The Influence of *Otolithes ruber* Consumption on Prey and Comparison with that Harvested by Fisheries

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Abstract

The *Otolithes ruber* is considered a valuable fish in the Indo-West Pacific. Estimates of the Q/B ratio and parameters of equations to 'predict' Q/B values for *O. ruber* in northwestern part of the Persian Gulf and the effects of different age-groups (age 1 to 6 year) on prey are presented. The age and food item of *O. ruber* were recorded on data collected from monthly samplings by bottom trawl during Oct 2007 to Sep 2008 and size frequency data were collected from commercial catches between Apr 2002 to Mar 2012. Food composition was analyzed by quantitative method. The effects of different age-groups on prey were calculated by biomass of the predator and the consumption rate of different age-groups. Six age group were identified. The biomass of stock was dominated by age-group 2 (3069 tons). Stomach contents of *O. ruber* included mostly shrimps and fish. Daily consumption of shrimp and all food items were 54 and 100 tons respectively. The highest and the lowest consumption rate and ratio of consumption to the stocked biomass were in age-groups 1 and 6, respectively. The Q/B ratios for shrimp and all food items were 3 and 5.57, respectively. Age-groups 2 and 3 had the most and age-group 6 the least effect on prey community. Shrimp consumption was greater during 2008-2009 than the minimum recorded in 2002-2003. Despite increasing biomass of *O. ruber* and increasing the consumption of shrimp, the shrimp catch was not much affected.

Keywords: *Otolithes ruber*, Persian Gulf, Shrimp, Consumption, Biomass

1. Introduction

The Tiger toothed croaker (*Otolithes ruber*) is a demersal fish living both in the bottom and on the surface of the water and obtains its food from the bottom, column and surface of the water (Fischer and Bianchi, 1984). Numerous teeth accompanied by short and few gill rakers and large stomach indicate carnivore habit of *Otolithes ruber*. Food of tiger toothed croaker generally consists of such crustaceans as shrimp and other invertebrates. Zoobenthos has been suggested as permanent food of juvenile and adult tiger toothed croaker in Alzobair creek (Nasir, 2000). Several studies in North of the Persian Gulf and Oman Sea have been suggested small fishes and crustaceans (particularly shrimp) as the main food of *O. ruber* (Niaaimandi, 1999, Kamali et al., 2006, Azhir, 2008). The *O. ruber* diet composition in Khuzestan coastal waters consists of smaller fish such as species of Mugilidae, Engraulidae and shrimp as secondary food (Eskandari, 1997).

Species within any ecosystem unit interact with each other and with species in other ecosystem units.
by means of a complex network called a food web (Bergh and Barkai, 1993). Aquatic food webs have been studied intensively with respect to the interaction of consumer (“top-down”) and resource (“bottom-up”) effects on species composition and abundance (Worm and Myers, 2003). Biological interactions in marine ecosystems, interspecies and intraspecies interactions may have a significant influence on stock dynamics and can contribute to the high variability which is frequently observed in recruitment and stock sizes (Magnússon, 1999). Fish stock dynamic is highly affected by predators and fishers (Whipple et al., 2000).

The effect of predator fishes on composition of aquatic ecosystems could be significant. Mortality induced by predation can reduce prey abundances locally and may limit prey recruitment in some systems. Predation by fishes is often size-dependent leading to increased mortality at specific life stages of prey and to potential shifts in size distribution of surviving individuals. To begin to quantify potential effects of fish predation on community structure and prey populations, detailed information is needed on the feeding habits of important predators (Scharf and Schlicht, 2000).

The main emphasis in theoretical and empirical studies of species interactions has been on predation, since it is relatively easy to observe and probably more important than competition. However, demonstrating that predation has a measurable and significant effect on stock dynamics and long-term stock sizes is more difficult (Magnússon, 1999).

Shrimp is one of the harvestable invertebrate species in the muddy habitats in the northwestern areas of the Persian Gulf. The catch rate has been reported about 3000 tons in 2009. Young O. ruber individuals feed on shrimp species (Eskandari, 1997) and as such, stocks of prey and predator could probably be affected with any change in population size of either (Figure 1).

*O. ruber* is distributed in the Oman Sea and the Persian Gulf. Many studies have been carried out regarding feeding habit of fish in Iran (Eskandari, 1997, Nair, 1980, Pillai, 1983, Euzen, 1987, Passoupathy and Natarajan, 1987, Nasir, 2000). Also, Buckel et al. (1999) has compared biomass consumption by predator fish and fishing harvest.

