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Zonation of Organisms on Rocky Shores of Northern Jeddah

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ABSTRACT. The intertidal zonation of rocky shore organisms in northern Jeddah was studied. The distribution of organisms on the shore is tide independent, and mainly affected by the degree of exposure to wave action. No zonation patterns were recognized in protected sites. Regardless of seasonal fluctuation in the sea level, distinctive zonation patterns were recognized all the year round, on an exposed shore. Some ecological remarks associated with destruction of limestone cliffs and increased exposure are discussed.

Introduction

Features of zonation of rocky shores in the northern and southern Red Sea have been dealt with by Safriel and Lipkin (1964) and Fishelson (1971), respectively.

More recently, a fairly good record of the ecology of rocky shores in the Central Red Sea (Jeddah) was made by Hughes (1977). Unaware of this study, Aleem (1978) compared the intertidal zonation at Al-Ghardaqa (Hurghada), south of Suez Gulf, Egypt, with that of Obhur, northern Jeddah, Saudi Arabia.

Physical features of the northern Jeddah shores were perturbed during the construction of the city Corniche Road. The characteristic limestone cliffs were destroyed, and the reef flats in front of them were filled to varying widths. The Corniche boulder revetments, which now represent the rocky shores are made of firestones ranging in size between 0.3 and 0.7 m^3 and these dip steeply into the sea at some sites.

The present work describes the intertidal zonation of organisms on rocky shores of northern Jeddah after the construction of the Corniche Road.

Ecology

The physical oceanography of the Red Sea has been reviewed by Morcos (1970) and Edwards (1987). The major Red Sea coastal habitats with physical factors affecting them have been discussed by Jones *et al.* (1987).

The peculiarity of the Red Sea is mainly due to its shallow constricted entrance and location in an arid region which is characterized by low rainfall. It is a warm sea with salinity well above the world ocean average of 35‰. The main characters affecting the ecology of both littoral and shallow sublittoral habitats in the Red Sea are the tides and the seasonal changes in the sea level (Morcos 1970, Hughes 1977, Jones *et al.* 1987). The tides in the Red Sea are semidiurnal and oscillate around a nodal point near 19° N, with southern and northern averages of about 50 cm (Morcos 1970). As Jeddah is near the nodal point (21° 30′ N), only irregular high and low waters are observed (Morley 1975, Hughes 1977). However, meteorological effects (atmospheric pressure and wind stress) can produce temporary fluctuations of ± 75 cm (Hughes 1977).

In the Red Sea, marked seasonal variations of the wind fields are controlled by the monsoon wind system. During summer, steady NNW winds occur throughout the entire sea, pushing the water out through the straight of Bab-al-Mandab.

During winter, northward of Latitude 20°N, the winds blow from the same direction, but in the southern half of the sea, the reversed windfield pattern is to the SSE, and drives the surface water northwards from the Gulf of Aden into the Red Sea. This variation in the monsoon system in summer and winter causes seasonal changes of up to 50 cm in the mean sea level throughout the Red Sea (Morcos 1970).

From the above, it is obvious that the sea shore boundaries in Jeddah are subject to both temporary and seasonal changes.

Data of the seasonal variations of air and ambient water temperature and salinity as well as of other physiochemical parameters of northern, middle and southern Red Sea waters are previously reported (Morcos 1970, Ghamrawy 1982, Edwards 1987).

Study Sites and Methods

Six sites were chosen for the description of the rocky shore zonation at Jeddah.

Site 1 is a cliff lying inside Obhor Creek (Fig. 1). It differs from those described by Hughes (1977) in topography, exposure to wave action, and aspect. It is short (1.5 m high); being protected from wave action, it has only shallow undercut of 50 cm. The face of the cliff has an eastern aspect, and is exposed to the sun most of the day. Those described by Hughes (1977) were mostly cliffs outside Obhor Creek, and due to their overhangs and western aspects are shaded most of the day.

Site 2 is composed of smooth concrete pillars of a jetty in front of the Faculty of Marine Science (Fig. 1). The reef flat has been dredged during the construction of the jetty, which extends into the sea for 30 m.

