CHAPTER 3

Distribution and Quantitative Study of Benthic Fauna

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1. DISTRIBUTION PROFILE OF BENTHIC FAUNA

The distribution of obtained benthic faunal species followed an estuarine gradient as per their individual tolerance level and habitat/microhabitat availability. The distribution profile can be further divided into distribution along the entire estuary and distribution along the downstream intertidal mudflat at Kamboi.

1. 1. Faunal Distribution Along the Estuarine Gradient

Salinity and physical processes undergoing in the estuarine ecosystem create an ecological barrier which limits various benthic organisms from microfauna to macrofauna within specific zone. Similar scenario was observed in Mahi river estuary wherein a gradient based distribution was seen from upstream to downstream which is represented as Fig. 3.1.

Traces of foraminiferans were found from slight upstream sediments which showed past marine evidences or rather occasional marine intrusion. Though the detailed qunatitative survey of foraminiferans was not possible during the study phase, the priliminary observations and sample analysis strongly suggests that the diversity and density of foraminiferans increased gradually as moving towards downstream. Mollusca remained predominantly distributed from upstream to downstream no matter the density varied from sparse to abundant. Rich molluscan assemblage was seen in upstream sites where diverse habitat was available as well as freshwater habitat remained for most of the year; the diversity and density though depleted moing towards downstream. Crabs and mudskippers showed their presence staring from midstream sites to downstream, though on less occasions at midstream. Larval stages of crabs were mostly seen seetling at the midstream site instead of adult ones with exeptional case of few larger species like *scylla serrata* which intruded midstream and upstream occassionally along with high tides. *Neries sp.* showed occassional sightings between midstream and downstream which increased ultimately towards downstream. In case of arthropods, most of them viz. amphipods, isopods, spider, insect larva, ant sp. were reported only from the downstream sites. Distribution of Sipuncula sp. was restricted to downstream especially in the calcritized hard sediments of Kamboi.

1.2. Distribution of Molluscs

A specific pattern of distribution was noted on the estuarine scale wherein a particular physico-chemical environment was selected by respective assemblage. Distribution of molluscan species in upstream, midstream and downstream is represented in Table 3.1. Further, diversity of species along the estuarine gradient can be represented by Fig. 3.2. Upstream sites (Vasad/ Fajalpur) showed maximum diversity with 14 species (52%) followed by downstream (Kamboi) with 11 species (30%) and midstream (Dabka) with only 5 species (18%) (Fig. 3.3). Family Thiaridae dominated with 6 species (25%) and was mostly confined to the fresh water zone. The heterogeneity in distribution pattern at different habitats were confirmed by various indices (Table 3.2).

In present study, relative increase in marine species was noted from upstream to downstream while opposite was the trend with freshwater species. Family Thiaridae dominated the estuarine molluscan assemblage, remained more confined to upstream showing low salinity tolerance. *Thiara lineata* dominated the upper reaches (=108 individuals/ m^2), followed by *Corbicula* sp. (=28 individuals/ m^2) while *Assiminea sp.* was dominant at Kamboi (=03 individuals/ m^2). Greater similarity was observed between Vasad and Dabka (upstream and midstream) sites as compared to Dabka and Kamboi sites (midstream and downstream).

2. DISTRIBUTION ON THE DOWNSTREAM INTERTIDAL MUDFLATS

Overall high distribution and density of benthic fauna was seen at downstream site, Kamboi. This may be the result of availability of wide intertidal area for different forms of benthic animals. Moreover, different zones defined from upper to lower intertidal zones served as varied habitat and a set of assemblage was seen zone wise (Plate 1). A specific benthic community assemblage was seen in each group wherein the animals mostly restricted to respective zones showing their affinity to the respecitive substrata and habitat conditions. A thematic diagram showing beach profile with benthic distribution and respective zones in actual manner is presented as Fig. 3.4.

Moreover, benthic community overlapping was also seen among different zones, especially at an interface between two zones. Total benthic diversity increased from Zone 2 to Zone 5 with 2 species in Zone 2, Zone 3: 8 species, Zone 4: 8 species and 12 species in zone 5. The overlapping and sharing of benthic community at different zones can be best represented by Venn diagram as in Fig. 3.5.

Mudskipper sp. shared a common and watery substrata of zone 4. The species was seen foraging in zone 4 within runnel, though they used that as a foraging ground and specially incase of young ones. Amphipods, isopod speciess and sipuncula sp. shared a common habitat, boring the hard substratum in Zone 4 and initial part of Zone 5.