![Figure 1: Variations of shrimp and *O. ruber* catch in Khuzestan coastal waters (2000–2010).](chart)

The consumption rate and proportion of consumption to biomass and relationship with prey has yet to be studied. Therefore, the aim of this study was to determine proportion of consumption to biomass stock (Q/B), prey consumption rate, harvest of prey and prey-predator relation using virtual population analysis data.

### 2. Materials and Methods

Monthly sea sampling surveys for collecting biological data were carried out in coastal waters of Khuzestan province in the northwestern Persian Gulf between 48°45′ and 49°50′ E and 29°48′ and 30°06′ N using fish trawl, during 2007 to 2008 (Figure 2). Samples were selected randomly and then, stored in ice boxes and transferred to the lab for identification of food items and age structure. Later, total length and fresh weight of each specimen were measured accurately. Stomach contents of all specimens were identified. The total number, wet weight, and frequency of occurrence of each prey item in the stomach of the fishes were recorded and weighed separately. Otoliths (sagittae) were removed from 1500 sampled fish, and analyzed using a stereomicroscope by an expert single age reader counting annuli in the whole otolith. The age
estimates derived after annuli counting were reported as ”true” age using for age – length - keys.

Food composition was determined using quantitative analysis technique of Sánchez and Olaso (2004).

Predator stock consumption rate was determined firstly, by obtaining required data for the model of virtual population analysis (VPA) (Weizhong et al., 2003) from local fishery offices and South of Iran Aquaculture Research Center to estimate Croaker biomass in different age-groups during 2002-2012 and secondly, using the following formula (Lilly et al., 2000) to calculate daily consumption rate.

\[
\hat{C}_i = \frac{24 \cdot \ln 2 \cdot e^{-\gamma T} \cdot B^\delta \cdot S_i}{\alpha_i \cdot \left( \sum_{j=1}^{n} S_j \right)}
\]

Ci= prey consumption rate
Si=prey weight, in the stomach at the time of sampling
B=predator, size
T=temperature (ºC)

Constants:
\( \gamma = 0.13 \)
\( \beta = 0.48 \)
\( \delta = 0.46 \)
\( \alpha_i = 117 \) for shrimp, 75 for fish, 70 for all invertebrates, and 73 for invertebrates and fish (Lilly et al., 2000).

Thirdly, the daily consumed prey biomass was obtained by multiplying prey biomass by prey consumption in different age-groups and accordingly, the annual consumption rate by multiplying daily consumption rate to 365. The consumption - to - biomass ratio (Q/B) was obtained from dividing sum total of annual consumption in different age-groups by predator biomass. In addition, (Q/B) was also calculated using Pauly and Palomares (1998) formula as follows:

\[
Q/B = 10^{4\cdot (7.964 - 0.204 \cdot \log \text{Winf} - 1.965 \cdot 1000 / (T+273.15) + 0.083 \cdot A + 0.532 \cdot h + 0.398 \cdot d)}
\]

In carnivorous species: \( h = 0, d = 0 \)
A (aspect ratio of caudal fin) = (height of the caudal) 2/ square centimeters for surface area for \( O. ruber \) in this study \( A=1.32 \)

\( \text{Winf} = \text{Weight infinite} \)
T= average annual temperature of water

Stock number trend, biomass, consumption and age-groups, and impacted predator biomass during 2009-2012 were analyzed. The average biomass of prey consumption by predator was calculated and compared to landed catch. Finally, predator prey interaction was considered.

Similarities in diet composition between age-groups were compared using nonparametric multi-dimensional scaling (MDS) (Clarke and Warwick, 1994).

3. Results

Stomach contents of O. ruber were composed for invertebrates and fish. The shrimp consumption rate by age-group 1 was higher than other age-groups decreasing sharply in older age-groups. 54.55 tons of shrimp and 100.1 tons of invertebrates and fish were consumed daily (Table 1).

The daily and annual (Q/B) of shrimp were 0.008 and 3, respectively based on VPA estimation. For all food items the annual (Q/B) were 0.015 and 5.57 (Table 1). The annual (Q/B) for all food was estimated 6.1 by using Pauly's model (1998). The annual (Q/B) of prey consumed showed relatively stable trend during 2000-2009. The annual (Q/B) of shrimps showed similar trend, with slight decrease in 2010 (Figure 3).

![Figure 3](image-url)  
Fig. 3: The annual Q/B estimates for O. ruber stock in Khuzestan coastal waters (2002-2012).

The (Q/B) is decreasing with increase in size. The smallest size class had the most (Q/B) for shrimp (12.6) and total consumption (13.7) and the largest size class had the lowest (Q/B) for shrimp (0) and total consumption (2.6) (Figure 4).

