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Research Article

Seasonal variations in diet and feeding habits of *Saurida tumbil* (Bloch, 1795) , *Netuma thalassina* (Rüppell, 1837) and *Pomadasys kaakan* (Cuvier, 1830) in the northern coasts of the Oman Sea

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Abstract

The aim of the present study was to explore seasonal variations in the diet of *Saurida tumbil*, *Netuma thalassina* and *Pomadasys kaakan* in the Iranian coasts of Oman Sea during 2018-2019. These abundant fishes share same habitats in the Oman Sea .Diet analysis including frequency of occurrence of prey, feeding intensity index, the index of empty stomachs and length weight relationship for 1166 individual were calculated.Based on Gastrosomatic (GaSI) and vacuity index, the maximum feeding intensity was noticed for *S.tumbil* and *P. kaakan* during post monsoon and for *N. thalassina* in pre monsoon time. *S. tumbil* showed the lowest GaSI index and the highest empty stomachs in monsoon.The findings of food composition indicated remarkable dietary overlap between species in this research, especially between *N. thalassina* and *P.kaakan* on decapods , gastropods and fishes (dominant prey) during all seasons. For *S. tumbil,* the most important prey items were fishes, following, cephalopod and penaeidae and it was determined that the feeding intensity of *P. kaakan* and *N. thalassina* could not be altered by monsoon but remarkable seasonal variation was noticed in their diet composition contents. The results showed that the pre-monsoon, monsoon and post-monsoon periods have significant effects on the diet composition of all three species under study, which could be explained by changes in resource abundance, availability and diversity of prey.

Keywords: Feeding intensity, Food composition, Monsoon, Oman Sea

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Introduction

The Sea of Oman (Gulf of Makran or Sea of Makran) is a gulf that connects the Arabian Sea with the Strait of Hormuz, which then runs to the Persian Gulf.The Strait of Hormuz is a strait between the Persian Gulf and the Sea of Oman. It provides the only sea passage from the Persian Gulf to the open ocean and is one of the world's most strategically important choke points (Jedari Attari *et al*., 2018).

Seasonal changes are the important features of marine and freshwater ecosystems regulating populations, communities and finally ecosystem processes by modifying the connectivity to habitat (Junk *et al*., 1989). The well known feature of the Oman Sea is the seasonal upwelling along the Iranian coast, with a peak in February-March, while the onset of the northeast monsoonal winds could happen in December (Piontkovski *et al*., 2012).

In the past decade many surveys have been conducted to study the biological characteristics of marine species during seasonal changes linked with monsoon in the Oman Sea (Toutouni et al., 2016, Eatemadi et al., 2012). Survey on feeding behavior of marine species not only provides useful information on trophic relationship between species, but also revealed ecosystem functioning by evaluating resource use efficiency (Chea *et al*., 2017). On the other hand, survey on feeding behavior of marine fish species could be used to develop the management and conservation strategies framework for sustainable exploitation of multi-species ecosystems (Aziz *et al*., 2006). Some species have been shown alteration to their diet across each season as a result of variations in the connectivity to fluctuation habitats. Thus, variations in diet composition, can reflect changes in the availability and the amount of food resources (Hahn *et al*., 2004), however according to Heng *et al*. (2018) same resources can be shared by several species and that each species can successively exploit dissimilar resources during the lifetime.

Lizardfishes *(Saurida tumbil*, family: Synodontidae), Giant Marine-catfish (*Netuma thalassina*) family: Ariidae) and javelin grunt *(Pomadasys kaakan*, family: Haemulidae), are important demersal fishery resources worldwide (Valinassab *et al*., 2006). According to (Taghavi Motlagh, 2019), *S.tumbil* and *P. kaakan* are commercially important, which targeted by Iranian fishermen in the Oman Sea, and constituted 0.44% and 0.70% of annual catch of Oman sea, on the contrary, *N. thalassina*, directly not targeted by fishermen in spite of its higher (4.15%) amount of catch.

Many reaserches have been conducted to explain feeding behavior of *S.tumbil* (Barakzaii *et al*., 2011, Vahabnezhad, 2015), *N. thalassina* (Alimohammadi et al., 2020, Cheraghi et al., 2013) and *P. kaakan* (Valinassab et al., 2011, Azhir et al., 2007). In the Oman sea, seasonal variation in feeding intensity of these species have been

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faced a least attention so far (Manojkumar and Pavithran, 2016).

The aim of this study was to describe feeding habit and seasonal variations of the diet, of *S.tumbil, N. thalassina* and *P. kaakan*. These fishes are distributed within the Oman sea during the whole year and are known to occur in similar habitats, thus providing potential for inter specific competition.

