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TROPHIC ECOLOGY OF SCIAENID FISH (*Otolithes ruber*) AND SPARID FISH (*Acanthopagrus arabicus*) IN THE NORTHWEST OF THE ARABIAN GULF

Abdul-Razak M. Mohamed* and Ali H. Al-Hassani

Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Iraq

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Abstract: Feeding habits of the tigertooth croaker, *Otolithes ruber* (Bloch & Schneider, 1801) and the Arabian yellowfin seabream, *Acanthopagrus arabicus* (Iwatsuki, 2013) in the Iraqi marine waters, northwest Arabian Gulf were considered from February 2020 to January 2021. Stomach contents of 327 *O. ruber* ranged between 17 and 60 in total length, and 318 *A. arabicus* ranged between 13 and 41 cm were analyzed and quantified with numerical and gravimetric methods, as well as with some complementary indices to the vacuity, the fullness, the relative importance and the similarity. The lowest and highest feeding activity values for both species were recorded in autumn and spring, respectively, while the lowest feeding intensity values were in winter for *O. ruber* and in summer for *A. arabicus*, and the highest for both species were in autumn. The annual values of the feeding index (%) for both species were 53.3±8.3 and 46.1±11.0, respectively, and of the vacuity index (%) were 58.8±17.4 and 41.7±8.3 for both species, respectively, so both species can be classified as middle alimentary. The results revealed that both species are carnivores. *O. ruber* preyed on fish (82.2%) and shrimp (17.5%), and *A. arabicus* on fish (56.1%), snails (28.3%), crabs (7.9%) and shrimp (7.8%). The similarity among diets of both species showed good similarity (Cλ= 0.75), where both of them were characterized by a high intake of fish.

Keywords: *Otolithes ruber and Acanthopagrus arabicus, feeding activity, diet composition, Arabian Gulf, Iraq.*

INTRODUCTION

Data on feeding habits in aquatic ecosystems are of great importance in determining the role that a certain fish species plays in its habitat and related ecosystems, as fish like other organisms require energy for proper growth, development, reproduction and their various physiological activities (Peyami, 2018). The estuary ecosystem is rich in organic matter, solutes, and nutrients, representing an important site for material exchange with the atmosphere, associated wetlands, and especially the sea, due to the marine-freshwater interaction (Silva *et al.*, 2022).

The tigertooth croaker *Otolithes ruber* (Bloch & Schneider, 1801) belongs to the Sciaenidae family, which is widely distributed throughout the world and has 564 species belonging to 129 genera (Fricke *et al*., 2023). The species inhabits the Arabian Gulf and Oman Sea, the Indian and Pacific Oceans, China and the Malayan archipelago (Nelson *et al*., 2016). *O. ruber* is a demersal fish that contributes significantly to Iraqi marine fish landings, landing about 1,137 t in 2021 and forming 8.3% of the total landings (Mohamed and Abood, 2023).

The Arabian yellowfin seabream, *Acanthopagrus arabicus* (Iwatsuki, 2013) is a member of the family Sparidae. To date, 440 species belonging to 89 genera have been ascribed to this family (Fricke *et al*., 2023). *A. arabicus* is common and widely distributed in the western Indian Ocean: Arabian Gulf and Oman east to Pakistan and India (Iwatsuki, 2013; Siddiqui *et al*., 2014; Parenti, 2019). The individuals of *A. arabicus* inhabit the Iraqi marine waters, and their juveniles enter the rivers and marshes of southern Iraq for feeding (Al-Daham *et al*., 1993; Hussain *et al*., 2001; Mohamed *et al*., 2009). The landing of this species in the Iraqi marine fisheries was reported as 976 t in 2021, 7.0% of the total landings (Mohamed and Abood, 2023).

The feeding ecology of *O. ruber* has been studied by different authors at different localities (Nair, 1980, in Calicut waters, India; Pillai, 1983 in Porto Novo coast, India; Ali *et al*., 1993, in the northwestern Arabian Gulf; Azhir, 2008, in Oman Sea and north Arabian Gulf; Fennessy, 2000, in the KwaZulu-Natal coast, South Africa; Hussain *et al*., 2007, in the northwestern Arabian Gulf; Eskandari *et al*., 2012 in the northern Arabian Gulf; Simanjuntak *et al*., 2022 in Pabean Bay, Indonesia). Also, several studies on diet composition and trophic ecology of *A. arabicus* have been done in different waters (Hussain *et al*., 1993, in Khor Al-Zubair, Iraq; Hosseini, 1998, in the northern Arabian Gulf; Taher, 2010, in the Shatt Al-Basrah Canal, Iraq; Sourinejad *et al*., 2015 and Vahabnezhad *et al.*, 2016, in the northern Arabian Gulf; Riaz, 2019, in Karachi coast, Pakistan; Mohamed and Abood, 2021, in the Shatt Al-Arab River, Iraq; Ahmed *et al*., 2022, in the coastal waters of Pakistan).

