## **Research Article**

# Feed comparison and feeding ecology in five sympatric teleost species of the northern Oman Sea

## Alimohammadi M.1; Valinassab T.2\*; Ramezani- Fard E.1; Ehteshami F.<sup>2</sup>

Received: March 2020 Accepted: May 2020

#### **Abstract**

Investigating the relations and mechanisms of coexistence among sympatric species is essential to comprehend their ecological roles in the food webs. In the present study, the diet and trophic interactions of 5 abundant teleost species coexisting in the northern Oman Sea were examined using stomach contents analyses. The cumulative prey curves showed that the sample size of each studied species was large enough to clarify the general dietary preferences. The vacuity indices of Netuma thalassina, Plicofollis dussumieri and Otolithes ruber were less than 50%, indicating the comparatively gluttonous behavior of these species, while the estimated vacuity indices of Lutjanus johnii and Carangoides malabaricus were more than 50%. Assessment of %IRI (index of relative importance) revealed that diets of N. thalassina, O. ruber and C. malabaricus were similar and consisted mostly of teleost fishes followed by crustaceans. Conversely, P dussumieri and L. johnii mostly fed on crustaceans followed by teleost fishes. Results showed that P. dussumieri and L. johnii occupied an intermediate trophic level, whereas N. thalassina, O. ruber and C. malabaricus occupied high trophic levels, placing them as top predators in the food web. In total, analyses indicated that there were no significant differences in diets between these 5 teleost species.

**Keywords:** Feeding ecology, Oman Sea, Sympatric species, Teleost fish

<sup>1-</sup>Department of Marine Biology, Tehran Science and Research Branch, Islamic Azad University, Tehran, Iran.

<sup>2-</sup> Iranian Fisheries Science Research Institute, Agricultural Research Education and Extension Organization (AREEO), P.O. Box: 19395-1113. Tehran, Iran.

<sup>\*</sup>Corresponding author's Email: t\_valinassab@yahoo.com

## Introduction

Knowledge habits of feeding is important for understanding ecological role and productive capacity of fish populations and understanding these processes is crucial to of development conservation and ecosystem-based management plans (Teixeira and Cortes, 2006). Food is an important limiting factor in determining competition between species in fish populations (Farooq et al., 2017). Species with similar feeding habits could compete with each other if they co-occur in a similar habitat. However, species coexist in the natural environment due to differences in their for feeding search food, reproduction, currents, and diurnal migrations. Pianka (1969) noted that separation may occur due to habitat, food and time. Prey-predator assembly is becoming increasingly familiar with the marine ecosystem (Persson et al., 1992; Vander Zanden et al., 1999).

Ariids, Carangids, Sciaenids and Lutianids are abundant species groups found in the northern Oman Sea. They contribute to a large portion in terms of biomass to the overall fish catch (Valinassab et al., 2006). Several studies have been carried out regarding their feeding habits in the Persian Gulf and the Oman Sea (Karimi et al., 2012; Cheraghi Shevi et al., 2013; Pourbabaie et al., 2013; Vahabnezhad, 2015; Taghavi Motlagh et al., 2015; Kamali et al., 2016; Behzadi, 2016; Ghorbani Ranjbari et al., 2016; Abdi and Ghazizadeh, 2019; Mohseni, 2019; Hashemipour et al., 2019). However, the comparative diets

of these teleost species have yet to be studied.

In the present study, the stomach contents of *Netuma thalassina* and *Plicofollis dussumieri* (Ariids), *Otolithes ruber* (Sciaenids), *Lutjanus johnii* (Lutjanids) and *Carangoides malabaricus* (Carangids) have been analyzed to characterize their diets and examine the comparative dietary of these five sympatric teleost species in the Oman Sea that could shed new light on what might allow these species to coexist.

#### Materials and methods

Study area

The present study was conducted in the northern part of the Oman Sea between latitudes 24° 15' N and 25° 17' N and longitudes 58° 50' E and 61° 25' E (Fig.1). The Oman Sea, with an area of 94,000 km<sup>2</sup> connects the Persian Gulf to the north-west Arabian Sea and then to the Indian Ocean. It borders on the north, Iran and Pakistan, in south Oman and the United Arab Emirates on the west. It is relatively deep, with a depth of more than 1,000 m in 3/4 of its waters (Reynolds, 1993), and reaches to a maximum depth of 3400 m (Valinassab et al., 2006). The coastal waters of Oman are described by one of the most intense coastal upwelling phenomena globally (Reynolds, 1993; Al-Hashmi et al., 2010). The monsoonal regime controls the wind-driven circulation of the mixed layer, with the frequent formation of cyclonic and anti-cyclonic eddies influencing the vertical flow of nutrientrich and low-oxygen subsurface waters. In the northern Oman Sea, in particular, such vertical motions of water cause a strong variability in the temperature of the water, stronger temperature variations between March and October, and the temperatures between November and February relatively cooler and less variable (Al-Hashmi *et al.*, 2010). The sub-surface water temperature (8 m depth) ranges on average from 23°C in

February to 33°C in June (Al-Hashmi *et al.*, 2010).

## Sample collection

All samples were collected seasonally between February and October 2017 during day-time from bottom-trawling cruises (R/V Ferdows1) and landing sites on the entire coast of the northern Oman Sea (Fig. 1).

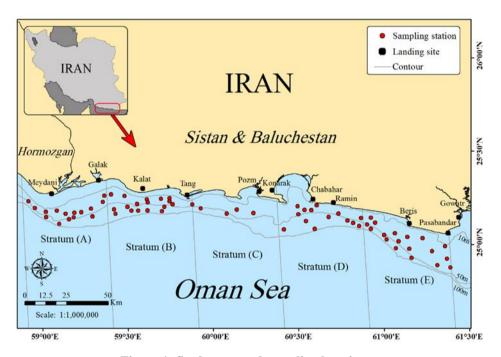


Figure 1: Study area and sampling locations.

