Research Article

Investigation of Ecological Relationships among Some Economical Species in the Oman Sea Using Ecopath Model

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Abstract | The purpose of this study is to provide a model for evaluating and managing some economical important species based on the Oman Sea ecosystem and to examine nutritional relationships among five economical species, including *Saurida tumbil*, *Sphyraena jello*, *Acanthopagrus arabicus*, *Rastrelliger kanagurta*, *Trichiurus lepturus* in the Oman Sea waters located in Sistan and Baluchestan Province. A total of 1065 fishes was randomly collected from fishing evacuation areas and fish market from April 2020 to May 2021, and examined in terms of nutritional and stomach contents. Nutritional Model of the species in the Oman Sea was presented using Ecopath Software ver 6.6, and based on aquatic species of the region. The results showed that trophic levels of the species studied varied from 2.8 to 4.6, which lowest rate of it is related to *Rastrelliger kanagurta*, and the highest rate of in to *Trichiurus lepturus*, among the species studied that placed at the top of food chain, and mean of trophic level 3.9 was estimated that indicates fishing pressure on the existing species at the bottom of food pyramid. System omnivory index was calculated too that showed that predators of ecosystem feed on a wide range of prey and focus on a diverse number of prey items. Connectivity index obtained in this study was 0.18, indicates possibility of relationship between connecting paths and groups, indicating the richness of species in the Oman Sea.

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Introduction

As management of single type or single source still being applied in the fishing and fishery sector in many parts of the world is not complete and comprehensive. These findings were derived from the inability of this type of management to provide a suitable strategy for conserving marine ecosystems. Instead of focusing on only one single type, scientists today consider the capacity of entire ecosystem for all species. Instead of defining just one reference point for species, ecosystem management seeks to achieve goals such as conserving ecosystem, maintaining its structure, and maintaining interspecies relationships

as well. In fact, ecosystem-based fishery management notices all fishing activities effects on all components of ecosystem, including biodiversity, and it determines exploitation effects of fish species on ecosystem set, so finally exploitation from fish species becomes completely sustainable (Christensen *et al.*, 2000). There is no doubt that achieving these goals requires to be considered the complexities of ecosystem, including aquatic species biomass, their biological behaviors, and even human interventions such as the amount of harvest of which. Also, the ecological relationships among fish species should be certainly taken into account through recognizing nutritional behavior, trophic levels, nutritional overlap, food competition and their ecological status.

Materials and Methods

Total 1065 number of fishes, among 5 aquatic species, was randomly collected and examined from April 2020 to May 2021 seasonally, including *Saurida tumbil*, *Sphyraena jello*, *Acanthopagrus arabicus*, *Trichiurus lepturus*, and *Rastrelliger kanagurta,* in order to determine the nutritional relationships among aquatic species in the Oman Sea from the fishing evacuation areas such as Bazm, Konarak, Chabahar, Ramin, and Beris (Figure 1).

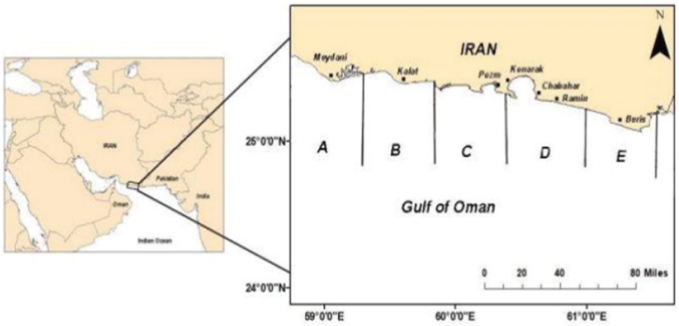

Figure 1: *Map of sampled stations in the Oman Sea.*

Biometrics of the samples includes measurement of fish lengths, tail fin heights, tail fin lengths, total weights (gr), full stomach weights and empty stomach weights were done by means of a digital scale with an accurate measurement of 0.1 g, then contents of their stomachs were identified and recorded using a loop and a microscope (Hyslop, 1980).

Food preference index (Fp) and Empty stomach (CV) index were examined and calculated using the following formula:

$$Fp = \frac{Nsj}{Ns} \times 100$$

Nsj: Number of stomachs that contains a specific prey (j). Ns: Number of stomachs that contains food ingredients.

If Fp is less than 10, it means that the prey fed is random. If Fp is between 10 to 50, it means that the prey fed is a second-hand food (secondary food), and if Fp is above 50, it means that prey fed is considered as the main food for aquatic species.

To calculate stomach emptiness index (CV), the following formula is used (Euzen, 1987).

$$CV = \frac{Es}{Ts} \times 100$$

CV: Stomach emptiness index; Es: The number of empty stomachs; Ts: The total number of the stomachs studied.

The value of this index is considered as follows: between 0 and 20, voracious feeder; between 20 to 40, Relatively voracious feeder; between 40 to 60, moderate feeder; between 60 to 80, relatively abstemious feeder; between 80 to 100, abstemious feeder (Chrisafi *et al.*, 2007).

Other information such as parameters and primary and secondary products, through the final report done, were used in the Iranian Fisheries Science Research Institute. Biomass, production, the ratio between production and biomass, the ratio between consumption and biomass, food composition and ecological efficiency were taken into account as the model inputs.

As mentioned before, the biomass of the fish species studied in this study was extracted from the results obtained from exploratory research by Swept-Area Method in the Persian Gulf carried out by the Fisheries Research Institute (Valinassab *et al.*, 2016).