![Figure 4](image-url)  
Fig. 4: The Q/B estimates for O. ruber by each age class in Khuzestan coastal waters.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Prey (all food items) consumption rate (g/(g.d))</th>
<th>Shrimp consumption rate (g/(g.d))</th>
<th>O. ruber biomass (kg*10^3)</th>
<th>Biomass of consumed shrimp per day (kg*10^3)</th>
<th>Biomass of consumed prey per day (kg*10^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.04</td>
<td>0.035</td>
<td>338</td>
<td>11.7</td>
<td>12.7</td>
</tr>
<tr>
<td>2</td>
<td>0.014</td>
<td>0.008</td>
<td>3069</td>
<td>25.5</td>
<td>42.5</td>
</tr>
<tr>
<td>3</td>
<td>0.013</td>
<td>0.007</td>
<td>2252</td>
<td>16.4</td>
<td>28.5</td>
</tr>
<tr>
<td>4</td>
<td>0.011</td>
<td>0.001</td>
<td>939</td>
<td>0.95</td>
<td>10.2</td>
</tr>
<tr>
<td>5</td>
<td>0.0096</td>
<td>0</td>
<td>482</td>
<td>0</td>
<td>4.6</td>
</tr>
<tr>
<td>6</td>
<td>0.007</td>
<td>0</td>
<td>221</td>
<td>0</td>
<td>1.6</td>
</tr>
<tr>
<td>Sum Daily consumption</td>
<td></td>
<td></td>
<td>7301</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q/B daily</td>
<td>0.008</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q/B annual</td>
<td>3</td>
<td></td>
<td>54.55</td>
<td>100.1</td>
<td></td>
</tr>
</tbody>
</table>
The greatest number of *O. ruber* stock over the period of 2005 to 2010 was at age-group 1. It decreased in older age-groups reaching the lowest number at age-group 6 (Figure 5A). *O. ruber* stock biomass peaked about age-groups 2 and 3 (Figure 5B). The maximum and minimum daily consumption rate for shrimp and all food items were at age-groups 1 and 6, respectively (Figure 5C).

The peak daily consumption of shrimp (Figure 5D) and all food items (Figure 6), occurred between approximately age-group 2 and age-group 3. No shrimp consumption was observed in age-group 5 and age-group 6.

![Fig. 5: Estimates of *O. ruber* impact on prey by age class for the northwestern part of Persian Gulf. *O. ruber* stock during 2009-2012. Numbers of *O. ruber* (A) and *O. ruber* weight at age were used to calculate *O. ruber* biomass (B). Impact (kg) on prey by each age class (D) was calculated by multiplying *O. ruber* biomass by maximum consumption rate for each age class (C).](image1)

![Fig. 6: Daily consumption rates by *O. ruber* in Khuzestan coastal waters (2002-2012).](image2)

Shrimp consumption by *O. ruber* was much higher than its landing during 2002-2012. The average consumption of shrimp by *O. ruber* was 12,175 t (6,202–21,158 t) from 2002 to 2012 (Figure 7). *O. ruber* biomass does not show inverse relationship with shrimp catch during that period (Figure 8).

![Fig. 7: Estimated biomass of shrimp consumed by *O. ruber* population in Khuzestan coastal waters and harvested by Khuzestan fisheries (2002-2012).](image3)

![Fig. 8: The relationship between *O. ruber* biomass and harvested shrimp in Khuzestan coastal waters (2002-2012).](image4)
The MDS plot showed three distinguished age-groups based on their diet composition with the stress value of 0.01. The smallest size age-group (age 1 year) had different diet composition from other size age groups. The age-groups 2 and 3 had similar diets and were separated from larger size age-groups (age 4, 5, 6 year) (Figure 9).

![Multi-dimensional scaling plot](image)

Fig. 9: Multi-dimensional scaling plot of the similarities in food composition of different age-groups.

4. Discussion

The *O. ruber* in northwestern part of the Persian Gulf feeds on shrimps and fish. The general diet pattern is related to size (age) of the *O. ruber*. The age-group 1 usually fed on shrimps but age-groups 4, 5 and 6 preferred fish in their diet similar to the dietary composition of blue fin tuna which has been shown to be dependent on prey availability and tuna body size. For a number of piscivorous species, prey size increases with increasing predator size. Previous studies of piscivores have found that minimum-sized prey remained relatively constant with increased predator size, whereas the maximum and median prey sizes increased significantly. Prey-predator length ratios generally average 20-30% for piscivores (Butler, 2007).

