

Macro and meiofaunal abundance in six sandy beaches of Lakshadweep islands

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The macro and meiofauna were investigated quantitatively. Of the 8 macrofaunal taxa recorded, the polychaetes and crustaceans made up the bulk of the population and biomass on all beaches. Total macrofaunal density varied from 71 to 3157.m⁻² and biomass from 5.22 to 325.1 g.m⁻². High meiofaunal density (2620-6555.10 cm⁻²) was recorded at most of the beaches and these were made up mainly of nematodes (46.7%) and benthic copepods (23.7%). On all beaches the meiofauna tended to be concentrated at those tide levels where no high degree of desiccation of the sand occurred. Macrofauna and meiofauna biomass were extrapolated to 1 m transect of beach giving macrofaunal values of 26.12 to 975 g. (1 m transect)⁻¹ and meiofaunal values of 295.7 to 794.5 g. (1 m transect)⁻¹. Based on biomass, meiofauna contributed more than 50% to the total production on all the beaches. The macrofauna/meiofauna ratio gave low values indicating the dominance of meiofauna on all beaches.

Sandy shores provide an environment of high physical stress to marine fauna, as a result of which relatively few species inhabit this zone. Different authors studying the intertidal macro and meiofauna, have reported impoverished macrofauna but abundant and diverse meiofauna¹⁻⁴. Quantitative studies on the intertidal coralline sandy sediment of Indo-Pacific coral atolls in general and Lakshadweep in particular, are very few. Some studies have been carried out on macro and meiofauna of Polynesian atolls⁵. From Lakshadweep archipelago reports⁶⁻⁸ on molluscan and benthic faunal distribution in the intertidal sand of Kavaratti atoll and other beaches are available. In the present study an attempt was made to give comparative account of intertidal macro and meiobenthos, on quantitative basis, of the 6 beaches, namely Agatti, Kalpeni, Bingaram, Kavaratti, Minicoy and Kadmat atoll of Lakshadweep.

Lakshadweep archipelago consists of 12 atolls and 5 submerged banks. Except Minicoy, the Agatti, Kalpeni, Bingaram, Kavaratti and Kadmat are located within the geographical limits of 10°-12°N and 71°40'-74°E. The Minicoy atoll (8°18'N and 73°E) is the southernmost atoll and the largest in the Lakshadweep archipelago. The shore of the lagoon side of the atolls are characterized with sandy beach having medium to coarse coralline sand and beach rocks exposed during low tide. The beaches are of semienclosed type with varying exposure and with minimum wave action.

The Lakshadweep Archipelago has a tropical climate where the year may be divided into three seasons e.g. the southwest monsoon (June-September), post-

monsoon (October-January) and premonsoon (February-May). During monsoon period heavy rainfall is reported in this region which terminates in late September or early October after which the weather is less varying. The air temperature fluctuates around 30°C except during monsoon time when it is below 25°C. The tides are of mixed type with a strong semidiurnal influence. The beaches are fairly stable except during the monsoon season when changes in beach profile take place due to erosion. The width of intertidal areas ranges from 7 to 15 m with gentle slope and little wave action.

Materials and Methods

Data presented here are based on 108 samples collected during different seasons and different years (1985-1987) during 3 cruises of *R. V. Gajeshani*. The results therefore do not necessarily pertain to the seasonal cycle. The comparisons depict a broad based picture of changes in macro and meiofauna of the 6 beaches, of 6 atolls studied. The sampling stations were located along a transect from high water mark (HW) to the low water mark (LW) and three transects were selected on each island. For macrofauna a quadrant (0.25 m² area) was forced into the sediment and the sand of the enclosed area was dug out to a depth of 15 cm and sieved (0.5 mm screen). The material remaining on the screen was fixed in a 5% buffered formalin Rose Bengal solution. Duplicate samples were taken at each level. Meiofauna was collected at each tide level in 3 replicate series of 10 cm² area to a depth of 10 cm. Each core sample was sliced into 2 sub samples of 5 cm layer and preserved in 5% formalin Rose Bengal

solution. All macrofauna were grouped, counted and wet weight mass was determined. Similarly all meiofauna were counted and average wet weight of the major taxa recorded. The biomass of macrofauna and meiofauna were extrapolated to get biomass values for 1 m wide transect⁹. The total biomass was then converted to production estimates by multiplying factor 8 for meiofauna¹⁰ and 2.5 for macrofauna¹¹. Mechanical properties of the sediment were analysed by the method of Folk¹². Organic content of the sediment was determined by the titration method¹³.

