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Research Article

Gillnet catch composition and biodiversity in Bushehr County, Persian Gulf, Iran

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Abstract

The main purpose of this study was to investigate gillnet catch composition and biodiversity caught by 130, 140, and 150 mm (STR) mesh sizes during fishing seasons. This research was conducted in the fishing ground of Bushehr County located in the Persian Gulf from autumn 2018 to spring 2019. Overall, 23 families including 36 genera and 43 species were identified. Spring season with 42 species and winter season with 32 species showed the highest and lowest species biodiversity, respectively. Carangidae family with 7 genera and 8 species, Scombridae family with 3 genera and 4 species, and Dasyatidae with 3 genera and 4 species were the families with the highest species biodiversity. *Scomberomorus commerson* and *Thunnus tonggol* with 23.45% and 21.84% in autumn, 20.15% and 25.85% in winter, 21.9% and 19.78% in spring showed the most abundance percentages, respectively. The 130 mm mesh size and spring season had the highest abundance, diversity, and the number of caught species in comparison with other mesh sizes and seasons. Two-ways ANOVA results showed that the effects of mesh sizes and seasons on the calculated metrics were significant ($P<0.05$), but their interaction effect was not significant ($P>0.05$). The highest and lowest Jaccard (J) and Sørensen (S) seasonal similarities were between autumn and spring (J: 0.805, S: 0.892) and autumn and winter (J: 0.561, S: 0.719), respectively. The results of non-metric multidimensional scaling analysis showed that 130 and 140 mm mesh sizes had overlap in terms of the fish abundance and catch composition. Cluster analysis also showed the highest similarity between *S. commerson* and *T. tonggol*, and *Euthynnus affinis* and *Scomberoides commersonnianus*.

Keywords: Catch composition, diversity, fish, fishing gear, similarity

Introduction

The Persian Gulf is located in a subtropical zone and is separated by the Strait of Hormuz from the Gulf of Oman. The surface area of the Persian Gulf is 239 000 km^2 and its mean volume and depth are 8630 km^3 and 36 m, respectively (Reynolds 1993). As a result, the distribution and penetration of the Indian Ocean species through the Gulf of Oman and the Strait of Hormuz form the fish fauna of the Persian Gulf (Krupp *et al.* 1997, Gerami *et al.* 2014). Mackerels, shrimps and various Perciformes fishes are the main target species in the Persian Gulf (Paighambari and Daliri 2012, Gerami *et al.* 2014).

Gillnets are a group of passive fishing gears that are deployed as a vertical wall in the migration and movement path of the target fish. Gillnets are usually used for surface and subsurface fishing of tuna and other medium-large fish.

This fishing gear is one of the most imperative fishing methods used internationally in the Black Sea, Mediterranean, Northeast Atlantic, and Western Pacific (Hameed and Boopendranath 2000). The suitable mesh size is one of the most important requirements for designing of gillnets to catch the target species. The inappropriate mesh size reduces the catch rate and may increase the volume of the discard and bycatch rates (Hameed and Boopendranath 2000).

Biodiversity can be explained as number, composition, and richness of species at levels of genetic diversity between species, within species, and ecosystem level. Studies on biodiversity assessments have been conducted to recognize the structure and evolution of the ecosystem, preserve the genetic resources, evaluate and control the ecological pressures, and recognize regions that are appropriate for the protection of biological diversity (Burely 2002). So far, several studies have been done about fishing by gillnet in Iran (Darvishi 2011, Dastbaz 2011, Moein 2013, Gerami *et al.* 2014, Parsa *et al.* 2014, Alimirzaei 2017, Hosseini *et al.* 2017, Paighambari *et al.* 2018a, Paighambari *et al.* 2018b, Eighani *et al.* 2020) and other countries (Millar and Holst 1997, Claereboudt *et al.* 2005, Campos *et al.* 2005, Batista *et al.* 2009; Emmanuel and Chukwu 2010, Allison and Okadi 2013, Mendonca and Pereira 2014, Khatavkar *et al.* 2017). Most Iranian studies are focused on the catch composition, catch per unit effort (CPUE), and determination of standard mesh sizes for target species in a short study period. In this study, it was hypothesized that changing the gillnet mesh size and season could affect the number and diversity of caught fish. Therefore, the main purpose was evaluating the effect of 130, 140, and 150 mm mesh sizes and different fishing seasons (autumn, winter, and spring) on the number and diversity of caught fish in the fishing grounds of Bushehr County, Persian Gulf).

