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Research Article

Efficacy of Sampling Design to Study Macrofaunal Assemblage on Exposed Sandy Beaches

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Abstract

Exposed sandy beaches are characterized by ecologically complex environments, which exhibit considerable spatial and temporal habitat heterogeneity. Further, exposed sandy beaches undergo diurnal variations such as desiccation during low tide and submergence during high tide. The amount of submergence and exposure varies as per the tidal amplitude and intensity due to lunar cycle. Considering spatial and temporal heterogeneity of macrofauna and variations in sampling designs used in hitherto studies, an attempt was made to find out most suitable sampling design with regard to quadrat size and interval between quadrat needed to obtain the most précised estimate of macrofaunal assemblage on exposed sandy beaches must be sampled at least for one complete year after taking appropriate number of transects on the beach with quadrat size of 0.25 sq. m, spaced 12 m apart from each other over a complete transect length to study macrofauna assemblage.

Keywords: Sampling Design; Macrofauna; Richness; Abundance

Introduction

Exposed sandy beaches are mostly studied to understand the species richness and abundance. These measures are most useful to know the biodiversity as well as to assess the ecosystem fitness [5]. To enhance the accuracy of such studies, sampling designs used must be trustworthy. Studies hitherto carried out in this field showed tremendous variations in sampling techniques. Number of transects sampled were one [2,9,10,12,15], two [4,15,17] and three [11,15] whereas quadrat size was 0.1m^2 [2,4,7,12], 25m^2 [10], 0.03m^2 cylindrical [9], 0.065m^2 [3,11], 0.32m^2 (Schoeman., *et al.* 2003) and 0.04m^2 [17]. Similarly, variations in the interval distance between the quadrat was also observed: 1m [9,15], 2m [12,15], 3m [15,17], 4m [11,15], 5m [1,5,6,13,15], 7.5m [15] and 10 m [2,3,15].

Ecological studies are more concerned about the establishment of association ships between habitat and species. Habitat heterogeneity in space and time plays an important role in species diversity. Number of species included in the sample represents only a subset of species richness in the community [14]. Therefore, monitoring distribution and abundance over time and space helps us to understand the status and changes in species diversity [5].

The Study focuses on abundance and richness of macrofauna on exposed sandy beach. Macrofauna are a group of animals defined by their size. They are usually inhabitants of soft sediments, that is, sands and muds, sometimes gravel, with the size determined by the mesh of a sieve on which they can be found after removal of some or all of the sediment particles. Considering spatial and temporal heterogeneity of macrofauna and variations in sampling designs used in hitherto studies, an attempt was made to find out most suitable sampling design with regard to quadrat size and interval between quadrat needed to obtain the most precised estimate of macrofaunal assemblage on exposed sandy beach.

Materials and Methods

Ratnagiri is a coastal district of the Maharashtra state. It is situated on the west coast of India. Sampling was carried out on

Mandovi beach for the period of one year and only once on Bhatye beach for testing efficacy of recommended sampling design was sampled. Sampling was done on three consecutive days after spring tide in every month i.e., at the time of lowest low tides. Mandovi beach is sandy beach and the total length of Mandovi beach is 0.95 km with rocky habitat at the north side of beach and the Arabian sea on west side. The intertidal zone i.e., the zone between high tide and low tide covers the area of 176 m. High water mark covers a strip of 154 m during neap tide whereas, it covers 210 m during spring tide. The gradient of Mandovi beach is 0.028 m. The sediment comprises of 92.86% sand, 0.254% silt and five per cent clay.

Materials used to carry out the present work were sampling grid to mark quadrats of required sizes, spades for sample collection, sieving bags for sieving samples, trays for segregating macrofauna, polythene bags and formalin for preservation of samples. A square shaped iron sampling grid with dimensions 0.5 m x 0.5 m x 0.15 m in length, breadth and height respectively was fabricated.

Three transects were marked at three locations on the beach with identification landmark after highest high tide mark which was designated as TS1, TS2 and TS3. Length of all the three transects was 25 m. All the quadrats sampled were uniformly excavated up to the depth of 15 cm as the sampling grid with 15 cm height was used while sampling. Different intervals were kept between two quadrats sampled. Intervals kept between two quadrats sampled were continuous strip of quadrats, half metre, one metre, one and half metre, two metre, two and half metre, three-metre, three and half metre, four-metre, four and half metre, five-metre, six-metre and twelve-metre intervals. A total of 15 sampling designs with different sampling area of quadrats and interval between two quadrats were used in the present study. These sampling designs were designated as 'SD'. All the 15 sampling designs from SD 1 to SD 15 with specification are given in table 1. Two means were compared with 'Z'-statistics while several means were compared by employing one-way Analysis of Variance (ANOVA). All statistical analyses were performed as per Snedecor and Cochran [16]. The per metre square number of macrofaunal organisms were compared according to transects for indicator species from SD-1 sampling design [8].

