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Ecological baseline analysis of mollusks in the intertidal stations of Ouli, Dayyer, and Kangan, in the Persian Gulf

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Abstract

Macrobenthos play an important role in aquatic ecosystems because they mineralize, promote, and mix the oxygen flux into the sediment, which recycles the organic matter. Sampling of macrobenthos populations for this study was carried out in the supratidal, mid tidal, low tidal, and subtidal regions of the Dayyer, Ouli, and Kangan stations in the Persian Gulf during both cold and warm seasons. Water parameters such as the temperature, salinity, pH, turbidity, and electrical conductivity were assessed, and were indicative of moderate water quality. Representatives of a total of 31 taxonomic families were identified during both seasons, of which 59 were identified to genus and species. The highest average number of species was observed in the low tidal region of Kangan in the warm season at 16.6 ± 1.2 species, and the lowest number was observed in the supratidal regions of Ouli and Kangan in the cold season at 6.6±2 species. The species diversity, as calculated using the Shannon–Wiener Index (H'), showed a significant difference between sampling seasons and sampling stations, as well as pollution level at the beaches. The species diversity index in Ouli, Dayyer, and Kangan stations also differed between the seasons. In both seasons, the Kangan station showed the highest species diversity while the Dayyer station showed the lowest. These results reveal a rich species diversity of macrobenthos and good water quality at the three beaches in the Persian Gulf. Re-assessment of species diversity during an environmental impact assessment prior to urban development should be further conducted to ensure that the community is not significantly affected and the ecosystem remains intact.

Key words: Species diversity, macrobenthos, Shannon–Wiener Index, water quality

Introduction

Coastal areas have high biological potential, providing habitats for feeding, rearing of offspring, and oviposition of numerous species (Jones et al., 2021). Natural stressors, as well as those brought by human mismanagement, have severely compromised these ecosystems and reduced their ecological quality (Hays et al., 2005). To conserve these highly vulnerable coastal areas, assessments of ecological changes caused by human activities and protection of sensitive biological stages of commercial aquatic species are required (Fahimi et al., 2021). Due to the physical and chemical characteristics of the coasts, the benthic region forms a habitat for a diverse range of species, from microorganisms to meiobenthos and macrobenthos (Heneghan et al., 2021).

Macrofaunal taxa, such as polychaete annelids, crustaceans, and mollusks are important components of aquatic ecosystems which play a main role in nutrient cycling, pollutant metabolism, dispersion and burial, and secondary production (Snelgrove, 1998; Herman and Heip, 1999). Benthic organisms are essential for mixing organic matter into the sediment, aerating the seabed for aquatic plant root systems, and increasing microbial and fungal activity, which decompose organic matter in the sediment to produce minerals (Kumar et al., 2022). Furthermore, they act as secondary and tertiary consumers in aquatic food chains and play a role in mineral cycling such as the carbon and nitrogen cycles. Indeed, 28 of the 29 known, non-symbiont animal phyla on Earth occur in marine environments (Ray and Grassle, 1991) and most are represented in marine sediments. Thus, the marine macrofauna, at the phylum level, represent the most diverse assemblage on Earth and is also evidence for extremely high diversity at the species level (Wilson, 2017). Thus, evaluating and understanding species diversity in marine sediments is both important and challenging.

Environmental factors, such as temperature, salinity, depth, primary production, physical disturbance of the environment, and types of sediment, affect the distribution of macrobenthos (Levine, 1984; Viitasalo et al., 2015). The various feeding behaviors of macrobenthos include herbivory (mollusks and crustaceans), scavenging, filter-feeding (polychaetes and bivalves), and carnivory (crustaceans and polychaetes) (Komarudin, 2003). Various organisms, such as fish, plankton, macroalgae, and zoobenthos are used in the evaluation of aquatic ecosystems; among them macrobenthos are of special significance (Blanchet et al., 2008). Seabed residence, relatively long life cycles, high species diversity with various sensitivities to environmental stressors, as well as their important roles in cycling nutrients between sediments and water are some of the advantages of using benthic communities in evaluating the quality of aquatic ecosystems (Snelgrove, 1998).

