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A COMPARATIVE STUDY OF MOLLUSCAN BIOMASS ON FOUR ROCKY SHORES OF KARACHI, PAKISTAN

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ABSTRACT

The overall mean dry biomass of molluscs was highest at Nathiagali (518.684 gm/m^2) followed by Buleji (418.938 gm/m^2), Manora (408.088 gm/m^2) and Cape Monze (337.365 gm/m^2) during a period of two years from December 1993 to December 1995. The average dry biomass of molluscs was highest in mid tidal zone followed by high and low tidal zone at Manora, Buleji and Cape Monze rocky shores whereas, the average biomass was high in low tidal zone followed by high and mid tidal zones at Nathiagali rocky shore. *Cerithium morus* (36.88%) predominated at Manora, *C. morus (29.15%) and* Turbo coronatus *(24.93%) co-dominated at Buleji, Cerithium rubus* (16.28%), *Trochus stellatus* (14.82%), *Turbo coronatus* (16.92%) at Nathiagali and *T. intercostalis (*44.52%) pre-dominated at Cape Monze. The analysis of variance revealed that biomass was significantly different among sites and also among tidal zones.

Key Words: Molluscan dry biomass, rocky shores of Karachi, Spatial variation, tidal level.

INTRODUCTION

Studies on biomass estimation provide pertinent information about the fertility of the area. Fairly good number of studies on species distribution and biomass of the intertidal benthic zone of rocky shores were undertaken (Seapy and Littler, 1978; Littler, 1980; Horn *et al*., 1983; Underwood *et al*., 1983; McQuaid and Branch, 1984, 1985; McQuaid *et al*., 1985; Marinopoulos, 1991; Hong, 1992; Le Loeuff and Intes, 1993; Lasiak and Field, 1995; Souza and Gianaca, 1995; Coates, 1998; Menconi *et al*., 1999; Gascón *et al*., 2009).

Very few such efforts were made on the status of biomass contribution and species composition of macrobenthos of rocky beaches of Pakistan. The most studied shore in this respect is Buleji (Barkati and Burney, 1995; Burney and Barkati, 1995; Ahmed and Hameed, 1999a). Studies of similar nature on other coasts of Pakistan include those of Ahmed *et al*. (1982) on Makran coast, Nasreen *et al*. (2000) on Manora; Hameed *et al*. (2001) on Pacha.

The present investigation was conducted exclusively on macromolluscs of four rocky beaches of the Karachi coast. This communication is first of its kind about a major group of marine invertebrates dealing with four spatially separated populations along the Karachi coast. The present paper deals with the distribution of species and biomass contribution with reference to tidal height and season. This is in continuation of a series of papers quantifying the effect of disturbance and pollution on molluscs through study of Abundance Biomass Curves and Biomass Abundance Ratio (Rahman and Barkati, 2004, 2009).

MATERIALS AND METHODS

The four sites selected for study were, namely, Manora, Buleji, Nathiagali and Cape Monze along the coast of Karachi, Sindh. Details about the location and ecology of the study sites are given in Rahman & Barkati (2004, 2009, 2010).

Visits were made on quarterly basis for a period of two years from December, 1993 to December, 1995. Physical parameters of each study site, including date, time, tidal level, air and water temperatures, pH and salinity were recorded at the time of each visit (details are given in Rahman and Barkati, 2004). One square meter quadrates were randomly placed in arbitrarily divided tidal zones i.e. high, mid and low zones. Three quadrate samples were taken from each tidal level. Total nine quadrate samples were obtained from each site. Small boulders and the stones in the quadrates were also examined. Rocks were scrapped and broken down to collect the molluscan borers if present.

Samples were kept in a deep freezer in the laboratory till further analysis. The total weights of animal sample of each quadrate were obtained on a top loading balance (Jyifa) corrected up to 1 mg. The molluscs of each quadrate (stations) were separated into species, identified and counted. All individuals of each species were than wrapped in a weighted aluminium foil. The wet weights were taken on an electric balance (Sartorius) to the nearest 0.01mg. The animals were then placed in a vacuum oven (Memmert) at 70^0 C for at least 48 hours. Oven dried individuals were reweighed on an electric balance. The shells of molluscs were included in the biomass calculations.