## Stomach content analysis

Before removing the stomachs, the total body weight (W) was weighed to the nearest 0.1 g. Then the stomachs of the specimens were weighed, and the stomach contents were recovered during the laboratory dissections. Most of the samples were adult with few juvenile ones. All recovered prey parts were separated, identified as the lowest possible taxon (Asadi and Dehghani, 1996; Carpenter *et al.*, 1997; Jereb and

Roper, 2005), counted, and weighed to the nearest 0.1 g. In order to avoid overestimation of the occurrence of a particular prey item, the number of individuals of each type of prey was determined to be the least number from which these fragments could have originated. The stomach contents data were merged into eight functional groups (teleosts, crustaceans, cephalopods, gastropods, bivalves,

polychaetes, echinoderms, and algae), and the vacuity index was calculated as:  $VI=(ES/TS) \times 100$  (1)

Where, ES is the number of empty stomachs and TS the total number of stomachs being examined (Hyslop, 1980).

whether a In order to assess sufficient number of individuals have been sampled for each species, the cumulative mean number of functional prey groups was plotted against the cumulative number of stomachs analyzed for each teleost species (Ferry and Caillet, 1996). Magurran (2004) noted that adequate sample size was if assumed the resulting approached the asymptote and showed a reduction in variability.

In this study, the composite index of relative importance (IRI) was used to describe fish diets and to determine the relative importance of the common food categories (Pinkas *et al.*, 1971; Prince, 1975) of each teleost species, in other words, and to allow interspecific comparisons as follows:

$$IRI_i = FO_i\% \times (N_i\% + W_i\%) \qquad (2)$$

Where,  $FO_i$  is the frequency of occurrence of a specific functional prey group ( $_i$ ) in relation to the total number of stomachs,  $N_i$  is the contribution of the type of prey group ( $_i$ ) in relation to the total content of the stomach and  $W_i$  is the weight of the prey group ( $_i$ ) in relation to the total content of the stomach (Ugwumba and Ugwumba, 2007).

IRI values have been expressed as a percentage to allow comparisons between prey groups and species (Cortés, 1997):

$$IRI_{i}\% = 100 \times IRI_{i} / \sum_{i=1}^{n} IRI_{i}$$
 (3)

Statistical analysis

The feeding strategy for each of the five teleost species was defined by plotting the prey-specific abundance of the prey groups against FO% (Amundsen et al., 1996). Prey-specific abundance was determined to be the number of prey (i) divided by the total number of prey in stomachs containing prey the expressed as a percentage. The vertical axis is the predator's feeding strategy (specialization or generalization). Points in the upper part of the graph represent preferred prey items, while points in the lower part indicate items that have been consumed rarely. If no points were located in the top right of the diagram and all points fell along or below the diagonal from the top left to the bottom right, the predator was thought to have a generalist diet and, therefore, a broad niche width.

Trophic level of each of the five teleost species was calculated based on each prey component's the proportion (by weight) in their diet using the TrophLab software (Froese and Pauly, 2000). TrophLab calculates the TL with the dietary composition and the TL of the different prey present in the diet, based on the percentage of weight (Pauly *et al.*, 2000):

$$TL_i = 1 + \sum_{j=1}^{G} DCij \times TL_j \qquad (4)$$

Where, DCij is the fraction of prey (j) in the diet of consumer i;TLj is the trophic level of prey (j); whereas G is the number of prey categories (Froese and Pauly, 2000).

For testing variation among the five teleost species, a similarity matrix with the transformed estimated contribution values of food items was used based on the weight of main zoological prey groups. The test was then developed the Bray-Curtis similarity using coefficient (Bray and Curtis, 1957). Diet similarity was analyzed with non-metric multidimensional scaling analysis (nMDS).

One-way analysis of similarity (ANOSIM) was used to investigate data. This test was used to check similarities (distance) within defined factors and calculates the R-value, which varies between -1 and +1. The R-value close to zero represents that there are no differences between the factors, and the R-value close to 1 indicates that the factors were dissimilar between the

levels of each factor. In addition, the similarity of percentages (SIMPER) was used to estimate the contribution of each main zoological prey to dietary differences. All statistical tests were carried out using PRIMER v.6 software (Clarke and Gorley, 2006).

#### Results

A total of 702 stomachs were studied, of which 40.91% of *N. thalassina*, 29.54% of *P. dussumieri*, 42.59% of *O. ruber*, 64.51% of *L johnii* and 56.43% of *C. malabaricus* were empty (Table 1). The cumulative prey curves based on diversity of prey exceeded an asymptote for all five species, showing that the sample size was large enough to clarify the general dietary preferences (Fig. 2).

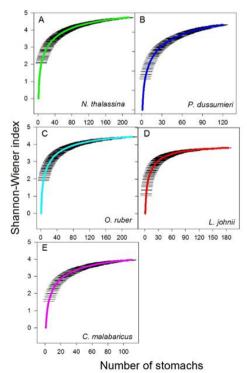


Figure 2: Cumulative prey curve for each new prey taxa in relation to the number of stomachs analyzed of five species sampled.

Feed composition of the teleost species In general, eight prey groups were identified in the stomach contents of the specimens of five teleost species (including teleosts, crustaceans, cephalopods, gastropods, bivalves, polychaetes, echinoderms, and alga). Besides, seventeen and five lower taxonomic groups were recorded within the teleosts and crustaceans, respectively. Assessment of %IRI revealed that teleosts were the most important ingested prey group in the stomach contents of *N. thalassina*, *O. ruber* and *C. malabaricus* (%IRI = 73.20, 87.13 and 96.50, respectively), whereas crustaceans were the most important feed of *P. dussumieri* and *L. johnii* (%IRI = 59.28 and 85.00, respectively) (Table 1).