Amphipods and isopods showed their restricted distribution to lower part of Zone 4 in hard substratum. In partially decayed sedements they showed a very high density of 5.3g/kg sediment.

Among the estuarine fauna, brachyuran crabs are noteworthy for their abundance and species richness. No significant distribution pattern was seen along the estuarine scale, yet a specific pattern in distribution was observed along the intertidal area at Kamboi (downstream) from upper intertidal zone to lower intertidal line. Distinct zonation was seen across the intertidal zone. *M. depressus* and *D. crepsylodactyla* were the dominant species in upper and lower intertidal area respectively.

3. DISTRIBUTION OF BRACHYURAN CRABS AT KAMBOI

Brachyuran crabs showed a heterogeneous distribution pattern on the estuarine intertidal area of Kamboi. Different crab species showed a zonal distribution starting from zone 2 to zone 5 respectively depending on the general beach profiling and sedimentological features.

Uca lacteal annulipes showed a distribution range in zone 2 and 3. Though, it showed a sparse distribution in zone 2, their density increased in initial part of Zone 3 while declined towards the end of Zone 3.

Uca dussumerie and ***Uca vocans*** showed occasional sightings and were reported only two to three times during the study period. Both the species were restricted to Zone 3.

Scylla serrata showed isolated distribution especially in the burrows under the hard substratum in Zone 4 and 5. Moreover, burrow seen in the mudflat (zone 4) were complex and horizontally spread.

Cardisoma carnifex, a medium sized bulky crab, showed its distribution from Zone 2 to Zone 4 with gradually decreasing frequency. Further, the species showed a sparse and isolated distribution.

Matuta lunaris was distributed in lower intertidal range in Zone 5 with fine sandy substratum. The crab showed predatory behavior and does not show a burrowing behaviour. The crab showed lower encounter rate and was sighted occasionally.

Macrophthalmus dilatatus was confined to the lower estuarine reaches and towards the low tide line in Zone 5. The species preferred fine sandy substratum and formed inclined burrows. Though the crab was not seen in compact densities, it showed homogenously adequate distribution.

Dotilla clepsyrodactyla, dominated the lower intertidal reaches starting from Zone 4 to further, apart from the dominance of *M. depressus* in Zone 2 and 3. The species showed rich congregation towards the initial part of Zone 5 which showed fine sandy substratum. Average number of 225 individuals/m^2 were noted which evident their high density after specific low tide exposure.

Parasesarma pictum *and* ***Metapograpsus messor*** were the occasional species, recorded at few instances only during the course of the study. *M. messor* was recorded from muddy substratum of Zone 3 and 4 while *P. pictum* was predominantly recorded from hard sediments (partially hardened substratum) towards the low tide line which was exposed only during spring tides. Distribution and overlapping of different crab species in different zones can be seen in Fig. 3.6. Further, based on the rarity of occurrence, the obtained species can be grouped into three categories viz. Abundant, Occasional or Isolated and Rare as per Table 3.3.

In case of brachyuran crab community, an increase in diversity of brachyuran species was noted as going from Zone 2 to Zone 5. Though, many of the species remained restricted to specific zone, few of the species even shared a common habitat/microhabitat and exhibited community overlapping (Table 3.4). Zone 3 and 4 were the most comfort zone harbouring many common species like *Uca lactea*, *Cardisoma carnifex* and *Macrophthalmus depressus*.

3.1. Distribution of *M. depressus* on lower intertidal mudflat, Kamboi

Macrophthalmus depressus was the dominant crab species at Kamboi and variably distributed throughout the lower intertidal mudflat. Burrow pattern and other characteristic field features were studied for unambiguous identification of *M. depressus* burrows. Line transects up to 175 m perpendicular to the shore line and covering all specified regions were laid, spreading nearly 5 km of the length of the estuarine downstream. Through different zones, the number of crab varied from 22 - 120 individuals/m^2. Zones 3 and 4 (units 13 to 24, linear length 65-120 m, profile elevation deceasing from 7.3 m to 4.6 m) had the highest crab density. Quadrate analysis showed that the density of *M. depressus* burrows was: Zone 2, 28.66±9.86; Zone 3, 83.20±33.87; Zone 4, 62.00±9.16; and Zone 5, 52.50±24.74 per m^2, respectively. The mean density of the crab varied from 0 to 83 individuals per linear meter along the transect all over the above described zones. The total burrow count along different zones is presented in Table 3.5. To be more specific, the average of burrow openings for respective zones at every 5 m was counted in order to see the distribution pattern in each zone (Tables 3.6, 3.7). The Kite diagram drawn from the means of all the transects describes the density per zone exhibited by the species (Fig. 3.7). Overall, a higher burrow count was obtained in Zones 3 and 4, with totals of 160 and 127 burrow openings, followed by Zones 5 and 2 with 71 and 15 burrows, respectively, with a less significant linear regression (R^2 = 0.007) (Fig. 3.8).