Material and methods

Study design

This investigation was performed in the fishing ground of Bushehr county located in the Persian Gulf (latitude 29° 18′ to 28° 40′ N; longitude 50° 04′ to 50° 32′ E) from autumn 2018 to spring 2019 (Figure 1). The marine fish specimens were caught using multifilament drift gillnet with stretched mesh sizes of 130, 140, and150 mm (STR) in the artisanal wooden dhows. Fish species were counted on the deck. Then fish were identified using the standard keys of marine fish species (Fischer and Bianchi 1984, Carpenter *et al.* 1997, Nelson 2016).

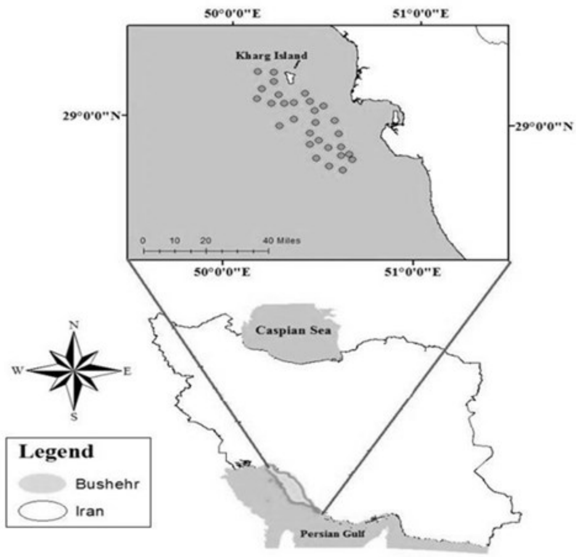

Figure 1. The geographical location of fishing grounds in the Bushehr County, Persian Gulf, Iran.

Measures of Diversity and Similarity

Shannon-Wiener (H') and Simpson indices (D) were used for the calculation of seasonal diversity as follow (Washington 1984):

$$H' = \sum_{i=1}^{s} P_i \ln P_i$$

$$D = \sum_{i=1}^{s} {P_i}^2$$

Where P_i is the relative abundance of the i^th^ species and S is the total number of species.

Margalef diversity index (d) was calculated as follow (Gamito 2010):

$$d = \frac{(S-1)}{lnN}$$

Where N is the total number of individuals in the sample.

Jaccard (S_J) and Sørensen indices (S_S) were used for calculation of monthly and seasonal similarity as follows (Washington 1984):

$$S_J = \frac{a}{(a + b + c)}$$

$$S_S = \frac{2a}{(2a + b + c)}$$

Where a is the number of species common to both time points, b is the number of species unique to the first time point, and c is the number of species unique to the second time point).

Statistical Analyses

The biodiversity and similarity indices were calculated using Ecological Methodology software (Krebs 2001). One-way and Two-way ANOVA were implemented using SPSS software (version 21) and Microsoft Office Excel 2013 to determine the effect of mesh sizes and season on abundance, the number of species, and the three measurements of diversity. Non-metric multidimensional scaling (nMDS) (according to the Bray-Curtis similarity matrix) and cluster analysis were performed using PRIMER software (Version 5.2.2) (Anderson *et al.* 2015).

Results

During this study, a total number of 23 families, including 36 genera and 43 species, were identified. Spring with 42 species and winter with 32 species showed the highest and lowest diversity, respectively. Carangidae family with seven genera and eight species, Scombridae family with 3 genera and 4 species, and Dasyatidae with 3 genera and 4 species were the families with the highest species biodiversity. Among the caught fish species, *Scomberomorus commerson* and *Thunnus tonggol* with 23.45% and 21.84% in autumn, 20.15% and 25.85% in winter, 21.9% and 19.78% in spring were the most abundant, respectively (Appendix table).

