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**Research Article**

# Assemblage structure of bottom associated fishes in relation to environmental variables in the northeastern Persian Gulf, Iran

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## Abstract

The assemblage structure of bottom associated fishes across the northern coast of the Persian Gulf has received little attention. The present study was conducted in the waters more than 10 m. of northeast coasts of the Persian Gulf. The autumn data of a bottom trawl survey targeting demersal fishes were used to describe the assemblage structures and their response to environmental variables. A total of 165 and 145 demersal fish species were sampled in 2014 and 2016, respectively. The assemblages were dominated by bony fishes, prevailed by Gilded goatfish (*Upeneus doriae*), followed by batoid fishes, prevailed by the Arabian banded whipray (*Maculabatis randalli*), and sharks, prevailed by Whitecheek shark (*Carcharhinus dussumieri*). The results indicated a reduction in the species richness over the two-year periods in the studied area. The highest species richness was observed at depths of 20 to 30 meters, with a downward trend to shallower and deeper waters. The BEST routine showed that temperature, EC, salinity and pH best described the distribution pattern of bottom-associated fishes in both years. Additionally, CCA analysis demonstrated three bathymetrical assemblage structures for bottom-associated fishes in the studied area. Among different environmental variables, the depth seems to be a major one distinguishing the communities.

**Keywords:** Demersal fish, Environmental variables, Community structure, Species richness, Persian Gulf

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## Introduction

Distribution patterns of organisms are principally related to the species reactions to the surrounding environment, because dominant abiotic variables probably act as a physiological sieve and play a vital role in the structuring of a community (Remmert, 1983). The distribution of some species, may include a vast geographical area; while, other species are found only in small areas. The main reason of these restricted distributions is the heterogeneity of the physical environment of the fishes. At a biogeographical scale, physical barriers can prevent a species that was grown in one locality, from immigrating to another physiologically adaptable area (Wootton, 1996).

Since, several characteristics of the marine environment usually change simultaneously and under the influence of each other; the effect of changing a single factor is rarely obvious in natural conditions; As a result, the distribution of a species is dependent to a complex of variables and assessing the role of each variable independently is not easy (Tait and Dipper, 1998).

Bottom-associated fishes, here, including demersal, benthic and benthopelagic fishes, live or feed on or near the sea floors, which usually consist of mud, sand, gravel or rocks. They are distinguished from pelagic fishes which live and feed away from the bottom in the open water column. Bottom-associated fishes were assumed to be more localized than migratory pelagic species to reflect physical impacts of the environment. On the other hand, bottom dwelling fishes are of the most important groups for both artisanal and industrial fisheries sectors in southern provinces of Iran including Hormozgan (Northeastern Persian Gulf and Northwestern Gulf of Oman); their yearly catch data in Hormozgan has increased from 39,650 t in 2010 to 79,189 t in 2016, while mean yearly landings has been reported 40, 212 t from 2003 to 2010 (Planning and Development, 2017). Furthermore a sharp decline in demersal and benthic fish catches has been reported in 2003 from the Iranian part of the Persian Gulf and the Gulf of Oman as well as Hormozgan and attributed to overfishing (Valinassab *et al*., 2006).

Several studies have been identified the environmental variables influencing the assemblage structure of fishes, mainly being focused on rivers, estuaries and inshore waters and mostly conducted in temperate regions (Horne and Campana, 1989, Marshall and Elliott, 1998, Gelwick *et al*., 2001, Araújo *et al*., 2002, Attrill and Power, 2002, Martino and Able, 2003, Prista *et al*., 2003, Akin *et al*., 2005, Leung and Camargo, 2005, Pombo *et al*., 2005, Mercado-Silva *et al*., 2012, Richards *et al*., 2012, Phinrub *et al*., 2015, Bilecenoğlu, 2016, Álvarez *et al*., 2017, Henriques *et al*., 2017).

The Persian Gulf as a young subset of the Indian Ocean is characterized by its diminished marine diversity (Sheppard *et al*., 1992). The Gulf ecosystems are ever increasingly affected by distressing natural variables such as extreme temperatures, high salinity and extreme low tides (Price *et al*., 1993, Sheppard, 1993) and anthropogenic processes (Price, 1993, Sale *et al*., 2011). Fishes include more than one-half - 32,000 species - of the world’s living vertebrates (Nelson *et al*., 2016), of which 877 species are reported from the Persian Gulf (FISHBASE, 2018). Despite the diminished diversity, the fishery potential in the Gulf is estimated about 550,000 t annually that is eight times greater than that of the Gulf of Oman (Kardovani, 1995, Sale *et al*., 2011).

Fisheries in the Iranian coastal waters of the Persian Gulf are mostly artisanal, catching a variety of species using multi-type gears. The wooden dhows and fiberglass boats are the most common fishing vessels using hook-and-line, gillnets, hemispherical wire traps (gargoor), and weirs as the most common gears; Traditional shrimp trawlers also operate about 45 days per year. (Gerami and Dastbaz, 2013). Aside from predominant artisanal fishery, Industrial improved bottom trawlers catch hairtail as the target species in the northeastern part of the Persian Gulf for nearly 4 months a year; their bycatch, mostly demersal and benthopelagic fishes, estimated to be 30% (Shojaei and Taghavi, 2011).

Despite the historical importance of fisheries in the northern Persian Gulf, the demersal fisheries remain under-studied and catch statistics remain inaccurate. Declining size and yield of most commercially important demersal fishes has prompted investigations into the response of demersal fishes to environmental variables in this region. In the present study, the autumn data (2014 and 2016) from a bottom trawl net survey targeting demersal fishes in soft-bottom habitats across the northeast of the Persian Gulf coast (Hormozgan territory in Persian Gulf ) were used to describe patterns of distribution and abundance between isobaths 10-20m, 20-30m, 30-50 m and midline of the Persian Gulf.

## Material and methods

### *Study area and biological sampling*

This research was conducted in the years 2014 and 2016 in Hormozgan marine area in the northeast of the Persian Gulf (Fig. 1). The autumn data from a bottom trawl survey targeting demersal fishes were used to describe their patterns of distribution and abundance at four depth strata (i.e., 10-20m, 20-30m, 30-50m isobaths and 50m to the midline of the Persian Gulf). One cruise was conducted for sampling, in the late autumn of each year. Cruises were carried out by RV Ferdows 1, equipped with a bottom trawl gear (Valinassab *et al*., 2006). The western boundary of the study area was near Ra's Nayband (marine boundary of Hormozgan and Bushehr provinces) with an eastern longitude of 52° 45´, and its eastern boundary was in the southeast of Qeshm Island with an eastern longitude of 55°, 18´; the northern boundary of the study area was restricted to the 10m isobath and its southern boundary were confined to the borderline between the waters of the Islamic Republic of Iran and the southern countries of the Persian Gulf. The study area was divided into four geographic strata along the coast and four depth strata, comprising 16 substrata (Fig. 1). Four depth strata included the area between 10-20m (1), 20-30m (2), 30-50m (3) isobaths and 50m isobath to the midline of the Persian Gulf (4). Sampling was designed and implemented based on stratified random method. In other words, the number of stations were considered as sample size and the area of substrata as population size. The area of the substrata was measured using digitized geographic map no. 62032 (the Persian Gulf, with a scale of 1: 1,000,000) published by the US National Geographic Intelligence Agency (released in 2014) and Photoshop CC software. The measurements were based on the number of pixels per square mile. A total of 61 stations in 2014 and 55 stations in 2016 were sampled. Sampling was done by bottom trawl net at randomly selected stations. Trawling at each station was lasted one hour and at a mean speed of 3 mph. After the evacuation of the catch, all operations i.e. species separation, identification, weighting, and counting as well as recording number and weight of each species, were carried out on board. Specifications of the starting and ending points of sampling stations including latitude, longitude, date, time, trawling speed and depth of water were recorded too.

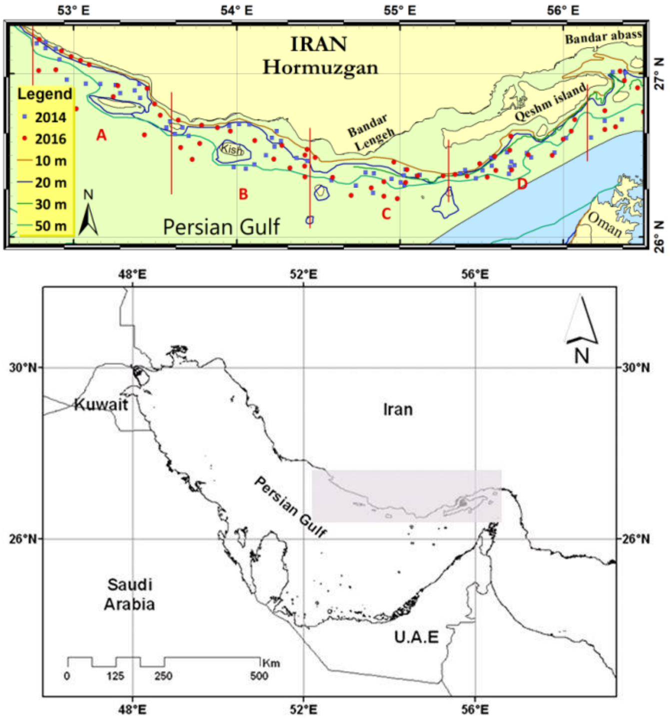

**Figure 1: The study area indicating positions of sampling stations in 2014 and 2016. The geographical strata are demonstrated by letters A to D and the vertical red lines are the boundaries between them. Isobathymetric lines show depth strata (depth layers).**

### *Environmental sampling*

Physical conditions of seawater were measured and recorded at the end position of each station by CTD multiparameter probes. In 2014, IDRONAUT OCEAN SEVEN 316Plus probe and in 2016, IDRONAUT OCEAN SEVEN 316 probe were used. The measured factors included depth, temperature, salinity, oxygen, pH, and electrical conductivity of sea water in 2014 and depth, temperature, salinity, pH, electrical conductivity, and seawater turbidity in 2016.

### *Data analysis*

Frequency per unit area (FPUA) was calculated as the standardized value of fish abundance at each sampling station. Mean FPUA at each substratum were obtained through taking arithmetic mean of their corresponding values (FPUA) at all relevant stations. Mean FPUA at each geographical or depth stratum were obtained through calculation of the weighted average of corresponding values in all related substrata. The weight factor here was the relevant area in term of square nautical mile/s. The total number of species, Margalef's species richness, Pielou's evenness index and Shannon and Gini-Simpson diversity indices were calculated using PRIMER v.6 (Clarke and Gorley, 2006). The main aim here was to reduce the multivariate (multispecies) complexity of assemblage data into a single index (or a small number of indices) evaluated for each sample, which can then be handled statistically by univariate analyses (Clarke and Warwick, 2001). The t-test was used to compare mean values of FPUA, total species, diversity indices and physical factors between two years of study. Analysis of variance with Duncan pairwise comparison test was used to compare these indices between geographic and depth strata. These tests were carried out in SPSS (v. 25) (IBM Corporation, 2017).

Non-metric multidimensional scaling (nMDS) ordinations were depicted using PRIMER v.6. In order to separate geographical and depth strata according to assemblage structure of the demersal fishes, nMDS ordinations were constructed based on Bray–Curtis similarity matrices and fourth-root transformed FPUA data of species in stations. FPUA data were fourth-root transformed to reduce the influence of dominant species and enhance the contribution of common, less common and rare species on the calculation of similarities (Clarke and Warwick, 2001). In order to separate geographical and depth strata according to physical factors of sea water, nMDS ordinations were constructed based on the Euclidean distance of samples and mean data values of physical factors at lowermost 7m depths of stations. The correlation between similarity matrices of fish assemblage structure and physical factors were determined by RELATE test in PRIMER v.6 based on the Spearman rank method for both years. One-way analysis of similarity (ANOSIM) in PRIMER v.6 was performed to test the differences in assemblage structure of bottom-associated fishes or distribution patterns of physical factors among spatial groups (geographical and depth strata) and to determine distinction level of significant distinct groups. BEST test in PRIMER v.6 was used to determine the effective physical factors on the assemblage structure pattern of the bottom-associated fishes.