In the present study, biomass is defined as the total amount (weight or number) of living animals per surface unit area. The average values of these quadrates were used for total wet and dry weight (including hard parts) for each tidal zone. Values of the three tidal zones were averaged to determine the standing stock per average square meter of each study site. Biomass or species composition in this paper refers only to “molluscan” benthos.

OBSERVATIONS

Manora Rocky Shore

Ninety percent of the total molluscan biomass was contributed by the following 11 species: *Cerithium morus, Turbo coronatus, Perna viridis, Cerithium sp., Morula granulata, C. rubus, Nerita albicilla, Calliostoma scobinatum, Turbo intercostalis, Cantharus rubiginiosus* and *Cerithidea cingulatus* (Table 1).

Some species like *Glossodoris, Onchidium daemelli* and *Octopus vulgaris* possesses low dry biomass compared to their high values in wet biomass composition. Some large size species of molluscs represented by few individuals contributed more in the dry biomass, for instance *Bursa subgranosa, Conus biliosus, C. coronatus, Thais carinifera, T. echinulata, T. hippocostanum, T. rudolphi, T. rugosa, Trochus stellatus* and *Turbo intercostalis.* There are species, which were collected in high numbers but have shown low dry biomass such as *Cerithium rubus, Cerithium sp., Cerithidea cingulatus* and *Pyrene misera.* A number of species found rarely and also had negligible dry biomass, for instance: *Astele sp., Cantharus undosus, Calliostoma scobinatum, Cantharus spiralis, Cerithium hanleyi, C. sinensis, Clanculus pharaonius, Diodora bombayana, Drupa subnodulosa, Epitonium scalare, Heliacus variegates* etc.

The average dry biomass was higher at mid tidal level (527. 48 gm/m^2) followed by high (388.46 gm/m^2) and low (308.25 gm/m^2) tidal zones (Table 2). The dry biomass of low tidal zone was low in winter (December) of 1993 and in summer (June) of 1995 but remained high in spring (March) in both the years of study. In mid tidal zone, the values fluctuated seasonally from low in spring (March) to high in autumn during 1994 but were low in summer (June) and high the following winter (December) during 1995. The values in high tidal zone varied from low in winter (December) to high in autumn (September) during first year but low in summer (June) and high in winter (December) during second year (Table 2). The biomass values of the total area were low in summer season during both the years (Fig. 1). The values were high in autumn month during first year and in winter month during second year.

Buleji Rocky Shore

Ninety per cent of the total molluscan dry biomass was contributed by following 7 species: *Cerithium morus, Turbo coronatus, Cerithium sp., T. intercostalis, Planaxis sulcatus, C. rubus* and *Nerita albicilla.* The remaining 62 species possessed less than 1 % dry biomass (Table 1).

Cerithium morus and *Turbo coronatus* shared jointly almost half of the total dry biomass. Species present in large number but had low dry biomass are *Cerithidea cingulatus, Cerithium rubus, Planaxis sulcatus* and *Pyrene misera.* On the contrary some species had high dry biomass although collected in less number includes *Bursa subgranosa, Perna viridis, Sunetta scripta, Euchelus asper, Crassostrea tuberculata, Lithophaga nigra, Thais rugosa, T. hippocostanum,* and *Turbo intercostalis* (Table 1). *Onchidium daemelli* and *Octopus vulgaris* had low contribution both in terms of abundance and dry biomass.

The average dry biomass was higher in mid tidal zone (499.66 gm/m^2) followed by high (396.80 gm/m^2) and low (360.09 gm/m^2) tidal zones (Table 2). The values of dry biomass in low tidal zone varied from high in winter to low in spring during both the years. In mid tidal zone, the values changed from high in spring to low in summer during first year but were high in winter to low in March during second year. In high tidal zone the values changed from low in winter to high in autumn during first year but were low in summer to high in autumn during second year. The values of dry biomass of the total area were low in spring and summer with high values in autumn and winter months during both the years of study (Fig. 1).