Comparison of mean values across mesh size and season showed that 130 mm mesh size had the highest abundance (except 140 mm mesh sizes in spring), diversity and number of caught species in comparison with 140 and 150 mm mesh sizes during sampling seasons. Also, there were significant differences between mesh sizes ($P>0.05$) (Table 1). Comparison across seasons showed that the highest diversity and number of species were caught in the spring season (Table 2). The results of Two-way ANOVA showed significant effects of mesh sizes and seasons on the abundance, the number of species and diversity of the caught fish ($P<0.05$), but their interaction effect was not significant ($P>0.05$) (Table 3).

Based on the calculated similarity by Jaccard and Sørensen indices in autumn and spring seasons, the highest similarity values were observed between 130 and 140 mm mesh sizes in October (J: 0.643, S: 0.783) and June (J: 0.556, S: 0.714). The highest similarity index in the winter was observed between 130 and 150 mm mesh sizes in March (J: 0.742, S: 0.852) (Tables 4-6). Comparison of seasonal similarity and mesh sizes showed that the highest similarity was between 130 and 140 mm mesh sizes in autumn (J: 0.909, S: 0.952), spring (J: 0.938, S:0.968) and winter (J: 0.929, S: 0.963) (Table 7). Also, a comparison of seasonal similarity showed that the highest and the lowest values between autumn and spring (J: 0.805, S: 0.892) and autumn and winter (J: 0.561, S: 0.719), respectively (Table 8).

Table 1. Comparison (Mean±SE) across mesh size and season of abundance, species number, biodiversity indices (Simpson, Shannon-Wiener, and Margalef) of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County from October 2018 to June 2019. Differences in uppercase letters indicate a significant difference (P <0.05)

Season	Mesh Size	Abundance	Species Number	Simpson	Shannon-Wiener	Margalef
Autumn	130	205.7±5.4 a	23±1.7 a	0.882±0.017 a	2.577±0.116 a	4.13±0.311 a
	140	193±9.1 b	21±1.2 b	0.885±0.012 a	2.535±0.077 b	3.809±0.255 b
	150	138.7±5.4 c	13.3±1.8 c	0.803±0.005 b	1.948±0.085 c	2.498±0.356 c
Winter	130	202.7±13.4 a	23±4 a	0.879±0.015 a	2.542±0.158 a	4.126±0.598 a
	140	193±7.8 a	18±2 b	0.872±0.011 a	2.393±0.107 b	3.227±0.365 b
	150	125.3±4.4 c	11±1 c	0.799±0.013 b	1.891±0.066 c	2.001±0.119 c
Spring	130	281.7±4.3 b	28.7±1.2 a	0.894±0.01 a	2.705±0.086 a	4.906±0.217 a
	140	329.7±6.6 a	25.3±2.2 b	0.887±0.082 a	2.591±0.091 b	4.198±0.379 b
	150	206±8.5 c	17.3±0.9 c	0.848±40.011 b	2.226±0.081 c	3.072±0.192 c

Table 2. Seasonal comparison (Mean±SE) of abundance, species number, biodiversity indices (Simpson, Shannon-Wiener, and Margalef) of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County from October 2018 to June 2019. Differences in uppercase letters indicate a significant difference (P <0.05)

Parameter	Autumn	Winter	Spring
Abundance	179.11±11.59 b	173.67±14.59 b	272.44±18.91 a
Species Number	19.11±1.68 b	17.22±2.04 c	23.77±1.85 a
Simpson	0.856±0.015 b	0.85±0.013 b	0.876±0.009 a
Shannon-Wiener	2.353±0.112 b	2.275±0.108 c	2.507±0.084 a
Margalef	3.479±0.293 b	3.118±0.349 c	4.058±0.3 a

The results of the nMDS analysis showed that there was an overlap between the monthly catch composition of the fish caught by 130 and 140 mm mesh sizes. While the catch composition of the fish caught by 150 mm mesh size did not show overlap with the other mesh sizes within sampling seasons (Fig. 2). In terms of species abundances, cluster analysis showed that the highest similarity between *S. commerson* and *T. tonggol*, and *Euthynnus affinis* and *Scomberoides commersonnianus* and the least similarity was among *Himantura gerrardi* and other caught fish species (Fig. 3).

