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Impact of turbidity on intertidal macrofauna at Gopnath, Mahuva and Veraval coasts (west coast of India)

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The effect of highly turbid seawater on the distribution, biomass and species diversity of intertidal macrofauna was studied in Gopnath, Mahuva and Veraval coasts during October 1998 and June 1999. The concentration of total suspended solids and turbidity were very high at Gopnath (518-583 mg/l and 632-713 NTU respectively) and Mahuva (328-412 mg/l and 566- 621 NTU respectively) during the period of study. The species diversity was minimum at Gopnath (1.14) and maximum at Mahuva (1.86). However, the biomass of benthic organisms was maximum at Veraval and the values were 2.03-5.82 and 2.02-2.03 times more as compared to Gopnath and Mahuva respectively. The data for similarity index revealed that Gopnath and Mahuva were more similar during October and June than Gopnath, Veraval and Mahuva and Veraval. *Astraea semicostata, Clibanarius clibanarius, Crassostrea cuculata* and *Littorina scabra* recorded only from Gopnath and Mahuva where seawater was highly turbid. The results indicate that these species could be cultivated in the coastal areas where seawater is significantly turbid.

[**Key words**: Intertidal macrofauna, turbid seawater, faunal diversity, biomass]

The intertidal region - a zone of interaction between the sea, land and air is one of the most interesting regions for the marine biota. The inhabitants of this region due to diel changes in exposure, desiccation and submergence are known to be hardy and diverse[1]. Very little work has been done on the ecology of clear water benthic macrofauna of the intertidal region of the Indian coasts[1-3]. However, some of the individual species have been studied from the different parts of India[4-6]. High turbidity in natural seawater may affect the species composition, community structure, biomass availability, growth rate and similar other parameters of marine organisms including macrobenthos in the intertidal region of the coast. There is lack of information from any part of the world including India, on impact of highly turbid seawater on the ecology of macrobenthic fauna in the intertidal region. However, effect of some of the turbidity related parameters like total suspended solids have been reported from the subtidal region of the coast[7-9]. The seawater in the Gulf of Cambay of Arabian Sea is very turbid, mainly due to suspended solids at Gopnath and Mahuva[10]. The turbidity is primarily due to presence of suspended particles (sand, silt and clay) brought by the perennial rivers of south Gujarat, narrow stretch of the gulf and very high tidal amplitude which keeps such particles in suspension. The concentration of total suspended solids and turbidity continuously decreases from Gopnath to Veraval as the mouth of the gulf area widens into the Arabian Sea. This has become a very good site for study, having very high turbidity of seawater towards the gulf side and normal clear seawater away from gulf side. Incidentally the whole area from turbid seawater to clear seawater regions had rocky substratum and also have similar geomorphological and hydrological conditions. Therefore, it was decided to study the impact of highly turbid seawater on the ecology of intertidal macrobenthic fauna. This study will be useful in identifying benthic fauna which could be cultivated in area where seawater is highly turbid. This will open an additional area for aquaculture of such species.

Materials and Methods

Benthic macrofaunal population along the intertidal region of Gopnath, Mahuva and Veraval on the Gujarat coast, northwest coast of India (Fig.1) were studied during October 1998 (postmonsoon) and June 1999 (summer). The littoral region of all these stations are rocky and their coastal waters are highly turbid except Veraval (control site) where the seawater is clear. The tidal amplitude on the day of the study during October and June at Gopnath (near

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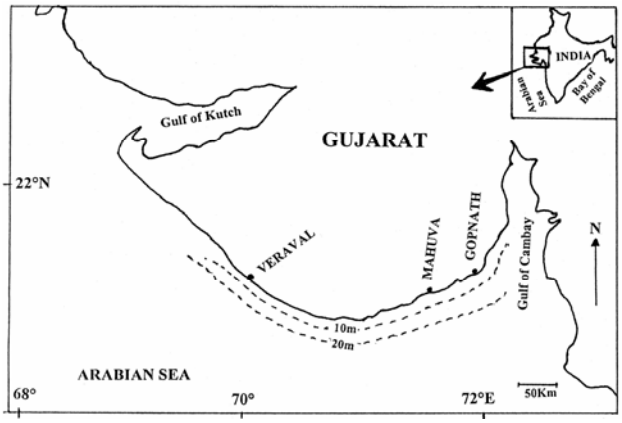