Two-way permutational multivariate analysis of variance (2-way PERMANOVA) was applied to test simultaneously spatial and temporal variations and their interactions in assemblage structure of bottom-associated fishes or distribution patterns of physical factors. Canonical correspondence analysis (CCA) was applied to show correlations of environmental factors both to fish species and to spatial factors (strata and substrata). Two-way PERMANOVA and CCA were undertaken using PAST v. 3.25 (Hammer, 2019) and CANOCO v. 4.5 (ter Braak and Šmilauer, 2002) softwares, respectively. Some necessary modifications were made to the CCA charts using Inkscape v. 0.92.4 vector image editing software (Bah, 2011).

## Results

### *Bottom-associated fish species composition*

A total of 165 and 145 bottom-associated fish species were sampled in 2014 and 2016, respectively (Table 1).

**Table 1: Observed bottom-associated fish species with their FPUA, total and group FPUA proportion (%) and their rank in the group.**

| Family | Species | Code | 2014 | | | | 2016 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | FPUA | % | group% | Rank | FPUA | % | group% | Rank |
| Carcharhinidae | *Carcharhinus dussumieri* (Valenciennes, 1839) | Cd | 67 | 0.2 | 62 | 1 | 87 | 0.2 | 75 | 1 |
| | *Carcharhinus macloti* (Müller & Henle, 1839) | Cmc | 2 | 0.006 | 2 | 7 | | | | |
| | *Carcharhinus melanopterus* (Quoy & Gaimard, 1824) | Cme | 3 | 0.01 | 3 | 6 | | | | |
| | *Carcharhinus sorrah* (Müller & Henle, 1839) | Cso | | | | | 0.4 | 0.001 | 0.4 | 6 |
| | *Rhizoprionodon acutus* (Rüppell, 1837) | Rac | 9 | 0.03 | 8 | 3 | 15 | 0.04 | 13 | 2 |
| | *Rhizoprionodon oligolinx* Springer, 1964 | Ro | 13 | 0.04 | 12 | 2 | 10 | 0.02 | 8 | 3 |
| Hemigaleidae | *Chaenogaleus macrostoma* (Bleeker, 1852) | Cmt | 5 | 0.02 | 5 | 5 | 3 | 0.006 | 2 | 4 |
| | *Hemipristis elongata* (Klunzinger, 1871) | He | 0.9 | 0.003 | 0.9 | 8 | 0.2 | 0.000 | 0.2 | 7 |
| | *Paragaleus randalli* Compagno, Krupp & Carpenter, 1996 | Pra | 0.07 | 0.000 | 0.07 | 9 | | | | |
| Hemiscylliidae | *Chiloscyllium arabicum* Gubanov, 1980 | Cab | 0.05 | 0.000 | 0.05 | 10 | | | | |
| Triakidae | *Mustelus mosis* Hemprich & Ehrenberg, 1899 | Mmo | 8 | 0.03 | 7 | 4 | 1 | 0.003 | 1 | 5 |
| | **Total Sharks** | | **108.02** | **0.4** | | | **116.6** | **0.3** | | |
| Dasyatidae | *Brevitrygon imbricata* (Bloch & Schneider, 1801) | Bi | 57 | 0.2 | 15 | 2 | 16 | 0.04 | 4 | 6 |
| | *Himantura uarnak* (Forsskål, 1775) | Hu | 0.5 | 0.002 | 0.1 | 12 | 5 | 0.01 | 1 | 8 |
| | *Maculabatis randalli* (Last, Manjaji-Matsumoto & Moore, 2012) | Mr | 157 | 0.5 | 41 | 1 | 187 | 0.4 | 44 | 1 |
| | *Maculabatis gerrardi* (Gray, 1851) | Mg | 1 | 0.005 | 0.4 | 10 | 1 | 0.002 | 0.2 | 10 |
| | *Pastinachus sephen* (Forsskål, 1775) | Pse | 17 | 0.06 | 4 | 7 | 45 | 0.1 | 11 | 3 |
| Glaucostegidae | *Glaucostegus granulatus* (Cuvier, 1829) | Gg | 0.2 | 0.001 | 0.04 | 13 | 0.1 | 0.000 | 0.03 | 15 |
| Gymnuridae | *Gymnura poecilura* (Shaw, 1804) | Gy.p | 56 | 0.2 | 15 | 3 | 105 | 0.3 | 25 | 2 |
| Myliobatidae | *Aetobatus flagellum* (Bloch & Schneider, 1801) | Afl | 0.5 | 0.002 | 0.1 | 11 | 0.2 | 0.000 | 0.05 | 13 |
| | *Aetomylaeus milvus* (Müller & Henle, 1841) | Ae.m | 2 | 0.008 | 0.6 | 9 | 0.2 | 0.000 | 0.04 | 14 |

| Family | Species | Code | 2014 | | | | 2016 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | FPUA | % | group% | Rank | FPUA | % | group% | Rank |
| | *Aetomylaeus nichofii* (Bloch & Schneider, 1801) | Anf | 38 | 0.1 | 10 | 4 | 17 | 0.04 | 4 | 5 |
| | *Rhinoptera javanica (*Müller & Henle, 1841) | Rj | 13 | 0.04 | 3 | 8 | 13 | 0.03 | 3 | 7 |
| Rhinidae | *Rhina ancylostoma* Bloch & Schneider, 1801 | Ran | | | | | 1 | 0.002 | 0.2 | 11 |
| | *Rhynchobatus djiddensis* (Forsskål, 1775) | Rd | | | | | 0.4 | 0.001 | 0.10 | 12 |
| Rhinobatidae | *Rhinobatos annandalei* Norman, 1926 | Rp | 25 | 0.08 | 6 | 5 | 27 | 0.07 | 6 | 4 |
| Torpedinidae | *Torpedo sinuspersici* Olfers ,1831 | Tsi | 18 | 0.06 | 5 | 6 | 3 | 0.008 | 0.8 | 9 |
| | **Total batoid fishes** | | **35.2** | **1.3** | | | **420.9** | **1** | | |
| Acropomatidae | *Acropoma japonicum* Günther, 1859 | Aj | 799 | 3 | 3 | 11 | 636 | 2 | 2 | 14 |
| Apistidae | *Apistus carinatus* (Bloch & Schneider, 1801) | Aca | 2 | 0.006 | 0.006 | 100 | | | | |
| Apogonidae | *Ostorhinchus fasciatus* (White, 1790) | Of | 6 | 0.02 | 0.02 | 78 | 26 | 0.06 | 0.06 | 52 |
| | *Verulux cypselurus* (Weber, 1909) | Vc | 5 | 0.02 | 0.02 | 81 | 6 | 0.01 | 0.02 | 80 |
| Ariidae | *Netuma bilineata* (Valenciennes, 1840) | Nb | 377 | 1 | 1 | 15 | 468 | 1 | 1 | 21 |
| | *Netuma thalassina* (Rüppell, 1837) | Nt | 16 | 0.05 | 0.06 | 64 | 18 | 0.04 | 0.04 | 63 |
| | *Plicofollis dussumieri* (Valenciennes, 1840) | Pdu | 5 | 0.02 | 0.02 | 83 | 11 | 0.03 | 0.03 | 70 |
| | *Plicofollis layardi* (Günther, 1866) | Pl | 43 | 0.1 | 0.1 | 41 | 580 | 1 | 1 | 18 |
| Ariommatidae | *Ariomma indicum* (Day, 1870) | Aim | 1,631 | 5 | 6 | 6 | 475 | 1 | 1 | 20 |
| Balistidae | *Abalistes stellatus* (Anonymous, 1798) | Ab.s | 0.2 | 0.001 | 0.001 | 127 | | | | |
| Bothidae | *Grammatobothus polyophthalmus* (Bleeker, 1865) | Gr.p | | | | | 0.10 | 0.000 | 0.000 | 122 |
| Carangidae | *Alectis ciliaris* (Bloch, 1788) | Aci | 4 | 0.01 | 0.01 | 84 | 6 | 0.02 | 0.02 | 79 |
| | *Alectis indica* (Rüppell, 1830) | Ain | 62 | 0.2 | 0.2 | 34 | 24 | 0.06 | 0.06 | 55 |
| | *Alepes djedaba* (Forsskål, 1775) | Ad | 0.9 | 0.003 | 0.003 | 108 | | | | |
| | *Atropus atropos* (Bloch & Schneider, 1801) | Aat | 133 | 0.4 | 0.5 | 25 | 320 | 0.8 | 0.8 | 25 |
| | *Atule mate* (Cuvier, 1833) | At.m | 11 | 0.04 | 0.04 | 70 | 7 | 0.02 | 0.02 | 78 |
| | *Carangoides armatus* (Rüppell, 1830) | Car | 17 | 0.06 | 0.06 | 60 | 19 | 0.05 | 0.05 | 60 |
| | *Carangoides bajad* (Forsskål, 1775) | Cb | 2 | 0.008 | 0.008 | 98 | 8 | 0.02 | 0.02 | 73 |
| | *Carangoides chrysophrys* (Cuvier, 1833) | Cch | 339 | 1 | 1 | 17 | 454 | 1 | 1 | 22 |
| | *Carangoides gymnostethus* (Cuvier, 1833) | Cg | 3 | 0.010 | 0.010 | 95 | | | | |
| | *Carangoides hedlandensis* (Whitley, 1934) | Chd | 0.02 | 0.000 | 0.000 | 142 | 0.8 | 0.002 | 0.002 | 107 |
| | *Carangoides malabaricus* (Bloch & Schneider, 1801) | Cml | 1,263 | 4 | 4 | 8 | 1,388 | 3 | 3 | 10 |
| | *Carangoides talamparoides* Bleeker, 1852 | Ct | 119 | 0.4 | 0.4 | 26 | 161 | 0.4 | 0.4 | 31 |
| | *Caranx ignobilis* (Forsskål, 1775) | Ci | | | | | 0.1 | 0.000 | 0.000 | 121 |
| | *Gnathanodon speciosus* (Forsskål, 1775) | Gsp | 1 | 0.004 | 0.004 | 103 | 0.1 | 0.000 | 0.000 | 119 |
| | *Megalaspis cordyla* (Linnaeus, 1758) | Mco | 33 | 0.1 | 0.1 | 43 | 8 | 0.02 | 0.02 | 76 |
| | *Parastromateus niger* (Bloch,1795) | Pn | 57 | 0.2 | 0.2 | 36 | 224 | 0.5 | 0.5 | 28 |
| | *Selar crumenophthalmus* (Bloch,1793) | Sc | 18 | 0.06 | 0.06 | 59 | 414 | 1.0 | 1 | 24 |
| | *Selaroides leptolepis* (Cuvier, 1833) | Slp | 43 | 0.1 | 0.1 | 40 | 12 | 0.03 | 0.03 | 68 |
| | *Seriolina nigrofasciata* (Rüppell, 1829) | Sn | 1.0 | 0.003 | 0.003 | 106 | | | | |
| | *Trachinotus mookalee* Cuvier, 1832 | Tmo | 4 | 0.01 | 0.01 | 88 | 0.1 | 0.000 | 0.000 | 120 |
| | *Ulua mentalis* (Cuvier, 1833) | Um | 21 | 0.07 | 0.07 | 55 | 46 | 0.1 | 0.1 | 43 |
| | *Uraspis helvola* (Forster, 1801) | Uh | 3 | 0.01 | 0.01 | 91 | 1 | 0.003 | 0.003 | 100 |
| Centriscidae | *Centriscus scutatus* Linnaeus, 1758 | Csc | 0.8 | 0.003 | 0.003 | 109 | 21 | 0.05 | 0.05 | 59 |
| Cepolidae | *Acanthocepola abbreviata* (Valenciennes, 1835) | Aab | 0.5 | 0.002 | 0.002 | 118 | | | | |
| Chaetodontidae | *Heniochus acuminatus* (Linnaeus, 1758) | Ha | 0.4 | 0.001 | 0.001 | 122 | 0.6 | 0.002 | 0.002 | 110 |
| Citharidae | *Brachypleura novaezeelandiae* Günther, 1862 | Bn | 0.5 | 0.002 | 0.002 | 120 | | | | |
| Clupeidae | *Anodontostoma chacunda* (Hamilton & Buchanan, 1822) | Ach | 17 | 0.06 | 0.06 | 63 | | | | |
| Cynoglossidae | *Cynoglossus arel* (Bloch & Schneider, 1801) | Cal | 3 | 0.009 | 0.009 | 96 | 0.6 | 0.001 | 0.001 | 111 |
| Diodontidae | *Cyclichthys orbicularis* (Bloch, 1785) | Co | 10 | 0.04 | 0.04 | 71 | 8 | 0.02 | 0.02 | 72 |
| Drepaneidae | *Drepane longimana* (Bloch & Schneider, 1801) | Dl | 0.2 | 0.001 | 0.001 | 128 | | | | |
| | *Drepane punctata* (Linnaeus, 1758) | Dpu | 93 | 0.3 | 0.3 | 29 | 58 | 0.1 | 0.1 | 40 |
| Echeneidae | *Echeneis naucrates* Linnaeus, 1758 | En | 3 | 0.01 | 0.01 | 93 | 2 | 0.004 | 0.004 | 98 |
| Engraulidae | *Thryssa mystax* (Bloch & Schneider, 1801) | Tmy | 24 | 0.08 | 0.08 | 51 | 80 | 0.2 | 0.2 | 34 |
| | *Thryssa setirostris* (Broussonet, 1782) | Tse | | | | | 3 | 0.008 | 0.008 | 88 |
| Ephippidae | *Ephippus orbis* (Bloch, 1787) | Eo | 83 | 0.3 | 0.3 | 31 | 47 | 0.1 | 0.1 | 42 |