Nathiagali Rocky Shore

Ninety one per cent of total molluscan dry biomass was contributed by following 9 species: High in dry biomass are *Turbo coronatus, Trochus stellatus, Nerita albicilla, T. intercostalis, Euchelus asper, Thais rudolphi, Cerithium rubus, Sunetta* sp. and *Planaxis sulcatus*. Rest 46 species contribute only 9 % (Table 1).

Large size *Turbo coronatus* dominated Nathiagali rocky shore both in terms of abundance and biomass followed by *Trochus stellatus*. Some species had relatively more dry biomass although found in less numbers, such as, *Crassostrea tuberculata*, *Sunetta sp.*, *Thais rudolphi*, *T. hippocostanum* and *Turbo intercostalis.* Species found abundantly with low biomass contribution are *Cerithium rubus*, *C. hanleyi*, *Cerithidea cingulatus*, *Planaxis sulcatus* and *Cellana radiata*. Species found in less number and also low in dry biomass are given in Table 1.

Table 1. Average per cent composition of biomass of major molluscan species at four localities of Karachi Coast, during the period December 1993 to December 1995.

Species	Manora	Buleji	Nathiagali	Cape Monze
	%	%	%	%
Gastropoda				
Calliostoma scobinatum	1.40	0.01	0.05	0.18
Cantharus rubiginiosus	1.08	0.27	0.37	0.23
Cerithedia cingulatus	1.07	0.71	3.95	0.08
Cerithium hanleyi	0.02	0.13	9.95	0.00
Cerithium morus	36.88	29.15	0.71	0.08
Cerithium rubus	3.57	4.99	16.28	0.67
Cerithium sinensis	0.69	0.12	0.86	0.02
Cerithium sp.	10.84	9.74	3.06	0.01
Euchelus asper	0.03	0.85	4.71	1.60
Morula granulata	3.61	0.85	1.48	6.07
Nerita albicilla	1.97	4.64	9.94	3.57
Nodilittorina picta	-	0.00	3.93	-
Planaxis sulcatus	0.09	7.02	2.96	-
Thais rudolphi	0.90	0.15	0.62	3.08
Trochus stellatus	0.33	0.43	14.82	19.64
Turbo coronatus	18.02	24.93	16.92	13.01
Turbo intercostalis	1.38	9.64	3.13	44.52
Bivalvia				
Perna viridis	10.98	0.22	-	-

The average dry biomass of individuals was highest in low tidal zone (611.00 gm/m^2) followed by high (592.82 gm/m^2) and mid (339.71 gm/m^2) tidal zones (Table 2). Values of molluscan dry biomass in low tidal zone changed from low in winter (December) to high in autumn (September) during first year, whereas it was high in winter (December) and low in spring (March) during the second year of study. In mid tidal zone the values were low in spring (March) and high in summer (June) during first year. However, during second year, the values were high in winter (December) and low in spring (March). In high tidal zone the dry biomass fluctuated seasonally from low in winter to high in summer during first year but was high in winter (December) and low in March during second year. The values of dry biomass of the total area were low in the beginning and high in rest of the year with a slight decrease in September during both the years (Fig. 1).

Cape Monze Rocky Shore

Nine species possess more than 1 % dry biomass and less than 1 % was shown by each of the remaining 48 species (Table 1). Species having higher dry biomass was *Turbo intercostalis* followed by *Trochus stellatus, Turbo coronatus, Morula granulata*, *Nerita albicilla*, *Thais rudolphi*, *T. hippocostanum*, *Euchelus asper* and *Conus biliosus*, contributing 94 % of the molluscan dry biomass.

Turbo intercostalis though dominates in dry biomass was found less abundantly as compared to *Trochus stellatus* and *Morula granulata*. Some species had high dry biomass although collected in few samples, for instance, *Bursa subgranosa, Conus biliosus, Nerita albicilla, Nerita textilis, Sunetta sp., Euchelus asper, Thais hippocostanum* and *T. rudolphi.* Majority of molluscan species were found in few samples and also had negligible biomass (Table 1).

