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Species composition and distribution of Alcyonacea (Octocorallia) in the northern Persian Gulf

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Original Article

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Abstract

Studies concerning octocoral species from the Persian Gulf coral reefs are few. This study documents the diversity and abundance of octocoral communities from three islands in the north Persian Gulf, namely, Larak Island, Hengam Island and Qeshm Island. Belt transects were used to survey the octocoral communities at these islands. We used a rapid ecological assessment technique (REA) to assess the status and abundance of octocorals. Also, K Independent sample analysis was conducted on abundance and Shannon Diversity index data to determine if octocoral abundance and species diversity varied between islands. A total of 22 morphospecies, belonging to seven alcyonacean families, including Plexauridae, Ellisellidae, Alcyoniidae, Nephtheidae, Briareidae, Acanthogorgiidae and Subergorgiidae, were identified in this study. Statistical analysis indicated octocoral abundance and diversity at Larak Island reefs were higher than those around Hengam and Qeshm islands. The primary data presented in this study could serve as the baseline data for long-term biomonitoring programmes to estimate the status of octocorals in the Persian Gulf.

Introduction

Climate change is an important environmental, economic and social issue of our time and these changes are happening fast (IPCC, 2007; Hoegh-Guldberg, 2011). The rate of change is 2–3 times faster than the rapid changes between glacial and interglacial periods observed over the last 740,000 years (Augustin *et al.*, 2004; Hansson *et al.*, 2006), and there is a lot of evidence to suggest that biological systems around the globe are changing (Walther *et al.*, 2002). One of these systems is coral reef ecosystems, which play a particularly important role in our understanding of how Earth's ecosystems respond to rapid climate change. They are seriously threatened by current and future changes in the temperature and acidity of the oceans and other factors, and are a good indicator to observe the state of climate change (Hoegh-Guldberg, 2011). Therefore, the study of coral ecosystems in a specific region such as the Persian Gulf, which is an important natural laboratory, can provide valuable information for planning to protect them in the future.

In general, the Persian Gulf is a very special region for coral reefs. Because it is home to some of the northernmost coral reefs in the western Indian Ocean and is the warmest sea in the world in summer while in winter it is among the coldest with abundant coral growth, this is especially important for scientists in a world that is subject to climate change (Riegl & Purkis, 2012). The Persian Gulf today is characterized by a thermal regime comparable to that predicted for other tropical oceans in the years 2090–2099 (IPCC, 2007; Riegl & Purkis, 2012). Riegl & Purkis (2012) reported that the Persian Gulf coral reef organisms have adapted to this climate regime for more than 6000 years and that many of the world's most crucial ocean lessons can be learned from study of this system. So, the Iranian reefs in the Persian Gulf are attracting international scientific attention due to their development and persistence in such extreme environmental conditions (Coles & Fadlallah, 1991).

The Persian Gulf is a shallow and semi-enclosed sea located in the tropics of the Indo-Pacific and connected to the Indian Ocean by a narrow waterway called the Strait of Hormuz. There is limited water exchange through this crater of the Persian Gulf (Pous *et al.*, 2004) with high salinity, high seasonal fluctuations in sea surface water temperature (14–34°C) (Riegl & Purkis, 2012), and very low tides generally leading to extreme conditions in the Persian Gulf (Coles & Fadlallah, 1991; Sheppard & Sheppard, 1991; Koupaei *et al.*, 2016). These factors have significant effects on coral reefs, which are one of the most varied and economically valuable ecosystems on the planet, and are mainly found on islands in the northern parts of the Persian Gulf (Rezai *et al.*, 2010; Koupaei *et al.*, 2016). Iran has 17 islands with fringing reefs in the Persian Gulf (Sheppard & Sheppard, 1991). Among them, Hengam, Larak, Qeshm and Hormuz islands are located in the Strait of Hormuz and are affected by oceanic waters with lower salinity and high nutrient levels originating from the Oman Sea, especially during the monsoon upwelling in summer. As a result, the reefs around