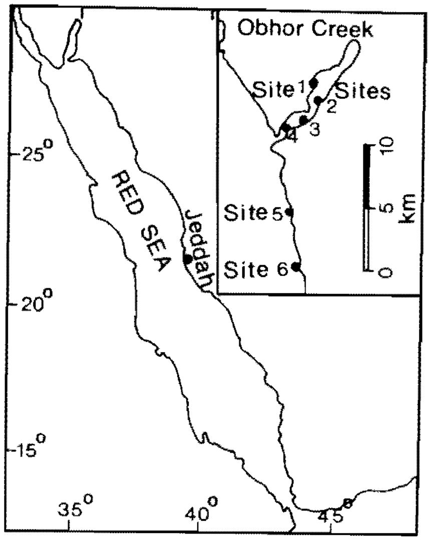

FIG. 1. Map of Red Sea showing position of Jeddah (inset shows the study sites north of Jeddah). (Site 6 is approximately 15 km northern of the city centre)

Site 3 is a fossil cliff 2.5 m in height and lying approximately 1 km south of site 2. The shallow reef flat in front of site 3 is approximately 30 m wide.

Site 4 is also a fossil cliff of the same height as that of site 3, but differs in that it has a sharp slope starting below the end of the overhang. This is because of dredging carried out in the area for navigation purposes.

Site 5 is a rocky revetment outside Obhor Creek. It is separated from the sea by a wide reef flat (ca 80m). The wave energy is decreased before reaching the shore, and is only enough to splash it up to 30-40 cm above the sea level.

Site 6 (Figs. 1 and 2) is also a rocky revetment and is one of the most exposed shores in northern Jeddah. Its base lies directly on the margin of the reef edge. In winter, the wave action at this site is enough to dampen the whole shore. During strong onshore winds, the sea spray splashes the road to varying widths. In summer, when the sea level is lower, the shore is splashed only up to 1.5-2 m above sea level.

At each site, a profile was measured from the top of the shore to the sea level, and faunal densities were determined during winter (February, 1988) and summer (July, 1988). Faunal densities were determined using a 25 × 25 cm metal quadrat at 30 cm intervals. Additional qualitative samples were also taken at each site to recover rare or fast moving animals. Quantitative and qualitative samples were preserved in 5% buffered formalin solution for identification.

Due to the submersion of some species during winter and the presence of fast moving animals, comparison between sites was carried out on the basis of species pre-