Materials and methods

Sampling was performed from commercial fish landings off the coastal waters of Sistan and Baluchistan in three periods of the monsoon phenomenon in the Oman Sea, ie, before the monsoon (March-April), monsoon (June-September) and after the monsoon (October-February) in 2018 and 2019 (Fig. 1).

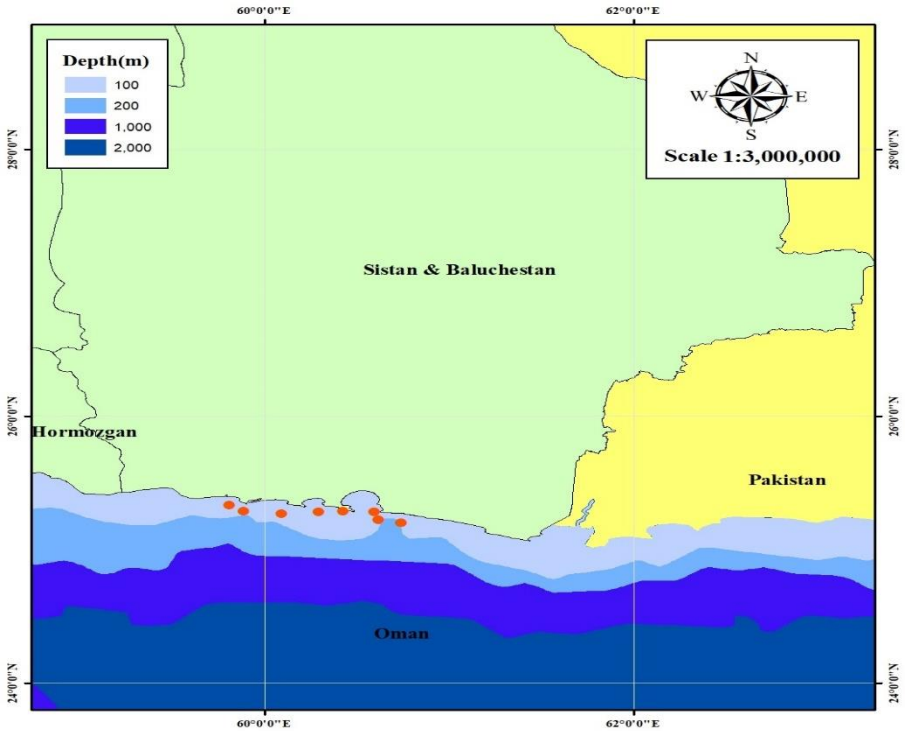


Figure 1: Location of fish sampling stations in the northern Oman Sea.

Altogether, 1166 specimens were collected randomly from 10 fish landing stations. Each specimen was measured to the nearest 0.1 cm fork length (FL), to the nearest 0. 1 g for both body mass (M_B) and 0.01 g for stomach content weight.

The digestive organ of individuals were separated and preserved in a 4% formalin solution. Back in the laboratory, the contents of each stomach and foregut were examined under a microscope and further taxonomic identification was done using identification guides (Silva et al., 2006, Asadi and Dehghani, 1996, Jereb and Roper, 2005).

The stomach contents were analyzed by numerical methods as described by (Hyslop, 1980)

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and feeding indices were evaluated using Equations I, II, III and IV (Biswas, 1993):

(I) The Vacuity Index (VI) (%)= (Number of empty stomachs)/(Number of total stomachs)×100

(II) Frequency of occurrence (%F)= (number of stomachs in which an especial food item was found/total number of full stomachs) ×100

(III) Percentage of numerical abundance (%N)= (number of each prey item in all full stomachs/total number of food items observed) × 100

(IV) The monthly Gastrosomatic index (GaSI) was calculated as: GaSI=(fresh weight of stomach/ total fresh weight of fish) ×100

The relationship between length and body mass for combined sex was calculated using: $M_B = aL_F{}^b$ (Equation V) , where a is a scaling constant and b is the allometric growth parameter (Beverton and Holt, 1993).

All data was analyzed using Graphpad Prism version 8.4.0 (GraphPad Software, San Diego, CA). To verify if b for each species is significantly different from the predictions assigned for isometric growth (b = 3), student t-test comparison was performed (Pauly and Gayanilo, 1996).

To compare the difference in vacuity index among seasons and months of GaSI, a global ANOVA-test was used Zar (1999).

Results

Table 1 presents the results of the fish biometry and preliminary analysis of the stomach condition.

Fork length and weight of *S.tumbil* were ranged from 11 cm to 50 cm and from 12.25 to 1140 g , respevtively (Table 1). The results of stomach content analysis and feeding intensity (40<VI<60) showed that *S.tumbil* is moderately feeder fish (53.24%) . The percentage of empty stomachs of *S.tumbil* showed higher Vacuity Index in summer (48%) and lower in autumn (19%).

