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Ecological study of two sea cucumbers (*Holothuria parva* and *Holothuria arenicola*) in the Hormozgan and Bushehr provinces of Persian Gulf

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Abstract

The understanding of the distribution and population structure of the various species in the marine environment is very helpful to effectual resource management and conservation. This study aimed to assess ecological factors relating to sea cucumber populations on the rocky shores of the Persian Gulf. Population of two species of sea cucumber were investigated along 6 intertidal rocky sites, including Deylam, Bushehr, Dayer, Nayband, Bostaneh, and Lengeh in Bushehr and Hormozgan Provinces. During the period of the sampling, no sea cucumbers were observed in Deylam and Lengeh stations. To address this, 500 individuals of sea cucumber were collected and transported from their natural habitat to the laboratory. During the whole study, two species were observed (*Holothuria parva* and *Holothuria arenicola*). The Highest abundance were obtained at the stations of Dayer (198 individuals) and Bostaneh (188 individuals). The maximum density (individuals per 200 m^2) was estimated for Dayer (49.5 ± 6.13) and Bostaneh (47 ± 8.79). The results of the study revealed a negative allometric growth for both species. The results showed that different ecological indices of sea cucumbers community in the study areas affected by physicochemical parameters such as pH, temperature, salinity and possibly lack of correct management in order to enforce more protective approaches relating to these animals.

Keywords:

Sea Cucumber, Biodiversity, Northern Persian Gulf, *Holothuria parva*, *Holothuria arenicola*, Iran Waters

Article history:

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Introduction

Coastal marine environments have great economic significance because they made fishing opportunities, recreation and other services. There is little knowledge about the biogeographical patterns of coastal marine species such as sea cucumbers, that the coasts of the Persian Gulf are no exception regarding the lack of data (Höpner et al., 2000; Blanchette et al., 2008). In order to the proper ecological management of the environment, an ecologist should have proper knowledge about different ecosystems to achieve that it requires sufficient information about the nature and functioning of the ecosystem (Jacobs, 1975).

Echinodermata (thorn-skinned), with about 7000 living species and 13,000 fossil species are proper creatures for environmental monitoring in both laboratory and ecological purposes (Pawson, 2007). These animals are sensitive to environmental changes and are considered as a densely populated in the coastal and shallow water of marine environments, benthic ecosystems (Izsak et al., 2002; Uthicke et al., 2009). These species are the main members of the food chain in the moderate and coral reef environment and play an important role in aquatic milieus. Furthermore, the eggs and larvae of these organisms are considered as an important source of food for other marine animals (Bruckner et al., 2003).

Sea cucumbers (Holothuroidea), as an abundant, diverse group of marine invertebrates, are fascinating and commercially valuable species. They are distributed in various marine ecosystems such as rocky, muddy, and sandy flats and are funded in the shore to the greatest depths (Conand, 1990; Preston, 1993). About 1717 of Holothurian species have been identified worldwide on the seafloor (Paulay, 2014). Sea cucumbers use of tentacles around the mouth to collect food (Moussa et al., 2018).

Holothuria parva is brownish in colour and lighter colour in ventral side and ventral mouth and its habitat is rocky shores in the intertidal zone, as the individuals was usually hidden under stones (Pauly, 1984). Mouth of this species is located in abdominal position, and anus is terminal type (Salari-Aliabadi & Monjezi-Veysi, 2020). *Holothuria arenicola* is usually filthy white, but sometimes has been observed in the yellow and red colores, and on the dorsal body surface two rowes of black spotes can be seen. Another characteristics of this species is medium size, cylindrical shape body with two narrow end, central mouth and termalinal or submiterminal anus. Calcareous rings are relatively larg and thick, and length of radius are more than plates between the radius (Moussa et al., 2018). The species is mostly distributed in the Western Indian Ocean, Red Sea, Persian Gulf, the Maldives, Bay of Bengal and Hawaii. (Salari-Aliabadi & Monjezi-Veysi, 2020).

