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RESEARCH PAPER

Biodiversity of Demersal Species from Trawl Surveys in the Iranian Waters of the Persian Gulf

Nassir Niamaimandi[1,*], Tooraj Valinassab[2], Reza Daryanabard[3]

[1] Iran Shrimp Research Center, Iranian Fisheries Science Research Institute (IFSRI), Agricultural Research Education and Extension Organization (AREEO), P.O.Box: 1374, Bushehr, Iran.
[2] Iranian Fisheries Science Research Institute (IFSRI), Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran.
[3] The Caspian Sea Ecology Research Center, Iranian Fisheries Science Research Institute (IFSRI), Agricultural Research Education and Extension Organization (AREEO), Sari, Iran.

* Corresponding Author: Tel.: +98.773 3331439 ; Fax: +98.773 3322782;
E-mail: nniamaimandi@yahoo.com
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Abstract

Data from trawl survey was used for estimate of biodiversity indices and abundance of demersal resources in the Iranian waters of the Persian Gulf. Sampling was done by R/V Ferdos 1 from 49 00E to 57 00E during January–March 2013.In this study, 130 stations within the 10-20 m, 20-30 m and 30-50 m depths were sampled. Abundance and biodiversity of demersal fish communities at different depth strata were evaluated by various indices. In summary, of 113 taxa identified, only 91 fish species were found typically demersal, 6 were pelagic and 16 were other marine organism groups. The results showed that 4.4% of 113 species have critically imperiled status, 5.3% are imperiled and 9.7% appear to be rare but not immediately imperiled. The indices value of Shannon for entire investigated area (10-50 m depths) were 3.14, Simpson 0.04 (D) and 0.96 (1-D), Pielou 0.72, Margalef 8.45 and Menhinick 0.15.Sorenson's coefficient between depths was 0.97 that shows high similarity in the depth strata. In general, the results of abundance and biodiversity indices indicate that, the health score is fair but this region is under stress.

Keywords: Species diversity, demersal resources, Northern Persian Gulf.

Introduction

The Persian Gulf is one of the world's youngest marine habitats, having been in existence for about 15,000 years. At the start of the Holocene this water body was nearly dry, and the areas that are currently 4–6 m deep have only been submerged for ~3000–4000 years (Sheppard *et al*., 2010).

Factors that can affect the biodiversity and abundance of marine species include fishing, pollution, habitat destruction, climate change, low productivity and predation. Commercial fishing exploitation in the Iranian waters of the Persian Gulf began in 1960 and followed by Saudi Arabia in 1963, Bahrain in 1966, Qatar in 1969 (Gulland & Rothschild, 1984) in the southern part. Fishing effort increased markedly within a relatively short period, resulting in over-exploitation of many species (Farmer & Ukawa, 1986). Increased competitive exploitation of fish resources using passive fishing techniques resulted in decreased catch rates that eventually required implementation of regulatory management measures. In the early 1990s, the Iranian fisheries organization banned the use of bottom trawling gear in the Persian Gulf, with the exception of the two month shrimping season during August-September. Artisanal fishers tend to focus upon demersal species using gillnets, traps and hand lines (Niamaimandi, 2006). Despite this new regulation, fishing remained high and uncontrolled of fishing effort, resulting in overfishing of target stocks.

The impacts on marine resources from increased commercial fishing have been compounded by other factors such as increased pollution and habitat destruction brought about by the development of new infrastructure for manufacturing, transportation, discharges from agriculture, energy and desalination processing, etc. The Persian Gulf is a shallow, marginal sea area, which absorbs more heat than typical oceanic inlets. CO_2 emission rates in the Persian Gulf are more than 3 times greater than the world average (Van Lavieren *et al*., 2011). Available information shows that high levels of hydrocarbon pollution throughout the Gulf, predominantly along the Iranian coastline (Rahmanpour, Ghorghani, & Ashtiyani, 2014). This contribution to global warming has an indirect impact on marine ecosystems. Pal and Eltahir (2015) stated that heat and humidity increases could occur in the Persian Gulf much earlier than previously anticipated.