Table 3.1: Distribution of molluscs on three sites representing upstream, midstream and downstream regions.

Species	Upstream	Midstream	Downstream
Bellamya bengalensis (Lamarck, 1882)	+	-	-
Bellamya crassa (Benson, 1836)	+	-	-
Thiara (Melanoides) tuberculata (Muller, 1774)	+	-	+
Thiara (Melanoides) tuberculata cerebra (Lea, 1850)	+	-	+
Thiara lineate (Gray, 1828)	+	-	-
Thiara scabra (Mueller,1774)	+	-	-
Thiara granifera (Lamarck, 1822)	+	-	-
Thiara (Sermyla) riqueti(Grateloup, 1840)	+	-	-
Indoplanorbis exustus (Deshayes, 1834)	+	+	-
Lymnia sp. (Lamarck,1799)	+	+	-
Parreysia favidens (sub sp.:- Deltae) (Benson, 1862)	+	-	-
Parreysia (Radiatula) pachysoma (Benson, 1862)	-	-	+
Parreysia (Radiatula) lima (Simpson, 1900)	+	-	-
Parreysia (Radiatula) chaudhuri (Preston,1912)	+	-	-
Corbicula striatella (Deshayes, 1854)	+	+	-
Gabbia alticola (Annandale, 1918)	-	+	-
Digoniostoma textum (Annandale, 1921)	-	-	+
Tricula Montana (Benson, 1843)	-	-	+
Segmentina sp.(Fleming, 1817)	-	-	+
Assiminea sp. (Fleming, 1828)	-	-	+
Gyralus sp.(Charpentier, 1837)	-	+	+
Corbicula krishnaea (Ray, 1967)	-	-	+
Corbicula sylhetica (Preston, 1908)	-	-	+
Donax incarnates (Gmelin, 1791)	-	-	+

Table 3.2: Diversity indices of obtained molluscan species at different sites representing upper, mid and downstream regions.

	No. of Individuals	Shannon	Simpson	Menhinick	Margalef	Berger-Parker
Vasad	13	2.70	0.93	3.8	5.17	0.06
Dabka	05	1.60	0.8	2.23	2.48	0.2
Kamboi	11	2.39	0.9	3.31	4.17	0.09

Table 3.3: Categorization of obtained crab species based on their occurrence.

Sr.No.	Species name	Abundant	Occasional/ Isolated	Rare
1.	*Uca vocans*			√
2.	*Uca lacteal annulipes*	√		
3.	*Uca dussumieri*		√	
4.	*Macrophthalmus depressus*	√		
5.	*Macrophthalmus dilatatus*	√		
6.	*Dotilla clepsydrodactyla*	√		
7.	*Scylla serrata*		√	
8.	*Cardisoma carnifex*		√	
9.	*Matuta lunaris*		√	
10.	*Parasesarma pictum*			√
11.	*Metopograpsus messor*			√

Table 3.4: Zone wise occupancy of different crab species with their overlapping.

Zones	Species	Common species
Zone 2	*Uca lactea*	*Uca lactea*
Zone 3	*Uca lactea, Macrophthalmus depressus, Cardisoma carnifex, Uca dussumerie*	*M. depressus, C. carnifex*
Zone-4	*Macrophthalmus depressus, Cardisoma carnifex, Scylla serrata, Dotilla crepsyrodactyla, Parasesarma pictum*	
Zone -5	*Dotilla crepsyrodactyla, Scylla serrata, Matuta lunaris, Metapograpsus messor, Macrophthalmus dilatatus, Parasesarma pictum*	*D. crepsyrodactyla, S. serrata, P. pictum*

Table 3.5: Open burrow count for *Macrophthalmus depressus* at Mahi river estuary falling on individual transects.