Discussion

Fisheries management has numerous objectives, including political, economic, social, and conservation purposes. Nevertheless, the best situation is reaching the maximum sustainable yield during fishing operations (Maunder *et al.* 2006). The catch composition, species growth rate, and size of the population in different regions may be diverse based on the ecological features of fishing regions (Paighambari and Daliri 2002). The study on the fishing gear catch composition and biodiversity usually has a high cost in the sampling process. Also, species are not caught by different fishing methods in all seasons. Conversely, the use of some efficient fishing equipment is prohibited for sampling in most seasons. However, these factors should not affect the research procedure (Hameed and Boopendranath 2000, Maunder *et al.* 2006). Identification of fish with considering the ecosystem sustainability can be important for different fisheries and commercial purposes and provides valuable information on fish biology in the fishing grounds (Parsa *et al.* 2014, Paighambari *et al.* 2018a).

Table 3. ANOVA analysis of abundance, species number, biodiversity indices (Simpson, Shannon-Wiener, and Margalef) of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County from October 2018 to June 2019

Parameter		Sum of Squares	Degrees of freedom	Man Square	F value	Significance
Mesh size	Abundance	36470.296	2	18235.148	35.833	0.000
	Species Number	582.296	2	291.148	26.829	0.000
	Simpson	0.026	2	0.013	31.826	0.000
	Shannon-Wiener	1.765	2	0.882	29.553	0.000
	Margalef	16.134	2	8.067	23.726	0.000
Season	Abundance	55493.407	2	27746.704	54.524	0.000
	Species Number	204.963	2	102.481	9.444	0.002
	Simpson	0.003	2	0.002	3.939	0.038
	Shannon-Wiener	0.251	2	0.126	4.207	0.032
	Margalef	4.054	2	2.027	5.569	0.01
Mesh size×Season	Abundance	5106.815	4	1276.704	2.509	0.078
	Species Number	8.37	4	2.093	0.193	0.939
	Simpson	0.002	4	0.000	1.099	0.387
	Shannon-Wiener	0.049	4	0.012	0.408	0.801
	Margalef	0.314	4	0.078	0.231	0.912

Table 4. Comparison across mesh size and month of the similarity of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County in the autumn season

Similarity Index	Mesh size	October			November			December		
		130	140	150	130	140	150	130	140	150
Jaccard	130	1			1			1		
Sørensen		1			1			1		
Jaccard	140	0.643	1		0.621	1		0.583	1	
Sørensen		0.783	1		0.766	1		0.737	1	
Jaccard	150	0.259	0.259	1	0.407	0.32	1	0.44	0.636	1
Sørensen		0.412	0.412	1	0.579	0.485	1	0.611	0.778	1

Table 5. Comparison across mesh size and month of the similarity of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County in the winter season

Similarity Index	Mesh size	January			February			March		
		130	140	150	130	140	150	130	140	150
Jaccard	130	1			1			1		
Sørensen		1			1			1		
Jaccard	140	0.433	1		0.462	1		0.483	1	
Sørensen		0.605	1		0.632	1		0.651	1	
Jaccard	150	0.267	0.316	1	0.556	0.478	1	0.346	0.368	1
Sørensen		0.421	0.48	1	0.714	0.647	1	0.514	0.538	1

Table 6. Comparison across mesh size and month of the similarity of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County in the spring season

Similarity Index	Mesh size	April			May			June		
		130	140	150	130	140	150	130	140	150
Jaccard	130	1			1			1		
Sørensen		1			1			1		
Jaccard	140	0.5	1		0.462	1		0.742	1	
Sørensen		0.667	1		0.632	1		0.852	1	
Jaccard	150	0.467	0.609	1	0.429	0.567	1	0.467	0.419	1
Sørensen		0.636	0.757	1	0.6	0.723	1	0.636	0.591	1