Over the past two decades due to the nutritional value of many sea cucumber species and high demand in world markets (especially in the Asian continent for its delicacy), severe overharvesting of some commercially important species was observed (Conand et al., 2006; Kinch et al., 2008; Conand, 2008) . Overexploitation of this animal can be considered as a worldwide phenomenon (Conand, 2008). In addition to useful nutritional properties, sea cucumbers display to having many useful properties such as antiviral, anti-tumor, anti-cancer and helpful to antifertility, and find useful in the pharmaceutical industry (Conand, 1990).

Study on body length-weight relationship (*LWRs*) of marine organisms provides useful data for fishery management (Pauly, 1983) and this data has very a key role in biological science especially in fisheries studies (Haimovici & Velasco, 2000). Although LWRs information for most fish species is available (Froese & Pauly, 2016), but they are not as readily available for aquatic invertebrate organisms such as sea cucumbers.

Condition factor is a very helpful index to investigate the well-being or relative fatness of an animal and the status of the aquatic ecosystem (Cren, 1951). Although, other studies have documented the coefficients and condition factor of multispecies sea cucumber (Sang, 1990; Purcell & Tekanene, 2006; Purcell et al., 2009; Kazanidis et al., 2010; Hannah et al., 2012; Steven et al., 2013; Poot-Salazar et al., 2014; Natan et al., 2015; Prescott et al., 2015; Aydın, 2016; Ram et al., 2016; Ahmed et al., 2018), these data are not enough as well as unknown for many species and supplemental researches are needed.

On the one hand, there are few studies related to the identification of holothurians in the Persian Gulf, which are often limited to the same considerations (Heding, 1940; Price, 1981; Dabbagh & Kamrani, 2011; Dabbagh & Keshavarz, 2011; Dabbagh et al., 2012; Salarzadeh et al., 2013). In the present study focused mainly on Holothuroidea of the western and eastern parts of the Persian Gulf. Accordingly, the objectives of the present study were to evaluate ecological conditions conducted to the two sea cucumbers in the Northern coasts of the Persian Gulf.

Materials and Method

Study area and sampling

This study was carried out at six sampling stations in the intertidal zone of rocky shores on the North coast of the Persian Gulf, including Deylam, Bushehr, Dayer, and Nayband in Bushehr Province, and Bostaneh and Lengeh in Hormozgan Province (Fig. 1). Because of the different tidal zone in the studied stations, the extent and number of quadrates were considered as the sampling criteria in our designed sampling protocol. Sampling was carried out seasonally by quadrat (10×20 m^2) and individuals collection on each transect (Conand et al., 2005).

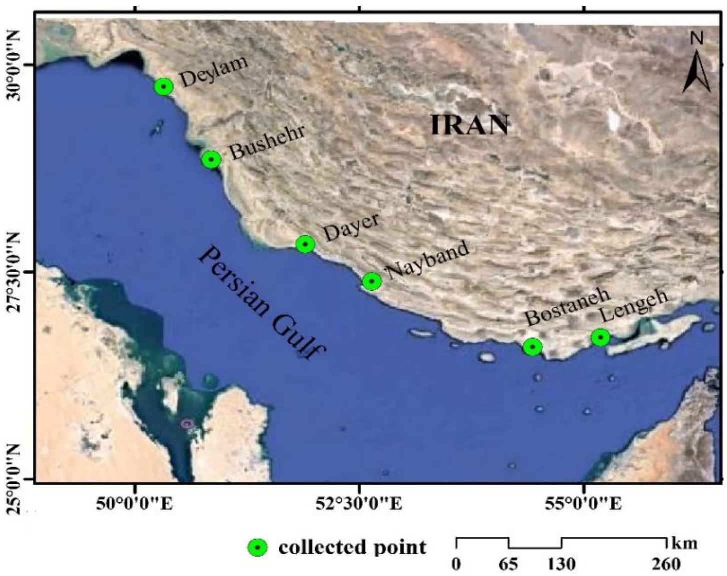

Figure 1. The location of the sampling sites of *Holothuria* individuals in the rocky shores of the Persian Gulf, Iran.