Table 1: Number of specimens, Trophic levels and diet composition of five teleost species caught from the northern Oman Sea expressed in percentage by number (N%), weight (W%), frequency of occurrence (FO%) and percentage of the Index of Relative Importance of food (IRI%).

Teleost species	eleost species Netuma thalassin			a Plicofollis dussumieri					Otolithes ruber			
N		198					108					
Trophic Level		4.24				3.75					4.43	
Food items	N%	W%	FO%	IRI%	N%	W%	FO%	IRI%	N%	W%	FO%	IRI%
TELEOSTS	31.8	82.91	74.35	73.20	12.42	61.03	25.80	22.47	86.01	86.21	93.54	87.13
Carangidae	3.53	15.34	8.54	3.73	4.76	31.66	12.00	15.70	2.92	6.41	17.74	2.66
Mullidae	2.28	6.46	5.98	1.21	1.83	6.75	5.33	1.61	6.06	9.54	29.03	5.46
Cynoglossidae	0.50	0.17	1.71	0.03	0.73	0.36	2.66	0.10	0	0	0	0
Nemipteridae	2.02	10.35	5.98	1.71	2.19	11.00	6.66	3.15	0	0	0	0
Haemulidae	0.50	10.38	1.71	0.43	0	0	0	0	0	0	0	0
Sphyraenidae	1.26	7.29	4.27	0.85	1.09	10.30	4.00	1.63	0	0	0	0
Myctophidae	0.25	0.02	0.85	0.01	0	0	0	0	0	0	0	0
Engraulidae	1.51	0.10	4.27	0.16	1.46	0.13	4.00	0.23	10.43	3.86	29.03	3.60
Hydrophiidae	0.50	1.70	1.71	0.09	0.36	0.83	1.33	0.06	0	0	0	0
Mugilidae	0	0	0	0	0	0	0	0	17.12	36.70	61.29	45.00
Clupeidae	0	0	0	0	0	0	0	0	22.13	14.05	17.74	20.2
Gerreidae	0	0	0	0	0	0	0	0	6.68	4.55	27.42	3.33
Leiognathidae	0	0	0	0	0	0	0	0	14.82	6.12	24.19	4.36
Pennahia												
anea	0	0	0	0	0	0	0	0	5.85	4.98	24.19	2.52
Synodontidae	0	0	0	0	0	0	0	0	0	0	0	0
Pristigasteridae	0	0	0	0	0	0	0	0	0	0	0	0
Platycephalidae	0	0	0	0	0	0	0	0	0	0	0	0
Digested fish	19.45	31.10	55.55	65.00	0	0	0	0	0	0	0	0
CRUSTACEANS	44.71	11.54	63.24	22.76	53.5	22.71	62.36	59.28	10.64	7.75	70.96	6.61
Portunidae	21.71	5.09	25.64	15.90	24.9	10.16	32.00	40.20	0	0	0	0
Xanthidae	8.84	1.23	13.67	3.19	11.37	3.00	17.33	8.93	Ö	0	Ö	0
Epialtidae	7.32	2.66	8.54	1.97	9.17	5.00	12.00	6.09	0	0	0	0
Squilla												
mantis	2.80	1.90	9.40	1.02	2.56	3.00	9.33	1.86	3.96	4.00	22.58	2.04
Penaeidae	1.26	0.11	2.56	0.08	1.83	0.25	4.00	0.30	6.68	3.75	35.48	4.57
Digested	1.20	0.11	2.00	0.00	1.00	0.20		0.00	0.00	5.75	221.0	1107
crustaceans	2.78	0.55	7.70	0.59	3.66	1.30	10.66	1.89	0	0	0	0
CEPHALOPODS	3.30	3.41	11.11	1.73	4.76	7.91	17.33	7.87	3.35	6.04	19.35	6.26
GASTROPODS	3.03	0.06	2.56	0.18	4.39	0.43	4.00	0.69	0	0.01	0	0.20
BIVALVES	0.50	0.21	1.70	0.03	0.73	0.51	2.66	0.12	0	0	0	0
POLYCHAETES	3.28	0.07	3.42	0.27	4.77	0.28	5.33	0.96	Ö	0	0	0
ECHINODERMS	10.35	0.74	6.83	1.75	15.04	6.91	10.66	8.39	Ö	Ö	Ö	0
ALGAE	3.03	1.06	0.85	0.08	4.39	0.22	1.33	0.22	Ö	0	0	0