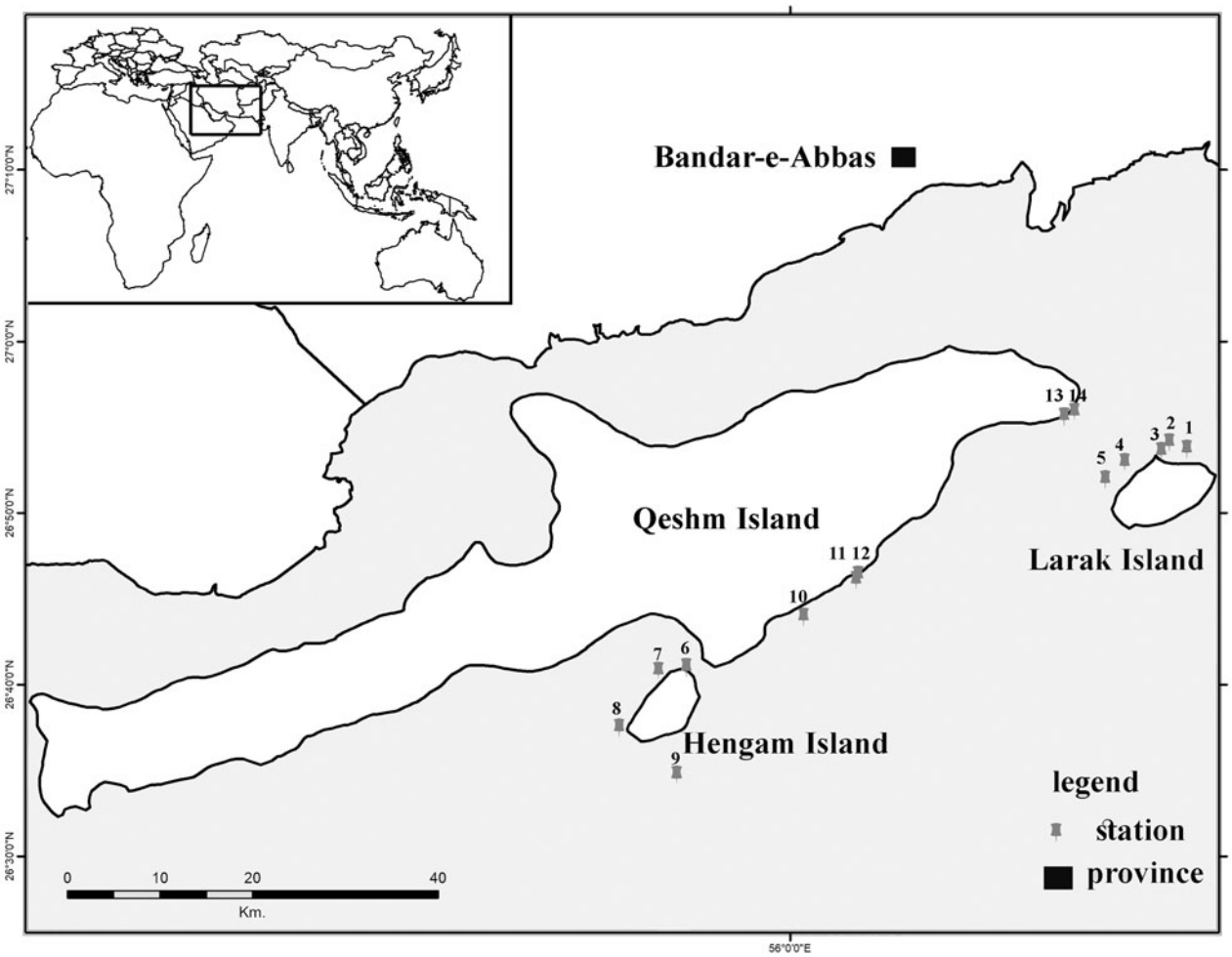

Fig. 1. Map showing the location of the islands and the sampling stations (1–14) in the northern Persian Gulf (Iran).

these islands have a relatively great variety and richness of species, so these areas are different from the interior of the Persian Gulf (Bauman *et al.*, 2013).

Octocorallia is a unique group with a substantial presence in benthic communities, which is significant due to their beauty, diversity, abundance and associations with other organisms (Williams & Cairns, 2013; Pérez *et al.*, 2016). Octocorals are distributed in all marine environments and are common on almost all coral reefs, but are generally most common on shallow tropical reefs and in deep sea habitats (Pérez *et al.*, 2016). However, despite their commonness, relatively little has been published on the distribution and ecology of most octocorals. In many cases, identification is done only from sclerites (microscopic skeletal elements) prepared from preserved specimens, and as a result of variation in the appearance of sclerites within species and even in colonies, they are difficult to identify (Bayer, 1961; Lasker & Coffroth, 1983). The rarity of environmental studies of octocorals in the Persian Gulf may be due to the difficulty of identifying species in this area, which makes many researchers not interested in studying them.

To date, most studies of the biodiversity of coral reefs on the Iranian shores of the Persian Gulf have been related to the order Scleractinia (Rezai & Savari, 2004; Rezai *et al.*, 2010; Samiei *et al.*, 2013; Salimi *et al.*, 2018) and other hexacorals (Koupaei *et al.*, 2014, 2016; Darvishi *et al.*, 2018). However, there have been a few studies on order Alcyonaria (Samimi-Namin & van Ofwegen, 2009; Shahbazi *et al.*, 2019) that address their taxonomy. More than 19 genera in nine families of Octocorallia (Samimi-Namin & van Ofwegen, 2009, 2012) have been described from the Persian Gulf to date. However, there are few data on the abundance and distribution of octocorals in the Persian Gulf.

The aim of this study was to investigate the distribution, abundance and diversity of octocorals in the three islands of Larak, Hengam and Qeshm in the northern part of the Persian Gulf. Therefore, a list of species and their distribution is provided.

Materials and methods

Study area

Octocoral surveys were conducted at coral reefs located at three northern islands of the Persian Gulf, namely Qeshm, Larak and Hengam Islands, during 2018–2019. These islands were selected based on previous reports (Samimi-Namin & van Ofwegen, 2009, 2012) of the occurrence of octocorals at these reef systems. The sampling sites were determined according to visual habitat characteristics such as occurrence of hard or sandy substrate and water quality. A total of 14 stations were surveyed using scuba (from 1–30 m depth), with five stations at Larak Island, four stations at Hengam Island and five stations at Qeshm Island (Figure 1 and Table 1).

Octocorals survey

Data on octocorals were collected by using visual census methods in combination with belt transects (BT) (English *et al.*, 1994; Seah *et al.*, 2015). A 200 m belt transect was applied at 14 stations

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Table 1. Coordinates of octocoral sampling stations in the north of the Persian Gulf

Station No.	Location	Coordinates	
		Latitude °N	Longitude °E
1	LI	26.889036	56.384958
2	LI	26.890524	56.372706
3	LI	26.889706	56.358587
4	LI	26.875515	56.326675
5	LI	26.862934	56.314206
6	HI	26.681690	55.897750
7	HI	26.678060	55.872835
8	HI	26.622695	55.836297
9	HI	26.576450	55.892576
10	QI	26.768035	56.059963
11	QI	26.772803	56.065317
12	QI	26.731371	56.012752
13	QI	26.925968	56.266032
14	QI	26.930875	56.275468

LI, Larak Island; HI, Hengam Island; QI, Qeshm Island.