	Zone -2		Zone - 3		Zone - 4		Zone - 5	
Transects	Mean	SD	Mean	SD	Mean	SD	Mean	SD
T - 1	1.6	3.0	8.6	6.12	5.62	4.1	1.2	1.2
T - 2	1.09	2.6	13.2	5.9	5	5	22.5	9.6
T - 3	0.09	0.3	2.4	1.2	5	2.7	0.1	0.3
T - 4	0.27	0.6	49.7	24.2	29.7	22.3	7.1	3.1
T - 5	0.9	2.1	18.6	8	8.7	3.7	1.4	1.6
T - 6	2	4.1	18.4	8.4	56.8	19.4	22.7	22.5
T - 7	2.9	4.4	36.3	35	15.1	6.3	9.1	12.3
T - 8	1.9	2.3	5.2	3.6	12.8	10.2	4.5	6.8
T - 9	0	0	6.8	4.8	10.5	4.4	1	1.4
T - 10	0.09	3	8.8	7.9	7.1	7.4	1.4	2.1
T - 11	2.9	5.2	37.2	20.6	10.2	6.4	0	0
T - 12	1.36	2.6	2.4	3.2	0	0	0	0
T - 13	3.18	4.4	10.7	6.2	2	1.7	0.01	0.3
T - 14	1.72	3	8.5	5.8	5.6	4.1	1.2	1.2
T - 15	2.63	3.3	1.2	1.7	0	0	0	0
T - 16	1	1.6	6.7	6.1	4.2	2.5	5.2	2.8

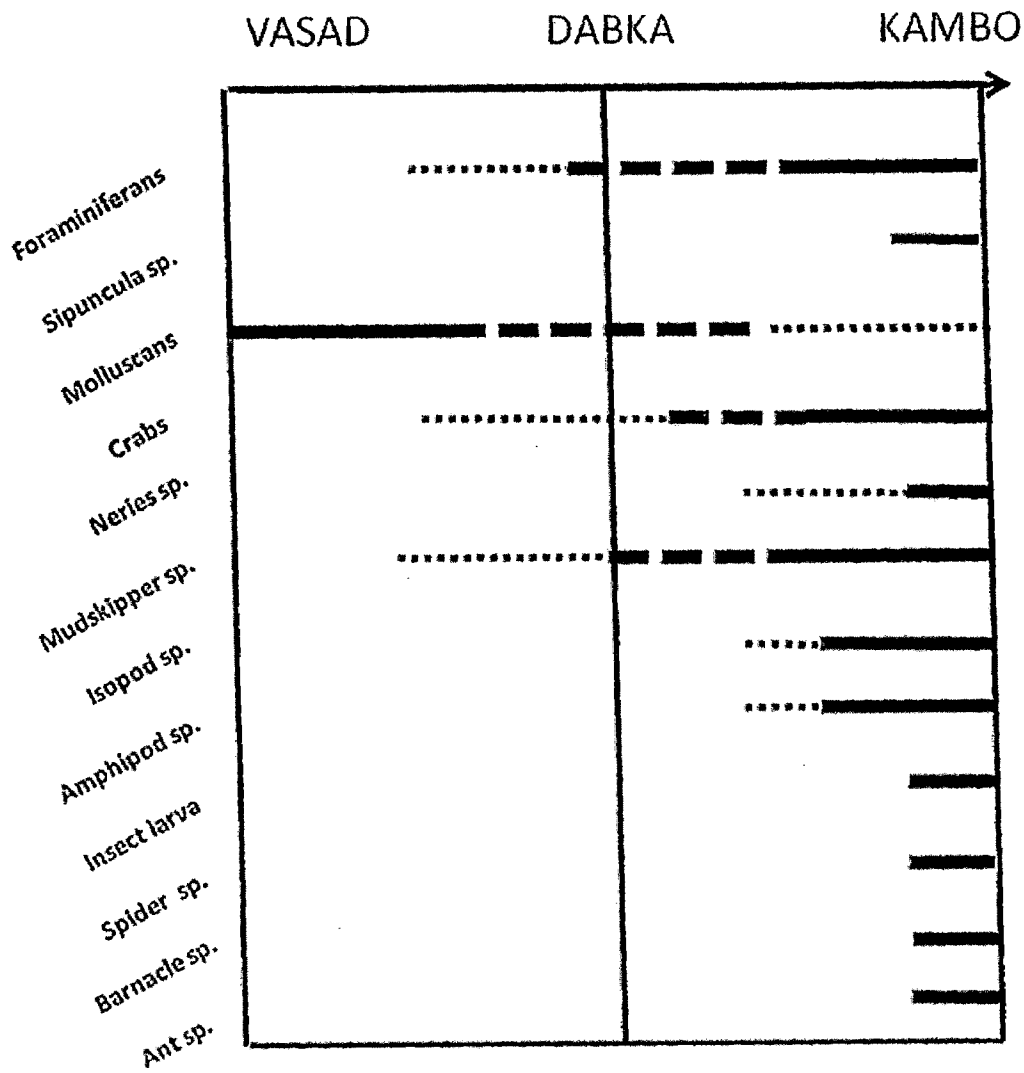
P value 0.003 i.e significant (ANOVA, $P(0.003)<0.005$, $F = 4.96$, $R^2=0.19$, df=3,confidence level 95%)