Macrobenthic communities are often used as indicators in ecological impact analyses. Changes in macrobenthic communities can influence changes in other communities within the ecosystem (Ejlali Khanghah et al., 2017; Pazira et al., 2017). The degree of impact and recovery of benthic communities is, however, dependent on the type and amount of pollutants, sediment gradation, water depth, and species mobility (Pazira et al., 2017). In quantitative analyses of benthic organisms, the quantity and types of organisms are typically used to estimate production levels (Pauly et al., 1998).

Species diversity is one of the most important components in determining the health of ecosystems, and one of the most key criteria in demonstrating the significance of protected habitats (Price, 2002). The study of ecological indicators in an ecosystem provides a clear vision of the environmental conditions and stability of a given region (Maghsoudlou et al., 2020). In order to determine the species diversity, the Shannon–Weiner index is used. As one of the most common indicators of diversity used in ecological studies, its relationship is as follows:

$$H' = \sum_{i=1}^{s} \left[\frac{(n_i)}{n} L_n \left(\frac{n_i}{n} \right) \right]$$

"H index" is zero when only one species is present in a given sample, and reaches its maximum only when all species present have the same number of individuals.

n= total number of individuals in sample

ni= number of individuals in species

s= total number of species

The Shannon–Weiner index can also be used to monitor pollution levels (Welch and Naczk, 1992; Albuaejee et al., 2020) where values < 1 or 0–1 are indicative of very high pollution, values between 1–3 are indicative of moderate pollution, and values above 3 indicate high species diversity and a lack of pollution (Welch and Naczk, 1992; Das et al., 2012).

The Kangan beaches in the Persian Gulf are especially endangered in relation to their marine habitats due to having a higher degree of industrial activity. The irregular exploitation of marine environments, as well as the existence of various industries in the coastal environment, have caused these three ecosystems to undergo changes and loss of natural features of their coasts, reduced biological diversity, reduced productivity, increased vulnerability, and reduction in their fauna and flora. Therefore, assessing the species diversity and recognizing the ecological value of these regions through this current study, specifically from the perspective of conservation and proper management practices, is of utmost importance and can aid in the protection and preservation of these areas in the future.

Material and Methods

The present study was conducted at the beaches of Ouli, Dayyer, and Kangan of the Persian Gulf (Fig. 1) during the cold and warm seasons in February and September of 2013, respectively. Using the Iranian Hydrography Association website (http://www.iranhydrography.org), optimal times for sample collection from intertidal zones were determined, and sampling was done during the lowest spring tide. The geographic coordinates of each transect were determined using a GPS device (GPSMap 78s, Garmin Inc.).

During the sampling process in each area, samples were collected from supratidal, mid-tidal, low tidal, and subtidal regions. Quadrats (50 cm × 50 cm) were used for sample collection in tidal regions, and a Van Veen grab sampler was used in subtidal regions (Nguyen et al., 2019). Larger specimens were collected by hand, while smaller specimens were washed in a 0.5 mm sieve, placed in plastic containers, and fixed with a 5% formaldehyde solution. The samples were then brought to the Iranian National Institute for Oceanography and Atmospheric Science laboratory where macrofauna were identified to species or genus level using valid identification keys such as: Kira, 1965; Tirmizi and Zehra, 1982; Jones, 1986; and Abbott and Dance, 1990. Additionally, taxa were checked against the WORMS website (https://www.marinespecies.org).

In each sampling session (season), physical and chemical factors of the water including salinity, temperature, turbidity, pH, and electrical conductivity (EC) were measured (Nguyen et al., 2019).

Data processing was done using SPSS 16 and Microsoft Excel. Prior to the application of statistical methods, the normality of data was analyzed with a Shapiro–Wilk test using SPSS software. The Welch index was used to determine the degree of contamination in each station. A *t*-test was performed to determine the differences in diversity between the seasons. Finally, graphs representing environmental factors, organic matter, the number of species in each region, and the species diversity index were illustrated using Microsoft Excel 2010.

Results

In the regions of Ouli, Dayyer, and Kangan, representatives from a total of 31 taxonomic families were identified in both warm and cold seasons, of which 59 taxa were identified to genus and species (Table 1).

