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Biodiversity of Macrobenthos along the East Coast of the Chabahar Bay, the Gulf of Oman

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Abstract

The Chabahar Bay with an important role in the Iran's international trade contains unique and diverse biota. This study has assessed the biodiversity of macrobenthos along the east coast of the Chabahar Bay at two stations in June- July and October-November 2019. Sampling was carried out by a 0.1 m^2 grabber from the soft bottom at the depth of 0.1 m to 2 m. Moreover, the attached fauna was carefully removed from the rocky substrates by scraping. The samples were sieved through a 1-mm mesh size sieve and preserved in 70% alcohol, counted, and identified based on their valid identification keys. A total of 101 species belonging to Gastropoda, Bivalvia, Polyplacophora, Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea, Crustacea, Polychaeta, Anthozoa, Demospongiae, Hexactinellida was recorded in this study. These macrofauna species including 6 phyla, 13 classes, 34 orders, 56 families, and 73 genera. Moreover, Mollusca and Echinodermata were the highest, respectively, in terms of species number. On the other hand, Mollusca and Arthropoda were the highest, respectively, in terms of abundance. According to the results of the measured indices, which confirmed the high diversity of macrobenthos in the East Coast of the Chabahar Bay, it can be concluded that the study area has a high potential to preserve the environmental richness of benthic invertebrates.

Keywords: Macrobenthos; Chabahr Bay; Biodiversity; Shannon index.

1- Introduction

The interactions between biodiversity and ecosystem function in marine systems have attracted considerable attention for many years. Climate change and anthropogenic activities lead to biodiversity changes, which consequently threaten ecosystems, productivity, and services to humans. Understanding the potential link between the structural features of faunal communities and their functionality can be helpful in the assessment of these threats. The diversity of habitats and species varies.
geographically across environmental and ecological gradients, and the structures and
functions of ecosystems vary across local and global scales. Ecosystem metabolism is intimately linked to carbon and nitrogen fluxes from primary producers to consumers of higher trophic levels (Shen et al., 2019). This trophic transfer determines the productivity of ecosystems and depends on the structure and efficiency of the food webs (Sokołowski et al., 2012). Macrobenthic animals are defined as invertebrates living in or on sediments or
attached to hard substrates (Bhowmik and Mandal, 2020). They play many important roles in the aquatic community, including mineralization, promoting, and mixing of sediments, fluxing of oxygen into sediments, and cycling of organic matter (Bozorgchenani et al., 2018). Moreover, they are used as bioindicators for environmental monitoring programs (Pastorino et al., 2020). Benthic organisms constitute an important component and significantly influence the productivity of habitats and assist the recycling of nutrients, which subsequently promote primary productivity. Detailed and complete knowledge of the sea bottom fauna is not only important for the determination of productivity but also helpful for understanding the diversity of the habitat (Thilagavathi et al., 2013). The biodiversity and variations in the macrobenthos community are some of the most important indexes in environmental impact assessment studies that could be revealed the habitat health status (Borja et al., 2009; Van Hoey et al., 2010).
Coastal habitats are sensitive regions, due to their high diversity and the high importance of specific species. These regions include the most elaborated and the richest ecosystems and provide a place for feeding and reproduction. Natural stresses originating from wrong management by humans have brought this ecosystem under pressure and have decreased the ecological quality of this region (Collins et al., 2020). Benthic animals have the most diversity among marine species, and play a significant role in food cycles and other relations between animals. Therefore, any change of and damage to these organisms can affect many other animals (Lam-Gordillo et al., 2020). Therefore, the assessment of benthic communities is important in marine ecological research. These communities are very important links in the energy and food chain of the ecosystem, and marine ecologists always paid their attention to the identification of these species. On the other hand, regarding little information about macrobenthos in Iran's waters, it is necessary to assess this community in this area.
Despite high biodiversity in Chabahar Bay, studies assessing the biodiversity of this specific area are scarce. Only a few studies have been conducted to evaluate the structure and composition of macrobenthos populations (often Mollusca) in the intertidal zone of the Gulf of Oman (Moradmand and Sari, 2007; Kazemian et al., 2009; Sadeghi and Loghmani, 2010; Taheri et al., 2010; Shahdadi and Sari, 2011; Asghari et al., 2011; Ghasemi, et al., 2011; Amini Yekta et al., 2013; Momtazi and Zarei, 2020).
The purpose of this paper is to study and identify any invertebrate populations, biodiversity patterns and community structure of tidal zone of the eastern coasts of the Chabahar Bay These data can play an important role in the protection and management of this ecosystem.

2- Materials and Methods

2-1- Study Area

The Chabahar Bay with an area near 320 km^2 is the largest bay on the northeast of the Oman Gulf along with the Iranian province of Sistan and Baluchestan. The average depth of this bay is 6 m and the deepest area is approximately 20 m. No major rivers exist in its vicinity.

2-2- Sampling and Identification

Sampling was carried out at two stations in the eastern coasts of Chabahar Bay (25° 17' 51"N 60° 37' 50" E - 25° 24' 21"N 60° 36.5' 17" E) that differented in substrate structures, twice a year (June- July and October-November 2019) in the cold and hot season as a comparison of diversity indicators (Fig. 1). Van Veen grab was used to obtain the sample from the soft bottom at the depth of 0.1 m to 2 m. Moreover, the attached fauna was carefully removed from the rocky substrates by scraping. Sampling was carried out with three replications. Macrobenthic samples were sieved through a 1mm mesh size sieve and fixed in 70% alcohol. Then, samples were counted and identified based on their valid identification keys (Abbott and Dance, 1983; price, 1983; Sharabati, 1984; Sterrer and Schoepfer-Sterrer, 1986; Sterrer and Schoepfer-Sterrer, 1986; Jegadeesan and Ayyakkannu, 1992; Bosch et al., 1995; McLaughlin and Clark, 1997; Kosuge, 1998; Apel and Spiridonov, 1998; Abbot and Dance, 2000; Hooper, 2000; Carpenter and Niem, 2001; Giannuzzi-Savelli et al., 2001; McLaughlin, 2002; Hooper and Van Soest, 2002; Babcock et al., 2003; Siddiqui et al., 2004; Shahdadi et al., 2011; Hosseini et al., 2012).