A diversity index is a quantitative measure that reflects how many different types of species are in a community, and how evenly are distributed among these types. The types of interest are usually species, but they can also be other categories, such as genera and families. These indices, measuring ecosystem health and help us to understand changes that occur in our environment (Price, Jones, & Krupp, 2002). The extent of different measures of biodiversity indicators that are related to ecosystem functioning in the Persian Gulf are not clear and warrant further research (Price *et al*., 2002).

Several sampling methods are useful for measuring biodiversity indices and species distribution. Stratified random sampling is the most common method for demersal resources. A number of studies using bottom trawl survey data to assess the biodiversity and species abundance have been described for other areas (Cryer, Hartill, & O'shea, 2002; Gonzalez & Sanchez, 2002; Madurell, Cartes, & Labropoulou, 2004; Nguyaen, 2008).Very little similar information on species distribution for our Persian Gulf study area is available. Hence, the present study aims to explore the status of species diversity, changes in abundances and species composition, threats and conservation concerns.

Materials and Methods

Sampling was carried out during winter season, the main catch season in the area, of January to March 2013 in the Iranian waters of the Persian Gulf from 49° 00 to 57° 00E (Figure 1). The depth range extended from the 10 to 50 m and was divided into 3 depth strata of 10 – 20 m, 20-30 m and 30-50 m. The shallow area (10 - 20 m) covered about 1987.5 nm^2, the mid-depth (20-30 m) 1507 nm^2, and the deepest strata (30-50 m) about 3145.6 nm^2. In total, the study area comprised approximately 6640.1 nm^2.

The swept-area method was used for sample collection (Sparre & Venema, 1998). Sampling was done from the research vessel Ferdows1 (45.5 m length; engine power 673 hp) equipped with single bottom trawl net of 72 m head rope and 80 mm mesh size of cod-end. A one-hour haul was undertaken at a speed of three knots, although due to wind and wave condition, water current and topography condition, speed was not always stable. In this study, 159 trawl stations were initially selected, however only 130 valid trawl hauls were completed throughout the survey area (10-20 m, 39 stations; 20-30 m, 37 stations; and 30-50 m, 54 stations). All of catch was distributed into equal-sized baskets, a random sample in every five baskets was selected, and the results were later raised to the value for the total samples. The samples were then sorted, counted, and classified to species level whenever possible.

Sorenson's coefficient was used to calculate species similarity between depth strata using the equation:

$$(CC) = 2C/S1+S2$$

Where CC is the number of common species in the different communities, S1 is the total number of species found in community 1, and S2 is the total number of species found in community 2.

Six different indices for describing the species diversity have been devised**.**

The Shannon (1948) index H' is computed from the formula:

$$H' = -\Sigma Pi \times \ln(Pi)$$

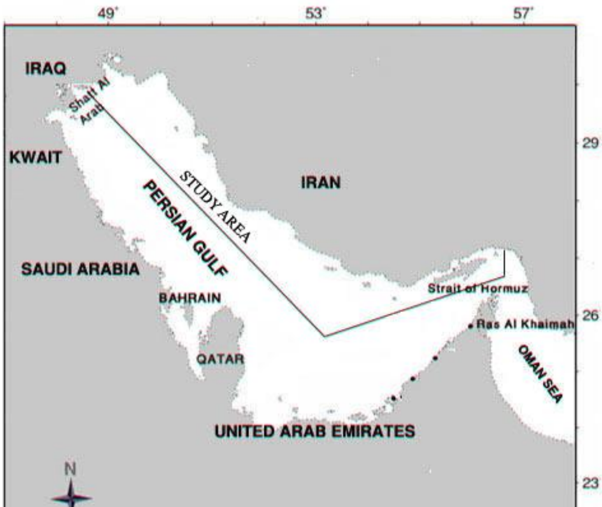

Figure 1. Sampling area of the demersal resources from northern Persian Gulf, Iranian waters in 2013.