Table 1: Range, Mean ±SD of length and weight and stomach condition in the Northern coasts of the Oman Sea.

Species	N	Length range (cm)	Mean FL±SD	Weight range (g)	Mean M_B±SD	Empty stomachs
S. tumbil	470	11-50	33.12±0.32	12.25 -1140	413.15±0.32	53.3%
N. thalassina	358	17.5-64	45.74±9.50	107.4 -4000	1123.65±2.2	48%
P. kaakan	338	18.5-63	34.9±7.04	112 -3612	787.37±0.25	57.7%

The lower mean of Gastro-somatic index (1.65±0.06) for *S.tumbil* was observed during the summer (August) whereas maximum (2±0.1) was recorded in Spring (May) (Fig. 2).There was significant variation (p<0.05) in GaSI values in different months .

The results of frequency (F%) and numerical (N%) occurrence of food items in the stomach content of *S.tumbil* are listed in Table 2. Seasonal

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variations of the major food items (Fish, cephalopod and penaeidae) were noticed with higher occurrence of fishes (F%=73) (F>50). *Nemipterus* sp., *Saurida* sp., *Trichiurus* sp., *Upeneus* sp., *Platycephalus* sp., Sardine and Ponyfishes were identified in the stomachs of *S.tumbil* . According to the results, fishes formed the dominant dietary of *S. tumbil* throughout the year. Among fish species, *Trichiurus* sp., was the dominant food item found in the stomach of *S. tumbil*, Penaeidae (F%=36.42) and cephalopod (F%=25.36) (10<F<50) were considered as secondary prey species except during summer.

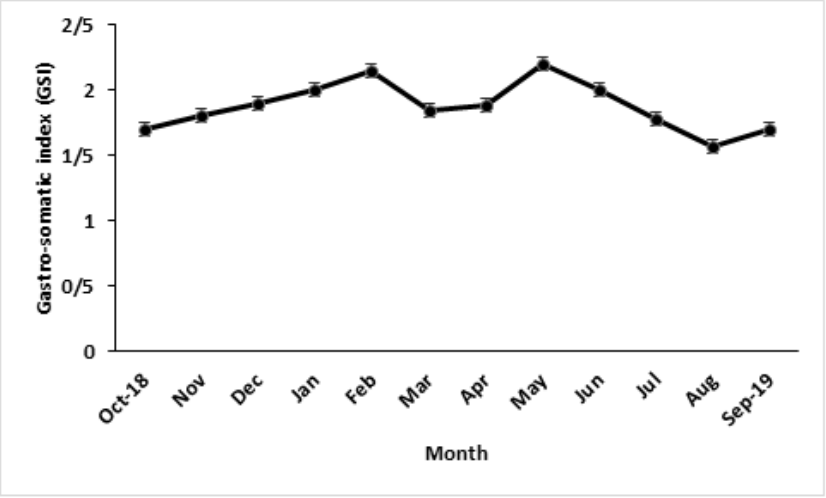


Figure 2: Monthly variations in mean Gastro somatic index of *s. Tumbil.*

Table 2: Seasonal variation in frequency (F%) and numerical (N%) occurrence of food items in the stomach contents of *S. Tumbil.*

Food items	Season							
	Autumn (N=143)		Winter (N=75)		Spring (N=190)		Summer (N=62)	
	%F	%N	%F	%N	%F	%N	%F	%N
Nemipterus sp.	2.16	0.52	2.34	0.86	2.03	0.63	0.67	0.06
Saurida sp.	5.00	6.73	12.21	5.51	16.95	4.52	6.08	3.22
Trichiurus sp.	1.87	0.25	37.22	22.07	12.70	31.30	-	-
Upeneus sp.	4.23	2.55	2.69	0.81	3.58	0.81	0.71	0.07
Platycephalus sp.	-	-	-	-	5.43	0.54	-	-
Mullet fish	29.56	35.36	-	-	0.74	0.76	-	-
Sardine	35.56	46.44	9.13	7.17	4.26	2.09	-	-
Ponyfishes	10.70	10.63	-	-	2.13	0.46	0.81	0.05
Penaeidae	22.47	18.80	1.15	3.33	12.8	8.39	-	-
Cephalopod	20.47	16.39	4.15	0.87	0.74	0.60	-	-
Squilla mantis	65.43	50.71	25.06	28.98	23.97	11.74	-	--

The length-weight relationship for *S. tumbil* were estimated as $M_B = 0.0087FL^{3.05}$ (R^2=0.97, *t*-test, p>0.05) (Fig. 3).