**Table 1 (continued):** 

Teleost species	Lutjani	us johnii		Carangoides malabaricus						
N			124		140					
Trophic Level			3.66		4.48					
Food items	N%	W%	FO%	IRI%	N%	W%	FO%	IRI%		
TELEOSTS	20.14	26.38	55.45	12.55	86.14	79.10	90.16	96.50		
Carangidae	1.05	2.62	18.18	0.69	0	0	0	0		
Mullidae	3.21	6.10	27.27	2.62	3.46	10.40	18.00	2.42		
Cynoglossidae	0	0	0	0	0	0	0	0		
Nemipteridae	0	0	0	0	0	0	0	0		
Haemulidae	1.20	2.97	15.91	0.68	0	0	0	0		
Sphyraenidae	0	0	0	0	0	0	0	0		
Myctophidae	0	0	0	0	0	0	0	0		
Engraulidae	9.62	6.10	38.64	6.27	27.90	16.40	27.90	9.47		
Hydrophiidae	0	0	0	0	0	0	0	0		
Mugilidae	0	0	0	0	0	0	0	0		
Clupeidae	0	0	0	0	0	0	0	0		
Gerreidae	0	0	0	0	0	0	0	0		
Leiognathidae	0	0	0	0	63.86	52.30	75.40	84.58		
Pennahia anea	0	0	0	0	0	0	0	0		
Synodontidae	3.21	5.06	20.45	1.75	0	0	0	0		
Pristigasteridae	1.05	2.18	11.36	0.38	0	0	0	0		
Platycephalidae	0.80	1.35	9.09	0.22	0	0	0	0		
Digested fish	0	0	0	0	0	0	0	0		
CRUSTACEANS	75.19	66.70	75.19	85.00	8.17	11.60	22.95	2.37		
Portunidae	21.00	17.3	65.91	26.04	2.72	5.02	11.50	0.86		
Xanthidae	25.8	22.2	56.82	28.72	0	0	0	0		
Epialtidae	0	0	0	0	0	0	0	0		
Squilla mantis	11.40	14.40	50.00	13.32	1.98	4.23	11.50	0.69		
Penaeidae	16.99	12.80	56.82	17.54	3.47	2.35	14.80	0.83		
Digested										
crustaceans	0	0	0	0	0	0	0	0		
CEPHALOPODS	2.14	5.57	20.45	1.63	1.73	7.50	9.84	0.88		
GASTROPODS	2.53	1.35	20.45	0.82	0	0	0	0		
BIVALVES	0	0	0	0	0	0	0	0		
POLYCHAETES	0	0	0	0	3.96	1.80	4.92	0.27		
<b>ECHINODERMS</b>	0	0	0	0	0	0	0	0		
ALGAE	0	0	0	0	0	0	0	0		

The ANOSIM found no significant differences in the diet composition among five studied teleost species (Global R statistic=0.122; p > 0.05) (Fig. 3). Also, pair-wise tests from the ANOSIM indicated that the diets of all the five species were similar (Table 2). SIMPER analysis revealed that the main categories of prey that contributed to the dissimilarity of the feed of the studied species were teleosts and crustaceans. Analyses were conducted between five teleost species using the Bray-Curtis dissimilarity index. Results have shown that the highest mean Bray-Curtis dissimilarity between P. dussumieri and

malabaricus 75.55% was consisted of teleosts (45.53%),crustaceans (35.12%) and cephalopods (10.06%). In contrast, the lowest dissimilarity was between O. ruber and C. malabaricus (32.11%). Feeding strategy plots further confirmed that teleosts and crustaceans were important prey categories for all five studied species, especially for N. thalassina, P. dussumieri and O. ruber. However, there was a high degree of specialization in the teleost prey category by L. johnii and C. malabaricus (Fig. 4).

Overall, *P. dussumieri* and *L. johnii* occupied an intermediate trophic level.

The values were 3.75 and 3.66, respectively. On the other hand, three species, *N. thalassina*, *O. ruber* and *C. malabaricus* occupied high trophic

levels, placing them as top predators in the food web. Values were 4.24, 4.43 and 4.48, respectively.

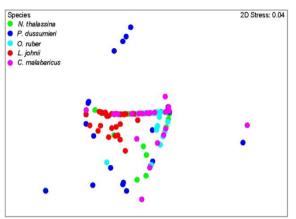


Figure 3: Non-metric multidimensional scaling (nMDS) analysis of the stomach contents of 5 teleost species sampled in the northern Oman Sea.

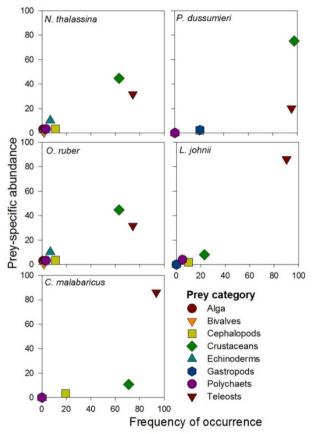


Figure 4: Graphical representation of the feeding strategy of five species sampled on the method proposed by Amundsen *et al.* (1996).

Table 2: Analysis of similarity pairwise tests to compare the diet of five teleost species from the northern Oman Sea.

	R significance				
Species × Species	R	P			
N. thalassina $\times$ P. dussumieri	0.124	>0.05			
N. thalassina $\times$ O. ruber	0.014	>0.05			
N. thalassina $\times$ L. johnii	0.013	>0.05			
N. thalassina $\times$ C. malabaricus	-0.027	>0.05			
P. dussumieri $\times$ O. ruber	0.29	>0.05			
P. dussumieri $\times$ L. johnii	-0.007	>0.05			
P. dussumieri $\times$ C. malabaricus	0.33	>0.05			
O. $ruber \times L$ . $johnii$	0.39	>0.05			
O. $ruber \times C$ . $malabaricus$	-0.016	>0.05			
L. johnii $\times$ C. malabaricus	0.597	>0.05			

#### Discussion

In the present study, we investigated the feeding ecology and comparative feeds of five sympatric teleost species in the northern Oman Sea using the direct stomach content analysis, which is a well-known method for researching the trophic ecology of teleosts and offers a qualitative and quantitative snapshot of the diet (Hyslop, 1980). It is suggested that the results obtained from this study provide general baseline may information, especially for the species whose diets have been poorly studied in the area. Moreover, this study is the first to analyze comparative dietary data of the sympatric teleost species in the northern Oman Sea to shed new light on what might allow these species to coexist.

