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A Comparison of the Macrofauna of Natural and Replanted Mangroves in Qatar

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The present investigation quantifies the biodiversity of the Brachyura and fish living within the natural mangrove *Avicennia marina*, salt marsh and replanted mangal, and compares relevant features of the abiotic and biotic environments of these habitats. Measurements of sediment organic matter, grain size, soil water pH and the moisture content indicate that the natural mangrove areas have lowest mean grain size, pH, and highest organic and moisture contents. Planted mangrove areas have a higher mean grain size and slightly higher pH, but lower organic and moisture contents. Differences occur between brachyurans in planted and natural mangrove areas, but the biodiversity was similar between salt marsh and natural mangrove areas. *Nasima dotilliformis* was the only crab which did not occur at all planted mangrove sites, while *Serenella leachii* was missing from natural mangrove. Juvenile fish species enter mangroves, using these as nursery grounds, and quantitative sampling indicates that mangrove areas, especially pneumatophores, form a special habitat for these small fish.

Keywords: mangrove; biodiversity; macrofauna; Qatar

Introduction

Although there have been comprehensive ecological surveys of the mangal and salt-marshes in the Gulf states, especially Saudi Arabia, no data exist regarding the mangal or salt-marsh fauna of Qatar, or on the recolonization of replanted mangal by macrofauna.

Most crab faunal zonation is limited by the three-dimensional ecosystem provided by the mangrove trees which changes ground texture, with the presence of channels and pools complicating this interaction. These factors together with the widely varying degree of development of mangals in different regions, have led to somewhat differing classifications of the mangal zones (Jones, 1984).

Crabs have a role in the recycling of organic nutrients within mangrove ecosystems (Robertson, 1986), by feeding on fresh and dead leaves and seedlings (Malley, 1978). The retention of organic matter within the ecosystem provides a stable food source, which is particularly important in arid regions which have a limited input of terrestrial nutrients to the ecosystem. The feeding ecology of mangal ocypodids will also influence species zonation within the mangal ecosystem, and as deposit feeding crab distribution is related to sediment particle size and organic content (Hartnoll, 1973; Simons & Jones, 1982), these are also influenced by the presence of mangroves. In Qatar, a replanting programme for mangrove *Avicennia marina* has been in operation for 10 years. Present qantitative sampling of replanted and natural mangroves provides an indication as to whether replanting stimulates the return of a typical burrowing crab fauna.

A further aim of the present study was to examine the differences in physical and biological conditions in natural mangroves, salt-marshes and planted mangroves to determine whether the fauna, particularly the decapod Brachyura, shows associations related to specific biotic or abiotic features in these habitats. A further nursery function has been ascribed to mangroves elsewhere in the Indo-Pacific region (Tzeng & Wang, 1992) and a fishery survey was conducted to determine whether pelagic biota recolonize replanted mangroves.

Materials and methods

This study was conducted from June 1993–June 1994, to investigate the mangrove, salt marsh and tidal flat communities around the coast of Qatar (Figure 1). At each site, permanent transect lines were used for counting crab burrows per $0{\cdot}25\ m^2$ with three replicates. Crabs were collected by hand, hand-net and by digging up burrows. The crab samples and all other specimens were preserved in 4% formalin/seawater and brought to the laboratory.

Air, water, and intertidal sediment temperatures were recorded at all stations. The water salinity was measured at the same sites using a refractometer