| **Family** | **Species** | **Code** | **2014** | | | | **2016** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **FPUA** | **%** | **group%** | **Rank** | **FPUA** | **%** | **group%** | **Rank** |
| | *Platax orbicularis* (Forsskål, 1775) | Po | 0.7 | 0.002 | 0.002 | 113 | 0.5 | 0.001 | 0.001 | 113 |
| Fistulariidae | *Fistularia petimba* Lacepède, 1803 | Fp | 19 | 0.06 | 0.06 | 58 | 126 | 0.3 | 0.3 | 32 |
| Gerreidae | *Gerres infasciatus* Iwatsuki & Kimura, 1998 | Gf | 56 | 0.2 | 0.2 | 38 | 76 | 0.2 | 0.2 | 36 |
| | *Gerres longirostris* (Lacepède, 1801) | Gl | 16 | 0.05 | 0.05 | 65 | | | | |
| | *Pentaprion longimanus* Cantor, 1850 | Plo | 794 | 3 | 3 | 12 | 1,496 | 4 | 4 | 9 |
| Gobiidae | *Trypauchen vagina* (Bloch & Schneider, 1801) | Tv | | | | | 1 | 0.003 | 0.003 | 103 |
| Haemulidae | *Diagramma pictum (*Thunberg, 1792) | Dpi | 11 | 0.04 | 0.04 | 69 | 18 | 0.04 | 0.04 | 62 |
| | *Plectorhinchus pictus* (Tortonese, 1935) | Ppi | 0.4 | 0.002 | 0.002 | 121 | | | | |
| | *Plectorhinchus schotaf* (Forsskål, 1775) | Psc | 0.06 | 0.000 | 0.000 | 138 | | | | |
| | *Pomadasys kaakan* (Cuvier, 1830) | Pk | 161 | 0.5 | 0.6 | 24 | 304 | 0.7 | 0.7 | 26 |
| | *Pomadasys stridens* (Forsskål, 1775) | Pst | 24 | 0.08 | 0.08 | 50 | 26 | 0.06 | 0.06 | 53 |
| Labridae | *Choerodon robustus* (Günther, 1862) | Cr | | | | | 3 | 0.008 | 0.008 | 87 |
| Lactariidae | *Lactarius lactarius* (Bloch & Schneider, 1801) | Lla | 6 | 0.02 | 0.02 | 80 | 3 | 0.007 | 0.007 | 91 |
| Leiognathidae | *Aurigequula fasciata* (Lacepède, 1803) | Afa | 1,245 | 4 | 4 | 9 | 1,922 | 5 | 5 | 6 |
| | *Leiognathus oblongus* (Valenciennes, 1835) | Lob | 459 | 2 | 2 | 13 | 498 | 1 | 1 | 19 |
| | *Nuchequula gerreoides* (Bleeker, 1851) | Ng | 441 | 1 | 2 | 14 | | | | |
| | *Photopectoralis bindus* (Valenciennes, 1835) | Pb | 2,843 | 10 | 10 | 3 | 4,236 | 10 | 10 | 3 |
| | *Secutor insidiator* (Bloch, 1787) | Si | 65 | 0.2 | 0.2 | 33 | 1,340 | 3 | 3 | 11 |
| Lethrinidae | *Lethrinus borbonicus* Valenciennes, 1830 | Lbo | 3 | 0.010 | 0.010 | 94 | 0.10 | 0.000 | 0.000 | 123 |
| | *Lethrinus lentjan* (Lacepède, 1802) | Lln | 0.7 | 0.002 | 0.002 | 112 | 5 | 0.01 | 0.01 | 83 |
| | *Lethrinus microdon* Valenciennes, 1830 | Lmi | 2 | 0.008 | 0.008 | 97 | | | | |
| | *Lethrinus nebulosus* (Forsskål, 1775) | Ln | 14 | 0.05 | 0.05 | 67 | 18 | 0.04 | 0.04 | 61 |
| Lutjanidae | *Lutjanus fulviflamma* (Forsskål, 1775) | Lf | 8 | 0.03 | 0.03 | 75 | | | | |
| | *Lutjanus johnii* (Bloch, 1792) | Lj | 9 | 0.03 | 0.03 | 74 | 4 | 0.01 | 0.01 | 84 |
| | *Lutjanus lutjanus* Bloch, 1790 | Llj | 1 | 0.004 | 0.004 | 104 | 24 | 0.06 | 0.06 | 56 |
| | *Lutjanus malabaricus* (Bloch & Schneider, 1801) | Lma | 39 | 0.1 | 0.1 | 42 | 37 | 0.09 | 0.09 | 49 |
| | *Lutjanus quinquelineatus* (Bloch, 1790) | Lq | | | | | 0.7 | 0.002 | 0.002 | 108 |
| | *Lutjanus indicus* (Bleeker, 1849) | Lu.i | 6 | 0.02 | 0.02 | 79 | 4 | 0.009 | 0.009 | 85 |
| Menidae | *Mene maculata* (Bloch & Schneider, 1801) | Mma | 188 | 0.6 | 0.6 | 23 | 591 | 1 | 1 | 17 |
| Monacanthidae | *Aluterus monoceros (Linnaeus, 1758)* | Al.m | 0.1 | 0.000 | 0.000 | 131 | 3 | 0.008 | 0.008 | 89 |
| | *Stephanolepis diaspros* Fraser-Brunner, 1940 | Sd | | | | | 2 | 0.005 | 0.005 | 97 |
| Mullidae | *Upeneus doriae* (Günther, 1869) | Ud | 4,701 | 16 | 16 | 1 | 7,270 | 17 | 18 | 1 |
| | *Upeneus sundaicus* (Bleeker, 1855) | Us | 1 | 0.003 | 0.003 | 105 | | | | |
| | *Upeneus vittatus* (Forsskål, 1775) | Uv | | | | | 0.7 | 0.002 | 0.002 | 109 |
| Muraenesocidae | *Muraenesox cinereus* (Forsskål, 1775) | Mci | 27 | 0.09 | 0.09 | 49 | 11 | 0.03 | 0.03 | 69 |
| Nemipteridae | *Nemipterus japonicus* (Bloch, 1791) | Nj | 1,624 | 5 | 6 | 7 | 1,965 | 5 | 5 | 4 |
| | *Nemipterus peronii* (Valenciennes, 1830) | Np | 29 | 0.10 | 0.10 | 47 | 74 | 0.2 | 0.2 | 37 |
| | *Nemipterus randalli* Russell, 1986 | Nr | 342 | 1 | 1 | 16 | 858 | 2 | 2 | 13 |
| | *Parascolopsis aspinosa* (Rao & Rao, 1981) | Pas | 4 | 0.01 | 0.01 | 87 | 6 | 0.01 | 0.01 | 82 |
| | *Parascolopsis eriomma* Jordan & Richardson, 1909 | Pem | 0.2 | 0.001 | 0.001 | 125 | | | | |
| | *Scolopsis bimaculata* Rüppell, 1828 | Sb | 2 | 0.006 | 0.006 | 101 | | | | |
| | *Scolopsis taeniata* (Cuvier, 1830) | Sta | 0.7 | 0.002 | 0.003 | 111 | 6 | 0.01 | 0.01 | 81 |
| | *Scolopsis vosmeri* (Bloch, 1792) | Sv | 4 | 0.01 | 0.01 | 89 | 8 | 0.02 | 0.02 | 71 |
| Ophidiidae | *Neobythites stefanovi* Nielsen & Uiblein, 1993 | Ns | 0.1 | 0.000 | 0.000 | 135 | | | | |
| Ostraciidae | *Tetrosomus gibbosus* (Linnaeus, 1758) | Tg | 0.6 | 0.002 | 0.002 | 114 | 0.3 | 0.001 | 0.001 | 117 |
| Paralichthyidae | *Cephalopsetta ventrocellatus* Dutt & Rao, 1965 | Cv | 17 | 0.06 | 0.06 | 62 | 46 | 0.1 | 0.1 | 45 |
| | *Pseudorhombus arsius* (Hamilton, 1822) | Pau | 82 | 0.3 | 0.3 | 32 | 78 | 0.2 | 0.2 | 35 |
| Pinguipedidae | *Parapercis alboguttata* (Günther, 1872) | Pal | 0.2 | 0.001 | 0.001 | 126 | | | | |
| | *Parapercis robinsoni* Fowler, 1932 | Pro | 0.5 | 0.002 | 0.002 | 117 | | | | |
| Platycephalidae | *Grammoplites scaber* (Linnaeus, 1758) | Gsc | 0.8 | 0.003 | 0.003 | 110 | | | | |
| | *Grammoplites suppositus* (Troschel, 1840) | Gsu | 260 | 0.9 | 0.9 | 20 | 270 | 0.6 | 0.7 | 27 |
| | *Platycephalus indicus* (Linnaeus, 1758) | Pi | | | | | 0.5 | 0.001 | 0.001 | 114 |
| Plotosidae | *Plotosus lineatus* (Thunberg, 1787) | Pli | 56 | 0.2 | 0.2 | 37 | | | | |
| Polynemidae | *Eleutheronema tetradactylum* (Shaw, 1804) | Et | 0.3 | 0.001 | 0.001 | 123 | 1 | 0.003 | 0.003 | 101 |

