CH 1

CH 2

RESULTS

CH 2

CH 4

CHAPTER 1

Habitat characterization

Habitat characterization

1.1. Mahi estuary general habitat

Habitat survey is an important component of any fo the ecosystem study. This provides baseline information about important physiographic features of habitat which can be the probable governing factors. The geomorphic features give a clue of paleo environment and important events taken place in the area. During initial phase of the work, Mahi estuary was surveyed to detail its habitat features. More than 15 approachable sites were visited along the 50km long estuarine stretch. These sites were looked into for overall physiography, bank features, available habitat for benthos, anthropogenic activities, pollution inputs and few geological features. Information on available bed forms may govern the benthic community dependent of it.

The preliminary survey and the prevalent hydrodynamics classify the Mahi estuary as a partially mixed kind wherein the marine influx mostly dominates the riverine output. The midstream and downstream shows high amount of churning of bed material during tides. Moreover, the estuary shows prominent meandering at several points which has caused prominent erosional and depositional sites. The generalized overview to the sedimentological features states that upstream site is dominated by sandy bed material and bank depositions. The upstream sites like Rayka and Fajalpur shows dominant exposed sections on the right bank showing paleo depositional feature (Plate 1.3). The bottom calcrete/marine clayey material on adjacent banks at Rayka and Fajalpur provide evidences of marine deposits pointing past marine influence in the area. Midstream habitat shows muddy as well as sandy substratum. Moreover, appearance of open beaches on many sites of midstream is apparent (Plate 1.4). Downstream shows estuarine mudflats and heavy deposition/erosion. The area towards main channel forms a flat plain with fine sandy ripples and patterns.

The geomorphic map described by previous researcher has detailed various geological features of the estuarine part of Mahi river (Fig.1.1).

Altogether, the ecosystem can be classified into ravine area, channel mud, younger terrace, alluvial plain and channel bar. The estuarine system has carved into healthy ravines which evidence the past meandering and riverine records. The estuary at several places supports open terraces, cliffs at few places which have preserved different sedimentological layers reflecting the important flooding and paleoclimatic events (Plate 1.1). Moreover, the complex ravines with undulating terrain supports good vegetation cover at many places which support good avian diversity and habitat for many creatures. Interestingly, the lower estuarine part prominently shows a mudflat zone on the intertidal side adjoining the younger terrace. These mudflats, distinctively seen at Kamboi and adjoining lower estuarine sites are one of the vital parts of the Mahi estuary serving as an important habitat for benthic fauna which are more discussed in chapter ahead.

A prominent terrace formation is seen at several places which probably show the depositional sites of the estuary. Moreover, channel bars at midstream divide the main channel into two parts. Most of the channel bars seen at midstream sites like Dabka and Mujpur were sandy in nature. The island at Dabka (Plate 1.2) and the terraces at adjoining upstream sites were seen with high sand deposits.

Furthermore, as an anthropogenic addition, the common industrial effluent channel running 55km from the industrial belt of Vadodara opens into the downstream site of Mahi estuary (Sarod) and releases treated effluent at an average rate of 145 million liters per day into the Mahi estuary (Plate 1.5). The detail of the effluent channel is presented in Table 1.1. This tremendous inflow of effluent plays a role in critically altering the natural estuarine habitat affecting the overall water quality of the nearby range (Plate 1.6). The daily tidal occurrence as an estuarine character flushes the effluent to other upstream sites and subsequently to the downstream with the receding tides. In addition to water quality, the effluent release has negative impact on local benthic fauna as well as other aquatic fauna and spreads over the habitats of benthic fauna (Plate 1.7). Even during the present study a very poor/negligible record of benthos was seen from the area. Moreover, during the field visits and as per the saying of local community it was known that at few instances this effluent wiped off the local fish catch of the area and the vicinity.

Parameter	Detail
Length of channel	55.30
Section length of channel	'U' shape
Width of conduit	2 m
Free Board	0.35
Invert level Dhanora	35.225 m
Invert level Sarod	11.70
Average velocity	0.65 m/sec
Average Flow	32.0MGD / 145.0 MLD
Peak Flow	48.0 MGD / 218.0 MLD
Capacity of each Lagoon	40 MGD / 181.25 MLD.

Table 1.1. Details of Effluent channel opening at Sarod.

1.2 Characterization of estuarine downstream, Kamboi

As discussed above, most of the downstream estuarine dominated in muddy areas. Secondly, many of the sites specially Kamboi, Badalpur and Dhuvaran represented a vast intertidal area during the low waters and showed regular estuarine process too with a river channel passing and opening in the gulf (Plate 1.8). Amongst them, Kamboi was the site of interest to be studied due to its varied habitat and microhabitat. Where most of the site represented one or other kind of sedimentology, Kamboi represented different zonations in term of sedimentological aspects and even different microhabitats as a result of hydrodynamics and morphological features. These microhabitats were effectively occupied by different kind of benthic forms.

Topographical feature of an area affects directly the hydrodynamics and the depositional and erosional processes of an area. This process further controls sediment sorting creating different zones. A beach slope was seen from upper intertidal zone to lower intertidal area at Kamboi. Overall, an elevation difference of 8 m was found over the study area, from the upper surf zone to the lower intertidal mark. Based on sediment analysis, five distinct zones were identified from upper to lower intertidal line respectively (Plate. 1.9);

Zone 1, sandy-silty;

Zone 2, silty-sandy;

Zone 3, silty-clayey; } Muddy

Zone 4, clayey-silty; and

Zone 5, silty-sandy.

Each zone represented a specific nature in terms of sedimentology or topographic features. A comparative diagram of beach profile of Kamboi is shown in Fig.1.3 with distinct zones while Fig. 1.4 shows actual representation of slope difference form Zone 1 to Zone 5.

The detailed description of different zones is presented herewith;

Zone 1: The uppermost surf zone occasionally gets the water inundation during highest high tides. Rest of the days the zone remains dry with loose silty/clayey sand eroded from wind as well as adjacent cliff. The belt is used as track by the local people and isolated vehicles. The zone confined to hardly few meters and no different microhabitats were seen. The zone was more or less free from any benthic fauna due to human disturbance and dryness, hence was not considered during the study.

Zone 2: This zone followed Zone 1 and represented a belt of coastal grass spread through the area. The Zone due to its coastal grass cover and hardsubstratum reported a sparse faunal diversity along with few terrestrial arthropods. (Plate 1.10a)

Zone 3: The zone was muddy in nature and topographically with negligible slope. Due to its regular tidal exposure and the suitable substrata, it was one of the richest zone in terms of diversity and density. Yet the zone was a homogenous mudflat with no other microhabitat seen within it. (Plate 1.10b)

Zone 4: This zone followed Zone 3 in terms of diversity and density. The Zone showed a prominent beach slope and a mosaic of muddy habitat with a plain sandy mosaic. The terminal part of Zone 4 showed rich watery area with a runnel system and soup ground (Plate 1.10c). Following microhabitats were seen in in Zone 4;

i). Mudflat ii). Silt with sand iii). Runnel system and iv). Soup ground

Zone 5: The lowermost intertidal area Zone-5, was mostly dominated by fine sand. The initial part of the zone was also interrupted at few patches by hard substratum (partially hardened soil). The area also possessed intertidal pools seen between the hard substratum. Remaining area was dominated by fine sandy plains with ripples. Various kinds of bidirectional ripples were seen in Zone 5, each one serving as a microhabitat for variety of benthic species (Plate 1.11). Most of the ripples found, reflected the weaker current and shallow bottom churning which never indicated unidirectional water current. Linguoid ripples typically characteristics of churning of water and sediment at sediment water interface usually form very small and small ripples (Plate 1.6 b &c). In case of smaller to medium sized ripples, the base (slope) of the crest was ideally used as a microhabitat by *M. dilatatus* whereas in second case the *D.crespydrodactyla* used the crest of ripple as a microhabitat for burrowing. Following type of microhabitat can be categorized in Zone 5; i). Plain fine sandy area ii). Tidal pools iii). Hard substratum iv). Soup ground v). Various type of bidirectional ripples (Sinuous ripples, Linguoid ripple).

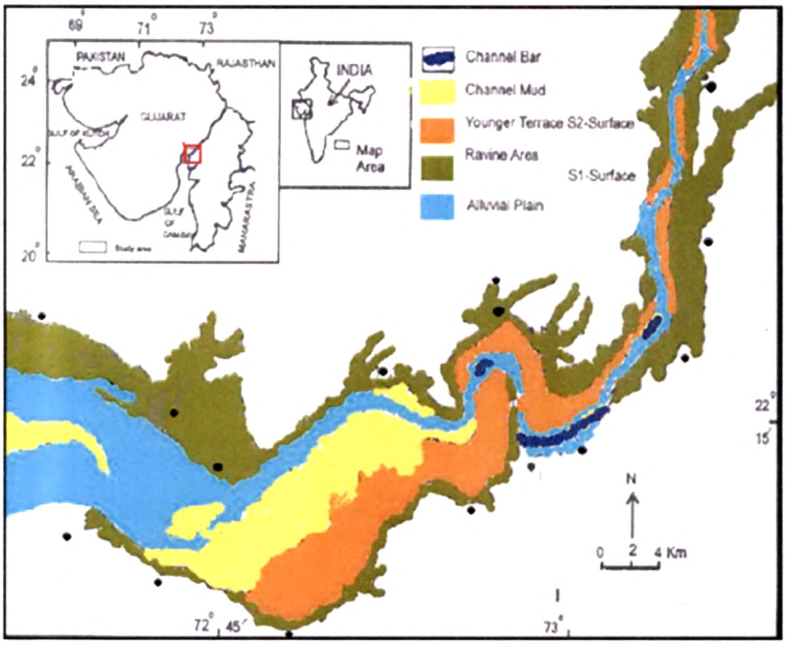

Fig. 1.1. Geomorphic map of Mahi river estuary showing characterization of the area. (Map modified from _______)

Plate 1.1.