Sea cucumbers sampling was undertaken at low tide in the intertidal zone by time survey while two persons were walking in an area approximately 200 m wide at each locality. After sampling, the valid identification keys were used to identifying the sea cucumber species (Conand C., 1993; Samyn Y., 2006).

Diversity indices

Two equations were applied to calculation diversity as follow:

1. The Simpson index (Dominance index): is a dominance index because it gives more weight to common or dominant species (Simpson, 1949).

$$\mathrm{D} = \sum \frac{\mathrm{n_i}(\mathrm{n_i} - 1)}{\mathrm{N}(\mathrm{N} - 1)}$$

Information: D: dominant index of Simpson, n: the total number of organisms of a particular species, N: the total number of organisms of all species

2. The Shannon index: is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled (Shannon & Weaver, 1949).

$$H' = -\sum_{i=1}^{s} p_i \, ln \, p_i$$

In this index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Measurement of species richness: Margalef's index was used as a simple measure of species richness (Margalef, 1958).

$$\mathrm{d} = \frac{(\mathrm{S} - 1)}{\ln(\mathrm{N})}$$

d= Margalef dominance index
S = total number of species
N = total number of individuals in the sample
ln = natural logarithm

Measurement of evenness: For calculating the evenness of species, the Pielou's Evenness Index (e) was used (Pielou, 1966).

$$\mathrm{J'} = \frac{\mathrm{H'}}{\log_2 \mathrm{S}}$$

J'= Pielou's Evenness Index
H' = Shannon – Wiener diversity index
S = total number of species in the sample

Condition factor (K): Fulton's condition factor (K) was calculated using the $K = 100W/L^3$ (Pauly, 1983);

Where, K = condition factor, W = total body weight (g), L = total body length (cm).

This index describes how different is the weight of a given individual from the expected value calculated for the entire population.

Length-weight relationship

The length-weight relationships (LWRs) were determined by the method of least squares using the equation $W = aL^b$ (Wang et al., 2012), where "*W*" was the weight of the samples in gram and "*L*" the length of the samples in centimeter, "*a*" parameter is the intercept and "*b*" parameter is the slope.

The value of b from the power function equation was tested and used to determine growth patterns of the sea cucumber (i.e. isometric growth (b=3) or allometric growth (b≠3) by using the Students t-test (Pauly, 1984). The coefficient of determination (R^2), that is, the degree of relation between the length and weight, was computed by linear regression analysis.

Physico-chemical factors

To an investigation of Chemical factors of habitat during the whole period of the study, four parameters including pH, dissolved oxygen (DO), temperature (T), and salinity (S) were measured (using portable multimeter WTW 350i, Germany).

Results

Water quality factors were measured in three replicates at each station. The heaviest mean values of DO (13.78 mg/L), Temperature (39.4 °C), Salinity (45.5 ppt) and pH (8.99) were detected in Dayer (winter), Nayband (summer), Deylam (Spring) and Nayband (winter), respectively (Table 1).

Table 1. Mean values of measured parameters of habitat during different seasons for *Holothuria* species in the rocky shores of the Persian Gulf.