| **Family** | **Species** | **Code** | **2014** | | | | **2016** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **FPUA** | **%** | **group%** | **Rank** | **FPUA** | **%** | **group%** | **Rank** |
| | *Polydactylus sextarius* Bloch & Schneider, 1801 | Psx | 109 | 0.4 | 0.4 | 28 | 428 | 1 | 1 | 23 |
| Pomacanthidae | *Pomacanthus maculosus* (Forsskål, 1775) | Pmc | 0.1 | 0.000 | 0.000 | 136 | 0.3 | 0.001 | 0.001 | 116 |
| Priacanthidae | *Priacanthus hamrur* (Forsskål, 1775) | Pha | 0.1 | 0.000 | 0.000 | 137 | 3 | 0.007 | 0.008 | 90 |
| | *Priacanthus tayenus* Richardson, 1846 | Pta | 61 | 0.2 | 0.2 | 35 | 8 | 0.02 | 0.02 | 75 |
| Pristigasteridae | *Ilisha compressa* Randall,1994 | Ic | 2 | 0.007 | 0.008 | 99 | | | | |
| | *Ilisha melastoma* (Schneider, 1801) | Im | 2,929 | 10 | 10 | 2 | 1,949 | 5 | 5 | 5 |
| Psettodidae | *Psettodes erumei* (Bloch & Schneider, 1801) | Per | 23 | 0.08 | 0.08 | 52 | 46 | 0.1 | 0.1 | 44 |
| Rachycentridae | *Rachycentron canadum* (Linnaeus, 1766) | Rc | 6 | 0.02 | 0.02 | 77 | 8 | 0.02 | 0.02 | 74 |
| Sciaenidae | *Johnius belangerii* (Cuvier, 1830) | Jbe | 23 | 0.08 | 0.08 | 53 | 70 | 0.2 | 0.2 | 38 |
| | *Johnius borneensis* (Bleeker, 1851) | Jbo | 3 | 0.01 | 0.01 | 90 | 3 | 0.006 | 0.006 | 92 |
| | *Otolithes ruber* (Schneider, 1801) | Or | 30 | 0.1 | 0.1 | 46 | 13 | 0.03 | 0.03 | 66 |
| | *Pennahia anea* (Bloch, 1773) | Pan | 16 | 0.05 | 0.05 | 66 | 43 | 0.1 | 0.1 | 47 |
| | *Protonibea diacanthus* (Lacepède, 1802) | Pdi | 227 | 0.8 | 0.8 | 22 | 0.3 | 0.001 | 0.001 | 118 |
| Scorpaenidae | *Pterois miles* (Bennett,1830) | Pt.m | 0.1 | 0.000 | 0.000 | 133 | | | | |
| | *Pterois russelii* Bennett, 1831 | Pru | 4 | 0.01 | 0.01 | 86 | 3 | 0.006 | 0.006 | 93 |
| | *Scorpaenopsis lactomaculata* (Herre, 1945) | Sla | 0.06 | 0.000 | 0.000 | 139 | 2 | 0.005 | 0.005 | 96 |
| Serranidae | *Cephalopholis hemistiktos* (Rüppell, 1830) | Chm | | | | | 2 | 0.006 | 0.006 | 95 |
| | *Epinephelus areolatus* (Forsskål, 1775) | Ea | 21 | 0.07 | 0.07 | 54 | 23 | 0.05 | 0.05 | 57 |
| | *Epinephelus bleekeri* (Vaillant, 1877) | Ep.b | 19 | 0.06 | 0.07 | 56 | 15 | 0.04 | 0.04 | 65 |
| | *Epinephelus coioides* (Hamilton, 1822) | Ec | 10 | 0.03 | 0.03 | 72 | 15 | 0.04 | 0.04 | 64 |
| | *Epinephelus diacanthus* (Valenciennes, 1828) | Ed | 0.3 | 0.001 | 0.001 | 124 | 2 | 0.006 | 0.006 | 94 |
| | *Epinephelus epistictus* (Temminck & Schlegel, 1842) | Ee | 31 | 0.1 | 0.1 | 45 | 28 | 0.07 | 0.07 | 51 |
| | *Epinephelus latifasciatus* (Temminck & Schlegel,1842) | El | 0.1 | 0.000 | 0.000 | 134 | | | | |
| | *Epinephelus polylepis* Randall & Heemstra, 1991 | Ep | 3 | 0.01 | 0.01 | 92 | | | | |
| Siganidae | *Siganus javus* (Linnaeus, 1766) | Sja | | | | | 0.5 | 0.001 | 0.001 | 112 |
| Soleidae | *Brachirus orientalis* (Bloch & Schneider, 1801) | Bo | 1.0 | 0.003 | 0.003 | 107 | 0.8 | 0.002 | 0.002 | 106 |
| Sparidae | *Acanthopagrus arabicus* Iwatsuki, 2013 | Aar | 10 | 0.03 | 0.03 | 73 | 35 | 0.08 | 0.09 | 50 |
| | *Acanthopagrus bifasciatus* (Forsskål, 1775) | Ab | 0.1 | 0.000 | 0.000 | 132 | 1 | 0.003 | 0.003 | 99 |
| | *Argyrops spinifer* (Forsskål, 1775) | As | 251 | 0.8 | 0.9 | 21 | 210 | 0.5 | 0.5 | 30 |
| | *Rhabdosargus haffara* (Forsskål, 1775) | Rh | 0.5 | 0.002 | 0.002 | 115 | 4 | 0.008 | 0.009 | 86 |
| Sphyraenidae | *Sphyraena forsteri* Cuvier, 1829 | Sf | 112 | 0.4 | 0.4 | 27 | 1,889 | 5 | 5 | 7 |
| | *Sphyraena jello* Cuvier, 1829 | Sje | 46 | 0.2 | 0.2 | 39 | 63 | 0.1 | 0.2 | 39 |
| | *Sphyraena obtusata* Cuvier, 1829 | So | 1,775 | 6 | 6 | 5 | 626 | 1 | 2 | 15 |
| | *Sphyraena putnamae* Jordan & Seale, 1905 | Sp | 322 | 1 | 1 | 18 | 1,063 | 3 | 3 | 12 |
| Stromateidae | *Pampus argenteus* (Euphrasen, 1788) | Par | 28 | 0.09 | 0.09 | 48 | 211 | 0.5 | 0.5 | 29 |
| Synanceiidae | *Minous dempsterae* Eschmeyer,Hallacher & Rama-Rao, 1797 | Md | 0.5 | 0.002 | 0.002 | 119 | | | | |
| | *Hippocampus kuda* (Bleeker, 1852) | Hk | 0.1 | 0.000 | 0.000 | 130 | | | | |
| Synodontidae | *Saurida tumbil* (Bloch, 1795) | Stu | 1,164 | 4 | 4 | 10 | 1,860 | 4 | 5 | 8 |
| | *Saurida undosquamis* (Richardson, 1848) | Su | 322 | 1 | 1 | 19 | 603 | 1 | 1 | 16 |
| Terapontidae | *Terapon jarbua* (Forsskål, 1775) | Tj | 12 | 0.04 | 0.04 | 68 | 25 | 0.06 | 0.06 | 54 |
| | *Terapon theraps* (Cuvier, 1829) | Tt | 91 | 0.3 | 0.3 | 30 | 81 | 0.2 | 0.2 | 33 |
| Tetraodontidae | *Arothron stellatus* (Bloch & Schneider, 1801) | Ar.s | 0.1 | 0.000 | 0.001 | 129 | 0.3 | 0.001 | 0.001 | 115 |
| | *Chelonodon patoca* (Buchanan, 1822) | Cpa | 0.06 | 0.000 | 0.000 | 140 | | | | |
| | *Lagocephalus guentheri* Riberio, 1915 | Lg | 19 | 0.06 | 0.06 | 57 | 52 | 0.1 | 0.1 | 41 |
| | *Lagocephalus inermis* (Temminck & Schlegel, 1844) | La.i | 7 | 0.02 | 0.02 | 76 | 22 | 0.05 | 0.05 | 58 |
| | *Lagocephalus lunaris* (Bloch & Schneider, 1801) | Llu | 5 | 0.02 | 0.02 | 82 | 0.9 | 0.002 | 0.002 | 105 |
| | *Lagocephalus suezensis* Clark & Gohar, 1953 | Lsz | | | | | 1 | 0.003 | 0.003 | 102 |
| | *Torquigener flavimaculosus* Hardy & Randall, 1983 | Tpo | 0.06 | 0.000 | 0.000 | 141 | | | | |
| Triacanthidae | *Pseudotriacanthus strigilifer* (Cantor, 1849) | Psg | 32 | 0.1 | 0.1 | 44 | 7 | 0.02 | 0.02 | 77 |
| Trichiuridae | *Eupleurogrammus muticus* (Gray, 1831) | Em | 2 | 0.005 | 0.005 | 102 | 13 | 0.03 | 0.03 | 67 |
| | *Trichiurus lepturus* Linnaeus, 1758 | Tl | 2,637 | 9 | 9 | 4 | 4,888 | 12 | 12 | 2 |
| Triglidae | *Lepidotrigla bispinosa* Steindachner, 1898 | Lbi | 4 | 0.01 | 0.01 | 85 | 1 | 0.002 | 0.003 | 104 |
| | *Lepidotrigla spiloptera* Günther, 1880 | Lsp | 0.5 | 0.002 | 0.002 | 116 | 45 | 0.1 | 0.1 | 46 |
| Uranoscopidae | *Uranoscopus guttatus* Cuvier, 1829 | Ug | 17 | 0.06 | 0.06 | 61 | 38 | 0.09 | 0.09 | 48 |

| Family | Species | Code | 2014 | | | | 2016 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **FPUA** | **%** | **group%** | **Rank** | **FPUA** | **%** | **group%** | **Rank** |
| | **Total bony fishes** | | **29,195** | **98.3** | | | **41,269** | **98.7** | | |
| | **Total bottom-associated fishes** | | **29,687** | | | | **41,807** | | | |
| | **Total species richness** | | | **165** | | | | **145** | | |

* 0.000 in the table cells means a value less than 0.0005.

These species belonged to 4 families and 7 genera of sharks, 6 families and 11 genera of batoids and 59 families and 95 genera of bony fishes in 2014. The corresponding values in 2016 were three families and 5 genera of sharks, 7 families and 13 genera of batoids and 53 families and 87 genera of bony fishes. Common species shared by two years were 6 sharks, 13 batoids and 111 bony fishes. Four sharks, no batoids and 31 bony fish species found only in 2014 and one shark, two batoids and 12 bony fish species were sampled only in 2016. Sharks included 10 and 7 species in two consecutive years with 0.4 and 0.3 percent of total fish FPUA, respectively. The assemblages were dominated by bony fish, prevailed by Gilded goatfish (*Upeneus doriae*), followed by Batoid fish, prevailed by the Arabian banded whipray (*Maculabatis randalli*), and shark fish, prevailed by Whitecheek shark (*Carcharhinus dussumieri*). *C. dussumieri* had the first rank of abundance (62% in 2014 and 75% in 2016) among all sharks in both years. Batoid fishes comprised of 13 and 15 species with 1.3 and 1 percent of total fish FPUA in the two years. *M. randalli*, *Brevitrygon imbricata*, *Gymnura poecilura* and *Aetomylaeus nichofii* were dominant batoid species comprising 81% of batoid relative frequency in 2014. *M. randalli*, *G. poecilura* and *Pastinachus sephen* dominated in 2016 with 79% of batoids relative abundance. Bony fishes formed the main part of species composition with 142 species and 98.3% of total FPUA in 2014; their contribution was 123 species and 98.7% of total abundance in 2016. Ten and 12 bony fishes were the common species accounting for 73.5% and 74.7% of total relative density in 2014 and 2016, respectively. Ten common species in 2014 were *U. doriae* (15.8% of total density), *Ilisha melastoma* (9.9%), *Photopectoralis bindus* (9.6%), *Trichiurus lepturus* (8.9%), *Sphyraena obtusata* (6%), *Ariomma indicum* (5.5%), *Nemipterus japonicus* (5.5%), *Carangoides malabaricus* (4.3%), *Aurigequula fasciata* (4.2%) and *Saurida tumbil* (3.9%). Twelve common species in 2016 were *U. doriae* (17.4%), *T. lepturus* (11.7%), *P. bindus* (10.1%), *N. japonicas* (4.7%), *I. melastoma* (4.7%), *A. fasciata* (4.6%), *S. obtusata* (4.5%), *S. tumbil* (4.4%), *Pentaprion longimanus* (3.6%), *C. malabaricus* (3.3%), *Secutor insidiator* (3.2%) and *Sphyraena putnamae* (2.5%) (Table 1).

### *Assemblage structure of bottom-associated fishes*

Arithmetic mean of total fish FPUA were 29,583 and 44,999 in 2014 and 2016, respectively. T-test showed a significant difference in FPUA between years (P=0.002), confirming an average increase of 52% in fish abundance in 2016 compared to 2014 (Table 2). The weighted mean of total fish FPUA were 29,687 and 41,807 for years 2014 and 2016, respectively, showing an average increase of 40% in fish abundance after 2 years (Table 1). Arithmetic mean of total fish FPUA in geographic strata A to D were 48,903, 32,869, 35,270 and 30,550, respectively. ANOVA test revealed a significant difference in relative abundance of total demersal fishes among four strata (P=0.03) and Duncan pairwise comparison test differentiated stratum A from three other strata. Arithmetic mean of total fish FPUA in depth strata 1 to 4 were 37,729, 28,586, 41,687 and 36,544, respectively. ANOVA test results did not show any significant difference between the relative abundance of demersal fishes in different depth strata (P=0.28).

