Pakistan J. Zool., vol. 36(2), pp. 111-123, 2004.

Development of Abundance – Biomass Curves Indicating Pollution and Disturbance in Molluscan Communities on Four Beaches Near Karachi, Pakistan

SOLAHA RAHMAN AND SOHAIL BARKATI
Department of Zoology, University of Karachi, Karachi, Pakistan
E-mail: sohailbarkati@yahoo.com

Abstract.- The abundance and biomass of rocky intertidal molluscs at four study sites along the Karachi coast were examined on quarterly basis, for a period of two years from December 1993 to December 1995 with reference to tidal level. Various stresses such as over-exploitation, pollution, industrialization and development of public facilities are known to affect adversely on the coastal fauna. Abundance / biomass comparison (ABC) plots showed undisturbed or unpolluted condition throughout the investigation period at Cape Monze. Nathiagali was unpolluted in most of the samples except in spring and autumn of first year. However, Manora and Buleji showed moderately disturbed or moderately polluted condition throughout the study period. At Nathiagali, the ABC curves generally show moderately disturbed condition at all tidal levels in most of the samples. The ABC curves in the low tidal zone generally show unpolluted or undisturbed condition in most of the samples at Manora and Buleji rocky shores. On the contrary, mid and high tidal zones of both sites indicates the moderately polluted situation during the whole study period.

Key words: Pollution, abundance, biomass, ABC curves, marine molluscs.

INTRODUCTION

Molluscs are one of the most diverse group of animals and are abundantly found on the beaches of Pakistan (Ahmed, 1977, 1987; Ahmed *et al.*, 1982; Barkati and Burney, 1995; Nasreen *et al.*, 2000). The littoral benthic organisms as a whole and the molluscs, in particular, play an important role in the local marine food chain. Molluscan shellfish have long been a source of protein food to the coastal communities. Karachi is the biggest coastal city and is the most thickly populated area with a population of about 10 million (Beg, 1993). Various stresses have adverse effects on coastal species and their habitats. Among them are overexploitation, conversion of natural area, pollution, urbanization of coastal areas, industrialization and development of public facilities (Ahmed, 1997).

The measurement of changes in the structure of benthic communities is widely used for interpreting the effects of disturbances, stress and marine pollution. Molluscs are sessile or slow moving and show effect of disturbance and pollutants after a short time. The patterns of species abundance and biomasses found are believed to reflect the effects of disturbance and pollution (Gray *et al.*, 1988). A number of methods are in practice for identifying these changes, for instance study of changes in total number of species, diversity indices and frequency of occurrence of opportunities species. However, Gray *et al.* (1990) considered these methods as relatively crude.

Few comparative studies have been conducted by marine biologists around the world to determine the effect of disturbance and pollution on marine organisms using the abundance-biomass comparison curves (Warwick and Ruswahyuni, 1987; Gray *et al.*, 1988, 1990; Beukema, 1988; Warwick *et al.*, 1990a,b,c; Shephard *et al.*, 1992; Agard *et al.*, 1993; Somerfield *et al.*, 1994; Lasiak and Field, 1995; Mahmoudi *et al.*, 2002). In Pakistan, Ahmed (1977, 1997) had attempted to assess the magnitude of coastal pollution through faunal survey, but no biological indices of community structure were used. Effects of pollution on marine molluscs of Pakistan are mostly restricted to heavy metal studies (Qasim *et al.*, 1985; Rizvi *et al.*, 1986; Fatima and Temuri, 1993). However, according to Warwick *et al.* (1990), assessing the patterns in the structure of benthic communities are more useful for the detection of anthropogenic disturbance as compared to experimental methods and also in assessing local

0030-9923/2004/0002-0111 $ 4.00/0

effects. This is the first paper, which detects disturbance and pollution on the molluscan fauna of four rocky shores along the Karachi coast through the development of abundance and biomass curves.

MATEIALS AND METHODS

Study sites

Four rocky ledges were selected, namely, Manora, Buleji, Nathiagali and Cape Monze along the coast of Karachi (Fig. 1) to examine the effect of disturbance and pollution on molluscan fauna. All sites are approachable by road. Two of these sites, Nathiagali (24°51'N; 66°45'E) and Cape Monze (24°49'N; 66°40'E) are located in the naval restricted area far from the city at a distance of 30 and 35 km, respectively and are thus relatively undisturbed. Conversely, Manora (24°46'N; 66°57'E) and Buleji (24°50'N; 66°48'E) are located at about 3 km SW and 18 km NW of Karachi, respectively. Of the four sites, Manora and Buleji are the most disturbed and polluted sites (Ahmed, 1977, 1997).