Table 3.6: Zone wise average burrow openings for respective zones in accordance to zonal extension at every unit (5 m).

zones	Distance in metre	Mean burrow count	SD
Zone - 2	5	0.13	0.34
	10	0.00	0.00
	15	0.44	1.50
	20	0.13	0.34
	25	0.19	0.40
	30	0.00	0.00
	35	0.63	1.26
	40	1.13	1.67
	45	3.06	3.26
	50	4.94	5.20
	55	5.13	3.72
Zone -3	60	7.13	7.84
	65	10.69	12.45
	70	15.94	18.09
	75	15.38	14.30
	80	18.19	19.37
	85	18.50	27.46
	90	17.69	21.85
	95	15.56	22.00
	100	13.44	17.45
	105	12.44	16.63
	110	13.94	18.37
Zone - 4	115	12.13	14.16
	120	8.81	9.50
	125	11.00	13.38
	130	12.06	16.95
	135	8.81	15.52
	140	10.19	23.13
	145	6.13	14.68
	150	7.50	14.25
	155	5.75	9.33
Zone - 5	160	5.63	8.40
	165	5.06	9.58
	170	4.06	9.84
	175	2.25	5.84

Table 3.7: Pearson's correlation between transects.

Transect	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	T 11	T 12	T 13	T 14	T 15	T 16
T 1	0.08	0.36	0.5	0.63	0.17	0.5	0.3	0.5	0.47	0.42	0.35	0.64	1	-0.14	0.23
T 2	.....	-0.18	0.08	0.14	0.13	0.23	-0.03	-0.09	-0.1	0.07	-0.02	0.12	0.08	-0.23	0.43
T 3	.....	.....	0.5	0.45	0.5	0.34	0.38	0.76	0.46	0.28	0	0.16	0.36	-0.27	0.26
T 4	.....	.....	.....	0.87	0.21	0.63	0.07	0.79	0.86	0.59	-0.06	0.4	0.5	-0.26	0.36
T 5	.....	.....	.....	.....	0.13	0.61	0.03	0.69	0.63	0.7	0.14	0.63	0.63	-0.15	0.41
T 6	.....	.....	.....	.....	.....	0.02	0.65	0.48	0.21	0	-0.23	-0.18	0.18	-0.38	0.06
T 7	.....	.....	.....	.....	.....	.....	-0.02	0.44	0.53	0.27	0.01	0.4	0.49	-0.23	0.12
T 8	.....	.....	.....	.....	.....	.....	.....	0.25	0.12	-0.05	-0.07	0.02	0.31	-0.18	0.03
T 9	.....	.....	.....	.....	.....	.....	.....	.....	0.76	0.26	-0.18	0.15	0.5	-0.3	0.21
T 10	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	-0.17	0.13	0.47	-0.3	0.06
T 11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.46	0.67	0.43	-0.02	0.51
T 12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.73	0.35	0.12	0.26
T 13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.65	0.08	0.54
T 14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	-0.13	0.24
T 15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	-0.07



..... Sparse/occasional distribution ------ Fair distribution ——— Dense/Fixed distribution

Fig.3.1: Thematic presentation of distribution range of different group of benthic fauna along Mahi river estuary.