The results from this study indicated that *N. thalassina* feed primarily on teleosts (74.35%), followed by crustaceans (63.24%) and this is in agreement with the results of the studies conducted in the same waters by Karimi *et al.* (2012) and Pourbabaie *et al.* (2013). Teleosts were also the most commonly occurring identifiable prey in

O. ruber (93.54%), similar to other studies (Nair, 1980; Euzen, 1987; Bandani et al., 2006; Azhir, 2008; Sadeghi et al., 2014; Vahabnezhad, 2015; Taghavi Motlagh et al., 2015; Ranjbari etGhorbani al., 2016: Hashemipour et al., 2019). However, Pillai (1983) and Abdel-Aziz et al. (1993), who studied the feeding habit of iuvenile O. ruber declared that younger forms of all sciaenids take prawns (crustaceans) as the main feed and the percentage of their fish feed goes on slowly increasing as they grow in size, thus it can be concluded that O. ruber is a highly carnivorous fish exhibiting a selectivity of feeding within various size groups. P. dussumieri mainly consumed crustaceans (62.36%) and this finding supplements the works done by other researchers (Cheraghi et al., 2013; Abdi and Ghazi zadeh, 2019). L. johnii feeds mainly on crustaceans, especially crabs (75.19%). These results are consistent with previous literature (Kamali and Valinassab, 2003; Behzadi, 2016). Kiso and Mahyam (2003), who worked on the feeding habit of L. johnii in a mangrove estuary in Malaysia noted that the most

occurring prey in L. johnii were crustaceans, especially prawns, and the large prawn biomass causes it in this estuary (Kiso and Mahyam, 2003). The most preferred food item of C. malabaricus were teleosts (90.16%). Similar results have been reported in C. malabaricus (Sadeghi et al., 2014, Kamali et al., 2016; Hashemipour et al., 2019). Conversely, Ibrahim et al. (2003), who worked on C. malabaricus in the south China Sea, found Penaeus sp. (Crustaceans) to be the most frequent and numerically dominant prey of C. malabaricus. This can be described as an adjustment to the available feed without the preferred prey (Sivakami, 1996). Generally, it is assumed that these differences are due to differences in the environment, including the density and composition of prey groups between different habitats.

Sympatric species are likely to consume slightly different prey to minimize niche overlap (Schoener, 1974). For instance, in the current study L. johnii and P. dussumieri are both benthophagous feeders, but to reduce the niche overlap the former has a fish-based diet and the latter has a crustacean-based diet, although the importance of teleosts and crustaceans as prey is not negligible in the study area (Fig. 4). Competition for food can affect habitat selection patterns, and niche overlap (Hilderbrand and Kershner, 2004; David et al., 2007). When food resources are shared, it has been proposed that the coexistence of fish species is related to differential use of space and resources over time (Amarasekare, 2003; Sandlund et al.,

2010). In the present study, competition for resources was observed among all five studied species. The high abundance of some prey in the study area may affect the significant diet overlap. Crowder and Cooper (1982) suggested that due to high catch rates when prey is plentiful, the feeding niche breadth of a predator will be narrowest when food in a particular site is abundant. While fish species included more than one type of food in their diet, the highest predominance of a single food item implies an abundance of food in the environment, besides may indicate active food selection (Novakowski et al., 2008).

Even though new methods have been developed to determine trophic levels for marine species, such as stable isotope approaches, the trophic level estimates are generally extracted from the analysis of stomach content (Stergiou and Polunin, 2000). In marine ecosystems, trophic levels ranged from 2 for detritivorous/herbivorous species to 5 carnivorous/piscivorous species (Pauly et al., 1998). In the present study, the estimated trophic level of P. dussumieri and L. johnii (3.5<TL<4.0) suggested that these species potentially important mesopredators within the Oman Sea food web. The estimated trophic level of *N. thalassina*, 0. ruber and C. malabaricus (4<TL<4.5) indicated that these species are top-level predators in this ecosystem and have a high degree of food consumption. The estimated trophic levels in different studies (Table 1) may vary due to changes in prey availability and geographical variations (Arendt *et al.*, 2001). Moreover, it may happen due to differences in feeding intensity (Hassler and Rainville, 1975). Pauly (2010) also noted that most fish have a lower trophic level when they are smaller and younger than when large and mature. Therefore, it can be concluded that the trophic level may change with the size and age of the fish. (Pauly and Watson, 2005). Rastgoo and Navarro (2017) also indicated a positive

correlation between trophic levels estimated from data on stomach content and the fish size in their literature. In the present study, T.L has not been compared for different age groups. However, this index is likely to vary based on changes in feeding habitats associated with the transition from the larval to the more mature stage (Table 3).

Table 3: Studied species, the trophic level calculated in the present study the northern Oman Sea and the trophic level of these species from other studies.

Species	Trophic level	Trophic level	References	Study Areas	
	(Present study)	(Other studies)			
N. thalassina	4.24	3.40	Nasir, 2000	Northwest Persian Gulf	
	-	4.07	Taghavi Motlagh <i>et al.</i> , 2015	Persian Gulf	
	-	4.31	Mohseni, 2019	Persian Gulf and Oman Sea	
P. dussumieri	3.75	3.99	Rastgoo and Navarro, 2017	Persian Gulf and Oman Sea	
	-	4.39	Mohseni, 2019	Persian Gulf and Oman Sea	
O. ruber	4.43	3.60	Nasir, 2000	Northwest Persian Gulf	
	-	3.64	Vahabnezhad, 2015	Persian Gulf	
	-	3.66	Taghavi Motlagh <i>et</i> al., 2015	Persian Gulf	
	-	3.39	Rastgoo and Navarro, 2017	Persian Gulf and Oman Sea	
L. johnii	3.66	3.59	Vahabnezhad, 2015	Persian Gulf	
	-	3.72	Taghavi Motlagh <i>et</i> al., 2015	Persian Gulf	
	-	4.20	Moniri et al., 2015	Persian Gulf and Oman Sea	
	-	4.00	Behzadi, 2016	Persian Gulf and Oman Sea	
	-	3.93	Rastgoo and Navarro, 2017	Persian Gulf and Oman Sea	
C. malabaricus	4.48	4.40	Salini <i>et al.</i> , 1994	Gulf of Carpentaria, Australia	

The study of feeding habits and the sharing of resources is closely related to fish species can be very useful for understanding energy flows across the food web and provides important insights into the trophic flexibility of the sympatric species (Darnaude et al., 2001; Platell et al., 2006; Russo et al., 2008). However, such findings need to be coupled with analyses of the benthic community composition and abundance of key species to find out detailed information of the prey-predator relations to help develop appropriate conservation and ecosystem-based management plans for the commercial fisheries that operate there.