The intertidal shores of Manora, Buleji and Cape Monze have one characteristic in common, that they are open to direct and surf action and can be classified as exposed and wave beaten open shores. However, Nathiagali may be recognized as semi-exposed rocky shore being protected from direct surf action of the sea due to the presence of a rocky cliff of considerable height allowing the water to reach the flat intertidal portion after reducing its force. Manora and Buleji rocky shores have gradually sloping shores, whereas Cape Monze has sharply steeped vertical cliff and small littoral width. These sites have rich animal and plant populations along the Pakistan coast.

Sampling and laboratory techniques

The patterns of abundance and biomass of the molluscan species were determined on all the four sites with reference to the tidal height. Visits were made during the ebb tides on quarterly basis for a period of two years from December, 1993 to December, 1995 *i.e.* nine times from each site. Physical parameters of each study site, including data, time, tidal level, air and water temperature, pH and salinity were recorded at the time of each visit (Table I).

The beaches were arbitrarily divided into three zones on the basis of the tidal height. The divisions are (a) high tidal zone (b) mid tidal zone and (c) low tidal zone. The quadrate samples were spaced in a random fashion over an area parallel with the shoreline. Nine 1-m^2 quadrate samples were obtained from the three tidal zones of each site. Extra sampling was also done in March 1995, September 1995 and December 1995. All samples were returned to the laboratory and were frozen until further laboratory analysis. The molluscs were sorted, identified, counted, blotted to remove excess water and weighted (with shells). The biomass of each species was determined on an electric balance (Sartorius) as blotted wet weight. The animals were then placed in a vacuum oven (Memmert) at 70°C for at least 48 hours. Oven dried individuals were reweighed on an electric balance for the dry weight.

Molluscan species were identified using the following literature: Subrahmanyam *et al.* (1952), Kundo (1965), Barnes (1974), Dance (1977), Lindner (1977), Kohn (1978) and George and George (1979).

Data analysis

In order to investigate the effects of pollution and disturbance on macrobenthic communities, the method of plotting ABC curves proposed by Warwick (1986) and Warwick *et al.* (1987) without reference to control samples in time and space was used. The k-dominance curves (Lamshead *et al.*, 1983) for species abundance and species biomass are plotted on the same graph to make a comparison of the forms of these curves. The two curves act as an "internal control" against each other (Warwick, 1993). The species are ranked in order of importance in terms of abundance and biomass on the x-axis (logarithmic scale) with percentage dominance on the y-axis (cumulative scale).

The distribution of individuals among species and the distribution of biomass among species would exhibit a different response to pollution and disturbance. In undisturbed communities the biomass is dominated by one or few large size species (conservative species), each represented by rather few individuals. The distribution of numbers

Table I.- Values of environmental variables of the four study sites along the Karachi coast.

Site	Date	Time (hrs)	Tide (m)	Temperature (°C)			pH	Salinity (°/oo)
				Air	Water	Sand		
Manora	13-1-94	1737	0.0	21.0	24.5	22.5	7.2	38
	15-4-94	0643	0.3	26.0	24.0	25.0	7.2	37
	25-6-94	0535	-0.2	30.0	28.0	29.0	7.0	37
	25-9-94	1931	0.4	24.5	26.5	25.5	6.8	35
	20-12-94	1756	0.2	19.0	22.0	21.0	6.8	38
	19-3-95	0613	0.0	21.0	22.0	21.5	7.0	37
	17-6-95	0725	0.1	29.0	28.5	28.0	6.8	39
	24-9-95	1631	0.4	31.0	27.0	30.0	6.8	40
	19-12-95	1426	0.2	22.0	24.0	22.5	7.2	39
Buleji	29-12-93	1648	0.0	24.0	22.0	23.0	7.2	38
	30-3-94	0628	-0.2	23.5	23.0	24.0	7.0	36
	26-6-94	0615	0.0	29.0	31.0	32.0	7.0	37
	21-9-94	1736	0.2	26.0	28.0	26.0	6.9	35
	17-12-94	1619	0.1	21.5	21.0	22.0	6.8	38
	22-3-95	0814	0.2	225	21.0	23.5	7.0	38
	18-6-95	0812	0.4	27.5	28.5	29.0	6.8	40
	25-9-95	1706	0.2	28.0	28.0	27.5	6.8	36
	18-12-95	1335	0.4	25.5	26.0	26.5	7.2	39
Nathiagali	30-12-93	1735	0.0	25.0	23.0	21.0	7.0	37
	31-3-94	0712	-0.1	25.0	24.5	25.0	6.8	41
	27-6-94	0659	0.2	28.0	29.0	29.0	6.8	37
	22-9-94	1805	0.2	25.5	26.2	27.0	6.6	36
	19-12-94	1724	0.1	26.5	28.5	26.5	6.8	39
	20-3-95	0643	0.0	21.5	21.0	22.0	6.8	39
	15-6-95	0553	-0.3	27.5	25.5	27.0	6.8	37
	26-9-95	1742	0.0	26.0	28.0	27.0	7.0	37
	21-12-95	1600	-0.3	21.0	24.0	22.0	7.2	36
Cape Monze	12-1-94	1659	-0.1	15.5	23.0	24.5	6.8	38
	29-3-94	0545	-0.1	24.0	22.5	23.0	7.0	40
	28-6-94	0737	0.5	28.5	29.5	29.5	6.8	37
	23-9-94	1833	0.2	26.0	26.5	27.0	6.7	36
	18-12-94	1652	0.1	21.0	23.5	22.0	6.8	38
	21-3-95	0726	0.0	22.5	21.0	21.5	6.8	39
	16-6-95	0639	-0.1	28.0	25.5	27.5	6.6	37
	27-9-95	1820	0.0	26.0	38.5	27.0	7.4	39
	22-12-95	1646	-0.4	21.5	24.0	20.0	7.0	36