The ratio between production and biomass weight mean (P/B)

In fishes, this ratio is the equivalent to total mortality (Z) that was calculated by Linear Catch-curve Method through FISATII Program (Christensen *et al.*, 2000).

The ratio between consumption and biomass weight mean (Q/B)

This index is used to measure coefficient and ecological

efficiency of food consumed (Palomares and Pauly, 1989).

$$Log\ Q/B = 7/964 + 0/204\ log\ W\infty - 1/965\ T + 0/083\ Ar + 0/532\ h + 0/398\ d$$

In this relation, W∞ is infinite weight, Ar is (Aspect ratio) that is the equal to h2/s, in which h is the height of tail fin and s is the area of tail fin part; h in vegetarians is the equal to 1, but in detritus and carnivores is the equal to 0; d in detritus feeders is the equal to 1, but in vegetarians and carnivores is the equal to 0. Infinite weight is also considered for the oldest fish that is obtained from the relationship between length and weight by placing infinite length in the relationship (King, 1995).

Ecological efficiency

It is a fraction of the entire production that is consumed by predators or caught by fishermen. This fraction will be close to number 1 for the majority of groups (Christensen *et al*., 2000).

$$Z = P/B$$

Z: Total mortality. P/B: The ratio between production and biomass.

Food level or trophic level, interactions index of trophic levels, omnivory index, overlap index, selectivity index, key species index, system omnivory index, and finally mutualistic relationships among the species studied, were from the outputs of Ecopath model in this survey (Christensen *et al*., 2000).

Results and Discussion

The rate of food consumed

This index which is used to measure coefficient and rate of ecological efficiency on consumed food is actually the amount of food consumed by the population of a type in a particular period of time. The rate of consumed food for the species studied is shown in the table below. According to the results obtained, *Rastrelliger kanagurta* with 11.60 had the highest rate, and *Saurida tumbil* with 2.48 had the lowest rate of food consumed in the study area (Table 1).

Preliminary estimation of trophic level

Trophic level (TL) represents the position of existing animals in food web. In this regard, at first, the initial data were parameterized in Ecopath Software, and then, the relevant model was fitted. The input parameters and the estimates of trophic level in the species studied in this research was obtained using Ecopath Software to analyze the Oman Sea ecosystem in (Table 2). What is obvious is that the species studied in this study had different diets and fed on different prey. This study identified 4 trophic levels in the food web studied. The basis of the food web begins with the phytoplankton group as the primary producer source at trophic level 1. Trophic level 2 contains vegetarians, including mainly benthic groups and zooplankton. Trophic level 3 includes carnivore species such as *Sphyraena jello* and *Trichiurus lepturus*, and Trophic level 4 has a high presence of predators at the top of the food web, including fishes (Table 2). In this study, the lowest trophic level trophic is related to *Rastrelliger kanagurta* fishes, and the highest rate is related to *Trichiurus lepturus* carnivorous fishes.

Table 1: *The rates of ecological efficiency and food consumed for the species studied.*

	Group name	Hab area (proportion)	Biomass in habitat area (t/km²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic Efficiency
1	Trichiurus lepturus	1.000	0.800	0.730	2.900	0.990
2	Rastrelliger kanagurta	1.000	0.800	3.300	11.60	0.330
3	Saurida tumbil	1.000	0.100	0.950	2.480	0.980
4	Acantapagrus arabicu	1.000	0.100	0.470	5.100	0.240
5	sphyraena jello	1.000	0.800	1.300	4.000	0.320

Table 2: *Estimation of trophic level of the species studied using Ecopath software.*

	Group name	Trophic level	Hab area (proportion)	Biomass in habitat area (t/km²)	Biomass (t/km²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic Efficiency	Production / consumption (/year)	Biomass accumulation (t/km²)	BA rate (/year)
1	Trichiurus lepturus	4.637	1.000	0.980	0.980	0.900	6.400	0.890	0.141	0.177	0.181
2	Sphyraena jello	4.096	1.000	0.200	0.200	1.700	8.000	0.650	0.213	0.055	0.275
3	Saurida tumbil	4.539	1.000	5.619	5.619	1.750	15.30	0.790	0.114	7.363	1.310
4	Acanthopagrus arabic	3.851	1.000	0.169	0.169	0.810	5.400	0.950	0.150	-0.115	-0.680
5	Atule mate	4.413	1.000	2.670	2.670	2.670	11.34	0.970	0.235	4.867	1.823
6	Sepia pharaonis	3.976	1.000	1.000	1.000	5.270	9.000	0.950	0.586	-10.091	-10.09
7	Squid	3.939	1.000	0.000600	0.000600	2.000	11.00	0.0700	0.182	-17.205	-28675
8	Nemipterus japonicus	4.137	1.000	17.56	17.56	1.000	9.400	0.890	0.106	-1.884	-0.107
9	Upeneus sulphurus	4.049	1.000	0.140	0.140	2.980	12.10	0.590	0.246	-18.523	-132.3
10	Rastrelliger kanagurta	2.822	1.000	0.122	0.122	3.300	12.90	0.990	0.256	-0.247	-2.028
11	Sardinella sp	2.500	1.000	0.416	0.416	4.300	16.00	0.890	0.269	-18.161	-43.66
12	Leiognathus aquulus	3.749	1.000	2.656	2.656	3.460	12.80	0.480	0.270	-28.928	-10.89
13	Crab	3.178	1.000	2.200	2.200	6.410	42.77	0.990	0.150	-67.089	-30.50
14	Peneaidae	2.920	1.000	0.00190	0.00190	1.300	6.000	0.560	0.217	-80.931	-42595
15	Echinoderma	2.790	1.000	2.270	2.270	5.000	18.57	0.990	0.269	-41.715	-18.38
16	Benthic invertebrate	2.300	1.000	11.00	11.00	1.370	11.00	0.850	0.125	-54.058	-4.914
17	Zooplankton	2.000	1.000	16.90	16.90	10.000	35.00	0.730	0.286	38.301	2.266
18	Sea weeds	1.000	1.000	0.240	0.240	11.90		0.960		-42.968	-179.0
19	Phytoplankton	1.000	1.000	129.0	129.0	134.0		0.0310		-71.692	-0.556
20	Benthic detritus	1.000	1.000	66.00	66.00			0.003			