**Table 2: Independent t-test results testing the difference in species richness, FPUA, Margalef's species richness, Pielou's evenness index, Shannon index and Gini–Simpson index of bottom-associated fishes between 2014 and 2016.**

| **Parameter** | **Year** | **Mean** | **Standard error of the mean** | **Levene's Test for equality of variances (*p*-value)** | ***P*-value (2-tailed when equal variances assumed)** | ***P*-value (2-tailed when equal variances not assumed)** |
|---|---|---|---|---|---|---|
| Species richness | 2014<br>2016 | 45.3<br>40.0 | 0.8<br>1.0 | 0.684 | 0.000 | 0.000 |
| FPUA | 2014<br>2016 | 29583.3<br>44999.3 | 2572.2<br>4015.0 | 0.020 | 0.001 | 0.002 |
| Margalef's species richness | 2014<br>2016 | 4.4<br>3.7 | 0.1<br>0.1 | 0.88 | 0.000 | 0.000 |
| Pielou's evenness index | 2014<br>2016 | 0.6<br>0.6 | 0.0<br>0.0 | 0.79 | 0.09 | 0.09 |
| Shannon index | 2014<br>2016 | 2.5<br>2.2 | 0.1<br>0.1 | 0.29 | 0.008 | 0.007 |
| Gini–Simpson index | 2014<br>2016 | 0.8<br>0.8 | 0.0<br>0.0 | 0.72 | 0.12 | 0.12 |

The data on total observed species indicated a reduction of 12% in species richness after two years. Rarefaction technique estimated 132 and 122 fish species for years 2014 and 2016, respectively, based on lower FPUA of 2014 (29,687). The estimated mean showed a 7.6% reduction in species richness. Calculating species richness in proportion to the number of sampled stations (assuming 61 stations per each year) yielded 148 species for 2016, showing a 10% decline in species richness. Mean values of fish species per station were 45.3 and 40 in 2014 and 2016, respectively. T-test result showed a significant difference between years ($P < 0.05$), confirming the decrease in fish species richness in 2016 compared to 2014. The same results were obtained from the test of Margalef's species richness and Shannon diversity index. Yet, Pielou's evenness and Gini–Simpson diversity index did not show significant difference between years (Table 2). Based on pooled data of both years, ANOVA test showed significant difference in all species diversity indices except Gini-Simpson, between geographic strata. A similar analysis did not exhibit significant difference in all species diversity indices except for Margalef's species richness, between depth strata. According to Duncan pairwise comparison test results, average of species number and Margalef's species richness per sampling were significantly lower in depth stratum 4 (40.3 and 3.83, respectively) than depth strata 1 (44.85 and 4.23) and 2 (45 and 4.37). Depth stratum 3 with values 43 and 4 did not differ significantly from other depth strata.

The nMDS ordinations of geographic and depth strata generated by the assemblage structure of bottom-associated fishes in 2014 and 2016 are illustrated in figures 2 and 3, respectively. The stress values associated with these two-dimensional plots were 0.14 and 0.18 respectively, revealing that these ordinations were sound. Based on the fish assemblage structure, the nMDS ordination plot in 2014 showed that stations over strata A and B were nearly separate; while, stations over strata C and D and some stations over strata B were mixed (Fig. 2a). According to the analysis of similarity (ANOSIM) test, a significant difference was found in assemblage structure of bottom-associated fishes between geographic strata [Global R= 0.31, P(perm)=0.001] in 2014. Pairwise tests showed significant difference between strata D and A [R = 0.579, P(perm)=0.001], C and A [R=0.48, P(perm)=0.001] and D and B [R=0.33, P(perm)=0.001]. The other nMDS ordination plot (Fig. 2b) for 2014 showed that stations over depth strata 1 to 3 and a few stations of depth stratum 4 were mixed, and most stations of depth stratum 4 were nearly separate. Results of the ANOSIM test also indicated a significant difference in the assemblage structure of bottom-associated fishes between depth strata [Global R=0.18, P(perm)=0.001] in 2014. The greatest differences were observed between depth strata 1 and 4 [R = 0.29, P(perm)= 0.009], 2 and 4 [R=0.26, P(perm)=0.001] and 3 and 4 [R= 0.17, P(perm)=0.001].

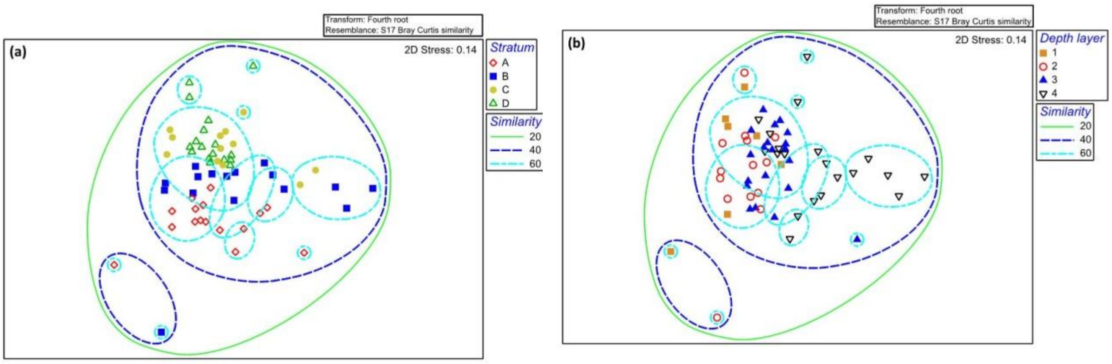

**Figure 2: Non-metric multidimensional scaling (nMDS) plots for assemblage structure of bottom-associated fish species based on Bray-Curtis index of dissimilarity among stations, derived from forth-root transformed FPUA data, in different geographical strata (a) and depth layers (b) (i.e., 1: 10-20m, 2: 20-30m, 3: 30-50m, 4: more than 50m) in 2014.**

The results of the two-way PERMANOVA showed significant difference in assemblage structure of bottom-associated fishes among four geographic [Pseudo-F=3.92, P(perm)=0.0001, df=3] and four depth strata [Pseudo-F=2.55, P(perm)=0.0001, df=3]. Yet, no significant interaction was found between geographic and depth strata [Pseudo-F=-1.04, P(perm)=0.10, df=9] in 2014.

Based on the fish assemblage structure, the nMDS ordination plot in 2016 showed that some stations over geographic strata A and D were distinct and most other stations over all strata were randomly placed (Fig. 3a). The results of the ANOSIM test showed a significant difference in the assemblage structure of bottom-associated fishes among geographic strata [Global R=0.22, P(perm)=0.001]. Pairwise tests showed significant difference between strata D and A [R=0.38, P(perm)=0.001], C and A [R=0.27, P(perm)=0.001], and D and B [R=0.26, P(perm)=0.001]. Differentiation of assemblage structure of bottom-associated fishes among geographical strata in 2016 was same as those for 2014. The nMDS plot for depth strata in 2016 (Fig. 3b) showed that positions of some stations which linked to the depth stratum 4 were apart from other randomly placed stations over all depth strata. Results of the ANOSIM test indicated a significant difference in the assemblage structure of bottom-associated fishes among depth strata [R=0.26, P(perm)=0.001]. Significant differences were detected between depth strata 1 and 4 [R=0.49, P(perm)=0.001], 2 and 4 [R=0.38, P(perm)=0.001], and 3 and 4 [R=0.31, P(perm)=0.001] based on pairwise tests. Differentiation of assemblage structure of bottom-associated fish among depth strata in 2016 was the same as those for 2014. The same as in 2014, the results of the two-way PERMANOVA showed significant difference in assemblage structure of bottom-associated fishes among geographic [Pseudo-F=2.06, P(perm)=0.0001, df=3] and depth strata [Pseudo-F=2.51, P(perm)=0.0001, df=3], but, no significant interaction between geographic and depth strata [Pseudo-F=-0.79, P(perm)=0.06, df=9] in 2016 too.

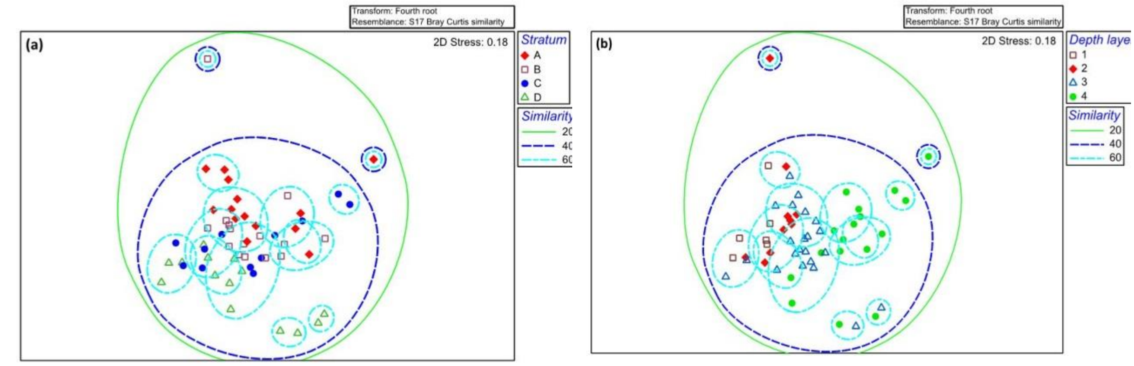

**Figure 3: Non-metric multidimensional scaling (nMDS) plots for assemblage structure of bottom-associated fish species based on Bray-Curtis index of dissimilarity among stations, derived from forth-root transformed FPUA data, in different geographical strata (a) and depth layers (b) (i.e., 1: 10-20m, 2: 20-30m, 3: 30-50m, 4: more than 50m) in 2016.**

The results of the two-way PERMANOVA test revealed significant differences in assemblage structure of bottom dwelling fishes between two studied years (Pseudo-F=3.75, P(perm)=0.0001, df=1), and among geographical strata (Pseudo-F=6.04, P(perm)=0.0001, df=3). Accordingly, there was significant interaction between years and strata (Pseudo-F=0.21, P(perm)=0.0015, df=3). Likewise, the results of two-way PERMANOVA test showed significant differences in assemblage structure between studied years (Pseudo-F=3.17, P(perm)=0.0001, df=1), and among depth strata (Pseudo-F=4.87, P(perm)=0.0001, df=3); Yet, no significant interaction was detected between years and depth strata (Pseudo-F=-5.07, P(perm)=0.17, df=3).

*Characteristics of the physical environment*

Table 3 summarized mean and standard error values for recorded physical factors in both years. This table also demonstrated the results of t-test comparing the means of each physical factor between years. The mean depth of all sampled stations did not differ significantly between two years ($P=0.57$). Mean temperature values of sea water were 25.16°C and 24.21°C in lowermost 7 meters of studied area in years 2014 and 2016, respectively. The result of t-test showed that water temperature has been nearly one degree cooler in 2016 ($p<0.05$). Average values of seawater electrical conductivity (EC) with 58.3 and 57.37 mS/cm in 2014 and 2016, respectively, were significantly different. Seawater salinity did not differ significantly between two years ($P=0.51$). The calculated mean values were 38.77 and 38.88 psu in 2014 and 2016, respectively. Average values of seawater pH with 8.29 and 8.15 in 2014 and 2016, respectively, were significantly different. Dissolved oxygen of seawater recorded only in 2014 with an average (±SE) of 4.83±(0.18) ppm. Water turbidity was measured only in 2016 with an average (±SE) of 15.93±(1.36) m.