### References

- Abdel-Aziz, S.H., Khalila, N. and Abdel-Magid, S.S., 1993. Food and feeding habits of common guitarfish, *Rhinobatos rhinobatos* in Egyption Mediterranean waters. *Indian Journal of Marine Science*, 22, 287-290.
- Abdi, R. and Ghazizadeh, M., 2019.

  Biometry and study of Diet
  Composition of *Plicofollis*dussumieri in the Oman Sea (Tiab
  Port). Journal of Marine Biology,
  Islamic Azad University, Ahwaz
  branch, 11(41), 1-12 (In Persian).

  http://jmb.iauahvaz.ac.ir/article-1717-fa.html
- Al-Hashmi, K.A., Claereboudt, M.R., Al-Azri, A.R. and Piontkovski, S.A., 2010. Seasonal changes of Chlorophyll-a and environmental characteristics in the Sea of Oman. *Open Oceanography Journal*, 4,

107-114.

DOI:10.2174/1874252101004010107

- **Amarasekare, P., 2003.** Competitive coexistence in spatially structured environments: A synthesis. *Ecology Letters*, 6, 1109–1122.
- Amundsen, P. A., Gabler, H. M. and Staldvik, F., 1996. A new approach to graphical analysis of feeding strategy from stomach contents datamodification of the Costello (1990) method. *Journal of Fish Biology*, 48, 607–614.
- **Arendt, M.D., Olney, J.E. and Lucy, J.A., 2001.** Stomach content analysis of cobia, *Rachycentron canadum*, from lower Chesapeake Bay. *Fishery Bulletin*, 99(4), 665-670.
- **Asadi, H. and Dehghani, R., 1996.**Atlas of the fishes of the Persian Gulf and Oman Sea. Iranian Fisheries Research and Training Organization Publication. 247 P.
- M.T., 2008. Azhir, **Biological** investigation of Tigertoothed Croaker, Otolithes ruber, in the Oman Sea along Sistan and Baluchistan Province. Iranian Fisheries Science Journal, 17(1), 1-10. DOI:10.22092/ISFJ.2008.11522
- Bandani, G., Hassanzadeh Kiaie, B. and Akrami, R., 2006. Diet Composition of (Otolithes ruber, Bloch & Schneider, 1801) in the Oman Sea (Chabahar). Journals of Gorgan University of Agricultural Sciences and Natural Resources, 14(2), 80-89 (In Persian).
- **Behzadi, S., 2016.** Using of Trophodynamic Indicators of

- Demersal and benthic commercial fishes to determination of the Persian Gulf and Oman Sea fisheries ecosystem health (Hormuzgun Province). PhD thesis in Marine Ecology, University of Hormuzgan, Bandar Abbas. 299 P. (In Persian).
- **Behzadi, S., Kamrani, E., Kaymaram, F. and Ranjbar, M., 2018.** Trophic level, food preference and feeding ecology of *Rachycentron canadum* (Linnaeus, 1766), in Hormuzgan Province waters (northern Persian Gulf and Oman Sea). *Iranian Journal of Fisheries Sciences*, 17(1), 179-193. DOI:10.22092/IJFS.2018.115608
- **Bray, R.J. and Curtis, J.T., 1957.** An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs*, 27, 325–349.
- Carpenter, K.E., Krupp, F., Jones, D.A. and Zajonz, U., 1997. FAO species identification guide for fishery purposes. The living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar and the United Arab Emirates. Rome, FAO. 293 P.
- Cheraghi, M., Valinassab, T. and Hafezieh, M., 2013. Evaluation of feeding indices of catfish *Arius dussumieri* in the Oman Sea. *Iranian Journal of Fisheries Sciences*, 22, 31–40.
- Clarke, K. R. and Gorley, R. N., 2006. PRIMER v6: user manual/tutorial. PRIMER-E, Plymouth.
- **Cortés, E., 1997.** A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch

- fishes. Canadian Journal of Fisheries and Aquatic Sciences, 54, 726–738.
- **Crowder, L. B. and Cooper, W.E., 1982.** Habitat structural complexity and the interaction between bluegills and their prey. *Ecology*, 63, 1802-1813.
- Darnaude, A.M., Harmelin-Vivien, M.L. and Salen-Picard, C., 2001. Food partitioning among flatfish (Pisces: Pleuronectiforms) juveniles in a Mediterranean coastal shallow sandy area. *Journal of the Marine Biological Association of the United Kingdom*, 81, 119–127.
- David, B.O., Closs, G.P., Crow, S. K. and Hansen, E.A., 2007. Is diel activity determined by social rank in a drift-feeding stream fish dominance hierarchy? *Animal Behaviour*, 74, 259–263. 10.1016/j.anbehav.2006.08.015
- **Euzen, O., 1987.** Food habit and diet composition of some fish of Kuwait. *Kuwait Bulletin Science*, 9, 65-85.
- Farooq, N., Qamar, N. and Panhwar, S.K., 2017. Characterization of feeding habits, prey diversity and diet overlap of two sympatric species: Bronze catfish, *Netuma bilineata* (Valenciennes, 1840) and blacktip sea catfish, *Plicofollis dussumieri* (Valenciennes, 1840) in the northern Arabian Sea. *Journal of Applied Ichthyology*, 33(4), 709-719. DOI:10.1111/jai.13377
- Ferry, L. and Caillet, G., 1996. Sample size and data analysis: Are we characterizing and comparing diet properly. In: MacKinlay D, Shearer K (eds) Feeding ecology and nutrition