Fork length of *N. thalassina* ranged from 17.50 cm to 64 cm, weight varied from 107.40 to 4000 g (Table 1). Results of stomach contents and

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feeding intensity analysis showed that *N. thalassina* was relatively edacious feeder (37.97%). The percentage of empty stomachs in different seasons showed lower Vacuity Index in Winter (14.10%) and higher in Autumn (25.14%).

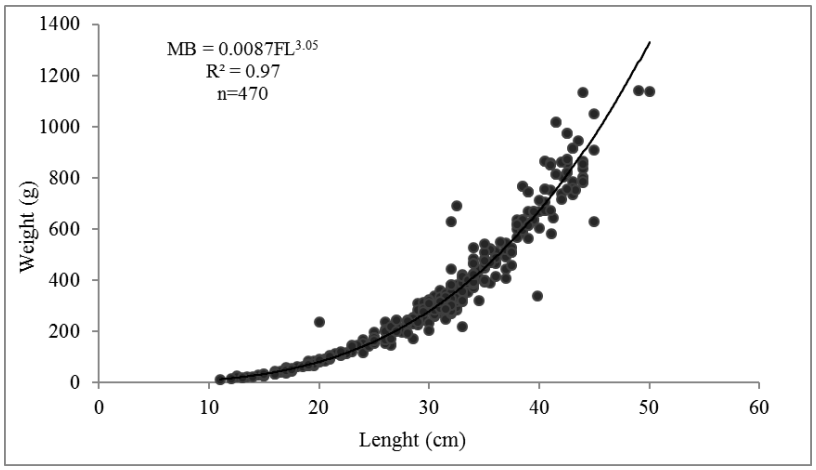


Figure 3: Length-weight relationship for *s. tumbil* from Sea of Oman.

Monthly mean variation of Gastro-somatic index For *N. thalassina* showed lower index (0.51±0.01) during the autumn season (December) and maximum (1.26±0.08) were observed in Spring (May) (Fig. 4). The mean GaSi was significantly different in different months (p<0.05).

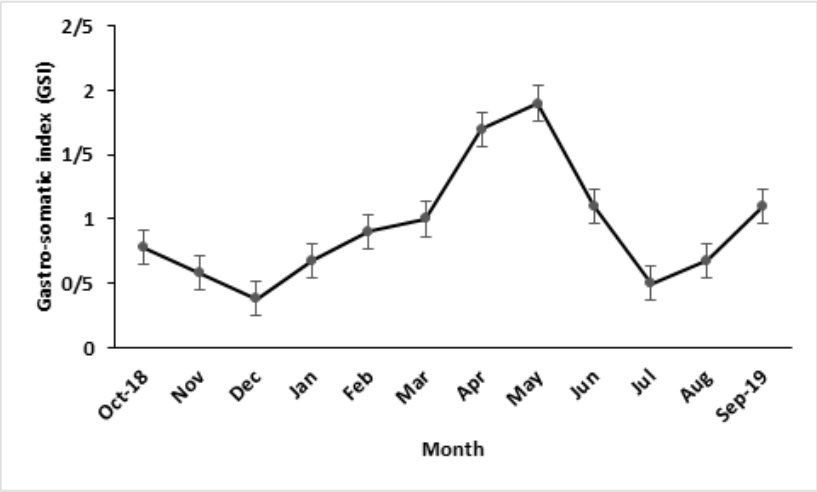


Figure 4: Monthly variations in mean Gastro somatic index of *N. Thalassina*

Frequency of prey in gut contents of *N. thalassina* showed decapod with F=50.79% as a major food items throughout the year whereas, fishes (F%=38.91), echinoderms (F%=35.73), cephalopods (F%=0.07), bivalves and gastropods (F%=23.78) and sea weeds (F%=24.33) could be considerd as a secondary food items except in summer. The family of Portunidae and

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Fishes (Carangid , Mullet and Sardine) were found in the stomach contents of *N. thalassina* in all seasons (Table 3).

The length-weight relationship for the combined sexes of *N. thalassina* was calculated as $M_B = 0.0105FL^{3.16}$ (R^2= 0.95) (Fig. 5).