Table 2. Seasonal variation in values of dry biomass (gm./m^2) of molluscan individuals in low, mid and high tidal zones of Karachi coast: Manora, Buleji, Nathiagali and Cape Monze.

Month	Manora			Buleji			Nathiagali			Cape Monz		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Dec.93.	202.39	564.38	279.90	455.37	466.57	197.92	523.65	197.12	336.61	202.65	333.92	431.04
Mar.94.	377.24	397.91	408.94	206.40	597.37	247.88	542.84	159.52	445.71	362.13	388.56	379.17
Jun. 94.	336.99	482.18	294.85	291.96	413.52	279.60	826.86	480.01	831.18	437.15	413.46	401.74
Sep. 94.	331.22	719.41	501.93	386.47	591.12	641.16	836.34	418.99	438.28	163.23	317.04	205.43
Dec. 94.	189.50	612.43	401.75	553.34	650.48	488.12	668.35	468.58	825.38	241.69	298.34	404.61
Mar. 95.	458.05	525.11	394.18	267.55	372.20	339.09	443.53	292.26	401.63	365.65	308.61	375.42
Jun. 95.	178.89	339.18	210.30	353.17	459.84	285.30	611.65	332.38	557.47	494.69	448.26	395.36
Sep. 95.	248.50	505.62	468.84	342.86	473.18	560.66	473.75	287.26	695.09	182.20	455.91	293.17
Dec.95.	451.54	601.17	535.52	383.73	472.68	531.54	572.09	421.33	804.12	166.49	434.14	212.39

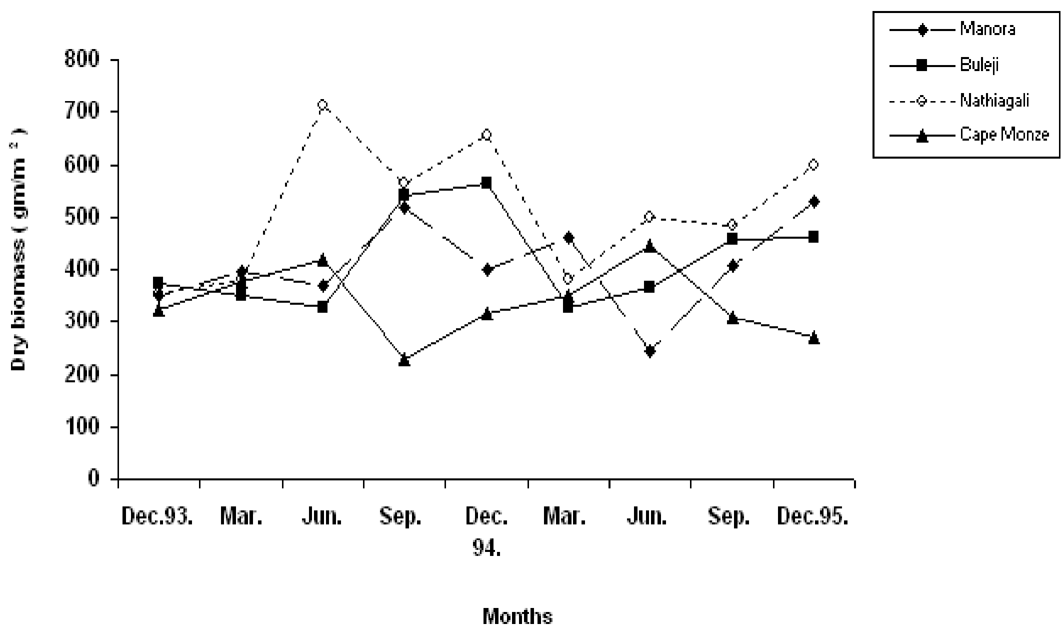

Fig. 1. Seasonal variation in values of dry biomass (gm./m^2) of molluscan individuals from the four study sites: Manora, Buleji, Nathiagali and Cape Monze.

Table 3. Seasonal variation in values of two-way nested analysis of variance based on estimates of molluscan dry biomass from four rocky sites.