Overlap index

Overlap index represents the common food items between aquatic species in which prey can be found in different abundance in different species stomachs. Since the range of this index varies between 0 and 1, so number 0 indicates a lack of common food source between predator and prey groups, and number 1 indicates a complete overlap between predator and prey groups.

The results showed that there are common food chains between *Trichiurus lepturus* and *Saurida tumbil*. Also, the *Sphyraena jello* has a nutritional overlap with the *Saurida tumbil*, and the *Saurida tumbil* has the highest food overlap with the *Acanthopagrus arabicus* and squid. *Acanthopagrus arabicus* has the most overlap with squid and *Nemipterus japonicus* and *Rastrelliger kanagurta* has the most overlap with sardinella fishes and this nutritional overlap in the ecosystem can cause the elimination of different types in food competition (Table 3).

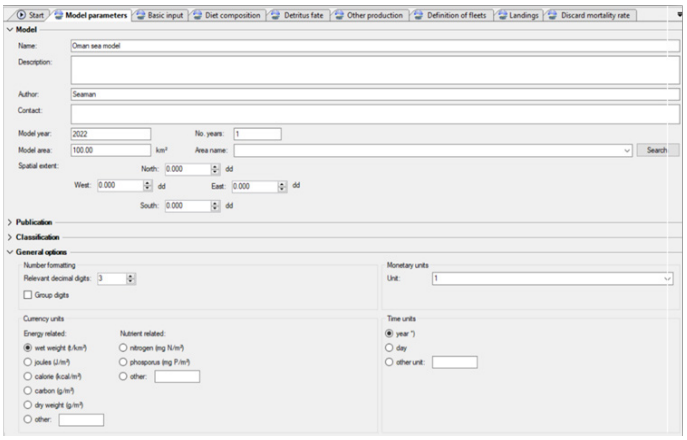

Figure 2: *Ecopath software for study of nutritional relationships in the samples.*

Table 3: *Overlap index between predator and prey groups in the Oman sea.*

	Group name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Trichiurus lepturus	1.000																		
2	Sphyraena jello	0.320	1.000																	
3	Saurida tumbil	0.611	0.435	1.000																
4	Acanthopagrus arabicus	0.391	0.286	0.429	1.000															
5	Atule mate	0.348	0.143	0.476	0.577	1.000														
6	Sepia pharaonis	0.286		0.316	0.625	0.667	1.000													
7	Squid	0.429	0.242	0.462	0.774	0.774	0.552	1.000												
8	Nemipterus japonicus	0.261		0.286	0.731	0.692	0.583	0.774	1.000											
9	Upeneus sulphurus	0.286		0.303	0.658	0.789	0.556	0.930	0.789	1.000										
10	Rastrelliger kanagurta	0.217	0.286	0.238	0.231	0.115	0.208	0.258	0.115	0.132	1.000									
11	Sardinella sp										0.789	1.000								
12	Leiognathus aquulus	0.222		0.240	0.633	0.600	0.857	0.686	0.600	0.714	0.233		1.000							
13	Crab				0.286		0.538		0.143		0.357	0.375	0.500	1.000						
14	Peneaidae				0.129		0.414				0.387	0.465	0.457	0.848	1.000					
15	Echinoderma				0.100		0.321				0.367	0.476	0.353	0.750	0.971	1.000				
16	Benthic invertebrate										0.370	0.513		0.414	0.563	0.677	1.000			
17	Zooplankton										0.635	0.667					0.156	1.000		
18	Sea weeds																			
19	Phytoplankton																			

Selectivity index

As shown in (Table 4), the figures of the selectivity index are shown with white to red background, and the figures between these ranges are with more light colors. This means that the closer the figures to number 1, the deeper red color background shows the rate of the food preferences increases. Also, the lighter color background shows the lower rate of the food preferences. As it can be observed in this model *Trichiurus lepturus* feeds on squid and crustaceans (shrimp). The preferred food for *Sphyraena jello* is *Saurida tumbil* and sardinella. *Saurida tumbil* preferred squid and shrimps are and crustaceans (shrimps) are preferred *Acanthopagrus arabicus*. *Rastrelliger kanagurta* preferred Crustaceans (shrimps) (Table 4).