The present work aims to describe the seasonal variations in the feeding intensity and activity, the percentage of empty stomachs and the diet composition of *O. ruber* and *A. arabicus* in the northwest of the Arabian Gulf and to determine the similarity in their diet.

MATERIALS AND METHODS

Fish Sampling

Fish specimens in the present study were collected from Iraqi marine waters in the northwest Arabian Gulf from February 2020 to January 2021, except April. The region is the estuary of the large rivers Euphrates, Tigris and Karun through the Shatt Al-Arab River (Pohl *et al*., 2014). Samples of fish were collected monthly from the Shaheen steel-hulled dhow (21 m length, 7 m wide and 2m draft with a horsepower of 150 horses). In addition, fish were purchased from the artisanal fishermen at the main fish landing site in Al-Fao port. Subsamples of fish were immediately preserved in crushed ice before dissection in the laboratory.

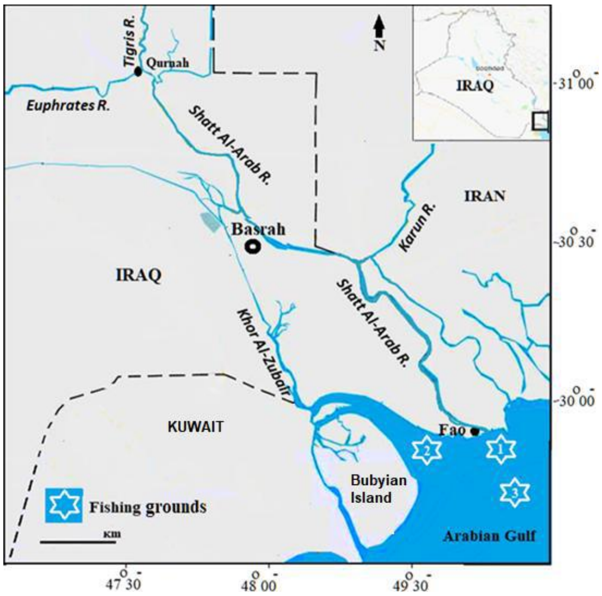

Fig. 1: Map of the northwest Arabian Gulf with locations of study sites.

Data Analysis

After recording total length to the nearest mm and body weight to the nearest gm, the fish were dissected for stomach content analyses. An important fact assessed by examination of the stomach is the fullness of the stomach. This is judged by the degree of distension of the stomach. The degree of stomach fullness was divided into five groups; empty, ¼ full, ½ full, ¾ full and full stomachs and scores were given from 0 (empty) to 20 (full) according to Hynes (1950).

The monthly feeding intensity was calculated from the fullness index based on the following formula (Dipper *et al*, 1977):

Feeding intensity= Sum of the fullness index scores/Number of fish fed x 100

Feeding activity It represents the percentage of feeding fish of the examined fish (Gordan, 1977):

Feeding activity= Number of fish fed/Total number of fish examined x 100

The percentage of empty stomachs to the total number of examined stomachs was expressed as the vacuity index, VI (Maia *et al*., 2006):

VI= Number of empty stomachs/Number of examined stomachs x 100

The interpretation of the obtained VI is determined under the following conditions (Euzen, 1987). If, $0 \leq VI < 20$, the logical conclusion is that the fish is gluttonous, $20 \leq VI < 40$, the fish is comparatively gluttonous, $40 \leq VI < 60$, the fish is middle alimentary, $60 \leq VI < 80$, the fish is comparatively hypo-alimentative, $80 \leq VI < 100$, fish is hypo-alimentative.

The feeding index was calculated after Sarkar and Deepak (2009):

Feeding Index= P/N x X x 100,

where; P= Total points of the stomachs that were examined, N= Number of stomachs examined and X= Total points allotted to the full stomachs.