- in fish: symposium proceedings. International congress on the biology of fishes, 14–18 July 1996, San Francisco. *American Fisheries Society*, Bethesda, MD, 71–80.
- Froese, R. and Pauly, D., 2000. Fishbase: Concepts Designs and Data Sources, Vol. 1594, World Fish.
- Ghorbani Ranjbari, N., Haghi, M., Zakeri, M., Yavari, V. and Shekari., M., 2016. Diet composition of *Otolithes ruber* (Bloch & Schneider, 1801) in the Persian Gulf (Khuzestan province). *Journal of Applied Ichthyological Research*, 5(2), 31-46. (In Persian).
- Hashemipour, F., Kaymaram, F., E., Jamili, Kamrani, S. and Fard, E., 2019. Ramezani Assessmet of feeding habitas of Carangoides chrysophorys (Cuvier, 1833) in Hormuzgan waters Province. Journal Animal 161-166. Environment. 11(1), DOI:20.1001.1.27171388.1398.11.1. 16.6
- Hassler, W.W. and Rainville, R.P., 1975. Techniques for hatching and rearing cobia, *Rachycentron canadum*, through larval and juvenile stages, North Carolina State University.
- Hilderbrand, R.H. and Kershner, **J.L., 2004.** Influence of habitat type on food supply, selectivity and diet overlap of Bonneville Cutthroat Trout and Non native Brook Trout in Creek. Beaver Idaho. North Journal **Fisheries** American of 24. 33 - 40.Management, DOI:doi.org/10.1577/M02-192

- **Hyslop, E.J., 1980.** Stomach contents analysis—a review of methods and their application. *Journal of Fish Biology*, 17, 411–429.
- Ibrahim, S., Muhammad, M., Ambak, M.A., Zakaria, M.Z., Mamat, A. S., Mansor -Isa, M. M. and Hajisamae, S., 2003. Stomach contents of Six commercially important demersal fishes in the south China Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, 3, 11-16.
- Jereb, P. and Roper, C.F.E., (eds.) 2005. Cephalopods of the World. An Annotated and Illustrated Catalogue of Cephalopod Species Known to Date. Vol. 1. Chambered nautiluses and Sepioids (Nautilidae, Sepiidae, Sepiolidae, Sepiolidae, Sepiadariidae, Idiosepiidae and Spirulidae). FAO Species Catalogue for Fishery Purposes, 4(1), 262 P. Rome: FAO.
- Kamali, A. and Valinassab, T., 2003. The study of diet composition of *Lutjanus johnii* in the Persian Gulf (Hormuzgan Province). *Iranian Journal of Fisheries Sciences*, 15(2), 153-162. (In Persian).
- Kamali, A., Dehghani, R., Darvishi, M. and Hosseini, A., 2016. The study of diet composition of *Carangoides malabaricus* in the Persian Gulf (Hormuzgan Province). 4<sup>th</sup> National Conference on Fisheries and Aquatic Animals in Iran. (In Persian).
- Karimi, M., Mohammadizadeh, F., Bahri, A. and Mojaz, A., 2012. The Study of diet composition of *Arius thalassinus* in the Persian Gulf (Costal water of Bandarabbas). 1<sup>th</sup>

- National Conference on Fisheries and Aquatic Animals Iran. (In Persian).
- **Kiso, K. and Mahyam, M.I., 2003.**Distribution and feeding habits of juvenile and young John's snapper *Lutjanus johnii* in the Matang mangrove estuary, west coast of Peninsular, Malaysia. *Fisheries Science*, 6, 63-568.
- Magurran, A. E., 2004. Measuring biological diversity. Blackwell Publishing, Oxford.
- Mariani, S., Boggan, C. and Balata, D., 2011. Food resource use in sympatric juvenile plaice and flounder in estuarine habits. *Marine Ecology*, 32, 96–101. DOI:10.1111/j.1439-0485.2010.00419
- Mohseni, F., 2019. Feeding habits and trophic level estimation of dominant species of catfishes in the Persian Gulf. PhD thesis in Marine Ecology, Science and Research Branch, Islamic Azad University, Tehran.160 P. (In Persian).
- Moniri, N. R., Moniri. N. R., Zeller, D., Al-Abdulrazzak, D., Zylich. K. and Belhabib, D., 2015. Fisheries catch reconstruction For I.R.of Iran, 1950-2010, Sea around Us Project. Fisheries Centre, University of British Columbia, 2202 Main Mall and Vancouver, BC, V6T 1Z4, Canada. 15-38.
- Nair, K.V.S., 1980. Food and feeding habits of *Otolithes ruber* (Schneider) at Calicut. *Indian Journal of Fisheries*, 26(182), 133-13.

- Nasir, N.A., 2000. The food and feeding relationships of the fish communities in the inshore waters of Khor Al-Zubair, northwest Arabian Gulf. *Cybium*, 24(1), 89-99 131.
- Novakowski, G. C., Hahn, N. S. and Fugi, R., 2008. Diet seasonality and food overlap of the fish assemblage in a pantanal pond. *Neotropical Ichthyology*, 6(4), 567-576. DOI:10.1590/S1679-62252008000400004
- Pauly, D., Trites, A., Capuli, E. and Christensen, V., 1998. Diet composition and trophic levels of marine mammals. *ICES Journal of Marine Science*, 55, 467–481.
- Pauly, D., Froese, R., Sa-a, P.S.,
  Palomares, M.L.D., Christensen,
  V. and Rius, J., 2000. TropLab
  Manual. ICLARM, Manila. Pianka
  ER (2000).
- Pauly, D. and Watson, R., 2005. Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. Philosophical Transactions of the Royal Society A, 360, 415–423.
  - DOI:10.1098/rstb.2004.1597
- Pauly, D., 2010. 5 Easy Pieces: The Impact of Fisheries on Marine Ecosystems (State of the World's Oceans). Island Press, 207, 61-62.
- Persson, L., Diehl, S., Johansson, L., Andersson, G. and Hamrin, S.F., 1992. Trophic interactions in temperate lake ecosystems: A test of food chain theory. *American Naturalist*, 59–84.