Plate 1.2.

Plate 1.1. Adjacent ravine area showing open cliff at upstream site.
Plate 1.2. Arrow mark showing Channel bar/Island at Dabka. Mixing during high tide is clearly seen displacing the freshwater.

Plate 1.3

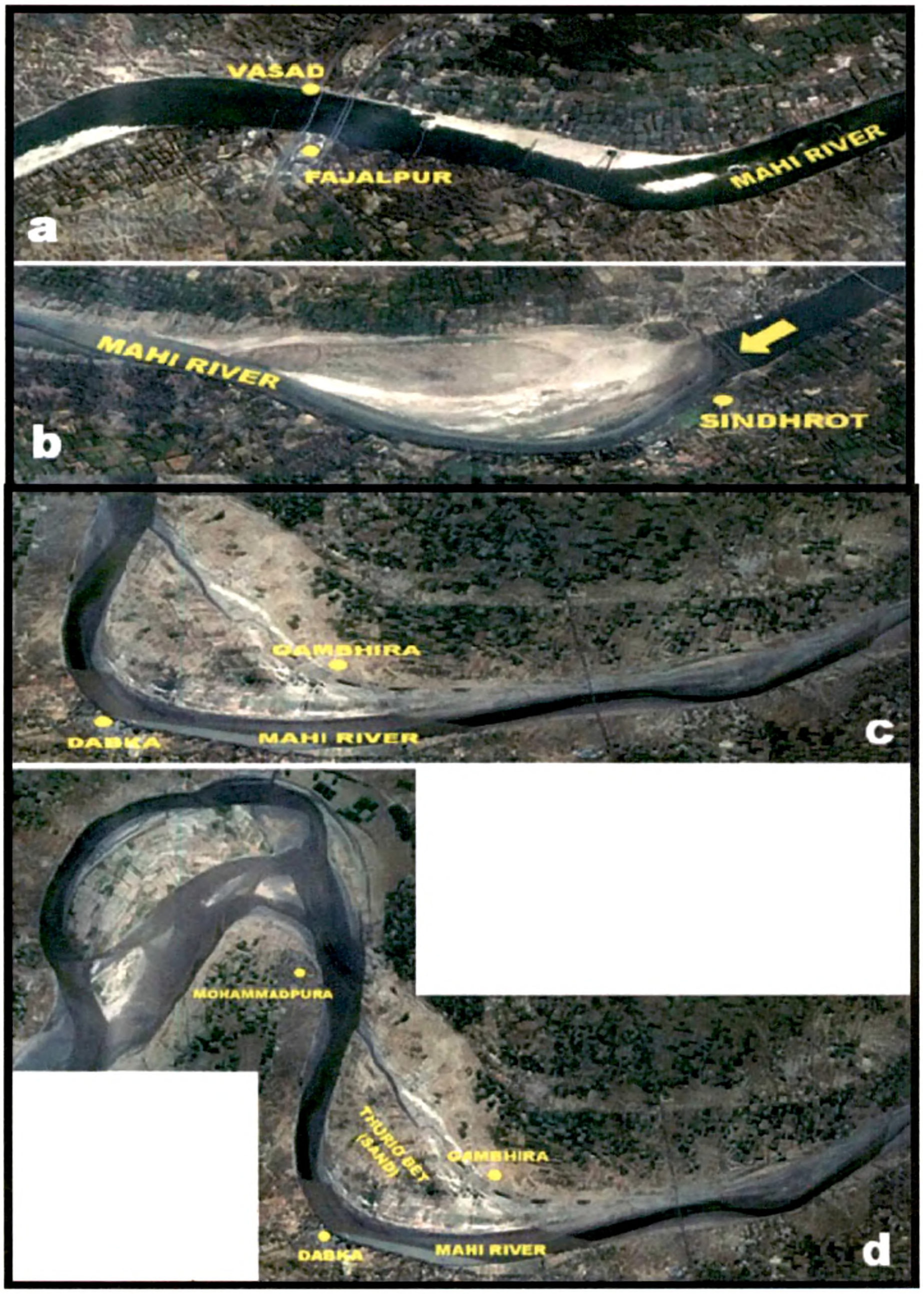

Plate 1.3. Upstream sites, a. Fajalpur with opposite bank having sand deposition b. A vast sand deposition at Sarod. c-d. Prominent meandering at Gambhira and Mohhadpura.

Plate 1.4

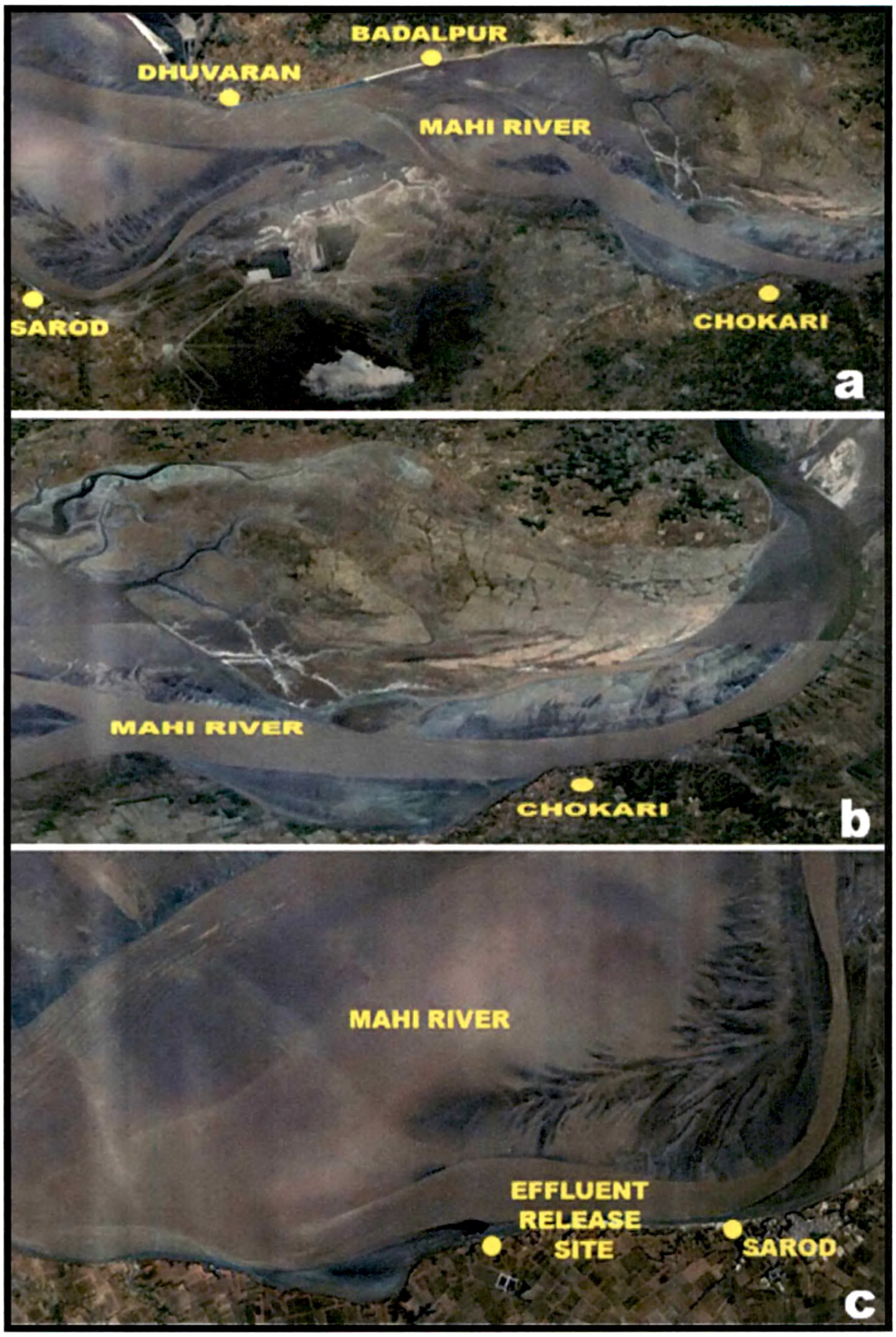

Plate 1.4. a-b. Showing geomorphic features at mid and downstream sites of Mahi river estuary.

Plate.1.5. Google image showing opening of Common industrial effluent channel at downstream site, Sarod.

Plate 1.6.