Where *Pi* is the proportion of individuals found in the i_{th} species and ln*Pi* is natural log of the proportion of species i.

The Simpson's index *D* (1949) was calculated by the formula:

$$D= \Sigma N_i(N_i-1)/N(N-1)$$

Where N_i is number of individuals in species i, N is the total number of individuals in the community. In the present study, this Index is also expressed as 1–D.

The Evenness (J) is computed from Pielou's index (1966):

$$J = H'/ \ln S$$

H′ is Shannon index and S is natural log of the total number of species.

Margalef (1958) index (R) measure the species richness. This index was calculated by the formula:

$$R= S-1/\ln(N)$$

Where S is the number of species and lnN is natural log of the number of individuals.

Menhinick's index I_{Men}, was calculated by using the formula given by Menhinick (1964).

$$I_{Men} = S/\sqrt{N}$$

Where S is total number of species and N is total number of individuals.

Results

In this study, demersal fishes were targeted using bottom trawling techniques, however other species were captured as well. Preliminary investigations indicated that omission of non-target species had no appreciable effects on results, so these species were not removed from the database.

A total of 113 species or species group was recorded from 10 to 50 depths, including 97 fishes, shrimps (4 species), crabs (3 species), cuttlefish, squid (2 species), lobster (1 species)and unidentified sea shell , sea cucumber, sea turtle, jellyfish, corals, seahorse and sea snake species (Table 1). These species were distributed in different depths. Detail on the composition of fish families, genera and species in the different depths and areas are provided in Table 2.

Throughout this study, the highest percent of species was detected at 30-50 m (38%), followed by 20-30 m (35.5%) and 10-20 m depth (26.5%) zones (Figure 2). Most of species (77%) were common at all three depth strata. Sorenson's coefficient in three depth strata was 0.97.

Abundance values calculated for 564389 individuals. 75% of species were less than 1000 individuals at depths of 10-20 m, 73% at 20-30 m and 30-50 m. In total, more than 50% of species were about 200 individuals and 70% were 1000 individuals. 6% of species were more than 10000 individuals (Figure 3).

There were some differences in the proportions of dominant and rare species in the different depth strata (Figure 4). From 113 species or species spp., 4.4% were less than 5 individuals, 5.3% were 10-20 individuals and 9.8% were 21-100 individuals. 13 species or species spp., included of *Argyrosomus amoyensis*, *Centriscus scutatus*, *Echeneis naucrates*, *Cyclichthys orbicularis*, *Paramonacanthus oblongus*, *Ostracion cyanurus*, *Platycephalus indicus*, *Pomacanthus maculosus*, *Euryglossa orientalis*, *Cynoglossus* spp., *Platax* spp., *Paragaleus randalli*, and *Squilla* sp. were less than 100 individuals. Three species or species group, *Nemipterus japonicus* (N= 48041), *Ilisha* spp. (N= 38012) and *Saurida tumbil* (N= 36467) showing highest total abundances.

Distribution of genera and species among families is quite anomalous. From 62 fish families, 55 families (88.7%) had only one genus represented. four families (6.5%) had two genera and three families (4.8%) had more than three genera (Table 3). The majority of species was belonging to Carangidae family. Scianidae, Sparidae, Platycephalidae, Scomberidae, Haemulidae, Leiognathidae, Lutjanidae, Serranidae and Ariidae were each represented three species, while other families had only two or one species. The family Carangidae, with seven genera and seven species of all reported families was the most diverse in the study area.