of individuals among species is more even than the distribution of biomass. Thus, the k-dominance curve for biomass lies above the curve for abundance along its entire length. Under moderate disturbance conditions, the large competitive dominance are less and the inequality in size between the numerical and biomass dominants is reduced so that the biomass and abundance curves are closely coincident and may cross each other one or more times. As pollution or disturbance becomes more severe, benthic communities become increasingly dominated by one or very few small size species (opportunistic species) and abundance curve lies above the biomass curve throughout its length. However, Warwick (1986) emphasized the need for adequate replication of sampling to determine the numbers and biomass of relatively rare biomass dominants accurately.

Information relating to total abundance, total wet weight (including hard parts) and total dry

Fig. 1. Map of Karachi coast showing sampling sites; Manora, Buleji, Nathiagali and Cape Monze rocky shores.

weight (including hard parts) of all species present were computed for all sites. The ABC curves were drawn using the statistical software "PRIMER" of Plymouth Marine laboratory, UK, for each tidal zone and of the total area of all the four study sites.

RESULTS

Environmental variables

The seasonal variation in temperature, salinity and pH values of the four study sites are detailed in Table I. The water temperature varied from a minimum of 21.0- to 31.0 with a yearly average around 25°C. The pH values ranged from a minimum of 6.6 to a maximum 7.4. The salinity values ranged from a minimum of 35 to a maximum of 41 with a yearly average of around 37.5 $^{o}/_{oo}$.

Manora rocky shore

The species abundantly present on low tidal zone are *Perna viridis, Thais rugosa, T. carinifera* and *Turbo intercostalis*. The molluscan species present on mid and high tidal zones include *Cerithium morus, C. rubus, C.* sp., *Turbo coronatus, Nerita albicilla, Cantharus rubiginiosus*.

The ABC curves for abundance and dry biomass in the low tidal zone generally show unpolluted or undisturbed condition in most of the samples (Table II). Unpolluted condition was observed mostly in pre or post-monsoon season (April 1994 and March 1995 and December 1994 and December 1995, respectively). Moderately polluted condition was noticed mostly in monsoon season (June 1994, September 1994 and June 1995). Samples of January 1994 and September 1995, however, do not fall in this scheme. On the contrary, mid and high tidal zones indicate the moderately polluted situation during the whole study period; the abundance and biomass curves closely coincide in all the samples collected in various seasons. No seasonal variation is observed in ABC curves from mid and high tidal zones.

The ABC curves for the total area do not show any seasonal pattern (Fig. 2). The total area of Manora display what Warwick (1986) and Warwick *et al.* (1987) define as the moderately disturbed

Table II.- **Seasonal changes in disturbance of molluscan fauna of four sites, at three tidal levels, based on k-dominance curves for species abundance and biomass between December 1993 and December 1995.**

Season	Manora			Buleji			Nathiagali			Cape Monze		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Winter	B	B	B	B	B	B	A	A	A	B	B	A
Spring	A	B	B	A	B	B	B	B	B	A	A	A
Summer	B	B	B	B	B	B	B	B	B	A	A	A
Autumn	B	B	B	B	B	B	A	B	B	A	A	A
Winter	A	B	B	A	B	B	B	B	A	A	A	A
Spring	A	B	B	A	B	B	B	B	B	A	A	A
Summer	B	B	B	B	B	B	B	B	B	B	B	A
Autumn	A	B	B	A	B	B	A	B	B	A	A	A
Winter	A	B	B	A	B	B	B	A	B	A	A	A

A, undisturbed; B, moderately disturbed communities.

condition where the abundance and biomass curves closely coincide and cross each other in all the samples throughout the study period. The k-dominance curves for abundance and wet biomass of molluscan species from three tidal levels and for total area give same results as that for abundance and dry biomass.