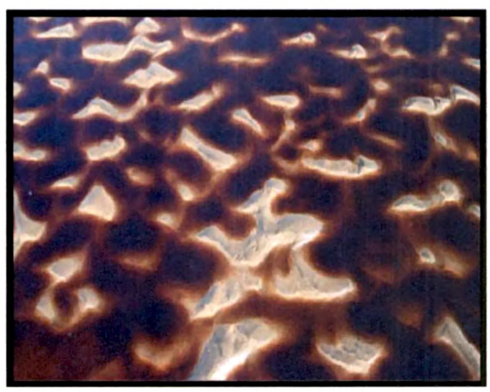

Plate 1.7.

Plate 1.6. Treated industrial effluent flowing into the estuary at Sarod.
Plate 1.7. Effluent spreaded over the ripples in the estuarine bed at Sarod.

Plate 1.8

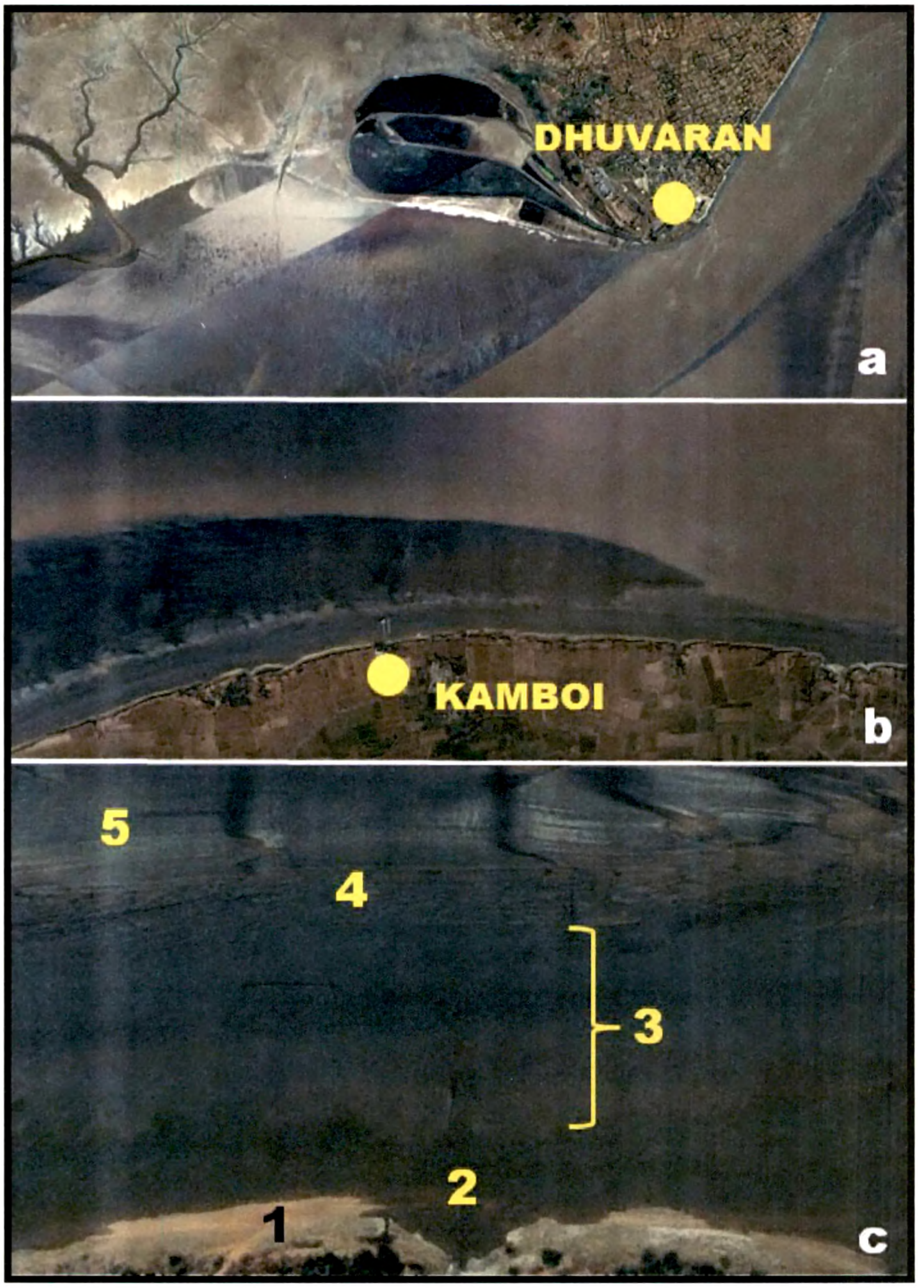

Plate 1.8. a-b. Showing downstream site Kamboi and Dhuvaran. c. Represents the intertidal zone exposed during the low tide.

Plate 1.9.

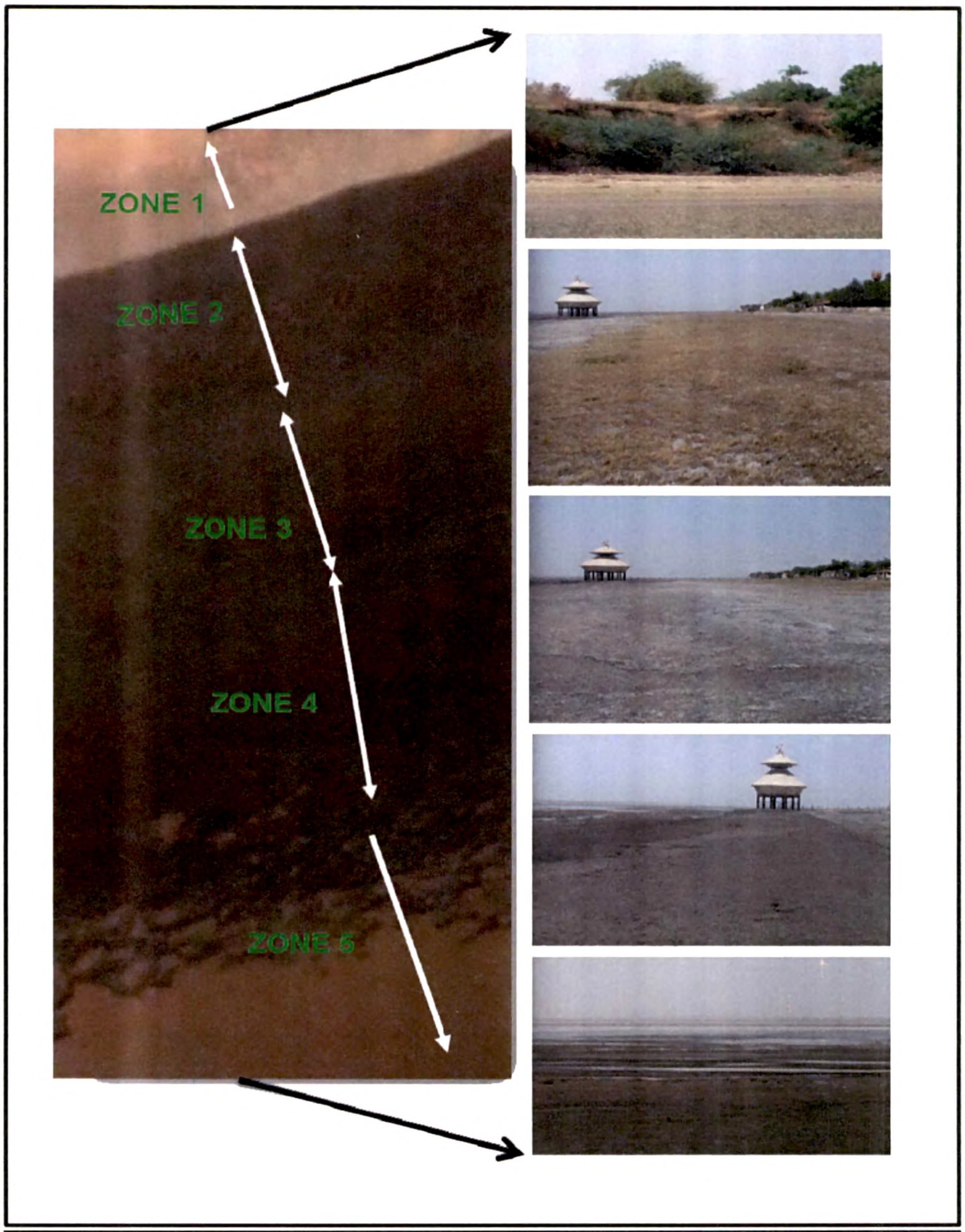

Plate 1.9. Plate represents three distinct zones at Kamboi. a. Zone 2: the Uppermost zone with sparse animal distribution, b). Benthos rich zone. c). Zone 4 with runnel system at the footstep of Zone 5.

