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Echinoderm Diversity in the Arabian Sea and the Sea of Oman

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ABSTRACT An extensive survey of most of the habitats of the coast of the Sultanate of Oman revealed an echinoderm biodiversity larger than anticipated. Survey dives were carried out in 5 regions of the Sultanate (Musandam, Capital area, Sur-Qalhat, Masirah and Dhofar) and all non-ophiuroid echinoderms were recorded. A total of 21 species of Holothuroids, 20 species of Echinoids, 6 Crinoids and 28 species of Asteroids were observed during the survey. The holothuroid *Holothuria nobilis* was observed for the first time north of the Red Sea and *Holothuria arenacava*, a burying sea cucumber, was observed near Muscat, the only other known population being from Kenya. In addition, the starfish *Ferdina sadhensis* was photographed life for the first time. Several specimens (2 holothuroids, 2 asteroids 3 crinoids and 1 echinoid), some quite abundant, could not be attributed to known species. We observed a significant shift in echinoderm community structure at Ras-Al-Hadd as a result of either major shift in environmental forcing factors or as a result of limited dispersal of species across this "bio-geographic barrier".

KEY WORDS Sea stars; sea urchins; sea cucumbers; Arabian Sea; Sea of Oman.

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INTRODUCTION

Echinoderms are one of the few exclusively marine Phyla and are widely distributed in benthic habitats from the intertidal zones to the deep sea. There are around 7000 species of extant echinoderms of which more than a 1000 inhabit the Indo-Pacific biogeographic region (Guille et al., 1986). A literature based review of both deep and shallow water echinoderms reports >190 species from the SE Arabian region (Price, 1982) but studies based on actual field observations lack almost completely in the region (Price, 1983; Campbell, 1988), particularly along the Sea of Oman and the Arabian Sea. The present papers gives a preliminary account of direct semi-quantitative observations of echinoderms in both the Sea of Oman and the Arabian Sea using Scuba diving and attempts to relate the zoogeography of the Phylum in the region to its unique oceanography.

MATERIAL AND METHODS

This study was conducted over two years (2007–2009) at 11 locations around the Sultanate of Oman (Fig. 1). At each location, several sites were surveyed by SCUBA from the surface to a maximum depth of 20 m and all echinoderms (except Ophiuroidea) encountered were identified to the species level on the basis of their gross morphological characteristics, habitat and posture; the characters commonly used by field researchers. All encountered species were photographed and some specimen collected and deposited at Sultan Qaboos University. The identification of species followed the description of Clark & Rowe (1971) and more recent reviews of Echinoderms in the Indian Ocean (Price, 1983; Samyn, 2003; Samyn et al., 2006; Schultz, 2006).

At each site, at the end of a series of at least 3 dives, the abundance of the various species was

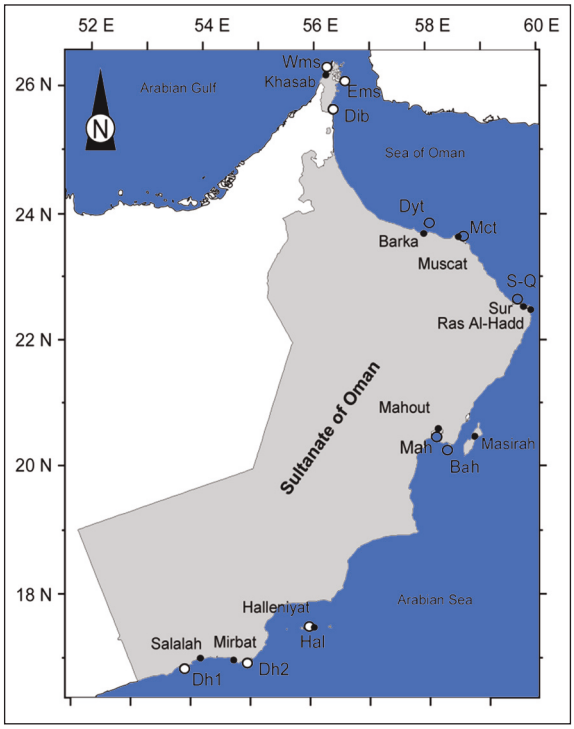

Figure 1. Map of the 11 sampling locations around the Sultanate of Oman. Filled circles are cities and towns and empty symbols sampling sites: Dh1 =Dhofar Rakhyut, Dh2= Dhofar Mirbat, Hal = Halleniyat, Mah = Mahout, Bah= Masirah-Bar Al-Hikman, S-Q = Sur-Qalhat, Mct = Muscat, Dyt = Damanyat, Dib= Dibab, Ems = East Musandam, Wms = West Musandam.

