growth (Valset *et al*., 2007; Manikandarajan *et al*., 2019).

Alternatively, the age distribution within stocks can be employed to identify environmental or ecological shifts. Differences in age among various stocks may be attributed to factors such as competition, limited food resources, overpopulation, and unfavorable ecosystems (Li *et al*., 2009; Rahnama *et al*., 2017). Age determination in fish can be achieved by examining hard structures such as scales, otoliths (sagitta), spines, and fin rays, where annual growth lines are counted. Otoliths are the most commonly used structure for this purpose (Ndjamba *et al*., 2022; Sigurðardóttir *et al*., 2023) and have been instrumental in fishery science for gathering information on age, fish size, and taxonomy, which can reveal differences among stocks (Mahé *et al*., 2016). This study aims to investigate the variations in morphological characteristics related to the length-weight relationships and age of *O. ruber*, collected by commercial fisheries from the Iranian waters of the Persian Gulf and the Oman Sea.

## MATERIALS AND METHODS

Sampling was carried out by commercial fishing vessels in June 2017 in the Iranian coastal waters of the Persian Gulf and Oman Sea (Figure 1). The mesh sizes of gillnets were 135 mm and 95 mm, and the shrimp trawl net was 25 mm and 40 mm. A total of 100 fish were collected for each sample site, and their total length (mm), standard length (mm), weight (g) and sex were taken. From each ûsh, left sagittal otoliths were extracted, cleaned with hypochlorite sodium 5%, washed out with running water and stored dry in labelled envelopes. The otolith dry weight (nearest 0.1 mg) was determined by a digital precision scale, and length-width (mm) were measured. For age determination, otoliths were sectioned into thin slices at the core region and posteriorly polished using sandpaper. Two researchers independently read the same samples to reduce estimative-related errors. All otoliths were photographed with a stereomicroscope (Matic-M2005A). In order to enhance the image resolution of the age lines, the images were transferred to the Adobe Photoshop-CS5 software (Campana, 2014). Data was transformed to $\log_{(x+1)}$ to observe normality and homoscedasticity assumptions. One-way ANCOVAs were performed to verify differences between the regions (Persian Gulf and Oman Sea) on the otolith length, width and weight, controlling the effect of the fish size (total length). Morphological and biometric studies on samples were analysed in R software and used multivariate ANOVA, One-way ANOVA and PCA data analysis (Graham *et al*., 1994; Rao, 1948). Kernel density estimation (KDE) was performed to compare the age between two groups. The length/weight relationship was calculated using the following equation: $W = a\,TL^b$ (Jones, 2002). The a factor depends on the shape of the body, and the b factor, when it is equal to 3, can indicate isometric growth. Both parameters were calculated by a linear regression and transformed into this equation: $\log W = \log a + b \log L$ (Koutrakis & Tsikliras, 2003and). The least-square residuals method was used to minimize errors in estimating parameters a and b (Haddon, 2011).


Figure 1. The sampling area of *O. ruber* in Iranian waters of the Persian Gulf and Oman Sea

## RESULTS AND DISCUSSION
### Results

The minimum and maximum total length were 17.78 cm at the age of one year and 47.99 cm at the age of five years in the Oman Sea, respectively. On the other hand, the minimum total length in the Persian Gulf was 17.05 cm at the age of six months and the maximum total length was 38.64 cm at the age of four years (Table 1). The principle study of morphological characteristics of *O. ruber* was compared and summarized in Table 2.

Comparing the average of morphological characteristics showed a significant slope in all parameters in the Persian Gulf and Oman Sea. One-way ANOVA corroborated this result, showing significant differences (P<0.05) for morphological characteristics (Table 3).

Relationship between the Persian Gulf and Oman Sea ($OL=0.2712SL^{2.6238}$ and $OL=0.2692SL^{3.0821}$ respectively) and the standard length-otolith weight relationship ($OW=0.0158SL^{0.1971}$ and $OW=0.0169SL^{0.3767}$ respectively) of *O. ruber* showed significant differences (F=693.2, p<0.001), also the effect of fish size were controlled by these relationships (Figure 2).