Results and Discussion

Sediment characteristics—The median particle diameter of all the beaches (Table 1) ranged from 0.27 to 0.55 mm indicating the dominance of median coralline sand particles. Narayanan and Sivasdas⁷ reported median particle size of 0.38 to 0.43 mm at Kavaratti. The low phi quartile deviation ($Qd\phi$) and very low values of skewness ($Sk\phi$) indicate that at all the beaches a high proportion of sand particles fall in narrow range around the median and the particles of both larger and smaller sizes were equally sorted. Harkantara¹⁴ working in a high energy beach reported strongly fine skewed to strongly coarse skewed sediment. The

differences in the sediment characteristics may be due to the differences in exposures between these beaches¹⁵. However it may be mentioned here that all the beaches are protected by reef which are several hundred meters away from the shore and therefore the wave action on these beaches is minimum. This was further confirmed by the fact that no significant relationship exists between the degree of exposure and beach slope.

The sediment organic carbon, as expected, was moderate. The values were highest (0.47%) at Kalpeni and lowest (0.24%) at Kavaratti. On these oceanic beaches the sources of organic input are limited. The main contribution of organic carbon are the dead and decaying seagrasses and seaweeds. Thomassin and Vitello¹⁶ also reported low value of organic carbon in the coralline sediment of Tulear reef Madagascar.

Macrofauna—Total macrofaunal density ($no.m^{-2}$) was highest at Agatti (3157) and lowest at Kadmat (71) (Table 2). Of the 8 groups, polychaetes were the most dominant group at all the beaches, contributing from 55 to 92% of the total population. Next in abundance were crustaceans and bivalves. Miscellaneous groups constituted of hydrozoans, echinoid worms, sea anemones, etc. formed a substant-

Table 1—Summary of abiotic factors at Lakshadweep

Island	Tidal level	Md (mm)	Qd(ϕ)	Sk(ϕ)	Mean Md (mm)	Mean organic carbon (%)	Salinity of interstitial water ($\times 10^{-3}$)
Agatti	HW	0.45	0.59	-0.05	0.55	0.39	34
	MW	0.54	0.60	-0.03			30
	LW	0.66	0.67	-0.04			32
Kalpeni	HW	0.28	0.34	+0.04	0.32	0.47	32
	MW	0.31	0.29	+0.05			33
	LW	0.37	0.33	+0.05			30
Bingaram	HW	0.28	0.53	-0.02	0.37	0.37	33
	MW	0.35	0.51	-0.02			32
	LW	0.48	0.52	-0.02			33
Kavaratti	HW	0.22	0.47	-0.05	0.27	0.24	36
	MW	0.24	0.52	-0.02			36
	LW	0.35	0.50	-0.04			34
Minicoy	HW	0.29	0.43	+0.07	0.35	0.25	34
	MW	0.34	0.49	+0.03			32
	LW	0.42	0.44	+0.05			35
Kadmat	HW	0.36	0.55	+0.03	0.40	0.28	33
	MW	0.42	0.50	+0.03			33
	LW	0.42	0.54	+0.04			30

ial portion of the population in the present study. Narayanan and Sivadas⁷ also reported polychaetes and crustaceans as the major macrobenthic components in the intertidal sand of Kavaratti. Ansell *et al.*⁹ found polychaetes and bivalves as the major group on the south Indian beaches. However, McLachlan¹¹ has reported the dominance of bivalves in the intertidal macrofauna of South African beaches. Among other studies Thomassin *et al.*⁵, reported the dominance of molluscs in the coral sediments of Polynesian atolls. Thus the intertidal macrofauna population at Lakshadweep atolls show wide variation from extremely poor at Kadmat to extremely high density at Agatti. These extreme range of macrofaunal density could be the result of differing food supply and the sediment characteristics. Beach exposure also plays important role in the distribution of intertidal fauna¹³.

There was a distinct zone of faunal distribution along the tidal gradients and several faunistic assemblages could be identified. While the polychaetes occurred consistently at all tidal levels, the upper zone was characterized by the presence of crustaceans such as *Eurydice* sp. and *Talorchesia* sp. The mid water level was characterized by the presence of pelecypods, ghost crab and mole crab (*Hippa* sp.). Among two species of pelecypods *Mesodesma glabratum* was recorded at all the beaches excepting Kadmat while *Donax* sp. was found only at Minicoy. The neap tide was unproductive in terms of macrofaunal density except at places of seagrass beds. The distribution of major taxa also varied along the exposure gradient. Similar observations have been made at Kavaratti⁷. Studies on intertidal fauna of South African beaches also revealed the pattern in the distribution of fauna along tidal gradient¹¹.