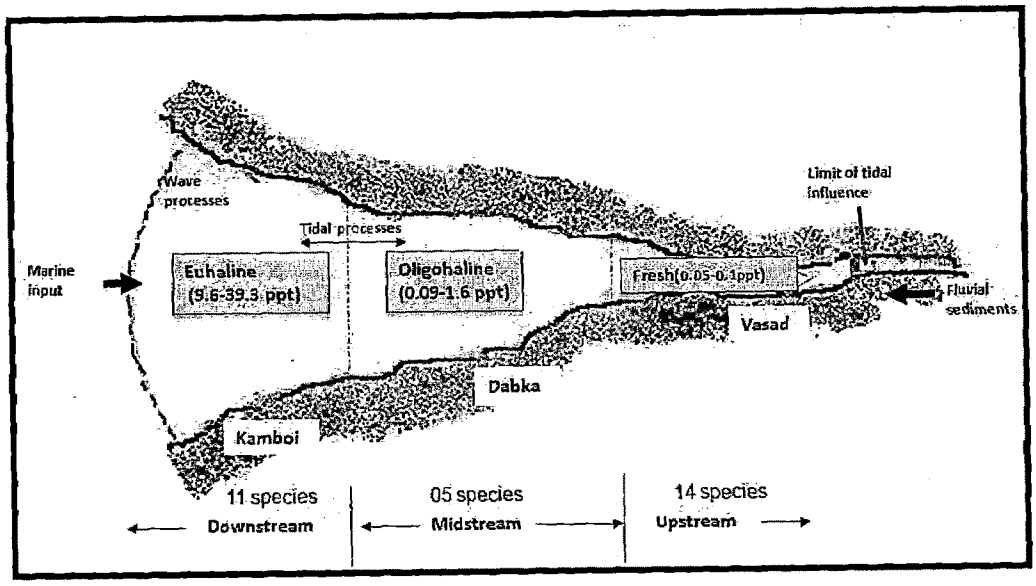


Fig. 3.2: Thematic presentation of distribution of molluscan fauna along estuarine gradient.

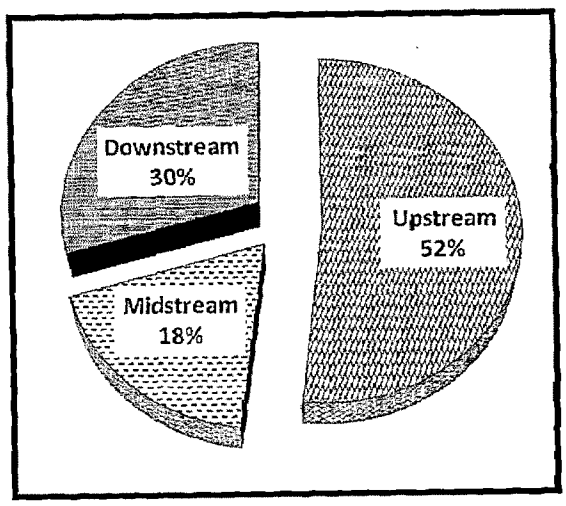


Fig. 3.3: Percentile of Molluscan fauna distribution.

