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Ecological Features of Oyster Beds Distribution in Qatari Waters, Arabian Gulf

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Abstract: The aims of the present investigation were to study the feature of biotic environment of oyster beds and to study quantitatively the biodiversity of fauna and flora living within these habitats. Eighteen selected oyster beds, within the Exclusive Economic Zone of Qatar were investigated by scuba diving. Most of the oyster beds were found in the area with sandy-rocky and Coral blocks bottom forms. Pearl oysters abundance varied widely between the different beds and within the same beds due to the variations in the bottom substrates. The associated biota was composed maiuly of Algae (4%), Porifera (3%), Cnidaria (8%), Polychaeta (4%), Echinodermata (13%), Mollusca (55%), Chordate (2%) and Crustacean (11%). The comparison of our findings on the occurrence and distribution of marine biota to previous studies has shown similarities between Qatar and other Gulf States particularly Saudi Arabia and Bahrain.

Key words: Oyster beds, abundance, community structure, Arabian Gulf, Qatar

INTRODUCTION

The Pearl oyster *Pinctada radiata* forms enormous beds in the western side of Arabian Gulf extending from the Kuwaiti coast in the north to the coast of the United Arab Emirates and Oman in the south (Somer, 2003). Qatar and other Arabian Gulf countries were endowed with a pearl oyster resource which had been exploited for natural pearls from time immemorial and had depended on its main economic resources.

The pearl oyster fishing industry in the Arabian Gulf declined with the development of cultured pearls in Japan during the 1930 and with the discovery of oil in the Gulf countries (Al-Matar *et al*., 1993; Somer, 2003; Mohammed, 1994; Al-Khayat and Al-Maslamani, 2001; Kimani and Mavuti, 2002; Mohammed and Yassien, 2003) have contributed much to our knowledge of the pearl oyster fishing industry and fouling in the pearl oyster beds, besides some valuable information on the anatomy, reproduction biology and growth of *P. radiata* in the Arabian Gulf. However, observations on the associated biota, their distributional abundance, the topographical features and general ecology as well as community structure of the pearl oysters and their habitat conditions of the oyster beds were either rarely considered or remain unknown. However, the genetics and taxonomy (Khamdan, 1988) and the morphometric characters (Al-Sayed *et al*., 1993; Al-Sayed, 1995; Mohammed, 1994, 1995) were studied in Kuwait, Bahrain and Qatari waters.

The fundamental objectives of this study were to determine the pearl oyster associated biota, abundance, distribution and compare the physical and chemical conditions within oyster beds.

MATERIALS AND METHODS

Pearl oyster beds were sampled from 18 locations by R/V Mukhtaber Al-Bihar of the University of Qatar (Fig. 1, Table 1). Each site was visited once during the period August 2002-December 2002.

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Seawater temperatures, salinity and pH measurements were carried out using a pre-calibrated water quality logging system (Model 3800 and 6690 sonde from YSI Incorporation). The Dissolved Oxygen concentration (DO) was determined by the classical Winkler method. Determinations of chlorophyll-a (phytoplankton biomass indicator) was carried out spectrophotometrically based on the acetone extraction method described by Parsons *et al*. (1984). Quantitative surveys for community assessment were carried out using SCUBA diving. A quadrate of one meter square was used to collect macro-benthic fauna from each station. The quadrate area was scooped using a hand shovel to a depth of 10 cm, sample transferred into a polythene bag and stored in ice box on board the research vessel. Samples were collected in triplicates and averaged. Additionally, dredge was used for more than 18 min on each location. Macrobenthos samples were obtained from pearl beds sites along the eastern, south

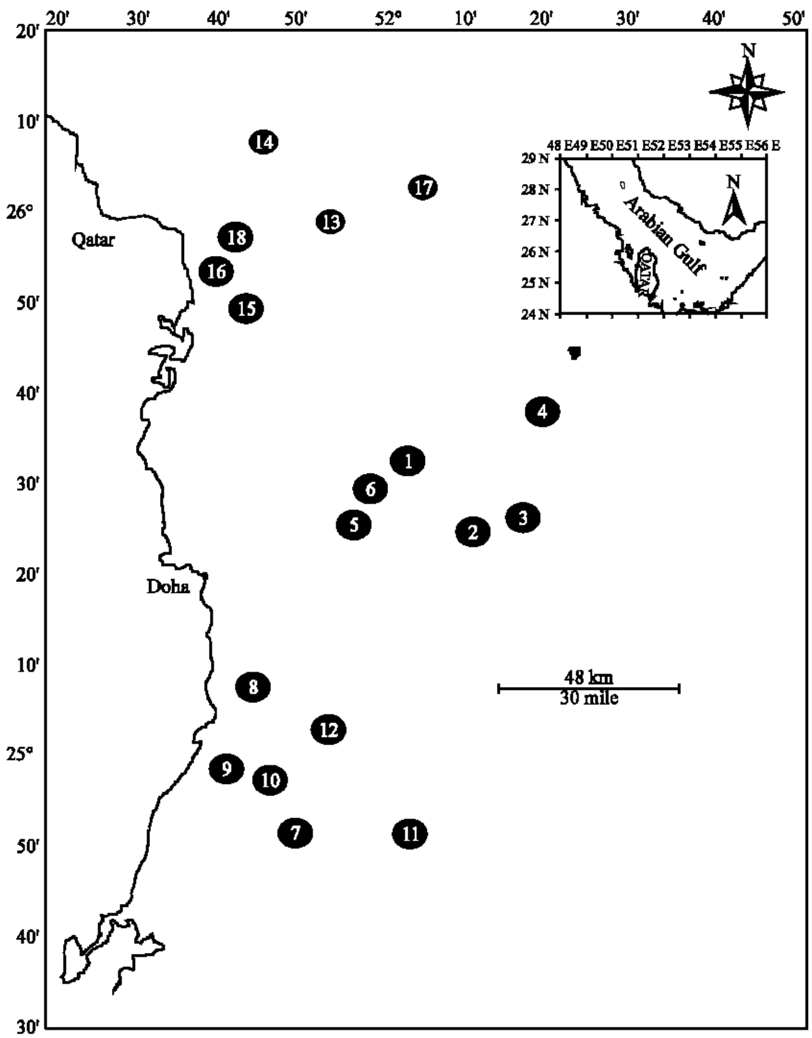

Fig. 1: Map shows the main pearl oyster beds studied in Qtari waters stations: East; 1: Al-ad Algharibi, 2: Um Khart, 3: Um Aljeteb, 4: Hadet Migbel, 5: Um Alotteam, 6: Khrayes; South: 7: Alhadid, 8: Tunob, 9: Botheal, 10: Bokombarah, 11: Halat Delma, 12: Um Alshwahin; North: 13: Belhwnbar, 14: Um Shaif, 15: Alhawad, 16: Alri`a, 17: Niwat Adam, 18: Um Aljesh