Macrobenthic biomass was highest at Agatti and lowest at Kadmat (Table 2). Biomass values followed the trend of population density in the distribution from high water to low water. High to very high biomass values have been reported from Indian beaches⁹ which are attributed to high density of bivalves.

Meiofauna—Nematodes are generally the dominant taxon in marine meiofauna¹⁷, although the proportion of harpacticoid copepods increases in coarser sand on exposed beaches. The meiofaunal density (Table 3) was highest at Agatti and lowest at Kavaratti. Total density (no. 10 cm⁻²) varied between 2620 and 6555. In an other study from Andaman islands, Ansari and Ingole¹⁸ reported meiofaunal density ranging from 2270 to 6116.10 cm⁻² in the fine intertidal sand which coincidentally is similar to the values observed in the present study. The meiofauna was mainly represented by nematodes, harpacticoids, turbellarians and polychaetes. Among other groups the gastro-

Table 2—Average macrofaunal density (no. m⁻²) and biomass (g. m⁻²) of six coralline beaches at Lakshadweep

Group	Agatti			Kalpeni			Bingaram			Kavaratti			Minicoy			Kadmat									
	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT							
Tides:	562	831	1244	2637	480	365	1122	1967	1944	198	—	2142	—	—	385	142	242	78	462	38	7	9	54		
Polychaeta	55	—	22	77	—	—	70	70	33	88	—	121	—	—	44	—	—	—	—	—	—	1	1	2	
Amphipoda	—	43	—	43	23	66	—	89	—	—	33	33	—	—	33	33	71	—	186	—	—	—	—	—	
Pelecypoda	—	—	11	11	—	23	132	155	110	23	—	133	33	22	—	55	33	10	25	68	—	—	—	—	
Isopoda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Hippa sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Decapoda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Others	43	300	23	366	—	10	—	10	11	11	—	22	—	—	22	22	31	17	—	48	1	2	2	5	
Total density (no. m ⁻²)	660	1197	1300	3157	503	475	1334	2312	2098	320	33	2451	33	102	502	637	232	451	132	815	44	15	12	71	
Total biomass (g. m ⁻²)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	325.1	—	—	—	238.1	—	—	—	252.4	—	—	43.1	—	—	—	—	86.2	—	—	—	—	5.2

trich, kinorhynchs, tardigrada, archiannelida and nauplii were present. On all the beaches except Agatti nematodes form numerically the most dominant group followed by harpacticoids and turbellarians (Fig. 1). At Agatti harpacticoids were dominant, followed by nematodes and turbellarians. Averaging the proportion (percentage wise) for the six beaches, it is observed that nematodes contribute 46.7%, harpacticoids 23.7%, turbellarians 12.3% and polychaetes 5.17%. Other groups also made significant contribution of 12.2%. While the distribution of meiofauna is largely determined by sediment particles, oxygen, temperature and food supply on the exposed beaches^{9,11,19}, meiofaunal densities in the present study and their variations were due to exposure, grain size and organic matter. Semiexposed beaches are reported to have large number of taxa than exposed beaches¹⁵. Thomassin *et al.*⁵ reported that meiofaunal distribution was more related to the grain size, organic matter and degree of oxygenation in the coral sands of the reef flat in Polynesia. Unlike macrofauna there was no correlation between meiofaunal density and tidal exposure but the fauna was generally concentrated at mid and high water mark.

Total meiofaunal biomass (wet weight, mg.10 cm⁻²) for each beach and tidal level was calculated and presented in Table 3. These beaches have highly variable meiofaunal biomass like their larger counterpart and do not show consistency with tidal exposure.