recorded on a semi-quantitative scale (Braun-Blanquet, 1932) from 0 to 5: 0 - not recorded, 1 - rare (observed once or twice, but not on every dive), 2 - present (observed on nearly every dive at this location), 3 - common (observed several times during each dive at that location), 4 - abundant (observed many times during each dive) and 5 - dominant (one of the species encounter in significant number during any given dive). The distribution patterns were analyzed by clustering analysis using Primer (Clarke & Gorley, 2006). The clustering algorithm for this analysis used the Bray-Curtis' (1957) index of similarity and an agglomerative clustering based on group averages.

RESULTS

A total of 75 species of echinoderms (21 echinoids, 27 asteroids, 21 holothuroids and 6 crinoids) were observed during this survey (Table 1). The overall number of species of all 4 classes of echinoderms decreased from the Arabian Sea (68) to the Sea of Oman (43) to the Arabian Gulf (38). Some species such as *Holothuria atra*, *H. leucospilota* or *Diadema setosum* were present and sometimes abundant in nearly all sites. Overall, 19 species were observed in all 11 locations but on the other hand 34 species were observed in only 1, 2, or 3 locations (Fig. 2).

A large group of species were restricted to the Arabian Sea coast (Table 1): 4 echinoids, 12 asteroids, 8 holothuroids. There were also a few species that were recorded in the Arabian Gulf or the Sea of Oman but were not observed during our survey of the Arabian Sea shores: *Asthenosoma varium, Clypeaster reticulatus, Lovenia elongata, Holothuria arenacava* and *Asteridiscoides belli*.

A large proportion (286/411 = 70%) of our observations consist of species that were either rare (1) or present (2), i.e. observed once or only a few times in a particular locations.

A clustering analysis distinguished 2 main groups of echinoderm communities (Fig. 3). The first group included sampling locations in the Sea of Oman and the second, locations in the Arabian Sea. A third small cluster included two locations located near Masirah Island (Fig. 3). This subdivision reflects the numerous species (28 in total) found only in Arabian Sea communities and absent from the Sea of Oman and the Arabian Gulf.

DISCUSSION

Our observations (75 species) underestimated the number of species (137 from waters <100 m deep) reported from the SE Arabian Region (Price, 1982). About 53 of these 137 were Ophiuroids that were not recorded in our study bringing the total of reported echinoderm to 84. The difference can be explained by our sampling strategy that was based on visual semi-quantitative observations that would underestimate cryptic (Dendrochirote holothuroids) and burying species (irregular sea-urchins). A similar argument explains why some species found in the Sea of Oman were not observed in our samples from the Arabian Sea. Four of these 5 "missing" species in the Arabian Sea are associated with soft substrates and were likely underestimated in our survey. A fifth one, *Asteridiscoides belli* was only observed once in a particularly deep dive near Mus-

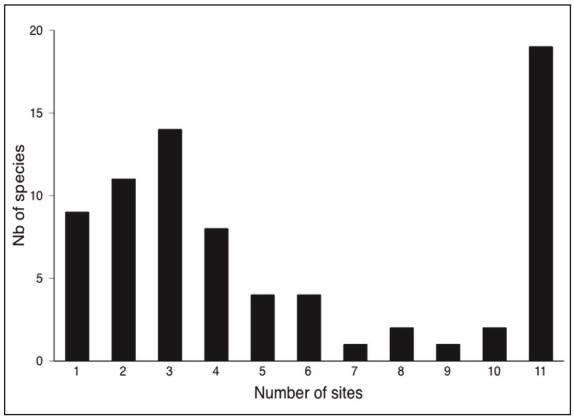

Figure 2. Fidelity plot for echinoderms in 11 locations of the Sea of Oman and the Arabian Sea. The y axis represents the number of species found in 1, 2, 3, n, …11 locations.

cat but has been observed by amateur divers at various locations near Muscat (Campbell, pers. com.).