- **Pianka, E. R., 1969.** Sympatry of *Ctenotus* in Western Australia. *Ecology*, 50, 1012–1030.
- **Pillai, P.K.M., 1983.** On the biometry, food and feeding and spawning habits of *Otolithes ruber* (Schneider). *Matsya*, 12(**13**), 152-161.
- **Pinkas, L., Oliphant, M.S. and Iverson, I.L.K., 1971.** Food habits study of albacore, bluefin tuna and bonito in California waters. *Fish Bulletin*, 152, 1–105.
- Platell, M.E., Orr, P.A. and Potter, I.C., 2006. Inter- and intraspecific partitioning of food resources by six large and abundant fish species in a seasonally open estuary. *Journal of Fish Biology*, 69, 243–262. DOI:10.1111/j.1095-8649.2006.01098.x
- Pourbabaie H.S.R., Kamrani, A., Golmoradi zadeh, A., Sajjadi, M. and Golmoradizadeh, A., 2013. The Study of Diet Composition of *Arius thalassinus* in Persian Gulf (East of the Qeshm Island). *JAPU*, 2(4), 113-128. (In Persian).
- Prince, E.D., 1975. Pinnixid crabs in the diet of young-of-the-year Copper Rockfish (Sebastes caurinus).

  Transactions of American Fisheries Society, 104, 539-540.
- Rastgoo, A.R. and Navarro, J., 2017.

  Trophic levels of teleost and elasmobranch species in the Persian Gulf and Oman Sea. *Journal of Applied Ichthyology*, 33, 403–408.

  DOI:10.1111/jai.13249
- **Reynolds, R.M., 1993.** Physical oceanography of the Gulf, Strait of Hormuz and the Gulf of Oman.

- results from the Mitchell Expedition. *Marine Pollution Bulletin*, 27, 35–60.
- Russo, T., Pulcini, D., O'Leary, A., Cataudella, S. and Mariani, S., 2008. Relationship between body shape and trophic niche segregation in two closely related sympatric fishes. *Journal of Fish Biology*, 73, 809–828. DOI:10.1111/j.1095-8649.2008.01964
- Sadeghi, M. S., Abdali, S. and Manavi, A., 2014. The study of Diet Composition of *Carangoides malabaricus* in the Persian Gulf (Hormuzgan Province). *Journal of Marine Science and Technology Research*, 9(1), 69-78. (In Persian). http://jfst.modares.ac.ir/article-6-15246-fa.html
- Salini, J.P., Blaber, S. J. M. and Brewer, D.T., 1994. Diets of trawled predatory fish of the Gulf of Carpentaria, Australia, with particular reference to predation on prawns. Australian Journal of Marine and Freshwater Research, 45(3), 397-411.
- Sandlund, O. T., Museth, J., Naesje, T. F., Rognerud, S., Saksgård, R., Hesthagen, T. and Borgstrom, R., 2010. Habitat use and diet of sympatric Arctic charr (Salvelinus alpinus) and whitefish (Coregonus lavaretus) in five lakes in southern Norway: Not only interspecific population dominance. Hydrobiologia, 650, 27–41.
  - DOI:10.1007/s10750-009-0075-4
- **Schoener, T.W., 1974.** Resource partitioning in natural communities. *Science*, 185, 27–39.

- **Sivakami, S., 1996.** On the food habits of the family Carangidae- A review. *Journal of the Marine Biological Association of India*, 38(1-2), 118-123.
- Stergiou, K. I. and Polunin, N., 2000.

  Executive summary. In F. Briand (Ed.), Fishing down the Mediterranean food Webs? Kerkyra, Greece: CIESM Workshop Series 12, 7-15.
- Taghavi Motlagh, A., Valinassab, T., Vahabnezhad, A., Hakimelahi, M., Eskandari, G. and Esmaili, A., 2015. Ecological Interaction Between Commercial Fishes in the Persian Gulf. Iranian Fisheries Research Organization, 127 P.
- **Teixeira, A. and Cortes, R.M.V., 2006.**Diet of stocked and wild trout, *Salmo trutta*: Is there competition for resources, Folia Zoologica, 55, 61–73.
- Ugwumba, A.A. and Ugwumba, O.A., 2007. Food and feeding ecology of

- fishes in Nigeria. Jodetan Ventures. Ibadan, 70 P.
- Vahabnezhad, A., 2015. Feeding habits and trophic levels of some demersal fish species in the Persian Gulf (Bushehr Province) using Ecopath model. PhD thesis in Marine Ecology, Science and Research Branch, Islamic Azad University, Tehran.160 P. (In Persian
- Valinassab, T., Daryanabard, G.R., Dehghani, R. and Pierce, G.R., 2006. Abundance of demersal fish resources in the Persian Gulf and Oman Sea. Journal of Marine Biological Associations of United Kingdom, 86, pp. 1-8.

DOI:10.1017/S0025315406014512

Vander Zanden, M.J., Casselman, J.M. and Rasmussen, J.B., 1999. Stable isotope evidence for the food web consequences of species invasions in lakes. *Nature*, 401, 464–467.