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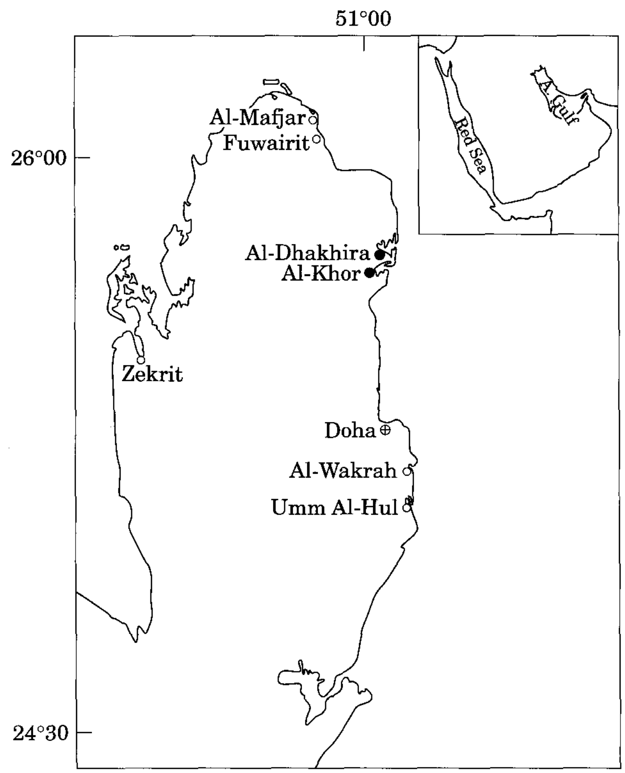

FIGURE 1. Map of The State of Qatar showing the study sites which include natural mangroves ●, planted mangroves ○, and salt marsh ⊕.

(American Optical Co., U.S.A.). A pH meter with digital display was used to determine hydrogen in sea water and soil water. A portable oxygen meter was used to determine oxygen concentration in open sea water, and in soil of planted, natural mangrove and salt marsh areas.

Sediment samples were collected along transects at each site and were analyzed to determine organic matter and particle size using the sieve method Buchanan (1971). The organic content was estimated as the loss of weight after ignition and expressed as a percentage of the dry weight prior to ashing.

Juvenile or small fish which inhabit relatively shallow regions of the intertidal, specially near pneumatophores of *A. marina* at mangrove sites, were caught by hand net by fishing for a fixed time, while larger fish which moved in amongst mangrove and salt marsh at high tide were sampled with a gill net (20 m × 1·5 m with 7 cm stretched mesh), and seine net (15 m × 1·5 m with 5 cm mesh size). The fish collected from all nettings in each site were preserved in 10% formalin-seawater solution and sorted and identified in the laboratory to species level, following the available literature (Silvasubraminiam & Ibrahim, 1983). Other macrofauna associated with the natural mangrove, planted mangrove and salt marsh were sampled quantitatively at the above sites. Cluster analysis was used to demonstrate the similarity relationship amongst the faunal communities of natural mangrove, salt marsh and replanted mangrove, using species presence–absence data.

Results

Physical environment

The maximum daily air temperature during the present survey was recorded in June (45 °C) and the minimum air temperature in January (10 °C). The surface water temperature varied from 10–36 °C. The maximum was recorded in June and the minimum in February.

The overall trend in shallow sea water is for lowest salinities (34–43) to be recorded between December (1993) and March (1994), and the highest value of 57 was recorded in August (1993). The pH value of open shallow water varied from 7·8–8·6. The lowest value in pools was 7·8 and highest value recorded was 8·6.

Table 1 shows the percentage of water and organic content for different stations at sites. The finer substrates of natural mangroves contained more water and organic material than the coarser substrates of other sites at planted mangroves and salt marsh.

The ground water of natural mangrove, planted mangrove and salt marsh areas was slightly alkaline (pH 7·11–7·55), while sea water pH was 7·91–8·30. All of the highest shore stations in natural and planted mangroves had the highest soil oxygen contents (Table 1), and although stations located in mangroves showed lower oxygen levels, none were anoxic.

Fauna

Mangrove and salt marsh communities sampled at natural and replanted mangrove sites reveal a biodiversity comprising 18 species of crustaceans, 19 species of molluscs, seven species of polychaetes and 30 species of fish (Tables 2–4). Species diversity was very similar in natural mangroves with 33–34 species, but varied from 27–33 species in replanted mangroves and 24 in salt marsh (Table 2).