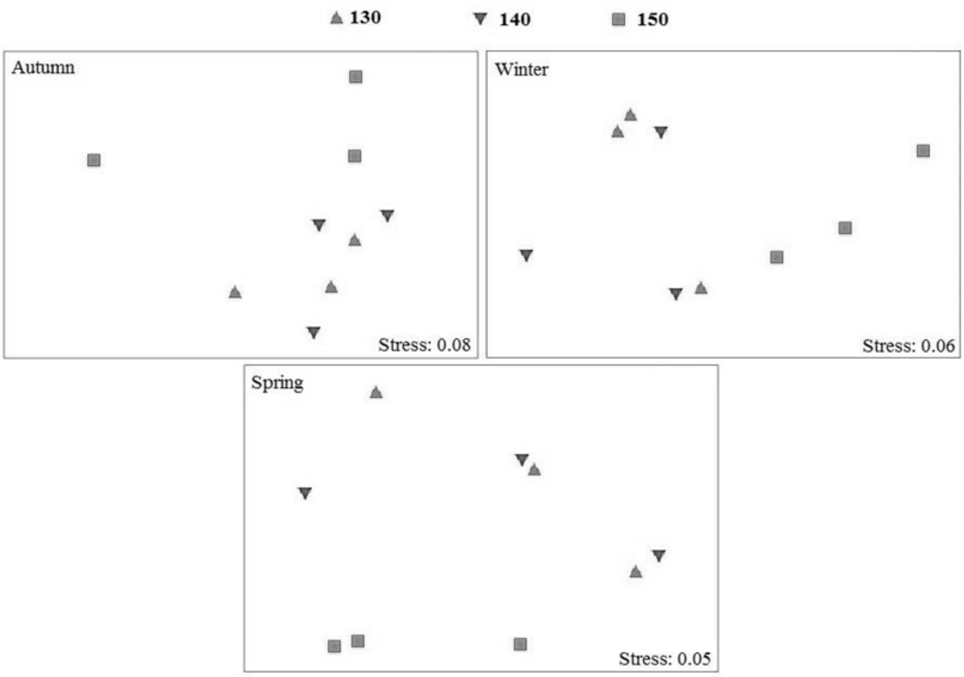

Figure 2. Comparison of 130, 140, and 150 mm mesh sizes catch composition based on the monthly species abundances using multidimensional scaling (nMDS) of gillnet catches in the fishing grounds of Bushehr County from October 2018 to June 2019

Table 7. Comparison across mesh size and season of the similarity of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County during the sampling period

Similarity Index	Mesh size	Autumn			Winter			Spring		
		130	140	150	130	140	150	130	140	150
Jaccard	130	1			1			1		
Sørensen		1			1			1		
Jaccard	140	0.909	1		0.938	1		0.929	1	
Sørensen		0.952	1		0.968	1		0.963	1	
Jaccard	150	0.727	0.636	1	0.5	0.484	1	0.548	0.564	1
Sørensen		0.842	0.778	1	0.667	0.562	1	0.708	0.721	1

Table 8. Comparison of seasonal similarity of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County during the sampling period

Similarity Index	Season	Sampling Seasons		
		Autumn	Winter	Spring
Jaccard	Autumn	1		
Sørensen		1		
Jaccard	Winter	0.561	1	
Sørensen		0.719	1	
Jaccard	Spring	0.805	0.714	1
Sørensen		0.892	0.833	1