Table 4: *The rate of selectivity index for the species studied in the Oman sea waters.*

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Trichiurus lepturus																	
2	Sphyraena jello																	
3	Saurida tumbil		-0.829															
4	Acanthopagrus arabicus																	
5	Atule mate	-0.981																
6	Sepia pharaonis		0.0500	-0.983		-0.985												
7	Squid	0.966		0.966		0.951	0.967											
8	Nemipterus japonicus			-0.998														
9	Upeneus sulphurus	-0.780		-0.780														
10	Rastrelliger kanagurta		0.951															
11	Sardinella sp	-0.921	0.744	-0.921	-0.706			-0.917			-0.704							
12	Leiognathus aquulus								-0.982									
13	Crab	-0.992		-0.992	-0.878	-0.990	-0.992	-0.968	-0.968	-0.968			-0.968					
14	Peneaidae	0.711		0.711	0.998	0.800	0.714	1.000	1.000	1.000	0.999		1.000					
15	Echinoderma				-0.939		-0.996		-0.979					0.561				
16	Benthic invertebrate				-0.994		-0.998				-0.994		-0.991	0.139	0.926	0.897		
17	Zooplankton										-0.992	0.986		-0.232	0.839	0.868	-0.576	
18	Sea weeds													0.965			0.998	
19	Phytoplankton										-0.998	0.427					-0.977	1.000
20	Benthic detritus														-0.0209	0.258	-0.873	

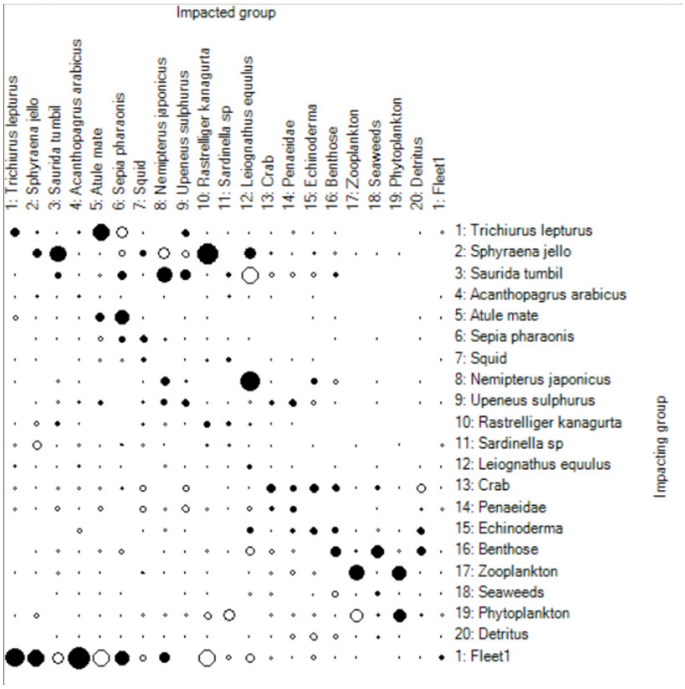

Figure 3: *Interactions index of on trophic levels of the species studied in the Oman Sea.*

Interactions index of trophic levels

This index indicating direct and indirect effects among the species on each other after making changes in ecosystem or making slight changes in aquatic species biomass. Cells in black color refer to two species positive effects and mutual benefits of each other, and white color cells refer to negative effects of two species on each other. In fact, these cells exhibit relative interactions and competitive ability between species. In general, predators at the top of chain in this system have a negative effect on their own preferred prey, and their prey also have positive effects on their own prey. The results shows that *Trichiurus lepturus* has a negative effect on *Acanthopagrus arabicus*, *Saurida tumbil* has a negative effect on *Sphyraena jello* and *Trichiurus lepturus* and *Sphyraena jello* has a negative effect on *Rastrelliger kanagurta*. Also, most of these

groups have negative effects on themselves reflecting an intraspecific competition for food sources. In fact, phytoplankton and zooplankton also have a positive effect on most consumers (Figure 3).

Omnivory index

Omnivory index (OI) shows the distribution of food interactions with trophic levels. If this index is 0, indicating nutrition from only one trophic level, and the higher rate of the index shows the more nutrition from several trophic levels. *Acanthopagrus arabicus* can be introduced as a dedicated predator that feeds on a food level, followed by the *Trichiurus lepturus. Sphyraena jello, Rastrelliger kanagurta* and *Saurida tumbil* feed on several food levels (Table 5).

Table 5: *Omnivorous index of the species studied in the Oman sea waters.*

	Name	Net migration (t/km²/year)	FlowToDet (t/km²/year)	Net efficiency	Omnivory index
1	Trichiurus lepturus		1.351	0.176	0.555
2	Sphyraena jello		0.439	0.266	0.528
3	Saurida tumbil		19.26	0.143	0.426
4	Acanthopagrus arabicus		0.189	0.188	0.0990
5	Atule mate		6.269	0.294	0.208
6	Sepia pharaonis		2.063	0.732	0.335
7	Squid		0.00244	0.227	0.0615
8	Nemipterus japonicus		34.95	0.133	0.114
9	Upeneus sulphurus		0.510	0.308	0.0166
10	Rastrelliger kanagurta		0.319	0.320	0.512
11	Sardinella sp		1.528	0.336	0.250
12	Leiognathus aquulus		11.58	0.338	0.145
13	Crab		18.96	0.187	0.229
14	Peneaidae		0.00337	0.271	0.230
15	Echinoderma		8.544	0.337	0.283
16	Benthic invertebrate		26.46	0.156	0.210
17	Zooplankton		163.9	0.357	
18	Sea weeds		0.114		
19	Phytoplankton		16750		
20	Benthic detritus				0.0650

Key species index

Key species index is to measure the role of ecological groups in food web as shown in (Table 6). The closer of this index is number 1 that shows much more high effect of the type on ecosystem. In this model, *Sphyraena jello* is the dominant group with the highest amount and with more nutritional relevance, followed by the *Trichiurus lepturus*, *Saurida tumbil* and *Rastrelliger kanagurta* were introduced by the software. It was also found that *Acanthopagrus arabicus* has a low index and has little effect on the region's ecosystem compared to other species (Table 6).