Sr. No	Sampling designs	Total area sampled (Sq. m)	Size of quadrat (Sq. m)
1	SD 1	12.1050	0.0269
2	SD 2	3.0666	0.0269
3	SD 3	1.7754	0.0269
4	SD 4	1.2105	0.0269
5	SD 5	0.9684	0.0269
6	SD 6	0.8070	0.0269
7	SD 7	0.6456	0.0269
8	SD 8	0.5649	0.0269
9	SD 9	0.4842	0.0269
10	SD 10	0.4842	0.0269
11	SD 11	0.4035	0.0269
12	SD 12	0.4035	0.0269
13	SD 13	0.2421	0.0269
14	SD 14	0.9375	0.0625
15	SD 15	2.2500	0.2500

Table 1: Sampling designs with specifications.

Results

Macrofauna was collected from three transects marked on the Mandovi beach for a period of one year by adopting 15 different sampling designs. Collected macrofaunal organisms were segregated and identified up to generic level or else up to groups in certain cases. Recorded data was analysed to understand efficiency of sampling designs to estimate macrofaunal richness and abundance.

Macrofaunal richness

Presence and absence of macrofaunal organisms recorded according to sampling designs after eliminating the organisms inhabitant of rocky as well as sandy-muddy shore and megalopa larvae of crab is given in Table 2. The maximum varieties of macrofaunal organisms were observed with SD-1 and SD-2 sampling designs. These sampling designs could record 15 different kind of macrofaunal organisms while SD-3 and SD-15 sampling designs could record 14 macrofaunal organisms, genera such as *Donax* and *Oliva* were not observed in SD-3 and SD-15 sampling designs respectively. Sampling designs such as SD-4 and SD-6 could record 13 macrofaunal organisms while sampling designs SD-5, SD-7, SD-8, SD-10, SD-11 and SD-14 could record 12 macrofaunal organisms. Least macrofaunal richness was recorded by SD-13 sampling design with value of nine number of macrofaunal organisms, while sampling designs SD-9 and SD-12 could record only 11 macrofaunal organisms.

Sr. no	Macrofaunal organisms	Sampling designs														
		SD-1	SD-2	SD-3	SD-4	SD-5	SD-6	SD-7	SD-8	SD-9	SD-10	SD-11	SD-12	SD-13	SD-14	SD-15
1	*Euchelus*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2	*Natica*	*	*	*	-	-	*	-	-	-	-	-	-	-	-	*
3	*Oliva*	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-
4	*Tibia*	*	*	*	*	*	*	*	*	*	*	*	*	-	*	*
5	*Trochus*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6	*Turitella*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
7	*Umbonium*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
8	Unidentified gastropod	*	*	*	*	*	*	*	*	*	*	*	*	-	*	*
9	*Anadora*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
10	*Donax*	*	*	-	-	-	-	-	*	-	-	-	-	-	*	*
11	Tellina	*	*	*	*	*	*	*	*	-	-	*	*	-	*	*
12	Dotilla	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
13	Hermit crab	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
14	Matuta	*	*	*	*	*	*	*	-	*	*	*	-	*	-	*
15	Annelids	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 2: Occurrence and non-occurrence of sandy beach macrofaunal organisms according to sampling designs. * Present, - Absent

Total pooled sampled area of three transects per month according to sampling designs along with size and number of quadrats is given in Table 3. The maximum area sampled was 12.1050 sq. m with SD-1 sampling design while the least was 0.2421 sq. m in SD-13 sampling design. Higher number of macrofaunal organisms was recorded in SD-1 sampling design in which larger area was covered while the lesser number of macrofaunal organisms were recorded in SD-13 in which least area was sampled. Second largest area sampled was 3.0666 sq. m through SD-2 sampling design, which could record 23 macrofaunal organisms, while 19 macrofaunal organisms were recorded in SD-3 and SD-14 sampling designs with 1.7754 and 0.9375 sq. m area. Therefore, it can be concluded that the amount of area sampled plays an important role in recording macrofaunal organisms and macrofaunal richness was directly proportional to amount of area sampled.