Table 1: Hydro-chemical parameters of the pearl oyster beds in Qatari waters

Station	Depth (m)	Temp. (°C)	Salinity (psu)	pH	DO^2 (mg L^{-1})	Chl-a (μg L^{-1})
East						
Al-ad Algharibi	16.5	33.85±0.68	41.18±1	8.35±0.06	3.82±0.16	0.06±0.01
Um Khart	16	34.20±1.02	41.33±1	8.34±0.09	3.73±0.82	0.06±0.01
Um Aljeteb	13	33.88±0.97	40.83±1	8.37±0.03	3.88±0.47	0.07±0.02
Hadet Migbel	N R	NR	NR	NR	NR	NR
Um Alotteam	19	33.90±1.08	41.60±1	8.36±0.07	4.29±0.52	0.03±0.01
Khrayes	13	33.98±1.00	41.43±1	8.36±0.02	4.00±0.63	0.07±0.01
South						
Alhadid	10	35.03±1.06	42.90±1	8.35±0.12	4.33±0.14	0.09±0.02
Tunob	10	35.30±0.90	43.47±1	8.35±0.02	4.17±0.64	0.17±0.04
Botheal	13	35.30±0.75	44.40±1	8.35±0.09	3.77±0.18	0.23±0.01
Bokombarah	13	34.93±0.93	44.53±1	8.33±0.07	3.59±0.35	0.19±0.01
Halat Delma	15	34.80±0.97	43.03±1	8.36±0.03	3.99±0.23	0.10±0.01
UmAlshwahin	12	NR	NR	NR	NR	NR
North						
Belhenbar	NR	NR	NR	NR	NR	NR
Um Shaif	15	28.95±1.13	40.08±1	8.47±0.01	4.28±0.15	NR
Alhawad	12	29.20±1.12	41.0±1	8.46±0.08	4.42±0.74	0.12±0.03
Alri`a	8	28.20±1.08	41.0±1	8.45±0.05	4.34±0.91	NR
Niwat Adam	22	29.56±1.08	39.50±1	8.47±0.01	4.61±0.11	0.09±0.02
Um Aljesh	9	27.95±1.11	41.15±1	8.46±0.08	4.60±0.32	NR

eastern coast of Qatar. Samples were sieved through 0.5 mm mesh sieve and retained specimens swere preserved in 5% buffered formalin in seawater. In the laboratory, the macrofauna and Algae were sorted according to their taxonomic rank and identified to the genus level. On each site, under water video and close up photographs were taken for the oyster beds and their associated living organisms.

Species diversity was determined following Shannon and Weaver Diversity Index (1963). Principal Component Analysis (PCA) was performed for all of the obtained data (depth, temperature, salinity, pH, dissolved oxygen, chlorophyll-a, Algae, Porifera, Corals, Polychaeta, Crustacea, Mollusca, Ascidiacea, Echinodermata and total species number) using SYSTAT® 10.2 for Windows. It was carried out to evaluate the effect of some physical/chemical parameters of sea water at different stations of oyster's beds on the benthic fauna and Algae abundance and the inter-relationship among benthic fauna and Algae species along the Qatari coast (Table 1).

RESULTS

Hydro-Chemical Parameters

The hydrochemical data obtained during the period of sampling covered the following parameters, water temperature, salinity (psu), pH, Dissolved Oxygen (DO) and chlorophyll-a.

Water temperatures recorded at different stations are shown in Table 1. The water temperature varied slightly from 33.03 to 35.30°C in August-September and from 27.95 to 29.90°C in November. The local variations in the water temperature was observed in each station has been attributed to the different time of the day during which the measurements were carried out (Table 1).

Salinity values showed little variations between northern, eastern and southern stations in August and September (Table 1). Values varied slightly from 39.50-41.15 psu in September at the northern stations and from 42.90 to 44.53 psu for the same period at the southern stations, whereas the salinity values were slightly lower (40.83-41.60 psu) in August at the eastern stations. In general, salinity values in the southern stations were usually high. This is mainly attributed to the shallowness of the area.

The pH of the study area falls on the Alkaline side. The average pH calculated for the northern stations was 8.4, as compared to 8.3 in the southern and eastern stations with no significant differences between different oyster beds or between sampling time.

The dissolved oxygen concentrations varied from 4.28-4.61 mg L^{-1} in September at the northern stations, from 3.59 to 4.33 mg L^{-1} in September at the southern stations and from 3.73 to 4.29 mg L^{-1} in August at eastern stations.

As shown from Table 1, Chlorophyll-a concentration which were mainly responsible for the increase of decrease in productivity fluctuating between 0.09 to 0.12 µg L^{-1} in the northern stations, 0.09 to 0.23 in southern stations in September and between 0.03 to 0.07 µg L^{-1} at eastern stations in August.

Depth

The pearl oyster beds were encountered at depths ranging from 2 to 36 m. The investigated oyster beds in the east of Qatar are representing about 42.9% of a mean depth of 16.42±0.8 m. The pearl oyster beds located in the north of Qatar coast represent about 38.6% with a mean depth of 13.7±0.9 m, while the oyster beds of the southern Qatari coast represent about 18.57% having a mean depth of 14.7±2.7 m (Table 1).

In Qatari waters the pearl oyster *Pinctada radiata* were found usually attached to the hard substratum such as rocks, dead Coral outcrops or sand grit encrusted with marine organisms. In few of the investigated stations, the seabed was sandy. Such substrates with no fragments do not encourage the settlement and establishment of pearl oyster communities.

Oyster Abundance

The abundance of pearl oysters in Qatari waters varied widely according to their locations (northern, southern and eastern beds) and the different substrates within the same bed. The abundance was highest (mean value of 50.0±15.4 individuals m^{-2}) at the eastern stations (Al-ad Algharibi and Um Khart), followed by the northern stations (Belhanbar and Um Aljesh) (mean values 45.0±15.4 individuals m^{-2}) and the lowest mean values of 21.7±9.0 individuals m^{-2} was observed at the southern stations (Halt Delma).

Associated Biota

In total 2443 specimens of benthic biota were collected comprising 189 species. Molluscs comprised the most abundant group with 104 species, followed by echinodermata with 25 species, Crustacea with 20 species, Coral with 12 species, Algae with 7 species, Polycheates with 7 species, Sipuncula, Actiniaria and Branchipoda with 1 species each.