The contents of each stomach were excised, and the items were identified to their lowest possible taxonomic levels. The dietary categories were fish, shrimp, crabs and snails. Based on prey items, the percentage of points (P%) and frequency of occurrence (O%) were calculated following Hyslop (1980).

To determine the main food items, the index of relative importance (%IRI) proposed by Pinkas *et al*. (1971) and modified by Stergion (1988) was used as follows:

IRI= O% × P%

This index has been expressed as: %IRI= (IRI/∑IRI) x 100

Feeding selectivity (PX_i) was measured according to the following equation (Lawlor, 1980):

$$PX_i = X_i / \Sigma\, i$$

where X_i = quantity of item (i) in the stomach of specie (i) and Σ i= sum of the item (i) in all stomachs of all species.

The similarity among diets of the two species in the study region was evaluated according to the Jaccard similarity index using the SPSS software (ver. 16) statistical package.

RESULTS

The monthly stomach contents of 327 *O. ruber* ranged between 17 and 60 in total length, and 318 *A. arabicus* ranged between 13 and 41 cm were examined in the present study. Also, the monthly data on the feeding parameters of both species were grouped to describe the seasonal variations in the feeding intensity and activity, feeding and vacuity indices, percentage of empty stomachs and the food habits of the two species. The seasons were spring (March-May), summer (June-August), autumn (September-November) and winter (December-February).

Feeding intensity and feeding activity

Figures 2 and 3 illustrate the monthly fluctuations in the feeding intensity and activity of *O. ruber* and *A. arabicus* in this study. The feeding intensity of *O. ruber* changed from 8.1 points/fish in February to 13.2 points/fish in August, while *A. arabicus* fluctuated from 8.2 points/fish in February to 9.4 points/fish in July. The lowest value of the feeding intensity of *O. ruber* was observed in winter (9.0 points/fish), and the highest was 12.0 points/fish in autumn, while for *A. arabicus* ranged from 8.7 points/fish in summer to 11.1 points/fish in autumn (Table 1). The annual averages of the feeding intensity (9.0 points/fish) for *O. ruber* and *A. arabicus* were 10.7 ± 1.7 and 9.4 ± 1.9 points/fish, respectively.

The feeding activity of *O. ruber* varied from 16.7% in October to 70% in February, and *A. arabicus* fluctuated from 26.7 % in October to 91.3% in February. The mean values of the feeding activity of both species were 40.3 and 58.3%, respectively. The lowest values of the feeding activity of *O. ruber* and *A. arabicus* were recorded during autumn, 30.0% and 49.0%, respectively and the highest values were detected during spring, 41.1% and 75.2%, respectively (Table 1). The annual averages of the feeding activity (%) for *O. ruber* and *A. arabicus* were 40.3 ± 15.3 and 58.3 ± 20.1 points/fish, respectively.