Cluster analysis comparing macrobenthic faunal communities found at each site (Figure 2) demonstrates 84% similarity between N1 and N3, 69% similarity between P1–P2 and 62% between P3–P4. However, all mangrove sites, both natural and planted, are linked at 61%, indicating that they are essentially similar communities (Figure 2).

TABLE 1. Overall mean of organic matter content (%) and mean grain size (mm) of sediment samples collected from natural (N), planted mangroves (P) and salt marsh (S)

Site	Date planted	Mean organic matter % ± SE	Mean grain size (mm) ± SE	Mean moisture content (g) ± SE	Mean soil pH ± SE	Mean O_2 % saturation ± SE
Al-Khor (N1)		2·70 ± 0·15	0·13 ± 0·01	21·34 ± 1·40	7·46 ± 0·10	8·38 ± 0·76
Al-Khor (N2)		3·05 ± 0·43	0·10 ± 0·05	22·62 ± 1·47	NR	11·81 ± 2·00
Al-Dhakhira (N3)		3·32 ± 0·14	0·01 ± 0·00	26·73 ± 1·67	7·11 ± 0·11	10·65 ± 0·93
Al-Dhakhira (N4)		2·71 ± 0·33	0·18 ± 0·03	21·05 ± 3·95	NR	15·75 ± 1·22
Umm Al-Hul (P1)	1981	2·30 ± 0·40	0·17 ± 0·03	17·96 ± 2·39	7·53 ± 0·15	12·16 ± 0·21
Al-Wakrah (P2)	1989	2·01 ± 0·08	0·23 ± 0·01	19·59 ± 0·79	NR	11·12 ± 1·39
Fuwairit (P3)	1981	2·51 ± 0·15	0·16 ± 0·01	19·98 ± 0·62	7·38 ± 0·13	13·90 ± 1·99
Al-Mafjar (P4)	1981	2·51 ± 0·15	0·18 ± 0·03	19·82 ± 0·56	NR	15·53 ± 1·86
Zekrit (P5)	1981	2·86 ± 0·23	0·15 ± 0·01	20·53 ± 2·57	7·73 ± 0·27	11·82 ± 0·69
Doha (S)		3·03 ± 0·26	0·09 ± 0·07	20·75 ± 4·32	7·53 ± 0·15	16·96 ± 3·51
Overall mean of (N)		2·95 ± 0·14	0·11 ± 0·04	22·94 ± 1·31	7·21 ± 0·17	11·65 ± 1·54
Overall mean of (P)		2·44 ± 0·15	0·18 ± 0·01	19·58 ± 0·43	7·55 ± 0·10	12·91 ± 0·80
Overall mean of (S)		3·03	0·09	20·75	7·53	16·96

(NR: not recorded).

Certain invertebrate species are excluded from salt marshes, either due to the absence of trees (*Littorina glabrata*), or to the relative high shore position of this habitat (*Nephtys* sp., *Gari roseus*, other bivalves and gastropods, *Metaplax indica*, *Macrophthalmus grandidieri*). *Ocypode rotundata*, a supralittoral sand beach inhabitant is present on replanted shores were sand is present at the top of the shore. Salt marsh, which normally forms the habitat above the mangrove in Qatar, is characterized by *Nasima dotilliformis*, so that this species is absent from some replanted mangrove sites (Table 2).

Table 5 presents the zonation pattern for intertidal soft substrata brachyurans in Qatar. Although all the species found in this study from natural, planted mangrove and salt marsh are new records for Qatar, they are species which have been described from elsewhere in the Arabian Gulf (Jones, 1986). It is notable, however, that Serenella leachii has not been recorded in the north Arabian Gulf (Kuwait, Saudi Arabia and Bahrain).

Scopimera crabricauda and *M. messor* are present on the upper intertidal zone at all sites. Zekrit site (P5) on the west coast is unique in the low number of crab species due to high salinity (60–90). *Ilyoplax frater* is absent from P1, P4 and P5 sites but present at other planted mangroves, all natural mangrove and salt-marsh sites in the mid-intertidal zone where there was a high proportion of silt and clay (Table 1). *Serenella leachii* prefers mud banks, and during the present survey was found only at P1, P2 and S at high abundance, but was absent from all natural mangrove and other planted mangrove sites.