Mutualistic relationships among the studied species

In this model, the mutualistic relationships of nourishment the species are shown by lines that indicate the percentage of the amount of consumption from prey. This model also shows how the mutualistic relationships between nutritional chains and four trophic levels, but it also shows that some of the major living organisms have an intermediate position among different trophic levels. In this model, cells represent the amount of type biomass at their respective trophic levels.

According to this model, *Trichiurus lepturus* is at the top of food web as a predator, followed by *Saurida tumbil*, *Sphyraena jello*, *Acanthopagrus arabicus* and *Rastrelliger kanagurta* with the highest trophic level in the food web of the species studied in the Oman Sea respectively (Figure 4).

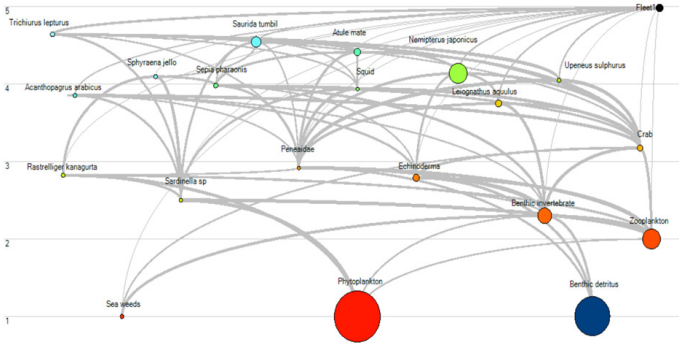

Figure 4: *Mutualistic relationships among species studied in the Oman Sea waters.*

Table 6: *The role of ecological groups in the food web among the species studied in the Oman sea waters.*

	Group name	Keystone index #1	Keystone index #2	Relative total impact	Keystone index #3
1	Trichiurus lepturus	-0.177	2.119	0.512	0.866
2	Sphyraena jello	-0.113	2.872	0.591	1.034
3	Saurida tumbil	0.103	1.652	1.000	0.815
4	Acanthopagrus ara...	-1.036	2.023	0.0706	0.141
5	Atule mate	-0.353	1.513	0.345	0.432
6	Sepia pharaonis	-0.564	1.724	0.210	0.438
7	Squid	-0.654	4.853	0.170	0.624
8	Nemipterus japonicus	-0.0768	1.006	0.706	0.266
9	Upeneus sulphurus	-0.540	2.600	0.221	0.665
10	Rastrelliger kanagu...	-0.566	2.634	0.208	0.665
11	Sardinella sp	-0.425	2.243	0.289	0.656
12	Leiognathus aquulus	-0.478	1.390	0.258	0.373
13	Crab	-0.239	1.709	0.447	0.720
14	Peneaidae	-0.317	4.690	0.369	0.938
15	Echinoderma	-0.432	1.503	0.287	0.476
16	Benthic invertebrate	-0.232	1.038	0.476	0.395
17	Zooplankton	-0.310	0.788	0.411	0.207
18	Sea weeds	-0.648	2.259	0.173	0.467
19	Phytoplankton	-0.584	0.0702	0.602	-0.105

The average food level was estimated by Ecopath software to be 3.9. This index is a criterion for

determining how to interact and distribute food components at the different levels of food chain so that if it is number 0, it indicates that predators act highly specialized and feed on from only one trophic level. According to study carried out, estimated rate in the present study was calculated the equal to 0.24, indicating the predators of this ecosystem have a limited range of prey and focus on a limited number of prey. In fact, these predators have a high ecological efficiency as well (Table 7).

Table 7: *Ecosystem analysis in the Oman sea waters.*

Parameter	Value	Units
Sum of all consumption	1191.812	t/km²/year
Sum of all exports	17000.730	t/km²/year
Sum of all respiratory flows	690.971	t/km²/year
Sum of all flows into detritus	17046.600	t/km²/year
Totsl system throughput	35930.109	t/km²/year
Sum of all production	17551.330	t/km²/year
Mean trophic level of the catch	3.978	t/km²/year
Gross efficiency (catch/netp.p)	0.00019	t/km²/year
Calculated total net primary production	17288.859	t/km²/year
Total primary production/total respiration	25.021	t/km²/year
Net system production	16597.881	t/km²/year
Total primary production/ total biomass	89.511	t/km²/year
Total biomass/ total throughput	0.005	t/km²/year
Total biomass (Excluding detritus)	193.148	t/km²/year
Total catch	3.073	t/km²/year
Connectance index	0.180	t/km²/year
System Omnivory index	0.246	t/km²/year
Ecopath pedigree	0.522	t/km²/year
Measure of fit. t	2.403	t/km²/year
Shannon diversity index	1.287	t/km²/year

Trichiurus lepturus

The study of gastric index (GaSI) and stomach emptiness index (CV) in this fish showed that this type is a member of voracious fish family and gastric index of this type calculated was the maximum in spring season, and the gastric index of this type calculated was minimum in summer season. Stomach emptiness index had an upward trend from spring to summer that reached its maximum in summer and had a downward trend after summer indicating a lack of nourishment of this fish in summer and the most nourishment of this fish in winter. In stomach contents of this type was observed the different groups of bony fishes, crustaceans and mollusca in order of priority; but the largest volume of stomach contents in this type consisted of bony fishes such as *Leiognathidae*. *Trichiurus lepturus* fish has a carnivore diet with a high variety of bony fishes, therefore it can be stated that the availability of foodstuff, seasonal fluctuations, and environmental conditions are very effective in diet of this type.