The overall percentage distribution of the different biota collected from all stations indicated that the mollusks and especially gastropods and bivalves were more abundant than other fauna and the Algae groups (Fig. 2). Lower species diversity and lower number of individuals are indicative of the macrobenthos fauna and habitats response to stressful environmental conditions.

The details of the distribution and percentage of the different taxa groups and their representation at the investigated stations are summarized in three sites namely: the eastern location which consists of Station 1-6, the eastern stations which consist of station 7-12 and the northern stations which consist of stations 13-18.

Since the biota of the pearl oyster beds comprised thousands of small and large animals and plants, the study of the interrelationship among these was further complicated by the nature and density of such an assemblage. The nature of these factors have profound effects on the well being of the stock of oysters in the beds. Molluscs (gastropods and bivalves particularly), crustaceans, star fish, annelids, coelenterates and Sponges were among the dominant fauna. A luxuriant growth of different species of Algae belonging to phaeophyta and rhodophyta dominated the pearls oyster beds (Table 2).

Table 2: Checklist of the examined stations biota on the principal of presence and absence densities

	Stations																	
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Algae																		
Division: Rhodophyta																		
Sargassum sp.	*	*	*		*		*	*	*				*	*				*
Harmophysa sp.	*	*	*			*												
Padina sp.	*	*	*										*					*
Hypnea sp.	*	*	*					*					*				*	*
Liagoradistenta		*											*					
Acanthophora sp.	*	*						*					*					*
Eucheuma denticulatum			*					*										
Phylum: Porifera																		
Class: Calcarea																		
Callyspongia sp.							*											
Class: Demospongiae																		
Halichondria sp.	*	*			*	*		*					*	*				*
Cliona sp.	*	*			*	*		*					*	*				*
Gellius cf. Fibulatus								*										
Haliclona sp.	*	*	*	*	*	*	*	*	*	*	*			*				*
Hyrtios sp.			*															*
Phylum: Cnidaria (Coelenterata)																		
Class: Hydrozoa																		
Obeliathecata		*																
Obelia sp.												*	*				*	
Order: Actiniaria (Sea anemon)																		
Sagartianthus sp.	*	*		*				*	*				*	*				*
Class: Alcyonaria (Octocorals)																		
Dendronephthia sp.												*						
Class: Anthozoa																		
Acropora sp.									*									
Porites sp.		*											*					*
Favites sp.					*		*	*		*			*					*
Platygyra sp. (Braincoral)	*	*	*	*		*		*	*		*			*		*		*
Fungia sp.								*	*	*								
Montipora sp.	*			*														
Turbinaria sp.			*	*				*		*	*	*						
Juncella sp.		*		*		*			*	*	*							
Tubastraea sp.	*	*	*			*		*	*	*						*		
Caryophyllia sp.							*	*						*				
Gorgononea sp.	*	*	*		*	*	*	*					*	*	*	*	*	*
Phylum: Annelida																		
Class: Polychaeta																		
Neries sp.	8	5	9	1	1	4		2	2	1	1	1	1	1	1		3	8
Syllis sp.		1															3	
Eunice anteunata	2	13		3			2			1			1			1		
Eunice sp.	4		3	8	3		9		1		1	2		1				2
Hydroides sp.	2	1	2		9		3	1							6			1
Janua kayi	1	1	1					1					1	1	2			1
Unidentified sp.	1	3	2		1		2				1				3		1	2
Phylum: Sipuncula																		
Phascolosoma meteori			1			1												1
Class: Gastropoda																		
Chromodoris anuulata			2															
Phyllidia sp.																1		
Phasianella solida					2	1												
Terebra sp.															1			
Hastula sp.												1						
Diodora funiculata	1	1																

Table 2: Continued

Species	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Diodora rueppellii	1	1																
Trochus (*Infundibuloes*) *erithreus*						1	2											
Trochus sp.		1				1	1			0						1		
Cerithium scabridum				1	1	4	5	7	1	9	3		1					
Rhinoclavis fasciata					1					1					2			
Potamides conicus															1			
Cerithidea sp.							3											1
Turritella cochlea					1			2				15	3		1			
Turritella fultoni									3	4								
Turritella sp.								1										
Strombus (Conomurex) *persicus*				1		1				3								
Strombus sp.	1																	
Terebellum sp.							1											
Naticavitellus											5	1						
Natica sp.												1						
Vermetus sulcatus		1	1															
Hypermastus sp.											1							
Hexaplex kuesterianus			3	1	8		3			2	2	4		1	6		4	2
Thais savignyi					21		3											
Thais tissoti					33	1	10						9		3		5	
Thais sp.							3							2				2
Cronia konkaneusis	4		3	4	8		13											
Mitrella blanda	3	1		1	2	2	4	3	2	8			1					
Pisania sp.								1										
Nassarius arculariusp licatus												2						
Nassarius (Niotha) *albesceus gemmuliferus*						3					18							1
Nassarius (Niotha) *jactabundus*	1	1				2	2			7	7							
Nassarius sp.						3	3				2							
Ancilla (Sparella) *castanea*					1	3	3		1	1								
Ancilla sp.	1								1		1							
Ziba pretiosa											1							
Ziba sp.												1						
Conus sp.						1												
Conus milesi										1								
Bullaria ampulla								6	7									
Class: Scaphopoda																		
Dentalium octangulatum				1	1				1	3								
Laevidentalium longitrorsum							2	3										
Class: Amphineura																		
Chiton sp.																	1	
Class: Bivalvia																		
Hyotissa hyotis											2							
Barbatia plicata												1	5			4		
Barbatia decussata													6			2		
Barbatia parva													2				1	
Barbatia setigera						1	2											
Barbatia sp.	1															2		
Arca sp.	1	1	1															
Acar plicata				1	5	5	1											
Anadra ehrenbergi										3								
Anadra birleyana											3							
Glycymeris pectunculus maskateusis	2	1		3	8	6	6	8	3	4				1			2	
Branchiodontes sp.											2							