The mudskipper *Boleophthalmus boddarti* was found in natural mangrove areas in the north of Qatar and in salt marsh creeks at Doha (Table 3), but was absent from all replanted mangroves. Fishing with hand net in the vicinity of the mangrove pneumatophores produced 26–30 species of juvenile fish in natural mangroves as opposed to 13–22 species in replanted mangroves and 16 species in salt marsh creeks. Abundances were also highest in natural mangroves with a mean catch number of 19 to 10 min^{-1}, as opposed to 12 in replanted and nine fish in the salt marsh.

Fishing for adult fish using gill nets (Table 4) caught 17 species in natural mangroves, nine to 14 in replanted and six species on sand beaches, with 11 species common to all mangrove sites. When seine nets were used 14 species were taken in mangroves, two to six species in replanted mangroves and only two species on the open shore, one species, *Gerres oyena*, was common on to all habitats.

Discussion

Physical environment

The climate of the mangrove areas in Qatar is typical of the arid region, with high temperature and high evaporation values at a level about 200 mm $month^{-1}$ during 6 months each year. Months with high evaporation values are those without rain and have high air temperature values. The rain fall is scant (54·6–76·1 mm $year^{-1}$), erratic, and variable in time and space, hence there is limited input of terrestrial sedimentation.

TABLE 2. Invertebrate macrofauna associated with salt marsh and mangrove areas on the east coast of Qatar (S: salt marsh, N: natural mangrove and P: planted mangrove)

Species	(N1)	(N3)	(P1)	(P2)	(P3)	(P4)	(S)
Phylum: Arthropoda							
Class: Crustacea							
Chthamalus malayensis	*	*	*	*	*	*	*
Balanus amphitrite	*	*	*	*	*	*	*
Penaeus semisulcatus	*	*	*	*	*	*	*
Ocypode rotundata	○	○	*		*	*	○
Nasima dotilliformis	*	*			*	○	*
Manningis arabicum	*	*	*	*	*	○	*
Serenella leachii	○	○	*	*	○	○	*
Macrophthalmus depressus	*	*	*	*	*	*	*
Macrophthalmus grandidieri			*	*		*	
Ilyoplax frater	*	*		*	*	○	*
Scopimera crabricauda	*	*	*	*	*	*	*
Metopograpsus messor	*	*	*	*	*	*	*
Metaplax indica	*	*	*	*	*	*	
Portunus pelagicus	*	*	*	*	*	*	*
Epixanthus frontalis	○	○	*	*	*		*
Eurycarcinus orientalis	*	*	*	*	*	*	*
Petrolisthes rufescens	*	*	*	*	*	*	*
Phylum: Mollusca							
Class: Gastropoda							
Clypeomorus caeruleum	○	○	○	○	*	○	○
Cerithidea cingulata	*	*	*	*	*	*	*
Cerithium scabridum	*	*	*	*	*	*	*
Euchelus asper	○	*	○	○	○	*	○
Clypeomorus bifasciata	*	*	*	*	*	*	
Pirinella conica	*	*	*	*	*	*	*
Planaxis sulcatus	*	*	*	*	*	*	*
Trochus sp.	○	*	○		○	○	○
Thais savignyi	*	*	*	*	○	○	○
Trochus erythraeus	*	*	○		*	○	○
Nodilittorina subnodosa	*	*	*	*	*	*	*
Littorina glabrata	*	*	*	*	*	*	
Class: Bivalvia							
Brachidontes emarginatus	*	*	*	*	*	○	○
Clypeomorus bifasciata	*	*			*		
Marcia optima	*	*	○	○	○	○	○
Monodonta vermiculata	○	○	○	○	*	*	○
Barbatia helbingii					*	*	
Isognomon dentifera	*	*	○	*	○	*	○
Gari roseus	*	*	*	*	*	*	
Phylum: Annelida							
Class: Polychaeta							
Eunice sp.	*	*	*	*	*	*	*
Nereis sp.	*	*	*	*	*	*	*
Nephtys sp.	*	*	*	*	*	*	
Perinereis sp.	*	*	*	*	*	*	
Sp. 1	*	*	*	*			*
Sp. 2	*	*	*				*
Sp. 3							*
Total	33	34	32	31	33	27	24

(○) no habitat, (*) present.