Seasons	Station	pH	DO (mg/L)	Temperature °C	Salinity (ppt)
Spring	Deylam	8.33	7.94	32.1	45.5
	Bushehr	8.45	10.76	30.8	43.8
	Dayer	8.67	9.54	29.2	43.8
	Nayband	8.76	12.63	35.2	43.9
	Bostaneh	8.33	13.65	34.6	41.6
	Lengeh	8.63	9.89	33.7	40.8
Summer	Deylam	8.26	6.40	36.5	43.2
	Bushehr	8.57	5.88	33.6	42.9
	Dayer	8.61	9.86	37.6	41.3
	Nayband	8.79	13.45	39.4	43.4
	Bostaneh	8.19	11.45	37.4	40.3
	Lengeh	8.24	10.42	38.3	40.1
Fall	Deylam	8.44	9.80	26.9	41.5
	Bushehr	8.65	8.88	23.8	43.9
	Dayer	8.78	11.86	27.4	42.3

	Nayband	8.83	13.45	28.4	42.5
	Bostaneh	8.53	12.41	28.9	41.3
	Lengeh	8.87	11.42	29.3	42.1
Winter	Deylam	8.32	9.55	24.8	41.8
	Bushehr	8.36	9.34	21.6	43.7
	Dayer	8.88	13.78	25.7	42.3
	Nayband	8.99	12.45	27.6	43.6
	Bostaneh	8.37	11.41	28.4	41.5
	Lengeh	8.69	12.55	26.5	42.8

Species richness and species abundance

Five hundred individulas of sea cucumbers of two species (mean weight 24.38 ± 0.82 g and mean length 9.99 ± 0.14 cm) were collected from the intertidal rocky coasts of the Northern Persian Gulf. The number of counting individuals shows that the highest number of sea cucumbers was observed in the fall (2-7 June) and summer (16-20 Agust) 2012 (139 individuals) and the lowest number was in the winter 2012 (86 individuals).

The collected individulas were identified as two species, namely *Holothuria parva* Krauss, 1885 and *Holothuria arenicola* Semper, 1868 (Fig. 2). In the whole sample collection period, we not found sea cucumbers in both Deylam and Lengeh sites.

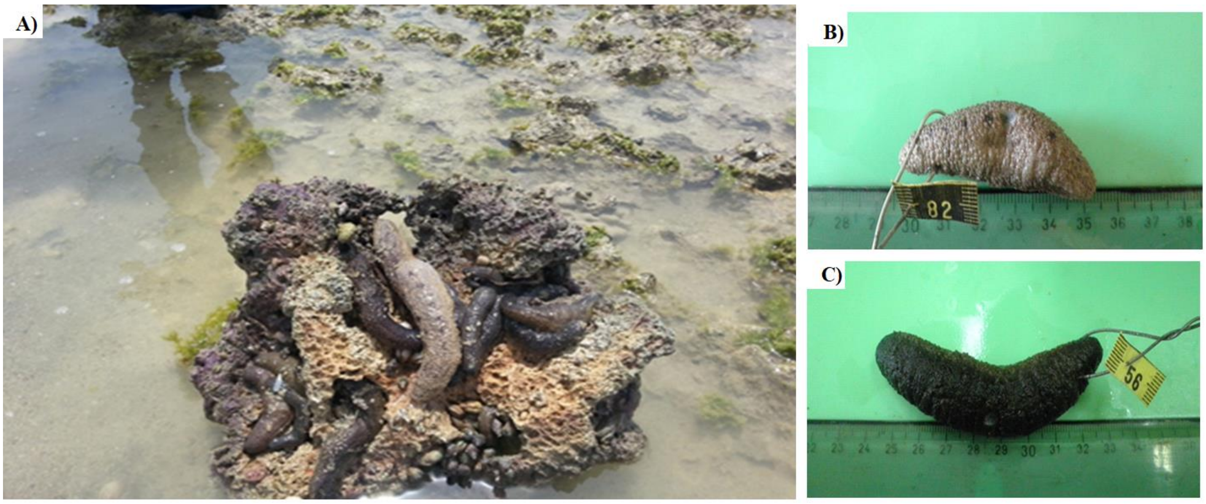

Figure 2. A: Sea cucumbers community (A) on the intertidal rocky shore in the Persian Gulf (Dayer station). Photos were taken by the authors, Bushehr Province, Iran. 2012. B and C are the pictures of *Holothuria arenicola* and *Holothuria parva*, respectively.