Buleji rocky shore

Species contributing more to the biomass at low tidal zone of Buleji are *Turbo intercostalis, Trochus stellatus, Thais rudolphi, T. rugosa, Cerithium sinensis*. Species abundantly present on mid tidal zone are *Cerithium morus, C. rubus, C.* sp., *Cerithidea cingulatus, Cerithidea* sp., *Turbo coronatus* and *Nerita albicilla*. Species such as *Planaxis sulcatus, Cerithium rubus, Cerithidae* sp., *Turbo coronatus, Nerita albicilla, Euchelus asper* were present on high tidal zone.

The ABC curves for abundance and dry biomass of low tidal zone display seasonal changes (Table II). The ABC curves in the low tidal zone indicate undisturbed condition in most of the samples (5 out of 9). Undisturbed condition was observed mostly in pre or post-monsoon season (March 1994 and 1995 and December 1994 and 1995, respectively). Moderately polluted condition was noticed mostly in monsoon season (June 1994, September 1994 and June 1995). Samples of December 1993 and September 1995, however, do not fall in the scheme. In December 1993, the biomass and numbers curves cross. This may have been due to sampling error and also due to low species diversity. However, the species diversity was relatively high in September 1995 and biomass curve lies well above the number curve. In December 1995, the biomass curve lies above the abundance curve for almost all of its length except for a single species probably due to sampling error. No seasonal variation in ABC curves was noticed in the mid and high tidal zones (Table II). Mid and high tidal zones displayed moderately disturbed condition with the abundance and biomass curves closely coinciding in all the samples during both the years.

The k-dominance curves for abundance and dry biomass of the total area show a moderately disturbed condition throughout the investigation period (Fig. 3). The k-dominance curves for abundance and wet biomass of molluscan species of three tidal levels and of the total study area showed similar results as that for abundance and dry biomass.

Nathiagali rocky shore

The low tidal zone *i.e.* side of the rocky cliff facing the shore consisted of large boulders and characterized by the presence of large size *Turbo intercostalis, T. coronatus, Nerita textilis, N. albicilla, Euchelus asper, Cantharus undosus, Planaxis sulcatus* and *Cerithium rubus*. The mid tidal zone of Nathiagali was mostly covered by water during the collection period and the bottom is muddy. The molluscan community at the mid tidal

Fig. 2. ABC plots for molluscs from Manora, Karachi between January 1994 and December 1995. k-dominance curves for species abundance and biomass are based on totals of 9 replicates.

Fig. 3. ABC plots for molluscs from Buleji, Karachi between December 1993 and December 1995. k-dominance curves for species abundance and biomass are based on totals of 9 replicates.

zone is dominated by small size species for example *Cerithium hanleyi, C. rubus, Cerithidea* sp. and *Pyrene flava*. Large size species were less abundantly present such as *Trochus stellatus, Turbo intercostalis* and *T. coronatus.* At high tidal zone, *Turbo intercostalis, T. coronatus, Euchelus asper, Thais rudolphi, T. hippocostanum, T. rugosa, Trochus stellatus, Cellana radiata, Onchidium daemelli, Nodilittorina picta* and *Nerita albicilla* were present.

The ABC curves of abundance and dry biomass for all tidal levels showed changes with the season (Table II). They generally show moderately disturbed condition at all tidal levels in most of the samples. In low tidal zone, undisturbed condition was noticed mostly in monsoon period (September 1994 and 1995). Moderately disturbed condition was observed mostly in pre or post-monsoon period (March 1994 and 1995 and December 1994 and 1995, respectively). Sample of December 1993, however, does not fall in the above criteria. In the mid tidal zone, undisturbed condition was observed mostly in post-monsoon period (December 1993 and 1995) and moderately disturbed condition was observed in pre and monsoon period (March 1994 and 1995 and September 1994 and September 1995, respectively). But moderately disturbed condition was seen in December 1994 sample. In the high tidal zone, undisturbed condition was noticed mostly in post monsoon season (December 1993 and 1994) and moderately disturbed condition was observed mostly in pre and monsoon season (March 1994 and 1995 and September 1994 and 1995). The sample of December 1995, however, does not fall in the scheme. The data are based on only three quadrate samples per tidal zone. These probably are insufficient to collect rare biomass dominants and gave false impression of moderately disturbed condition.