TABLE 3. Fish species caught using a hand net in salt marshes and mangroves on the east coast of Qatar (S: salt marsh, N: natural mangrove and P: planted mangrove)

Species	(N1)	(N3)	(P1)	(P2)	(P3)	(P4)	(S)
Phylum: Chordata							
Superclass: Pisces							
Allanetta forskali	*	*		*	*	*	*
Ablennes hians	*	*	*	*	*	*	*
Tylosurus leiurus	*	*	*	*	*	*	*
Pseudorhombus arsius	*		*		*	*	
Scomberoides commersonianus	*	*		*	*	*	*
Nematalosa nasus	*	*	*			*	
Gerres filamentosus	*	*	*	*	*	*	*
Gerres oyena	*	*	*	*	*	*	*
Hemiramphus marginatus	*	*	*	*	*	*	*
Lethrinus nebulosus	*	*	*	*	*	*	*
Lutjanus fulviflamma	*	*	*		*	*	
Liza macrolepis	*	*	*				
Liza subviridis	*	*					
Platycephalus maculipinna	*	*	*				
Platycephalus indicus	*	*		*	*	*	*
Scolopsis vosmeri	*	*	*		*	*	
Scomberomorus commersoni	*	*				*	
Siganus canaliculatus	*	*				*	
Mylio bifasciatus	*	*	*				
Mylio latus	*	*			*	*	
Rhabdosargus sarba	*	*			*	*	
Pelates quadrilineatus	*	*	*	*	*	*	*
Therapon jarbua	*	*	*			*	*
Chelonodon patoca	*	*	*	*	*	*	*
Parachirus marmoratus	*						
Sillago sihama	*		*				*
Rhinobatos granulatus	*						
Boleophthalmus boddarti	*	*					*
Cryptocentrus luthrus	*	*	*	*	*	*	*
Aphanius dispar	*	*	*	*	*	*	*
Total	30	26	19	13	18	22	16

The salinities recorded in the present study, although higher on the west coast (Table 1) do not appear to differ greatly from those recorded in the other parts of the Gulf region. Salinity has been suggested to be a limiting factor restricting mangrove height (Price *et al.*, 1987) and species numbers and infaunal diversity (Por *et al.*, 1977). This appears to operate at Zekrit on the west coast of Qatar were only three species of crab were found (Table 5).

In summer, pH was lowest in natural mangroves, perhaps reflecting the higher organic content of the soil (Table 1). However, apart from Zekrit salinity, the pH of the seawater and the soil varied slightly between natural mangrove, planted mangrove and salt-marsh sites, suggesting that these conditions are not the major limiting factors for the distribution of macrobenthic fauna in Qatar.

Natural mangrove showed a smaller sediment grain size compared to that of the planted mangrove areas (Table 1). This decrease in grain size is probably related to the extensive pneumatophore system which acts to slow water motion and cause settlement of fine sediment particles in established mangrove areas. This is also reflected in a higher level of silt and clay found in natural mangroves, accumulated over time in comparison to planted mangroves which have only been in existence for 10 years. Similar sediment particle sizes have been recorded from mangals throughout the region (MacNae & Kalk, 1962; Icely & Jones, 1978; Day, 1974; Ismail & Ahmed, 1993).