Sr. No	Sampling designs	Number of macrofaunal organisms
1	SD 1	27
2	SD 2	23
3	SD 3	19
4	SD 4	18
5	SD 5	17
6	SD 6	17
7	SD 7	16
8	SD 8	16
9	SD 9	14
10	SD 10	15
11	SD 11	16
12	SD 12	13
13	SD 13	10
14	SD 14	19
15	SD 15	21

Table 3: Number of macrofaunal organisms according to sampling designs.

In general, macrofaunal organisms recorded in SD-1 sampling design were maximum while SD-2 sampling design stood second in recording better macrofaunal richness. Performance of SD-4, SD-5, SD-6, SD-10, SD-11, SD-14 and SD-15 in recording macrofaunal richness was also better as compared to rest all sampling designs. Presence and absence of macrofaunal organisms in different sampling designs after retaining purely sandy beach inhabiting macrofaunal organisms has clearly indicated that SD-3, SD-4, SD-5, SD-6, SD-7, SD-8, SD-7, SD-8, SD-10, SD-11, SD-14 and SD-15 were the better sampling designs. Therefore, SD-15 with lesser sampling effort could be the better sampling design to sample exposed sandy beach to record macrofaunal richness.

Macrofaunal abundance

Average values of macrofaunal abundance for different sampling designs were compared with average value recorded for the macrofaunal abundance in SD-1 sampling design and results are given in Table 4. Analysis revealed that the macrofaunal organisms recorded in the SD-10 and SD-14 designs were significantly different from the macrofaunal organisms recorded in SD-1 sampling design ($P < 0.05$), while macrofaunal organisms recorded in rest all sampling designs were not significantly different ($P > 0.05$) from the macrofaunal organisms recorded in SD-1 sampling design. Total as well as average number of macrofaunal organisms in a month per metre square and total area sampled according to sampling designs is given in Table 5. Higher values for number of macrofaunal organisms were recorded in SD-1 sampling design in which sampled area was maximum, on the contrary, the least values for number of animals were recorded in the SD-13 sampling design and was with least sampled area. Therefore, it can be concluded that the number of macrofaunal organisms was directly proportional to the total area sampled. Number of macrofaunal organisms was highly correlated with total area sampled and the correlation coefficient (0.9995) was significant ($P < 0.05$).

Sr. No	Sampling design	Mean	Significance
1	2	165.4384 ± 4.6110	P > 0.05
2	3	159.9640 ± 4.5414	P > 0.05
3	4	164.6014 ± 6.5225	P > 0.05
4	5	159.8857 ± 5.9702	P > 0.05
5	6	156.5469 ± 7.9240	P > 0.05
6	7	164.0593 ± 15.5489	P > 0.05
7	8	161.9756 ± 8.4267	P > 0.05
8	9	154.5505 ± 9.6407	P > 0.05
9	10	135.7910 ± 3.0719	P < 0.05
10	11	153.2425 ± 15.5396	P > 0.05
11	12	183.3953 ± 23.1769	P > 0.05
12	13	160.0578 ± 16.5329	P > 0.05
13	14	204.4610 ± 23.1451	P < 0.05
14	15	172.1852 ± 10.0162	P > 0.05

Table 4: Comparison between sampling designs by Z-statistics.

Sr. No	Sampling designs	Total area sampled (Sq. m)	Number of organisms / m^2
1	SD 1	12.1050	158.8531
2	SD 2	3.0666	165.4384
3	SD 3	1.7754	159.9640
4	SD 4	1.2105	164.6014
5	SD 5	0.9684	159.8857
6	SD 6	0.8070	156.5469
7	SD 7	0.6456	164.0593
8	SD 8	0.5649	161.9756
9	SD 9	0.4842	154.5505
10	SD 10	0.4842	135.7910
11	SD 11	0.4035	153.2425
12	SD 12	0.4035	183.3953
13	SD 13	0.2421	160.0578
14	SD 14	0.9375	204.0889
15	SD 15	2.2500	172.1852

Table 5: Total area sampled per number of macrofaunal organisms according to sampling designs.

Estimated value of 'b' is 158.8854 ± 1.3061 which is almost near to the number of macrofaunal organisms per metre square recorded in the SD-1 sampling design, while it was less than the estimated value of SD-15 sampling design but number of macrofaunal organisms recorded in SD-15 were not significantly different from the number of macrofaunal organisms recorded in SD-1 sampling design.