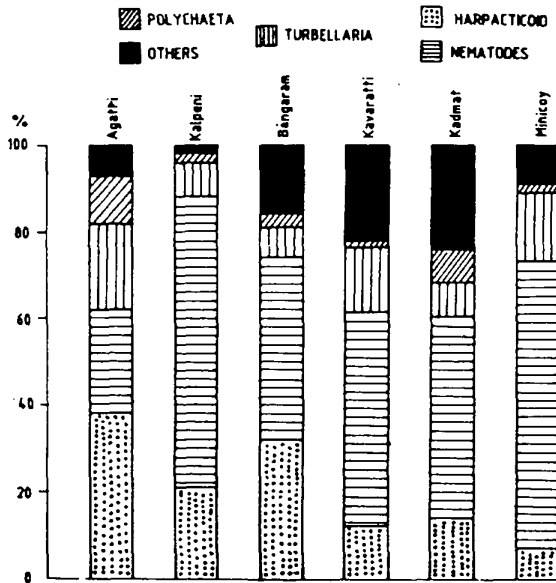


Fig. 1---Taxonomic composition of the meiofauna of the six beaches studied

Table 3---Average meiofaunal density (no.10 cm⁻²) and biomass (mg. 10 cm⁻²) of six coralline beaches at Lakshadweep

Group	Agatti			Kalpeni			Bhangaram			Kavaratti			Mimicoy			Kadmat									
	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT	LW	MW	TOT							
Tides	144	208	1142	1494	1587	827	1239	3653	337	476	930	1743	462	238	591	1291	783	430	700	1913	376	347	1516	2239	
Nematoda	631	1633	308	2572	14	620	407	1041	666	393	228	1287	219	51	46	316	40	112	245	397	263	247	135	645	
Harpacticoida	393	11	265	669	—	50	7	57	37	21	72	130	21	1	10	32	18	55	7	80	113	162	125	400	
Polychaeta	165	820	352	1337	76	186	150	412	54	114	124	292	82	203	115	400	201	205	91	497	160	62	100	322	
Turbellaria	175	186	122	483	30	47	—	77	190	269	206	665	271	108	202	581	88	219	—	307	380	460	270	1110	
Others	1508	2858	2189	6555	1707	1730	1803	5240	1284	1273	1560	4117	1055	601	964	2620	1133	1021	1043	3194	1292	1278	2146	4716	
Total density (no.10 cm ⁻²)	25.91	23.59	82.52	132.02	100.17	58.46	81.44	240.08	27.37	33.42	62.77	124.06	31.71	15.69	38.18	85.58	50.33	30.18	46.22	126.74	29.56	29.08	100.35	158.99	
Total biomass (mg.10 cm ⁻²)																									

From Table 4 it appears that the fauna at all tide levels was aggregated mainly in the top 0-5 cm layer except at Kavaratti which may be due to changes in sampling time. Because of a better drainage (coarse sand) and high atmospheric temperature and exposure, the fauna seems to migrate downward in the sand column²⁰. This emphasizes the importance of drainage on oceanic sandy beaches. The meiofauna of the present study appears to be concentrated more at those levels where desiccation is not too severe and oxygen is available. Others have also reported concentration of meiofauna in the upper layer of sandy beaches^{1,14,21}. Due to varying degrees of exposure and flooding different tidal level will experience different temperature and oxygen regime, depending on the width of the beach. This accounts for the differences in faunal density at various tidal levels.

Comparison of meiofauna—An attempt has been made in the present study to compare the density of meiofauna with other areas (Table 5). Total density recorded in the present study area is comparable with other areas except that of Malaya, Porto Novo and Stockholm where densities were comparatively low. One of the reasons for differences in meiofauna densities recorded by other is the methodology used by different workers. It may be noted that in the coral sand at Malaya the dominant group was copepoda²⁴. In the coarse sand of 0.55 mm median diameter Jansson²⁵ also observed dominance of benthic copepoda and so did McLachlan¹³ in the median grain size of 0.27 mm diameter. In the present study only Agatti showed dominance of copepoda in the sediment of 0.55 mm diameter. It reemphasizes that benthic copepod increases in coarser sand on exposed sandy beaches^{13,19}. In the medium and fine sand the copepods were second most important group.

Comparison of macrofauna and meiofauna—The macrobenthos and meiobenthos of the six beaches under investigation are compared on the basis of their density, biomass values and production estimates for

1 m transect of beach (Table 6). For macrofauna, total density per 1 m transect was highest at Agatti and lowest at Kadmat. Similarly the biomass was highest at Agatti and lowest at Kadmat. Total macrofaunal biomass (g per 1 m transect) of all the beaches varied from 26.12 to 975. Narayanan and Sivasdas⁷ reported an average value of 90.47 g.(1 m transect)⁻¹ from Kavaratti beach, while Ansell *et al.*⁹ found maximum wet weight biomass value of 500 g.(1 m transect)⁻¹ from the south Indian beaches. Wide range of biomass values between 7.04 and 6600 are reported from south African beaches¹¹ which was attributed to the presence or absence of bivalves and gastropods. A noticeable feature of the beaches under investigation is the very low number of bivalves and the absence of gastropods. This is probably due to the textural properties of the sediment and beach exposure. Namboodiri and Sivasdas⁶ reported only one species of bivalve in the sandy beach and 19 species in the lagoonal floor of Kavaratti. They reported that poor representation of mollusca was due to increased exposure of the beach. Ganapati and Lakshman Rao²⁴ found paucity of the fa-