Table 3: Seasonal variation in frequency (F%) and numerical occurrence (N%) of food items in stomach contents of *N. thalassina*

Food items	Season							
	Autumn (N=128)		Winter (N=40)		Spring (N=140)		Summer (N=50)	
	%F	%N	%F	%N	%F	%N	%F	%N
Nematoda	-	-	14.28	1.9	25.55	34.45	18.32	9.45
Bivalves and Gastropods	47.5	24.07	38.9	31.42	49.28	24.05	19.99	6.48
Fish	37.5	14.07	18.9	31.42	39.28	14.05	9.99	6.48
Carangidae	20	8	9	12	11	6	2.99	6
Mullet	10	4	7	10	16	5	5	-
Sardine	5.5	1.07	2.9	9.42	10.28	3.05	2	0.48
Unidentified fish	2	1	-	-	2	-	-	-
Decapods	15.17	2.31	14.34	2.58	20.47	16.39	0.81	0.64
Cephalopods	12.5	8.39	55.01	40.71	22.71	20	-	-
Echinoderms	25	11.73	-	-	80.99	50.71	-	-
Seaweed	40.87	34.56	30.17	21.17	1.97	1.02	-	-

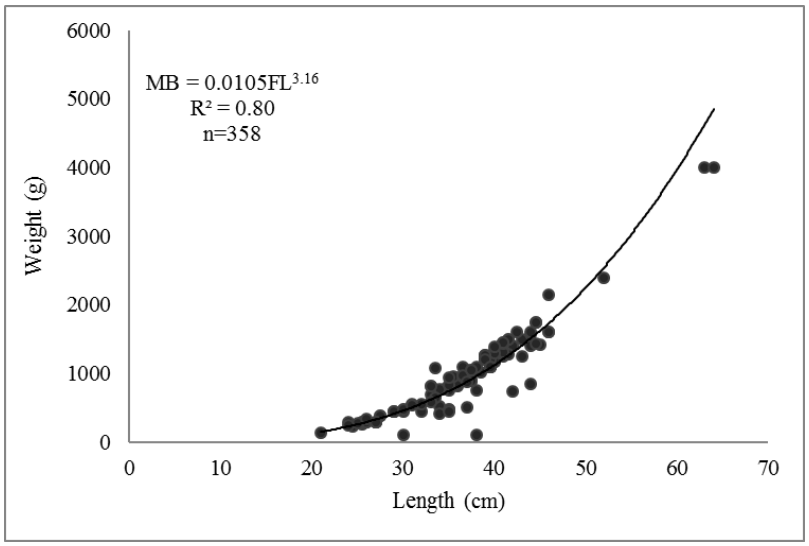


Figure 5: Length-weight relationship for *N. thalassina* from Sea of Oman.

The fork length of *P. kaakan* ranged from 18.50 cm to 63 cm, their weights varied from 112 to 3612 g (Table 1). The results of stomach contents and feeding intensity analysis showed that *P. kaakan* is a moderate feeder species (57.69%)(40<VI<60). The percentage of Vacuity Index showed lower percentage in the winter (14.10%) and higher in autumn (25.14%).

The lower mean of Gastro-somatic index was observed (0.73±0.16) during the Spring season (May) whereas the maximum (1±0.21) was recorded in Autumn (November) (Fig. 6). The mean GaSi in different months were significantly different (p 0<0.05).

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Table 4 shows the result of stomach contents analysis of *P. kaakan* which comprise of fishes (F%=50.91) and decopod (F%=50) as a main diet. The frequency of decapods prey such as *Epialthidae*, *Portunidae* and *Xanthidae* were different throughout the year but *Portunidae* was predominant. Based on the frequency occurrence, Bivalves and Gastropods (F%=35.91) were considered as minor prey species and other negligible diet groups were echinoderms, mantis shrimp and cephalopod.

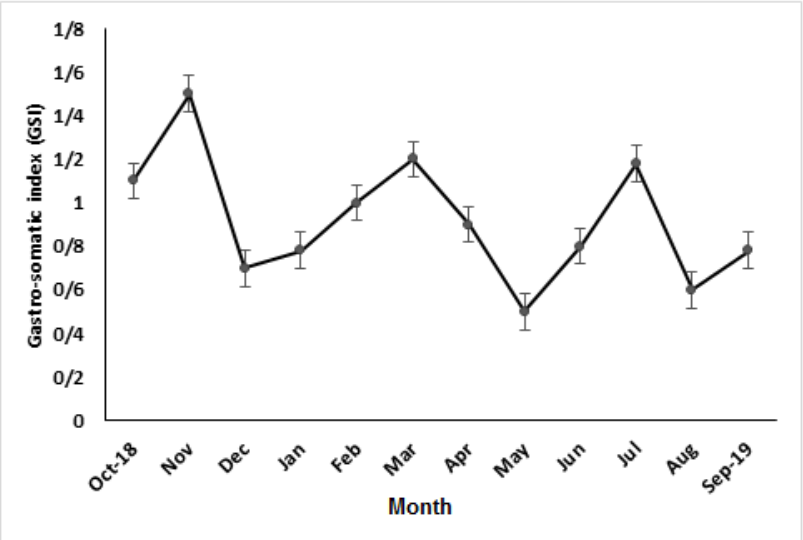


Figure 6: Monthly variations in mean Gastro somatic index of *P. Kaakan.*

Table 4: Seasonal variation in frequency of occurrence (F%) and numerical composition (N%) of food items in *p. kaakan*