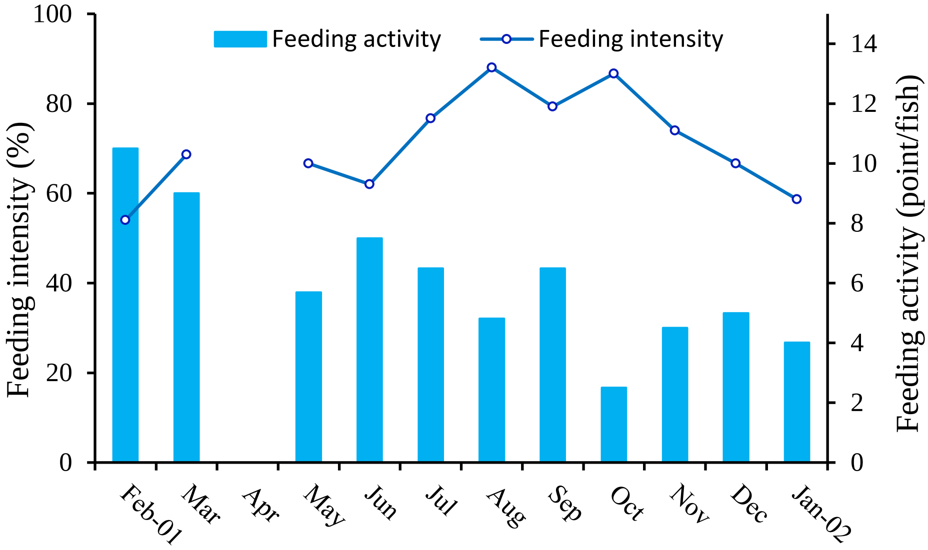

Fig. 2: Monthly variations in feeding activity and intensity of *O. ruber*

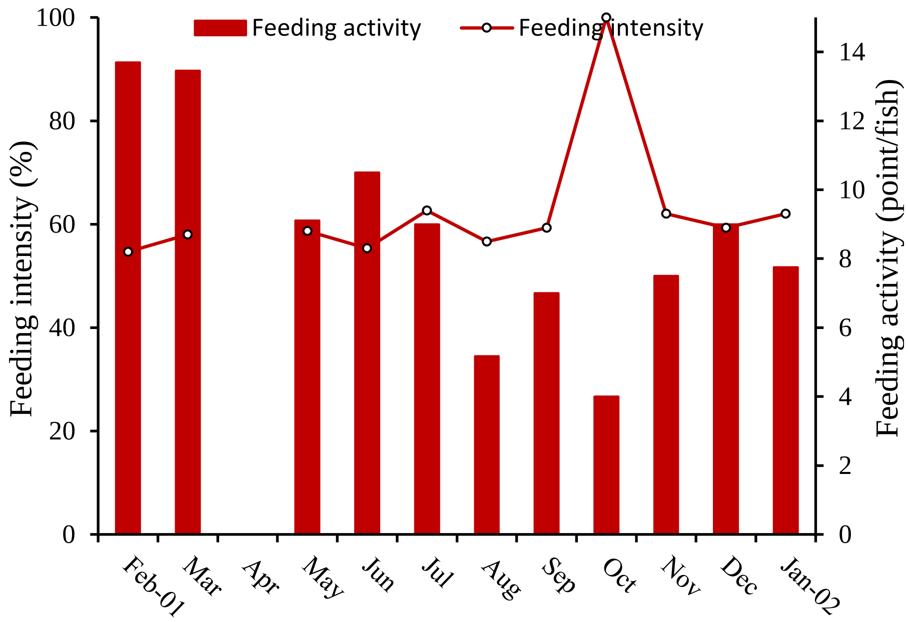

Fig. 3: Monthly variations in feeding activity and intensity of *A. arabicus*

***Corresponding Author:** Abdul-Razak M. Mohamed

Table 1. Seasonal variations in the feeding parameters of *O. ruber* and *A. arabicus*

Species	Winter	Spring	Summer	Autumn
O. ruber				
Feeding activity	43.3	49.0	41.8	30.0
Feeding intensity	9.0	10.2	11.3	12.0
Feeding index	44.8	50.7	56.8	60.1
Vacuity index	53.3	51.1	58.2	70.0
A. arabicus				
Feeding activity	67.7	75.2	54.8	41.1
Feeding intensity	8.8	8.8	8.7	11.1
Feeding index	47.0	43.7	42.1	50.7
Vacuity index	32.3	24.8	45.2	58.9

Feeding and vacuity indices

The monthly variabilities in the feeding and vacuity indices of *O. ruber* and *A. arabicus* in the study region are explained in Figures 4 and 5. The feeding index of *O. ruber* fluctuated from 40.5% in February to 66.1% in August, and for *A. arabicus* varied from 30.4% in September to 50.0% in February. The seasonal change in the feeding index of *O. ruber* varied from 44.8% in winter to 60.1% in autumn, and for *A. arabicus* fluctuated from 42.1% in summer to 50.7% in autumn (Table 1). The annual averages of feeding index (%) for both species were 53.3 ± 8.3 and 46.1 ± 11.0, respectively.

The vacuity index of *O. ruber* ranged from 20% in February to 83.3% in October, and for *A. arabicus* varied from 8.7% in February to 73.3% in October. The lowest values of the vacuity index (VI) of *O. ruber* and *A. arabicus* were detected during spring, 51.1% and 24.8%, respectively, and the highest values were observed during autumn, 70.0% and 58.9%, respectively (Table 1). The annual averages of this index (%) for both species were 58.8 ± 17.4 and 41.7 ± 8.3, respectively. It means that both species can be classified as middle alimentary.