Fig. 1 — Study area along Gujarat coast

Bhavnagar), Mahuva (near Pipavav port) and Veraval ranged from 0.66-11.65, 0.12-3.89 and 0.63-2.06 m above the zero of the *chart datum*. The macrofaunal distribution and their density in the intertidal belt were studied during the low tide by quadrat method. The half square meter quadrat having 10×10 cm subquadrats were employed along the line transect at every 10 m interval on the intertidal region perpendicular to the shoreline starting from highest high water mark to lowest low water mark at the time of the study. However the data was condensed for every 50m stretch of intertidal belt. Different species from every quadrat were counted, collected and their wet weight was determined along with shells. They were preserved in 5% formaldehyde for the confirmation of species identification. The macrobenthic invertebrate species were identified by using the standard manuals[11-13]. The numerical density and biomass of each species in every quadrat were calculated per m^2 area. The species diversity was also calculated according to the Shannon-Weaver[14] formula:

$$H' = \Sigma \, Pi \log e \, pi$$

where, pi = proportion of the i^{th} species in the collection and H' = diversity of a theoretically infinite population. The Similarity Index (S) was calculated by using the following formula[15]

$$S = (2C / a + b) \times 100$$

where, 'C' = number of species common at any two stations and 'a' = number of species at one station and 'b' = number of species at the other station.

The seawater samples were collected during low tide and high tide at every stations and their physico-chemical parameters, phytoplankton and zooplankton counts were analysed as per the procedure described earlier[16,17]. However, the major quantity of seawater was passed through 20µ and 200µ mesh net for phytoplankton and zooplankton respectively. The turbidity was measured by turbidity meter (Model HANNA Instruments, H 193703).

Results and Discussion

The concentration of total suspended solids, turbidity and other physico-chemical parameters of seawater at Gopnath, Mahuva and Veraval during October 1998 and June 1999 are depicted in Table 1. The highest concentration of total suspended solids (TSS) and turbidity was observed at Gopnath (518 to 583 mg/l) followed by Mahuva (328 to 412 mg/l) and least at Veraval (48.0 to 63.2 mg/l ,control site). The salinity and *p*H were slightly low at Gopnath than Mahuva and Veraval during October and June as well as at high and low tides ($p<0.05$, $r = 0.85$). The dissolved oxygen did not show considerable variation at these stations but it was comparatively higher during high tide than low tide at all the three stations. The BOD was always low at all the stations and continuously increased from Gopnath to Veraval at both the tides during June. But it did not show any clear trend of variation during October. The concentration of NO_2-N($p<0.05$, $r = 0.81$), NO_3-N ($p<0.01$, $r = 1$), total nitrogen($p<0.01$, $r = 1$), PO_4-P ($p<0.01$, $r = 1$) and total phosphorus($p<0.01$, $r = 1$) were always lower at Veraval during both the tides and seasons as compared to Mahuva and Gopnath.

Total number of 32 species of macrofauna belongs to 24 families were recorded from three study sites during two months. They were *Balanus amphitrite, Porites lutea* Milne Edwards and Haime, *Neries diversicolar*, *Portunus pelagicus*(Linnaeus), *Clibanarius clibanarius* Herbst, *Angulus sinuate* (Melvill & Ambercrombie), *Cardium asiaticum* Bruguisere, *Cavolina tridentate* Forskal, *Crassostrea cuculata* Born, *Donax scortum* Linne, *Meretrix meretrix* (Linne), *Sunetta effossa* Hanley, *Modiolus metcalfei*, *Pecten crassicostatus* Soweby, *Chiton tuberculatus* Linne, *Astraea semicostata* (Kiener), *Trochus radiatus* Gmelin, *Patella vulgata* Linne, *Bursa spinosa* (Lamarck), *Cymatium pileare* (Linne), *Littorina intermedia* Philips, *Littorina scabra* Linne, *Oliva gibbosa* (born), *Conus acuminatus* Burg, *Drupa konkanensis* Blainville, *Murex brunneus* Link, *Ocenebra bombayana* (Melvill), *Thais bufo* (Lamarck) and *Thais tissoti* (Petit) *Balanus amphitrite* was recorded from all three places during both the season studied. The species diversity was least at Gopnath (1.14) and maximum at Mahuva (1.86).