Plate 1.10

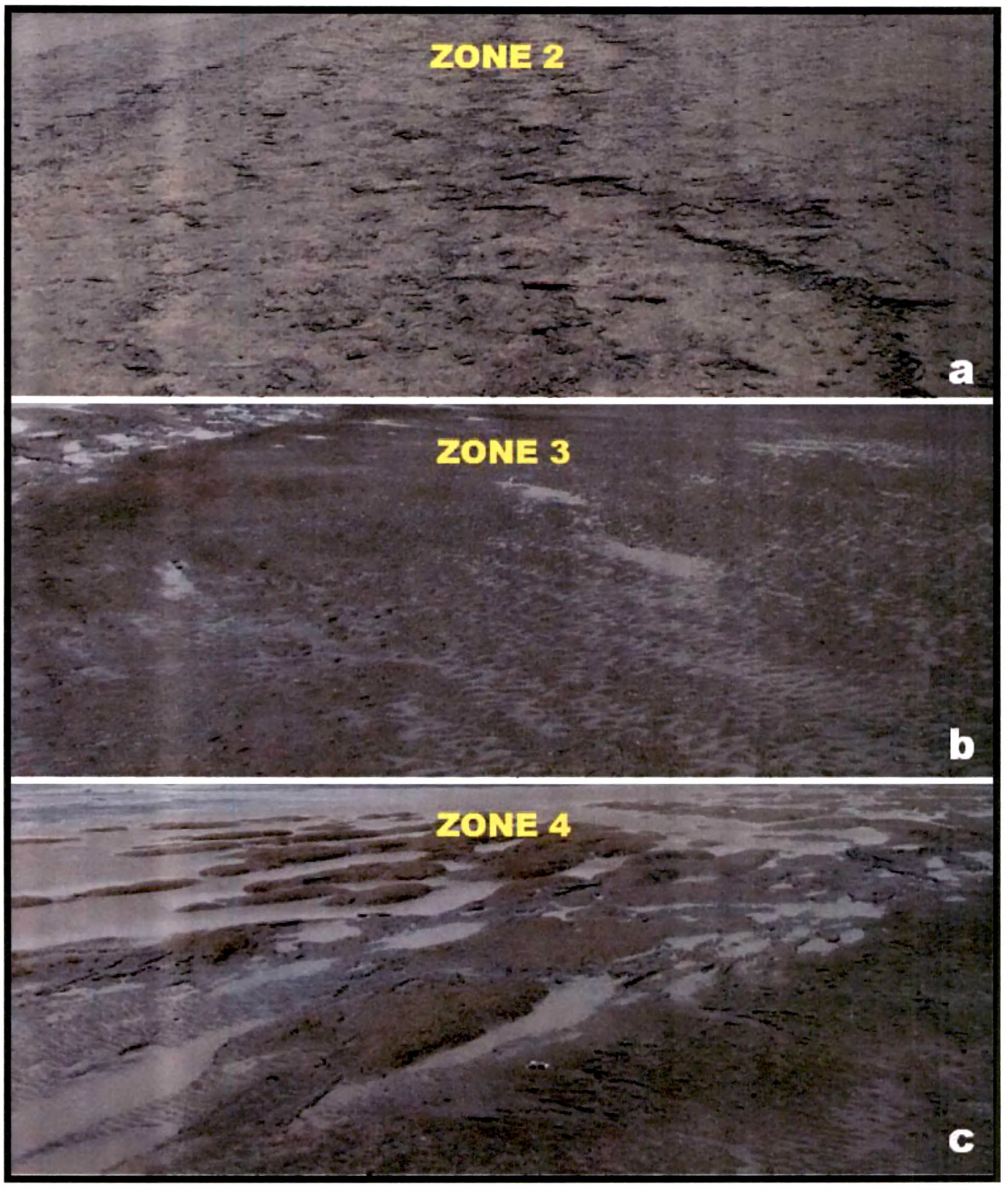

Plate 1.10. Representation of different zones at Kamboi with actual images.

SAND %	77	40	33	66	80
SILT+ CLAY %	23	60	67	34	20

Fig.1.2. Non scaled representation of beach profile at Kamboi showing different zones with sedimentological features.

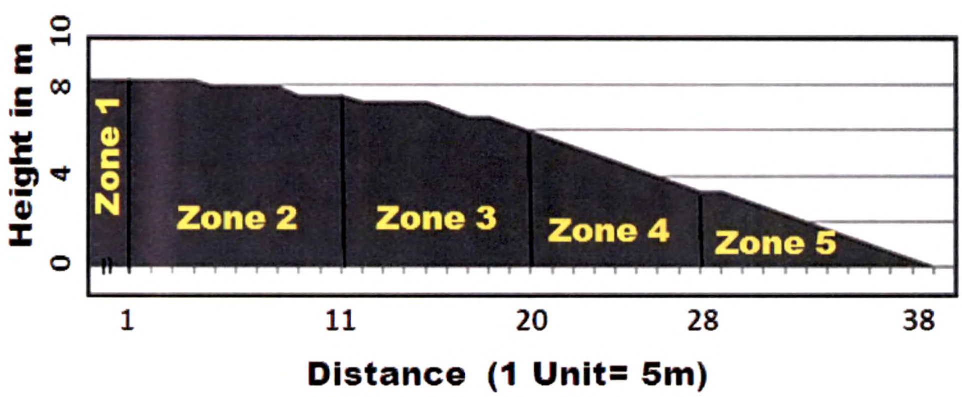

Fig 1. 3. Beach profile and slope (cross sectional view) from the upper surf zone to the lower intertidal mark at Kamboi.

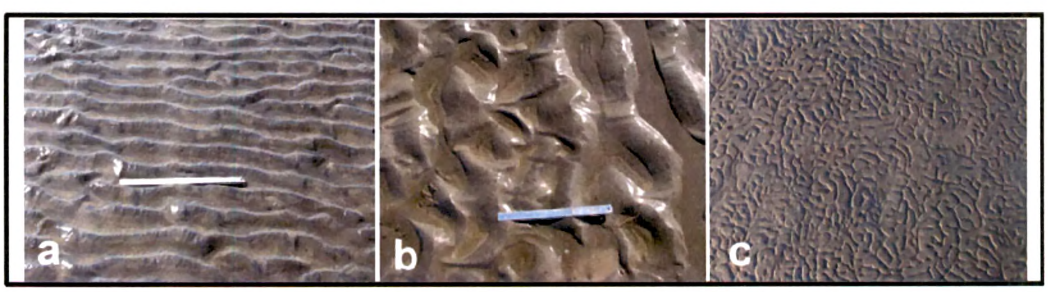

Plate 1.11. Different type of ripples found at Zone 5. a). Ripples formed due to unidirectional flow. b). Linguoid small to medium ripples formed due to churning or water

c). Complex and very small sized ripples formed due to churning of current and bed material.

1.3. General estuarine water quality

Estuaries are dynamic ecosystem which can be better called as an ecotone: an area of overlapping of two ecosystems. It represents the overlapping of freshwater as well as marine ecosystem which causes resultant fluctuation in abiotic parameters especially the water quality. Tidal fluctuation twice a day with different velocity and amplitude as per moon day amplifies the gradation pattern and water quality too. Unlike other aquatic ecosystems, it is difficult to mark a trend or specific pattern in estuarine water quality which changes time to time, day to day and season to season governed by several factors, Keeping in mind this fact the objective was set to overview the general features of water quality ruling out the seasonal fluxes.

Data compiled for about 3 years (2006 to 2009) for different water quality parameters like pH, total alkalinity, acidity, phosphate, salinity, total hardness and total and dissolved solids (TS and TDS) were analyzed individually for upstream, midstream and downstream as well as compared. One way ANOVA was used to compare and signify the parameters at three estuarine grades (Upstream, midstream and downstream) while column statistics with one sample t test was applied individually.

One way ANOVA for pH at different estuarine zones stated that pH at mid and downstream was confined to a small range (7.4 – 8.8 ±0.4 and 7.6 – 8.6 ± 0.3 respectively) while that at upstream showed a wide range (6.9 – 10.6). The shifting of mean line in upstream box diagram shows the effect of single higher pH value influencing the overall mean. Non significant correlation was obtained form comparison using one way ANOVA ($p>0.05$ ns) while pH as an individual parameter using one sample t test showed significance at ($p<0.0001$) (Fig. 1.4, Table 1.2).

Like pH, total alkalinity at upstream varied from that obtained at Midstream and downstream (Fig. 1.5). Midstream showed a wide range of total alkalinity value (3.3mg/l – 240mg/l ±0.48, $p<0.037^*$) as compared to upstream (164 mg/l - 260mg/l ± 36.26, $p<0.0015^*$s) and downstream (80mg/l – 224mg/l ± 39.10, $p<0.0003^*$) (Table 1.3). One way ANOVA between three zones showed non significant relationship with p=0.27(p >0.05 ns). On the contrary, no significant difference in acidity of Upstream (5mg/l – 40mg/l ± 13.73, $p<0.0001^*$) and midstream (5mg/l – 50mg/l ± 11.72, $p<0.0001^*$) was observed. Downstream showed broad acidity range (20mg/l – 100mg/l ± 29.32, $p<0.0002$) with higher mean attributed by few higher values as compared to upstream and midstream.(Fig.1.6, Table 1.4)

A broad range in phosphate values was observed at midstream (0.01mg/l – 0.53mg/l ±0.17, $p<0.0001^*$). Mean upstream (0.01mg/l – 0.25mg/l ± 0.09, $p<0.0001^*$) and downstream (0.21mg/l – 0.46mg/l ± 0.09, $p<0.0001^*$) values showed lower and higher values compared to midstream. Yet, one way ANOVA of 3 sites showed a non significant result, (p=0.08 > 0.05 i.e. ns). (Fig. 1.7, Table 1.2)

Salinity and total solids are an important variable at an estuarine scale and the cause of estuarine gradient. Salinity from upstream to downstream showed a prominent increase with mean upstream (0.05 ppt – 0.1ppt ± 0.01, $p<0.0001^*$) 0.09 ppt, mean midstream (0.05ppt – 22ppt ± 6.42, $p<0.0001^*$) and mean downstream (5.7ppt – 39ppt ± 11.55, $p<0.0001^*$) (Fig.1.8, Table 1.2, 1.3, 1.4) .Moreover, one way ANOVA between three sites showed a significant result with $p < 0.0001^*$. A similar kind of trend was noticed in total hardness. A steep increase was seen from upstream mean of 184.5mg/l (156mg/l – 250mg/l ± 31.8, $p<0.0002^*$), midstream (mean 854.9mg/l; 156mg/l - 5000mg/l ± 1454.9, $p<0.09$ ns) to downstream average of 3879mg/l (500mg/l – 11360mg/l ± 3449.2, $p<0.01^*$) (Fig. 1.9). Analysis of one way ANOVA suggests significance level with $p=0.002^*$.