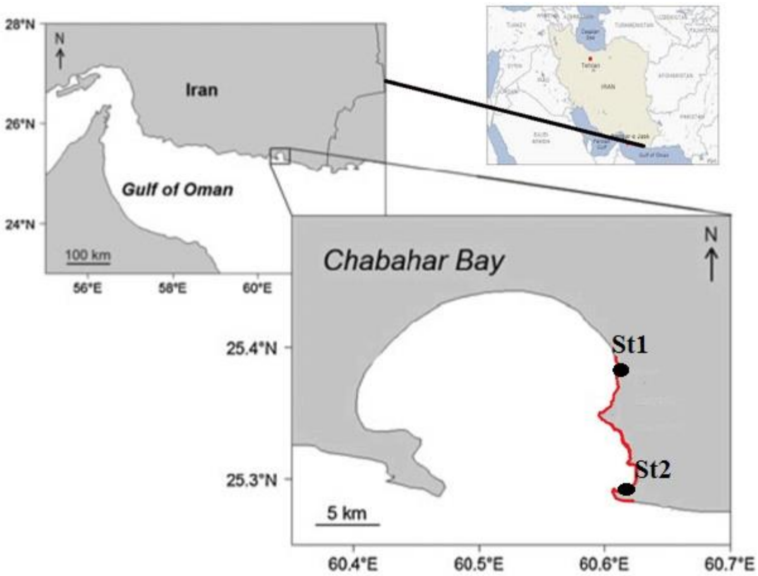

Fig 1- Study area in the Chabahar Bay. St indicates sampling stations.

2-3- Data analysis

The Shannon, Simpson, and Margalef indices were used to describe the community structure. These indices were computed using the online calculator (https://www.alyoung.com/labs/biodiversity_calculator.html). SPSS (ver.24) software was used to perform statistical analysis. One-way ANOVA was used to evaluate the effect of seasons and sampled stations on these indices. $P<0.05$ was considered a significant level in this study.

3- Results

A total of 101 species belonging to Gastropoda, Bivalvia, Polyplacophora, Asteroidea, Ophiuroidea, Echinoidea, Holothuroidea, Crustacea, Polychaeta, Anthozoa, Demospongiae, Hexactinellida was recorded in this study. Dominant gastropods in the macrobenthic fauna had 28 species, 19 genera, 16 families, and 7 orders. Bivalves consisted of 22 species, 21 genera, 12 families, and 8 orders. Echinoderms consisted of 17 species, 9 genera, 9 families, and 8 orders. Brachyuran crabs consisted of 8 species, 4 genera, 1 family, and 1 order, and Hermit crabs consisted of 7 species, 3 genera, 2 families, and 1 order. Amphipod, Barnacle, and Chiton each included 1 species, 1 genus, 1 family, and 1 order. Polychaetes consist of 6 species, 6 genera, 6 families, and 3 orders. Corals consisted of 6 species, 5 genera, 4 families, and 2 orders. Sponges consist of 4 species, 3 genera, 3 families, and 2 orders (Table 1). Table 2 showed density of Macrobenthos species in the East Coast of the Chabahar Bay in the two stations in cold and warm period.

The number of species was the highest in Gastropoda, Bivalvia, and Crustacea, respectively (Figure 2). On the other hand, the average abundance of macrobenthos was the highest in Gastropoda (7.55 ind/m^2), Holothuroidea (7.15 ind /m^2), Echinoidea (6.7 ind /m^2), and Bivalvia (3.48 ind /m^2), respectively (Figure 3). The Shannon index, Margalef richness index, and Simpson dominance index were

counted as 5.17±0.11, 0.05±0.004, and 15.53±0.95, respectively. According to figure 4, warm and cold seasons did not have a significant effect on the Shannon and Simpson index ($P>0.05$). However, the sampled stations had some significant effect on these two indices ($P<0.05$). Nevertheless, there was no significant difference between these groups based on the Margalef index. The effect of season and sampled stations on these indices were assessed ($P<0.05$). Different letters on each column show siginificant difference (Figure 4).

Table 1- Classifications of Macrobenthos species in the East Coast of the Chabahar Bay

Phylum	Class	Sub class	Order	Superfamily	Family	Subfamily	Genus	Species
Mollusca	**Gastropoda**	Vetigastropoda	Archaeogastropoda	Trochoidea	Turbinidae	Turbininae	Turbo	*Turbo coronatus* (Gmelin, 1791)
								Turbo brunneus (Roding, 1798)
						Umboniinae	Umbonium	*Umbonium vestiarium* (Linnaeus, 1758)
		Heterobranchia	Cephalaspidea	Bulloidea	Bullidae	-	Bulla	*Bulla ampulla* (Linnaeus, 1758)
			-	Architectonicoidea	Architectonicidae	-	Architectonia	*Architectonia laevigata* (Lamarck, 1816)
		Caenogastropoda	Caenogastropoda	Cerithioidea	Turritellidae	Turritellinae	Turritella	*Turritella terebra* (Linnaeus, 1758)
					Cerithiidae	Cerithiinae	Clypeomorus	*Clypeomorus bifasciata* (G.B. Sowerby II, 1855)
		Patellogastropoda	-	Patelloidea	Patellidae	-	Patella	*Patella rustica* (Linnaeus, 1758)
								Patella lusitanica (Gmelin, 1791)
		Caenogastropoda	Neogastropoda	Olivoidea	Olividae	-	Ancilla	*Ancilla farsiana* (Kilburn, 1981)
							Oliva	*Oliva bulbosa* (Roding, 1798)
				Buccinoidea	Columbellidae	-	Mitrella	*Mitrella cartwrighti* (Melvill, 1897)
					Nassariidae	Nassariinae	Nassarius	*Nassarius goudiosus* (Hinds, 1844)
								Nassarius marmoreus (A.Adams, 1852)
								Nassarius dashayesianus (Issei, 1866)
				Muricoidea	Muricidae	Rapaninae	Rapana	*Rapana rapiformis* (Born, 1778)
							Thais	*Thais savignyi* (Deshayes, 1844)
								Thais bufa (Lamarck, 1822)
								Thais rugosa (Born, 1778)
								Thais tissoti (Petit de la saussaye, 1852)
					Babyloniidae	-	Babylonia	*Babylonia areolata* (Link, 1807)
								Babylonia spirata (Linnaeus, 1758)
			Littorinimorpha	Naticoidea	Naticidae	Naticinae	Natica	*Natica vitellus* (Linnaeus, 1758)
								Natica alapapilionis (Roding, 1798)
						Polinicinae	Polinices	*Polinices mammilla* (Linnaeus, 1758)
				Cypraeoidea	Cypraeidae	-	Erosaria	*Erosaria turdus* (Lamarck, 1810)

		Heterobranchia	Systellommatophora	Onchidioidea	Onchidiidae	-	Peronia	*Peronia peronei* (Cuvier, 1804)
		Neritimorpha	Cycloneritimorpha	Neritoidea	Neritidae	-	Nerita	*Nerita albicilla* (Linnaeus, 1758)