The organisms identified belong to the classes Gastropoda and Bivalvia in the phylum Mollusca. The highest average number of molluscan species was observed in the low tidal region of Kangan in the cold season with 16.6 ± 1.2 species, and the lowest number was observed in the supratidal region of Ouli and Kangan in the warm season with 6.6 ± 2 species (Fig. 2). The number of species identified in the warm and cold seasons were 54 and 49 species in the Ouli station, 45 and 34 species in Dayyer station, and 63 and 53 species in Kangan station, respectively (Figs. 2 and 3). The Kangan station had the highest species diversity in both seasons in comparison to the other two regions. The highest number of species in all three regions was significantly observed during the warm season (*t*-test, $P< 0.05$) (Fig. 3).

The Shannon–Weiner Ecological Index

The average Shannon–Weiner index in the Ouli, Dayyer, and Kangan stations were 3.18, 3.05, and 3.18 in the warm season, and 2.96, 2.86, and 3.22 in the cold season, respectively (Fig. 4).

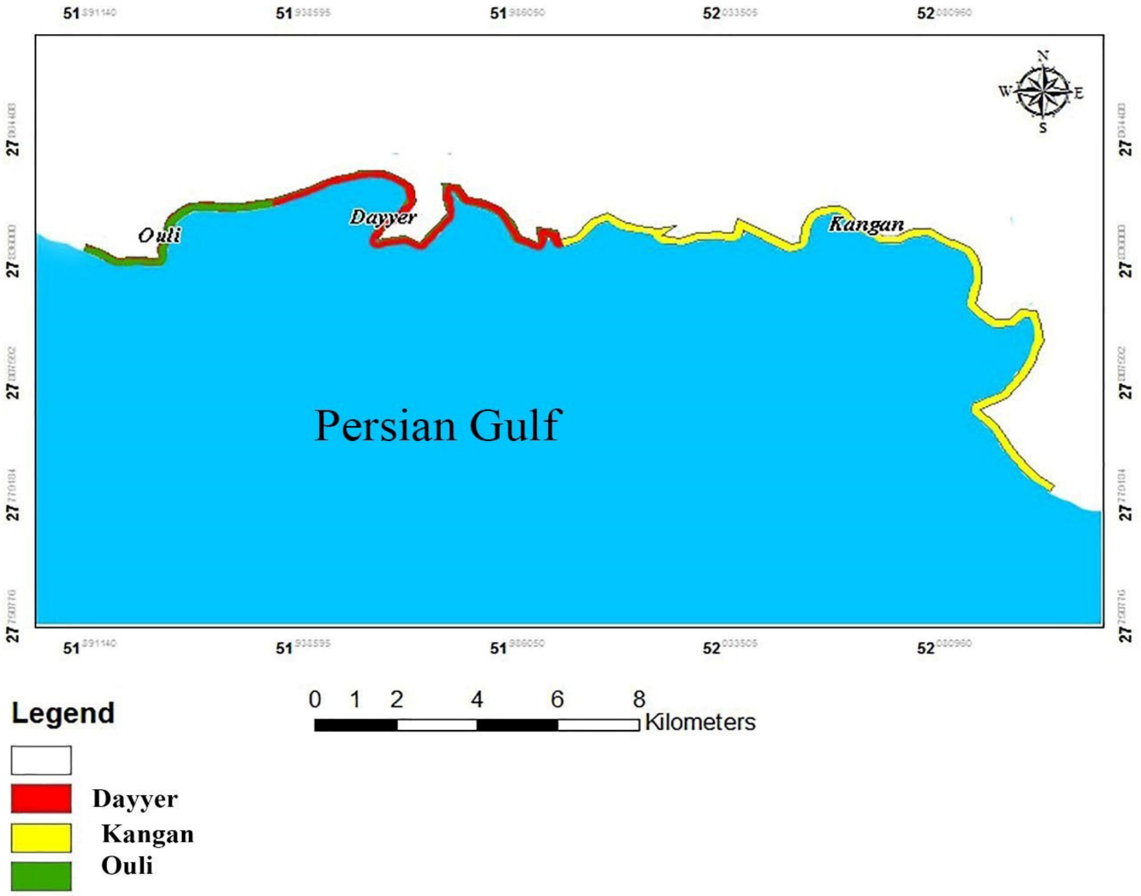


Figure 1: Geographical map of sampling locations in Ouli, Dayyer, and Kangan, Persian Gulf.