The ABC curves drawn for the total area (all tidal levels combined) mostly shows undisturbed condition. The moderately disturbed condition was observed only in pre and monsoon season during first year of study. This is probably due to sampling error and comparatively low species diversity giving false impression of moderately disturbed condition. The undisturbed situation was noticed in all seasons of the second year (Fig. 4). The results for abundance and wet biomass from three tidal levels and for the total area are exactly same as described for abundance and dry biomass of molluscan species.

Cape Monze rocky shore

The species present on low and mid tidal zones at Cape Monze include *Trochus stellatus, Turbo intercostalis, Thais rudolphi, Conus coronatus* and *C. biliosus*. On high tidal zone *Morula granulata, Nerita albicilla, Turbo coronatus, T. intercostalis* and *Euchelus asper* were abundantly present.

The ABC curves of all tidal zones show undisturbed condition in most of the samples (Table II). In low and mid tidal zones, moderately disturbed condition was observed only in pre and monsoon seasons during first and second years (January 1994 and 1995, respectively) whereas undisturbed condition was noticed in rest of the season. In low tidal zone the biomass curve lies above the abundance curve for almost all of its length except for one species *i.e. Trochus stellatus* in pre and monsoon season (March 1994 and 1995 and September 1994 and 1995) probably due to sampling error. In mid tidal zone the biomass curve lies above the abundance curve for almost all of its length except for one species in December 1994. Noteworthy is the fact that in unpolluted condition, only few individuals contribute to biomass and thus chances of sampling error may exist. In the high tidal zone unpolluted condition was observed throughout the study period except in September 1994. In this zone the biomass curve lies above the abundance curve for almost all of its length except for one species in September 1995.

The ABC curves of the total area of Cape Monze show undisturbed condition throughout the study period (Fig. 5). The biomass curve lies above the abundance curve for almost all of its length except for one species in December 1994. The abundance and wet biomass curves give results similar to those of abundance and dry biomass curves.

Comparison between sampling sites

The ABC curves of Cape Monze show undisturbed condition throughout the investigation period. Nathiagali is undisturbed in most of the

Fig. 4. ABC plots for molluscs from Nathiagali, Karachi between December 1993 and December 1995. k-dominance curves for species abundance and biomass are based on totals of 9 replicates.

Fig. 5. ABC plots for molluscs from Cap Monze, Karachi between January 1994 and December 1995. k-dominance curves for species abundance and biomass are based on totals of 9 replicates.

samples except in spring and autumn of first year. However, Manora and Buleji show moderately disturbed condition throughout the study period.

DISCUSSION

Coastal areas receive a multitude of inputs from land-based sources through riverine discharge, drainage and through outfalls. Various contaminants are also introduced through shipping activities and atmospheric inputs. The ABC curves are a sensitive indicator of natural, physical and biological disturbance as well as pollution induced disturbances (Warwick, 1986; Warwick *et al*., 1987). These curves are used by some authors for representing patterns of species abundance and biomass in a community structure. According to Gray *et al*. (1988), Warwick *et al*. (1990a,c), Agard *et al*. (1993) and Mehmoudi *et al*. (2002), the physical disturbances and stress was confirmed by the ABC curves. However, in some cases, ABC method is not particularly sensitive, *e.g.* when applied to the `Amoco-Cadiz' oil spill (Ibanez and Dauvin, 1988). Working on intertidal macrozoobenthos communities living on the tidal flats in the Dutch Wadden Sea, Beukema (1988) found this method confounded by the erratic occurrence of large numbers of small mobile species. According to Shepherd *et al*. (1992), the ABC method does not seem appropriate for assessing the level of disturbance to the fish assemblage. Warwick *et al*. (1990b) documented that k-dominance curves revealed significant differences in the relative species abundance distribution for nematodes but not for copepods on a sheltered intertidal sandflat at southeastern Tasmania.