Table 2: Continued

	Stations																	
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Brachidontes variabilis				2	3						1							
Brachidontes sp.												1				1	3	
Modiolus ligneus					1	1												
Musculus sp.							10	6										
Pinna sp.			6								1			1				
Pinna bicolor						2								3			1	
Pinctada radiata	95	95	41	38	0	31	10	94	46	0	25	0	98	44	1	33	1	93
Pinctada sp.																10		
Malleus malleus	3				3	6	8											
Malleus sp.					7			4		2		2					12	
Malvufundus normalis					9													
Malvufundus regnla	10	10				5	16		2									
Isognomon sp.	1													6				
Chlamys sp.							2	3										
Chlamys ruschenbergerii	1		3			1	3	4							1			
Chlamys (Scaeochlamys) *livida*					4	1	3											
Chlamys senatorius													1					
Spondylus exilis				2	1		4											
Anomia sp.											1							
Lncina dentifera											2							
Chama sp.		10			9		9	7	8			3	1	7	4		1	
Chama asperella	4	12	10		2	6					12		15	9				4
Chama reflexa	17	10			2		5											
Nemocardium sp.							1											
Nemocardium aurantiacum			3		2	3												
Trachycardium lacunasum		1	1	4														
Cardium sp.					1													
Fulvia australe					2			3										
Acrosterigma maculosa		1					2											
Acrosterigma sp.					1	2												
Tellina sp.						2	2				4							
Gari maculosa					1	1												
Circenita callipyga					1													
Circe corrugata				1		9												
Circe intermedia					1	2												
Circe scripta					2	4					2							
Circe sp.						5	7											
Callista florida			2			1												
Lioconcha ornata					3	3												
Bassina calophylla								5										
Bassina foliacea								16										
Sunetta effossa								3										
Gafrarium sp.			1															
Dosinia sp.					1	2				1								
Callista florida					2													
Tapes sulcarius								8		1								
Sunetta effossa					1	1	1	1	5		1							
Corbula taiteusis					1	1	1											
Phylum: Echinodermata																		
Class: Ophiuroidea																		
Macrophiothrix sp.	1												1				1	1
Ophithrix sp.	13	1	3		2	3		3						1				
Ophithrix purpurea	2		1															
Ophithrix savignyi	1	20			3			2	2		1			1			1	1
Ophionereis dubia	4				2			3	2									
Ophionereis sp.	1														2		2	
Ophiothela venusta	1						1						3			1	1	
Ophiothela sp.	9			3								1	1					
Ophiura sp.					1	4							2				3	
Ophiocoma sp.			5															

Table 2: Continued

	Stations																	
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Class: Asteroidea																		
Pentaceraster mamillatus										1								
Pentaceraster sp.												1						
Astropecten indicus	1							1										
Astropecten sp.											1							
Asterina burtoni		1			7	4							1					
Linkia multiflora											4	1		2				
Ophidiaster sp.												1						
Class: Echinoidea																		
Echinodiscus auritus								1										
Echinometra mathaei	1	5	2		3	1		1		1		1			2			
Clypeaster humilis				2							1	1					1	
Clypeaster sp.		5		2	3				1									
Unidentified sp.	5																	
Class: Holothuroidea																		
Holothuria atra	1	1								2								1
Holothuria sp.									2					1				
Phylum: Arthropoda																		
Class: Branchiopoda																		
Gonodactylus cf. demanil	1						3		1			1						
Class: Crustacea																		
Petrolisthes sp.	2	1	3				2	1	6		1	12						
Pilumnus longicornis	1																4	1
Pilumnus sp.	1														2		6	9
Crab sp.1		1	4					1		1			1					
Crab sp.2			1															
Crab sp.3			2							1			1					
Crab sp.4		1	6															
Crab sp.5			3															
Crab sp.6			2															
Spider crab	1	1													2		3	1
Dardanus sp.	1					3	3					1	1				3	
Menaethius monoceros													2					
Alpheus lobideus														1				
Athanus sp.	1	1																
Synalpheus sp.		2																
Alpheus sp.	1	1			1			3		2		2			4	4		1
Caridean prawus												1						
Cymodoce sp.	1																	
Amphipoda sp.	5																1	
Balanus amphitrite	3	15	8	2		2	4	12		2		1		6	2			2
Phylum: Chordata																		
Class: Ascidiacia																		
Phallusia nigra	3	1	7					1				1	3	1				1
Styela canopus	1	1											1	1				
Didemnum sp.	1						1					1	1					

The Biota is Described under the Following Groups

Algae

Throughout the density of Algae on the rocky expanse and other hard substrate studied seemed to be moderate especially at the eastern stations. *Sargassum* sp. dominated most stations. Other brown Algae of the genera *Hormophysa* and *Padina* were most common at eastern stations. Among the red Algae the genus *Hypnae* was common at some of eastern stations whereas the species *Acarthophora* sp. *Liagora distenta* and *Eucheum denticulatum* were recorded at some stations (Table 2).

Sponge

The class Calcarea was represented by only one species *Callyspongia* sp. at station 7. The bread crumb sponge (*Halichondria* sp. and *Haliclona* sp.) were observed attached to rock or hard surface of dead shells and Coral at some stations, but boring Sponges (*Cliona* sp.) were rarely recorded on pearl oyster shells. Other sponge species encountered with limited distribution include *Gellius* cf. *fibulatus* and *Hyrtios* sp.

Hydroids

Hydroids mostly settle on the outer surface of lift and dead oyster shells and dead corals as well as hard surfaces. Hydroids were represented by only two species: *Obelia thecata* and *Obelia* sp., the former occurred at station 2 only and the latter was confined to stations 12, 13 and 17.

Sea Anemones

The small anemone *Sagartianthus* sp. was recorded in eight stations of the oyster beds. This species usually lives on the surfaces of hard rocks or may be attached to the rock underside.

Coral

There are two classes of Coral Alcyonaria and Anthozoa represented in oyster beds. Very small colonies of the octacoral *Dendronephthia* sp. occurred only at Station 12. The whip Coral *Cirrhipathia* sp. and the sea fan Coral *Gorgonia* sp. were recorded in different oyster beds. The Gorgonian sea fan (*Gorgonia* sp.) was found in high density at Station 2 (Umm Khart).

Reef building Coral s such as the genera *Acropora*, *Porites* and *Montipora* were found (alive or dead) in small colonies, widely dispersed in the oyster beds. Dead forms act as a good surface for settlement of the pearl oyster spat and other biofauling organisms. Other Corals Reef species of the genera *Favites*, *Platygyra*, *Fungia*, *Tubastraea* and *Turbinaria*, were found at several stations.

Polychaetes

Polycheates are common on pearl shells, dead Coral and large boulders and in substrata of oyster beds. Unidentified tube worms were found in several stations. Among the polycheates *Neries* sp., was recorded in several stations. *Eunice antennata* and *Eunice* sp. were present in 7 and 10 stations respectively. *Hydroides* sp. was represented in 8 stations and *Janua kayi* was present in 8 stations and *Syllis* sp. was only present in Stations 2 and 17.