In both seasons, the Kangan station showed the highest species diversity while the Dayyer station showed the lowest (Fig. 4). These observations show that the molluscan macrobenthos diversity can vary between seasons, probably due to the difference in the environmental conditions that ensures their survival.

Pollution status

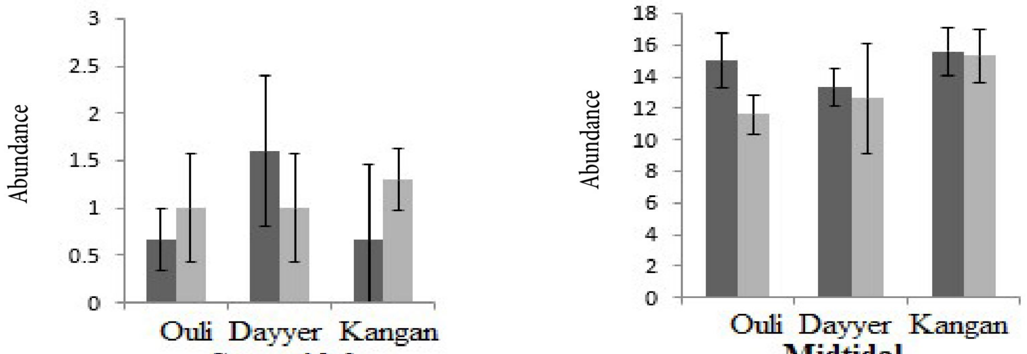
According to our analysis, the stations under study in this research have a moderate level of pollution (Table 2). In the warm season the stations of Dayyer and Kangan showed moderate pollution, while Ouli showed higher pollution. In the cold season Ouli and Dayyer were placed in the moderate rank of pollution while Kangan showed the highest rank for pollution.

Table 2: Pollution status determined via the Welch Index for the Ouli, Dayyer, and Kangan stations, Persian Gulf in different seasons.

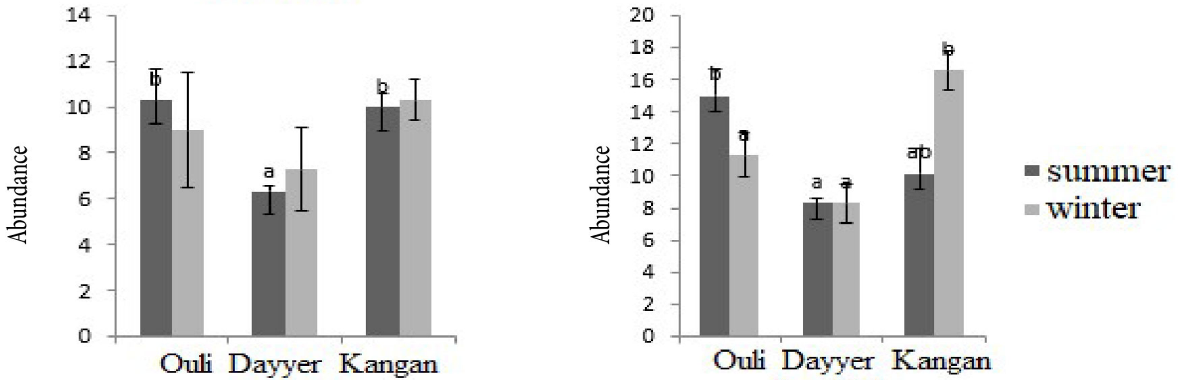
Ouli	Dayyer	Kangan	Sampling season
0.864	1.19	1	Warm season
1.652	1.32	0.0199	Cold season

Table 1: Classification of molluscan species identified in the sampling regions of Ouli, Dayyer, and Kangan in the Persian Gulf.