The difference in community structure between the Sea of Oman and the Arabian Sea is not very surprising given the strong seasonal effect of the Monsoon on the coastal habitats in the Arabian Sea. (Barratt, 1984) but the relative endemism of some of the species is.

The difference in community structure between the Sea of Oman and the Arabian Sea is not very surprising given the strong seasonal effect of the Monsoon on the coastal habitats in the Arabian Sea. (Barratt, 1984) but the relative endemism of some of the species is. At least two species of starfish (*Ferdina sadhensis* and *Patiriella paradoxa*) appear endemic to the Dhofar region of Oman with a geographic range that correspond closely to that of other endemic species in the region such *Amphiprion omanensis* (Randall, 1995), *Haliotis mariae* (Bosch et al., 1995), *Scarus zhofar* (Randall, 1995) and *Porites decasepta* (Claereboudt, 2006). Despite the cold water climate during the monsoon and the growth of numerous species of seaweed at that time these endemic species belong to genera characteristic of tropical coral communities. If the seasonal development of seaweeds along most of the Arabian Sea shore is likely the cause of the abundance of herbivorous echinoderms such as *Tripneustes gratilla* or *Stomopneustes variolaris* (Campbell, 1988),

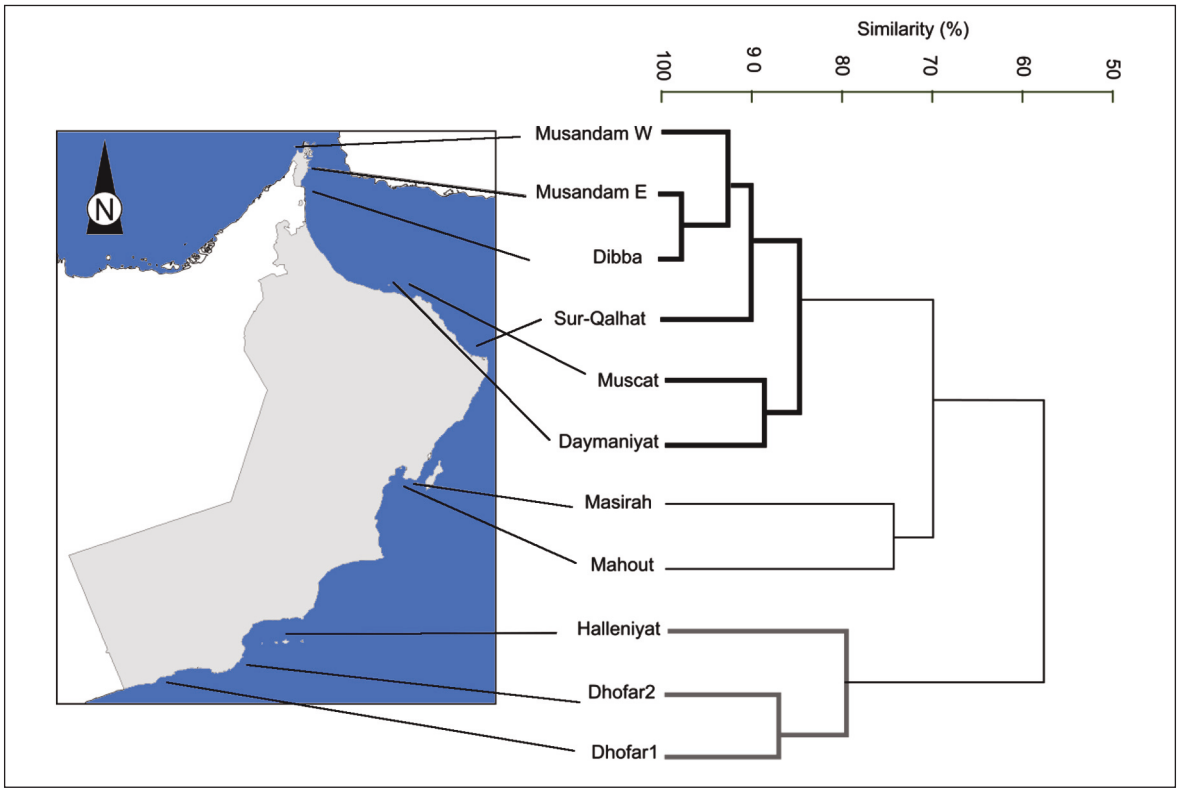

Figure 3. Clustering dendrograph of the 11 sampling locations around the Sultanate of Oman according to their echinoderm community structure. Lines linking locations the Sea of Oman and the Arabian Gulf are thickned.