(three transects per station), in which observations of octocorals were made within an area 2 m to the left and right sides of the transect. If possible, all octocorals observed in the area were photographed *in situ*, counted and some specimens were collected for further identification and molecular study (Shahbazi *et al.*, 2021). Specimens of *Viminella* sp., *Verrucella* cf. *reticulata* (Thomson & Simpson, 1909), *Acanthogorgia* sp., *Echinomuricea* sp. d and *Euplexaura* sp. c were collected by a local fisherman (with gillnet) at Hengam Island from 60–70 m depth.

We used a rapid ecological assessment technique (REA) to assess the status of abundance of octocorals (Fabricius & De'ath, 2001; Fabricius *et al.*, 2007). Relative abundances of species were visually estimated on the following rating scale for each island: 0 = absent; 1 = one or few colonies; 2 = uncommon; 3 = common; 4 = abundant; and 5 = dominant (Fabricius & De'ath, 2001).

Octocoral identification

The specimens were identified using morphological characteristics of the colony and sclerites. The overall structure of the colonies was examined by stereomicroscope. To extract the sclerites for identification, first a small piece of tissue from the collected samples was dissolved in 10% sodium hypochlorite (Fabricius & Alderslade, 2001). Extracted sclerites were viewed under a light microscope at magnifications of 100×. Dimensions of sclerites were measured and they were photographed with Dino Capture. The latest related references were used to identify the species (Bayer & Grasshoff, 1994; Grasshoff, 2000; Fabricius & Alderslade, 2001; Kumar *et al.*, 2014; Williams & Chen, 2011). The identified species of octocorals were compared with previously published studies from the Persian Gulf such as Samimi-Namin & van Ofwegen (2009, 2012). The specimens, preserved in 75% ethanol, were deposited temporarily in the Khoramshahr University of Marine Science and Technology (KMSU); they will be transferred to the Museum of the University of Tehran following the completion of ongoing taxonomic studies.

Statistical analysis

The abundance of octocoral species encountered during each transect was calculated for each island. Octocoral diversity for each island surveyed was represented by the Shannon–Wiener index of diversity (Hutcheson, 1970). This index of diversity was computed for each island based on species richness and abundance (number of colonies) of octocoral species.

K Independent sample analysis was conducted on the abundance and Shannon Diversity index data to determine if octocoral abundance and species diversity varied between islands. The Kruskal–Wallis test was used to further determine significant differences between islands in terms of species diversity and abundance. Analysis of data was conducted using SPSS 19 (IBM SPSS Statistics 19, released 2010). Excel 2011 (Microsoft Office 2011) was used to draw the charts.

Octocoral community composition at the three islands was assessed using the PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software package (Clarke & Green, 1988; Clarke, 1993). Bray–Curtis similarity matrices were used for this purpose. The Bray–Curtis similarity results were illustrated using hierarchical clustering with group-average linkage and a non-parametric multi-dimensional scaling (nMDS) ordination plot. Then, one way analysis of similarity (ANOSIM) was used to test for dissimilarity among the octocoral communities at the islands. In cases where the pairwise R value determined for the survey islands was greater than the Global R, it indicated significant dissimilarity in community structure between the islands ($P < 0.02$).

Results

Octocoral identification

The result of species identification indicates that there are 22 species of octocorals present at the three islands (Table 2). All of the 22 species of the subclass Octocorallia belonged to the order Alcyonacea (soft corals and sea fans). In the Alcyonacea, members of four of the six informal subordinal groups were found, representing seven families and 14 genera (Table 2). The four subordinal groups comprised three genera of Alcyoniina, two Scleraxonia, six Holaxonia and three Calcaxonia. Fifteen taxa were identified to the genus level and only seven taxa to the species level (Table 2). Family Plexauridae was represented by 12 species, followed by Ellisellidae (three species); Alcyoniidae (two species); Nephtheidae (two species); Briareidae (one species); Acanthogorgiidae (one species); and Subergorgiidae (one species).

Abundance and diversity of octocorals

In Larak Island, 17 species of 11 genera were observed, of which the genus *Menella* (four species) and then *Echinogorgia* (three species) were the most diverse. Other genera were of low diversity and only one species was observed from each except genus *Dendronephthya* which had two species. An examination of the abundance of octocorals at Larak Island revealed that *Juncella juncea* (Ellisellidae) (Figure 2E) is dominant. *Sinularia erecta* (Figure 2C) (Alcyoniidae) and *Subergorgia suberosa* (Subergorgiidae) were both abundant; *Dendronephthya* sp. b (Figure 2D) (Nephtheidae), *Menella* sp. g (Figure 2I), *Echinogorgia* sp. b (Figure 2H), *Echinogorgia* sp. c and *Astrogorgia fruticosa* (Figure 2G) (Plexauridae) species were common; *Dendronephthya* sp. a (Nephtheidae), *Briareum hamrum* (Briareidae), *Menella* sp. d, *Menella* sp. e and *Echinogorgia* sp. a (Figure 2B) (Plexauridae) were uncommon species; while other species that were present were all rare (Table 2).