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Phylum	**Class**	**Subclass**	**Infraclass**	**Order**	**Superfamily**	**Family**	**Genus**	**Species**
Mollusca	**Bivalvia**	Heterodonta	Euheterodonta	Veneroida	Veneroidea	Veneridae	Callista	*Callista erycina* (Linnaeus, 1758)
							Amiantis	*Amiantis umbonella* (Lamarck, 1818)
							Circentia	*Circentia callipyga* (Born, 1778)
							Timoclea	*Timoclea imbricate* (G.B. SowerbyII, 1853)
							Sunetta	*Sunetta effossa* (Hanley, 1843)
							Paphia	*Paphia gallus* (Roding, 1798)
					Cardioidea	Cardidae	Trachycardium	*Trachycardium asiaticum* (Bruguiere, 1789)
							Trachycardium	*Trachycardium lacunosum* (Reeve, 1845)
							Laevicardium	*Laevicardium papyraceum* (Bruguiere, 1792)
					Tellinoidea	Semelidae	Ervilia	*Ervilia castanea* (Montagu, 1803)
							Semele	*Semele sinensis* (A.Adams, 1854)
						Tellinidae	Apolymetis	*Apolymetis angulata* (Gmelin, 1791)
						Psammobiidae	Sanguinolaria	*Sanguinolaria acuminata* (Reeve, 1857)
			Euheterodonta	Myoida	Myoidea	Carbulidae	Carbula	*Carbula modesta* (Reeve, 1843)
			Archiheterodonta	Carditoida	Carditoidea	Carditidae	Cardita	*Cardita bicolor* (Lamarck, 1819)
		Pteriomorpha	-	Arcoida	Arcoidea	Arcidae	Anadara	*Anadara rufescens* (Reeve, 1844)
							Barbatia	*Babatia barbata* (Linnaeus, 1758)
							Arca	*Arca ventricosa* (Lamarck, 1819)
							Acar	*Acar plicata* (Dillwyn, 1817)
				Pterioida	Pterioidea	Pteriidae	Pinctada	*Pinctada sp.* (Roding, 1798)
				Ostreoida	Ostreoidea	Ostreidae	Saccostrea	*Saccostrea cucullata* (Born, 1778)

		Heterodonta	Euheterodonta	Lucinoida	-	Lucinidae	Burdotia	*Burdotia boschorum* (Dekker and Goud, 1994)
	Polyplacophora	Neoloricata	-	Chitonida	Chitonidea	Chitonidae	Acanthopleura	*Acanthopleura vaillantii*

Table 1- Classifications of Macrobenthos species in the East Coast of the Chabahar Bay

Phylum	Subphylum	Class	Superorder	order	Family	Genus	Species
Echinodermata	**Asterozoa**	**Asteroidea**	Valvatacea	Valvatida	Asterinidae	Aquilonastra	*Aquilonastra burtonii* (Gray, 1840)
				Paxillosida	Astropectinidae	Astropecten	*Astropecten phragmorus* (Fisher, 1913)
							Astropecten hemprichi (Muller and Troschel, 1842)
							Astropecten polyacanthus (Muller and Troschel, 1842)
		Ophiuroidea	-	Ophiurida	Ophiocomidae	Macrophiothrix	*Macrophiothrix elongata* (H.L.Clark, 1938)
							Macrophiothrix cheneyi (Lyman, 1862)
						Ophiocoma	*Ophiocoma scolopendrina* (Lamarck, 1816)
	Echinozoa	**Echinoidea**	Echinacea	Camarodonta	Echinometridae	Echinometra	*Echinometra mathaei* (Blainville, 1825)
				Stomopneustoida	Stomopneustidae	Stomopneustes	*Stomopneustes variolaris* (Lamarck, 1816)
			-	Diadematoida	Diadematidae	Diadema	*Diadema setosum* (Leske, 1778)
			Neognathostomata	Clypeasteroida	Clypeasteridae	Clypeaster	*Clypeaster humilis* (Leske, 1778)
							Clypeaster reticulatus (Linnaeus, 1758)
		Holothuroidea	-	Aspidochirotida	Holothuriidae	Holothuria	*Holothuria (Mertensiothuria)* leucospilota (Brandt, 1835)
							Holothuria (Thymiosycia) arenicola (Semper, 1868)
							Holothuria (Selenkothuria) parva (Krauss in Lampert, 1885)
							Holothuria insignis (Ludwig, 1875)

	Holothuria (Selenkothuria) bacilla (Cherbonnier, 1988)

Table 1- Classifications of Macrobenthos species in the East Coast of the Chabahar Bay

Phylum	**Subphylum**	**Superclass**	**Class**	**Subclass**	**Superorder**	**Order**	**Suborder**	**Infraorder**	**Superfamily**	**Family**	**Subfamily**	**Genus**	**Species**
Arthropoda	Crustacea	Multicrustacea	Malacostraca	Eumalacostraca	Eucarida	Decapoda	Pleocymata	Brachyura	Portunoidea	Portunidae	Portuninae	Portunus	*Portunus segnis* (Forskal, 1775)
													Portunus sanguinolentus (Herbst, 1783)
											Thalamitinae	Thalamita	*Thalamita crenata* (Ruppell, 1839)
													Thalamita pyrmna (Herbst, 1803)
													Thalamita admete (Herbst, 1803)
												Charybdis	*Charybdis feriata* (Linnaeus, 1758)
												Charybdis	*Charybdis helleri* (A. Milne Edwards, 1867)
											Portuninae	Scylla	*Scylla serrata* (Forskal, 1775)
										Coenobitidae	-	Coenobita	*Coenobita scaevola* (Forskal, 1775)
										Diogenidae	-	Clibanarius	*Clibanarius signatus* (Heller, 1861)
													Clibanarius virescens (Krauss, 1843)
													Clibanarius longitarsus (De Haan, 1849)
													Diogenes avarus (Heller, 1865)

										Diogenes	*Diogenes custos* (Fabricius, 1798)
											Diogenes tirmiziae (Siddiqui and Mclaughlin, 2003)
			Peracarida	Amphipoda	Gammaridea	-	-	Urothoridae	-	Urothoe	*Urothoe grimaldi* (Chvreux, 1895)
	Maxillopoda	Thecostraca	Thoracica	Sessilia	Balanomorpha	-	Tetraclitoidea	Tetraclitidae	Tetraclitinae	Tetraclita	*Tetraclita ehsani*