Table 1 — Physico-chemical parameters of seawater at Gopnath, Mahuva and Veraval at low tide (L) and high tide (H)

Parameter	Gopnath		Mahuva		Veraval	
	L	H	L	H	L	H
October 1998						
Seawater temperature (°C)	27.5	27.1	25.4	25.6	26.8	26.5
Total suspended solids (mg l^{-1})	518.0	573.0	398.0	412.0	48.0	51.3
Turbidity (NTU)	632	636	581	621	1.28	1.31
Salinity(‰)	33.8	33.8	34.3	34.2	34.4	34.6
*p*H	8.12	8.11	8.16	8.16	8.32	8.34
Dissolved oxygen (ml l^{-1})	4.56	5.02	4.32	5.01	4.11	4.96
BOD (mg l^{-1})	0.98	1.01	1.12	0.86	0.91	1.12
NO_2-N(µ mol l^{-1})	0.31	0.42	0.86	0.58	0.31	0.2
NO_3-N(µ mol l^{-1})	2.52	2.61	3.02	3.16	2.12	2.10
NH_4-N(µ mol l^{-1})	ND	ND	0.72	1.06	ND	ND
Total N(µ mol l^{-1})	69.00	71.00	71.3	71.0	68.2	65.6
PO_4-P(µ mol l^{-1})	1.18	1.21	1.98	2.16	1.01	1.21
Total P(µ mol l^{-1})	4.56	5.11	8.12	7.56	3.12	4.13
June 1999						
Seawater temperature (°C)	29.0	28.5	26.0	26.0	27.0	26.5
Total suspended solids (mg l^{-1})	518	583	328	486	63.2	58.6
Turbidity (NTU)	635	713	556	611	1.51	1.63
Salinity(‰)	33.9	32.7	34.3	34.4	34.6	34.6
*p*H	8.12	8.12	8.17	8.17	8.33	8.33
Dissolved oxygen (ml l^{-1})	4.88	5.16	4.18	4.96	4.36	5.01
BOD (mg l^{-1})	1.02	0.99	1.11	1.01	1.31	1.26
NO_2-N(µ mol l^{-1})	0.28	0.31	0.75	0.66	0.28	0.16
NO_3-N(µ mol l^{-1})	2.66	2.92	3.26	3.49	2.16	2.19
NH4-N(µ mol l^{-1})	1.01	ND	1.12	0.81	0.66	ND
Total N(µ mol l^{-1})	70.00	71.00	69.00	71.50	66.50	68.00
PO_4-P(µ mol l^{-1})	1.28	1.32	2.43	2.77	1.36	1.28
Total P(µ mol l^{-1})	5.28	4.12	7.16	6.31	5.16	5.11

Gopnath harboured 7 and 11, Mahuva 20 and 17 and Veraval 17 and 11 species during October and June respectively. *Bursa spinosa*, *Cavolina tridentata*, *Littorina intermedia*, *Neries diversicolar*, *Ocenebra bombayana*, *Pecton crassicostatus*, *Portunus pelagicus* and *Thais tissoti* were recorded only from Mahuva while *Turbo coronatus*, *Thais rudolphi*, *Cymatium pileare* and *Angulus sinuata* were recorded only from control site at Veraval. The results indicate that these species prefer to grow in less turbid and clear seawater respectively. The availability of different species of benthic macrofauna at Gopnath where seawater is highly turbid is least (9 species). The *Astraea semicostata*, *Clibanarius clibanarius*, *Crassostrea cuculata* and *Littorina scabra* were recorded only from Gopnath and Mahuva where seawater was highly turbid. These species were not recorded from control site. The species at all the three stations did not exhibit any clear zonation pattern.

The distribution of different species, numerical density, biomass and species diversity of benthic macrofauna at Gopnath, Mahuva and Veraval are shown in Tables 2-4. The faunal parameters at three stations varied and did not show any clear trend of variation in the different parts of the intertidal region. Similarly the numerical density also did not show clear trend of variation. However, the species diversity and biomass (with one exception) showed clear trend of variation at three stations during both the months. The minimum values for the above said parameters were observed at Gopnath and maximum at Veraval. Specially the biomass at Veraval was 2.03 to 5.82 and 2.02 to 2.03 times more as compared to Gopnath and Mahuva respectively.