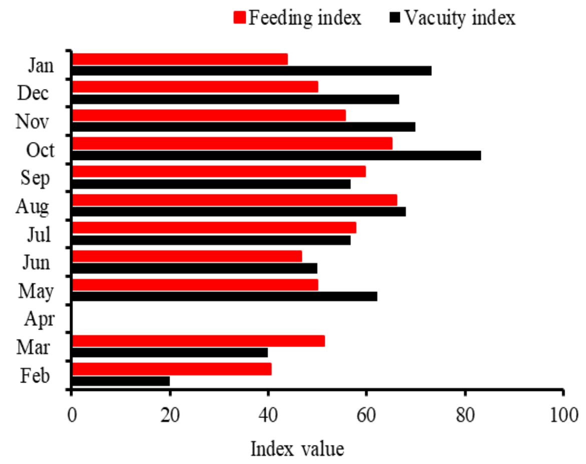

Fig. 4: Monthly variations in the feeding and vacuity indices of *O. ruber*

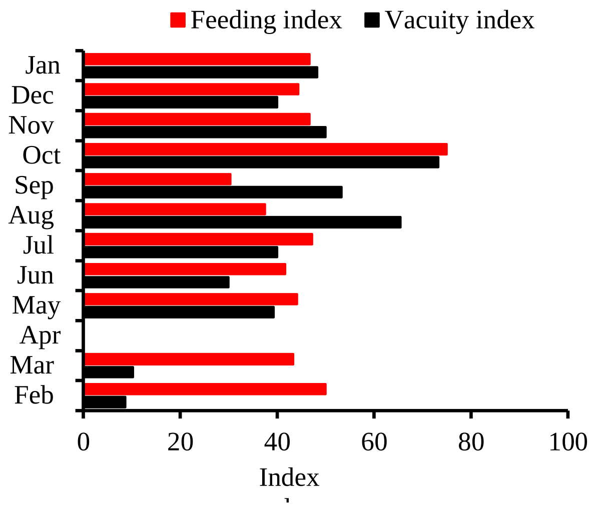

Fig. 5: Monthly variations in the feeding and vacuity indices of *A. arabicus*

Food habits

The index of relative importance (IRI%) of the different food items in the stomachs of both investigated species based on the point method (P%) and frequency of occurrence method (O%) are illustrated in Figure 6.

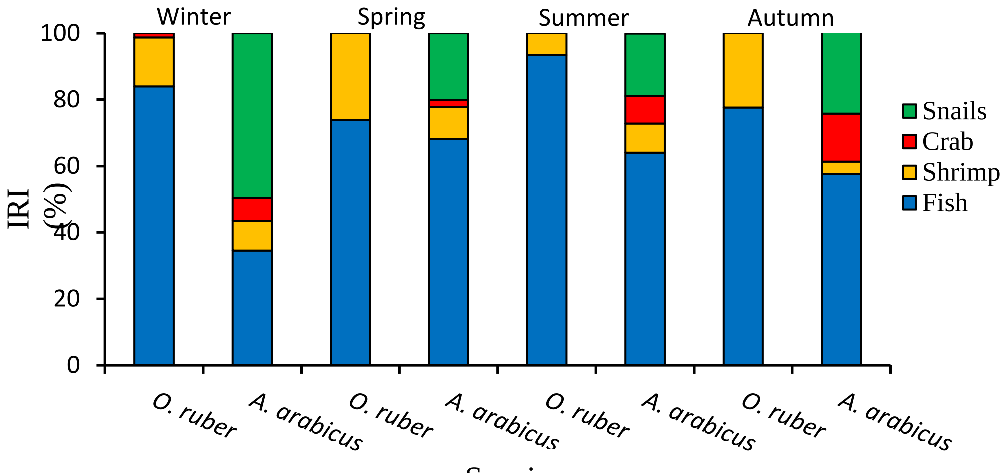

Fig. 6: Seasonally changes in the relative importance index (IRI%) of food items in the diet of *O. ruber* and *A. arabicus*

The results of the food habits revealed that *O. ruber* preyed mainly on fish, where the lowest value was recorded in spring (73.9%), and the highest value was 93.4% in summer. Shrimps existed in the food content of the species throughout the seasons, where the highest value (26.1%) was observed in spring and the lowest value (6.6%) in summer. Crabs were found in winter only and formed 1.3%. Generally, *O. ruber* primarily preyed on fish (82.2%) and shrimp (17.5%) and was classified as a carnivore.