Phylum or Class	Order or Subclass	Family	Genus/Species
Gastropoda	Neotaenіogloss	Planaxidae	*Planaxis sulcatus* (Born, 1778)
		Cerithiidae	*Clypeomerous bifasciatus* (G. B. Sowerby II, 1855)
		Cerithiidae	*Clypeomerous* Jousseaume, 1888
			Cerithium sp. Bruguière, 1789
		Thaididae	sp.
		Muricidae	*Thais savignyi* (Deshayes, 1844)
		Naticidae	*Natica* Scopoli, 1777
		Epitoniidae	*Epitonium* Röding, 1798
		Conidae	*Conus* Linnaeus, 1758
		Coronaviridae	*Cronia* H. Adams and A. Adams, 1853
	Caenogastropoda	Plesiotrochidae	*Trochocerithium* Sacco, 1896
		Cypraeidae	*Cypraea* Linnaeus, 1758
			Naria turdus (Lamarck, 1810)
			Cypraea pulchra Gray, 1824
		Strombidae	*Conomurex decorus* (Röding, 1798)
		Potamididae	*Pirenella cingulate* (Gmelin, 1791)
	Vetigastropoda	Chilodontidae	*Euchelus* Philippi, 1847
		Turbinidae	*Turbo* Linnaeus, 1758
		Trochidae	*Trochus maculatus* Linnaeus, 1758
			Umbonium Link, 1807
			Umbonium vestiarium (Linnaeus, 1758)
		Syclostrematidae	*Cyclostrema* Marryat, 1819
		Columbellidae	sp.
	Neogastropoda	Olivoidea	*Oliva* Bruguière, 1789
		Nassariidae	*Nassarius* Duméril, 1805
	Archaeogastropoda	Phasianellidae	*Phasianella solida* (Born, 1778)
	Patellogastropoda	Nacellidae	*Cellana* H. Adams, 1869
	Chitonida	Chitonidae	*Chiton* Linnaeus, 1758
	Eumalacostraca	Porcellionidae	sp.
		Columbellidae	*Mitrella* Risso, 1826
	Neritimorpha	Neritidae	*Nerita* Linnaeus, 1758
Bivalvia	Arcoida	Arcidae	*Barbatia lacerate* (Bruguière, 1789)
			Barbatia Gray, 1842
	Lucinoida	Lucinidae	sp.
	Veneroida	Psammobiidae	*Soletellina diphos* (Linnaeus, 1771)
		Veneridae	*Protapes gallus* (Gmelin, 1791)
		Tellinidae	*Tellina* Linnaeus, 1758
	Pectinoida	Pectinidae	sp.



Supratidal **Midtidal**



Subtidal **lowtidal**

Figure 2: Graph depicting the number of mollusk species in each season in the Ouli, Dayyer, and Kangan stations, Persian Gulf.

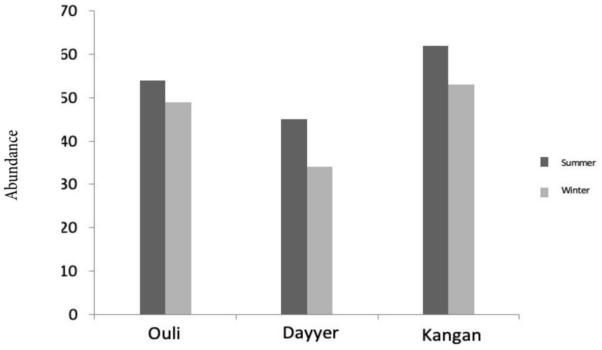


Figure 3: Comparison of the number of mollusk species in the Ouli, Dayyer, and Kangan stations in the Persian Gulf, for both seasons.

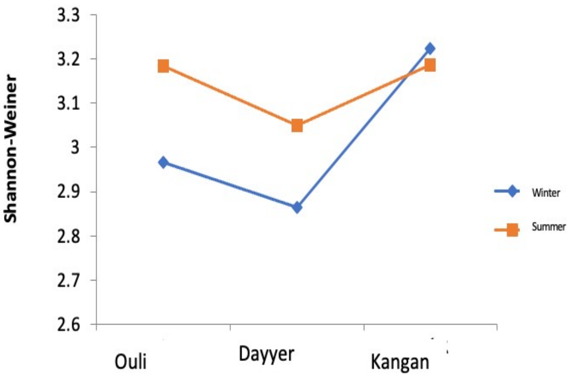


Figure 4: Graph of the Shannon–Weiner index values for both seasons in the Ouli, Dayyer, and Kangan stations, Persian Gulf.