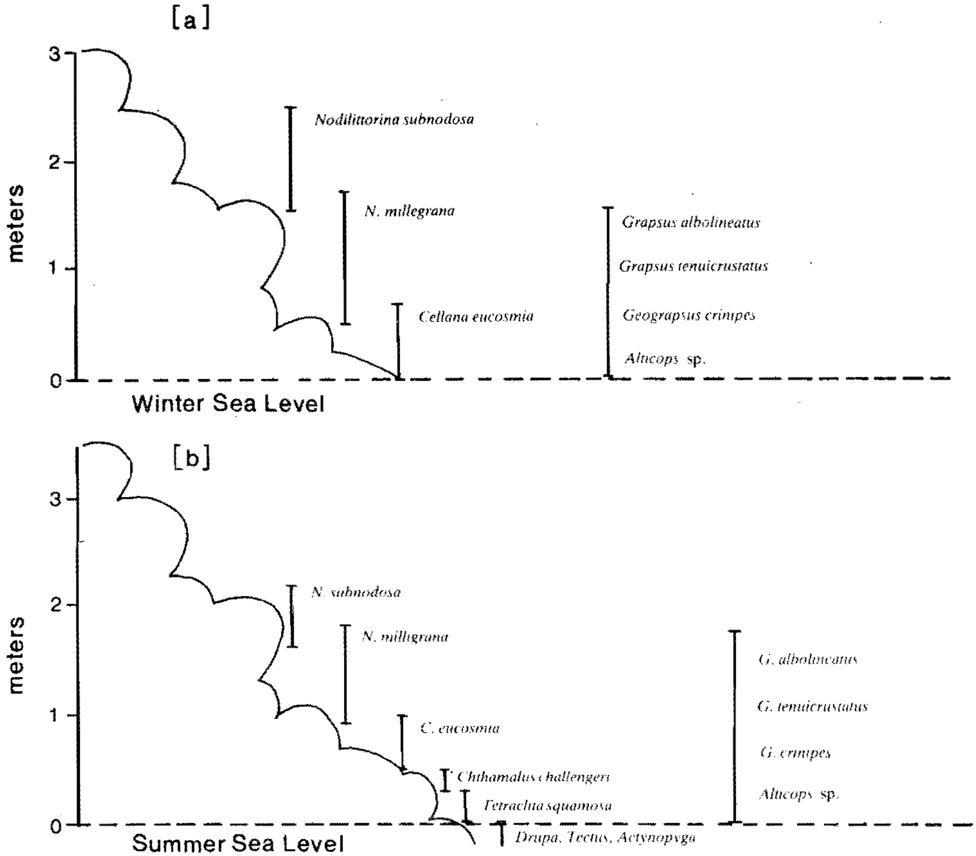

FIG. 2. Faunal zonation patterns at site 6. a) during winter and b) during summer.

sence or absence during summer. This was done using Jaccard's similarity index (Jaccard 1908). The formula for Jaccard's coefficient is as follows:

$$JC = \frac{c}{a + b + c} 100 \text{ (Jaccard's similarity)}$$

where,

a = number of species in site A only,
b = number of species in site B only, and
c = number of species common to both sites.

Results

Site 1

Table 1 illustrates the densities of the main faunal species recorded at the study sites. In this table, presence of rare and fast moving faunal is indicated. These data are used to calculate the indices of similarity in per cent between the faunal communities in the study sites (Table 2).

TABLE 1. Species recorded at different study sites in summer.

Species / Sites	1	2	3	4	5	6
Planaxis sulcatus	32	48	96	32	48	
Nerita undata	224		64	48	16	
Nerita albicilla	32		16	160	960	
Nodilittorina subnodosa			16	16		16
Nodilittorina milligrana	+		16	32	96	48
Morula granulata		16		+		
Cellana eucosmia		32		16		64
Chthamalus challengeri		160		64		320
Tetraclita squamosa rufotincta						32
Pagurus sp	+		+	+		
Coenobita scaevola		+				
Metapograpsus messor	+		+			+
Geograpsus crinipes				++		+++
Grapsus tenuicrustatus				++		+++
Grapsus albolineatus				++		+++
Ligia exotica	+					
Alticops sp	+			+		+++

Numbers indicate the density of species per m^2 at different shore gradients, for rare or fast moving species + (rare), ++ (common), +++ (abundant).

TABLE 2. Matrix of indices of the similarity in per cent for the rocky shore fauna of the study sites.

Sites	6	5	4	3	2
1	14.28	25.00	22.22	27.27	7.69
2	12.50	11.11	19.04	7.69	
3	14.28	25.00	22.22		
4	25.80	19.04			
5	6.66				

The main littoral species present at site 1 are limited to the gastropods *Nodilittorina millegrana* Phillipi, *Planaxis sulcatus* Born (Identified as *P. savigni* by Aleem 1978), *Nerita albicilla* Linne and *Nerita undata* Linne. The distribution of these species are restricted to the base of the cliff. They have no distinctive pattern of zonation, but show seasonal migration colonizing the shore up to the top of the shallow undercut in winter and its lower part in summer hence, following the rise and fall of the sea level.

Site 2.

Faunal species recorded on the pillars of the jetty are *Cellana eucosmia* (Pilsbry) (identified as *C. rota* by Hughes 1977 and Aleem 1978), *Morula granulata* (Duclos), *P. sulcatus* and the barnacle *Chthamalus challengeri* Hoek. These species adjust their distribution to colonize a zone of about 25 cm above sea level all the year round, except for *C. challengeri* which is permanently inundated during winter months.

Site 3

In addition to the main species recorded at site 1, the littorinid *Nodilittorina subnodosa* Phillipi was recorded at site 3. All species, except *N. subnodosa,* are restricted in their distribution to 20 or 30-40 cm above sea level in summer and winter months, respectively. *N. subnodosa* distribution is extended to a maximum of 1 m above sea level during winter, but does move in summer to overlap with other species.