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Table 2. Octocorals species composition at three islands in the northern Persian Gulf

Taxa	Abundance			Depth (m)
	LI	HI	QI	
Alcyoniidae				
Sarcophyton minusculum Samimi Namin & van Ofwegen, 2009	1	0	0	10–20
Sinularia erecta Tixier-Durivault, 1945	4	2	1	1–8
Acanthogorgiidae				
Acanthogorgia sp.	0	1	0	60–70
Briareidae				
Briareum hamrum (Gohar, 1948)	2	1	0	12–20
Ellisellidae				
Junceella juncea (Pallas, 1766)	5	4	3	5–25
Verrucella cf. *reticulata* (Thomson & Simpson, 1909)	0	1	0	60–70
Viminella sp.	0	1	0	60–70
Nephtheidae				
Dendronephthya sp. a	2	2	1	12–25
Dendronephthya sp. b	3	0	1	30
Plexauridae				
Astrogorgia fruticosa Samimi-Namin & van Ofwegen, 2009	3	3	0	25–30
Echinogorgia sp. a	2	0	0	20
Echinogorgia sp. b	3	2	1	5–12
Echinogorgia sp. c	3	2	0	12–25
Echinomuricea sp. c	1	0	0	20
Echinomuricea sp. d	0	1	0	60–70
Euplexaura sp. c	0	1	0	60–70
Euplexaura sp. d	1	0	0	30
Menella sp. d	2	0	0	15–25
Menella sp. e	2	0	0	20–25
Menella sp. f	2	0	0	8–15
Menella sp. g	3	0	2	8–15
Subergorgiidae				
Subergorgia suberosa (Pallas, 1766)	4	0	2	8–15

LI, Larak Island; HI, Hengam Island; QI, Qeshm Island.
Abundance according to REA (Fabricius & De'ath, 2001). Morphospecies designations follow Samimi-Namin & Ofwegen (2009, 2012) and Shahbazi *et al.* (2021).

In the waters of Hengam Island, 12 species of 11 genera were observed (five of which were collected by local fishermen). The genus *Echinogorgia* was the most diverse with two species, and the other genera each had one species. An examination of the abundance of octocorals at this island revealed that *J. juncea* is abundant; *Echinogorgia* sp. c and *A. fruticosa* were both common; *S. erecta* and *Dendronephthya* sp. a were uncommon; while two species, *B. hamrum* and *Echinogorgia* sp. b, were rare (Table 2).

At Hengam Island five species, i.e. *Viminella* sp., *V. reticulata* (Figure 2F) (Ellisellidae), *Echinomuricea* sp. d, *Euplexaura* sp. c (Plexauridae) and *Acanthogorgia* sp. (Acanthogorgiidae), were collected by local fishermen from a depth of ~60–70 m with gill-net. Therefore, since they were collected in a way other than the transect belt and only one colony of each species has been observed, we do not know their abundance status in deep water.

Qeshm Island had the least diversity among these three islands with seven species from six genera. *Dendronephthya* (Nephtheidae) with two species was more diverse than the other genera, each of which had one species. The survey of the abundance of octocorals in this island determined that *J. juncea* (Ellisellidae) was common, *S. suberosa* (Subergorgiidae) and *Menella* sp. g (Plexauridae) were both uncommon, while other species and genera that were present were all rare (Table 2).

Relative abundance was measured as the percentage of each species with respect to the total number of specimens (Figure 3).

Fourteen stations were surveyed for octocorals. Three stations had no octocorals present (stations 7, 13 and 14). Twenty-two species were recorded from the 11 stations where octocorals were present. The results of octocoral abundance showed that among the studied islands, Larak Island had the highest abundance of octocorals, followed by Hengam and Qeshm islands (Figure 4). K Independent sample analysis of abundance and diversity data indicated significant differences between the three islands. The Kruskal–Wallis test indicated that octocoral abundance at stations 4 and 5 at Larak Island were significantly higher than other stations at Hengam Island and Qeshm Island at $P < 0.05$ (Figure 4). The Shannon Diversity index was also significantly higher at stations 4 and 5 at Larak Island than at the other stations (Figure 5).

nMDS analysis of octocoral communities

The 2D MDS plot indicated that Larak Island octocoral communities were distinct from those at Hengam Island and Qeshm Island (Figure 6). At Larak Island, the difference in community structure between stations 4 and 5 and other stations is clear (Figure 6). Additionally, the Analysis of Similarities (ANOSIM) test results indicated that there were significant dissimilarities in octocoral community structure between Larak Island and the two other islands (Hengam and Qeshm) ($P < 0.02$; Table 3). Also, ANOSIM results indicated that the octocoral community structures between Hengam Island and Qeshm Island were not significantly dissimilar ($P > 0.1$; Table 3).

Discussion

Overall, 22 distinct octocoral morpho-species were identified based on colony morphologies as well as comparison of sclerites (Table 2). Molecular analyses support the distinction of these morphotypes as different species (Shahbazi *et al.*, 2021). So far, no study has been done on the abundance, diversity and species composition of octocorals in the Persian Gulf, and this study surveyed them for the first time. Accordingly, due to the lack of previous studies, we do not have a comparison point. Almost half of the octocorals identified in the current study had been reported by Samimi-Namin & van Ofwegen (2012) from the Persian Gulf.