The study of nutritional behavior of *Trichiurus lepturus* in the Persian Gulf waters (within the waters of Bushehr Province) showed that different groups of bony fishes with 82 percent, and each of crustaceans and mollusca with 9 percent had consisted of the stomach contents of these fishes. Nutritional indices calculated for each month showed that yellow tailed carangidae with the highest frequency of predatory (Fp), 57.2%, are as the main food for this fish, and sardines, secondary food and mollusca are as random food for this fish. The results obtained from the study of nourishment for this type given the fact that the dietary type of *Trichiurus lepturus* is the carnivorous type of Yurifagus with a high diversity of the food items, which is completely in line with the results obtained from a research carried out in Brazil in 2009. The results of the research showed that a wide range of prey from the bony fishes group fed by *Trichiurus lepturus* fishes. In this investigation during autumn and winter seasons, cannibalism was observed among *Trichiurus lepturus,* which a high proportion of cannibalism can be attributed to the abundance of this type in the Persian Gulf waters and their cumulative nutritional behavior (Vahabnejad *et al*., 2018).

In the study was conducted on nourishment of *Trichiurus lepturus* on Qeshm Island, a wide range of prey belonged to the bony fishes group, indicating the nutrition of this type is in a combined way. In the present study, the mean of trophic level obtained from *Trichiurus lepturus* was 3.53, which with the rate of 4.45 is lower than the mean of trophic level obtained from the study done on Qeshm Island in 2018 and the study done in the western coastal region of India with the rate of 4.45 as well as the results obtained from the study done in the Mediterranean waters reported with the rate of trophic level 4.10 (Portsev, 1980).

In the Arabian Sea in 2015, the type of diet in this carnivore type was identified with food preferences of fish, crustacean and cephalopod, respectively (Rohite *et al*., 2015).

A study conducted in the China Sea in 2011 confirmed a carnivore diet with a food preference of fish, crustacean and cephalopod for this type as well (Yan *et al*., 2015).

In a study conducted on *Trichiurus lepturus in* the Persian Gulf waters, the trophic level of *Trichiurus lepturus* was obtained 4.6. It is asserted that if this type is not specifically exploited and its population increased, it will threaten the species on which being preyed (Vahabnejad, 2014). The mean of trophic level can be due to differences in harvest amount, differences in diet in different geographical areas, prey sizes, and availability to foods in the environment (Akhtar, 2008).

The results of omnivorous index in the study on this type in the Persian Gulf waters was 0.66 and showed 0.55 in the present study, which indicates that this type feeds on almost several trophic levels.

On the whole, it can be concluded that this type has a negative effect on ecosystem in terms of other species cannibalism and predatory.

Rastrelliger kanagurta

Fp index value or food preference in *Rastrelliger kanagurta* showed that 68.33 percent of this type forms phytoplankton and algae, 30.00 percent of this type forms mollusca, and 1.67 percent of this type forms fishes. Therefore, phytoplankton, algae and aquatic plants are considered as the main food and prey of this type, and mollusca and fishes are considered as random food of this type.

Stomach emptiness index (CV), which determines an estimate of voracious in fish, showed that in this index concerning *Rastrelliger kanagurta* is increasingly from spring to autumn, and nourishment goes from moderate feeder status to abstemious feeder status, and it reaches its lowest value in winter, which is a sign of voracious in fish. In fact, due to the spawning of this fish in summer season, the process of nourishing is not clearly done in this type and reaches a minimum, however it is obviously increasing after spawning. The results obtained from a study conducted on nourishment of this type in 2013 showed that the main diet of this fish is plankton with 93 percent, and a smaller percentage includes pelagic fishes (7 percent). Among plankton, zooplankton formed the massive bulk of the food (55 percent) that mostly included crustaceans (mostly copepods) with 81 percent and mollusca (mostly bivalves) with 10 percent. Copepods with 71 percent play the most role among zooplankton, but phytoplankton accounted for a lower percentage (45 percent). Also, *Engraulidae* was the only existing fish in stomach of the samples studied, and the fish stomach emptiness index with the rate of 36.1 showed that this fish is relatively voracious feeder (Bagheri *et al*., 2013).

In the southeastern coasts of the Arabian Sea, this type feeds mainly on zooplankton, and as it grows, its diet will change to calanoida copepods (Rohite *et al*., 2015).

According to the results of a study conducted on Qeshm Island in 2018, *Rastrelliger kanagurta* was among plankton feeder fishes that feeds on planktonic organisms. It was also stated that this type shows extremely little competition with its cotype and with other species in ecosystem, or no competition at all (Hakimelahi, 2018).

The investigation into the mean of Trophic level in this study was the equal to 2.82 as well. The amount of food consumed with a rate of 11.60 in the present study showed that this type has the most food consumed among other species, for which the index in the study of the Persian Gulf waters was calculated at 13.1 and with a greater rate. In the study of Persian Gulf waters, omnivory index of this type was 0.82 and representing nourishment from several trophic levels (Taghavi-motlagh, 2015).