Crustacea

The number of crustacean species was low in most stations and ranked third species in abundance (11%) in the oyster beds. However, the sample contained a considerable number of taxa belonging to the subclass Cirripidia and the orders Cumacea, Isopoda, Amphipoda and Decapoda (Caridea, Anomura and Brachyura). *Amphipoda* species was highly abundance at Station 1 and Station 17. The most dominant crustaceans species were *Peterolisthes* sp., Spider crab and *Alpheus* sp. and they were represented by 8, 5 and 9 species respectively. The barnacles *Balanus amphitrite* were also found highly abundant in the most stations of oyster beds. Other crustaceans known as fouling species were encountered in varying quantities.

Mollusca

The molluscan fauna are numerous and contributed about 55% of the recorded fauna (104 species). The most abundant groups were gastropods (41 species) and bivalves (60 species). The gastropods *Cerathium scabridum*, *Hexaplex kuesterianus*, *Thais tissoti*, *Mitrella blanda*, *Nassarius* (Niotha) *jatabunus* were dominant at station 6, 9-11.

Oyster

The oyster *Pinctada radiata* were the most dominant and present in 15 stations. Other bivalves such as *Glycymeris pectunculus maskatensis*, *Malleus malleus*, *Malleus* sp., *Malvufundus regulla*, *Chama asparella*, *Chama refexa* and *Chama* sp. were commonly found either on pearl oyster shells or vigorously attached to rock surfaces or Coral crevices or no Coral bonlders. In areas with soft substratum, the pen shell (*Pinna* sp.) were found in few stations and with low numbers. These were rooted deeply with their siphones protruding above the bottom surface filtering water. Amphineura was represented by 1 species (*Chiton* sp.) at station 17. In the present investigation only two species of Scaphineura (*Dentalium octangulatum* and *Laevidentalium longitrorsum*) were encountered at station 4 and station 2 respectively.

Echinoderms

Among the echinoderms, the brittle stars *Opithrix* sp. and *Opiothela venusta* were the most common in rocky crevices and on Sponges. The stars *Pentaceraster mamillatus* and *Pentaceraster* sp. were frequent. These starfish are considered as enemies of pearl oysters because they feed on them. Other starfish's species were present in small numbers at selected stations.

By far the sea urchin, the sea sand-dollar *Echinometra mathaei* was the most common at 9 different stations. The other sea stars *Clypeaster humilis* and *Clypeaster* sp. were rarely seen. In general, although the echinoderms found were of 25 species, yet they were never in abundance as a whole.

Asidians

The black ascidian *Phallusia nigra* and *Styela canopus* were occasionally found under rocks or in crevices. The former was common at 7 stations and the latter in only 3 stations. The colonial ascidians *Didemnum* sp. were common and always found spreading over dead corals or on hard substratum and covering a wide area of the rocky surfaces.

Branchiopods

The branchiopods were represented by only one species namely *Gonodactylus* cf. *demanil* which was dominate at only different 4 stations (Table 2).

Details of the Dominance for All Stations

The Eastern Area (Stations 1-6)

Six stations (stations 1-6) represent the eastern location. Biota found at this area belongs to 12 groups. Of the 104 moullscs species encountered (71%), 41 species were recorded at station 6 and between 10-18 species were found at stations 1-5 (Fig. 2).

Of the 25 echinoderms, 9 species (representing 18%) were found in this area of which 7 different species were present at station 2 and station 5 and the lowest number (1) was found at station 1.

The highest number of Crustaceans species was found at station 3 (10 species), followed by 9 species at station 7 and 7 species at stations 1 and 2.

Of 7 Algae species, 6 were recorded at station 2 and one species was recorded at stations 5-6

Polycheates were represented by 6 species at stations 1 and 2.

Four of the 12 Coral species were found at stations 1, 3-4 and 6. The lowest number of Coral species was recorded at station 5. Some fauna groups were represented by up to 3 species (Table 2).

The Southern Area (Stations 7-12)

Six stations (stations 7-12) are located within this area. Biota found at this area belongs to 11 groups. Molluscs are usual, were highly abundance 73% particnlarly at station 7 (40 species) followed by 22, 20 and 19 species at stations 8, 9 and 11 respectively. The lowest number of molluscs was recorded at station 10 (41 species) and station 12 (17 species).

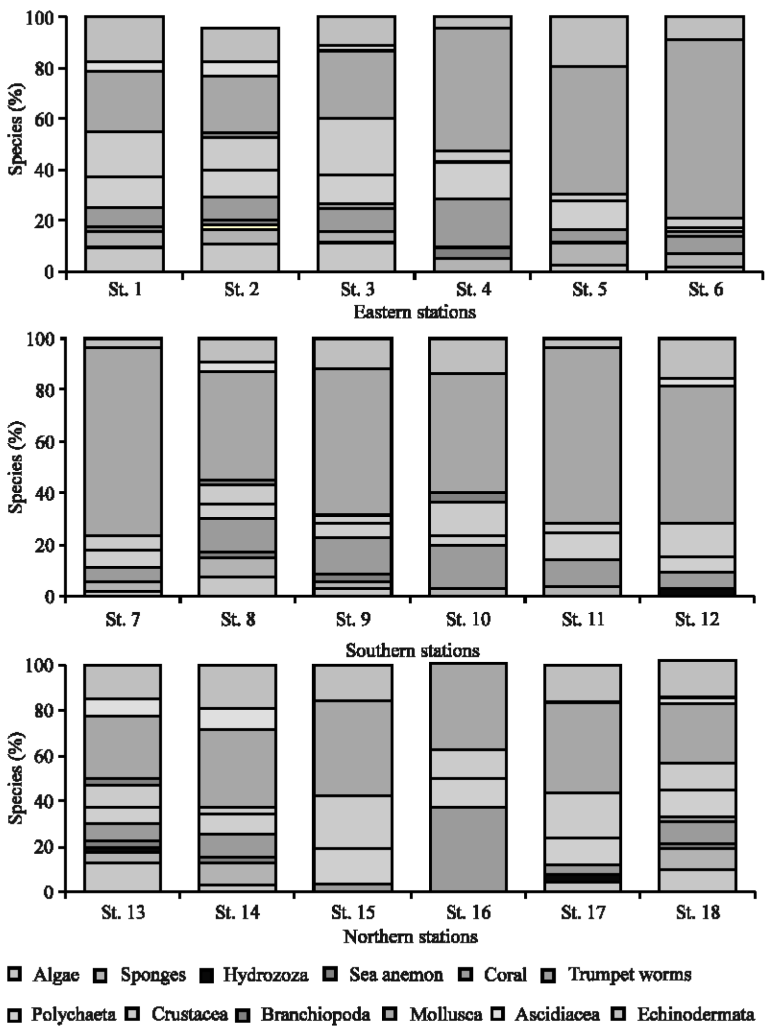

Fig. 2: Percentage distribution of different taxa collected from different stations

Echinoderms were represented by 5 species at stations 8 and 12 and with 4 for each of stations 9 and 10. The lowest number of echinoderms were recorded at station 7 (2 species) and station 11 (1 species).