Mean values of abundance for *H. parva* and *H. arenicola* were estimated 18.54 individulas /200 m^2 and 2.29 individuals /200 m^2, respectively (Table 2).

Table 2. Average values relating to the abundance of *H. parva* and *H. arenicola* on intertidal rocky shores of the Northern Persian Gulf during the study period.

Station	Species	Spring	Summer	Fall	Winter	Total
Deylam	*H. parva*	0	0	0	0	0
	H. arenicola	0	0	0	0	0
Bushehr	*H. parva*	12	15	22	0	49
	H. arenicola	1	2	2	1	6
Dayer	*H. parva*	54	47	38	41	180
	H. arenicola	4	3	7	4	18
Nayband	*H. parva*	17	13	15	0	45
	H. arenicola	5	2	4	3	14
Bostaneh	*H. parva*	37	55	47	32	171
	H. arenicola	6	2	4	4	17
Lengeh	*H. parva*	0	0	0	0	0
	H. arenicola	0	0	0	0	0
Total		136	139	139	86	500

Evaluation of the trends of abundance changes illustrates the highest abundance of *H. parva* in the fall, there was no significant difference between seasons (Tukey, $p > 0.05$). Also, there was no significant difference for *H. arenicola* (Mann-Whitney, $p > 0.05$) during the various seasons, with the most abundance recorded in the summer. Besides, *H. parva* showed the more abundant in compared to *H. arenicola*.

Distribution

The study of the distribution pattern in different study areas showed that *H. parva* has a uniform distribution throughout the year in the stations of Dayer and Bostaneh (Tukey, $p > 0.05$). There was no significantly difference (Mann-Whitney, $p > 0.05$) distribution of *H. arenicola* in different seasons (Fig. 3).

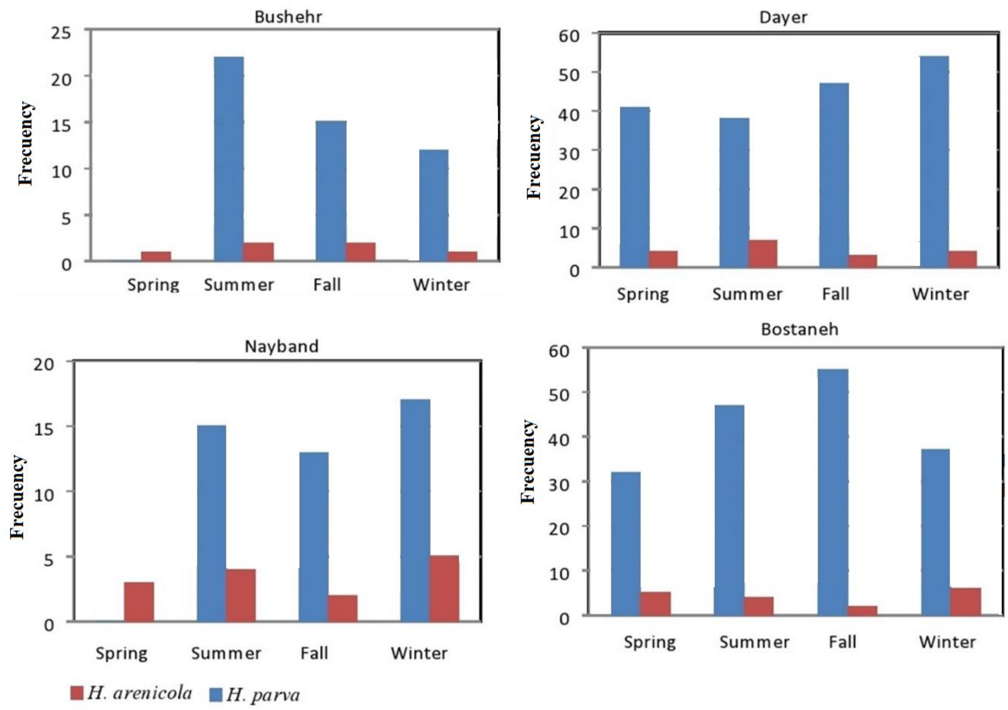

Figure 3. The frequency of occurence of *H. parva* and *H. arenicola* in intertidal rocky shores of the Northern Persian Gulf during the different seasons.