**Table 3: Independent t-test results testing the difference in environmental factors between 2014 and 2016. (*: t could not be done because at least one of the groups was empty.)**

| Parameter | Year | Mean | Standard error of the mean | Levene's Test for equality of variances (*p*-value) | ***P*-value (2-tailed when equal variances assumed)** | ***P*-value (2-tailed when equal variances not assumed)** |
|---|---|---|---|---|---|---|
| Depth (m) | 2014 | 46.15 | 2.10 | 0.49 | 0.57 | 0.57 |
| | 2016 | 44.50 | 1.95 | | | |
| Temperature (ºC) | 2014 | 25.16 | 0.11 | 0.05 | 0.000 | 0.000 |
| | 2016 | 24.21 | 0.08 | | | |
| EC (mS/cm) | 2014 | 58.30 | 0.11 | 0.00 | 0.000 | 0.000 |
| | 2016 | 57.37 | 0.21 | | | |
| Salinity (psu) | 2014 | 38.77 | 0.11 | 0.49 | 0.51 | 0.51 |
| | 2016 | 38.88 | 0.12 | | | |
| pH | 2014 | 8.29 | 0.01 | 0.00 | 0.000 | 0.000 |
| | 2016 | 8.15 | 0.01 | | | |
| DO (ppm) | 2014 | 4.83 | 0.18 | * | * | * |
| | 2016 | * | * | | | |
| Turbidity | 2014 | * | * | * | * | * |
| | 2016 | 15.93 | 1.36 | | | |

The nMDS ordinations of geographical and depth strata configured based on physical factors of seawater in 2014 and 2016 were illustrated in figures 4 and 5, respectively. The stress values associated with these two-dimensional plots were 0.01 and 0.08, confirming high accuracy of 2-dimensional configurations of these ordinations. In 2014, the nMDS ordination plot formed based on physical factors of seawater showed that stations of all geographic strata were randomly positioned and no distinct group could be distinguished (Fig. 4a). ANOSIM test did not show any significant difference between strata (Global R=0.008, P(perm)=0.328).

Another nMDS ordination plot (Fig. 4b) for 2014 showed that all depth strata were separated, except for a few stations. Results of ANOSIM test indicated significant differences in physical factors of seawater between depth strata (Global R=0.51, P(perm)=0.001) in 2014. Pairwise tests showed significant differences between all depth strata as follows: 1 and 4 (Global R=0.75, P(perm)=0.001); 1 and 3 (Global R=0.74, P(perm)=0.001]; 2 and 4 (Global R= 0.70, P(perm)=0.001); 2 and 3 (Global R=0.62, P(perm)=0.001); 1 and 2 (Global R=0.43, P(perm)=0.001) and 3 and 4 (Global R= 0.36, P(perm)=0.001).

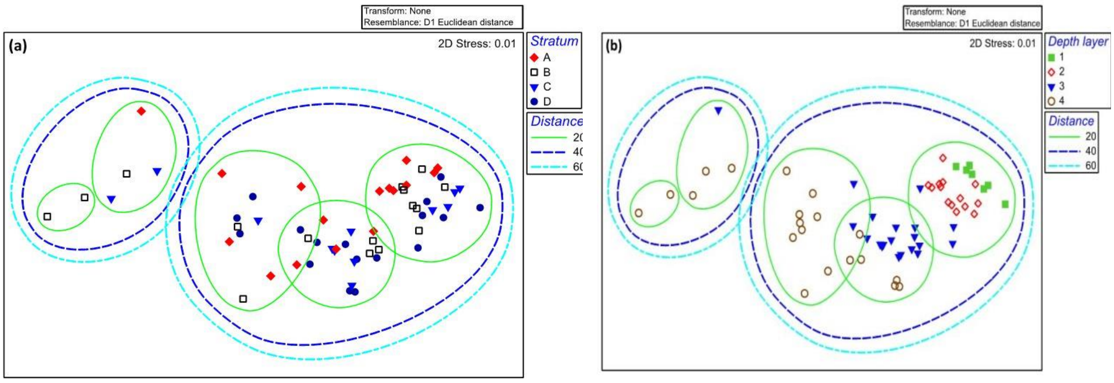

**Figure 4: Non-metric multidimensional scaling (nMDS) plots of environmental factors based on Euclidean distance derived from mean values of factors at lowermost 7m depths of stations, representing different geographical strata (a) and depth layers (b) (1: 10-20m, 2: 20-30m, 3: 30-50m & 4: more than 50m) in 2014.**

The results of the two-way PERMANOVA showed significant difference among the physical status of the seawater across four depth strata (Pseudo-F=12.16, P(perm)=0.0001, df=3); but no significant difference among geographic strata (Pseudo-F=0.78, P(perm)=0.31, df=3) and no interaction between geographic and depth strata (Pseudo-F=-1.45, P(perm)= 0.73, df=9) in 2014.

In 2016, the nMDS ordination plot formed based on physical factors of seawater showed that most stations of strata A and B were grouped together. This was true for strata C and D too (Fig.5a). According to ANOSIM test, significant difference was found in physical factors of seawater between strata (Global R=0.41, $P_{(perm)}$=0.001). Pairwise tests showed significant difference between D and B (R=0.89, P(perm)=0.001), D and A (R=0.69, $P_{(perm)}$=0.001), C and B (R=0.49, $P_{(perm)}$=0.001) and C and A strata (R=0.30, $P_{(perm)}$=0.001). There was insignificant difference between C and D (R=0.09, $P_{(perm)}$=0.04) and no difference between A and B strata (R=-0.02, $P_{(perm)}$=0.65).

The alternative nMDS plot for depth strata in 2016 (Fig. 5b) showed that most stations related to depth strata 1 and 2 were randomly arranged in two groups; The areas occupied by stations related to depth strata 3 and 4 are nearly separated both from each other and from depth strata 1 and 2.

Results of ANOSIM test inferred a meaningful difference between depth strata [R = 0.357, P(perm)=0.001] based on physical factors of seawater in this year. In addition, significant differences were concluded between depth strata 1 and 4 [R = 0.664, P(perm)=0.001], 2 and 4 [R=0.578, P(perm)=0.002], 3 and 1 [R=0.388, P(perm)=0.001], 3 and 4 [R=0.315, P(perm)=0.001] and a lower meaningful difference between depth strata 3 and 2 [R=0.196, P(perm)=0.014] by pairwise tests; Accordingly, depth strata 1 and 2 had no difference [R=0.133, P(perm)=0.1].

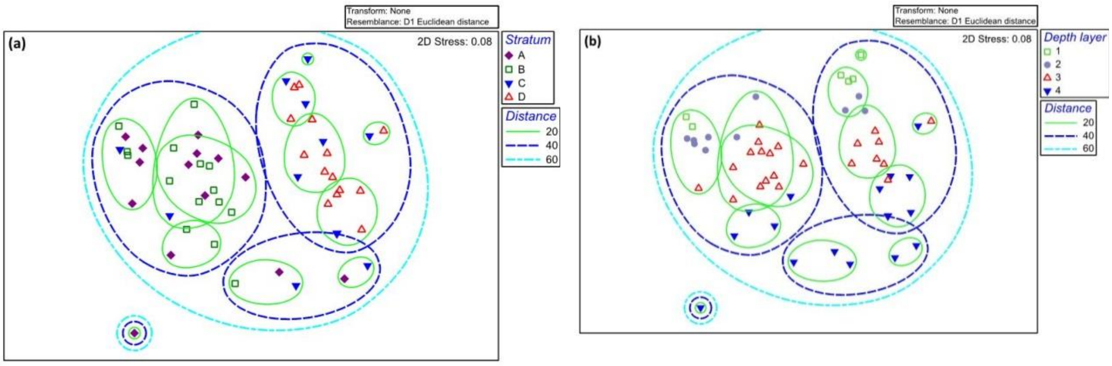

**Figure 5: Non-metric multidimensional scaling (nMDS) plots of environmental factors based on Euclidean distance derived from mean values of factors at lowermost 7m depths of stations, representing different geographical strata (a) and depth layers (b) (1: 10-20m, 2: 20-30m, 3: 30-50m & 4: more than 50m) in 2016.**

The same as in 2014, results of the two-way PERMANOVA showed significant difference between the physical status of the seawater across four depth strata [Pseudo-F=13.86, P(perm)=0.0001, df=3] but no difference among geographic strata [Pseudo-F=0.944, P(perm)=0.189, df=3] and no interaction between geographic and depth strata [Pseudo-F = -1.25, P(perm)=0.85, df=9] in 2016.

The simultaneous comparison of the physical conditions of sea water among two years of study and four depth strata using a two-way PERMANOVA test indicated only a significant difference between the depth strata (Pseudo-F=48.335, P(perm)=0.0001, df=3); No significant difference between years (Pseudo-F=-0.156, P(perm)=0.9469, df=1) and no significant interaction between years and depth strata (Pseudo-F=-10.703, P(perm)=1, df=3) were found. Accordingly, the simultaneous comparison of years and geographic strata resulted no significant difference between two years of study (Pseudo-F=-0.0767, P(perm)=0.9106, df=1) and four strata (Pseudo-F=0.4797, P(perm)=0.7076, df=3) and no significant interaction between years and strata (Pseudo-F=-0.387, P(perm)=0.254, df=3).

### *Inter-relating bottom-associated fishes and the physical environment*

According to the BEST test results, temperature, EC, salinity and pH ($\rho$=0.432; P=0.01) in 2014, and depth, temperature, EC, salinity and pH ($\rho$=0.412; P=0.01) in 2016 described the distribution pattern and assemblage structure of bottom-associated fishes in the studied area.

CCA ordination diagrams illustrate relations between different environmental variables associated with variation in the spatial patterns of bottom-associated fish species in 4 geographic strata (A– D), 4 depth strata and 16 substrata (A1– D4) of the Hormozgan studied area in 2014 (Fig. 6) and 2016 (Fig. 7).

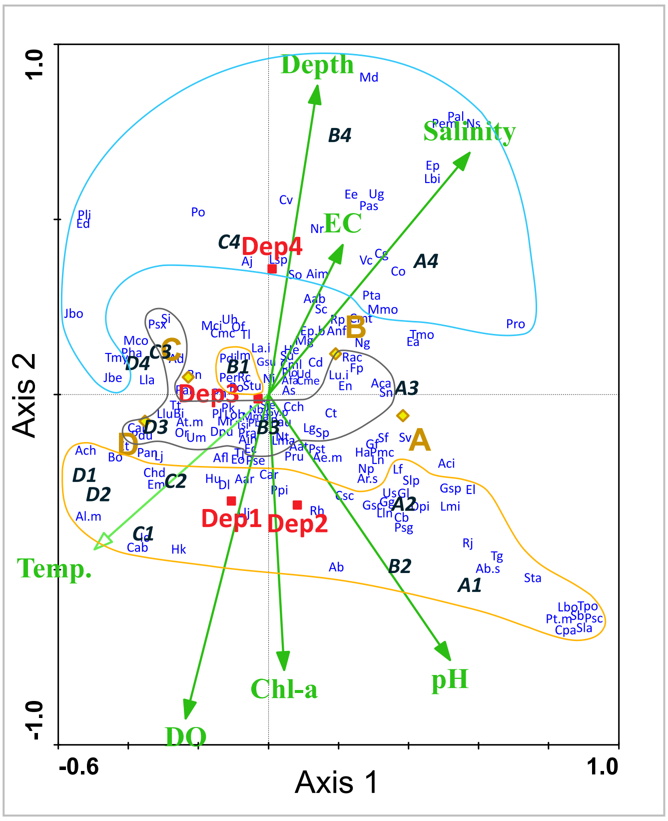

**Figure 6:** **Canonical correspondence analysis (CCA) ordination diagram relating the assemblage structure of bottom-associated fishes (4th rooted FPUA) to environmental variables recorded across the 4 geographical strata (A - D), 4 depth strata and 16 substrata (A1 - D4) in 2014.**

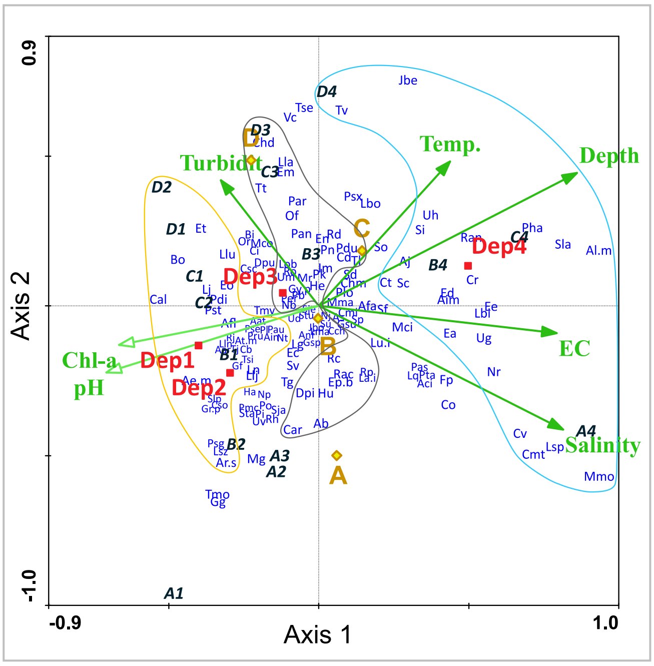

**Figure 7:** **Canonical correspondence analysis (CCA) ordination diagram relating the assemblage structure of bottom-associated fishes (4th rooted FPUA) to environmental variables recorded across the 4 geographical strata (A - D), 4 depth strata and 16 substrata (A1 - D4) in 2016.**

Axes 1 ($\lambda1=0.191$) and 2 ($\lambda2=0.156$) explained a total of 15.4% of variation in the structure pattern of bottom dwelling fish communities and 59.3% of the relationship between environmental factors and species structure pattern based on 4th root transformed FPUA of the species and measured environmental variables in 2014. Monte Carlo test confirmed the importance of these axes in explaining the structure of bottom dwelling fish communities and explaining the relationship of species with environmental factors ($P_{Perm}=0.002$). The test also showed a strong correlation between the measured environmental variables with the fish species around the first ($R_1=0.879$) and the second ($R_2=0.843$) axes, which means that the studied environmental variables affected impressively on species composition. The Monte Carlo test in the "automatic forward selection" routine of CANOCO software revealed that except for water temperature ($P_{Perm}=0.314$), all other environmental factors had a significant role in fish species composition changes in 2014 ($P_{Perm}<0.05$).