Site 4

The main species present at this site are the same as those of site 1, in addition to *C. eucosmia, M. granulata* and *N. subnodosa.* These species do not show signs of zonation, except *N. milligrana* and *N. subnodosa.* In winter, *N. subnodosa* occupies a zone of 75 cm, directly 50 cm below the top of the cliff. *N. milligrana* occupies a zone of 85 cm immediately below *N. subnodosa* to reach the upper limits of other species which occupy a zone of 50 cm above sea level. During, summer *Nidolittorina* spp. overlap and move down the shore to occupy a zone of 50 cm above that of the other species which are restricted in distribution to 30 cm above sea level. At this level, *C. challengeri,* which is permanently inundated during winter, is present together with scattered individuals of the hermit crab *Pagurus sp and the blenny Alticops* sp. The grapsid crabs *Geograpsus crinipes* (Dana), *Grapsus albolineatus* Lamark and *Grapsus tenuicrustatus* (Herbst) are seen occasionally on the face of the cliff.

Site 5

The species present at this site are the gastropods recorded at site 1. Similarly, they colonize a narrow zone above sea level and do not show any distinctive vertical zonation.

Site 6

This site is characterized by the absence of *P. sulcatus, N. undata,* and *N. albicilla* which live in most other sites. The gastropod species recorded at this site are *N. subnodosa, N. milligrana,* and *C. eucosmia.* Grapsid crabs recorded at site 4 are numerous at this site and can be seen scraping algal food [*Ectocarpus siliculosus* (Dillwyn) Lyngbye] from wave-washed rocks during daytime. Figure 2 (a,b) shows a profile of the shore at site 6 and zonation pattern of the littoral species in winter and summer, respectively.

In winter, *N. subnodosa* occupies a zone 1 m wide, 50 cm below the top of the shore. It is usually found in shallow depressions in the surface of the rocks. *N. milligrana* occupies a zone 1 m wide immediately below *N. subnodosa* (with some overlappings). *C. eucosmia* inhabits a zone of approximately 50 cm, extending from the lower limit of *N. milligrana* to sea level. Fast moving fauna (grapsid crabs and the blenny *Alticops* sp) live in a zone extending from sea level up to the upper limit of *N. millegrana* zone, but mainly concentrated at the *Cellana* zone or a little above.

During summer, when the sea level is lower, the wave action is insufficient to splash the entire width of the shore, and the upper shore fauna aggregate and migrate toward sea level. However, they retain their distinctive zonation pattern, with the same order as in winter, but with more overlapping (Fig. 2b). Animal communities which were permanently inundated during winter become exposed during summer on the lower part of the shore. The barnacle *C. challengeri* is present at the lower limit of *Cellana,* colonizing a belt of 20 cm wide. The giant barnacle *Tetraclita squamosa rufotincta* Pilsbury is present just below *Chthamalus* zone and extends 30 cm. The *Tetraclita* zone is permanently wave beaten and rarely uncovered. The rocks from the *Cellana* zone down to *Tetraclita* zone are covered with a filamentous lawn of *E. siliculosus.* A number of animal species were recorded at the base of the rock revetment. These included the gastropods *Drupa ricinis hadari* Emerson and chernhorsky and *Tectus dentatus* Forskal, and the sea cucumber *Actynopyga muritania* (Quoy and Gaimard). The alga *Padina* sp. also grows sparely at the base of the revetment. Beyond this, the bottom drops directly into a zone of living corals dominated by the genera *Millipora* and *Acropora.*

Discussion

The indices of similarity between faunal communities at different sites show that similarity between faunal communities is related to several factors. High values of similarity between faunal communities of limestone cliffs (22-27%) indicate the importance of substrate texture. The effect of this factor is reflected in the high dissimilarity between the faunal community of the smooth pillars and those of other sites (11-19%).

Exposure to wave action affects both species compositions and their zonation patterns. Inside Obhor Creek, signs of zonation were observed only at the exposed site (site 4). The similarity between faunal communities at this site and at site 6 (26%) is more than that between sites 5 and 6 (7%), since site 5, which is of the same substratum as that of site 6, is protected, and, hence is less exposed to wave action.

It is of interest to follow the effect of wave action on rocky shore faunal zonation at the most exposed site (site 6). It is apparent that increased wave action extends the vertical range of the shore. This lessens the harshness of the physical factors and enables the animals to become vertically zoned during summer instead of being concentrated near the base of the shore.