Testing

In addition to Mandovi beach, three transects were sampled at Bhatye beach in the month of April to test the precision of sampling designs. Macrofaunal richness recorded in the SD-1 sampling design was maximum for all the transects as well as in case of pooled data. Sampling design SD-15 could record more macrofaunal richness next to SD-1 sampling design in TS1 and TS3 as well as in case of pooled data. Therefore, it can be concluded that SD-15 was better sampling design to record macrofaunal richness after SD-1. Macrofaunal richness recorded through SD-15 was five organisms against eight in the SD-1 sampling design for TS1, while macrofaunal richness recorded in TS3 was same for SD-1 as well as SD-15 and when data was pooled for all the three transects, SD-15 could record most of the organisms except *Dotilla*. Genus *Dotilla* was absent in TS2 and TS3 and *Dosinia* was absent in TS2. Therefore, the macrofaunal richness recorded in those transects was less, and this factor has contributed significantly to the efficacy of sampling designs in the recording of macrofaunal richness. Similarly, pooled macrofaunal number did not show much variation according to different sampling designs. Therefore, it can be concluded that though the beaches are heterogenous in distribution of macrofaunal abundance, sampling designs with the different intervals between the quadrats as well as quadrats with different sizes can record almost similar macrofaunal abundance. Sampling design SD-15 with much less sampling effort has shown better performance in recording macrofaunal richness and abundance on Bhatye beach as it has performed on Mandovi beach.

Discussion

Different sampling designs with various quadrat sizes and also with variation in distance between two quadrats were tested to know the efficacy of sampling designs to record macrofaunal richness and abundance.

Macrofaunal richness

The genus *Umbonium* was with continuous distribution over a strip of 25 m transect, while all other organisms were with discontinuous distribution over a strip of transect. Occurrence and non-occurrence of macrofaunal organisms in different transects have also shown variation, similarly variation in occurrence of macrofaunal organisms during different period of year was also observed. Therefore, it can be concluded that the total beach must be covered by taking appropriate number of transects to record spatial occurrence of the macrofaunal organisms and the considered transects must be sampled atleast for one year to notice temporal variation in macrofaunal richness.

Schoeman., *et al*. [15] have studied the macrofaunal richness with various intervals between quadrats. They have suggested 3 m interval between the two quadrats with quadrat size of 0.10 sq. m for sampling exposed sandy beaches to record macrofaunal richness, as 3 m interval between two quadrats was capable of recording better macrofaunal richness as compared to other sampling designs, they have tested. In the present study almost 15 different sampling designs were used with combination of varied quadrat size and various distance between the quadrats. Sampling design SD-1 with continuous strip could record 27 macrofaunal organisms of which 15 organisms were from sandy habitat, ten from rocky and two from sandy-muddy habitat. Each transect sampled was nearby the rocky patch, this might be the reason that the organisms from rocky shore were represented in the samples. The Kajali estuary is located towards the southern side of the beach, which might have brought in the organisms from sandy-muddy shore in the samples of the present study. Considering the richness of exclusively sandy shore organisms SD-2 and SD-3 sampling designs could record 15 and 14 macrofaunal organisms respectively. Sampling design SD-15 with 0.25 sq. m quadrats size, sampled at 12 m interval has also recorded 14 sandy beach inhibiting macrofaunal organisms. The genera missed in SD-3 and SD-15 were *Donax* and *Oliva* respectively; of which *Donax* was recorded only once in SD-1, while *Oliva* was present with patchy distribution on Mandovi beach, thus it can be said that the only genus *Oliva* was not with close distribution to 12 m interval. Against these sampling designs SD-1 could record 15 pure sandy beach macrofaunal organisms. Thus, it can be said that SD-2, SD-3 and SD-15 were the better sampling designs to record sandy beach macrofaunal organisms, but the efforts required in SD-2 and SD-3 sampling design were too high as compared to SD-15. Therefore, SD-15 is recommended to sample macrofaunal richness on exposed sandy beaches and effort required to sample exposed sandy beaches with this sampling design will be much less than the sampling design suggested by Schoeman., *et al*. [15].

Macrofaunal abundance

Jaramillo., *et al*. [9] studied 10 sandy beaches of south-central Chile. They collected samples from one metre interval along a transect. The macrofaunal abundance for 1 m interval in the present study was 159.9640 organisms/m^2, which was almost similar to the true value having the abundance of 158.8531 organisms/m^2. Thus, it can be said that even though the beach may have the dissipative characteristics rather than sampling a continuous strip, sampling at one metre interval may provide with better results for macrofaunal abundance on exposed sandy beach. Schoeman., *et al*. [15] obtained similar results while working on sandy beaches of South Africa. They found that sampling at one metre interval between two quadrats along a transect performed to be the best to estimate macrofaunal abundance. They also observed that sampling at two-metre interval did not performed well while in the present study two-metre interval sampling could provide better results. This may be because Schoeman., *et al*. [15] have sampled each beach only once, while the present study was carried out for one year. As the macrofaunal abundance has much impact of seasonal variation, sampling should be carried out for all the seasons to get better results.