In general, Plexauridae had the highest diversity and abundance in the whole study area. This family of gorgonians is one of the richest in genera and species (Bayer, 1981; Lopez-Gonzalez, 2006), which are well represented in temperate and tropical waters (Grasshoff, 2000; Fabricius & Alderslade, 2001). Among the genera of this family, *Menella* was most diverse, which was observed in Larak and Qeshm Islands. Samimi-Namin & van Ofwegen (2009, 2012) reported this genus as one of the most common genera throughout the Persian Gulf. They reported species of this genus from the islands of Larak, Hengam, Farur, Kish and near the Strait of Hormuz, as well as from Kuwait. *Echinogorgia* is another of the most common genera in the Persian Gulf. We identified species of this genus from all three islands (Table 2). In previous studies, species of this genus have been reported from Farur and Qeshm Islands and near the Strait of Hormuz (Rezai, 1996; Samimi-Namin

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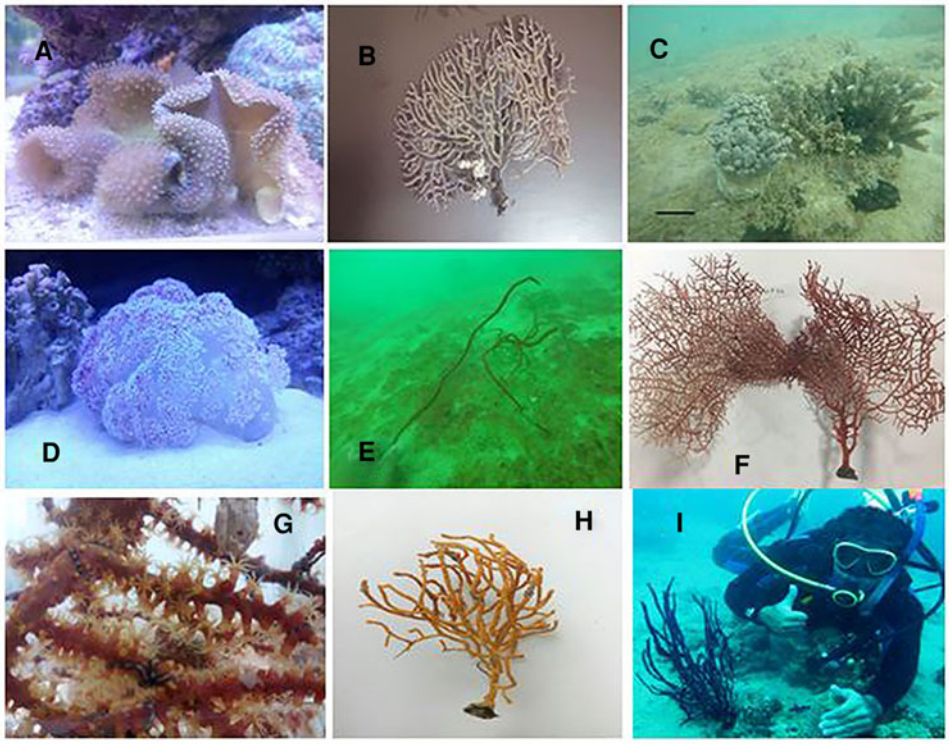

Fig. 2. Some species identified in this survey. (A) *Sarcophyton minusculum* Samimi-Namin and Ofwegen, 2009; (B) *Echinogorgia* sp. a; (C) *Sinularia erecta* Tixier-Durivault, 1945; (D) *Dendronephthya* sp. b; (E) *Junceella juncea* (Pallas, 1766); (F) *Verrucella* cf. *reticulata* (Thomson and Simpson, 1909); (G) close up of *Astrogorgia fruticosa* Samimi-Namin and Ofwegen, 2009; (H) *Echinogorgia* sp. b; (I) *Menella* sp. g.

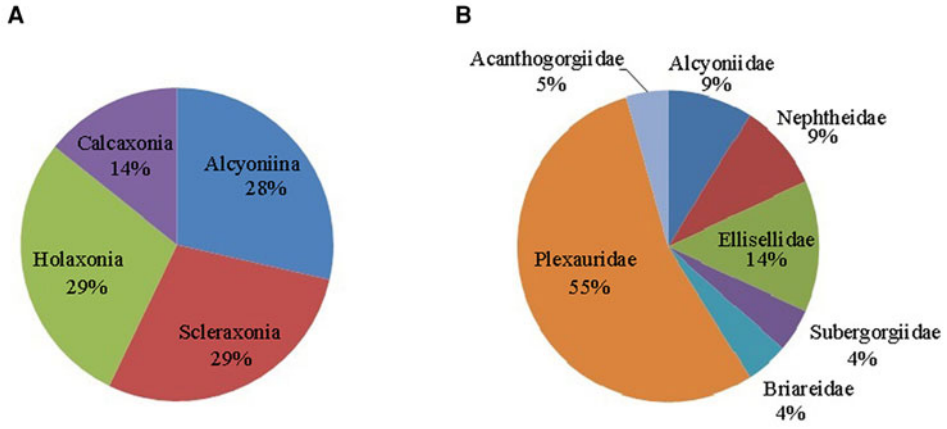

Fig. 3. Per cent composition of octocoral taxa comprising the 22 identified species in the survey. (A) percentages of genera in subordinal groups; (B) percentages of identified octocoral species within Alcyonacea families (rounded to the nearest percentage).

& van Ofwegen, 2009, 2012). Two species of *Euplexaura* were observed during this study, one in the waters of Larak Island and the other in Hengam Island. Samimi-Namin & van Ofwegen (2009, 2012) stated that this genus is one of the most common genera in the Persian Gulf. They reported some species of this genus from different parts of the Persian Gulf. So far, of the genus *Astrogorgia*, only *Astrogorgia fruticosa* Samimi-Namin & van Ofwegen, 2009 has been reported from the Persian Gulf. This species has only been reported from the waters around Hengam Island (Samimi-Namin & van Ofwegen, 2009, 2012), which is also the only location where we found it. *Echinomuricea* also seems to be a common genus in the Persian Gulf. We identified two species of this genus, one in the waters of Larak Island and the other in Hengam Island. Samimi-Namin & van Ofwegen (2009, 2012) reported two different species from those in this study, from Farur, Hengam, Kish and Kharku Islands and Kuwait.