Higher levels of organic material and substrate moisture were also found in natural mangrove substrates, than in salt marsh or planted mangrove sites. This is likely to be correlated with increased settlement of material derived partly from the trees themselves. Mean organic and moisture content were higher and grain size lower in natural mangroves, whereas planted mangrove areas contained larger

TABLE 4. Species caught by using seine net (2·5 cm mesh size) (D) and gill net (7 cm mesh size) (G) in natural mangrove areas (N), planted mangrove areas (P) and sandy beach (SR) by fishing for 15 min using seine net and 4 h using gill net, at each site

	(N1)		(N3)		(P3)		(P4)		(SR)	
Species	D	G	D	G	D	G	D	G	D	G
Crustacea										
Family: Portunidae										
Portunus pelagicus	*	*	*	*	*	*	*	*		*
Family: Penaeidae										
Penaeus semisulcatus	*	*	*	*						
Pisces										
Family: Atherinidae										
Allanetta forskali	*		*		*		*			
Family: Belonidae										
Ablennes hians		*		*		*				
Tylosurus leiurus		*		*				*		
Family: Bothidae										
Pseudorhombus arsius	*		*				*			
Family: Carangidae										
Gnathanodon speciosus		*		*		*		*		
Scomberoides commersonianus		*		*		*		*		
Family: Clupeidae										
Nematalosa nasus	*	*	*	*		*		*		
Family: Gerreidae										
Gerres filamentosus	*	*	*	*						*
Gerres oyena	*	*	*	*		*	*	*	*	*
Family: Hemiramphidae										
Hemiramphus marginatus	*	*	*	*						
Family: Lethrinidae										
Lethrinus nebulosus		*		*				*		
Lethrinus kallopterus										*
Family: Lutjanidae										
Lutjanus fulviflamma								*		
Family: Mugilidae										
Liza macrolepis	*	*	*	*						
Liza subviridis	*		*							
Family: Platycephalidae										
Platycephalus indicus	*		*				*			
Platycephalus maculipinna									*	
Family: Pomadasyidae										
Scolopsis vosmeri	*	*	*	*			*			
Plectorhynchus sordidus										*
Family: Scombridae										
Scomberomorus commerson								*		
Family: Siganidae										
Siganus canaliculatus		*		*				*		
Family: Sparidae										
Mylio bifasciatus	*		*							
Mylio latus		*		*		*		*		
Rhabdosargus sarba	*	*	*	*		*		*		
Family: Serranidae										
Epinephelus areolatus										*
Family: Theraponidae										
Therapon jarbua		*		*		*		*		
Family: Rhinobatidae										
Rhynchobatus djiddensis								*		
Total	14	17	14	17	2	9	6	14	2	6

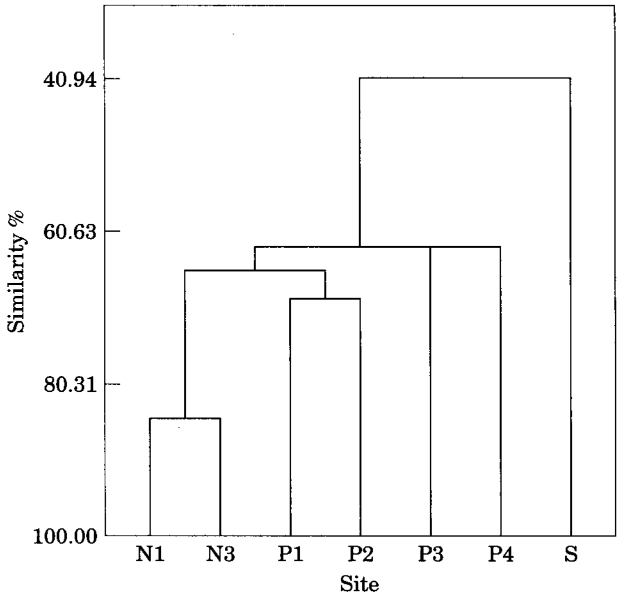

FIGURE 2. Cluster analysis based on macrobenthic fauna at different sites (N: natural mangrove; P: planted mangroves; S: salt marsh).

sediment grain sizes, but lower organic and moisture contents (Table 1). The lowest organic content was found in the planted mangrove substrate at P2 which had highest mean grain size. There were, however, differences in the relative proportions of the grain size depending upon the top shore habitat above the mangrove. All natural mangroves were bordered by salt marshes with typical sediment characteristics (Table 1) while planted mangroves were backed by sand beaches with low organic content and a particle size of over 0·2 mm.