Discussion

Benthic communities play a major role in the energy transfer within aquatic ecosystems, which makes their analysis a suitable criterion for the assessment of the ecological status of an aquatic ecosystem (Kosari et al., 2012). They are special animals because most show limited mobility or are sessile and are therefore directly dependent on environmental conditions. They also show clear reaction to environmental changes depending on their species-specific tolerance and sensitivity (Ferraro and Cole, 1995; Paiva, 2001; Lancellotti and Stotz, 2004).

In general, with regard to the findings in the literature (e.g., Vazirizadeh, 1997) it can be claimed that factors such as salinity, water currents, depth, and pollutants are some of the most significant factors contributing to the density and distribution of macrobenthic populations in tropical and subtropical regions, including the Persian Gulf and the Sea of Oman (Nabavi et al., 2011; Salehi et al., 2015). The presence of macrobenthic populations all year round can be attributed to their resistance to harsh environmental conditions as well as their long life cycles (Faghihnezhad et al., 2019). However, in accordance with the findings of Salehi et al. (2015), the absence of some representatives of macrobenthic communities can be attributed to their short life spans (Salehi et al., 2015). Vazirizadeh (1997) stated that differences in environmental conditions (food quantity, seabed type, physical and chemical conditions of the habitat), as well as biological variation (competition, predation, etc.) can cause differences in density and abundance among macrobenthic populations, and that populations with higher environmental adaptation will naturally have a greater ability to increase their range and numbers.

The results of this study show that the species diversity of benthic species was higher in the cold season in comparison to the warm season, which is in accordance with the findings of Faghihnezhad et al. (2019). Our statistical analysis revealed that there was a significant difference between the degree of abundance observed in the cold season and that of the warm season. The result of this study indicates an increase in the total number of species and individuals in winter season, which characteristically has the lowest seasonal temperatures and highest rainfall. The reason for this variation may be related to the change in the temperature, rain, or other environmental factors that remain to be studied. Price (1982) and Sheppard et al. (1992) noted that environmental conditions in the Persian Gulf are known to depress species richness and may be more critical. Extreme levels of salinity and temperature have pronounced effects on physiological aspects of marine organisms as well as the diversity, abundance, and spatial distribution of marine organisms (Breitburg and Riedel, 2005). During the sampling seasons, the density of bivalve and gastropod species showed many fluctuations. Fluctuations in abundance may be a result of variation in reproduction rates (Nabavi et al., 2011). According to Bouchet et al. (2003), nutrient shortages or increases in energy expenditure resulting from environmental stressors, such as fluctuations in temperature or salinity, lack of oxygen, and changes in food quantity and quality can lead to decreased oviposition or an inability to oviposit.

In the present study, the highest degree of abundance was observed in the warm season. Conversely, Soleimani Rad et al. (2011) in their ecological analysis of macrobenthic populations in the protected region of Khoor-E-Gabrik in the City of Jask (situated by the Sea of Oman) showed that the abundance and diversity of these populations decreased in the warmer seasons and that the most important contributing factor had been the rise in temperatures. This was also confirmed by an earlier study by Vazirizadeh (1997). In addition, Abowei et al. (2014), who analyzed the effects of water pollution on the benthic macrofauna of the Koluma region in Nigeria, stated that the diversity of benthic macroinvertebrates in the regions under study was generally low, which was attributed to the low tolerance of these species to water pollution. This contrasted with the predominance of opportunistic species, such as polychaetes, which are often an indicator of pollution in brackish waters, and this can be attributed to their level of tolerance to pollution (Lancellotti and Stotz, 2004).

Conclusion

While the results from the species diversity index reflected positive baseline data at the three beaches, it is notable that only the classes Gastropoda and Bivalvia (Phylum Mollusca) were identified. Organisms from other phyla may have been present but could be absent during the time or location of sampling. In order to have a better idea prior to any coastal development, further species diversity assessment during an environmental impact assessment is required. It is also recommended that, as the species diversity varies between seasons, wise logistic planning of sampling times should be taken into account so that more information can be captured. Wise decision making can ensure that the community and its ecosystem are least impacted while allowing sustainable development to take place.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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