The family Ellisellidae is widely distributed throughout the Indo-Pacific region, the eastern and western Atlantic Ocean, the Red Sea and the Mediterranean Sea (Grasshoff, 2000; Cairns, 2007; Fabricius & Alderslade, 2001; Bilewitch *et al.*, 2014). This family is smaller than some other octocoral families, and currently has 10 genera and about 110 species (Bayer & Grasshoff, 1994; Bilewitch *et al.*, 2014). We diagnosed three species of three genera in the Persian Gulf of which *Junceella juncea* was abundant at all three islands. According to Samimi-Namin & van Ofwegen (2012) this species is widely distributed in the Persian Gulf. The other two species belonging to this family are *Verrucella reticulata* and *Viminella* sp. that were collected only in waters between 60–70 m on Hengam Island by local fishermen. We find that these species are rare and are probably distributed in deeper waters of the Persian Gulf. Samimi-Namin & van Ofwegen (2009, 2012) stated that *V. reticulata* is rare throughout the Persian Gulf, and they only recorded this species from Qeshm Island. *Viminella* sp. previously was reported only from Hengam Island by Shahbazi *et al.* (2019).

Acanthogorgiidae and Subergorgiidae were two other families of gorgonians, each of which had one species observed throughout the study area. They are widely distributed in the Indo-Pacific region (Fabricius & Alderslade, 2001; Samimi-Namin & van Ofwegen, 2012). So far, only two genera including

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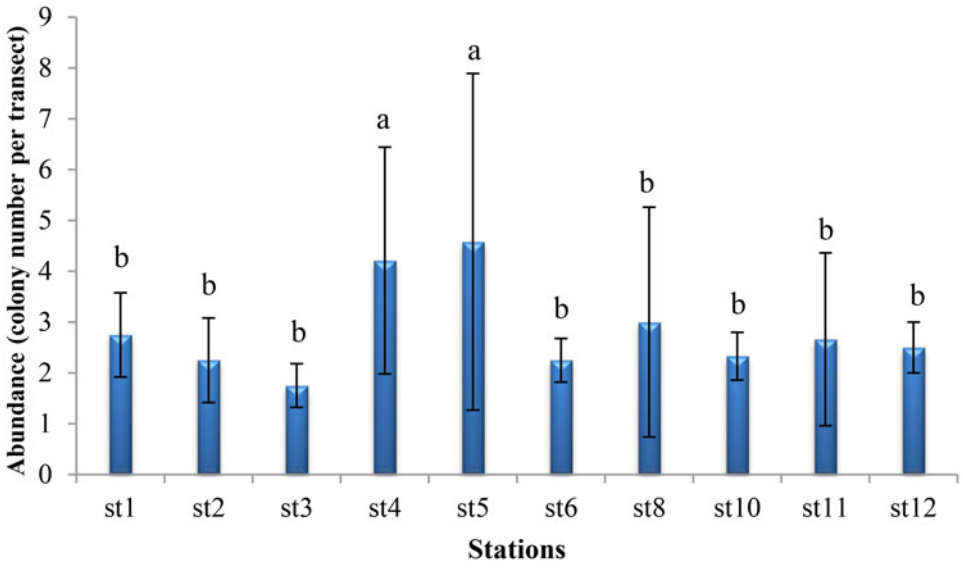

Fig. 4. Mean (± S.E.) abundance (colony number per belt transect) of octocorals at survey stations (n=3 transects per station). Different letters (a, b) indicate significant differences (P < 0.05). (No octocorals found at stations 7, 13 and 14).

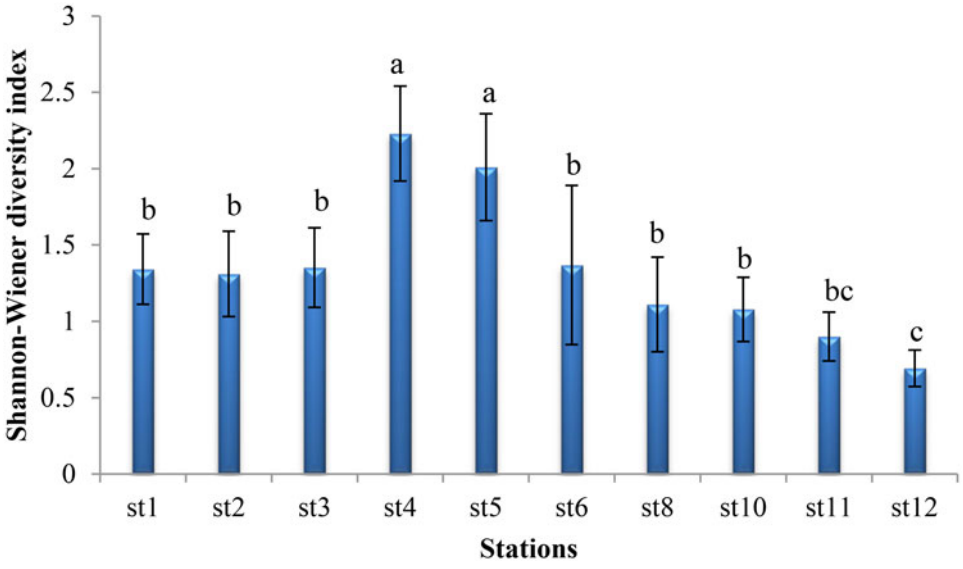

Fig. 5. Mean (± S.E.) Shannon-Wiener diversity index (colony number per belt transect) of octocorals at survey stations (n=3 transects per station). Different letters (a, b and c) indicate significant differences (P < 0.05). (No octocorals found at stations 7, 13 and 14.)