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Phylum	**Class**	**Subclass**	**Infraclass**	**Order**	**Suborder**	**Family**	**Genus**	**Species**
Cnidaria	Anthozoa	Hexacorallia	-	Scleractinia	-	Mussidae	Favia	*Favia favus* (Forskal, 1775)
								Favia mathaii (Vaughan, 1918)
						Siderastreidae	Siderastrea	*Siderastrea savignyana* (Mline Edwards and Haime, 1850)
						Merulinidae	Cyphastrea	*Cyphastrea microphthalma* (Lamarck, 1816)
							Platygyra	*Platygyra daedalea* (Ellis and Solander, 1786)
		Octocorallia	-	Alcyonacea	-	Alcyoniidae	Sinularia	*Sinularia sp.* (May, 1898)
Porifera	Demospongiae	Heteroscleromorpha	-	Haplosclerida	-	Chalinidae	Haliclona	*Haliclona simulans* (Johnston, 1842)
								Haliclona oculata (Linnaeus, 1759)
						Callyspongiidae	Callyspongia	*Callyspongia sp.* (Duchassaing and Michelotti, 1864)
	Hexactinellida	Hexasterophora	-	Lyssacinosida	-	Rossellidae	Acanthascus	*Acanthascus baculifer* (Schulze, 1904)
Annelida	Polychaeta	Errantia	-	Phyllodocida	Incertae sedis	Nephtyidae	Nephtys	*Nephtys hombergii* (Lamarck, 1818)
					Nereidiformia	Pilargidae	Synelmis	*Synelmis albini* (Langerhans, 1881)
					-	Glyceridae	Glycera	*Glycera sp.* (Savigny, 1818)

Sedentaria	Canalipalpata	Spionida	Spioniformia	Magelonidae	Magelona	*Magelona cornuta* (Wesenberg-Lund, 1949)
				Spionidae	Prionspio	*Prionspio sp.* (Malmgren, 1867)
	Scolecida	Opheliida	-	Opheliidae	Armandia	*Armandia leptocirris* (Grube, 1878)

Table 2- Density of Macrobenthos species in the East Coast of the Chabahar Bay in the two stations in cold and warm period

Phylum	**Species**	**Station1**		**Station 2**	
		Mean Density (ind /m^2)		**Mean Density (ind /m^2)**	
		Warm season	**Cold season**	**Warm season**	**Cold season**
Gastropoda	*Turbo coronatus*	*28*	*0*	*30*	*0.3*
	Turbo brunneus	*12.6*	*13*	*16*	*12*
	Umbonium vestiarium	*2*	*2*	*3.3*	*1.6*
	Bulla ampulla	*34*	*26*	*36*	*30*
	Architectonia laevigata	*0.6*	*0*	*1*	*0*
	Turritella terebra	*5*	*0*	*6*	*0*
	Clypeomorus bifasciata	*30*	*28.6*	*34.6*	*34*
	Patella rustica	*20*	*69*	*23*	*50*
	Patella lusitanica	*2*	*2*	*2.6*	*3.3*
	Ancilla farsiana	*1*	*0*	*1.6*	*0*
	Oliva bulbosa	*4*	*3*	*5.3*	*3.3*
	Mitrella cartwrighti	*18.3*	*9*	*19*	*10*
	Nassarius goudiosus	*8*	*12*	*9.3*	*13.3*
	Nassarius marmoreus	*7*	*6*	*8.3*	*6.3*
	Nassarius dashayesianus	*10*	*7*	*11*	*7*
	Rapana rapiformis	*0.6*	*0*	*1*	*0*
	Thais savignyi	*1*	*1*	*1.6*	*1*
	Thais bufa	*2.3*	*0*	*3*	*0*

	Thais rugosa	*2*	*1*	*3.3*	*1*
	Thais tissoti	*0.6*	*0*	*1*	*0*
	Babylonia areolata	*1.3*	*1*	*2*	*1*
	Babylonia spirata	*1*	*1*	*1.3*	*1*
	Natica vitellus	*1*	*1*	*1*	*1*
	Natica alapapilionis	*1*	*0*	*1*	*0*
	Polinices mammilla	*0.6*	*1*	*1*	*1*
	Erosaria turdus	*1*	*1*	*1.6*	*1*
	Peronia peronei	*0.6*	*1*	*1*	*1*
	Nerita albicilla	*18*	*6.6*	*19*	*16*

Table 2- Density of Macrobenthos species in the East Coast of the Chabahar Bay in the two stations in cold and warm period

Phylum	**Species**	**Station1**		**Station 2**	
		Mean Density (ind /m^2)		**Mean Density (ind /m^2)**	
		Warm season	**Cold season**	**Warm season**	**Cold season**
Bivalve and Chiton	*Callista erycina*	*1*	*0.6*	*1*	*1*
	Amiantis umbonella	*3.6*	*3*	*4*	*3*
	Circentia callipyga	*1*	*1*	*1.6*	*2*
	Timoclea imbricate	*0.6*	*1*	*1*	*1*
	Sunetta effossa	*3*	*10.6*	*5*	*11*
	Paphia gallus	*1*	*1*	*1*	*1*
	Trachycardium asiaticum	*10*	*40*	*14*	*36*
	Trachycardium lacunosum	*1*	*1*	*1.3*	*1.6*
	Laevicardium papyraceum	*1.6*	*1*	*1*	*1.6*
	Ervilia castanea	*1*	*0.6*	*1*	*1*
	Semele sinensis	*5*	*1*	*4.3*	*1.6*
	Apolymetis angulata	*2*	*8*	*3.3*	*9.3*
	Sanguinolaria acuminata	*0.6*	*1*	*1*	*1*
	Cardita bicolor	*1*	*1*	*1*	*1*
	Carbula modesta	*1*	*1*	*0.6*	*0.6*
	Anadara rufescens	*16*	*9*	*20*	*13.3*
	Babatia barbata	*1*	*0.6*	*1*	*1*
	Arca ventricosa	*3*	*3*	*3.3*	*3.3*
	Acar plicata	*2*	*2*	*2*	*2*

	Pinctada sp.	*1.6*	*2*	*2*	*2*
	Saccostrea cucullata	*1*	*1*	*1*	*1*
	Burdotia boschorum	*1*	*0.6*	*1*	*1*
	Acanthopleura vaillantii	*0.6*	*1*	*1*	*1*

Table 2- Density of Macrobenthos species in the East Coast of the Chabahar Bay in the two stations in cold and warm period