According to Warwick (1993), undisturbed communities tend to be dominated by conservative species, characterized by large body size and along life span, which are usually dominant in terms of biomass but not in numbers. In polluted conditions, the conservative species are often at disadvantage and opportunistic species usually became numerical dominants. Lasiak and Field (1995) stated that sites D1, D2 and N2 on Transkei coast of South Africa would be categorized as undisturbed as their biomass curves are located well above the abundance curves. Site N1 where the abundance and biomass curves are closely coincident, would be classed as moderately disturbed and site N3, where the abundance curve lies in close proximity to, but also distinctly above, the biomass curve would be categorized as moderately severely disturbed. The ABC curves were generally more consistent in their abilities to discriminate between exploitable and non-exploitable sites. The abundance biomass comparison curves clearly showed the major community changes following the El-Nino and South Pari and South Tikus Islands, Indonesia (Warwick *et al*., 1990a). According to Gray *et al*. (1990), oil stress resulted in increased abundance of some and reduction of other species.

The results of present investigation are in conformity with those of Gray *et al*. (1988), Warwick *et al*. (1990), Agard *et al*. (1993) and Lasiak and Field (1995). The unpolluted or undisturbed condition of Cape Monze is confirmed by the ABC curves throughout the study period. Nathiagali is unpolluted in most of the samples except in spring and autumn of first year. However, Manora and Buleji showed moderately disturbed condition throughout the study period probably due to regular visits by humans, oil pollution from ships and due to Lyari and Malir rivers discharge, which are the major source of pollution in the Manora Channel (Beg, 1984a,b; Beg, 1993; Ahmed, 1977, 1987, 1997). However, according to El-Komi (1996), the change in benthic structure depends not only on the state of pollution but also on the type of substrate.

Warwick and Ruswahyuni (1987) and Warwick *et al*. (1990) documented that the physical disturbance and instability of sediments were the main factors rather than pollution in maintaining the macrobenthic communities at an intermediate stage, respectively. Gray *et al*. (1988) also suggest that the differences in curves resulted from the effects of natural environmental variables than pollution at six sites in Norway. The results of the present study are in accordance with the above studies. ABC plots indicate that the community at Manora and Buleji are at an intermediate stage due to physical disturbance. Cape Monze and Nathiagali showed undisturbed condition.

In the present investigation, gastropods dominate the biomass on the four rocky shores studied. Same inference were drawn by Ahmed and Hameed (1999), Nasreen *et al*. (2000) and Hameed *et al*. (2002) while working on the macroinvertebrates on Buleji, Manora and Pacha rocky ledges, respectively. Ahmed and Hameed (1999) found that *Turbo coronatus, Cerithium carbonarium, C. morus, C.* sp., *Tiara tuberculata, Nerita albicilla, Turbo intercostalis, Planaxis sulcatus* and *Cerithidea fulviatilis* possess the highest biomass on Buleji rocky shore. Nasreen *et al*. (2000) documented that the snails *Cerithium rubus, C.* sp., *Drupa tuberculata, Turbo cornatus, Nerita albicilla, Thais tissoti, Nassarius obockinensis* and *C. obeliscus* contributed more to the biomass on exposed rocky ledge of Manora. Hameed *et al*. (2002) recorded that the dominant animals were *Turbo coronatus* and *Nerita albicilla* on Pacha rocky ledge at Karachi. The other abundant snails were *Astraea semicostata, Turbo intercostalis, Thais rudolphi, Astraea stellaris, Cellana radiata, Monodonta australis* and *Nodilittorina picta*.

The molluscan species are of large body size and dominated in terms of biomass at less polluted and undisturbed sites *i.e.* Cape Monze and Nathiagali. Whereas, the species are of small size and numerically dominant in relatively disturbed and polluted sites *i.e.* Manora and Buleji. Earlier Ahmed (1997) had observed that on Pakistani beaches number of species was large but the size and biomass of individual species was small. Publications dealing ABC curves on seasonal basis or on tidal basis are not available.

ACKNOWLEDGEMENTS

The first author is extremely grateful to Dr. K.R. Clarke, Mrs. Linda Horsfield (Office Administrator) and Prof. R.F.C. Mantoura (Director) of Plymouth Marine Laboratory, U.K., for sending her the `PRIMER' software for analyses of the data, publications and for many helpful comments and suggestions. She is also thankful to Ray Gorley and Martin Carr of Plymouth Marine Laboratory in running and solving the problems of the statistical package (PRIMER). The authors are indebted to Ms. Sheeba Afsar of the Geography Department for help in preparing the map.

REFERENCES

AGARD, J.B.R., GOBIN, J. AND WARWICK, R.M., 1993. Analysis of marine macrobenthic community structure in relation to pollution, natural oil seepage and seasonal disturbance in a tropical environment (Trinidad, West Indies). *Mar. Ecol. Prog. Ser*., **92**: 233-243.