As degree of penetration is also dependent upon sediment particle size the upper intertidal zone contained the highest levels of oxygen saturation (24·31–34%), while stations located in mangrove areas contained lowest saturation values (7·09%). Substrates with a high organic content and high levels of bacterial action further reduce oxygen, but present measured values of oxygen content were above those considered as minimum values for mangrove plants to be in good condition.

Benthic macrofauna

Of the 18 crustaceans collected 14–15 species were found in natural mangrove sites (N1 and N2), and between 14–16 species were found in planted mangrove, while 15 species were found in the salt marsh. Of the 19 molluscs species collected between nine to

TABLE 5. Zonation pattern of intertidal Brachyura on different transects at several sites in Qatar

Zone	Species	N1	N2	N3	N4	N5	P1	P2	P3	P4	P5	S
Upper intertidal	*Scopimera crabricauda*	*	*	*	*	*	*	*	*	*	*	*
	Metopograpsus messor	*	*	*	*	*	*	*	*	*	*	*
	Nasima dotilliformis	*	*	*		*	○	○	○	○	○	*
	Eurycarcinus orientalis	*		*	*	*			*			*
Mid intertidal	*Scopimera crabricauda*	*	*	*	*	*	*	*	*	*		*
	Eurycarcinus orientalis	*		*	*		*		*	*		*
	Serenella leachii	○	○	○	○	○	*	*	○	○	○	*
	Ilyoplax frater	*	*	*	*	*	○	*	*	○	○	*
	Manningis arabicum	*	*	*	*	*		*	*	○	○	*
	Nasima dotilliformis	*	*	*	*	*	○	○	○	○	○	*
	Macrophthalmus depressus	*	*	*	*	*	*	*	*	*	○	*
Lower intertidal	*Macrophthalmus depressus*	*	*	*	*	*	*	*	*	*	○	
	Metaplax indica	*	*	*	*	*			*	*	○	
	Macrophthalmus grandidieri	*		*			*	*		*		
	Ebalia sp.	*										
Sub-littoral fringe	*Portunus pelagicus*	*	*	*	*	*	*	*	*	*	*	*
	Charybdis natatur	*	*	*	*	*	*	*	*	*	*	*
Total		11	8	10	9	8	7	8	8	7	3	9

(○) no habitat
Key to area:
N1: Al-Khor (natural mangrove); N2: Al-Khor (natural mangrove); N3: Al-Dhakhira (natural mangrove); N4: Al-Dhakhira (natural mangrove); N5: Al-Dhakhira (natural mangrove); P1: Umm AL-Hul (planted mangrove); P2: Al-Wakrah (planted mangrove); P3: Fuwairit (planted mangrove); P4: Al-Mafjar (planted mangrove); P5: Zekrit (planted mangrove); S: Doha (salt marsh).

11 species occurred at natural mangrove (N1 and N3), and eight to nine species were found in planted mangrove (P1–P4), while only five species were found in the saltmarsh. Six of the seven polychaetes collected were found in natural mangrove (N1 and N3) and four to six species were found at planted mangrove sites (P1–P4), while five species were found in salt-marsh (S). Crab species diversity at natural mangrove sites in Qatar was eight to 11 species and at planted mangrove sites from three to eight species, while on salt marshes nine species occur. *Scopimera crabricauda* was present in the upper intertidal zone in sandy substrates with an overall abundance of 16 m^{-2} at all sites. Most crab species were absent from P5, except *S. crabricauda* and *M. messor*, due to high salinity, and *Nasima dotilliformis* was restricted to natural mangrove and salt marsh sites in the upper and mid-intertidal zone, with a mean abundance of 8 m^{-2}. Where sand beach replaced salt marsh on the top shore *N. dotilliformis* was replaced by *Ocypode rotundata*. *Ilyoplax frater* was present at salt marsh and natural mangrove sites at 36 m^{-2} on the latter sites, but was absent from most planted mangrove sites, with exception of site P3, where a suitable sediment occurred. *Serenella leachii* was absent from all natural mangrove and planted mangrove P3, P4, P5, but present only at sites P1 and P2 in the south of Qatar, and at the salt marsh, as this species prefers mud banks which are water-logged at low tide and sediment with a high proportion of sand.