Total solids (TS) and total dissolved solids (TDS) are also the key factors at estuarine scale. Increasing trend was observed in TS and TDS from upstream to downstream. A mean TS at upstream was recorded as 275.2 mg/l (82mg/l – 360mg/l ± 112.6, $p<0.025^*$) followed by midstream (mean 9432mg/l; 100mg/l – 33080mg/l ± 14066.8m, p=0.10 ns) and downstream (mean 51314.5mg/l; 15300mg/l – 142000mg/l ± 38433; p = 0.007* respectively (Fig.1.10 & Table 1.2, 1.3, 1.4).

However, TDS at upstream was too low and was beyond detectable range. As a normalized feature a very sharp increase was observed in TDS at midstream and upstream (Fig. 1.11). Even midstream showed a very high and fluctuating range of TDS with mean 10049.2mg/l ± 14110.6 (505mg/l – 31000mg/l, p =0.11 i.e. ns) (Table 1.3). The mean value drawn at midstream showed a bottom value shift as a result of majority of lower values. An opposite trend in mean value shift was noted at downstream where the mean value (mean 30980.8 mg/l ± 9563.5, 14150mg/l – 39045mg/l, p = 0.0005*) was influenced by majority of higher values.

Pearson correlation within water quality parameters of each zone did not showed any specific pattern other then positive correlation between linked parameters like salinity, total hardness and total and suspended solids. (Tables 1.4, 1.6, 1.7).

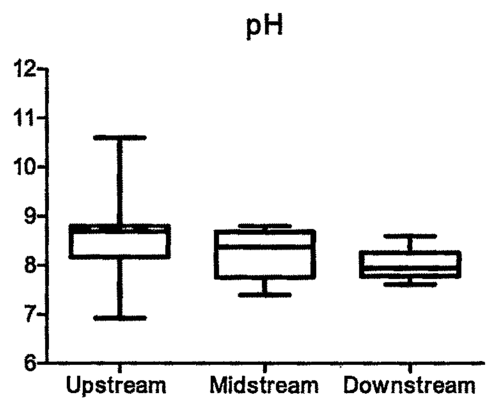
pH
12
11
10
9
8
7
6
Upstream
Midstream
Downstream

Fig. 1.4

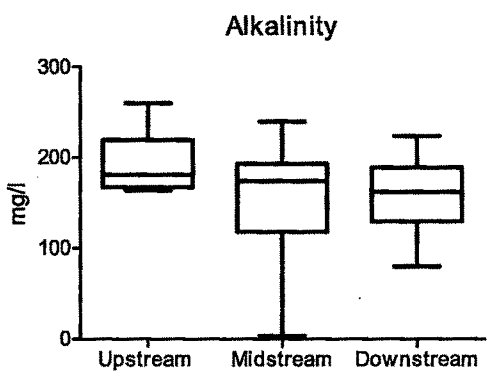
Alkalinity
mg/l
300
200
100
0
Upstream
Midstream
Downstream

Fig.1.5

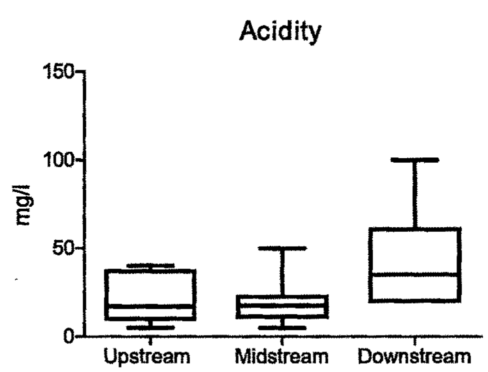
Acidity
mg/l
150
100
50
0
Upstream
Midstream
Downstream

Fig. 1.6

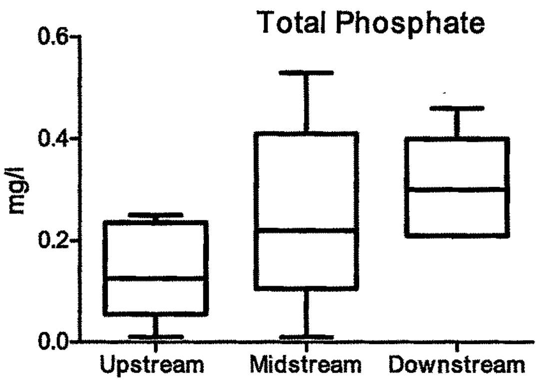

Fig. 1.7

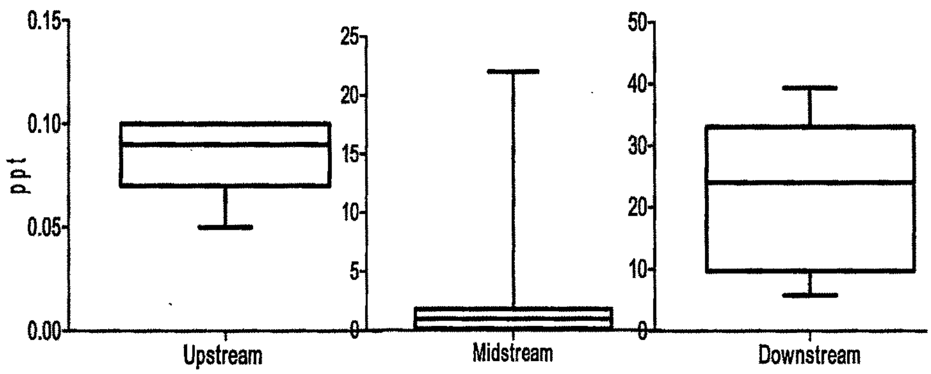

Fig. 1.8. Salinity

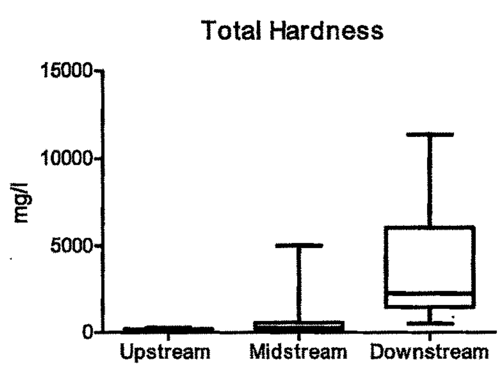

Fig.1.9.

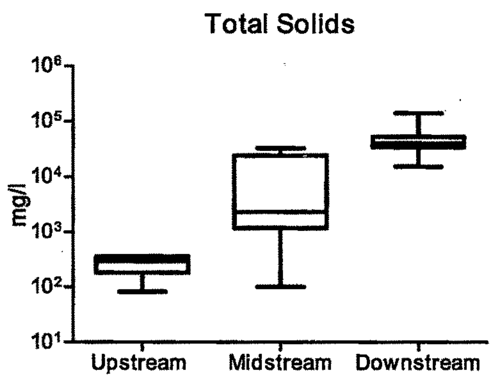

Fig. 1.10

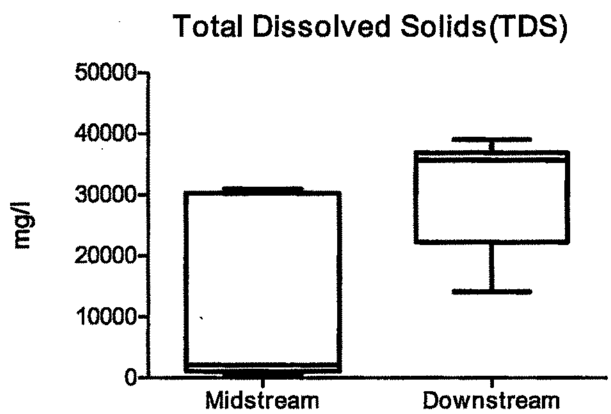

Fig. 1.11

Table 1.2: Upstream one sample t test

	pH	Alkalinity	Acidity	Salinity	Total Posphate	Total Hardness	TS
Minimum	6.93	164	5	0.05	0.01	142	82
Median	8.7	181	17	0.09	0.12	176	298
Maximum	10.6	260	40	0.1	0.25	250	360
Mean	8.659	193.3	20.88	0.08	0.13	179.3	275.2
Std. Deviation	1.08	36.26	13.73	0.02	0.09	31.84	112.60
t, df	t=223.4 df=6	t=6.30 df=5	t=16.30 df=7	t=15302 df=7	t=2645 df=5	t=7.040 df=7	t=3.478 df=4
P value (two tailed)	P<0.0001	0.0015	P<0.0001	P<0.0001	P<0.0001	0.0002	0.0254
Significant (alpha=0.05)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 1.3: Midstreamstream one sample t test