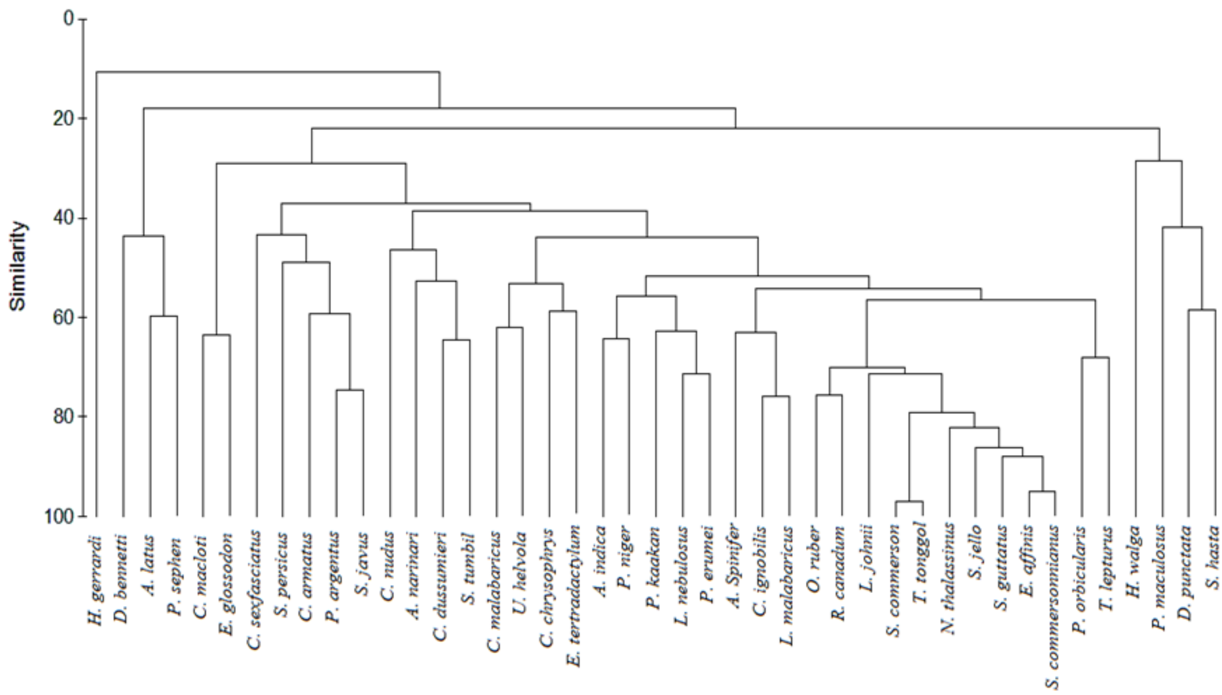

Figure 3. Species abundance similarity comparison of marine fish species caught using drift gillnet in the fishing grounds of Bushehr County from October 2018 to June 2019

The fish biodiversity in the Persian Gulf (including the Strait of Hormuz and the Gulf of Oman border region) comprises 907 species in 157 families. There are 62 families with mono species and 25 families with more than 10 species. Bony fishes families such as Gobiidae (53 species), Carangidae (48 species), Labridae (41 species), Blenniidae (34 species), Apogonidae (32 species), Lutjanidae (31 species) and cartilaginous fishes families such as Carcharhinidae (25 species) and Dasyatidae (12 species) are the most diverse families in terms of the species number (Owfi *et al.* 2016). The findings of this study showed *S. commerson*, *T. tonggol*, *E. affinis,* and *S. commersonnianus* as dominant species during fishing seasons. In the study by Parsa *et al.* (2014), the dominant fish species caught by gillnets (0.5 and 0.6 hanging ratios) were: *T. tonggol*, *E. affinis*, *S. commersonnianus*, *Carcharhinus amblyrhynchoides*, *S. commerson*, *Rachycentron canadum,* and *Sphyraena jello*. Alimirzaei *et al.* (2017) reported seven families including Scombridae (73.03%), Carangidae (12.67%), Carcharhinidae (7.88%), Sphyranidae (1.36%), Stromatidae (0.73%), Belonidae (2.24%), and Pesttodidae (2.06%) in Hormozgan waters that *E. affinis* had the highest total catch (33.26%) and weight (27.9%) percentages. Paighambari *et al*. (2018a) caught 19 fish species by gillnet in the Gulf of Oman with the dominant species of *Otolithes ruber* (29.1%), *Saurida tumbil* (16.98%), *Netuma thalassinus* (7.45%), *Ephippus orbis* (6.32%), *Pomadasys kaakan* (6.23%), *Nemipterus japonicus* (4.41%) and other marine organisms (29.5%). In another study by Paighambari *et al*. (2018b), gillnet catch composition was comprised of 11 families including Scombridae (48.46%), Carangidae (25.01%), Ariidae (7.3%), Lethrinidea (3.93%), Sphyraenidae (3.53%), Lutjanidae (3.37%), Haemulidae (3.04%), Stromateidae (2.74%), Sciaenidea (1.44%) and Dasyatidae (0.32%) in Konarak fishing ground. In their study, the highest weight percentages belonged to the Scombridae family with 30.67 % and 41.42 % in winter and spring, respectively. Also, Sadough Niri (2018) reported 8 families of Scomboridae, Istiophoridae, Coryphaenidae, Alopiidae, Carcharhinidae, Carangidae, Sphyraenidae and Trichiuridae with 17 species in the Konarak and Ramin fishing grounds, Gulf of Oman.