Acanthopagrus arabicus

The Fp index or food preference in *Acanthopagrus arabicus* showed that 44 percent of the diet consisted of crustaceans, 37 percent of the diet consisted of mollusca and worms, and 19 percent of the diet consisted of fishes, so it can be concluded that almost all three groups are considered as the dietary constituent of this type and according to the percentage obtained from its secondary foods.

In fact, food preference index is used for determining the type of food to which fish prefer and mostly consumes, and it showed that this type has a carnivore diet. Crabs, worms, shells, and squids were regarded as the important species fed by this type.

Stomach emptiness index (CV), which determines

an estimate for the appetite of fish and the desire of fish to eat, showed that in *Acanthopagrus arabicus* the highest value of this index is in spring and indicated that this type in this season, when is its breeding season, is very abstemious feeder and with anorexia, however, this type is relatively voracious in autumn and especially in winter because this index in winter reaches its lowest value and shows a high nourishment and voraciousness in this type in this season.

The study conducted in the waters of Bushehr Province in 2014 showed that the food preferences of this type are mainly benthic invertebrates (crustaceans, mollusca and echinoderms). In fact, Bivalves are as the main food, whereas crustaceans and sea urchin are as the secondary food; and bony fishes are as the random food in this type, also the rate of TL for *Acanthopagrus arabicus* was estimated at 4.09 in a study conducted in 2013 (Vahabnezhad, 2014), so the higher rate can be due to the greater abundance and density of prey in the region. In a study conducted on *Acanthopagrus arabicus* in the Persian Gulf in 2015, it was found that its main food preference includes (crustaceans, mollusca and echinoderms), and the most nourishment is done from trophic levels 2.42 to above. Furthermore, this type had the most nutritional overlap with cuttlefishes, carangidae, catfishes, and squids (Taghavimotlagh, 2015).

In study conducted on this type on Qeshm Island, stomach contents of this type included bony fishes, crustaceans, and mollusca, respectively. Also, the selectivity index of the type in the study showed that the type feeds on shrimp, crab, and *Saurida tumbil* on average, and is weaker in selecting mollusca (Hakim elahi, 2018).

In the present study, the rate of food consumed by this type was identified 5.10. In the study conducted in the waters of the Persian Gulf in 2014, the rate of food consumed was estimated at 9.4 and it was found that this type does most nourishment from trophic level 2 to above and this type had much more food consumed than the Oman Sea (Taghavimotlagh, 2015).

In the present study, the mean of food levels in this type was estimated at 2.82 that is similar to the study done on Qeshm Island by (Hakim-Elahi, 2018) and in general, the selectivity of this type in the present study shows that it highly feeds on crustaceans such as crabs, and this type has a weaker selection than Mollusca.

Saurida tumbil

Fp index or food preference in *Saurida tumbil* showed that 87.72 percent of the diet consisted of fishes, 7.02 percent of the diet consisted of mollusca, and 5.26 percent of the diet consisted of shrimps, so it can be concluded that mollusca and shrimps are among the random prey, but fishes are the main diet constituent of this type. In fact, this index showed that this type has a carnivore diet, and fishes include the main diet of this type. *Sphyraena jello*, *Carangidae*, *Nemipterus japonicus*, *Leiognathidae* and *Trichiurus lepturus* fishes were considered as the important species fed by this type in this study.

Stomach emptiness index (CV), which determines an estimate for the appetite of fish and the desire of fish to eat, showed that in *Saurida tumbil,* the highest value of this index is in summer and indicated that this type is very abstemious feeder and with anorexia in this season, when is its breeding season, but is relatively voracious feeder in spring and autumn, so this index reaches its lowest value in winter representing to high nourishment and voraciousness in this type in this season.

In a study done on this type in the Persian Gulf in 2006, the diet of this carnivore type was determined that it feeds on levels 2 and 3 (Soofiani *et al.*, 2006).

In a study conducted on this type in the Persian Gulf and the Oman Sea waters in 2011, the diet of this carnivore type was determined. *Mullidae* and *Trichiurus lepturus* were the secondary food, but cephalopods and crustaceans were as random prey. In general, *Saurida tumbil* lacks of the main food and preys to its food based on the availability of existing species. Concerning stomach emptiness index with 51.7 percent was determined that the aquatic type has a moderate nourishment, and the highest rate of stomach fullness was in winter season and the lowest rate of that was in summer (Barakzai *et al.*, 2011).

Investigation into nourishment of this type in the waters of Bushehr Province showed that *Saurida tumbil* is a carnivore so that *Nemipterus japonicus,* sardines and *Saurida tumbil* are considered as the main food of this type. In this study also was found that the type feeds mainly on bony fishes (92 percent). Their

nourishment rate obtained from cephalopods was 6 percent and from crustaceans was 2 percent. Also, the mean of trophic levels in this type was obtained 4.61, which is higher compared to the Indian waters, where estimated at 4.40 (Vahabnezhad, 2014).

In the present study. The trophic level of this type was estimated at 4.53 that corresponds to the mean of trophic level in this type in the Indian Ocean waters, where is estimated at 4.40 (Rao, 1983). In terms of the rate of food consumed among these species studied, this type had the lowest food consumed; whereas in the study conducted on this type in the Persian Gulf waters, the rate of food consumed by this type was estimated at 3.15 (Taghavimotlagh, 2015). In terms of cannibalism and predatory concerning the other species, *Saurida tumbil* has a negative effect on the lower groups of food web and on ecosystem. With regard to key species index in this study, this type is also as the dominant type and with more nutritional relationship. It feeds on trophic levels 3 and 4 and is competing with *Trichiurus lepturus* and *Sphyraena jello* for food. In fact, *Saurida tumbil* has a negative effect on these two species and it is also a cannibal type. In the present study, *Saurida tumbil* was placed in the food pyramid as a predator.