	pH	Alkalinity	Acidity	Salinity	Total Posphate	Total Hardness	TS	TDS
Minimum	7.4	3.3	5	0.05	0.01	156	100	505
Median	8.375	174	17.5	1	0.22	250	2311	2130
Maximum	8.8	240	50	22	0.53	5000	33080	31000
Mean	8.249	147.9	19.12	2.883	0.25	854.9	9432	10049
Std. Deviation	0.4833	74.06	11.72	6.412	0.1784	1455	14067	14111
t, df	t=657.7 df=11	t=2.334 df=12	t=24.89 df=12	t=50.24 df=10	t=1677 df=8	t=1.797 df=11	t=1.876 df=7	t=1.865 df=6
P value (two tailed)	P<0.0001	0.0378	P<0.0001	P<0.0001	P<0.0001	0.0997	0.1027	0.1114
Significant (alpha=0.05)?	Yes	Yes	Yes	Yes	Yes	No	No	No

Table 1.4: Downstream one sample t test

	pH	Alkalinity	Acidity	Salinity	Total Posphate	Total Hardness	TS	TDS
Minimum	7.62	80	20	5.76	0.21	500	15300	14150
Median	7.955	162	35	24	0.3	2220	40265	35715
Maximum	8.6	224	100	39.3	0.46	11360	142000	39045
Mean	8.03	159.4	44.05	23.59	0.3129	3879	51315	30981
Std. Deviation	0.34	39.10	29.32	11.55	0.09	3449.00	38433.00	9564.00
t, df	t=863.0 df=9	t=5.263 df=11	t=6.035 df=9	t=21.93 df=10	t=2868 df=6	t=3.287 df=8	t=3.769 df=7	t=7.909 df=5
P value (two tailed)	P<0.0001	0.0003	0.0002	P<0.0001	P<0.0001	0.0111	0.007	0.0005
Significant (alpha=0.05)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 1.5: Upstream Pearson correlation

	pH	Alkaliniity	Acidity	Salinity	Total phosphate	Total hardness	TS
pH	-	-0.75	-0.55	-0.001	0.28	-0.15	-0.92
Alkaliniity	-	-	0.76	0.1	-0.29	0.13	0.52
Acidity	-	-	-	-0.12	-0.2	-0.08	0.54
Salinity	-	-	-	-	0.82	0.22	-0.23
T.phosphate	-	-	-	-	-	-0.64	-0.45
Tot.hard	-	-	-	-	-	-	0.84
TS	-	-	-	-	-	-	-

Table 1.6. Midstream Pearson correlation

	pH	Alkaliniity	Acidity	Salinity	Total phosphate	Total hardness	TS	TDS
pH	-	0.13	0.09	-0.35	0.31	-0.43	-0.93	-0.93
Alkaliniity	-	-	0.15	-0.05	0.02	-0.25	-0.39	-0.73
Acidity	-	-	-	0.27	-0.35	0.24	0.1	0.04
Salinity	-	-	-	-	0.09	0.99	0.56	0.57
T.phosphate	-	-	-	-	-	0.07	-0.47	-0.47
Tot.hard	-	-	-	-	-	-	0.59	0.6
TS	-	-	-	-	-	-	-	0.99

Table 1.7. Downstream Pearson correlation

	pH	Alkaliniity	Acidity	Salinity	Total phosphate	Total hardness	TS	TDS
pH	-	0.69	-0.56	-0.23	0.66	-0.89	-0.26	-0.39
Alkaliniity	-	-	-0.14	-0.44	-0.1	-0.69	-0.76	-0.66
Acidity	-	-	-	0.27	0.01	-0.22	-0.22	0.33
Salinity	-	-	-	-	-0.21	0.23	0.26	0.96
T.phosphate	-	-	-	-	-	-0.49	0.49	-0.74
Tot.hard	-	-	-	-	-	-	0.33	0.42
TS	-	-	-	-	-	-	-	0.97

1.4. Sedimentological Study

As benthic organisms are directly dependent on the available sediment or substrata, the variation in physical and chemical sediment properties governs the benthic faunal diversity, distribution and their behavioural pattern. In present investigation important sediment features like sediment composition (Silt/Clay and sand), bulk density, water holding capacity, total carbon and organic matter were taken in account. Considerable variation along the estuarine gradient was noticed in sediment composition and was also noted site wise especially at downstream site. Other parameters showed interesting results spatially and depthwise which can be correlated with density and diversity of an animal.

All the sites along estuary were divided and pooled in 3 zones viz. upstream, midstream and downstream for better interpretation of results. Data were analyzed and represented at 3 levels in following fashion;

- At estuarine gradient (Upstream, midstream, downstream)
- Comparison among different zones at Kamboi
- Depthwise comparison for selected zones in Kamboi.

1.4.1. Sediment composition

Considerable variation in sediment composition was observed between upstream and midstream/downstream. Further, a very less variation was noticed overall between midstream and downstream. Upstream dominated in sandy composition (78 ± 21%) with scattered patches of silt and clay. The data from midstream suggested more of silt and clay (64±32% compared to sand (36±32) which was dominating only at few midstream sites. Looking at the depth wise results of core taken from midstream site Dabka, composition at 0-13cm and 13-25cm remained nearly equal (88.2 % & 89 % sand) while the lower portion 25-38cm represented more sandy nature(77% sand) (Fig. 1.12).

Furthermore, downstream site Kamboi showed a vast estuarine intertidal flat which was divided into 5 zones (Zone-1 to Zone-5). As downstream represented different zones depending on varied sediment composition, overall 54±24% silt & clay and 44±24% sand as an average of all zones. Zone-1 was excluded as being devoid of any benthic forms and was surf area only during selected high tidal days. Zone-2 represented upper intertidal terrace covered with coastal grass and showed a loamy composition (sand 68% and silt & clay 32%) with more of fine sand and calcrete eroded from the adjacent exposed bank section. Zone – 3 showed silty clay composition with 68% silt & clay and 32% sand and were important in terms of rich animal density for a specific species and biogenically active zone. Interestingly, Zone-4 showed merely similar values of sediment composition (63% silt & Clay and 37 % sand) like Zone-3 but differed in terms of sloppy terrace instead of flat terrace. Moving towards the low tidal line/river channel, Zone-5 represented vast flat plain with fine sandy composition domination an area (37 ±22.9 % silt & clay and 63 % sand) (Fig. 1.13).

Sediment composition was analyzed to 3 depths (0-13 cm, 13-25 cm and 25-38cm respectively) for Zone-3, Zone-4 and Zone-5. No significant variation was observed at various depths in different zones. More or less no variation was seen in sediment composition at the three depths at Zone-3 with silt & clay proportion ranging between 63 – 68 % (fig.1.14). In case of Zone-4 composition at 0-13cm and 13-25cm remained same dominated by silt & clay (71 % and 78 % respectively) while more of sand proportion (68 %) was seen at 25-38cm depth (Fig 1.15). Zone-5 dominated with fine sand proportion with 94% sand in upper 0-13 cm which showed a gradual decline from 54% and 45 % as depth increased (Fig. 1.16). Slight upstream to Kamboi, the downstream site sarod showed silt & clay dominance with 84.5 %, 86 % and 87 % of silt & clay respectively from upper to lower depth (fig. 1.17).

1.4.2. Total Carbon and Soil organic matter

As Soil organic matter (SOM) is derived from Total carbon (TC), results in both cases showed a similar trend and up-downs. Comparison of TC and SOM between upstream, midstream and downstream showed nearly closer values (fig. 1.18). Results of SOM and TC states that upstream showed lowest value of TC (0.16 ± 0.24) and SOM (0.48 ± 0.07). Moreover, downstream also showed a broad range of values followed by mid and upstream.

Pertaining to varied sedimentological aspect, variation was seen in TC & SOM among different zones at Kamboi. Zone-3 appeared as an organic matter rich zone (SOM 3.26 ± 0.86) followed by Zone-4 (1.38 ± 1.14), Zone-5 (1.0 ± 0.83) and Zone-2 (0.84 ± 0.66) (fig.1.19, fig. 1.20). High amount of organic matter in Zone 3 and 4 can be one of the strong reason of high density of crabs in the zone.

Depthwise estimation of TC/SOM from Zone- 3 and 5 of kamboi suggested an overall increasing trend from surface (0-13cm) to subsurface (25-38cm). Zone-3 showed a maximum SOM value of 4.33% at 25-38cm followed by 3.54% at 0-13cm and 2.89% at 13-25cm (Fig. 1.21). Sharp increase in SOM/TC was observed in Zone-5 from 0.11% to 1.33% from 0-13cm to 25-38cm respectively (Fig. 1.22). A reverse trend was observed at Sarod wherein TC/SOM values decreased gradually depthwise from 2.89% to 1.15% (Fig.1.23).