According to Figure 4, the preys that dominated the stomach contents of *A. arabicus* based on the results of the index of relative importance were fish, snails, crabs and shrimps. Fish were also prominent in the food items of the species varying from 34.5% in winter to 68.2% in spring (Fig. 6). The second most important food item was snails constituting 18.8% in summer and 49.7% in winter. Crabs were another food item and were always found in the stomach of the species fluctuating from 2.1% in spring to 14.5% in autumn. The other food item included shrimps varying from 3.7% in autumn to 9.5 in spring. Generally, the species consumed mainly fish (56.1%), snails (28.3%), crabs (7.9%) and shrimp (7.8%) and can be categorized as carnivores.

Feeding selectivity index

Fish was the most selected food item with the maximum value of the index (52.2%), with the extreme value (58.3%) for *O. ruber* (Fig. 7). Shrimps were the second most selected food item (22.4%), with the peak value (61.9%) observed for *O. ruber*. Snails came third in the value of the index (21.2%), with the maximum value (100%) for *A. arabicus*. Finally, crabs arranged fourth (9.9%) with the highest value (94.6%) for *A. arabicus*.

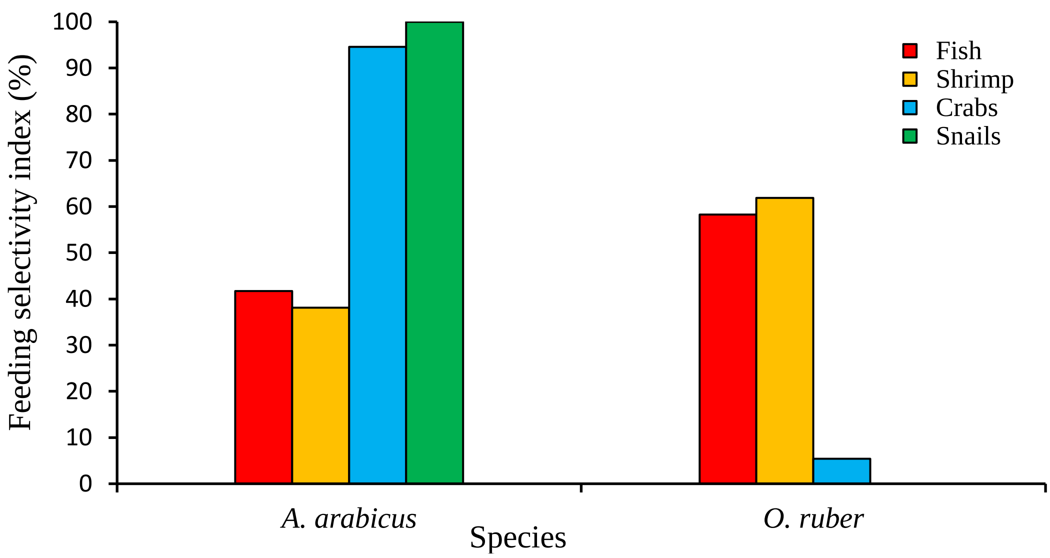

Fig. 7: Feeding selectivity index for the different food items of *O. ruber* and *A. arabicus*

***Corresponding Author:** Abdul-Razak M. Mohamed

The Jaccard similarity coefficient showed good similarity (Cλ= 0.75) between the food items of the two species, which was characterized by a high intake of fish and shrimp by *O. ruber*, and fish, snails, crabs and shrimp by *A. arabicus.*

DISCUSSION

Food is one of the key factors that greatly influence the biological characteristics of fish such as distribution, growth, reproduction, migration and other activities of fish, so the fish feeding ecology is thoroughly linked to the subjects of resource partitioning, habitat preferences, prey selection, interspecific competition, and energy transfer within the ecosystem (Braga *et al*., 2012; Priyadharsini *et al*., 2012; Ramana and Manjulatha, 2014).