Coral species were represented with 8 species at station 8 and by only 2 at station 12. They were equally represented by 5 species at stations 9 and 10. Some fauna groups were represented by 1-4 species (Table 2).

The Northern Area (Station 13-18)

Six stations (station 13-18) are located within this area. Biota found at his area belongs to 12 groups. Molluscs were represented by 11 species at stations 13-15 and 10 species at stations 17 and 18. The lowest number of molluscs were recorded at stations 16 (3 species).

The second highest groups are echinoderms. They were represented equally with 6 species at stations 13 and 14. The highest numbers of echinoderms were found at station 18 (7 species).

Table 3: Species diversity indicates of biota at 18 sampling stations of pearl oyster beds (Shannon index analysis)

Station	No. of species	Species diversity (H')	Evenness (J')
1	51	2.503	0.637
2	55	2.736	0.683
3	45	3.131	0.827
4	21	2.034	0.668
5	36	2.876	0.803
6	58	3.542	0.872
7	55	3.722	0.929
8	53	2.771	0.698
9	35	2.802	0.788
10	30	3.075	0.904
11	28	2.636	0.791
12	32	3.000	0.866
13	40	1.943	0.527
14	32	2.536	0.732
15	26	3.079	0.945
16	8	0.949	0.456
17	25	2.940	0.913
18	42	2.216	0.593

Coral reef species were represented with 3 species at stations 13, 14 and 16. The lowest number of Coral species were recorded at stations 15 and 17 (1 species). Some fauna groups were represented with ouly 1-4 species, or they were absent at some stations.

Species Diversity

The species diversity indices differ slightly between 18 stations (Table 3). The overall species diversity (H`) was greater at station 6 (H` = 3.542), Station 7 (H` = 3.722) and the lowest species diversity index was recorded at station 16 (H` = 0.949). The difference uneveuness followed those in species diversity (H`) for all stations. The overall evenness based on number of individual was at station 15 (J' = 0.949) and station 7 (J' = 0.929). The lowest value of species eveuness occurred at Station 16 (J' = 0.456).

DISCUSSION

Distribution

The pearl oysters belong to the genus *Pinctada* (Röding) under the family Pteriidae, enjoys a world wide distribution occurring in almost all the seas of the tropical belt and also in the subtropical regions. Seven species of the family Petriidae belong to 3 genera occur in the Arabian Gulf viz., *Pteria macroptera* (Lamarck, 1819), *Pteria tortirostris* (Dunker, 1848), *Pteria penguin* (Röding, 1798), *Electroma (Pterelectroma) zebra* (Reeve, 1857), *Pinctada margaritifera* (Liunaeus, 1758), *Pinctada radiata* (Leach, 1814)) and *Pinctada* cf. *nigra* (Gould, 1850), of which *Pinctada radiata* (from 95% of the pearl oyster beds), *Pinctada margaritifera* and *Pteria marmorata* (from 5% of the pearl oyster beds) have contributed to the pearl fisheries in Qatari waters and the Arabian Gulf in general. *Pinctada radiata* is found in the Arabian Gulf, Red Sea and the Indian Ocean. *Pinctada margarififera* is distributed in the Arabian Gulf, Red Sea and the Indo-Pacific and is cultured in the Pacific. In Qatari waters, the black-lip pearl oysters *Pinctada margaritifera* is mostly confined to the deeper waters around Halul Island. Most settlements of spat of *P. radiata* and *P. margaritifera* are usually found on the ridges of rocks and corals.

The pearl oyster beds highly dominate Al-ed Al-Gharbi, Umm Al-Jesh, Balhambar and Tunob where the sea bottom is formed from hard and rocky substrate, dead Coral blocks, sand with highly shell fragments, Algae and other solid objects. Few of the oyster beds investigated were found in areas that have sandy bottoms such as Halat Dalma, Kherees, Halat Mejaeble, Newhat Adams and Al-Hawad where the sandy substrate does not encourage the settlement and establishment of the pearl oyster communities.

Oyster beds investigated were with depth ranges of 6 to 25 m. These varied widely even within the same bed.

Hydrographic Parameters

The hydrographic data obtained during the period of study does not show a significant differences in the temperature readings between the different oyster beds. The summer-winter differences in water temperature in the Arabian Gulf are remarkably high (Hunter, 1986; Sheppard *et al.*, 1992). Salinity reading varied with a range of 39.5 psu to 44.6 psu in the oyster beds between summer and autumn. Pearl oysters are truly a marine form in its entire life cycle and can tolerate great variation in salinity (Alagarswami and Victor, 1976). Salinity readings indicate a normal pattern of variation acceptable for the normal life in the pearl oyster beds. As a matter of fact, detailed assessment of salinity effects may be increased, decreased or masked by other simultaneously effective environmental factors such as light, temperature, water movement and interactions between co-existing organisms (Nayar and Mahadevan, 1987). Dissolved oxygen values obtained ranging from 3.35 to 4.72 mg L^{-1} in the oyster beds between summer and autumn and it appears to be common in the pearl oyster beds of Qatari waters. The oyster is not stressed much due to the limited range of high and low oxygen concentration. It is a known fact that the metabolism of many molluscs is independent of the ambient oxygen tension until some low oxygen tension is reached (Nayar and Mahadevan, 1987).

Chlorophyll-a concentration fluctuated between 0.01 to 0.28 μm L^{-1}. Sheppard (1993) and Basson *et al.* (1977) stated that the chlorophyll-a concentration fluctuated between 0.2 and 0.86 mg L^{-1} and showed a wide seasonal variation. Also densities of total plankton in Arabian Gulf waters, between the Saudi Arabia and Karan Island were 100-150×10 m^3 in snmmer and up to 250×10m^3 in winters (Basson *et al.*, 1977).

Associated Biota

The very fact that the biota of the pearl oyster beds comprises the whole assemblage of more than 189 species is considered an important ecological parameters affecting oyster communities. They can compete with oyster spot for space, getting food and for growth (Nayar and Mahadevan, 1987). Al-Khayat and Al-Maslamani (2001) reported that a total of 111 fouling organisms from 12 different pearl oyster beds occur in the Qatari waters of the Arabian Gulf.