Phylum	**Species**	**Station1**		**Station 2**	
		Mean Density (ind /m²)		**Mean Density (ind /m²)**	
		Warm season	**Cold season**	**Warm season**	**Cold season**
Asteroidea / Ophiuroidea / Echinoidea/ Holothuroidea	*Aquilonastra burtonii*	*1*	*0.6*	*1.6*	*1.6*
	Astropecten phragmorus	*1*	*1*	*2*	*1.6*
	Astropecten hemprichi	*2*	*3*	*3*	*2.6*
	Astropecten polyacanthus	*1*	*1.3*	*1*	*1*
	Macrophiothrix elongata	*1*	*1*	*1*	*1.6*
	Macrophiothrix cheneyi	*0.6*	*1*	*1*	*1*
	Ophiocoma scolopendrina	*1*	*1*	*1*	*1.6*
	Echinometra mathaei	*12*	*10*	*15*	*12*
	Stomopneustes variolaris	*2*	*2*	*3.3*	*3.6*
	Diadema setosum	*1*	*10*	*2*	*12.3*
	Clypeaster humilis	*4*	*7*	*5*	*6.6*
	Clypeaster reticulatus	*1*	*1*	*1*	*1*
	Holothuria leucospilota	*1*	*1*	*1*	*0.6*
	Holothuria arenicola	*1*	*1*	*0.6*	*1*
	Holothuria parva	*57*	*13*	*40*	*18*
	Holothuria insignis	*1*	*1*	*1*	*1*
	Holothuria bacilla	*1*	*1*	*1*	*1*

Anthozoa / Coral	*Favia favus*	*1*	*1*	*1.6*	*1*
	Favia mathaii	*1*	*0.6*	*0.6*	*1*
	Siderastrea savignyana	*0.6*	*1*	*1*	*1*
	Cyphastrea microphthalma	*1*	*1*	*0.3*	*1*
	Platygyra daedalea	*1*	*1*	*1.3*	*0.3*
	Sinularia sp.	*0.6*	*1*	*0.3*	*1.6*
Sponge	*Haliclona simulans*	*0.6*	*1*	*1*	*1*
	Haliclona oculata	*1*	*1*	*1*	*1.3*
	Callyspongia sp.	*1*	*0.6*	*1.3*	*1.3*
	Acanthascus baculifer	1	*1*	*0.6*	*1.3*

Table 2- Density of Macrobenthos species in the East Coast of the Chabahar Bay in the two stations in cold and warm period

Phylum	**Species**	**Station1**		**Station 2**	
		Mean Density (ind /m^2)		**Mean Density (ind /m^2)**	
		Warm season	**Cold season**	**Warm season**	**Cold season**
Brachyuran crab / Hermit crab / Amphipod / Barnacle	*Portunus segnis*	*1*	*1*	*0.6*	*1*
	Portunus sanguinolentus	*0.6*	*1*	*1*	*1*
	Thalamita crenata	*1*	*1*	*1*	*1.3*
	Thalamita pyrmna	*1*	*0.6*	*1*	*1*
	Thalamita admete	*0.6*	*1*	*1*	*1*
	Charybdis feriata	*1*	*1*	*1.3*	*1.6*
	Charybdis helleri	*1*	*1.3*	*1*	*1*
	Scylla serrata	*0.6*	*1*	*1*	*1*
	Coenobita scaevola	*1*	*1*	*0.6*	*0.6*
	Clibanarius signatus	*1*	*1*	*1.6*	*1*
	Clibanarius virescens	*1*	*0.6*	*0.6*	*1*
	Clibanarius longitarsus	*1*	*1*	*1*	*1*
	Diogenes avarus	*0.6*	*1*	*0.6*	*0.6*
	Diogenes custos	*1*	*1*	*0.6*	*1*
	Diogenes tirmiziae	*1*	*1.3*	*1.6*	*1.3*

	Tetraclita ehsani	*1*	*1.3*	*1*	*1*
	Urothoe grimaldi	*1*	*1*	*0.6*	*0.6*
Polychaete	*Nephtys hombergii*	*2*	*2*	*2.6*	*2.3*
	Synelmis albini	*1.3*	*1*	*1*	*1*
	Glycera sp.	*0*	*3*	*0.3*	*2.6*
	Magelona cornuta	*1*	*1*	*0.6*	*0.3*
	Prionspio sp.	*1*	*0.6*	*1.3*	*1*
	Armandia leptocirris	*0*	*3*	*0.3*	*3.3*

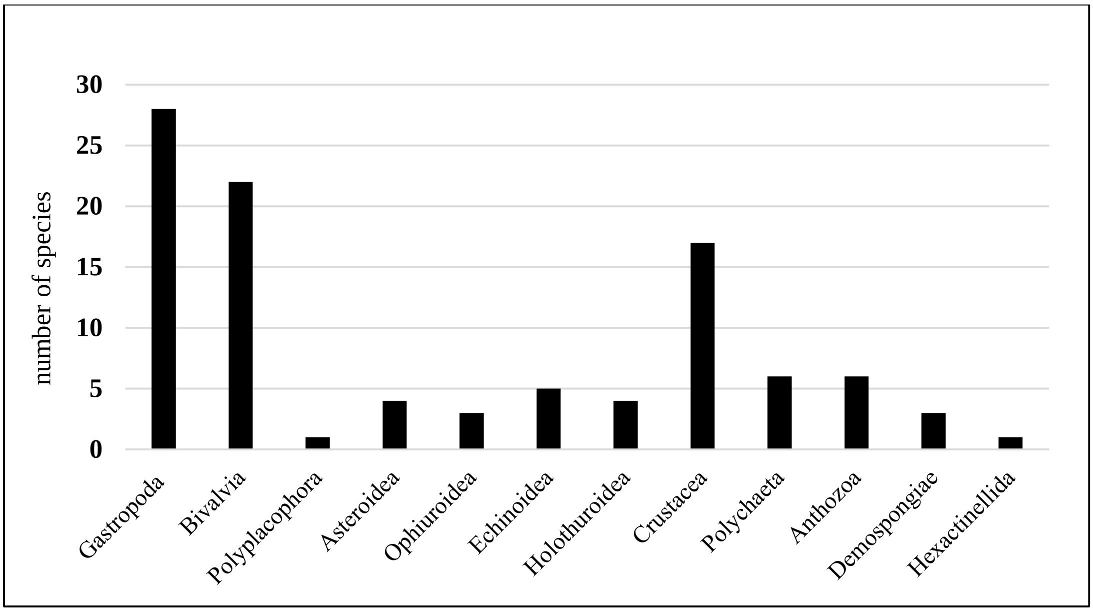

Fig 2- Comparing the number of macrobenthic species in various classes identified in the East Coast of the Chabahar Bay