The centroid of the Dep3 (30 to 50 m) depth stratum was placed approximately at the coordinate origin of the diagram, the Dep4 (over 50 m) depth stratum in the upper half, and the Dep1 (10 to 20 m) and Dep2 (20 to 30 m) depth strata were located in close proximity in the lower half of the graph. The ecological conditions at depths of 10 to 30 m look almost the same; Shallow coastal waters (10–20 and 20–30 m) were influenced by high amounts of dissolved oxygen and chlorophyll a, albeit pH and the seawater temperature were also above average. Water depth was the most important environmental factor affecting species composition of deep sea (50–100 m) fishes; higher electrical conductivity and salinity, and lower dissolved oxygen, chlorophyll a, sea water temperature and pH, than shallower coastal waters are other ecological features of the Dep4 depth stratum. The average values of environmental factors are predictable at depths of 30 to 50 m; In other words, in the autumn of 2014, from shallow coastal waters to deep waters of the Persian Gulf, chlorophyll a, dissolved oxygen, temperature and pH of the water were decreased and the salinity and electrical conductivity were increased.

Hereafter, successive names that are in pair brackets, belong to the species that are very close together or overlapped in the diagram. These are species that seem to occupy a similar ecological niche. The species whose names are typed in bold had more abundance (species with at least 3% of the total fish fourth rooted FPUA in the original data matrix) within each of 3 above mentioned species groups in each year.

It was estimated that the species whose name codes were located nearer to the Dep1 and Dep2 centroids and associated substrata are more frequent in coastal waters with depths of 10 to 30 m. in 2014. The name codes of these species were surrounded by two orange closed lines; *Ilisha melastoma* (Im), *Protonibea diacanthus* (Pdi), *Psettodes erumei*

(Per), *Rachycentron canadum* (Rc), *Saurida tumbil* (Stu), *Rhizoprionodon oligolinx* (Ro), *Anodontostoma chacunda* (Ach), *Brachirus orientalis* (Bo), *Aluterus monoceros* (Al.m), *Ilisha compressa* (Ic), *Chiloscyllium arabicum* (Cab), *Hippocampus kuda* (Hk), *Carangoides hedlandensis* (Chd), *Eupleurogrammus muticus* (Em), *Himantura uarnak* (Hu), *Drepane longimana* (Dl), *Acanthopagrus arabicus* (Aar), *Carangoides armatus* (Car), *Plectorhinchus pictus* (Ppi), *Lutjanus lutjanus* (Llj), *Rhabdosargus haffara* (Rh), *Centriscus scutatus* (Csc), *Acanthopagrus bifasciatus* (Ab), *Lutjanus fulviflamma* (Lf), *Selaroides leptolepis* (Slp), [[*Gerres longirostris* (Gl), *Upeneus sundaicus* (Us), *Glaucostegus granulatus* (Gg), *Grammoplites scaber* (Gsc), *Lethrinus lentjan* (Lln), *Diagramma pictum* (Dpi), *Carangoides bajad* (Cb), *Pseudotriacanthus strigilifer* (Psg)]], *Gnathanodon speciosus* (Gsp), *Epinephelus latifasciatus* (El), *Lethrinus microdon* (Lmi), *Rhinoptera javanica* (Rj), *Tetrosomus gibbosus* (Tg), *Abalistes stellatus* (Ab.s), *Scolopsis taeniata* (Sta), [[*Lethrinus borbonicus* (Lbo), *Takifugu poecilonotus* (Tpo), *Pterois miles* (Pt.m), *Scolopsis bimaculata* (Sb), *Plectorhinchus schotaf* (Psc), *Chelonodon patoca* (Cpa) and *Scorpaenopsis lactomaculata* (Sla)]] can be attributed to this group.

Species whose name codes were closer to the Dep3 centroid and A3 to D3 substrata than to the other depth strata or substrata were likely to be more abundant at depths of 30 to 50 m in autumn 2014, including *Secutor insidiator* (Si), *Polydactylus sextarius* (Psx), *Alepes djedaba* (Ad), *Terapon theraps* (Tt), *Lagocephalus lunaris* (Llu), *Brevitrygon imbricata* (Bi), *Atule mate* (At.m), *Cynoglossus arel* (Cal), *Plicofollis dussumieri* (Pdu), *Otolithes ruber* (Or), *Ulua mentalis* (Um), *Pomadasys kaakan* (Pk), *Plicofollis layardi* (Pl), *Leiognathus oblongus* (Lob), *Maculabatis randalli* (Mr), *Drepane punctata* (Dpu), *Torpedo sinuspersici* (Tsi), *Paragaleus randalli* (Pra), *Alectis indica* (Ain), *Epinephelus coioides* (Ec), *Siganus javus* (Sje), *Netuma bilineata* (Nb), *Gymnura poecilura* (Gy.p), *Mene maculata* (Mma), *Photopectoralis bindus* (Pb), *Pseudorhombus arsius* (Pau), *Netuma thalassina* (Nt), *Lutjanus malabaricus* (Lma), *Carangoides chrysophrys* (Cch), *Carangoides talamparoides* (Ct), *Lagocephalus guentheri* (Lg), *Sphyraena putnamae* (Sp), *Echeneis naucrates* (En), *Lutjanus indicus* (Lu.i), *Fistularia petimba* (Fp), *Rhizoprionodon acutus* (Rac), *Apistus carinatus* (Aca) and *Seriolina nigrofasciata* (Sn), which are separated from the rest of the species in the CCA diagram by a dark gray closed line.

It was also expected that species closer to the Dep4 centroid and A4 to D4 substrata were mostly observed in waters with depths exceeding 50 m; the name codes of these fishes were confined by a cyan closed line. *Johnius belangerii* (Jbe), *Thryssa mystax* (Tmy), *Johnius borneensis* (Jbo), *Epinephelus diacanthus* (Ed), *Plotosus lineatus* (Pli), *Platax orbicularis* (Po), *Acropoma* *japonicum* (Aj), *Lepidotrigla spiloptera* (Lsp), *Sphyraena obtusata* (So), *Ariomma indicum* (Aim), *Nemipterus randalli* (Nr), *Cephalopsetta ventrocellatus* (Cv), [[*Epinephelus epistictus* (Ee), *Parascolopsis aspinosa* (Pas), *Uranoscopus guttatus* (Ug)]], *Verulux cypselurus* (Vc), *Carangoides gymnostethus* (Cg), *Cyclichthys orbicularis* (Co), *Priacanthus tayenus* (Pta), *Mustelus mosis* (Mmo), *Parapercis robinsoni* (Pro), [[*Epinephelus polylepis* (Ep), *Lepidotrigla bispinosa* (Lbi)]], [[*Parapercis alboguttata* (Pal), *Parascolopsis eriomma* (Pem), *Neobythites stefanovi* (Ns)]] and *Minous dempsterae* (Md) were in this group. Other species with name codes in the upper half of the diagram were adapted with changes in environmental conditions at depths of 30 to 100 m.

Referring to the CCA diagram in figure 7, axes 1 ($\lambda1=0.173$) and 2 ($\lambda2=0.113$) explained 13.7% of the variance in assemblage structure pattern of bottom-associated fish species and 56.1% of the relationship between environmental factors and species structure pattern based on 4th root transformed FPUA of the species and measured environmental variables in 2016. Monte Carlo test confirmed the significance of these axes in explaining the structure of bottom-associated fish communities and explaining the relationship between fish species composition and environmental factors ($P_{Perm}<0.005$). The test also showed that there were correlation between the measured environmental variables with the fish species around the first ($R_1=0.915$) and the second ($R_2=0.837$) axes, which means that the studied environmental variables have affected the fish species composition. The Monte Carlo test in the "automatic forward selection" procedure of CANOCO software revealed that except for pH and chlorophyll a ($p>0.2$), other environmental factors have significantly affected the species composition of fish in 2016 ($P_{Perm}<0.05$).

The Dep3 centroid (30 to 50 m) was located in the second quadrant and near the coordinate origin of the diagram, Dep4 (over 50 m) centroid in the first quadrant and adjacent to the first axis and Dep1 (10 to 20 m) and Dep2 (20 to 30 m) centroids were in the third quadrant and close together. The ecological conditions at depths of 10-30 m seemed relatively similar in 2016 too; Shallow coastal waters (10-20 and 20-30 m deep) had higher levels of pH and chlorophyll a and lower levels of salinity, electrical conductivity and temperature. The opposite was the case at depths of more than 50 meters. The average values of environmental factors were estimated at depths of 30 to 50 m in this year too; In other expression, in the autumn of 2016, moving close to the seabed, from shallow coastal waters to deep waters of the Persian Gulf, chlorophyll a content and pH of the water have been decreased and water salinity, electrical conductivity and temperature have been increased.

It can be estimated that species whose name codes are at the left side and closer to Dep1 and Dep2 centroids or their related substrata were most commonly found at depths of 10 to 30 m. An orange line is drawn around the name codes of these species; *Eleutheronema tetradactylum* (Et), *Lagocephalus lunaris* (Llu), *Brachirus orientalis* (Bo), *Ephippus orbis* (Eo), *Lutjanus johnii* (Lj), *Protonibea diacanthus* (Pdi), *Pomadasys stridens* (Pst), *Cynoglossus arel* (Cal), *Aetobatus flagellum* (Afl), [[*Atropus atropos* (Aat), *Pastinachus sephen* (Pse), *Plicofollis layardi* (Pl), *Pseudorhombus arsius* (Pau), *Netuma thalassina* (Nt), *Alectis indica* (Ain), *Pterois russelii* (Pru)]], [[*Atule mate* (At.m), *Rhinoptera javanica* (Rj), *Lethrinus lentjan* (Lln), *Acanthopagrus arabicus* (Aar), *Terapon jarbua* (Tj)]], *Carangoides bajad* (Cb), *Torpedo sinuspersici* (Tsi), *Gerres infasciatus* (Gf), [[*Lethrinus nebulosus* (Ln), *Lutjanus lutjanus* (Llj)]], *Aetomylaeus milvus* (Ae.m), [[*Selaroides leptolepis* (Slp), *Carcharhinus sorrah* (Cso), *Grammatobothus polyophthalmus* (Gr.p)]], [[*Pseudotriacanthus strigilifer* (Psg), *Lagocephalus suezensis* (Lsz)]] and *Arothron stellatus* (Ar.s) can be listed into this group.