Results from our study reveal that *O. ruber* and *A. arabicus* were continuous feeders and never ceased feeding all year round, despite notable monthly and seasonal variabilities in their feeding activities and intensities. The highest values of the feeding activity of both species were recorded during spring, and the maximum values of the feeding intensity were observed during autumn. The periods of intense feeding activity correspond with the appropriate ambient water temperature and the availability of preferred prey in the environment. This assumption broadly agrees with the thermophiles fish growth model from seas of medium geographic latitudes with the lowest growth rate in winter due to the temperature-dependent physiological process and lesser abundance of prey (Santic *et al*., 2005). The study region receives huge amounts of fluvial input via the Shatt Al-Arab River, which historically plays an important role in providing the northwestern Arabian Gulf with nutrient-rich freshwater (Al-Yamani, 2021) and serves as a major spawning, feeding and nursery ground for several economically important marine species (Hussain and Ahmed, 1995; Al-Yamani, 2008). Water temperature is one of the most important environmental variables affecting the distribution and abundance of different fish species, and feeding activity and food consumption are affected by temperature (Chorbley, 2011). Okgerman *et al.* (2013) stated that the water temperature is the principal environmental factor affecting the gut fullness of fish. Volkoffa and Rønnestad (2020) stated that the impacts of temperature on feeding vary depending on species, but usually, voluntary food intake increases with moderate temperature increases and decreases when temperatures are outside the fish's optimal temperature range. Lagler *et al*. (1977) indicated that the importance of shrimps in diet composition may be due to their abundance and nutritional profitability. Ye and Mohammed (1999) observed high catchability at the beginning of the shrimping season (August-September) and between December and February and attributed the reason to the schooling behaviour and inshore movement of adults to spawn in the region. Due to the low depth and estuarine condition of the northwestern part of the Arabian Gulf, juvenile fish and shrimps were observed throughout the year (Eskandari *et al*. 2012).

However, Nair (1980) mentioned the predominance of poorly fed fish in almost all the months of observation ruled out any seasonal intense feeding activity of *O. ruber* in the Indian waters. Sourinejad *et al.* (2015) showed that the heaviest stomachs and subsequently, the highest feeding activity of *A. arabicus* in the northern region of the Arabian Gulf occurred in autumn and reduced during the summer. Vahabnezhad *et al*. (2016) found that *A. arabicus* fed throughout the year in the northern Arabian Gulf, but feeding intensity was variable with the highest intensity occurring in February. Riaz (2019) mentioned that *A. arabicus* has active feeding during autumn, winter and spring on the Karachi coast, Pakistan, and moderate feeding during summer. Ahmed *et al.* (2022) cited that the maximum value of feeding activity of *A. arabicus* in the offshore waters of Pakistan observed in summer is associated with temperature and higher abundance of benthic organisms.

The results showed that the lowest values of the vacuity index (VI) were during spring and the highest values during autumn for both studied species, and the annual average values of the index were 58.8% and 41.7% for *O. ruber* and *A. arabicus*, respectively, so they classified as middle alimentary species according to Euzen (1987). In general, the percentage of empty stomachs of both species was relatively high compared to previous studies results, which could be attributed to excessively long fishing periods during which digestion continues. Pillai (1983) found that the food intake of *O. ruber* in Porto Novo, India was intense in lower size groups (8.1-12.0 cm), poor feeding conditions in the intermediate size groups (15.1-19.0 cm) and exhibited more or less moderate feeding in the larger size groups (21.1-25.0 cm). Hussain *et al*. (2007) found that the vacuity index of *O. ruber* in Iraqi marine waters ranged from 22.0 to 56.2% with a mean annual value was 31.0%. However, Nair (1980) stated that the percentage of empty stomachs of *O. ruber* in the Indian waters was high and showed no regular periodicity, while Fennessy (2000) mentioned that the percentage of empty stomachs of *O. ruber* on the KwaZulu-Natal coast, South Africa was 63.7% of stomachs. Hosseini (1998) stated that the vacuity index of *A. arabicus* was calculated to be 0.13 in the northern region of the Arabian Gulf and classified as an active predator. Moreover, Sourinejad *et al.* (2015) found that the vacuity index of *A. arabicus* in the same region was 30.1% and categorized as comparatively gluttonous. Riaz (2019) stated that the highest percentage of empty stomachs was observed during summer for the species on the Karachi coast, Pakistan.

The present study revealed that the *O. ruber* was carnivorous in its diet, preying primarily on fish and shrimps. This is consistent with other studies on the species in some waters, but the proportion of shrimps consumed was more than fish in the diet of the species such as in the Indian waters (Suseelan and Nair, 1969; Nair, 1980; Pillai, 1983), the Arabian Gulf (Hussain *et al*., 2007; Eskandari *et al*., 2012) and the east coast of South Africa (Fennessy, 2000). However, Ali *et al.* (1993) and Azhir (2008) found that *O. ruber* preyed mainly on fish in the Iraqi marine waters, Arabian Gulf and in Oman Sea along Sistan and Baluchistan Province, respectively, while Simanjuntak *et al.* (2022) mentioned that *O. ruber* fed mainly on shrimps and the species was a high specialist consumer in Pabean Bay, Indonesia.