				Arabian Sea						Sea of Oman				
	Arab. G.	Oman Sea	Arab. Sea	Dh1	Dh2	Hal	Mah	BAH	S-Q	Mct	Dyt	Dib	EMs	WMs
Echinoidea (Regularia)														
Athenosoma varium	+ a													
Prionocidaris baculosa	+	+	+	2	3	3	2	2	2	2	2	2	2	2
Diadema setosum	+	+	+	1	1	1	2	3	4	4	4	4	4	3
Echinometra mathaei	+	+	+	3	3	3	2	2	2	3	3	2	2	2
Temnopleurus toreumaticus	+	+	+	0	0	0	1	2	1	1	0	0	0	0
Temnotrema siamense	+													
Diadema paucispinum		+	+	4	4	4	2	2	0	0	0	0	0	0
Stomopneustes variolaris			+	3	3	3	0	0	0	0	0	0	0	0
Microcephus rousseaui			+	1	1	1	2	2	0	0	0	0	0	0
Salmacis bicolor		+	+	3	3	3	1	2	1	0	0	0	0	0
Tripneustes gratilla			+	3	3	3	2	1	1	0	0	0	0	0
Toxopneustes pileolus		+	+	3	3	3	3	3	3	3	3	3	3	3
Echinostrephus molaris		+	+	3	3	3	2	2	2	3	3	3	3	3
Echinotrix diadema		+	+	3	3	3	3	3	3	4	4	4	4	4
Echinoidea sp. 1			+	2	3	3	1	2	0	0	0	0	0	0
Echinoidea (irregularia)														
Echinodiscus auritus	+	+	+	0	0	0	1	0	0	1	0	0	1	0
Echinodiscus biperforatus			+	0	0	0	1	0	0	1	0	0	0	0
Clypeaster humilis	+	+	+	0	0	0	1	0	0	0	1	0	1	0
Clypeaster reticulatus	+	+		0	0	0	0	0	0	1	0	0	0	0
Lovenia elongata	+	+		0	0	0	0	0	0	3	0	0	0	0
Brissopsis persica	+		+	0	1	0	1	0	0	0	0	0	0	0
Metalia sternalis	+		+	0	0	0	1	1	0	0	0	0	0	0
Metalia townsendi	+	+	+	1	0	0	0	0	0	0	0	0	0	0
Echinoneus cyclostomus			+ b											
Holothuroidea														
Stichopus variegatus	+	+	+	3	3	3	2	3	3	4	4	3	3	3
Labidodemas semperianum	+													
Holothuria atra	+	+	+	3	3	3	4	3	3	3	3	3	3	3
Holothuria edulis	+	+	+	3	1	2	2	2	3	4	3	3	3	3
Holothuria rigida	+													
Holothuria leucospilota	+	+	+	3	4	4	3	3	3	4	3	3	3	3
Holothuria arenicola	+	+	+	0	0	1	1	0	0	0	1	0	0	0
Holothuria hilla	+	+	+	1	1	1	1	1	2	3	2	2	2	2
Holothuria impatiens	+	+	+	2	2	0	0	1	0	2	1	0	1	0
Holothuria scabra			+	0	0	0	3	1	0	0	0	0	0	0
Holothuria arenacava		+		0	0	0	0	0	0	1	0	0	0	0
Holothuria nobilis			+	1	1	0	0	0	0	0	0	0	0	0
Holothuria difficilis		+	+	2	2	0	0	1	1	1	1	1	1	0
Holothuria impatiens		+	+	1	2	1	2	2	2	1	1	1	1	1
Holothuria cinerescens			+	1	1	1	0	0	0	0	0	0	0	0
Holothuria pervicax		+	+	2	1	1	0	1	1	1	1	1	1	0
Actinopyga milliaris			+	2	2	1	0	0	0	0	0	0	0	0
Actinopyga mauritiana		+	+	2	2	1	2	3	2	3	4	3	3	2