The littorinids *Planaxis* and *Littorina glabrata* were found on the trunks of both natural and newly planted mangroves but were absent from salt marshes where this habitat is missing. Other mobile benthic species are distributed across all habitats, with the exception of *Boleophthalmus boddarti* which is absent from planted mangroves. This species is an important member of the mangrove and mud flat fauna throughout the Indo-Pacific region (Clayton & Vaughan, 1988), and lives in the upper intertidal zone burrowing into thick, organically enriched mud which is absent in recently planted mangroves.

Analysis of the macrobenthic fauna recorded at different sites reveals that sites N1 and N3 are relatively richer in species than planted mangrove and salt marsh sites. This appears to be linked to lack of suitable fine sediment with a high organic content and firm texture (Table 1) which reduces evaporation and provides a habitat for burrowers, together with a rich food source. Although wave action and extremes of temperature are considerably reduced most planted mangrove areas still retain a high percentage of coarse sediments with low organic content 10 years after establishment.

At top shore levels the original sand beach is still present and although it is predicted that over time shelter provided by planted mangroves will encourage further sedimentation, future planting should be in front of existing salt marsh to produced a more typical habitat (Jones *et al.*, 1996).

Although species diversity is highest on natural mangrove shores it is encouraging that after 10 years there are many species already shared between all sites. The overall low benthic species diversity for all study sites is similar to that recorded for central Gulf mangroves and salt marshes (Jones *et al.*, 1996), but well below the high diversity seen on salt marshes and mud flats in Kuwait where lower salinity occur (Jones, 1986). Comparison with previous studies conducted in the region, demonstrates that the mangal in Qatar is most similar to that of Saudi Arabia (Jones *et al.*, 1996) and Bahrain (Jones, 1985), whilst also showing some similarity to the rest of the region.

Pelagic biota

Present results confirm that mangroves attract a high diversity and abundance of fish species (Robertson & Duke, 1990). Although further work is required to substantiate reasons why fish congregate in mangroves on the coast of Qatar, it is likely to be a combination of protection, predation and food source. Natural mangroves contained the highest diversity and abundance of both juvenile and adult species, but it is clear that replanted mangroves attract more species than salt marsh or open sand beach coastal areas (Table 3 and 4). It has been postulated that the mangrove habitat provides food, shelter, absence of turbulence and reduction in predation (Tzeng & Wang, 1992). Present hand net fishing near the pneumatophores of *Avicennia marina* supports this view as the highest catches of juveniles were near pneumatophores which shelter, enabling them to avoid predation. Most adult fish were caught in open mangrove lagoons by gill and seine nets, and similar fishing effort produced only two species by seine and six species by gill net on sandy beaches (Table 4).

The present survey demonstrates that the re-introduction of mangroves in areas where salinities do not exceed 45 is likely to initiate the re-establishment of a typical Gulf mangrove benthic macrobiota. However, full species diversity has not been attained even after 10 years, and this is attributed to the slow the accretion of sufficiently fine and organically rich substrata. Selection of future planting sites, in association with salt marsh, may enhance the transfer of detrital material and benthic macrobiota, thus reducing the time for the production of full biodiversity. The high diversity and abundance of both juvenile and adult fish species, in both natural and replanted mangroves, confirms that this habitat acts as an important nursery site (Robertson & Duke, 1987, 1990). This is particularly important in the Gulf where estuaries and other coastal nursery habitats are minimal (Sheppard *et al.*, 1992).

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