Density

The mean density of both species in the four stations of Bushehr, Dayer , Nayband , and Bostaneh were 13.75 ± 9.63, 49.5 ± 6.13, 14.75 ± 8.34 and 47 ± 8.79 (individuals per 200 m^2), respectively. The assessment of density in Dayer and Bostaneh did not show significant difference between various seasons (ANOVA, $p>0.05$).

Margalef species richness

The average of Margalef species richness index was estimated 0.203, 0.202, 0.224 and 0.160 in spring, summer, and fall, winter, respectively. Based on the results did not detect significant difference between different seasons (Tukey HSD, $P>0.05$). According to the obtained results, the highest species richness was in Bushehr and Nayband in the summer.

Shannon diversity index

The mean value of diversity according to this index were obtained 0.497 (spring), 0.313 (summer), 0.513 (C) and 0.579 (winter). Kruskal-Wallis did not show significant difference in different seasons ($P>0.05$). This investigation revealed that the highest diversity was in winter and the least was to summer.

Pielou's Evenness Index

The average values of the Pielou index in the spring, summer; fall and winter were determined 0.522, 0.346, 0.535 and 0.612, respectively. The Kruskal-Wallis test was performed to investigate the Evenness Index about different seasons, which did not observe significant differences (P>0.05). The heaviest value of this index founded in winter and the fewest was in summer.

Simpson dominance index

A widely used dominance index is Simpson's diversity index. The results obtained from data analyzed about this index showed in all of the seasons no significant difference (Kruskal-Wallis, P>0.05). The mean value were estimated 0.198 (spring), 0.109 (summer), 0.205 (fall) and 0.242 (winter). The maximum value of the dominance index was obtained in winter (Dayer) and the maximum was in summer (Nayband).

Condition factor

The mean value of condition factor (K) was estimated for *H. parva* 1.05±0.01, with a minimum average in spring (0.31) and a maximum average in summer (2.52). There are significant differences in the K values among different seasons (ANOVA, P<0.05). The average value of the condition factor was obtained for *H. arenicola* 1.08±0.06. The least and highest average were estimated 0.21 and 2.34 during all seasons. No statistical differences were detected in the *K* values among seasons (ANOVA, P<0.05). *K* index present a similar rate in various lengths of both *H. parva* and *H. arenicola*.

Length-weight relationship

The sampled population of *H. parva* display a mean length value 9.99 ± 0.14 cm and a mean value 24.38 ± 0.82 g for weight. The mean vales of length and weight for *H. arenicola* were 11.43 ± 0.72 and 38.20 ± 3.34, respectively. The length-weight relationship plots (Fig. 4) evidenced that the "*b*" value for *H. parva* and *H. arenicola* species are 1.99 and 1.88, respectively. In terms of type of growth, scaling exponent's b were significantly smaller than 3, indicating a negative allometric growth pattern for both species. Point of view length, studied species demonstrated no significant difference, but in term of weight shown significant difference (Mann-Whitney, P > 0.05).