Actinopyga sp.			+	0	1	0	0	0	0	0	0	0	0	0
Euapta goddefroyi		+	+	0	0	0	1	1	1	2	2	1	1	0
Holothuria sp.			+	4	4	2	0	2	0	0	0	0	0	0
Thyone dura	+		+	2	3	1	0	2	0	0	0	0	0	0
Oshmimella ehrenbergi	+	+	+	1	2	0	0	0	0	1	1	0	0	0
Leptosynapta chela	+													
Crinoidea														
Decametra mollis	+	+	+	2	2	1	0	0	0	1	0	1	1	0
Tropiometra carinata			+	1	0	0	0	0	0	0	0	0	0	0
Heterometra savignii			+	1	3	2	1	2	2	2	2	2	2	2
Lamprometra klunzingeri			+	1	2	1	0	2	0	0	0	0	0	0
Comatulidae sp. 1			+	0	2	2	0	0	0	0	0	0	0	0
Comatulidae sp. 2			+	0	1	0	0	0	0	0	0	0	0	0
Asteroidea														
Luidia hardwicki	+	+	+	0	0	1	1	0	0	1	0	0	0	0
Luidia maculata	+	+	+	0	0	1	0	0	0	0	1	0	0	0
Astropecten polyacanthus	+	+	+	2	2	2	2	2	2	2	2	2	2	2
Astropecten monacanthus	+	+	+	1	1	1	2	2	2	2	2	2	2	2
Astropecten pugnax	+													
Astropecten hemprichi	+													
Astropecten indicus	+	+	+	2	1	2	3	1	1	2	2	2	1	1
Pentaceraster mammillatus	+	+	+	0	1	1	0	0	0	1	0	0	0	0
Euraster cribosus	+													
Leiaster leachi	+	+	+	2	1	1	0	0	0	0	1	0	0	0
Linckia multiflora	+	+	+	4	4	4	2	2	2	3	2	2	2	2
Asteropsis carinifera	+	+	+	0	1	0	0	1	0	0	0	0	0	0
Asterina burtoni	+	+	+	2	2	2	2	3	2	2	2	2	2	2
Ferdina sadhensis			+	2	2	2	0	1	0	0	0	0	0	0
Culcita coriacea		+	+	1	0	0	0	1	2	3	3	3	2	2
Culcita cf. *schmideliana*		+	+	4	4	2	2	2	2	2	2	1	1	0
Linckia laevigata			+	1	1	1	0	0	0	0	0	0	0	0
Linckia guildingi			+	2	2	1	0	1	0	0	0	0	0	0
Acanthaster planci	+ a	+	+	2	1	1	2	1	2	1	1	1	2	2
Patiriella paradoxa			+ c	0	1	1	0	1	0	0	0	0	0	0
Asteridiscoides belli		+		0	0	0	0	0	0	1	0	0	0	0
Mythrodia clavigera		+	+	0	1	0	0	0	0	1	0	0	0	0
Dactylosaster cylindricus			+	1	1	1	2	2	0	0	0	0	0	0
Fromia indica			+	3	3	0	1	0	0	0	0	0	0	0
Leiaster coriaceus			+	2	3	3	0	0	0	0	0	0	0	0
Echinaster sp. 1			+	1	1	0	0	2	0	0	0	0	0	0
Echinaster sp. 2			+	0	0	0	0	1	0	0	0	0	0	0
Ophidiasteridae sp.			+	1	2	0	0	0	0	0	0	0	0	0
Protoreaster lincki			+	0	0	3	0	1	0	0	0	0	0	0
Stellaster cf. *equestris*			+	0	1	1	0	1	0	0	0	0	0	0