Sample	Source of variation	Degree of freedom (df)	Sum of squares (SS)	Mean squares (MS)	F ratio	Probability
1	Among sites	3	011715.53	03905.18	0.05	N.S
	Among zones within site	8	596443.02	74555.38	1.83	< 0.10
	Within zone	24	980237.86	40843.24		
2	Among sites	3	09380.55	03126.85	0.05	N.S
	Among zones within site	8	517621.63	64702.70	2.03	< 0.10
	Within zone	24	766291.15	31928.80		
3	Among sites	3	817401.18	272467.06	6.48	< 0.05
	Among zones within site	8	336405.51	42050.69	1.05	N.S
	Within zone	24	962339.85	40097.49		
4	Among sites	3	666963.46	222321.15	2.51	< 0.25
	Among zones within site	8	707280.27	88410.03	3.08	< 0.05
	Within zone	24	689898.37	28745.77		
5	Among sites	3	637050.65	212350.22	3.14	< 0.10
	Among zones within site	8	541273.58	67659.20	1.93	< 0.25
	Within zone	24	840833.32	35034.72		
6	Among sites	3	90399.35	30133.12	2.76	< 0.10
	Among zones within site	8	87298.04	10912.26	0.36	N.S
	Within zone	24	723669.24	30152.88		
7	Among sites	3	338346.09	112782.03	3.82	< 0.05
	Among zones within site	8	236154.53	29519.32	1.35	N.S
	Within zone	24	526625.91	21942.75		
8	Among sites	3	160796.27	53598.76	0.78	N.S
	Among zones within site	8	551886.26	68985.78	3.34	< 0.05
	Within zone	24	496291.66	20678.82		
9	Among sites	3	538103.87	179367.96	3.47	< 0.10
	Among zones within site	8	412996.02	51624.50	1.00	N.S
	Within zone	24	1234612.13	51442.17		

The average dry biomass of molluscs of the total area was highest on mid tidal zone (377.58 gm/m^2) followed by high (344.25 gm/m^2) and low (290.65 gm/m^2) tidal zones (Table 2). The biomass in low tidal zone changed from high in summer (June) to low in autumn (September) during both the years of investigation. Mid and high tidal zones differed from low tidal zone during second year of study. The values in mid tidal zone were low in winter (December) and high in autumn (September) whereas in high tidal zone it changed from high in winter (December) to low in autumn (September). The values of molluscan dry biomass of the total area were relatively high in spring and summer months and low in autumn and winter months during both the years (Fig. 1).

Comparison between Sampling Sites

A comparison of the mean dry biomass of molluscs of the four sites shows that it is highest at Nathiagali (518.684 gm/m^2), followed by Buleji (418.938 gm/m^2), Manora (408.088 gm/m^2) and Cape Monze (337.365 gm/m^2; Figure 1). The dry biomass of Nathiagali was significantly higher than the other three sites. Nathiagali posses more dry biomass in most of the samples. The dry biomass of Cape Monze highly fluctuated seasonally.

In terms of dry organic mass, *Cerithium morus* and *Turbo coronatus* dominates on Manora and Buleji rocky shores. *Turbo coronatus* and *Trochus stellatus* had high biomass at Nathiagali, whereas, *Turbo intercostalis* and *Trochus stellatus* possess high biomass at Cape Monze. *Cerithium morus* was available in abundance at Manora and Buleji (Table 1).

Two-Way Nested Analysis of Variance showed that dry biomass of individuals among sites is significantly different at 5 % level in summer (June) season of both years. There are three samples in which the dry biomass of molluscs is not significantly different (December 1993, March 1994 and September 1995). The dry biomass among four sites is different at 25 % in September 1994 whereas samples of December 1994, March 1995 and December 1995 are different at 10 % significance level (Table 3).

The molluscan dry biomass among zones within sites is significantly different at 5 % level in two samples (September 1994 & 1995). In December 1993 and March 1994, the biomass among zones is different at 10 % significance level (Table 3). The dry biomass among zones is different at 25 % significance level in December 1994. There are four samples in which the dry biomass of molluscs is not significantly different in zones among sites (June 1994, March 1994, June 1995 and December 1995).