Winter and summer zonation patterns described at site 6 could be related to those described in the northern Red Sea by Safriel and Lipkin (1964), and to the universal scheme proposed by Stephenson and Stephenson (1949). However, the zones described here are unique in that they are tidal-independent, but are related to the degree of exposure to wave action. In the terminology of Stephenson and Stephenson (1949), the supralittoral fringe is inhabited in winter by *N. subnodosa,* the midlittoral zone by *N. millegrana,* and the infralittoral fringe by *C. eucosmia.* In summer, the zones occupied by *N. subnodosa* correspond to the supralittoral fringe, *N. millegrana* and *C. eucosmia* to the midlittoral zone, and the barnacles *(Chthamalus* and *Tetraclita)* to its infralittoral fringe. *Drupa, Tectus* and *Actynopyga* also inhabit the infralittoral zone.

Planaxis sulcatus, Nerita undata, N. albicilla, and *Morula granulata* (Duclos), which were reported on the cliff by Hughes (1977), were absent at site 6. These species are present at all other sites except *Morula.* This reflects their need for shelter. More interesting is that *Nodilittorina subnodosa* and *N. millegrana,* reported only as occasional species by Hughes (1977), have well established zones at site 6. The barnacle zones reported at site 6 were not reported by Hughes (1977). These ecological differences are due to modification in the topography and, in particular, to increased exposure to wave action, and are comparable to examples of the effect of exposure on both the distribution and quality of rocky shore organisms given by Newell (1970).

The environmental changes which took place in Jeddah affected not only the fixed and slow moving fauna, but also fast mobile animals. Thus, increased exposure at site 6 has widened *Alticops* sp. zone (Fig. 2) which was previously confined to immediately above water level at the foot of the shore (Hughes 1977). Grapsid crabs which previously occurred at all heights of the cliff are now living mainly in the *Cellana* zone. This is most probably due to the lack of shade. The temperature on the surface of the rocks may exceed 60°C on the upper part of Jeddah shores. According to Newell (1970) behavioural responses to temperature may themselves exert an influence on zonation pattern. Living in a frequently wave-washed zone may have allowed the behaviour pattern of grapsid crabs to become diurnal (as seen at site 6) instead of nocturnal as described by Hughes (1977).

The littoral fauna of the central Red Sea are impoverished in comparison with other regions of the Indo Pacific (e.g. Fishelson 1971, Taylor 1971, Chelazzi and Vannini 1980, and Jones *et al.* 1987). This is clearly related to the narrow range of tidal amplitude (Hughes 1977, Mastaller 1978, and Taylor and Reid 1984). It is also related to the isolation of the Red Sea by its constructed entrance at Bab-al-Mandab and to changes which occur in the physical and chemical properties of the water from south to north. The latter factors also affect the diversity of Red Sea pelagic and sublittoral benthic species (Halim 1969, UNESCO 1982, and Bemert and Ormond 1981).

There is increasing evidence (Fishelson 1977, Ghamrawy 1987, and Dicks 1987) that industrial and domestic pollution, as well as land reclamation, are serious problems in the Red Sea. Referring to the construction of the road built in the region of the present study, Dicks (1987) states that any further building in this manner could cause serious losses to coastal habitats. This shows that the cooperation between marine scientists and local authorities in connection with conservation and management of the Red Sea environment is a must. This together with studies on the effect of land reclamation and/or other activities on the near shore waters, will make it possible to avoid decisions with short-term gain at the expense of sustained long term value.

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تمنـطق الكائـنات على الشواطيء الصخريـــة شمالي جـــدة

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المستخلص . لايخضع توزيع كائنات الصخور بمنطقة الدراسة لظاهرة المد والجزر ، إنما يتـأثـر أســاسًا بدرجة حماية الشواطئ من فعل الأمواج . بينما ينعدم تمنطق الكائنات في الشواطئ المحمية ، نلاحظ تمنطقًا لهذه الكائنات على الشواطئ المعرضة لفعل الأمواج ، وعـلى مدار العام ، وبغض النظر عن التغيرات الموسمية في مستوى ماء البحر . يتناول البحث مناقشة بعض الظواهر البيئية المرتبطة بزيادة تعرض الشواطئ لفعل الأمواج وبهدم الجرف الجيري الذي مَيَّز منطقة الدراسة قبل إنشاء طريق كورنيش المدينة .