The first two axes of PCA explained 91.23% of the total variation for the *O. ruber*, with PC1 (59.38%) related to otolith weight, otolith length and otolith width and PC2 (32.85%) associated to fish weight, total and standard length (Figure 3). A high variation was

Table 1. The Minimum and Maximum of morphological characteristics of *O. ruber* from Iranian waters of the Persian Gulf and Oman Sea

| | Factor Range | Total length (cm) | Standard length (cm) | Weight (g) | Otolith width (mm) | Otolith length (mm) | Otolith weight (mg) | Age (year) |
|---|---|---|---|---|---|---|---|---|
| Oman Sea | Minimum | 17.78±6.65 | 16.51±6.29 | 54±198.22 | 5±0.89 | 8±1.76 | 0.091±0.11 | 1±0.85 |
| | Maximum | 47.99±6.65 | 43.19±6.29 | 999±198.22 | 9.54±0.89 | 16±1.76 | 0.716±0.11 | 5±0.85 |
| Person Gulf | Minimum | 17.05±6.36 | 16.51±6.29 | 28.5±186.46 | 3.75±0.87 | 6.7±1.76 | 0.003±0.11 | 0.5±0.80 |
| | Maximum | 38.64±6.36 | 36.83±6.29 | 686.5±186.46 | 8.25±0.87 | 14.7±1.76 | 0.615±0.11 | 4±0.80 |

Table 2. The averages and variances of morphological characteristics of *O. ruber* from Iranian waters of the Persian Gulf and Oman Sea

| | Oman Sea | | | | Persian Sea | | | |
|---|---|---|---|---|---|---|---|---|
| | N | Average | S.D. | Variance | N | Average | S.D. | Variance |
| Total length (cm) | 100 | 28.70 | 6.65 | 44.24 | 100 | 26.67 | 6.36 | 40.51 |
| Standard length (cm) | 100 | 25.59 | 6.29 | 39.63 | 100 | 25.19 | 6.24 | 39.01 |
| Weight (g) | 100 | 271.82 | 198.22 | 39307.63 | 100 | 241.89 | 186.46 | 34768.86 |
| Otolith width (mm) | 100 | 6.21 | 0.89 | 0.78 | 100 | 4.96 | 0.87 | 0.78 |
| Otolith length (mm) | 100 | 10.86 | 1.76 | 3.11 | 100 | 9.56 | 1.76 | 3.11 |
| Otolith weight (mg) | 100 | 0.23 | 0.11 | 0.01 | 100 | 0.13 | 0.11 | 0.01 |
| Age (year) | 100 | 2.35 | 0.85 | 0.73 | 100 | 1.87 | 0.80 | 0.64 |

Table 3. The significant difference of averages (P<0.05) in morphological characteristics of *O. ruber* from Iranian waters of the Persian Gulf and Oman Sea

| | SS | F | P-value |
|---|---|---|---|
| Total length(cm) | 206.02 | 4.86 | 0.00 |
| Standard length(cm) | 7.83 | 0.19 | 0.02* |
| Weight(g) | 44730.40 | 1.20 | 0.00 |
| Otolith width(mm) | 78.12 | 99.61 | 0.00 |
| Otolith length(mm) | 84.49 | 27.16 | 0.00 |
| Otolith weight(mg) | 0.50 | 41.79 | 0.00 |
| Age (year) | 11.09 | 13.71 | 0.00 |

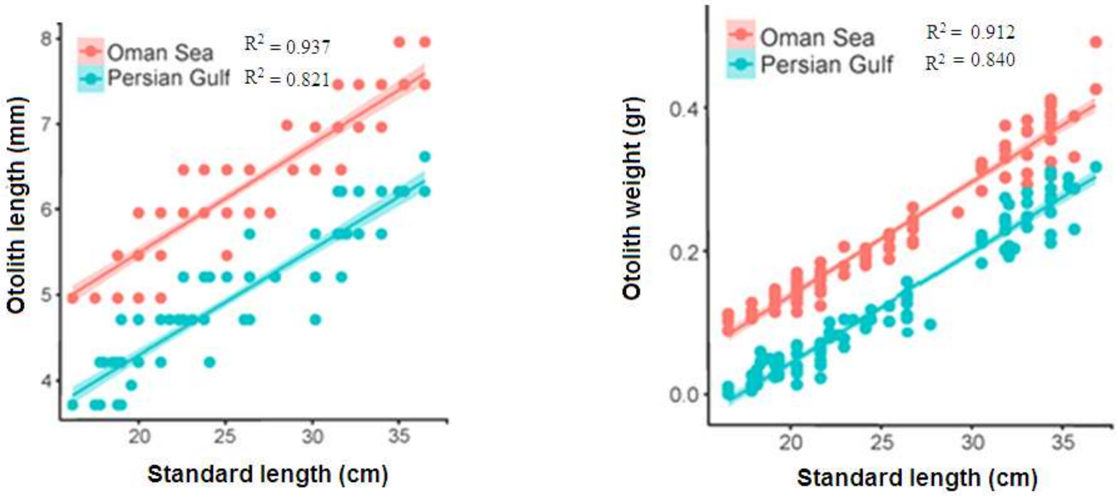


Figure 2. Variations in relationship of otolith length-standard length and otolith weight-standard length of *O. ruber* between the Persian Gulf and Oman Sea, controlling the effect of fish size

recorded among morphological characteristics. This test was corroborated by discriminant analyses that showed a classification of 85% for all samples. Also, samples from the Persian Gulf (86.23%) and the Oman Sea (93.33%) were correctly classified in each region.