Food items	Season							
	Autumn (N=103)		Winter (N=57)		Spring (N=110)		Summer (N=68)	
	%F	%N	%F	%N	%F	%N	%F	%N
Nemipterus sp.	10.47	6.39	2.07	0.39	2.33	1.02	2.67	0.34
Saurida sp.	1.41	0.79	0.71	0.95	-	-	0.38	0.14
Trichiurus sp.	88.61	31.48	61.18	24.43	47.79	11.62	6.03	0.73
Sillaginidae	3.61	2.69	5.21	7.11	-	-	-	-
Blenniidae	-	-	-	-	0.71	0.11	0.81	0.37
Upeneus sp.	13.00	16.68	6.52	12.66	8.03	2.11	-	-
Platycephalus sp.	0.65	0.07	-	-	0.81	0.37	-	-
Mullet	5.71	3.67	1.52	0.33	0.68	-	-	-
Sardine	1.41	0.23	0.71	0.95	1.75	1.10	-	-
Ponyfishes	-	-	0.71	0.48	-	-	-	-
Penaeidae	9.16	2.34	1.17	0.76	0.71	0.19	0.71	0.98
Cephalopod	2.60	1.44	0.62	0.07	1.85	1.04	-	-
Decapods	85.68	44.40	50.42	15.33	49.28	18.40	13.5	0.2
Bivalves and Gastropods	25.06	28.98	65.43	50.71	29.20	19.95	23.97	11.74
Echinoderms	-	-	2.6	0.87	-	-	-	-
Squilla mantis	1.48	0.15	0.71	0.19	-	-	-	-

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The length-weight relationship for the combined sexes for *P. kaakan* were calculated as, $M_B = 0.0035FL^{2.78}$ ($R^2 = 0.98$) (Fig. 7).

Feeding index, comparison between species (Seasonal variations in mean Gastro-somatic index)

Figure 8, demonstrated the variations in mean Gastro-somatic index for the species under studied based on monsoon's season. According to results, the maximum feeding intensity (GaSI) during post monsoon was belonged to *S.tumbil* (2.3%) and *P. kaakan* (1%) while for *N. thalassina* the maximum were observed in pre monsoon period (1.26%).

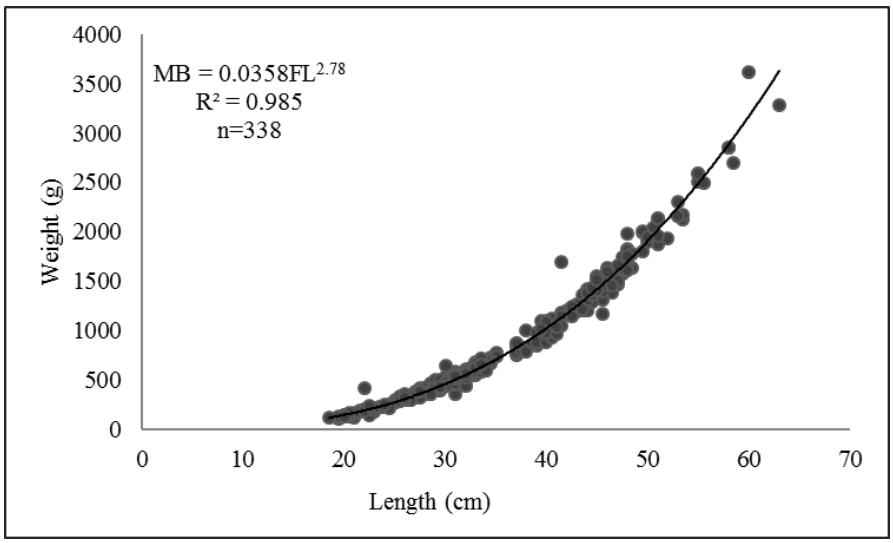


Figure 7: Length-weight relationship for *p. kaakan* from Sea of Oman.