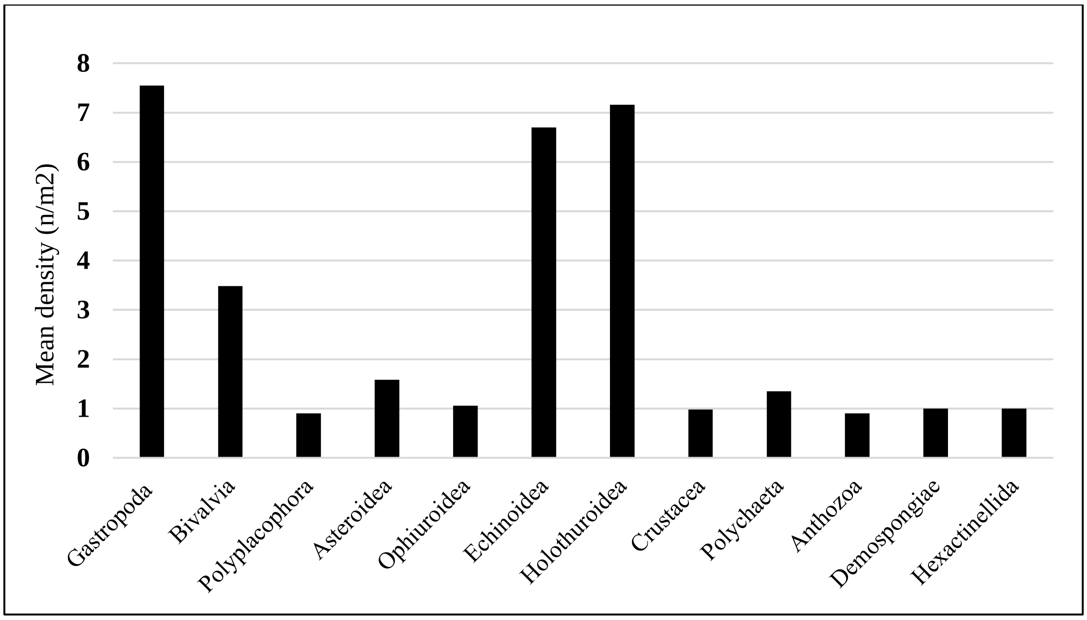

Fig 3- The abundance of macrobenthos in the East Coast of the Chabahar Bay

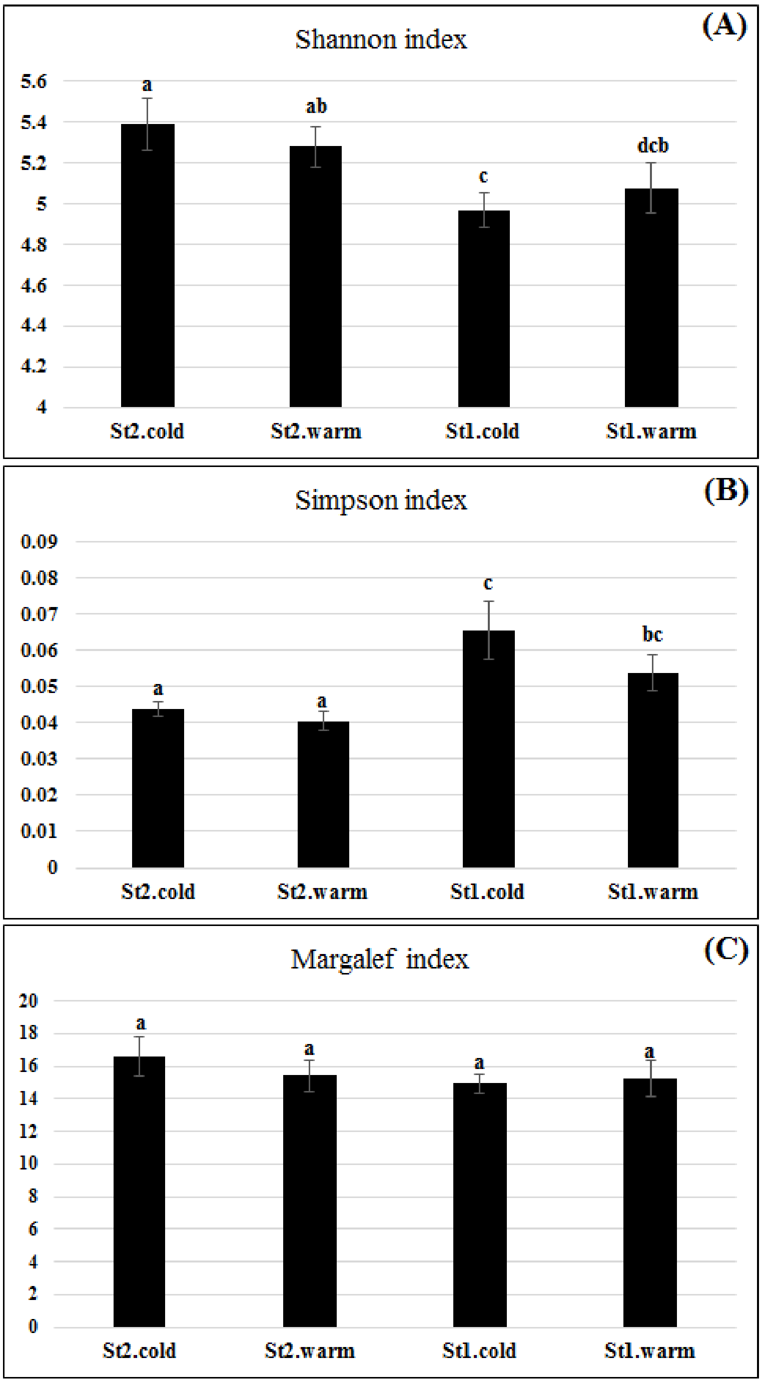

Fig 4- Shannon diversity index, Margalef species richness, Simpson dominance index of macrobenthos species

4- Discussion

A total of 101 macrofauna species were identified during the present study, including 6 phyla, 13 classes, 34 orders, 56 families, and 73 genera. Moreover, Mollusca and Echinodermata were the highest, respectively, in terms of species number. On the other hand, Mollusca and Arthropoda were the highest, respectively, in terms of abundance.

Mollusks are the second most diverse metazoan phylum with more than 100,000 living species (Barnes, Calow, Olive, Golding, & Spicer, 2009; Osca, Irisarri, Todt, Grande, & Zardoya, 2014), and many mollusk species are used as bio-indicators (Abbas, 2012; Mohammad Karami, Riyahi Bakhtiari, Kazemi, & Kheirabadi, 2014; Osca et al., 2014; Saeedi, 2012).

After Gastropoda, Bivalves are the second biggest group among mollusks with more than

20000 species (Barnes et al., 2009). The dominance of gastropods and bivalves was also observed by Kathiresan et al. (2000) in the Vellar estuary on the southeast coast of India (Kathiresan, Rajendran and Palaniselvam, 2000). They reported that gastropods had the highest abundance, due to their high tolerance to different environmental situations. Moreover, other studies reported that mollusks were the most abundant groups in the Persian Gulf (Al-Yamani et al., 2009).