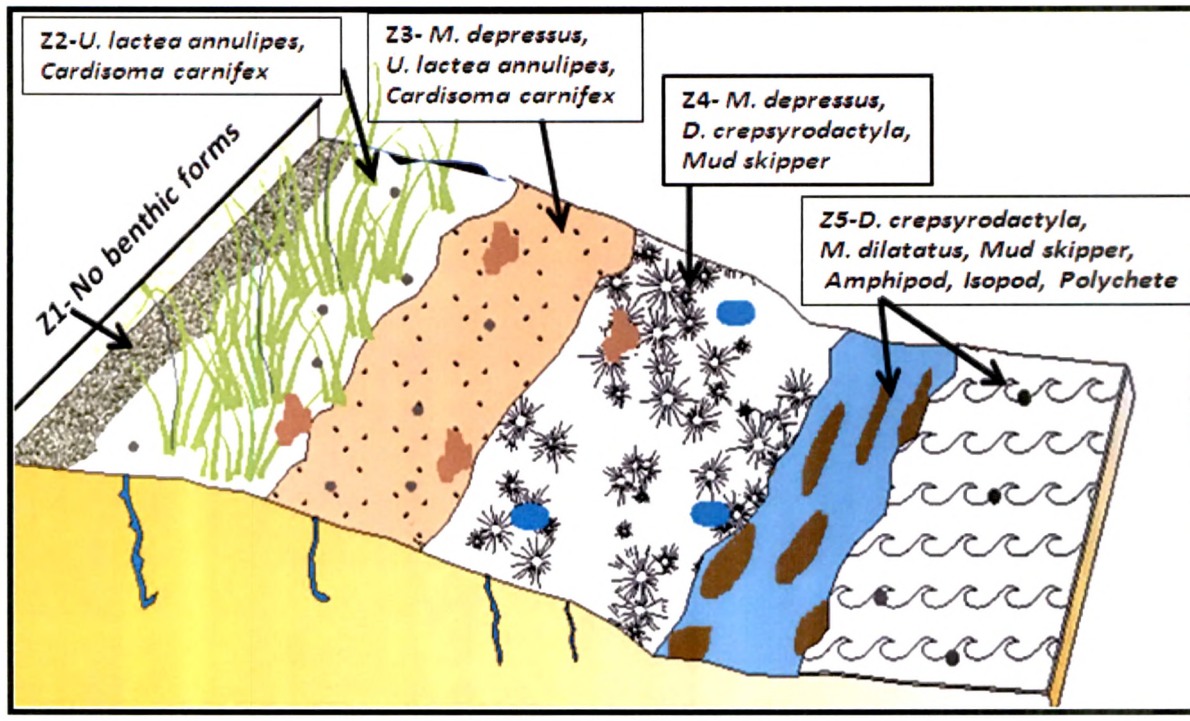


Fig. 3.4: Schematic diagram representing beach profile at Kamboi with different defined zones and respective species occurrence. Zone 2: with grassy belt, Zone 3: a muddy zone with high preference by crab species, Zone 4: A clayey silty zone having sloppy physiography with high density of crabs, Zone 5: with fine sandy substratum towards lower intertidal side.

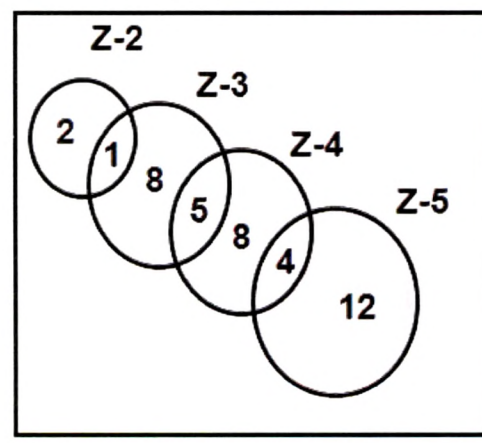


Fig. 3.5: The Venn diagram shows the total macrofaunal species reported in each zone and number of common species shared by respective zones.

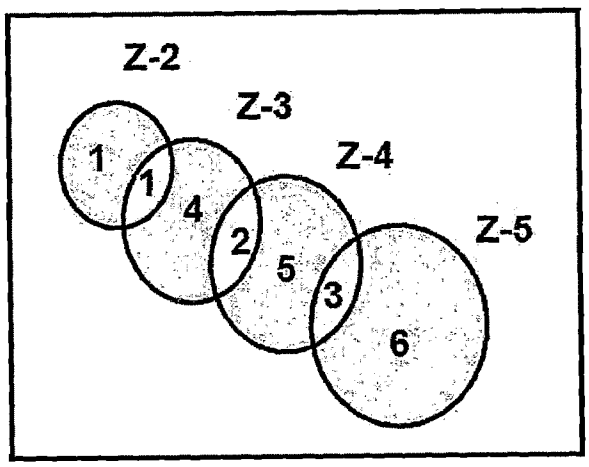


Fig. 3.6: Venn diagram representation of distribution and overlapping of different crab species along different zones at downstream site Kamboi.

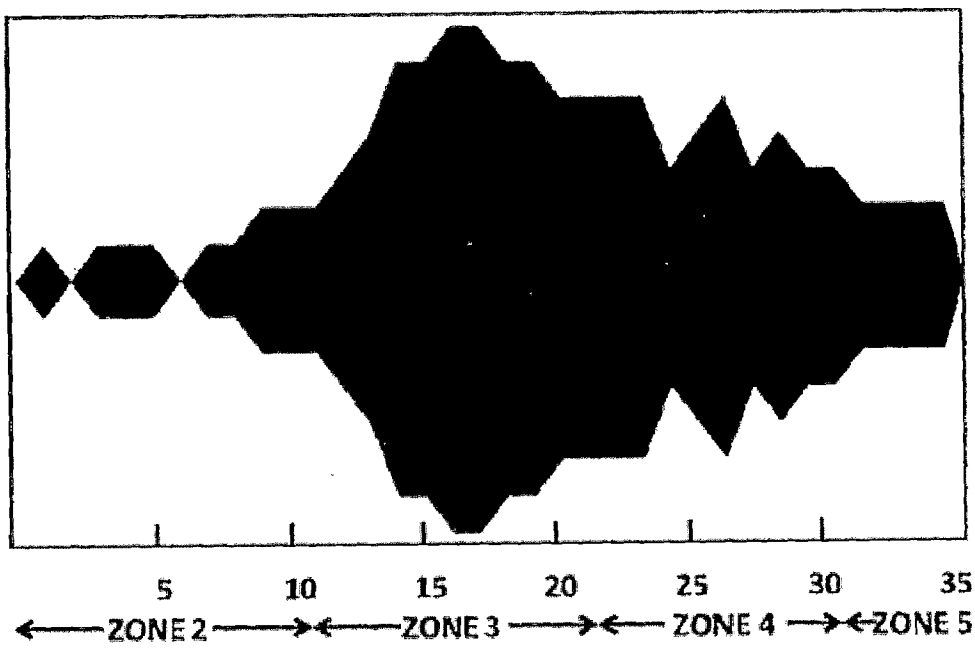


Fig. 3.7: Representation by kite diagram of *M. depressus* distribution along different zones at Kamboi.