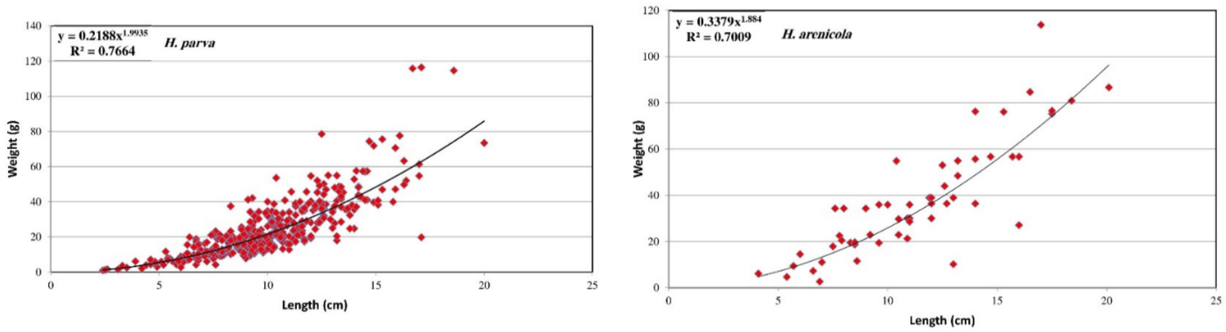

Figure 5. Length-weight relationship (LWRs) of *H. parva* and H. *arenicola*.

Discussion

Seabed characteristics, light intensity, energy levels, food availability, fluctuations in salinity and the presence of predator or adults are among the major variables that affect the distribution of sea cucumbers community (Mercier et al., 2000). The highest diversity and density of sea cucumbers in tidal zones and rocky coasts have been reported (Dissanayake & Stefansson, 2010). Rocky shores provide a suitable environment for living these animals, as well as protecting them against predators, waves and currents (Seaman, 2002; Dissanayake & Stefansson, 2010). There are several expansive coastal areas in Iran, such as the Persian Gulf, that in most coastal cities can find some species of holothurians. The first study on holothurians carried out by Heding, (1940) in which recorded 17 species sea cucumbers in the Iranian water of the Persian Gulf. In this study, a total of five hundred individuals belonging to two species of the Holothuroidea family were collected. During the period of the sampling, no sea cucumbers were observed in Deylam and Lengeh stations. Previous studies has shown that the type of substrate (such as bed materials, sdiment grain size and bed slope) is the factor affecting the community structure of macro-epiphytic echinoderms and the number of species (Ellis & Rogers, 2000; Mercier et al., 2000). Therefore, it can be concluded that the high slope of the coast as well as the topography (geomorphological characteristics) of Deylam and Lengeh stations may be effective factors in the absence of sea cucumbers.

Environmental factors can affect marine invertebrates such as sea cucumber. These parameters can change some biological processes such as gametogenesis and spawning in marine invertebrates animals (Giese et al., 1974; Todd & Doyle, 1981). One of the most important factors that affect the distribution of sea cucumbers is pH of seawater (Mitchell et al., 1988). Asha and Muthiah (2005) reported the effect of pH on sea cucumbers larvae *Holothuria spinifera* (Asha & Muthiah, 2005). Thus, pH fluctuations can affect the community structure of sea cucumbers. In the present study, no significant differences in pH values in different seasons was observed (Kruskal-Wallis $P< 0.05$). Temperature and salinity are two important non-biological factors that influence the growth and survival of aquatic organisms (Hu et al., 2010; Li & Li, 2010). Lawson, (1995) detected that changes in water physicochemical parameters such as temperature (T) and salinity can affect other factors as DO, $CO2$, $NH3/NH4$ and pH (Lawson, 1995). It is probably that even slight changes in salinity cause serious impacts on the reproduction of sea cucumbers. Dong et al. (2008) introduced that changing in the water quality factors lead to changing in coelomic body fluid osmotic pressure, in the bodies of sea cucumbers (Dong et al., 2008). Temperature as a physical water quality parameter has a direct and controlling effect on organisms and their activities, while salinity indirectly affects physiological traits such as metabolism, growth, life cycle, nutrition (Kinne, 1971). Previous studies have shown that excessive temperature tolerance changes can cause thermal stress in sea cucumbers in them (Hofmann & Somero, 1995; Helmuth & Hofmann, 2001). These thermal stresses significantly affect enzymatic activities (Hardewig et al., 2004) and some other physiological activities such as the antioxidant defense of organisms (Portner, 2002). In addition, thermal stress can indirectly alter the energy metabolism, growth, and reproduction of aquatic organisms by altering some proteins (Krebs & Loeschcke, 1994), and may reduce the adaptability of organisms. In the present study, the annual temperature variations of the study sites show that this parameter in fall and winter decrease dramatically, then increases in spring and a maximum in summer.