1.4.3. Bulk density

Bulk density suggests the compactness of the sediments in the given area. Though, bulk density values shows slight variation, are of important consideration. Overall, a very small variation was seen between upstream and downstream values, while midstream showed lower values (fig.1.24). Downstream however, showed a wide range of bulk density values, depending on different zones and sediment property.

Negligible but significant difference was observed between bulk densities of different zones (fig. 1.25). Zone-3 and 4 showed comparatively low compactness compared to Zone-2 and 5. No considerable difference was seen in deptwise bulk density at Zone-3, 4 and 5 (fig.1.26).

1.4.4. Water holding capacity

Water holding capacity more or less depends on the bulk density of the sediments. Increasing trend was seen in WHC from upstream to downstream from 24± 0.82 % to 47±13% respectively (fig.1.27).

Zonewise, Zone-3 showed higher WHC compared to other zones. Further, Zone-5 showed wide range (24-76%) of WHC value followed by zone-4, zone-2 and zone-3(Fig. 1.28). Depthwise no significant difference was seen at zone-3. A stepwise decrease in WHC was noted at zone-4 and zone-5 from 0-13cm, 13-15cm and 25-38cm respectively (fig. 1.29).

A comparative account of different parameters studied across upstream, Midstream and downstream is represented in Table.1. 9. Similarly, a comparative presentation of various parameters at different zones at Kamboi is presented in Table 1.8.

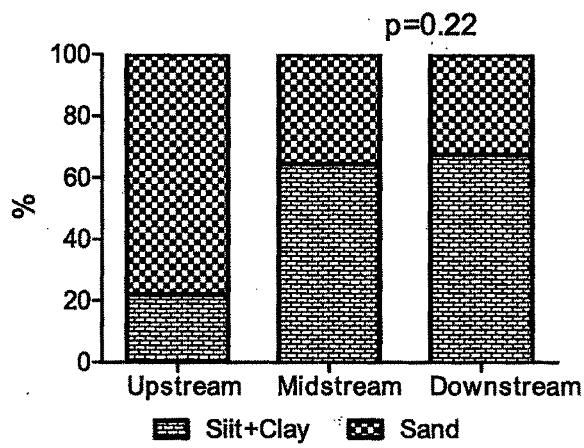

Fig. 1.12. Sediment composition at US, MS and DS of Mahi estuary.

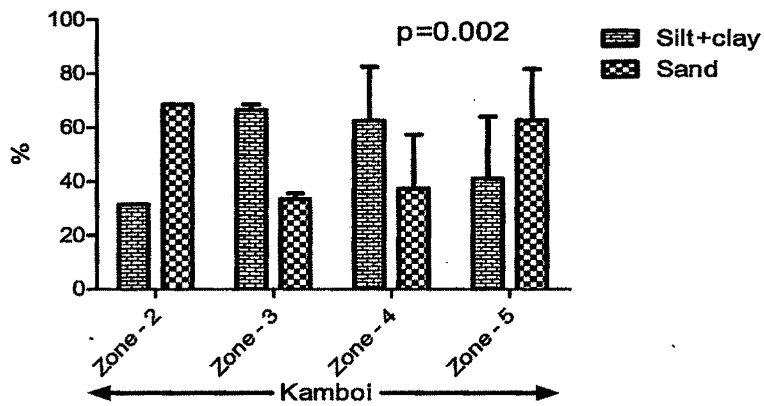

Fig. 1.13. Zone wise sediment composition at Kamboi.

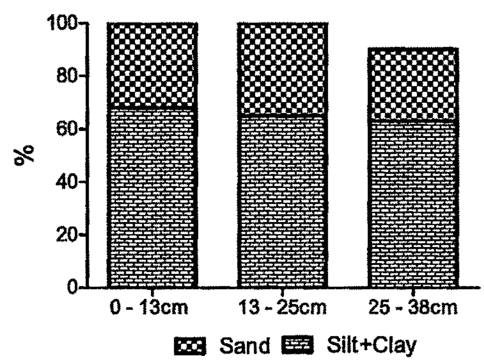

Fig. 1.14. Depthwise sediment composition at Zone 3.

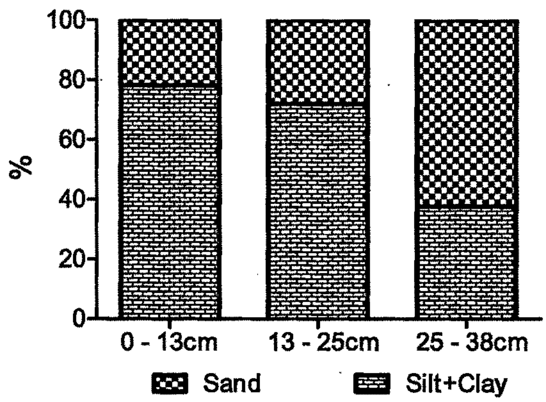

Fig. 1.15. Depthwise sediment composition of Zone 4.

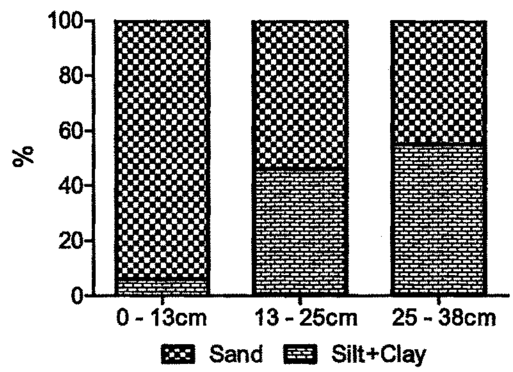

Fig. 1.16. Depthwise sediment composition at Zone 5.

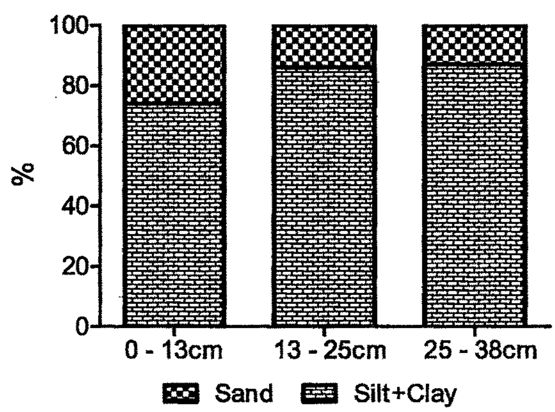

Fig. 1.17. Depthwise sediment composition at Sarod.

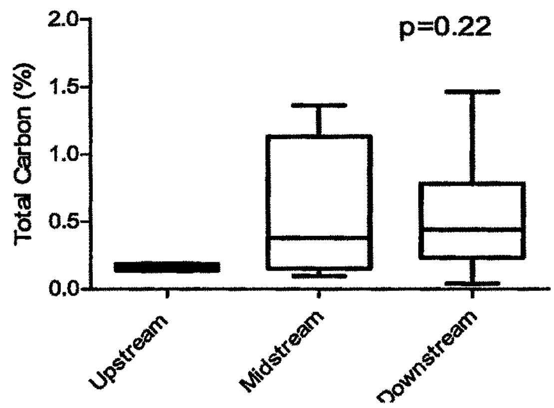

Fig. 1.18. Total carbon at US, MS and DS.

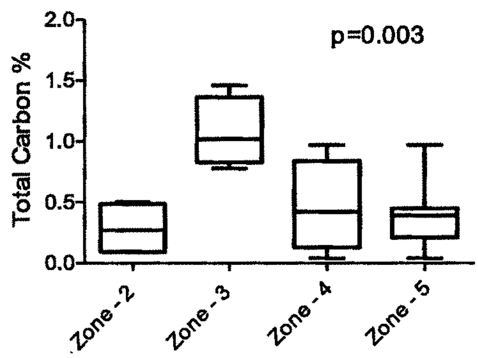

Fig. 1.19. Total Carbon percentage at different zones in Kamboi.

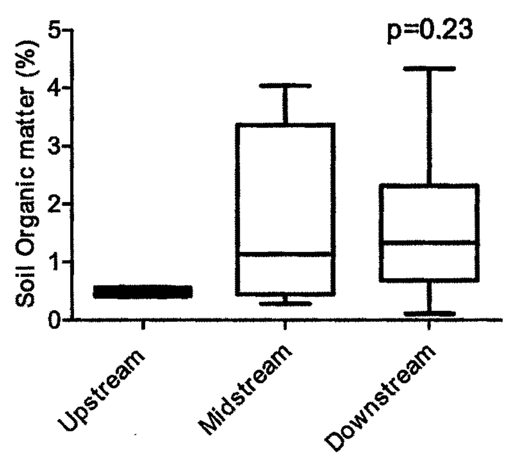

Fig. 1.20. Soil Organic matter at US, MS and DS.