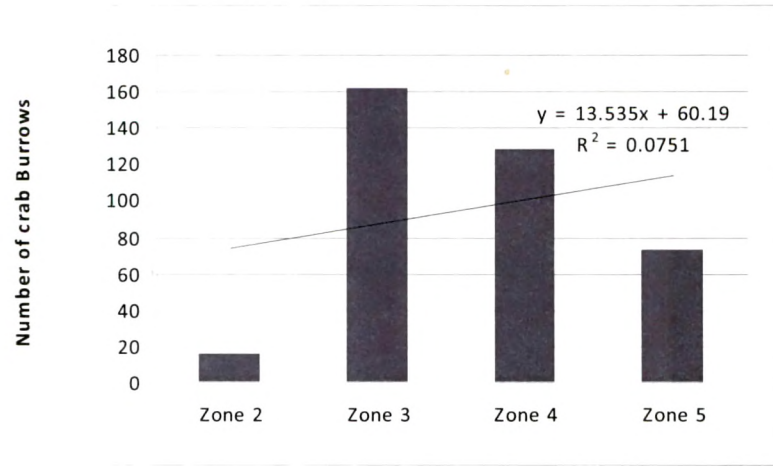


Fig. 3.8: Sum of total burrow openings per zone of *Macrophthalmus depressus* Rüppell, 1830, falling on each transect.

Plate 1

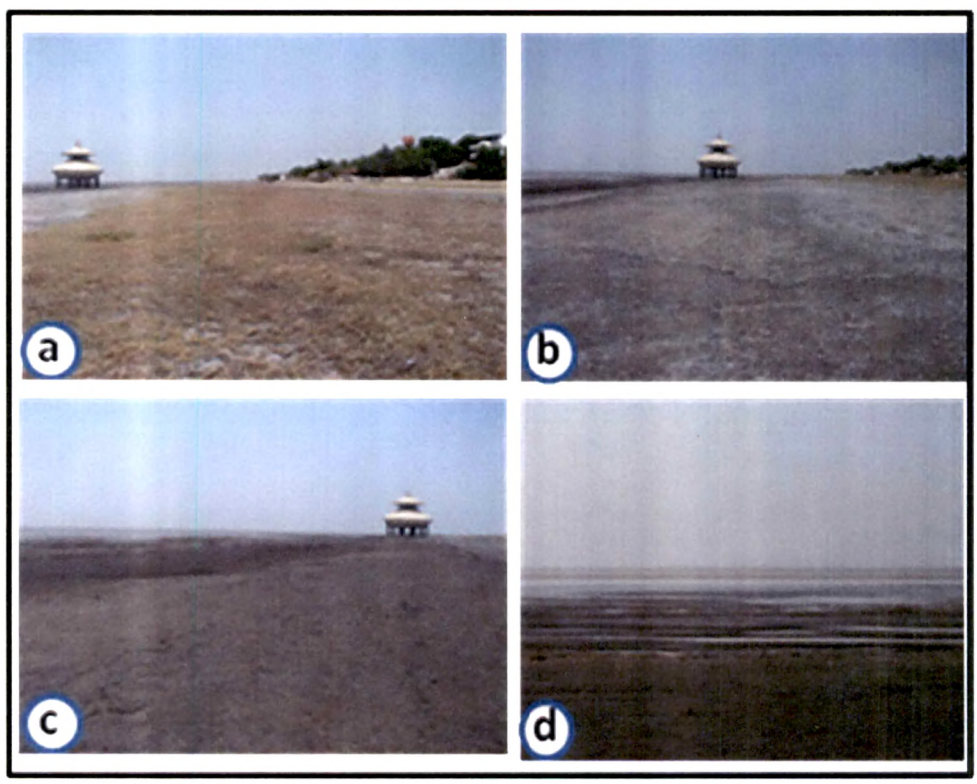


Plate 1: Different zones along Kamboi beach showing different zones a: Zone 2, b: zone 3, c: Zone 4, d: Zone 5.