Six different indices for describing the species diversity of demersal resources were calculated separately at each of the three depth areas (Table 4). Shannon index at different depths ranged from 3.10 to 3.21, Simpson (D) and (1-D) 0.6 and 0.94 respectively, Pielou evenness from 0.69 to 0.70 and Menhinick index from 0.22 to 0.24. The average indices value for Shannon for whole area were 3.14, Simpson 0.04 (D) and 0.96 (1-D), Pielou 0.72, Margalef 8.45 and Menhinick 0.15.

Discussion

The total number of fish species in the Persian Gulf have been estimated at 542 (Krupp *et al*., 2000), and 600 (Price *et al*., 2002). This area is known the second highest number for any enclosed or semi-enclosed sea in the world (Price *et al*., 2002). Sheppard, Price, & Roberts (1992) and Price (1982) reported that the most major benthic groups of the Persian Gulf are corals and echinodermsbut this area has an impoverished reef-building corals in the Indian Ocean (Sheppard, Price, & Roberts, 1992) and occupies 24th position among 26 Indian Ocean sites in terms of species richness.

In our study area, species abundance increased with deeper strata. The maximum abundance (38%) was observed at 30-50 m, and minimum (26.5%) at

Table 1. Identified aquatic species in different depths (m) of northern Persian Gulf (Iranian waters) by bottom trawl survey in 2013.

Fish species	*Epinephelus coioides*	*Pegasus volitans*	*Thryssa* sp.
Acanthopagrus latus	*Eupleurogrammus* sp.	*Parastromateus niger*	*Thryssa hamiltonii*
Acanthopagrus berda	*Euryglossa orientalis*	*Parupeneus heptacanthus*	
	(*Brachirus orientalis*)		*Thysanophrys celebica*
Acanthopagrus	*Fistularia petimba*	*Pelectorhinchus* sp.	
bifasciatus			*Triacanthus biaculeatus*
Acropama japonicum	*Gerres* sp.	*Platax* spp.	*Uranoscopus dollfusi*
Aetomylaeus spp.	*Grammoplites suppositus*	*Platycephalus indicus*	**Crabs**
		Plotosus lineatus	
Alectis spp.	*Gymnothorax phasmatodes*		*Portunus pelagicus*
Apogon cookii			*Portunus sanguinolentus*
(*Ostorhinchus cookii*)	*Heniochus acuminatus*	*Polydactylus sextarius*	
Argyrops spinifer	*Himantura* spp.	*Pomacanthus maculosus*	*Charybdis natator*
Argyrosomus spp.	*Hyporhamphus* spp.	*Pomadasys kaakan*	**Shrimps**
Ariomma indica			
(*Ariomma indicum*)	*Ilisha* spp.	*Pomadasys* sp.	*Penaeus semisulcatus*
Arius dussumiri			
(*Plicofollis*			
dussumiri)	*Johnius* sp.	*Priacanthus tayenus*	*Metapenaeus affinis*
Arius tenuispinis		*Pristotis obtusirostris*	
(*Plicofollis*			
dussumiri)	*Lactarius lactarius*		*Parapenaeopsis stylifera*
Arius thalassinus	*Leiognathus bindus*		*Fenneropenaeus merguiensis*
(*Netuma thalassinus*)	(*Photopectoralis bindus*)	*Protonibea diacanthus*	
	Leiognathus decorus		
Arothron stellatus	(*Nuchequula grreoides*)	*Psettodes erumei*	**Cuttlefish and squid**
Atule mate	*Leiognathus equulus*	*Pterois* spp.	*Sepia pharaonis*
Carangoides			*Loligo duvauceli* (*Uroteuthis*
malabaricus	*Lepidotrigla* sp.	*Pseudorhombus arsius*	*duvauceli*)
		Pseudosynanceia	
Caranx sp.	*Lethrinus lentjan*	*melanostigma*	**Lobster**
Carcharhinus	*Liza subviridis* (*Planiliza*		
dussumieri	*subviridis*)	*Rachycentron canadum*	*Thenus orientalis*
Centriscus scutatus		*Rastrelliger kanagurta*	**Other unidentified species**
	Lutjanus ehrenbergii		
		Rhinobatos granulatus	
Chirocentrus dorab	*Lutjanus johnii*	(*Glaucostegus granulatus*)	Mantis shrimp (*Squilla* sp.)
Chirocentrus nudus	*Lutjanus malabaricus*	*Saurida tumbil*	Corals
Cyclichthys			
orbicularis	*Megalaspis cordyla*	*Saurida undosquamis*	Jellyfish
Cynoglossus spp.	*Mene maculata*	*Scarus* sp.	Sea shells
Dactyloptena			
orientalis	*Nematalosa nasus*	*Scomberoides* spp.	Pleuronectiformes
Drepane longimana	*Nemipterus peronii*	*Scomberomorus commerson*	Sea snakes
Drepane punctata	*Nemipterus japonicus*	*Scomberomorus guttatus*	Sea turtle
Echeneis naucrates	*Ostracion cyanurus*	*Siganus canaliculatus*	Sea cucumber
Eleutheronema			
tetradactylum	*Otolithes ruber*	*Sphyraena* spp.	sea horse
Ephippus orbis	*Pampus argenteus*	*Terapon* spp.	
Epinephelus bleekeri	*Paragaleus randalli*	*Thamnaconus modestoides*	