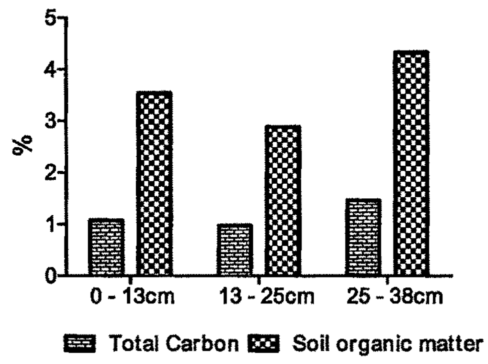

Fig. 1.21. Depth wise TC and SOM at Zone 3.

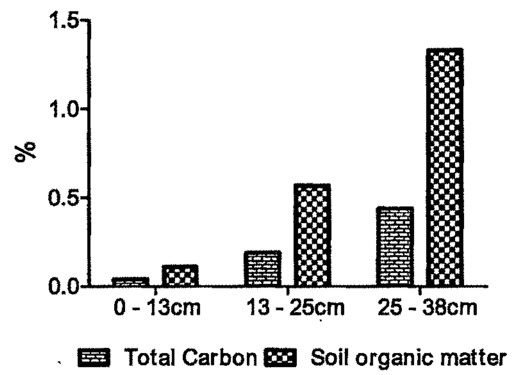

Fig. 1.22. Depth wise TC and SOM at Zone 5.

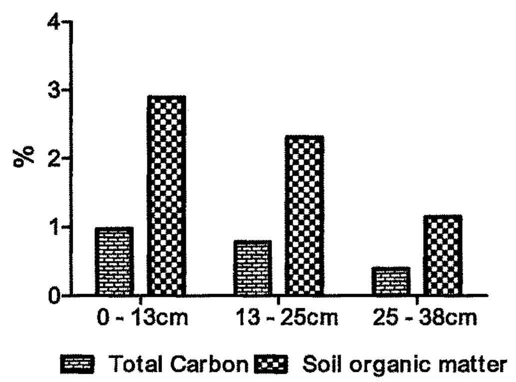

Fig. 1.23. Depth wise TC and SOM at Sarod.

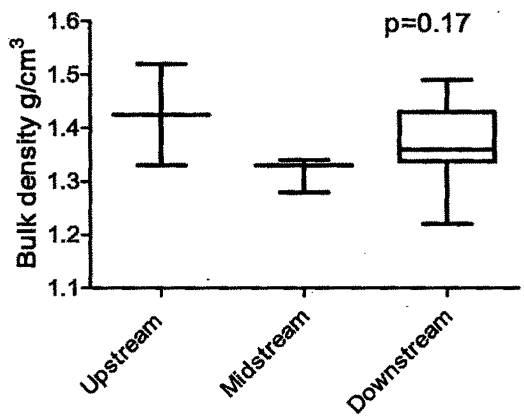

Fig. 1.24. Bulk density at US, MS and DS of Mahi river estuary.

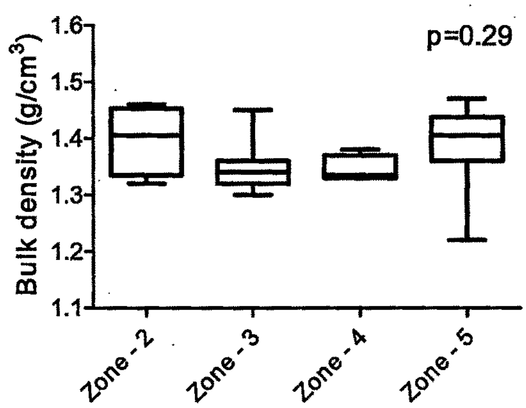

Fig. 1.25. Bulk density at different zones at Kamboi(downstream).

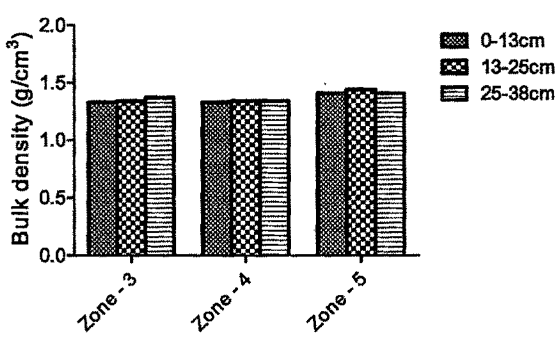

Fig. 1.26. Depth wise Bulk density at three zones at Kamboi.

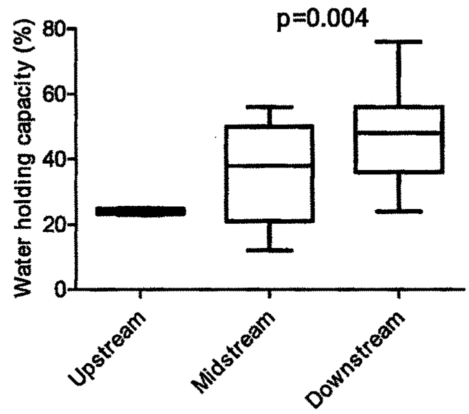

Fig. 1.27. Water holding capacity at US, MS and DS of Mahi river estuary.

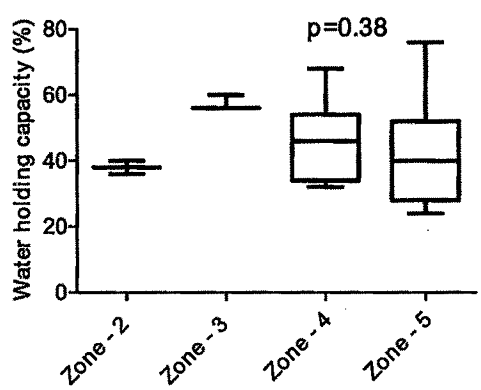

Fig. 1.28. Water holding capacity at different zones at Kamboi.

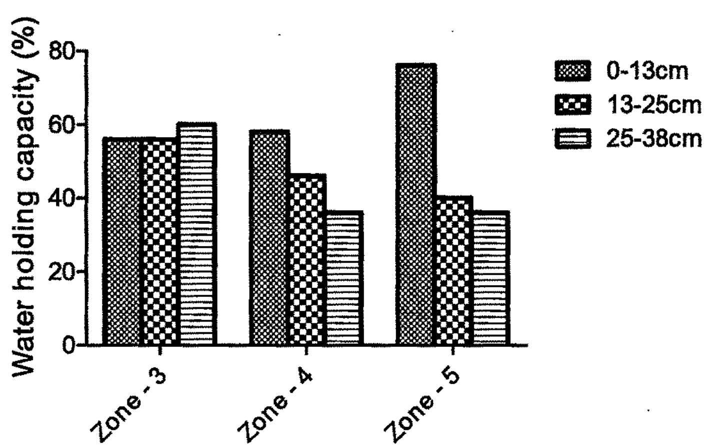

Fig. 1.29. Depth wise WHC at different zones of Kamboi.

Table 1.8: Shows representation of parameters along different zones at Kamboi

	Sediment composition (%)		Organic matter (%)		Bulk density (gm/cm3)	Water holding capacity (%)
	Silt+Clay	Sand	Total carbon	Soil organic matter		
Zone – 2	31.55	68.50	0.28±0.21 (0.09 – 0.50)	0.84±0.66 (0.26 – 1.50)	1.39±0.06 (1.32 – 1.46)	38 ±2.82 (36 – 40)
Zone – 3	66.50 (63 - 68)	33.5 (27 - 35)	1.07±0.28 (0.78 – 1.46)	3.26±0.86 (2.31 – 4.33)	1.35 ± 0.04 (1.30 – 1.45)	57.33 ± 2.30 (56 – 60)
Zone – 4	62.55±20.4 (35 - 79)	37.5±20.06 (21 – 65)	0.46 ± 0.38 (0.03 – 0.97)	1.38±1.14 (0.11 – 2.89)	1.34 ± 0.02 (1.33 – 1.38)	46 ±12.09 (32 – 68)
Zone – 5	41.2±22.90 (55-66)	62.8±18.96 (45-94)	0.37 ± 0.26 (0.03 – 0.97)	1.00 – 0.83 (0.11 – 2.89)	1.39 – 0.06 (1.22 – 1.47)	42.86 ± 17.39 (24 – 76)

Table 1.9: Comparison of parameters along the estuarine zones

	Sediment composition (%)		**Organic matter (%)**		**Bulk density (gm/cm^3)**	**Water holding capacity (%)**
	Silt+Clay	**Sand**	**Total carbon**	**Soil organic matter**		
Upstream	22±21 (10 - 46)	78±21 (54 – 90)	0.16±0.24 (0.14 – 0.19)	0.48±0.07 (0.40 – 0.57)	1.4 ±0.13 (1.3 – 1.5)	24±0.82 (23 – 25)
Midstream	64±32 (22 – 90)	36±32 (10 – 78)	0.55±0.56 (0.09 – 1.4)	1.6±1.7 (0.28 – 4)	1.3±0.03 (1.28 – 1.34)	36±16 (12 – 56)
Downstream	58±24 (6 – 95)	44±24 (5 – 94)	0.49±0.36 (0.03 – 1.5)	1.5±1.1 (0.11 – 4.3)	1.4±0.06 (1.2 – 1.5)	47±13 (24 – 76)