Density variations in observed species are influenced by various factors such as reproductive success. In numerous species of sea cucumbers has proven that various physiochemical factors including water temperature (Toral-Granda & Martínez, 2007), dark/light period (Foster & Hodgson, 1995), salinity (Harriott, 1985) and fresh water runoff (Hamel & Mercier, 1995) involved in reproduction and spawning. Reduction in spawning or inability to spawning can be due to food shortages or increased energy consumption for stress-induced metabolic processes and environmental conditions such as salinity and temperature fluctuations, oxygen depletion, and changes in food quantity and quality (Bochert et al., 1996). In numerous species of sea cucumbers have been proven that various physiochemical factors such as water temperature (Toral-Granda & Martínez, 2007), light/dark period (Foster & Hodgson, 1995), salinity (Harriott, 1985) and fresh water runoff (Hamel & Mercier, 1995) are effective in reproduction and spawning. According to the results of statistical analysis, the density variations were not significantly different between the study seasons, while between stations in each season, Dayer station show a significant difference from the others and always had the highest density. Similarly, a study on the sea cucumbers of the genus Holothuria in Brazilian waters detected no significant changes in density between seasons (Mendes et al., 2006).

Because variety of reasons such as specific morphological characteristics and high flexibility, is somewhat difficult to perform biometric process for sea cucumbers. Pauly (1983) revealed that if b=3, growth pattern is isometric where body length increment is proportionate to body weight increment. If it is greater than 3, the growth is positive allometric and if it is lower than 3, the marine organism exhibits negative allometric growth, so, the species grows pattern are allometric. Veronika et al. (2018) reported that the “*b*” values of *H. spinifera*, *B. marmorata*, *S. naso* and *H. atra* were 1.887, 1.108, 1.021, and 1.223, respectively, and showed that the growth patterns of these species are negative allometric (Veronika et al., 2018). The investigation LWRs for *Holothuria tubulosa* (Bulteel et al., 1992) and *Holothuria scabra* (Al-Rashdi et al., 2007) show allometric growth rates. Similarly, in our study the "*b*" values were 1.99 and 1.88 for *H. parva* and *H. arenicola*, respectively, so the growth pattern of these were negative allometric, too. In studied Samples, condition factor (*K*) values for *H. parva* and *H. arenicola*, was 1.05±0.01 and 1.08±0.06, respectively. Slightly, Veronika et al. (2018) reported a mean condition factor greater than 1 for four species *H. spinifera* (3.89±1.03), *B. marmorata* (4.12±2.21), *S. naso* (3.558±1.73) and *H. atra* (2.688±1.34), that this illustrates a suitable nutritional condition in all four sea cucumbers species (Cone, 1989).

This work was an attempt to introduce some aspects of the biodiversity of sea cucumber fauna on the Northern coasts at different seasons in the Persian Gulf. The results of the present study indicate that two species exist in the study areas, that it can be related to habitat conditions and due to the low depth of sampling regions. This study has provided essential data on LWRs for *H. parva* and *H. arenicola*, such information is necessary for sustainable management of sea cucumber resources. Since our study is not comprehensive, it is essential to consider length- weight relationships of male and female should be consider in the future studies.

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Author Contributions

All author contributions are equal for the preparation research in the manuscript.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Conflict of Interest

The authors declare that they have no conflict of interest.

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