(Some of species names have now changed and the currently accepted name based on World Register of Marine Species is given in parentheses).

Table 2. Diversity of fish species in different depths (m) of northern Persian Gulf (Iranian waters) by bottom trawl survey

Depths (Area nm^2, percentage)	10-20 (1987.5 29.9%)	20-30 (1507, 22.7%)	30-50 (3145.6, 47.4%)	10-50 (6640.1,100%)
Total family	60	62	56	62
Total genera	80	81	75	83
Total species	84	91	88	97

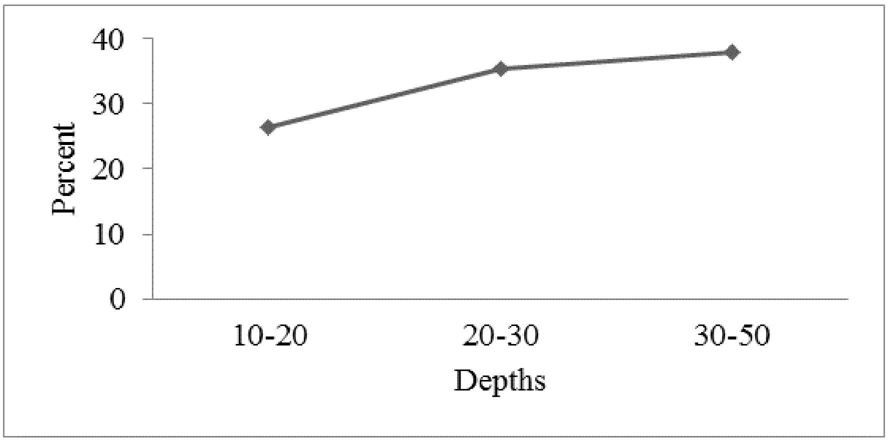

Figure 2. Percentage of species number at different depths from northern Persian Gulf, Iranian waters.