Table 1. Historical record of shallow water echinoderms in the Arabian Gulf, the Sea of Oman, the Arabian Sea (Price, 1982) and at the 11 locations surveyed in this study along the coast of the Sultanate of Oman. Numbers are semi-quantitative abundances (0-5; Braun-Blanquet, 1932). Arab. G. = Arabian Gulf, Oman Sea = Sea of Oman, Arab. Sea = Arabian Sea, Dh1 = Dhofar Rakhyut, Dh2 = Dhofar Mirbat, Hal = Halleniyat, Mah = Mahout, Bah = Masirah-Bar Al-Hikman, S-Q = Sur-Qalhat, Mct = Muscat, Dyt = Damanyat, Dib = Dibab, Ems = East Musandam, Wms = West Musandam. References: a- Price & Rezai, 1996; b- Campbell, 1988; c- Campbell & Rowe, 1997.

they are not found in the Sea of Oman. For many other species however, such as *Diadema paucispinum*, *Linkia laevigata* or *Holothuria nobilis*, which are typically associated with coral reefs, it is not. It is certainly possible that the extreme variations in temperature, up to 8 ºC variations in a few hours encountered during the summer in the shallow waters of the Sea of Oman (Coles, 1997), limit the distributional range of some of these species, adapted to the relatively narrower temperature ranges characteristic of reef communities (Coles, 2003). Temperature patterns also explains relatively well the community structure of algal communities (Schils & Wilson, 2006) but for instance fails to explain the distribution of many species of corals absent in the Sea of Oman and found in the Arabian Sea (Sheppard & Sheppard, 1991). An alternative hypothesis resides in a hydrodynamic reduction of larval dispersal. Modelling experiments have shown that larval connectivity between communities in the Sea of Oman and the Arabian Sea is negligible (Claereboudt, in prep) and that Ras-Al-Hadd could be considered as a marine Wallace line (Barber et al., 2000) resulting from local recurring hydrodynamic mesoscale structures and nearly isolating the Sea of Oman from the Arabian Sea. This supports the hypothesis that the existing biogeographical patterns around the Arabian Peninsula result from insufficient time for complete dispersal after the start of the Holocene period and incomplete mixing of the Fauna through all the suitable habitats of the Indian Ocean (Sheppard et al., 1992).

Several observations are worth discussing. For some species, although they were present in both the Arabian Sea and the Sea of Oman, their relative abundances was strikingly different. In the Sea of Oman, nearly all specimens of *Diadema* are clearly *D. setosum*, however, a few specimens showed the distinct "blue-star pattern" of *Diadema paucispinum*. In the Arabian Sea, it is *Diadema paucispinum* that dominated the echinoid community.

Although *Holothuria scabra* was known from the Red Sea (Hasan, 2005) its presence in the Arabian Sea and even its exploitation by fishermen was unknown and unexpected. These first observations triggered an ecological study that showed a very rapid decrease in abundance and size after the beginning of the exploitation phase of the population in 2005 (Al-Rashdi et al., 2007). The same is true for *Holothuria nobilis* which was known from the Red Sea (Price, 1982) and East-Africa (Samyn et al., 2006) but had not been recorded yet in the Arabian Sea.

We also observed the first known population of *H. arenacava* (Samyn et al., 2001) outside of Kenya. This species is probably more common than its known distribution suggests but because of its burying habits is likely to remain unnoticed. One holothuroid, particularly abundant in Dhofar is still unidentified. It resembles *Holothuria difficilis* but has a very distinct and distinctive color pattern with darker dorsal side and pale ventral side. A common sea urchin remains also unidentified. It is characteristized by 5 bands of short spines alternating with 5 large areas nearly without spines or with spines so short they are hidden below numerous erected pedicellariae. Finally, two morphs of the pillow starfish, *Culcita*, were observed regularly. On morph has a clear star shape and bears numerous large, conical spines on the aboral side whereas the other is nearly pentagonal with a few, if any conical spines, usually restricted to the apex of the arms.

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REFERENCES

Al-Rashdi K.M., Claereboudt M.R. & Al-Busaidi S.S., 2007. Density and Size Distribution of the Sea Cucumber, *Holothuria scabra* (Jaeger, 1935), at Six Exploited Sites in Mahout Bay, Sultanate of Oman. Agricultural and Marine Sciences, 12: 43–51.

Barber P.H., Palumbi S.R., Erdmann M.V. & Moosa M.K., 2000. A marine Wallace's line. Nature, 406: 692–693.