Comparisons of prey sizes consumed by red drum with sizes occurring in the field indicated that red drum fed in near shore shallow water habitats, which serve as nursery areas for many juvenile fishes and crustaceans. These findings demonstrated that red drum fed on several prey species of commercial and recreational value and might insert important effects on estuarine community structure (Scharf and Schlicht, 2000). There is a positive relation between predator size and prey size, both in penaeid and piscine prey. However, the largest predator size class apparently selected fewer but larger teleostei prey (Krumme et al., 2005). Due to low depth and estuarine condition of the northwestern part of the Persian Gulf, juvenile fishes and shrimps were observed throughout year. Therefore, the young *O. ruber* individuals fed on small shrimps which were available as a frequent prey in the region. The adult *O. ruber* immigrated into the region from autumn to early spring (spawning migration). During this period, the adult *O. ruber* (age-group 4 to age-group 6) mainly fed on fish. However, in this study, larger shrimps were observed in their food items. In addition to size factor, the differences in preferred prey were closely linked to temporal changes in prey availability (Scharf and Schlicht, 2000) because concurrent with the immigration of adult croakers in the region, adult shrimps migrated to deeper zone for spawning.

The MDS plot showed that diet composition was affected by the size. Specimens were divided into three different groups based on their diet. In fact young *O. ruber* preferred shrimp but with increasing size they started to consume fish and in larger *O. ruber* fish dominated the diet. Finally, the diet of the largest size class was only fish.

The estimated “Q/B” based on the VPA was lower than its estimation with PauLy and Palomares model (1998). This difference could be result of underestimation of the “Q/B” of adult fishes in the VPA. Since, species have different growth rate, “Q/B” was different among species so in general, “Q/B” has an inverse relationship with Linf and trophic level (Angelini and Agostinho, 2005). Fish with high growth rates reach their Linf at faster rates and "Q/B" value is higher in older individual (fish). Therefore, the "Q/B" values in younger age-groups of *O. ruber* are higher than older age-groups because the growth rate of younger age-groups are higher than older age-groups.
Moreover, in some years the "Q/B" value of \(O.\ ruber\) is lower than other years which could be due to the population structure of \(O.\ ruber\).

We know that fish eat shrimps and that many small demersal fish feed on organisms are also consumed by shrimps. Thus, generally speaking, fish are both the predators and the competitors of shrimps, while both fishes and shrimps are prey of a demersal fishery. The demersal fishery, by offsetting the natural balance between shrimps and fishes, can indirectly increase the survival of shrimps by removing their predators and competitors. In Gulf of Thailand, recruitment of shrimp stocks is determined solely by biological and fishery-induced changes in biomass and species composition, and not, as in temperate waters, predominantly by fluctuations in the abiotic environment (Pauly, 1982). Over 50 years of research on Arcto-Norwegian cod feeding in the Barents Sea indicated that cod predation was one of the most important factors influencing northern shrimp population dynamics. Analysis of the Russian-Norwegian cod stomach data base showed that cod at age 3-6 have the strongest impact on the Barents Sea shrimp stock and preferred to consume shrimp with a total length range of 5-10 cm (Berenboim et al., 2000). In another study, the timing of both the increase in the shrimp stock and the decline in the cod stock remained unclear and there was considerable uncertainty in the estimates of consumption of shrimp by cod (Lilly et al., 2000). In Massachusetts (USA), coastal waters most consumption by individual striped bass of ages 3–8 came from crustaceans and fish (Nelson et al., 2006). The direct impacts of predators on prey required that predator and prey overlap in time and space and that prey was available for capture during that time (Bax, 1998). The per capita feeding rate on shrimp was highest for cod in the 63-71 cm length-group, but population consumption of shrimp was highest in the 45-53 cm group. The rate of consumption of shrimp by cod was calculated to be 57 tons per day (Lilly et al., 2000). The diversity of \(O.\ ruber\) preys was increased with increasing age and food sources were formed from different species of fish and shrimp, but it decreased in older age-groups. The age-group 2 had the most impact on prey population. It appeared that the different age classes had different impact rates on population of their prey. Buckel et al. (1999) suggested the same result about bluefish.

The fluctuation of fish populations may be affected by prey density and many other factors (Liu et al., 2006). Comparison of annual shrimp consumption by \(O.\ ruber\) and shrimp landing during 2002-2012 showed that the prey abundance did not influence the population of predators because the low abundance of shrimps led to changes in dietary composition and consumption of other food items. In some species (Carcharhinidae), prey density might not be the factor affecting variations of predator abundance (Liu et al., 2006). Various factors affected population variations of \(O.\ ruber\). However, it could not be concluded that young \(O.\ ruber\) preferred shrimp in their diet. The relation of consumption to stocked biomass in the young fishes were more than that of older age-groups. Age-group 2 had the most effect on shrimps but shrimp frequency did not have significant influence on \(O.\ ruber\) variations.

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