The MANOVA test showed that two areas based on comparison of all morphological characteristics have a significant difference ($P \leq 0.05$) (Table 4).

The length and weight (LWRs) relationship of specimens from two regions was calculated (Figure 4). The two regressions (LWRs) are significantly different from each other ($P<0.05$). The LWRs equation was ($w = 0.001794TL^{3.5309}$ and $w = 0.00523TL^{3.1844}$) for

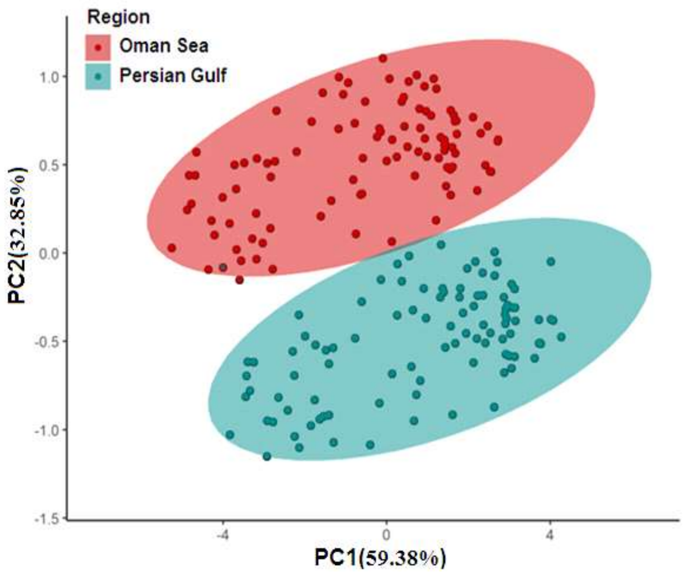


Figure 3. The Principle component analysis (PCA) of all Morphological characteristics of *O. ruber* from the Persian Gulf and Oman Sea

Table 4. The multivariate MANOVA test showed high significant difference between *O. ruber* from the Persian Gulf and Oman Sea

| | Effect | Value | Sig. |
|---|---|---|---|
| Intercept | Wilks' Lambda | 0.001 | 0.00 |
| Locality | Wilks' Lambda | 0.003 | 0.00 |

the Persian Gulf and Oman Sea respectively. The kernel density estimation (KDE) is a non-parametric way to estimate the probability density function of age variable, that showed the Oman Sea has a larger age density and distribution than the Persian Gulf and there is a significant difference between regions ($P<0.05$) (Figure 5).

## Discussion

Morphological characteristics can be used to identify different stocks. Typically, multivariate morphometric analyses are employed for this purpose (Rawat *et al*., 2017). However, a significant limitation of using morphological characteristics is that phenotypic diversity is not entirely controlled by genotype; it is largely influenced by environmental factors. (Quadroni *et al*., 2023). The flexibility of fish phenotypes enables them to adapt to environmental changes. This adaptation is reflected in alterations in physiology, behaviour, and ultimately, morphology and reproduction (Donelson *et al*., 2019). Several studies indicate that the Oman Sea is significantly affected by the Indian Ocean monsoon during the summer. The monsoon's extensive transpiration in this region leads to an increase in marine nutrient production (Charabi & Abdul-Wahab, 2009). Increases in primary production, such as algal blooms, lead to a rise in herbivore populations, followed by an increase in carnivores in these areas (FAO, 2010). The nutrient

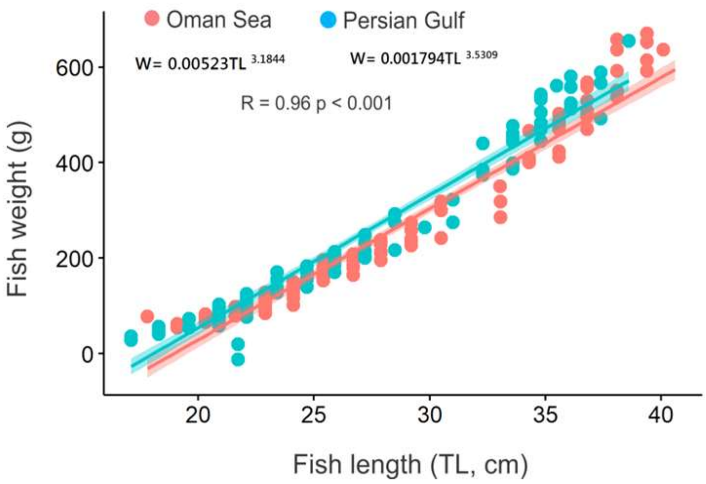


Figure 4. Comparison of the length-weight relationship of *O. ruber* from Iranian waters of the Persian Gulf and Oman Sea