Sphyraena jello

The Fp index or food preference in *Sphyraena jello* showed that 94 percent of the diet consisted of bony fishes such as *Sphyraena jello* and *Saurida tumbil*; and 3 percent of the diet consisted of *Rastrelliger kanagurta*; and 3 percent of the diet consisted of carangidea, so it can be concluded that fishes are the main food of this type, and this type has a carnivore diet. *Rastrelliger kanagurta* and carangidea were regarded as important species fed by the type in this study.

In a study conducted on *Sphyraena jello* in the waters of Sistan and Baluchistan Province in 2012, the results showed that this type is extremely carnivore one (Piscivorous), and over 96 percent of stomach contents is composed of fishes. Food preference index for this type was recognized sardines, *Rastrelliger kanagurta*, and *Stolephorus indicus*, but stomach emptiness index represented low nourishment of this fish; but considering the type of prey, the index in September can be only benchmarked that was the equal to 32 percent representing relatively voraciousness of this fish. The mean of stomach fullness index in this type was also calculated at 28.48% throughout this period (Vossoughi *et al*., 2011).

In the similar study conducted was stated that the main food of *Sphyraena jello* in the waters of Bushehr Province is *Planiliza abu* and *Tenualosa ilisha*, and then baby cuttlefish consisted of the least amount of stomach contents, and it seemed that *Sphyraena jello* fishes prefer to feed on *Clupeidae* (Hosseini, 2010). The results of the present study showed that carangiade, *Rastrelliger kanagurta*, and fishes digested consisted of the major stomach contents of this type. The position of big mouth of this fish indicates a carnivore diet and nourishment from water column.

In this study, trophic level of this type was estimated at 4.09 and it is as a prey for *Saurida tumbil* and *Trichiurus lepturus*. Furthermore, in terms of nourishment from several trophic levels, this type ranked the first among the studied species, and therefore this type has less ecological efficiency than other species but the greatest effect on the region ecology, followed by *Saurida tumbil, Rastrelliger kanagurta,* and *Trichiurus lepturus.*

Also, the exploitation coefficient of this type was calculated at 0.61, while the exploitation coefficient of this type in the study conducted in the Bushehr waters was calculated at 0.68 per year. The present study showed that conditions and reserves status of this type is below average (Doustdar *et al*., 2021).

Conclusions and Recommendations

Considering the numerical value of the mean of trophic levels is an indicator to stop fishing activity, calculated at 3.25 by the researchers, the mean of trophic level lower than 3.25, is followed to eliminate vegetarians, saprophagous and plankton feeders (Pauly *et al*., 2000). Nourishing from primary producers and detritus shows that its reason is high fishing and poor and average productions of the ecosystem.

The declining trend of trophic level in consecutive years also indicating fishing pressure on the species close to the top of food pyramid and the overexploitation of larger fishes. The nutritional model of the ecosystem of the southwestern coastal region of India showed that there is a high level of predatory, particularly for large-sized and medium-sized predators and predators from the floor as well as detritus feeders. And, the mean of trophic level was calculated at

3.61 (Vivekanandan *et al*., 2003). Also, research on the Arabian Sea showed that predator species in the coastal ecosystem of the Arabian Sea extremely feed on shrimps, crabs and detritus, and the mean of trophic level was calculated at 3.04 (Abdurahiman *et al*., 2006).

In a study conducted in the Persian Gulf waters (within Bushehr Province), the trophic level was estimated of 3.6, which still indicated that the species close to pyramid were eliminated by fishing activity, and these results obtained that the fishing activities pressure is focused on small species of fish and on species belonging to the bottom of food pyramid (Vahabnezhad, 2014). Also, in a study conducted in the Persian Gulf (on Qeshm Island), the mean of trophic level in the ecosystem studied was calculated at 3.081, which was very close to the mean of trophic level calculated in the Arabian Sea in 2008 (Hakim Elahi, 2018).

In the study carried out in the north of the Oman Sea, the mean of trophic level was estimated at 3.4l, and it was concluded that the food web is mostly composed of plankton, and phytoplankton have a positive effect on the other groups. And the North of Oman Sea is regarded as an immature ecosystem, including detritus feeders, plankton feeders and carnivores (Tajzadeh *et al*., 2020).

In this study, the rate of trophic levels was estimated at 3.9. It shows that exploitation in the Oman Sea waters is done through the middle level of food pyramid and indicating the species close to the top of the food pyramid were eliminated by fishing activity. Benthic invertebrates play an important role in nourishment the species studied, and it can be stated that the fishing pressure on species of the bottom of the food pyramid is high, so precautionary approaches are to be applied in fishing activities to exploit these species.

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Novelty Statement

This study is to provide a model for evaluating and managing some economical important species based on the Oman Sea ecosystem and to examine nutritional relationships among five economical species in the Oman Sea waters located in Sistan and Baluchestan Province of Iran.

Author's Contribution

Mastooreh Doustdar: Performed the experiment, conceptualization, execution, drafting the manuscript.
Seyed Ahmed Reza Hashemi: Helped in editing, supervision and proof reading.
Asadullah Ali Muhammad: Helped in literature, format setting and proof reading.
Maryam Frouzad: Helped in editing and proof reading.

Conflict of interest

The authors have declared no conflict of interest.

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