Table 5—Summary of the data on intertidal meiofauna

Locality Reference	Type of deposit	Total meiofauna (no. 10 cm ⁻²)	Dominant group
Malaya ²²	Coral sand	244	Copepoda
Porto Novo ¹	Sand	969-1960	Nematoda
Goa ¹⁴	Medium sand	24-3525	Nematoda
Andamans ¹⁸	Fine sand	2323-6116	Nematoda
Kakinada ²³	Fine sand	680-4095	Nematoda
Stockholm ²³	Coarse sand	391-1529	Copepoda
Sardinia Bay ⁴	Medium sand	3710	Copepoda
Present study			
Agatti	Coarse sand	6555	Copepoda
Kalpani	Medium sand	5240	Nematoda
Kadmat	Medium sand	4716	Nematoda

Table 4—Vertical distribution of meiofauna (no. 10 cm⁻²)

Islands	High water		Mid water		Low water	
	0-5 cm	5-10 cm	0-5 cm	5-10 cm	0-5 cm	5-10 cm
Agatti	1954	335	1944	914	1416	92
Kalpeni	1627	276	1152	578	1365	342
Bingaram	1282	278	682	641	1062	322
Kavaratti	480	484	283	318	632	425
Minicoy	513	530	589	432	730	400
Kadmat	1197	1052	450	570	587	756

Table 6—Density (no. 1 m transect⁻¹), biomass (g. 1 m transect⁻¹) and production estimates (g. 1 m transect⁻¹) for macro and meiofauna and percentage contribution of the total macro and meiofaunal production at 6 coralline beaches of Lakshadweep

Islands	Macrofauna				Meiofauna			
	Density	Biomass	Production	% P	Density	Biomass	Production	% P
Agatti	9471	975.00	2437.50	42.93	1966 × 10 ³	405.08	3240.00	57.06
Kalpeni	6163	635.04	1587.60	23.65	1397 × 10 ³	640.20	5121.60	76.34
Bingaram	8987	925.65	2314.13	37.04	1509 × 10 ³	491.57	3932.56	62.95
Kavaratti	2211	157.88	394.70	13.58	959 × 10 ³	313.83	2510.64	86.41
Minicoy	2511	201.11	502.78	17.52	745 × 10 ³	295.71	2365.68	82.47
Kadmat	—300	26.12	65.29	1.01	2358 × 10 ³	794.50	6356.00	98.98

P = Production

una in the intertidal sand having poor organic matter. The organic matter coming from the sea is mainly in the form of washed up algae and seagrasses. The quantity of organic matter lying on and in the sediment is of great importance to the deposit feeding molluscs²¹. The meiofaunal component showed less variation in both density and biomass. The density (no. × 10³ per 1 m transect) varied between 745 and 2358 and biomass (g. 1 m transect⁻¹) between 295.71 to 794.50. This reemphasizes the fact that small metazoans can maintain more stable population on sandy beaches than their larger counterparts¹. The macrobenthos/meio-benthos ratio in terms of their density varied from 1/626 to 1/167 among the six beaches. Low ratios again indicate the dominance of meiofauna on sandy beaches. Thomassin *et al.*⁵ have estimated ratio between 1/190 and 1/12 in the coral sediment of Tiahura reef of Polynesia.

The production estimates indicate that the meiofauna are quantitatively more important than the macrofauna on these oceanic sandy beaches and contribute > 50% to the secondary production on these beaches. McLachlan¹¹ has estimated macro and meiofauna production from ELWS to a height of 2 m at sandy beaches of South Africa. He reported a macrofaunal contribution of 53% and meiofauna contribution of 47% in the secondary production of these beaches. He, however, emphasized that, had estimates of production for transect been extended to a height of > 2 m above the ELWS, as in the present study, the meiofaunal contribution would have been greater than macrofauna. The high contribution of meiofauna in the secondary production of intertidal sandy areas of Lakshadweep atolls is therefore justified.

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