The Algae flora found in pearl oyster beds consists mainly of the same types as those found on the Coral beds of rocky regions in tropical seas. This is in accordance of Verma (1960) observation in Indian pearl banks.

In this study is has been noticed that the Coral reefs were found in some stations, no Coral existed, while in others 1 to 4 Coral species were found. The occurrences of Coral in the oyster beds enhance the diversity of taxa. Most of the biota found in the pearl oyster beds consisted maiuly of the same types as those found on the Coral beds in Qatar (Al-Ansi and Al-Khayat, 1999).

Principal Component Analysis (PCA)

The raw data of depth, corals and polychaetes have normal distribution; therefore the raw data for them were used for PCA application. Whereas, log-transformed values were used for test application of temperature, dissolved oxygen, chlorophyll-a, Mollusca, Ascidiacea and total species number. Square root-transformed values were used for test application of salinity, pH, Porifera, Crustacea and echinodermata; and second square root-transformed values were used for test application of Algae. However, hydrozoa, Actiniaria (Sea anemon), Sipuncula (trumpet worms) and Branchiopoda were absent in most of the studied sites, so there data gave error when trying to compute PCA for those species separately, therefore their records were included only in the total species number.

In considering the assessed community structure of benthic fauna and Algae, the following three PCA were computed:

Bottom Fauna Species-Abundance

This analysis was done to illustrate inter-relationship among benthic fauna and Algae along the Qatari waters. It was done on data of Algae, Porifera, Corals, Polychaetes, Crustacea, Mollusca, Ascidiacea, Echinodermata and total species number.

Mollusca-Physical/Chemical Analysis of Sea Water

This test was made to assess the importance of depth, temperature, salinity, pH, dissolved oxygen, chlorophyll-a, in controlling Mollusca abundance along the Qatari waters.

The obtained results from application of factor analysis (PCA) indicated that the analysis *Bottom fauna* species-Abundance yielded three main components retained with eigenvalues greater than 1.0 (Table 4, Fig. 3). They accounted for 91.621% of the total variance. The first and second extracted components accounted for the largest part of the total variance (74.108%), while the third component added 17.513%. The eigenvalue for the first component is the highest (3.822) followed by component-2 (2.847), then component-3 (1.576). The eigenvalues for the rest of the components were lower than 1.0 with a significant level at 0.5.

The number of loaded species decreased from PC1 to PC3 (Table 5). Six species were loaded highly on PC1 (Algae, Corals, Polychaetes, Crustacea, Mollusca and Total Species number). The PC2 retained with five highly loaded species (Porifera, Corals, Polychaetes, Crustacean and Mollusca), whereas, two species were loaded highly on PC3 (Ascidiacea and Echinodermata).

Table 4: Produced components from the Principle Component Analysis (PCA) of bottom fauna species-abundance at different stations of oyster beds during the present study

Extracted components	Eigen value	Proportion (%)	Cumulative (%)
Component 1	3.822	42.471	42.471
Component 2	2.847	31.637	74.108
Component 3	1.576	17.513	91.621
Component 4	0.616	6.845	98.466
Component 5	0.138	1.534	100
Component 6	0	0	100
Component 7	0	0	100
Component 8	0	0	100
Component 9	0	0	100

Table 5: Correlation level loading of considered variables in the first two principle components in bottom fauna species-abundance at different stations of oyster beds during the present work

Variables	Component 1	Component 2	Component 3
Algae	**0.817**	-0.323	-0.093
Porifera	0.255	**0.813**	0.429
Corals	**0.677**	**0.731**	-0.080
Polychaeta	**0.674**	**-0.559**	0.318
Crustacea	**0.818**	**-0.542**	-0.177
Mollusca	**0.570**	**0.817**	-0.062
Ascidiacea	-0.425	0.239	**0.730**
Echinodermata	0.212	-0.452	**0.832**
Total species No.	**0.978**	0.116	0.124

The bold values indicate correlation coefficient higher than |0.5|; Raw data were used for test application of corals and polychaeta; Log transformed values were used for test application of mollusca, Ascidiacea and total species No; Square root transformed values were used for test application of Porifera, Crustacea and Echinodermata; Second square root transformed values were used for test application of Algae

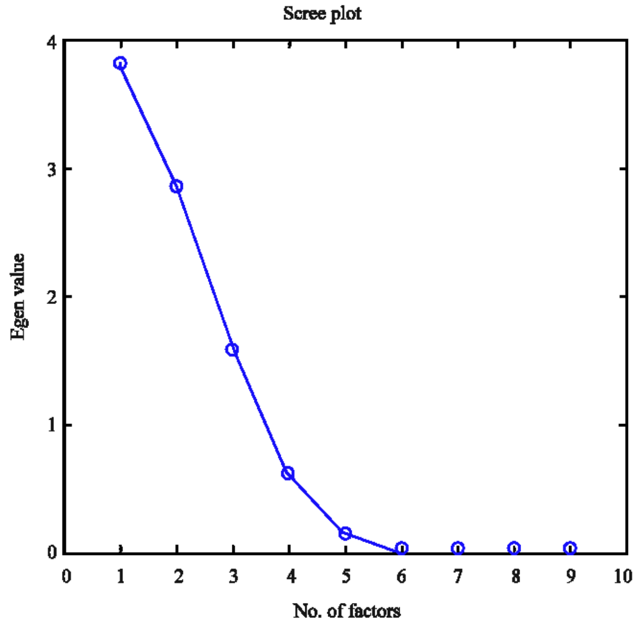

Fig. 3: Produced scree plot of computed eigenvalues in different components in bottom fauna species-abundance at different stations of oyster beds during the present study

Plotting PC1 against PC2 (Fig. 4A) revealed that the most dominant species on PC1 were total species number, followed by Crustacea and Algae then Corals and Polychaetes after that Mollusca. An indirect relation between Ascidiacea and previously mentioned species is obvious from their negative loading on PC1. On PC2 there was indirect relation between two groups of species. The first group includes mollusca, porifera and corals loaded positively on PC2. The second group includes polychaetes and Crustacea loaded negatively on PC2. The both groups were loaded positively on PC1.

Plotting PC1 against PC3 (Fig. 4B) revealed a high positive loading of both echinodermata and Ascidiacea on PC3, this indicate the indirect relation between echinodermata and Ascidiacea and those species loaded positively on PC1 (those species might feed on echinodermata and ascidiacea).