Barratt L., 1984. Ecological study of rocky shores on the south coast of Oman. Kowait Action Plan, 127 pp.

Bosch D.T., Dance S.P., Moolenbeek R.G. & Oliver P.G., 1995. Seashells of eastern Arabia. Motivate Publishing, Dubai.

Braun-Blanquet J., 1932. Plant sociology: The study of plant communities. McGraw-Hill Book Company, New York, 439 pp.

Bray J.R. & Curtis J.T., 1957. An ordination of the upland forest communities of sourthern Wisconsin. Ecological Monographs, 27: 325–349.

Campbell A.C., 1988. The echinoderm fauna of Dhofar (southern Oman) excluding Holothuroids. In: Burke R.D., Mladenov P.V. & Lambert P. (Eds.), Sixth International Echinoderm Conference. Aa Balkema, Victoria, Canada, pp. 369–378.

Campbell A.C. & Rowe F.W.E., 1997. A new species in the asterinid genus *Patiriella* (Echinoderma, Asteroidea) from Dhofar, southern Oman: a temperate taxon in a tropical locality. Bulletin of the Natural History Museum London (Zoology), 63: 129–136.

Claereboudt M.R., 2006. *Porites decasepta* Nov. Sp. a new species of corals (Scleractinia, Poritidae) from the Arabian Sea coast of Oman. Zootaxa, 1188: 55–62.

Clark A.M. & Rowe F.W.E., 1971. Monograph of shallow-water Indo-West Pacific echinoderms. Trustees of the British Museum (Natural History), London, 238+XXXI Plates pp.

Clarke K.R. & Gorley R.N., 2006. Primer V6: User Manual/Tutorial. Primer-E, Plymouth.

Coles S.L., 1997. Reef corals occurring in a highly fluctuating temperature environment at Fahal Island, Gulf of Oman (Indian Ocean). Coral Reefs, 16: 269–272.

Coles S.L., 2003. Coral species diversity and environtmental factors in Arabian Gulf and Gulf of Oman: a comparison to the Indo-Pacific Region. Atoll Research Bulletin, 507: 1–21.

Hasan M.H., 2005. Destruction of a *Holothuria scabra* population by overfishing at Abu Rhamada Island in the Red Sea. Marine Environmental Research, 60: 499–511.

Price A.R.G., 1982. Echinoderms of Saudi Arabia. Comparison between Echinoderm Faunas of Arabian Gulf, SE Arabia, Red Sea and Gulfs of Aqaba and Suez. Fauna of Saudi Arabia, 4: 3–21.

Price A.R.G., 1983. Echinoderms of Saudi Arabia. Echinoderm of the Arabian Gulf coast of Saudi Arabia. Fauna of Saudi Arabia, 5: 28–108.

Price A.R.G. & Rezai H., 1996. New echinoderm records for the Gulf including Crown-of-Thorns starfish, *Acanthaster planci* (Linnaeus), and their biogeographical significance. Fauna of Saudi Arabia, 15: 386–390.

Randall J.E., 1995. Coastal fishes of Oman. Crawford House Publishing, Bathurst, Australia, 440 pp.

Samyn Y., 2003. Shallow-water regular echinoids (Echinodermata; Echinoidea) from Kenya. African Zoology, 38: 193–212.

Samyn Y., Vandenspiegel D. & Massin C., 2006. Taxonomie des holothuries des Comores. Abc Taxa, 1: 1–130.

Schils T. & Wilson S.C., 2006. Temperature threshold as a biogeographic barrier in northern Indian Ocean macroalgae. Journal of Phycology, 42: 749–756.

Schultz H., 2006. Sea-Urchins, a guide to worldwide shallow water species. Heinke & Peter Schultz Partner, Hemdingen, Germany.

Sheppard C.R.C. & Sheppard A.L.S., 1991. Corals and coral communities of Arabia. Fauna of Saudi Arabia, 12: 1–171.

Sheppard C.R.C., Price A. & Callum R., 1992. Marine Ecology of the Arabian Region. Pattern and processes in extreme tropical environments. Academic Press, Harcourt Brace Jovanovitch, London, 359 pp.