AHMED, M., 1977. An assessment of the magnitude of coastal pollution in Pakistan through a study of its fauna. *Thalassia jugosalavice, THJUAP*, **13**: 395-412.

AHMED, M., 1987. Conservation strategies for the marine environment and marine fisheries of Pakistan. In: *Towards a National Conservation Strategy for Pakistan*, pp. 177-202. Proceedings of the Pakistan Workshop, August 1986. Government of Pakistan, Environmental and Urban affaires Division.

AHMED, M., 1997. Natural and human threats to biodiversity in the marine ecosystem of coastal Pakistan. In: *Coastal zone management imperative for maritime developing nations* (eds. B.U. Haq, S.M. Haq, G. Kullenberg and J.H. Stel), pp. 319-332. Kluwer Academic Publishers, Netherlands.

AHMED, M. AND HAMEED, S., 1999. Species diversity and biomass of marine animal communities of Buleji rocky ledge, Karachi, Pakistan. *Pakistan J. Zool*., **31**: 81-91.

AHMED, M., RIZVI, S.H.N. AND MOAZZAM, M., 1982. The distribution and abundance of intertidal organisms on some beaches of Makran coast in Pakistan (Northern Arabian Sea). *Pakistan J. Zool*., **14**: 175-184.

BARKATI, S. AND BURNEY, S.M.A., 1995. Benthic dynamics of a rocky beach macroinvertebrates. II. Cyclical changes in biomass at various tidal heights at Buleji, Karachi (Arabian Sea). *Mar. Res*., **4**: 63-76.

BARNES, R.D., 1974. *Invertebrate Zoology*. Third edition. W.B. Saunders Company, Philadelphia, London, Toronto. pp. 870.

BEG, M.A.A., 1993. Status of some environmental problems of Karachi. *Wildl. Environ*., **2**: 14-17.

BEG, M.A.A., MAHMOOD, S.N., NAEEM, S. AND YOUSAF ZAI, A.H.K., 1984a. Land based pollution and the marine environment of Karachi coast. *Pakistan J. sci. ind. Res*., **27**: 199-205.

BEG, M.A.A., BASIT, N., SIDDIQUI, F., MAHMOOD, I. AND SIDDIQUI, M.A., 1984b. Studies on the biological contamination of the coastal environment of Karachi. *Pakistan J. sci. ind. Res*., **27**: 206-210.

BEUKEMA, J.J., 1988. An evaluation of the ABC-method (abundance / biomass comparison) as applied to macrozoobenthic communities living on tidal fltas in the Dutch Wadden Sea. *Mar. Biol*., **99**: 425-433.

DANCE, P., 1977. *The encyclopedia of shells*. Blandford Press Limited, Poale, Dorset: pp. 288.

EL-KOMI, M.M., 1996. Coastal development and pollution impact on the distribution of macrobenthic communities along the eastern coast of the Gulf of Suez (Egypt). *Pakistan J. Mar. Sci*., **5**: 1-13.

FATIMA, M. AND TEMURI, I., 1993. The study of heavy metals in limpets collected from Karachi coast. In: *Proceedings of National seminar on study and management in coastal zones in Pakistan* (eds. N.M. Tirmizi and Q.B. Kazmi), pp. 285-290. M.R.C.C. University of Karachi and Pakistan Nat. Comm. for UNESCO.

GEORGE, J.D. AND GEORGE, J.J., 1979. *Marine life, an illustrated encyclopedia of invertebrate in the sea*, pp. 287. Wiley-Interscience, New York.

GRAY, J.S., ASCHAN, M., CARR, M.R., CLARKE, K.R., GREEN, R.H., PEARSON, T.H., ROSENBERG, R. AND WARWICK, R.M., 1988. Analysis of community attributes of the benthic macrofauna of Frierfjord / Langesunfjord and in a mesocosm experiment. *Mar. Ecol. Prog. Ser.*, **46**: 151-165.

GRAY, J.S., CLARKE, K.R., WARWICK, R.M. AND HOBBS, G., 1990. Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfield: North Sea. *Mar. Ecol. Prog. Ser.*, **66**: 285-299.

HAMEED, S. AND AHMAD, M., 2002. The distribution of marine macro-animals with reference to their tidal heights on the rocky shore of Pacha, near Karachi, Pakistan. *Pakistan J. Zool.*, **34**: 1-8.

IBANEZ, F. AND DAUVIN, J.C., 1988. Long-term changes (1977-1987) in a muddy fine sand *Abra alba-Melinna palmata* community from the western Engligh Channel: multivariate time-series analysis. *Mar. Ecol. Prog. Ser.*, **49**: 65-81.