Plotting PC2 against PC3 (Fig. 4C) confirmed the inverse relation between Mollusca and porifera (a high positive loading) from one side and polychaetes and crustacean (a high negative loading) from the other side.

The second PCA Mollusca-physical/chemical analysis of sea water yielded seven components. Two extracted components retained with eigenvalues greater than 1.0 (Table 6, Fig. 5). They accounted for the largest part of the total variance (77.83%). The eigenvalues for these two components are 3.711 and 1.736, respectively. The eigenvalue for the rest of the components were lower than 1.0.

Component loadings revealed that water depth, temperature, salinity, pH, dissolved oxygen and chlorophyll-a were loaded highly on PC1 (Table 7). Chlorophyll-a and Mollusca have a high load on PC2. Plotting PC1 against PC2 (Fig. 6) revealed that, on PC1 there was indirect relation between two groups of parameters. The first group includes salinity, temperature and chlorophyll-a loaded positively on PC1. The second group includes water pH, dissolved oxygen and depth loaded negatively on PC1. On PC2, Mollusca loading was high and it had a positive relation with chlorophyll-a, pH and dissolved oxygen. The inverse association is indicated by depth and temperature which was loaded negatively on PC2 against mollusca.

Table 6: Produced components from the Principle Component Analysis (PCA) of Mollusca-physical/chemical analysis of sea water during the present study

Extracted components	Eigen value	Proportion (%)	Cumulative (%)
Component 1	3.711	53.02	53.02
Component 2	1.736	24.80	77.83
Component 3	0.765	10.93	88.76
Component 4	0.560	8.00	96.76
Component 5	0.142	2.03	98.79
Component 6	0.077	1.10	99.89
Component 7	0.008	0.11	100.00

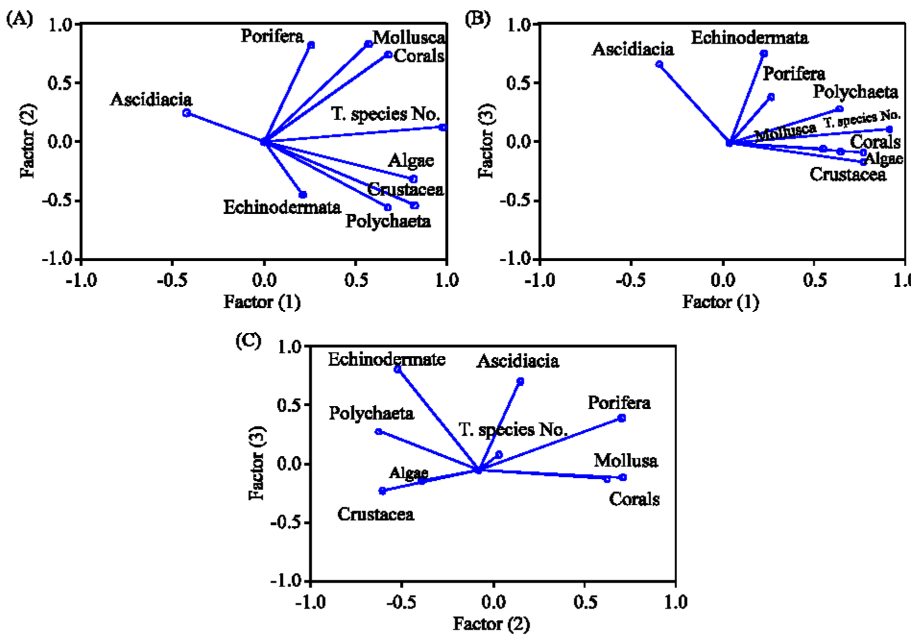

Fig. 4: Vector plot of component loadings from *Bottom fauna* species-abundance at different stations of oyster beds during the present study

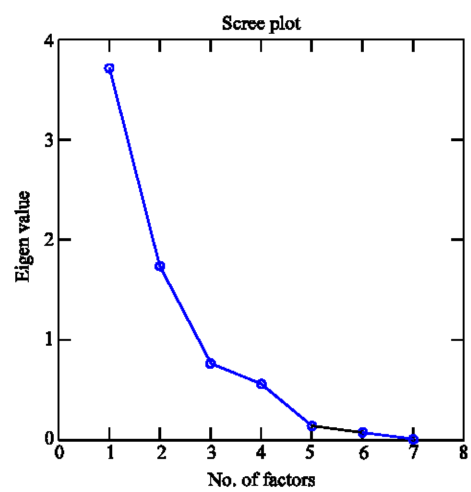

Fig. 5: Produced scree plot of computed eigenvalues in different components in mollusca-physical/chemical analysis of sea water during the present study

Table 7: Correlation level loading of considered variables in the first two principle components in Mollusca-physical/chemical analysis of sea water during the present study

Variable	Component 1	Component 2
Depth	-0.672	-0.32
Temperature	0.883	-0.304
Salinity	0.922	0.237
pH	-0.867	0.438
Dissolved oxygen	-0.747	0.43
Chlorophyll-a	0.514	0.673
Mollusca	0.235	0.81

The bold values indicate correlation coefficient higher than |0.5|; Raw data were used for test application of depth; Log transformed values were used for test application of temperature, dissolved oxygen, Chlorophyll-a and Mollusca; Square root transformed values were used for test application of Salinity and pH

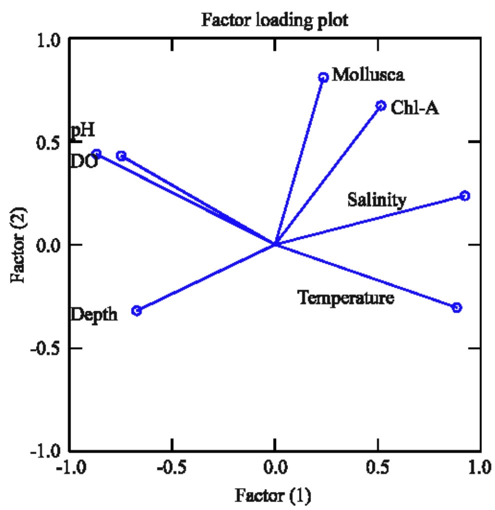

Fig. 6: Vector plot of component loadings from Mollusca-physical/chemical analysis of sea water during the present study

Generally, the two most important parameters are water salinity followed by water temperature. Rise in these two parameters affect negatively the total species number and positively Mollusca abundance in Qatari waters.

Comparing with previous studies of biota occurrence and distribution conducted in the region, demonstrates that the biota of Qatari waters is most similar to that of Saudi Arabia and Bahrain, whilst also expressing some similarity to the rest of the region.

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