Echinoderms are among the most familiar groups of sea invertebrates and some of them, e.g., starfishes, are known as the symbol of life in the sea (Barnes et al., 2009). Echinoderms with 7000 species are important communities on the bottom of the sea from poles to tropical regions (Castro & Huber, 2003). Their history goes back to the Precambrian period. These animals are the most abundant benthos and play important economic, ecological, and nutritional roles (Brusca and Brusca, 2003; Schlager and Murphy, 2003).

In the present study, Crustacean showed a relatively high number of species. Mohammed and Kumar (1995) observed the dominance of Mollusca and Crustacea in some mangrove environments of India (Kumar, 1995). Crabs belong to a group of animals known as decapod crustaceans (Hosseini et al., 2012). In the present study, crabs consisted of two groups including brachyuran and hermit crabs. More than 6500 species of crabs have been identified until now, and most of them live in Indo-West Pacific. The largest and most specialized group of echinoderms is Brachyura (Poore, 2004).

All of the observed brachyuran crabs belong to the Portunidae, and most of the marine crabs found along the Persian Gulf coasts belong to this family. The marine crabs that are commercially fished are commonly found in tropical and subtropical estuarine and near-shore habitats (Hosseini et al., 2012). Hermit crabs are crustaceans belonging to the order Decapoda and the infraorder Anomura. There are five families of hermit crabs: Coenobitidae, land hermit crabs; Diogenidae, left-handed hermit crabs; Paguridae, right-handed hermit crabs; Parapaguridae, deep-water hermit crabs; and Pylochelidae, non-gastropod shelter-using hermit crabs (Billock, 2008). The infraorder Anomura has long attracted the attention of evolutionary biologists due to its impressive morphological diversity and ecological adaptations. The infraorder Anomura represents a highly diverse group of decapod crustaceans comprised of hermit crabs, mole crabs, king crabs, squat-lobsters, and porcelain crabs. Anomurans also represent an important economic commodity. However, some of these species are threatened or endangered due to rarity in nature, overfishing, and habitat loss. Thus, an improved understanding of these groups will not only attract our attention to their diversity and ecology but also improve strategies for their conservation (Bracken-Grissom et al., 2013). Al-Wakeil et al. (2009) in the intertidal and shallow subtidal region in the Red Sea coast of Egypt surveyed three families (Coenobitidae, Paguridae and Diogenidae) of hermit crabs.

Polychaeta was also observed in our study belonging to the phylum Annelida, which are segmented worms and found worldwide in most habitats. Although earthworms and leeches are the most familiar members of this group, polychaetes have the highest diversity in this phylum (Rousset, Pleijel, Rouse, Erséus, & Siddall, 2007). Currently, approximately 15,000 species of annelids are known, and possibly many hundreds remain undiscovered and undescribed (McHugh, 2000). Polychaete exhibits a great diversity of forms, ranging from sedentary tube-dwellers to pelagic worms. Some of these animals have body segments with uniform morphology, but others have fused segments to form specialized regions for feeding, respiration, or supporting embryos. Polychaetes are equally diverse in their habitat. Although they are mostly marine, their dispersion ranges from estuarine mudflats to deep-sea hydrothermal vents. Some polychaetes are suspension-feeders, others are scavengers or predators, and a few, e.g., Histriobdellids, are parasitic on other invertebrates (McHugh, 2000).

Anthozoans are almost exclusively marine cnidarians, with only a few species living in brackish water. Approximately 7,500 extant species are described worldwide from intertidal to deep-sea habitats and at least the same number of species, mainly scleractinians, are known from fossil records (Häussermann & Försterra, 2009). Sinularia comprises a group of soft corals belonging to the phylum Cnidaria, class Alcyonaria, and family Alcyoniidae. They are widely distributed from East Africa to the western Pacific, inhabited in coral reefs or rocks in shallow water, but rarely form large aggregates (Chen, Li, and Guo, 2012). Recent work has identified 107 reef-building coral species in the Gulf of Oman (Rezai, Wilson, Claereboudt, and Riegl, 2004).

Sponges have only four species from three genera, including Haliclona, Callyspongia, and Acanthascus. Sponges (phylum Porifera) are the oldest metazoan group that has survived. This survival with vast numbers in sea and freshwater habitats is closely related to the adaptation of their bauplan to dramatic changes in the environment (Müller, 2012). Sponges are an important component in many benthic communities and can dominate in some regions, in terms of biomass and diversity (Duckworth and Wolff, 2007). Sponges are exclusively aquatic animals, which are fixed on substrates, and obtain food by filtering water and trapping microscopic-size nutrient particles. Recent research also indicates their ability to take up dissolved organic matters (De Goeij, Van Den Berg, van Oostveen, Epping, and Van Duyl, 2008). Chalinid sponges (order Haplosclerida) have a global distribution, with potentially hundreds of extant species (Hooper and Van Soest, 2002). Despite their dispersion in all depths, they tend to be found in shallow sub-tidal zones(Hooper & Van Soest, 2002). Their classification is very difficult in the taxonomical studies, due to their highly variable and simple morphological characteristics (Hooper and Van Soest, 2002). Among the four valid genera of chalinid sponges, the genus Haliclona consists of sponges with variable morphology and consistency. Haliclona was firstly reported by Grant (Grant, 1836) by introducing *Spongia oculata* (England, 1766). The genus has 436 valid species presently identified worldwide (Van Soest et al., 2018).

Only one species of Barnacle, Amphipod, and Chiton was observed during this study. Barnacles belonging to the phylum Arthropoda and class Maxillopoda are good model organisms for coastal zoographical studies because they exhibit a high abundance on rocky shores and are the major space occupiers. Intertidal barnacles belonging to the genus Tetraclita are common and widespread in tropical and subtropical oceans including the West Indian Ocean (Tsang, Achituv, Chu, and Chan, 2012). *Tetraclita ehsani* was present in the subtidal zone, mainly found attached to rocks, and sometimes observed on mollusk shells and the shell surfaces of barnacle species (Megabalanus) in the Gulf of Oman. This species is only found on the Iranian coast of the Gulf of Oman and not in the Persian Gulf (Shahdadi, Sari, and Naderloo, 2014).