DISCUSSION

Biomass estimation may be a more biologically-relevant measure of assessing a community structure (Warwick and Clarke, 1993). Studies on biomass estimation of a rocky intertidal macrofauna particularly on molluscs are limited as compared to those on abundance. Nevertheless, few comprehensive investigations are available. Batzli (1969) found the community biomass was divided among the few dominant species, greater numbers of moderately abundant species and a few rare species on San Juan Island, Washington. In the present investigation, few gastropod species dominate the biomass of the four rocky shores studied. The same inference was also drawn by Gopalakrishnan (1970), Littler (1980), McQuaid and Branch (1984), McQuaid *et al*. (1985), Kalejta and Hockey (1991), Carvajal and Capelo (1993), Lasiak and Field (1995), Barkati and Burney (1995), Ahmed and Hameed (1999b), Hameed *et al*. (2000), Nasreen *et al*. (2000) and Hameed *et al*. (2001) working on different rocky shores of the world.

A number of factors influence the biomass of macrofauna on various rocky shores. The macroinvertebrates had the greatest standing stock at those sites where wave surge was highest on various rocky shores (Littler, 1980; Ricciardi and Bourget, 1999). Moreover, disturbed sites showed the lowest standing stocks. McQuaid and Branch, 1984 and McQuaid *et al*., 1985 recorded significantly higher biomass under exposed conditions of Cape of Good Hope, South Africa. They also found that the sessile filter feeders dominated exposed shores and algae and mobile herbivores on sheltered shores. According to Pearson *et al*. (1982), macrobenthic fauna had relatively low density but high size range and biomass at the control station, Scotland. Greater complexity and greater biomass in more stable communities was reported by Margalef (1963), Lasiak and Field (1995) and Lasiak (1998).

The healthiest season for macroinvertebrate biomass was dissimilar on various rocky shores at Karachi coast. Highest biomass occurred between October to December at Buleji and Pacha rocky shores (Barkati and Burney, 1995; Hameed *et al*., 2001). Nasreen *et al*. (2000) and Hameed *et al*. (2000) found that the premonsoon season (February-April) to be more productive in macrofaunal dry tissue weight at Manora and Buleji rocky shores. However, Ricciardi and Bourget (1999) reported a weak correlation between macroinvertebrates biomass and mean annual water temperature.

Biomass and Tidal Height: The biomass of macrofauna in relation to tidal height was studied by only few authors and maximum biomass was found at different tidal zones. Barkati and Burney (1995) recorded minimum values of biomass in the high tidal zone and maximum in the mid tidal zone on Buleji rocky shore. Hameed *et al*. (2000) recorded the maximum biomass of animals at the high tide zone at Pacha, Karachi. Littler (1980) found that peak biomass of macroinvertebrates in relation to tidal height varied in different sites within the southern California bight, USA. According to McQuaid *et al*. (1985) and Ricciardi and Bourget (1999) biomass showed an up shore decrease on rocky shores. The values of biomass in relation to tidal height in the present study are in general conformity with the published literature. The peak biomass on various shores of the Karachi coastal site occurred at different tidal zones.

The biomass of molluscs on the 4 rocky shores studied, are influenced with tidal height, degree of exposure, temperature, substratum stability, algal production and near shore primary production. Generally, the biomass was high in winter probably due to high level of food supply i.e. phytoplankton in the northern Arabian Sea during winter (Kabanova, 1964) and also high algal production during winter (Ahmed and Hameed, 1999b; Hameed *et al*., 2001). Low biomass was observed in spring and summer probably because most macroinvertebrates recruited during the winter-spring period and because of low plankton production in the monsoon period. The results also clearly showed the effect of tidal height on the biomass as also shown by Barkati and Burney (1995). The molluscan biomass was also found affected by substratum stability. The biomass was comparatively higher on Nathiagali and Cape Monze than Manora and Buleji rocky shores having more stable substratum and unexploited by visitors. The occurrence of filter feeders i.e. *Perna viridis* in Manora resulted in significantly higher biomass. Nevertheless, the gastropod dominates in the biomass on the four sites studied. The two-way nested analyses of variance revealed that biomass in most of the samples were significantly different among sites and also among tidal zones.

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