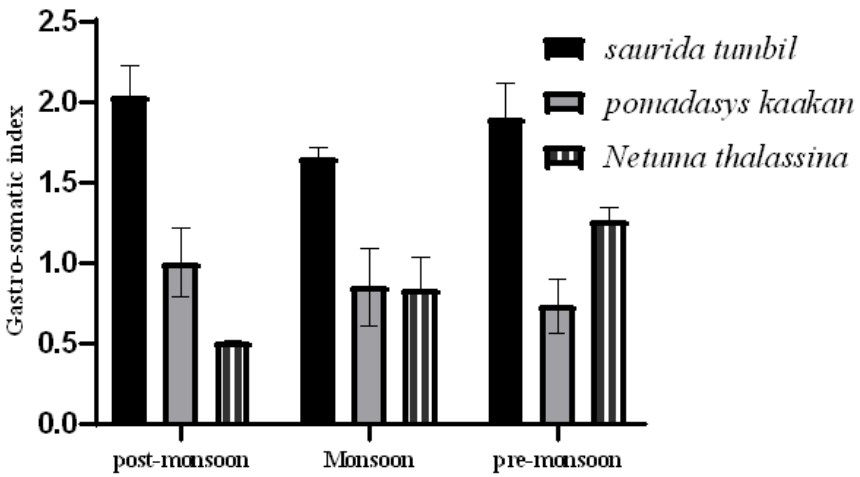


Figure 8: Sesonal variations in mean Gastro somatic index (±SD) of *S.tumbil, p. kaakan* and *N. thalassina* in the Oman Sea.

As provided Fig. 9, crustacean constituted the most food composition of the three fish species under study, followed by fishes, gastropods, cephalopods and seaweeds.

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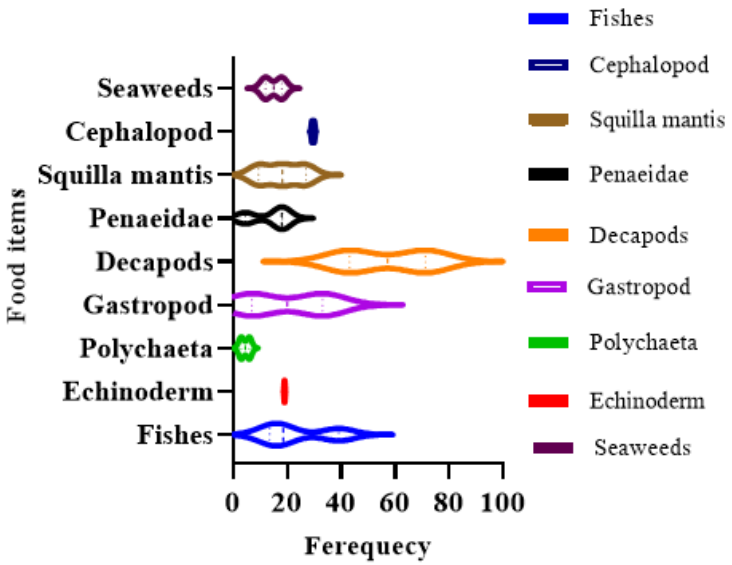


Figure 9: Diet composition of *S. tumbil, P. kaakan* and *N. thalassina* in the Oman Sea.

According to the results, fishes were constituted an important part of the diet composition of *S.tumbil* throughout the year and their occurrence peak was observed during post monsoon period, the occurrence of fish in the diet of this species was lower in pre monsoon. *Nemipterus* sp., *Saurida* sp., *Upeneus* sp. and ponyfishes were lower in the diet composition of the *S.tumbil* during monsoon .

Fishes with 13.48% during post-monsoon and decapods with 85.68% during pre monsoon were the most frequent items, whereas small fishes, cephalopods and penaeids were absent in the stomach contents of *P. kaakan* .

Fishes were contributed major food items throughout the year in the stomach contents of *N. thalassina*, and their occurrence peak was observed during pre monsoon period (%F=39.28). Moreover cephalopods and echinoderms were absent in the stomach contents during monsoon period. Mean number of prey items in the stomach contents of *N. thalassina* among the seasons was significantly different (p<0.05) .

Discussion

The results of the present study suggest high dietary overlap between three species under study (Fig. 9). The percentage of empty stomachs was calculated as, 53.3%, 48% and 57.7% for *S.tumbil, N. thalassina and P. kakkan* during study period, respectively. According to the results, the maximum feeding intensity for *S.tumbil* and *P. kaakan* were appeared during post monsoon and for *N. thalassina* in pre monsoon . *S.tumbil* has showed lowest GaSI index with empty stomachs in monsoon , similar to the finding of Barakzaii *et al.* (2011) in northern Oman Sea waters . The results of the present study showed highest VI index during summer season for *s.tumbil*. According to Mirzaei *et al.*

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(2015) spawning of *S.tumbil* occurs at the summer (August-September) and the high number of the empty stomachs of S.*tumbil* during summer could be attributed to the spawning time, when the fish usually decrease their feeding activity and use their lipid reserves (Sakamoto and McCormick, 2006, Lizama and Ambrosio, 2002).

The highest feeding intensity in fall and lowest in summer of this species in the northern part of the Persian Gulf were pointed out by Vahabnezhad *et al*. (2013) which is in conformity with the results of the present study.