KOHN, A.J., 1978. The Conidae (Mollusca: Gastropoda) of India. *J. Nat. Hist.*, **12**: 295-335.

KUNDU, H.L., 1965. On the marine fauna of the Gulf of Kutch. Part-III – Pelecypods. *J. Bomb. Nat. Hist. Soc.*, **62**: 84-103.

LAMSHEAD, P.T.D., PLATT, H.M. AND SHAW, K.M., 1983. The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. *J. Nat. Hist.*, **17**: 857-874.

LASIAK, T.A. AND FIELD, J.G., 1995. Community level attributes of exploited and non-exploited rocky infratidal macrofaunal assemblages in Transkei. *J. exp. Mar. Biol. Ecol.*, **185**: 33-53.

LINDNER, G., 1977. *Seashells of the world* (ed. G. Vevers), pp. 271. Blandford Press Poole, Dorset, UK.

MAHMOUDI, E., BEYREM, H., BACCAR, L. AND AISSA, P., 2002. Response of free-living Nematodes to the quality of water and sediment at Bou Chrar Lagoon (Tunisia) during winter 20002. *Mediterr. Mar. Sci.*, **3/2**: 133-146.

NASREEN, H., AHMED, M. AND HAMEED, S., 2000. Seasonal variation in biomass of marine macro-invertebrates occurring on the exposed rocky ledge of Manora Island, Karachi, Pakistan. *Pakistan J. Zool.*, **32**: 343-350.

QASIM, R., AFTAB, N. AND BARKATI, S., 1985. Inorganic elements in four species of oysters from Karachi coast. *Pakistan J. sci. ind. Res.*, **28**: 126-128.

RIZVI, S.H.N., SALEEM, M. AND BAQUAR, J., 1986. Steel mill effluents. Influence on the Bakran creek environment. In: *Marine science of the Arabian sea* (eds. M.F. Thompson and N.M. Tirmizi), pp. 549-570. American Institute of Biological Sciences, Washington, DC.

SHEPHERD, A.R.W., WARWICK, R.M., CLARKE, K.R. AND BROWN, B.E., 1992. An analysis of fish community responses to coral mining in the Maldives. *Environ. Biol. Fishes*, **33**: 338-367.

SOMERFIELD, P.J., GEE, J.M. AND WARWICK, R.M., 1994. Soft sediment meiofaunal community structure in relation to a long-term heavy metal gradient in the Fal estuary system. *Mar. Ecol. Prog. Ser.*, **105**: 79-88.

SUBRAHMANYAM, T.V., KARANDIKAR, K.R. AND MURTI, N.N., 1952. Marine gastrpoda of Bomaby – Part II. General characters, habits and habitat of the Bomaby gastropods. *J. Univ. Bombay*, **20**: 1-73.

WARWICK, R.M. AND RUSWAHYUNI, 1987. Comparative study of the structure of some tropical and temperate marine soft-bottom macrobenthic communities. *Mar. Biol.*, **95**: 641-649.

WARWICK, R.M., 1986. A new method for detecting pollution effects on marine macrobenthic comunities. *Mar. Biol.*, **92**: 557-562.

WARWICK, R.M., 1993. Environmental impact studies on marine communities: Pragmatical considerations. *Australian J. Ecol.*, **18**: 63-80.

WARWICK, R.M., PEARSON, T.H. AND RUSWAHYUNI, 1987. Detection of pollution effects on marine macrobenthos: further evaluation of the species abundance / biomass method. *Mar. Biol.*, **95**: 193-200.

WARWICK, R.M., CLARKE, K.R. AND SUHARSONO, 1990a. A statistical analysis of coral community responses to the 1982-1983 El Nino in the Thousand Islands, Indonesia. *Coral Reefs*, **8**: 171-179.

WARWICK, R.M., CLARKE, K.R. AND GEE, J.M., 1990b. The effect of disturbance by soldier crabs *Mictyris platycheles* H. Milne Edwards on meiobenthic community structure. *J. exp. Mar. Biol. Ecol.*, **135**: 19-33.

WARWICK, R.M., PLATT, H.M., CLARKE, K.R., AGARD, J. AND GOBIN, J., 1990c. Analysis of macrobenthic and meiobenthic community structure in relation to pollution and disturbance in Hamilton Harbour, Bermuda. *J. exp. Mar. Biol. Ecol.*, **138**: 119-142.

(Received 18 September 2003, revised 24 November 2003)