Acanthogorgia (*Acanthogorgia spinosa* Hiles, 1899, recorded from off Bahrain) and *Muricella* (*Muricella* sp., recorded from the south of Hengam Island) have been reported from the Persian Gulf that belonged to family Acanthogorgiidae (Samimi-Namin & van Ofwegen, 2009, 2012). Also, only one species of family Subergorgiidae has been reported from the Persian Gulf. This species is *S. suberosa*, which has been recorded from Qeshm, Farur and Lesser Tonb Islands. This species was first reported in the Persian Gulf by Rezai *et al.* (2004) from Lesser Tonb. Samimi-Namin & van Ofwegen (2009, 2012) stated that this is not a common species. We identified this species from Larak and Qeshm Islands, where it was an abundant species on Larak Island (Table 2).

Among the non-gorgonian octocorals, we observed the three families Alcyoniidae, Nephtheidae and Briareidae throughout the study area. Samimi-Namin & van Ofwegen (2012) reported these three families plus Clavulariidae. These families are widely distributed in the Indo-Pacific region (Fabricius & Alderslade, 2001). Alcyoniidae is represented by two genera, *Sarcophyton* and *Sinularia*, in the Persian Gulf. *Sarcophyton* was first reported by Rezai (1996) from Larak and Lesser Tonb islands as *Sarcophyton* sp. Samimi-Namin & van Ofwegen (2009) described and reported *Sarcophyton minusculum* (Figure 2A) from Larak Island. *Sarcophyton* has not been reported from any other part of the Persian Gulf. In the present study, *S. minusculum* was observed only in the waters of Larak Island. Fabricius & Alderslade (2001) stated that *Sarcophyton* is widespread from the Red Sea to Polynesia. *Sinularia* is also one of the most widespread and common genera of soft corals found in the coral reefs of the Indo-Pacific (McFadden *et al.*, 2009). They are widely distributed from Africa and the Red Sea to Hawaii (Fabricius & Alderslade, 2001). So far, this genus has two representatives (*Sinularia erecta* Tixier-Durivault, 1945 and *Sinularia polydactyla* (Ehrenberg, 1834)) in the Persian Gulf. Both species have previously been reported from the Larak, Hengam and Farur Islands (Samimi-Namin & van Ofwegen, 2009, 2012). In this study, we observed only *S. erecta* at Larak, Hengam and Qeshm, where it was more abundant at Larak Island than the other two islands.

According to previous studies, the family Nephtheidae has two genera, *Dendronephthya* and *Umbellulifera*, represented in the Persian Gulf. This family is widely distributed in the Indo-Pacific region and also extends from Africa to Micronesia and Polynesia (Samimi-Namin & van Ofwegen, 2012). Samimi-Namin & van Ofwegen (2009, 2012) reported two species, *Dendronephthya* sp. a (only from Hengam Island) and *Dendronephthya* sp. b, that they stated could be found in most

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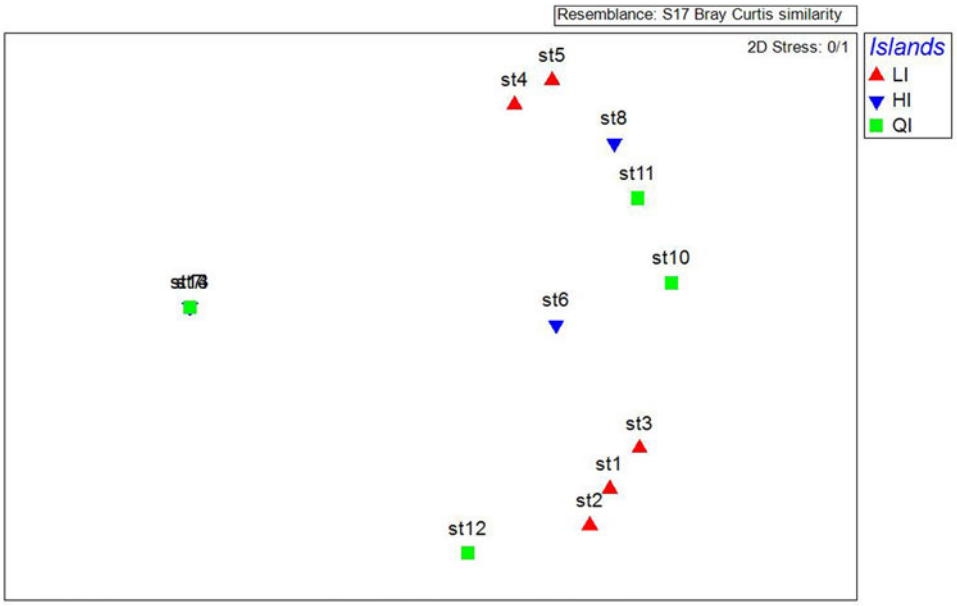

Fig. 6. Two-dimensional MDS configuration of octocoral communities at Larak Island (LI), Hengam Island (HI) and Qeshm Island (QI). A stress value of 0.1 gave a good representation of the data.