According to the results it appeared that monsoon condition do not alter the feeding intensity of *P. kaakan* and *N. thalassina*. The lowest GaSI index for *N. thalassina* was observed in pre-monsoon and for *P. kaakan* was in post monsoon which coincided with the peak of their spawning period (Kamali *et al*., 2004). The explanation for decreasing feeding activity during spawning time might be related to seasonal changes in water temperature and foraging behavior of the fish (Sakamoto and McCormick, 2006).

The identification of prey items revealed that the most important prey taken by *P. kaakan* and *N. thalassina* were decapods, gastropods and fishes throughout the year. Meanwhile the most important prey for *S. tumbil* was mostly fishes, *Upeneus* sp., *Trichiurus* sp., *Nemipterus* sp. and sardine. Based on the results it could be concluded that the *S. tumbil* has the carnivorous diet behavior, feeds on wide range of fishes, which is consistent with the findings of Barakzaii (Barakzaii *et al*., 2011) in the Oman Waters.The finding of the present study showed that small pelagic and demersal fishes like ponyfishes, mullet and sardine were absent or negligible in the diet of *S. tumbil* during the monsoon season. A possible explanation may be due to drop in the phytoplankton and zooplankton biomass in coastal waters during monsoon (Gal *et al*., 2016).

Based on the stomach contents analysis, *P. kaakan* could be categorized as carnivorous fish species in which the main diet composition were, decapod, gastropod and fishes. Cephalopod and other benthose group were found to be a minor prey species in the diet of this species. The finding of present study is in agreement with Cheraghi *et al*. (2013) results, which mentioned that *P. kaakan* feeds mostly on crustaceans (crab and shrimp), fish, mollusks (bivalves, gastropods and cuttlefish), stomatopoda, and brittle stars. The seasonal variation in the diet composition of *P. kaakan* also noticed by Cheraghi *et al*. (2013). According to their finding crab and asteroid were dominant in autumn and Spring, while bony fishes were dominant in winter.

Based on the results of the present study, fishes including Carangid, mullet and sardine are the main prey items, consumed by *N. thalassina*, following by Portunidae (decapod), which constituted parts of stomachs contents of this species in all seasons. The high frequency of fishes and Crustaceans as a most abundant prey items in the Oman Sea have been notified by

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Alimohammadi *et al*. (2020) which is in conformity with the results of the present study.

According to different studies, monsoon period causes to decline the total biomass of zooplankton to its lowest level which has negative effects on the higher trophic level consumers and specially those feeding directly on zooplankton, because of limited diet resources (Kim et al., 2000, Gal et al., 2016). According to Soleimanirad *et al*. (2013) there appeared to be considerable differences in the composition of macrobenthos classes during pre and post-monsoon seasons while during monsoon, the composition of crustacean and polychaete densities were only 10%. The lack of cephalopod as an important prey in the Summer (July-September) in the diet conposition of three fish species under study could be attributed to the negative impact of rainfall on the fish habitats as well as on the environmental variables, especially SST and dissolved oxygen, which indirectly influence the cephalopd availability and its abundance (Mohamed *et al*., 2018).

The results of LWR of present study were compared with some of other marine ecosystem and presented in Table 5. The differences between values estimated for LWRs might be related to the condition of the species including phenotype and geographic distributions and hence their environments as several researchers have pointed out (Xu *et al*., 2019).

Table 5: Output of the LWRs of the north part of Oman Sea in comparison with other ecosystems.

Species	Ecosystem	a	b	Reference
S. tumbil	Northern part of Oman Sea	0.0087	3.05	present
	India	0.0047	3.14	(Abdulrahiman *et al*., 2004)
	Southerne east China Sea	0.00467	3.21	(Tzeng *et al*., 2002)
	Oman Sea	0.063	3.10	(Barakzaii *et al*., 2011)
	Malaysia	0.0020	3.340	(Ahmad *et al.*, 2003)
N. thalassina	Northern part of Oman Sea	0.0105	3.16	present
	Kuwait	0.00877	3.022	(Bawazeer, 1987)
	western Indonesia	0.00970	3.05	(Pauly, 1998)
	Oman Sea	0.00498	3.04	(Alimohammadi *et al*., 2020)
P. kaakan	Northern part of Oman Sea	0.0035	2.78	present
	Persian Gulf	0.02070	2.90	(Eatemadi *et al*., 2012)
	Oman Sea	0.0106	2.98	(Saberi *et al*., 2017)

In conclusion the results of the current study showed that the pre-monsoon, monsoon and post-monsoon periods have significant effects on the diet composition of fishes under study, which can be explained by changes in

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resource abundance, availability and diversity of prey. The results of the present study suggest that the monsoon period plays a crucial role in competitive interactions between the three species by shifting their diets as the availability of resource changes during this time.

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