A. arabicus was also carnivorous in the present study but consumed mainly fish, snails, crabs and shrimp. Generally, these food items of *A. arabicus* were also noted by several authors in different waters as food preferences by the species. Al-Daham *et al.* (1993) found that immature species consumed crustaceans, fish, molluscs, algae, higher plants and insects in the Shatt Al-Basrah Canal, Iraq. Hussain *et al.* (1993) noted that the species fed on bivalves, isopods, amphipods, crabs, shrimps and fish in Khor-Al-Zubair, Iraq. Crabs, fish, shrimps and snails were the main food items preyed on by the species in the northern region of the Arabian Gulf (Hosseini, 1998). Hussain *et al.* (2001) stated that the juveniles and immature species preyed on shrimps, fish, insects, isopods and crabs in Khor-Al-Zubair, Iraq. Hussain *et al.* (2009) mentioned that the diet of this species in southern marshes consisted of crustaceans, snails and fish. Mohamed and Hussain (2012) found that the species preyed mainly on shrimps (60%) and insects (40%) in the East Hammar marsh, Iraq. Sourinejad *et al*. (2015) and Vahabnezhad *et al*. (2016) declared that the food items of the species in the northern Arabian Gulf were bivalves, shrimps, crabs and cephalopods. Moreover, Riaz (2019) stated that *A. arabicus* on the Karachi coast, Pakistan preyed on fish, shrimps, crabs, bivalves, gastropods and cephalopods. Mohamed and Abood (2021) found that the species consumed mainly shrimps (38.4%) followed by crabs (20.2%), crustaceans (12.9%), snails (10.8%) and insects (10.2%) in the Shatt Al-Arab River.

Several authors postulated that shrimps and fish constituted a stable food supply for many fish predators in Iraqi marine waters (Ali *et al*., 1993; Hussain *et al*., 2001; Hussein *et al*., 2001; Hussain *et al*., 2004; Mohamed *et al*., 2004; Hussain *et al*., 2007; Mohamed *et al*., 2007; Mohamed and Abood, 2020; 2021). The estuaries are complex and dynamic hydrological environments and are considered one of the most productive areas in the biosphere (Filho *et al*., 2020). It is generally known that fish preferentially consume the most abundant prey in the environment. Ahmed and Hussain (2000) mentioned that Iraqi marine waters are nurseries and feeding grounds for many juveniles and young marine fish. Moreover, Mohamed *et al.* (2002) considered these waters one of the essential shrimp fishing grounds in the Arabian Gulf (shrimps species constituted about 20% of the total catch) and this ratio was more than the ratio of the commercial fish species (18.4% of the total catch). Due to the low depth and estuarine condition of the northwestern part of the Arabian Gulf, juvenile fish and shrimps were observed throughout the year (Eskandari *et al*. 2012). Recently, Mohamed and Abood (2023) stated that shrimps species formed 16.1% of the total landings during 2021 by the Iraqi artisanal marine fisheries in the northwest Arabian Gulf, which is the highest percentage compared to the ratio of other fish species. The abundance of shrimps could be attributed to the fact that they inhabit estuaries (Khan *et al.*, 2001). The seasonal use of estuaries by migratory fish and crustaceans has been postulated to reduce the competition for food and space (Mariani *et al.* 2002).

Despite both species consuming mainly fish and shrimp but the analysis of food similarity between them showed no high similarity in their food items, which was characterized by a high intake of fish and shrimp by *O. ruber*, and fish, snails, crabs and shrimp by *A. arabicus*. These species might not be directly competing for food in the study waters. The seasonal use of estuaries by migratory fish and crustaceans has been postulated to reduce the competition for food and space (Mariani *et al.* 2002).

CONCLUSION

This study has revealed that despite both species consuming mainly fish and shrimp, but the analysis of food similarity between them showed no high similarity in their food items, which was characterized by a high intake of fish and shrimp by *O. ruber*, and fish, snails, crabs and shrimp by *A. arabicus*. These species might not be directly competing for food in the study waters.

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***Corresponding Author:** Abdul-Razak M. Mohamed

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***Corresponding Author:** Abdul-Razak M. Mohamed