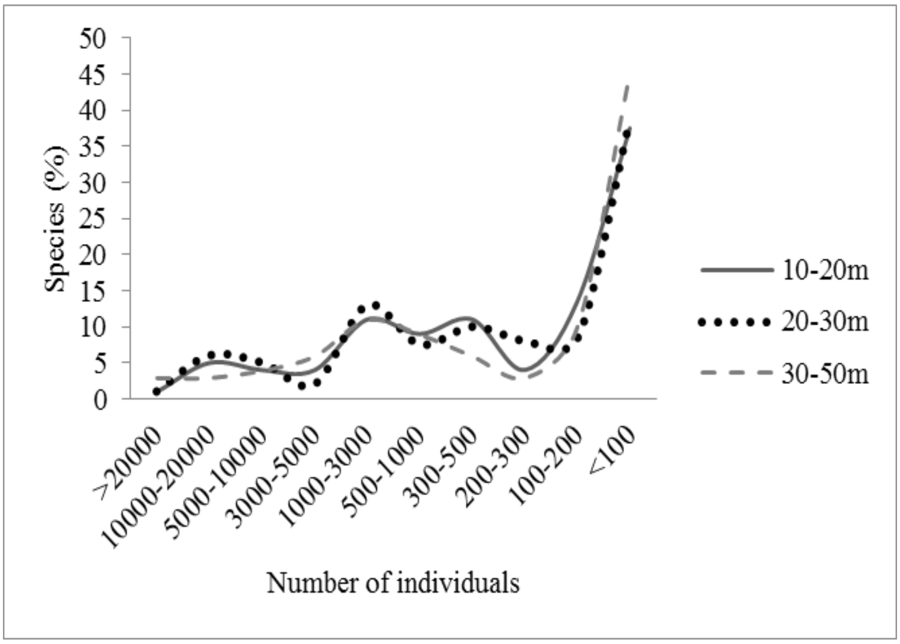

Figure 3. Number of individual species at different depths from northern Persian Gulf, Iranian waters.

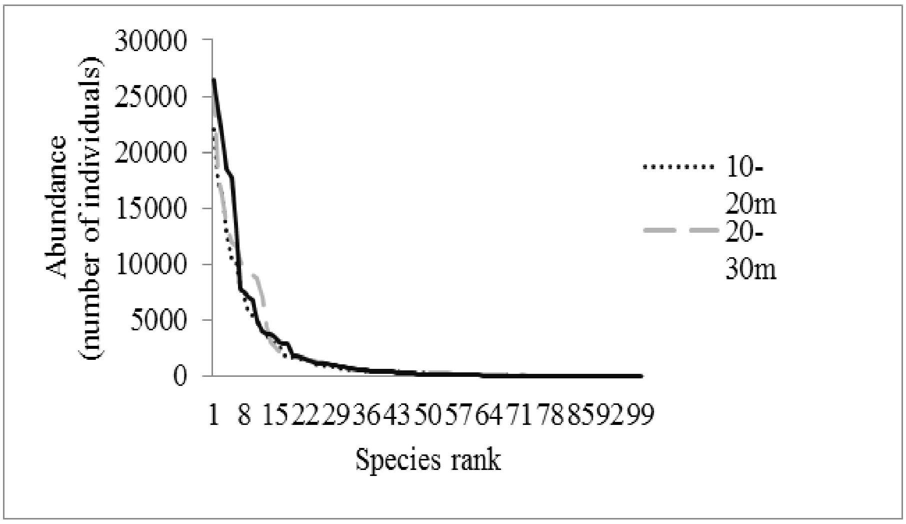

Figure 4. Rank-abundance plot of each species at different depths from northern Persian Gulf, Iranian waters.

Table 3. Number of recorded genera in different fish families from northern Persian Gulf (Iranian waters) by trawl survey

Family	Number of genera	Number of species
Carangidae	7	7
Sciaenidae	4	4
Platycephalidae	3	3
Sparidae	2	4
Scombridae	2	3
Haemulidae	2	3
Scorpaenidae	2	2
Ariidae	1	3
Leiognathidae	1	3
Lutjanidae	1	3
Nemipteridae	1	2
Synodontidae	1	2
Polynemidae	1	2
Ephippidae	1	2
Chirocentridae	1	2
Serranidae	1	2
Drepanidae	1	2
Engraulidae	1	2
	33	51

Table 4. Diversity indices of trawl survey from different depths of northern Persian Gulf, Iranian waters