The results of this study showed that the mesh size of the drift used gillnets had a significant effect on the abundance, number, and diversity of caught species. The larger mesh size had lower abundance and diversity in comparison with smaller mesh sizes. The structure and design of the gillnet increase the catch of non-standard length and non-target fish and makes it challenging to manage the catch based on the mesh size of the net. Therefore, a high percentage of small fish are caught by small meshes (Gray *et al*. 2005). Due to the lack of control over the mesh size of gillnets and the increase in fishing effort, overfishing occurs, which reveals the lack of catch management (Mendonca and Pereira 2014). According to studies by Gray *et al.* (2003), Salerno *et al.* (2009), Ago *et al*. (2014), Kalaycı and Yeşilçiçek (2014), and Sadough Niri (2018), the number of species caught decreased as the mesh size of the gillnets increased. Also, due to the fish length selectivity of different used mesh sizes, length sizes of the caught fish increased as the size of the gillnet mesh increased, and the larger fish were caught. Generally, the effect of fishing gear on the selection of a particular species depends on fish exposure and trapping by the fishing tool (Ago *et al*. 2014).

The exhibited species biodiversity in a specific community has different degrees at the genetic, species, and environment level (Luck *et al*. 2003, Tuomisto 2010, Paighambari *et al*. 2020). The result showed that season changes had a significant effect on the abundance, number and diversity of species and the highest amounts of caught fish were observed in the spring season.

Environmental conditions are important factors in the changes in fishing rates. Climate change affects all life stages of living organisms (Tian *et al*. 2004, Stenseth *et al*. 2008). The effects of climate change such as temperature change and its associated phenomena have direct effects on the presence and distribution of aquatic species (Pondella *et al*. 2002). In some cases, the effect of seasonal climate changes on species indirectly or directly changes the composition and connections of the food chain. Therefore, the concept of season change for the marine fish population is seen at four interconnected levels of biological structures. Physiological changes help adaptation of aquatic organisms to the environment and improve their tolerance against some environmental changes. Behavioral changes tend to avoid situations and move to a more appropriate location. Demographic changes cause variations in mortality, growth, and reproduction rates. Also, ecosystem changes cause changes in the production and function of the food web and the physiological responses of living organisms at different levels of the food chain (Liming *et al.* 2006). Kitagawa *et al.* (2000) stated that the temperature had an excessive effect on the vertical distribution and the movement of *Thunnus thynnus orientalis* in Tsushima Island. Ozbilgin and Wardle (2002) reported that temperature had a direct effect on motion and swimming of *Melanogrammus aeglefinus* and reduced the selectivity of the fishing gear and the catch rate in winter. Moreover, Gerami *et al*. (2014) declared that temperature changes decreased the catch rates of the tuna fish gillnets in winter. Distribution and abundance of fish species rely on favorable conditions for species, effective habitat features such as biotic factors, physicochemical factors and the adaptability degree in their aquatic environments (Wootten 2012).

Conclusion

S. commerson, *T. tonggol*, *E. affinis,* and *S. commersonnianus* were dominant species throughout fishing seasons. Mesh size of used drift gillnets and seasonal changes had a significant effect on the abundance, number, and diversity of caught species. Larger mesh sizes had lower abundance and diversity in comparison with smaller mesh sizes. Also, the spring season had the highest amounts of abundance, and the number and diversity of caught species during the study period. Therefore, the hypothesis of this study is accepted. Study on the effect of net hanging ratio, yarn number, fish visibility on the net, elasticity of the mesh sizes, the proportion of yarn diameter and physicochemical parameters is suggested in order to estimate the effect of other effective factors on catch ratio and diversity of caught fish during fishing operations in the future studies.

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