Table 3. R statistics derived from pairwise tests using ANOSIM to compare dissimilarities of octocoral communities among the three islands

	Hengam Island	Qeshm Island
Larak Island	0.453[a]	0.408[a]
Qeshm Island	0.264	–

[a]Values above the Global *R* (0.357) indicate significant dissimilarities between islands ($P < 0.02$).

of the Iranian Islands. We observed *Dendronephthya* sp. a in all three islands of Larak, Hengam and Qeshm, and *Dendronephthya* sp. b from the two islands of Larak and Hengam. Family Briareidae is widespread in the Indo-Pacific region (Fabricius & Alderslade, 2001). Only the species *Briareum hamrum* (Gohar, 1948) has been reported from the Persian Gulf. We have seen this species in the Larak and Hengam Islands. Samimi-Namin & van Ofwegen, 2012 recorded this species from Larak, Farur and Kish Islands and stated that it is most likely to occur in other Iranian Islands close to the Strait of Hormuz.

Octocorals encountered in this study comprised members of families widespread in the Indo-Pacific region (Fabricius & Alderslade, 2001; Samimi-Namin & van Ofwegen, 2012). In this study, gorgonians (17 species) clearly had a higher density and diversity than soft corals (five species). In previous studies, this is completely clear; Samimi-Namin & van Ofwegen (2012) reported eight soft corals and 20 gorgonians. This could be due to the climatic conditions of the Persian Gulf (Riegl & Purkis, 2012). Coles (2003) noted that the low abundance and diversity of corals in the Persian Gulf are likely due to harsh conditions such as wide range of temperature changes, high salinity, sedimentation and oil pollution. Therefore, it seems that gorgonians in the Persian Gulf have a higher ability to adapt to harsh climatic conditions than soft corals. Fabricius *et al.* (2007) state that the abundance and diversity of soft corals in the shallow waters of the Indo-Pacific region are strongly influenced by factors such as high water temperatures, storms with high wave energy, water pollution and sedimentation.

K Independent sample analyses suggested that two stations (4 and 5) at Larak Island had a significantly higher octocoral abundance and diversity compared with other stations at this island. Interestingly, in terms of community structure, Hengam and Qeshm Islands' octocoral communities were not significantly dissimilar (Figures 4 and 5). Also, based on nMDS analysis, Larak octocoral communities were significantly dissimilar from the two other islands (Figure 6). This is due to the presence of more soft corals (*Sinularia*, *Sarcophyton*, *Dendronephthya* and *Briareum*) at Larak Island. Also, the existence of two different octocoral communities at Larak Island is due to the fact that gorgonian species at stations 4 and 5 have a higher diversity and density than the other three stations, which include more soft corals. Given that all three islands are adjacent to each other near the Strait of Hormuz, probably localized environmental factors at these study islands may have influenced the octocoral diversity, abundance and community structures. Anthropogenic stresses could perhaps be one contributing factor for the observed differences, particularly in community structures. Field observations of the first author suggest excessive tourism in the coral beaches of Qeshm and Hengam Islands and also uncontrolled harvesting of octocorals for economic and commercial activities is one of the reasons for the decrease in the diversity and abundance of octocorals in these two islands. Rezai *et al.* (2010) state that due to the rapid expansion of tourism on Qeshm Island, many boats transport tourists to the coral reefs around Hengam Island for recreational activities such as diving. Serious damage to corals has been observed, mostly due to their theft by tourists as well as local people.

Another factor contributing to the observed differences could be the sharp rise in water temperature in recent years and the occurrence of bleaching. Bleaching would primarily affect zooxanthellate species and a few genera (ex: *Sarcophyton*, *Sinularia* and *Briareum*) of these have been reported from the Persian Gulf; this could be a reason for the fact that gorgonians seem to be dominant in the Persian Gulf whereas in places like the northern Red Sea soft corals are very abundant and gorgonians quite rare in shallow water (see Benayahu, 1985, 1990, 2002). Numerous researchers, (Fabricius & De'ath, 2001; Ricklefs, 2004; Fabricius *et al.*, 2007), have described the negative effects of bleaching on the frequency and diversity of octocorals in an area. The Persian Gulf has experienced bleaching at least three times in 1996, 1998 and 2002 (Rezai *et al.*, 2004). However, unpublished field reports indicate widespread bleaching in recent years. Mohammadizadeh *et al.* (2013) in a study of the coral reefs of Larak Island reported that the island's coral reefs are improving and are likely to be recovered in the coming years. Kavousi

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et al. (2011) in a study of the coral reef communities on Qeshm Island, reported that the island's coral status has not improved as a result of bleaching in recent years. Kavousi *et al.* (2014) reported an improvement in the coral ecosystem due to bleaching in the northern Persian Gulf. So, there is disagreement among authors about the health of coral reefs in the area. Sedimentation is another effective factor in reducing octocoral abundance and diversity. Fabricius *et al.* (2007) state that sedimentation is one of the causes of reduced octocoral diversity and abundance, which causes suffocation of colonies or inhibition of larval habitat. Kavousi *et al.* (2011) reported sedimentation in coral sites of Qeshm Island as a result of various factors such as human activities.

Conclusions

The present study investigated for the first time the diversity, abundance and species composition of octocorals in the three islands of Larak, Hengam and Qeshm in the Persian Gulf. The data obtained from this study can serve as a baseline for future studies of octocorals in this region. Also, due to various factors in the Persian Gulf, such as special climatic and ecological conditions and human activities, especially in Qeshm (the largest island in the Persian Gulf) and Hengam Islands, the information obtained from this study can help management, conservation and maintenance programmes of octocorals in this region.

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