Depths	H'	D	1-D	J	R	I_{Men}
10-20	3.21	0.06	0.94	0.70	8.15	0.24
20-30	3.21	0.06	0.94	0.69	8.12	0.22
30-50	3.10	0.06	0.94	0.66	8.58	0.23
10-50	3.41	0.04	0.96	0.72	8.45	0.15

10-20 m depths. In total, about 113 identified species, the greatest number of species was observed in strata of 20 – 30 m with 91 species, then the deeper water (30 – 50 m) with 88 species and shallow area (10-20 m) with 84 species. However, 30-50 m depth zone area was larger than other investigated areas and is twice (3145.6 nm^2) as large as the 20-30 m (1507 nm^2) depth strata. On the other hand, the number of species and abundance per area, which were observed in the different strata, were very different and 20-30 m depths has considerably higher number of species and abundance per area compared to the other areas.

Species were mostly common in the depth strata. Sorenson's coefficient gives a value between 0 and 1, the closer the value is to 1, the more the communities have in common and dissimilarity is equal to 0. The result of Sorenson's coefficient in three depth strata was 0.97 that showed high similarity between depths.

Ranking state of the species in the studied areas was described by using Oregon Biodiversity Information Center (2013). Of the 113 species or species group, 5 (4.4%) species were less than 5 individuals that are vulnerable condition and critically imperiled, 6 (5.3%) species were 6-20 individuals that are of imperiled concern and 11 (9.7%) species appear to be rare but not immediately imperiled. From these, *Argyrosomus amoyensis* is critically imperiled, two species, *Echeneis naucrates* and *Pomacanthus maculosus* are imperiled and three species, *Platycephalus indicus*, *Thenus orientalis*, *Cynoglossus* spp. are rare. Two shark species, *Carcharhinus dussumieri* and *Paragaleus randalli* were less than 5 individuals. *P. randalli* is taken by trawl and gillnet in the Persian Gulf (Carpenter, Krupp, Jones, & Zajonz, 1997). Therefore, identified shark species are especially vulnerable.

The most diversity indices used in ecology are the Shannon (1948) and Simpson (1949) however, richness and evenness are the components of diversity. Diversity cannot be estimated just by one index (Hayek & Buzas, 1997; Purvis & Hector, 2000). To overcome these limitations different diversity matrices have been assessed in the present study.

Shannon index determines diversity characteristics. This diversity index varies from zero to five. According to this index, values less than 1 characterize heavily polluted condition, and values in the range of 1 to 2 are characteristics of moderate polluted condition while the value above 3 signifies stable environmental conditions (Magurran, 1988). In the present study, Shannon index varied from a lowest of 3.10 at depths 30-50 m to a highest of 3.21 at 10-30 m depths. These values signify stable environmental conditions of the studied area. Simpson index ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. The Simpson index also represents the possibility that two randomly observations belong to the same class (D) or to different classes (1-D). Simpson index in different classes (1-D) ranges also from 0 to 1, but in this index, the greater the value, the greater the diversity. This index is used as the index, with values close to 1 (0.94 at different strata) showing a community of many species with equally low abundances.

Evenness index represents a standardization form of the Shannon index, displaying the relations between the class frequencies (Pielou, 1966). The index equals one when the class frequencies are similar and it tends to zero when the majority of observations belong to a single class. In the studied area, different strata had an evenness index of 0.66 at depths 30-50 m to 0.70 at depths 10-20 m. The results of Pielou's index (J) indicate the level of equality between species within a community. The result of Sorenson's coefficient shows, studied communities in different depth strata have quite of overlap or similarity. However, there was no balance or evenness among species either in terms of the number of individuals in the present study.

During this study, parallel relationship of Shannon diversity index with high evenness index was observed. This result indicates that community is dominated by less number of species and dominance is shared by large number of species. The low diversity associated with 30-50 m depths that larger than two other areas, as ascribed by the Shannon's and Palou's indices, can be attributed to lesser number of species and environmental degradation.