The concentration of chlorophyll-*a*, count of phytoplankton and zooplankton (Table 5) were always least at Gopnath and highest at Veraval during low tide and high tide. The concentration/count of

Table 2 — The distribution, numerical density, biomass and species diversity of benthic macro fauna in highly turbid seawater at Gopnath

Distance from the HHWL (m)	Species	Numerical density (No. m^{-2})		Biomass (g m^{-2})		Species diversity	
		Oct. 1998	June 1999	Oct. 1998	June 1999	Oct. 1998	June 1999
0	*Trochus radiatus*	4	8	28.72	12.60		
	Total	4	8	28.72	12.60	0.00	0.00
10-50	*Trochus radiatus*	22	4	116.00	14.48		
	Cerithium morus	18	-	104.00	-		
	Littorina scabra	8	-	52.00	-		
	Crassostrea cuculata	-	8	-	29.08		
	Astraea semiscostata	4	5	20.44	25.60		
	Balanus amphitrite	-	6	-	18.08		
	Total	52	23	292.44	87.24	1.38	1.38
60-100	*Trochus radiatus*	7	16	57.91	94.79		
	Cerithium morus	8	-	19.31	-		
	Littorina scabra	-	4	-	6.88		
	Oliva gibbosa	-	4	-	19.44		
	Astraea semiscostata	4	5	25.20	30.20		
	Crassostrea cuculata	8	21	29.34	51.76		
	Clibanarius clibanarius	-	4	-	56.48		
	Balanus amphitrite	-	6	-	18.84		
	Total	27	60	131.76	278.39	1.38	1.95
110-150	*Trochus radiatus*	9	8	72.66	49.01		
	Cerithium morus	-	12	-	36.16		
	Crassostrea cuculata	13	17	61.13	57.48		
	Sunetta effosa	-	4	-	10.00		
	Donax scortum	-	4	-	8.28		
	Balanus amphitrite	16	4	86.28	17.28		
	Total	38	49	220.07	178.21	1.09	1.79
160-200	*Trochus radiatus*	4	28	24.60	211.40		
	Cerithium morus	12	-	38.52	-		
	Oliva gibbosa	-	12	-	39.00		
	Crassostrea cuculata	61	14	179.04	25.38		
	Balanus amphitrite	12	13	37.23	49.83		
	Total	89	67	279.42	325.61	1.38	1.38
210-250	*Trochus radiatus*	15	18	160.30	47.24		
	Drupa konkanensis	-	20	-	195.60		
	Astraea semicostata	8	12	59.15	81.93		
	Oliva gibbosa	-	16	-	200.32		
	Crassostrea cuculata	19	150	69.50	660.46		
	Clibanarius clibanarius	4	-	18.24	-		
	Total	46	216	307.19	1185.55	1.38	1.60
260-300	*Trochus radiatus*	10	19	146.24	147.2		
	Cerithium morus	14	-	48.18	-		
	Drupa konkanensis	-	10	-	89.92		
	Crassostrea cuculata	15	180	94.88	730.52		
	Sunetta effosa	-	8	-	29.76		
	Balanus amphitrite	-	38	-	87.78		
	Total	39	255	289.30	1093.18	1.09	1.60
310-340	*Trochus radiatus*	20	16	150.00	75020		
	Cerithium morus	9.33	-	60.00	-		
	Drupa konkanensis	-	16	-	116.00		
	Crassostrea cuculata	16	164	64.00	691.22		
	Clibanarius clibanarius	4	8	20.00	182.72		
	Balanus amphitrite	-	36	-	109.56		
	Total	49	240	294	1174.7	1.38	1.60
Transect Mean-		43.00	114.7	230.36	541.96	1.14	1.41

– = Absent

Table 3 — The distribution, numerical density, biomass and species diversity of benthic macro fauna in turbid seawater at Mahuva