Amphipods belonging to the phylum Arthropoda and class Malacostraca are macroscopic crustaceans, classified in the superorder Peracarida along with the isopods, cumaceans, mysids, and tanaidaceans(Väinölä et al., 2007). Gammaridean amphipods are the most abundant and familiar suborder of the order Amphipoda. They represent a very diverse group of organisms found all over the world with 5,700 species and 1060 genera (Philips, 2006). The genus Urothoe (Dana, 1852) is known to be cosmopolitan and is one of the most diverse genera of the family Urothoidae (Bousfield, 1978). They are easily identified by their small bodies furnished with various fossorial adaptations in the form of extremely setose appendages. Moreover, these animals are known to be very diverse in shallow habitats, act as an important component of the burrowing fauna of intertidal and shallow sub-tidal zones, and are scarce in the deep sea (Azman and Melvin, 2011).

Chitons are ancient molluscan lineage with a generally conservative appearance and grazing habit. Most chitons (Polyplacophora) live in the intertidal zone and shallow water, but some species dwell in rather deep water. Chitons are distributed in all oceans from the Polar regions to the tropics (Sadeghi and Loghmani, 2010). *Acanthopleura vaillantii* lives in the northwestern Indian Ocean, the Persian Gulf and Gulf of Oman (Kaas & VANBELLE, 1988), Strait of Hormuz (Tadjalli-Pour, 1974), mainland Yemen and Socotra Island (Dinapoli and Janssen, 2009), Red Sea (Strack, 1993), Suez Canal (Dinapoli and Janssen, 2009), and Chabahar Bay (Sadeghi & Loghmani, 2010).

Although there is no report focusing on the community structure of macrobenthos in Chabahr Bay, some previous studies evaluated these animals in the adjacent water areas. Pourjomeh et al. (2014) evaluated the distribution and abundance of macrobenthic invertebrates in the Hormozgan Province, the Persian Gulf, Iran. Their study led to the identification of 5677 individuals of macrobenthos belonging to 8 taxa (i.e. gastropods, bivalves, polychaetes, crustaceans, scaphopods, echinoderms, sipunculids), among of which Gastropoda had the highest abundance (52.67±18.94) (Pourjomeh, Hakim Elahi, Rezai, & Amini, 2014). Moreover, Farsi et al. (2015) assessed the effects of environmental conditions on the spatial distribution of macrobenthic communities in the Bushehr coasts of the Persian Gulf. They identified a total of 17 groups (taxa) of macrobenthos, among of which Mollusca, Annelida, and Arthropoda had the highest abundance, respectively.(Farsi, Seyfabadi, Owfi, and Aramli, 2015).

In this study, species diversity was determined by using the Shannon-Weiner index, dominant species were investigated using the Simpson index and species richness was calculated using the Margalef index. Results showed that warm and cold seasons did not have a significant effect on the Shannon and Simpson index ($P>0.05$). However, the sampled stations had some significant effect on these two indices ($P<0.05$). The significant effect of the station on these two indices can be related to different substrate structures in the two stations. In other words, station 2 had more rocky beds compared to station 1. The results of the present study also showed that there was no significant difference between stations and seasons based on the Margalef index.

Momtazi and Zarei (2020) identified 21 species belong to 14 genera and 12 families of amphipods communities of Chabahar Bay. Amplisidae was the most abundant family. Shannon index was 0-2.9 with average value of 1.2. The highest distribution of amphipod communities was on the east, northeast and southwest coasts of the bay. The highest average taxonomic distinctness index (AvTD) was calculated for west, southwest and southeast. Therefore, considering that higher taxonomic distinctness indices indicate more suitable ecological conditions, it can be concluded that the middle part of Chabahar Bay has more unfavourable ecological conditions for amphipods and other macrobenthos.

Pazira et al. (2019) evaluated species diversity and richness of Gastropoda in the intertidal zone of Bushehr Port coastal area (the Persian Gulf waters). They identified 14 species from 12 families belonging to 7 orders. Their results also showed that Shannon and Margalef indices had significant differences between the sampled stations and seasons ($P<0.05$). Moreover, the results of the Simpson index showed no significant differences between the sampled stations and seasons ($P<0.05$)(Pazira, Salehi, and Obeidi, 2019).

Amini Yekta et al. (2013) identified Forty-nine mollusks taxa in which, 28 and 21 taxa belong to gastropods and bivalves, respectively in Chabahar Bay and surrounding waters. Kruskal Wallis test yielded significant differences in mollusks abundance among different sites ($P<0.05$), but not among different sampling periods ($P>0.05$).

Asghari et al. (2011) studied on diversity and density of Gastropoda in sediments of Oman Sea (Hormoz strait Quatr Bay. In this study 71 genera of 43 families of Gastropoda were identified. Among the identified groups, Nassaridae 27%, Retusidae 16%, Pyramidellidae 12%, Cyclostrematidae 8% and Scaphandridae 7% were dominant groups. Results show that diversity and density of Gastropoda in Oman Sea, affected by the southwest Indian Ocean monsoon winds. As far as the frequency of them will be increased and their diversity will be decreased after summer monsoon. But the density of Gastropoda did not show significant difference among before and after Monsoon.

Taheri et al. (2010) studied biodiversity and community structure of macrofauna of the intertidal sandy beach at Chabahar Bay for a period of ten months in 2007. A total of 32 species were observed and identified in this study so that polychaete with 16 species was numerically dominant. The results showed changing densities were influenced by monsoon season so that maximum density (1935.47 ind/m^2) was observed at pre-monsoon while minimum (181 ind/m^2) was obtained at monsoon. The highest and lowest value of diversity and richness indices were obtained at pre-monsoon and during monsoon, respectively.

The intertidal zones are the best-known areas of the world’s oceans. In the present study, macrobenthic fauna were highly diverse. On Goa Beach in India, 6 species of macrofauna were reported (Harkantra & Parulekar, 1985) and at the Godavari Delta, on India’s east coast, 37 species of macrofauna were recorded (Raut, Ganesh, Murty, & Raman, 2005)

Sherman et al. (2001) found that the more structural diversity the bed has, the more biological diversity on the bed appears (Sherman, Gilliam, & Spieler, 2001). Since there is a high structural diversity on the bed of the area including rock coasts with alga coverage, tidal pools, interstices and gaps on rocks, stony coasts with spaces between stones

and under stones, rubble, sandy, and coral beds, there is high biological diversity in this region.
Biodiversity is essential for ecosystems to function efficiently. Ecosystems provide services to organizations and society, including food, freshwater, wood and fiber, medicines, soil fertility, climate regulation, building materials, an opportunity for scientific and technical development, genetic resources, flood regulation, and recreation facilities. All organizations make use of one or more of these ecosystem services, either directly through their activities or indirectly through supply chain partners (GRI, 2007).
Such studies on Gulf of Oman's coasts are very necessary to identify and know benthos. Moreover, it helps us to assess the habitat and biodiversity of the Gulf of Oman's bottom fauna.

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