Margalef index is used to measure the species richness. In general, the higher the index value the greater the diversity. However, this index is very sensitive to sample size. Moreover, the species richness of the studied area is not highly varies in different strata. Menhinick index estimates species richness and resulted after a comparative study on diversity indices but independent on the sample size (Menhinick, 1964). The index value is not taking into account class frequencies. In this study, Menhinick index ranged from 0.22 for 20-30 m depths to 0.24 for 10-20 m depths. Overall, the results show low species richness in the area. Low species richness in the Persian Gulf was reported in studies of Basson, Burchard, Hardy, and Price (1977) and was confirmed by later research (Sheppard *et al.*, 1992; Price & Rezai, 1996; Price, 2002). However, as noted earlier the Persian Gulf has 542 known fish species (Krupp *et al.*, 2000), the second highest number for any enclosed or semi-enclosed sea in the world (Price *et al.*, 2002). Hence, in terms of species richness, the Gulf is not necessarily impoverished, although any conclusions about biodiversity drawn from one biotic group must be tentative, pending compilation and analysis of comprehensive data sets for other fauna and flora (Price & Izsak, 2005).

Studied area attributed to stressful environmental conditions, in particular fluctuations in sea temperatures and high salinities (Sheppard *et al.*, 1992), coupled with post-Pleistocene sea level fluctuations (Price, 1982). Stressful environmental conditions in the Persian Gulf may be a critical factor for depressed species richness. (Sheppard *et al.*, 1992). Warwick and Clarke (1995) noted that conceptually in the Persian Gulf, diversity is reduced in smaller areas when comparing with oceanic basins. Pollution due to various anthropogenic factors is a serious problem in the Persian Gulf. Oil exploration and shipping traffic are the main factors involving oil spills in the Persian Gulf. A number of studies have found elevated levels of contaminants including polychlorinated biphenyls (PCBs) and other persistent organic pollutants (POPs) and heavy metals in the Persian Gulf (Al-Sayed, Al-Saad, Madany, & Al-Hooti, 1996; de Mora, Fowler, Wyse, & Azemard, 2004; Fowler, Villeneuve, Wyse, Jupp, & de Mora, 2007; Saeidi, Abtahi, Seddiq Mortazavi, Aghajery, & Ghodrati Shojaeii, 2008; Rahmanpour, Ghorghani, & Ashtiyani, 2014). In a report of the impacts of the oil spill from Gulf War in 1991, Al-Ghadban *et al.* (2007) concluded that the oil pollution reflected on less biodiversity, disappearance of some important species and the occurrence of some new species in the area.

Food limitation can be a factor in species declines (Pitcher, 1990; Trites, 1991; Rosen & Trites, 2000). Food chain of the most of demersal resources is small benthic animals. In the shrimp season, trawlers weighted with chains, steel beams or other equipment, destroying habitat of benthic animals. Furthermore, trawling is known to impact corals and sponges, which provide habitat for many demersal species. Rezai, Wilson, Claereboudt, and Riegl (2004) reported a general sharp decrease in living coral, with an accompanying modification of coral species distribution. Although the role and size of food limitation and habitat destruction by trawl nets in the studied area has been unknown and controversial. The results indicating that several species are of conservation concern. For many of these species, positive changes in management could prevent further decline but if current trends continue, this unique marine environment encounter to serious socio ecological implications in the future.

Conclusion

Because the depth strata are so geographically close to one another, the results showed that there were very similar levels of diversity indices in different depths. Results of the biodiversity indices and abundance in the region indicate that, this area has a fair quality, but it has low abundance and under stress. Of 91 demersal species, 6 species have vulnerable status. Two shark species (*Carcharhinus dussumieri* and *Paragaleus randalli*) are also categorized as vulnerable. To create a more reliable and elaborate results, this research needs to follow up for the entire area of the Persian Gulf. The results of the present study could be made a good foundation for future scientific research.

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