Macrofaunal abundance recorded during the present study was of higher magnitude in the month of April as well as May as compared to all other months in all the sampling designs, on the contrary lowest values for number of macrofaunal organisms were recorded in the month of August in all the sampling designs. It can be concluded that all the sampling designs were capable of recording the exact magnitude of the macrofaunal abundance. To understand the efficacy of the sampling designs for recording the macrofaunal abundance on exposed sandy beach, the true value recorded with continuous sampled strip (SD-1 sampling design) was compared with the average number of macrofaunal organisms recorded in other sampling designs. Most of the sampling designs except SD-10 and SD-14 were capable of recording equal number of macrofaunal organisms as that of SD-1 sampling design. Therefore, it can be concluded that except SD-10 and SD-14, all the sampling designs could be used to record the macrofaunal abundance on the exposed sandy beach, but the least effort is needed to sample macrofaunal abundance with SD-15 sampling design as compared to other sampling designs. Macrofaunal abundance recorded with SD-1 sampling design was 158.8531 organisms/m^2/month while macrofaunal abundance recorded with SD-15 sampling design was 172.1852 organisms/m^2/month, and macrofaunal abundance recorded in both the methods did not show significant difference. Thus, SD-15 sampling design with 0.25 m^2 quadrat size and 12 m interval between two quadrats is recommended for recording macrofaunal abundance on the exposed sandy beach. Schoeman., *et al*. [15] has also compared different sampling designs with quadrat size of 0.10 sq. m and varied interval between two quadrats. They have concluded that 0.10 sq. m quadrat with three metre interval between two quadrats recorded actual macrofaunal abundance, but rest of the sampling designs tested were not appropriate in recording the macrofaunal abundance. Area of quadrat used by Schoeman., *et al*. [15] was 0.10 sq. m against that area of quadrat used in the present study was 0.25 sq. m, which is almost 2.5 times more than area reported by them. This larger size of quadrat with an interval of 12 m between two quadrats has recorded appropriate number of macrofaunal abundance just because of increased area of quadrats.

There was strong association ship between the number of macrofaunal organisms per metre square and total area sampled. The relationship established showed that on an average 158.8854 number of macrofaunal organisms were increasing with per metre square increment in sampling area. The value of macrofaunal abundance estimated at 158.8854 is almost similar to the value estimated with SD-1 sampling design. It indicates that with various quadrat sizes with varied interval, the estimated number of macrofaunal organisms per metre square were almost same as that of number of macrofaunal abundance recorded with SD-1 sampling design. Jaramillo., *et al*. [9] had stated that minimum 4 m^2 area must be sampled to record almost 95% of macrofaunal abundance, but during the present study 2.2500 sq. m area sampled with SD-15 sampling design and this sampling design had recorded almost similar macrofaunal abundance as that of true value. Schoeman., *et al*. [15] had sampled 12 m^2 area with quadrat size of 0.10 sq. m with a interval of 3 m between two quadrats, on the contrary SD-15 sampling design with 0.25 sq. m quadrat size with 12 m interval covering 2.2500 sq. m area was employed to sample macrofaunal abundance. The macrofaunal abundance recorded by this sampling design was same as that of true value. It indicated that the area to be sampled on exposed sandy beach need not to be 12 m^2.

All the sampling designs were tested on another sandy beach, Bhatye. After analysis of data on macrofaunal abundance heterogeneity on beach was observed, but SD-15 sampling design has recorded almost same macrofaunal abundance as that of SD-1 sampling design.

Conclusion

Mandovi beach is sandy dissipative beach. Macrofaunal richness and abundance has shown spatial and temporal heterogeneity. Maximum macrofaunal richness was observed in winter in the month of October whereas, maximum macrofaunal abundance was recorded in the month of April. Total 27 macrofaunal organisms were recorded of which 15 were purely sandy inhabiting, 10 were rocky and two were sandy-muddy inhabitant. Genus *Umbonium* in molluscan group was recorded throughout the year with higher magnitude. Sampling design with 0.25 sq. m quadrat size and with 12 m interval has recorded 96.60% of macrofaunal richness and 97.10% of macrofaunal abundance. The amount of effort required to sample exposed sandy beach was quite less than the effort exercised in sampling continuous strip of quadrats. Therefore, it is recommended that to sample macrofaunal richness and abundance on exposed sandy beach 0.25 sq. m quadrat with 12 m interval is to be used for better results.

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