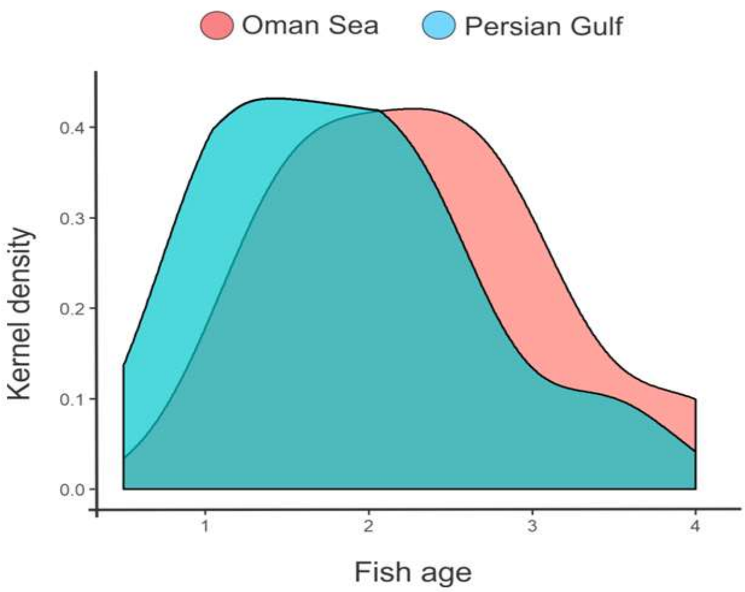


Figure 5. The kernel density estimation (KDE) of age frequency of *O. ruber* from Iranian waters of the Persian Gulf and Oman Sea

influx, coupled with more stable temperatures and freshwater input in the Oman Sea, has resulted in fewer environmental stresses on fish compared to the Persian Gulf (Hermida *et al*., 2005; Stirling & Philips, 1990). Consequently, the higher density of age (KDE) in the Oman Sea stock can likely be attributed to these favourable conditions. The parameter b in length-weight relationships depends on the body condition and shape of the species (Mekonnen & Tizazu, 2018). This relationship in fish species is influenced by several factors such as gender, maturity, diet, health, stomach fullness, and habitat (Galindo-Cortes *et al*., 2015). Rojas-Herrera *et al*. (2009) noted that when b is close to 3, the species exhibits isometric growth. Other studies have identified values around 2.8 and 2.3 as indicative of isometric growth, while values above 3 are considered positive allometric and those below 3 are considered negative allometric in various sources. In this study, the obtained b value for both regions is similar and greater than 3, indicating uniformity in this aspect. However, the length-weight relationships (LWRs) show a significant difference between the Persian Gulf and Oman Sea ($P < 0.05$). Various factors such as genetic traits, food availability, pollution, and environmental conditions likely influence the growth patterns of fish in these regions. Furthermore, *O. ruber* from the Persian Gulf and Oman Sea exhibited significant differences in morphological characteristics ($P < 0.05$), suggesting a high likelihood of distinct stocks between the two regions. This finding is consistent with previous studies. Dustdar *et al*. (2017) identified different stocks of *Acanthopagrus arabicus* based on morphometric parameters in the Persian Gulf and Oman Sea. Similarly, Sedighzadeh *et al*. (2014) suggested that the two stocks of *Lutjanus johnii* in these regions should be considered separately. Additionally, Rahimi and Rahnama (2018) demonstrated through Principal Component Analysis (PCA) that morphometric parameters of Rainbow Sardines (*Dussumieria acuta*) differed significantly (95% variation) between the Persian Gulf and Oman Sea.

The observed diversity in morphological parameters of *O. ruber* in this study likely reflects adaptations to varying environmental conditions. Factors such as salinity and heat stresses in the Persian Gulf, alongside higher nutrient availability and moderate seawater temperatures due to summer monsoon upwelling in the Oman Sea, may contribute to the observed phenotypic differences in this species.

## CONCLUSION

Overall, our findings indicate that the stocks of *O. ruber* from the Persian Gulf and Oman Sea are distinct and should be managed accordingly. Additionally, while phenotypic adaptation does not always signify genetic variation, distinguishing these phenotypic differences between stocks may not necessarily entail genetic changes (Swaine *et al*., 1991). Nevertheless, further molecular studies are essential over time to assess the genotypic differences between these stocks in both regions.

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