Species whose name codes are closer to the Dep3 centroid and A3 to D3 substrata than to the other depth strata or substrata were probably more abundant in the depths of 30 to 50 m in autumn 2016; Among these species, determined by a dark gray closed line, can mention *Carangoides hedlandensis* (Chd), *Lactarius lactarius* (Lla), *Eupleurogrammus muticus* (Em), *Terapon theraps* (Tt), *Pampus argenteus* (Par), *Ostorhinchus fasciatus* (Of), *Pennahia anea* (Pan), *Echeneis naucrates* (En), *Rhynchobatus djiddensis* (Rd), *Parastromateus niger* (Pn), *Plicofollis dussumieri* (Pdu), *Carcharhinus dussumieri* (Cd), *Trichiurus lepturus* (Tl), *Leiognathus oblongus* (Lob), *Rhizoprionodon oligolinx* (Ro), *Ulua mentalis* (Um), *Ilisha melastoma* (Im), *Pomadasys kaakan* (Pk), *Maculabatis randalli* (Mr), *Hemipristis elongata* (He), *Gymnura poecilura* (Gy.p), *Photopectoralis bindus* (Pb), *Psettodes erumei* (Per), *Netuma bilineata* (Nb), *Rachycentron canadum* (Rc), *Rhinobatos punctifer* (Rp), *Lagocephalus inermis* (La.i), *Rhizoprionodon acutus* (Rac), *Epinephelus bleekeri* (Ep.b), *Diagramma pictum* (Dpi), *Himantura uarnak* (Hu), *Acanthopagrus bifasciatus* (Ab) and *Carangoides armatus* (Car).

Species situated at the right side and nearer to the Dep4 centroid and A4 to D4 subdivisions are expected to be more abundant in waters deeper than 50 m, in 2016; a surrounding cyan line distinguishes these species on the CCA diagram. This group includes *Johnius belangerii* (Jbe), *Trypauchen vagina* (Tv), *Uraspis helvola* (Uh), *Secutor insidiator* (Si), *Rhina ancylostoma* (Ran), *Priacanthus hamrur* (Pha), *Scorpaenopsis lactomaculata* (Sla), *Aluterus monoceros* (Al.m), *Acropoma japonicum* (Aj), *Carangoides talamparoides* (Ct), *Selar crumenophthalmus* (Sc), *Choerodon robustus* (Cr), [[*Epinephelus diacanthus* (Ed), *Ariomma indicum* (Aim)]], *Epinephelus epistictus* (Ee), *Lepidotrigla bispinosa* (Lbi), *Epinephelus areolatus* (Ea), *Uranoscopus guttatus* (Ug), *Nemipterus randalli* (Nr), *Cephalopsetta ventrocellatus* (Cv), *Chaenogaleus macrostoma* (Cmt), *Lepidotrigla spiloptera* (Lsp) and *Mustelus mosis* (Mmo).

## Discussion

Total number of sampled demersal fish species within the studied area decreased from 165 in the year 2014 to 145 in 2016. This reduction has not been limited only to the species richness, but also was observed in the richness of families and genera of both bony fishes and sharks; Batoid fishes group showed increased species, genus and family richness as an exception.

In comparison to the report by Niamaimandi *et al*. (2018) in which 91 demersal fish species recorded in January–March 2013 across the northern Persian Gulf, the results of the present study was indicated an increase in the species richness of demersal fishes in 2014 and 2016. This contradicts the general accepted principle "the larger the sampling area, the more species richness" (Connor and McCoy, 1979, Coleman *et al*., 1982, Rosenzweig, 1995) and makes it difficult to explain the reason for increasing species richness of demersal fishes since winter 2013 toward autumn 2014. Sampling in the present study was focused on the northeastern area of the Persian Gulf while Niamaimandi *et al*. (2018) had studied a much wider area. They Aslo accounted for all marine organisms caught by trawl net, while in the present study only bottom dwelling fishes were examined; this makes the explanation of the cause or causes of increased species richness more complicated too. In fact, they have counted and summed species together with higher taxa as species groups (genus, family, order); this has caused underestimation of species richness and can be the main reason for lower fish species richness in 2013. The depth range in the study of them covered 10 to 50 m but in the present study extended from 10 m depth contour to midline of the Persian Gulf. Species that occurred only in depths more than 50 m increased species richness in this study too. Eight and 12 fish species have found only at depths more than 50 m in years 2014 and 2016, respectively.

Despite decrease in species richness and Shannon diversity index, Pielou's evenness and Gini–Simpson diversity (evenness) index did not show significant difference between the years and total density increased after two years. The results also showed that the assemblage structure of bottom-associated fishes was significantly different between two years. Therefore, we can conclude that different community structures are due to a decrease in the species richness and an increase in FPUA. It should be noted, however, that in addition to species richness, species composition has been changed somewhat during two years, so that 35 species (21%) were observed in 2014 which were not identified in 2016, and 15 species (10%) sampled in 2016 were not seen in 2014.

The abundance of demersal fishes did not show a significant difference between depth strata but was significantly higher in stratum A than other geographic strata. Species richness was significantly different between both geographic and depth strata. Demersal fish species richness in depth stratum 4 (>50m) specifically was lower than depth strata 1 and 2 (depths between 10 to 30 m). Depth stratum 3 (30 to 50m) had a moderate state. Reduced fish species richness with increasing depth has been reported by others as well (Fariña *et al*., 1997, Moranta *et al*., 1998, Labropoulou and Papaconstantinou, 2004).

The results of this study showed that the assemblage structure of bottom-associated fishes was significantly different between two years and among four geographic strata with a significant interaction between years and strata. Likewise, the assemblage structure of fishes was significantly different between the four depth strata but no significant interaction between years and depth strata was shown. These results suggested that the assemblage structure of demersal fishes have been changed over two years, but fluctuations in different depth strata have been nearly constant while changes in four geographic strata were not similar. Non-metric MDS plot and results of ANOSIM tests for both years depicted that the assemblage structures in neighboring strata were not significantly different; but, non-adjacent strata differed significantly. Results of these analyses demonstrated that the assemblage structure of demersal fishes in depth stratum 4 was significantly different from those in other depth strata. Based on pooled data of both years, average species number and Margalef's species richness per sampling were significantly lower in depth stratum 4 than depth strata 1 and 2. Depth stratum 3 did not differ significantly from other depth strata. These results were partially consistent with those reported by Niamaimandi *et al*. (2018) in which the highest species number was detected at 20-30 m (91 out of 97 species), followed by 30-50 m (88 species) and 10-20 m (84 species) depth strata recorded in January–March 2013 across the northern Persian Gulf. In other word the highest demersal fish species richness in the northern Persian Gulf can be found at depth stratum 2 (20-30 m) and the lowest at depth stratum 4 (over 50 m).

Comparing the environmental condition of seawater between two years, four geographic and four depth strata indicated just a significant difference between the depth strata. Accordingly, no significant differences between two years and four geographic strata, and no interaction between years and depth strata, or between years and geographic strata were detected. These results affirm that the environmental condition of near bottom water in the studied area was relatively homogenous both between two studied years and across four geographic strata, but heterogeneous between depth strata. Different assemblage structures of demersal fishes in the depth strata were consistent with their heterogeneous environmental conditions so it can be concluded that physical factors of seawater have affected assemblage structures of demersal fishes depending on their optimum living depth. Difference in assemblage structures of demersal fishes between studied years and across strata were not related to physical factors of environment.

CCA results at both years of study indicate that the environmental conditions of the 10–20 and 20–30 m depth strata are very similar. Accordingly, three structures may be predictable for Hormozgan (and possibly the rest of the Persian Gulf) bottom dwelling fish communities; One structure at depths of 10 to 30 m, the other at depths of 30 to 50 m and a third one at depths more than 50 m.

A total of 47 and 33 demersal fish species were observed in 2014 and 2016 respectively, more frequently at depths of 10 to 30 meters than other depth strata, among them *Acanthopagrus arabicus*, *Brachirus orientalis*, *Carangoides bajad*, *Lutjanus lutjanus*, *Lethrinus lentjan*, *Protonibea diacanthus*, *Pseudotriacanthus strigilifer*, *Rhinoptera javanica* and *Selaroides leptolepis* have been more dependent on this depth stratum in both years. Similarly, the highest abundance of 38 fish species in 2014 and 33 species in 2016 were obtained at 30 to 50 m depth stratum, among them *Echeneis naucrates*, *Gymnura poecilura*, *Leiognathus oblongus*, *Maculabatis randalli*, *Netuma bilineata*, *Photopectoralis bindus*, *Plicofollis dussumieri*, *Pomadasys kaakan*, *Rhizoprionodon acutus*, *Terapon theraps*, and *Ulua mentalis* have been more dependent on these depths in both years. Likewise, 27 and 23 fish species had their highest density at depths more than 50 m in 2014 and 2016 respectively, among them *Ariomma indicum*, *Acropoma japonicum*, *Cephalopsetta ventrocellatus*, *Epinephelus diacanthus*, *Epinephelus epistictus*, *Johnius belangerii*, *Lepidotrigla bispinosa*, *Lepidotrigla spiloptera*, *Mustelus mosis*, *Nemipterus randalli* and *Uranoscopus guttatus* have been more related to these depths in both years.

Labropoulou and Papaconstantinou (2004) identified four depth associated structures for demersal fish communities in the Northern Aegean and Thracian seas based on cluster analysis and MDS ordination of sampling stations. These four structures were identified at depth strata<30 m, 30 to 100 m, 100 to 200 m and 200 to 500 m. The first two depth strata correspond to the four depth strata in the present study; Fish community structures in depths less than 30 m are separable from the other structures in both studies, but there identified only one single structure at 30 to 100 m in the Northern Aegean Sea while two structures can be distinguished in the same depth stratum in the Persian Gulf. Another difference is that the specimens of the four depth associated Aegean fish structures are completely separated in the cluster and MDS diagrams, but there is no complete distinction between specimens (substrata) belonging to the four depth strata in the Persian Gulf.

Commercial fishes in the Northern Aegean Sea were predominated in shallow-water (less than 30 m), whereas almost all deep-water fishes (below 200 m) were non-commercial. Almost half of the demersal fish species at intermediate depths (30 to 200 m) were commercial (Labropoulou and Papaconstantinou, 2004). In the Persian Gulf, both commercial and non-commercial fish species were observed in all three depth strata (and in both years). The highest commercial species ratio (55-60 percent) was related to 30 – 50 m and the lowest ratio (41-48 percent) to>0 m depth strata in both years.

Labropoulou and Papaconstantinou (2004) also found that 46 species had the highest contribution to the formation of the four fish community structures, of which 24 species participated in only one structure, one species in all four structures, and the rest species in two or three structures. They concluded that the dominant species were widely dispersed and that the structure differences were more quantitative rather than qualitative. The same seems true in the Persian Gulf too, where the three identified structures have many species in common, but the abundance of some species is more pronounced in a specific depth stratum and indicates some relative ecological preference.

Although, in the present study, water temperature, EC, salinity and pH were the most influencing environmental factors on assemblage structure of demersal and benthic fishes in both years, changing these variables and fish assemblage structure at different depths, as shown in CCA diagrams too, means that environmental factors have been affected primarily by depth. These results have partially mirrored the findings of previous studies. Mueter and Norcross (1999) reported that the depth - temperature gradient was the most effective factor on the composition of small demersal fish species around Kodiak Island in Alaska. In a study by Araújo *et al*. (2002), depth, followed by transparency and salinity, and, to a lesser extent, temperature were the factors influencing demersal fish assemblages in the Sepetiba Bay, Brazil.

The effects of climate change and fisheries on fish have been investigated by Genner *et al*. (2009). This long - term study was carried out using the English Channel data from 1911 to 2007. Their study was focused on 30 species that accounted for more than 99 % of the total fish abundance. They concluded that the rapid change of small species is a rapid response to climate change and a decrease in the abundance and size of larger species indicated over-exploitation.

Building on a 2-year study, we may not be able to provide a definitive idea about the impacts of climate or fishing on changes in the assemblage structure of fishes. However, the lack of significant differences between environmental conditions in 2014 and 2016 may imply that the changes in fish species composition and abundance during these years are either not caused by climate change or are the result of changes in many previous years. If observed temporal changes in fish assemblage structures were related to increase fishing effort, indicates that the fishing effort is higher than optimum level for a sustainable fishery.

Species richness of demersal fishes in northeastern of the Persian Gulf has been decreasing. Three bathymetrical assemblage structures for bottom-associated fishes could be distinguished in the studied area; one assemblage in depths 10 to 30m, another in depths more than 50m and the third one between these two. Unlike assemblage structures of demersal fishes that changed over the time (2014 until 2016), no significant variation was detected in environmental conditions during the study period. Both distribution pattern of environmental conditions and assemblage structure of demersal fishes significantly differed between depth strata. A few fish species showed the same tendency to each depth stratum in both years.

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