Distance from HHWL (m)	Species	Numerical density (No. m^{-2})		Biomass (g m^{-2})		Species diversity	
		October 1998	June 1999	October 1998	June 1999	October 1998	June 1999
0	*Littorina scabra*	120	150	285.66	375.25		
	Littorina intermedia	180	200	385.20	400.00		
	Total	300	350	670.86	775.25	0.69	0.69
10-50	*Trochus radiatus*	40	46	259.91	234.78		
	Drupa konkanensis	4	4	39.12	32.84		
	Bursa spinosa	12	4	126.48	32.84		
	Thais bufo	4	4	39.12	32.84		
	Pecten crassicostatus	12	10	83.35	68.76		
	Chiton tuberculaltus	20	24	160.88	199.44		
	Crassostrea cuculata	81	62	324.61	200.66		
	Total	173	154	1034.26	802.16	1.95	1.95
60-100	*Trochus radiatus*	4	-	28.26	-		
	Thais bufo	6	4	63.16	31.80		
	Drupa konkanensis	4	4	33.24	29.63		
	Conus acuminatus	-	12	-	18.6		
	Chiton tuberculatus	-	6	-	39.72		
	Pecten crassicostatus	16	4	48.38	14.56		
	Patella vulgata	4	-	12.69	-		
	Crassostrea cuculata	20	30	47.88	89.01		
	Modiolus metcalfei	4	-	12.86	-		
	Portunus pelagicus	4	4	37.40	42.72		
	Balanus amphitrite	-	6	-	25.18		
	Total	62	70	283.84	291.22	2.08	2.08
110-150	*Murex brunneus*	6	4	46.19	16.28		
	Trochus radiatus	4	4	20.58	14.68		
	Thais bufo	6	-	44.40	-		
	Thais tissoti	24	28	81.88	122.08		
	Ocenebra bombayana	26	26	81.41	106.03		
	Astraea semicostata	16	20	96.90	113.51		
	Pecten crassicostatus	-	4	-	16.86		
	Chiton tuberculatus	-	6	-	43.50		
	Patella vulgata	4	-	16.20	-		
	Crassostrea cuculata	10	20	48.49	67.08		
	Cavolina tridentata	4	-	18.20	-		
	Angulus sinuate	8	-	16.00	-		
	Clibanarius clibanarius	10	-	248.70	-		
	Balanus amphitrite	12	13	92.55	50.83		
	Neries versicolar	-	4	-	5.52		
	Total	130	129	517.75	556.37	2.48	2.30
160-190	*Thais tissoti*	23	36	60.96	101.63		
	Ocenebra bombayana	26	41	83.38	133.25		
	Murex brunneus	-	4	-	16.28		
	Trochus radiatus	6	-	76.33	-		
	Drupa konkanensis	-	4	-	36.28		
	Astraea semicostata	26	48	131.56	255.24		
	Chiton tuberculatus	4	8	20.24	19.20		
	Crassostrea cuculata	6	12	28.33	28.20		
	Cavolina tridentata	15	-	98.79	-		
	Porites lutea	4	-	80.00	-		
	Total	110	165	668.12	590.08	2.08	1.95
Transect Mean		150.00	173.60	694.96	603.01	1.86	1.79

– = Absent

Table 4 — The distribution, numerical density, biomass and species diversity of benthic fauna at Veraval

Distance from HHWL (m)	Species	Numerical density (No. m^{-2})		Biomass (g m^{-2})		Species diversity	
		October 1998	June 1999	October 1998	June 1999	October 1998	June 1999
0	*Thais bufo*	-	12	-	205.44		
	Oliva gibbosa	-	8	-	48.88		
	Cerithium morus	-	4	-	16.72		
	Sunetta effossa	4	-	17.36	-		
	Patella vulgate	12	-	37.44	-		
	Total	16	24	54.80	271.04	0.69	1.09
10-50	*Thais bufo*	10	12	281.38	215.99		
	Thais rudolphi	18	9	670.38	194.57		
	Drupa konkanensis	6		-	21.74		
	Murex brunneus	8	-	148.48	-		
	Conus acuminatus	4	10	22.28	199.64		
	Cymatium pileare	-	4	-	28.20		
	Cymatium femorale	12	-	243.36	-		
	Turbo canaliculatus	-	20	-	283.36		
	Oliva gibbosa	4	-	50.72	-		
	Sunetta effossa	8	-	24.16	-		
	Cardium asiaticum	8	-	68.16	-		
	Angulus sinuate	8	-	25.44	-		
	Donax scortum	8	-	29.96	-		
	Modiolus metcalfei	4	-	19.72	-		
	Meretrix meretrix	-	4	-	10.48		
	Patella vulgata	8	-	17.28	-		
	Balanus amphitrite	8	15	14.00	46.29		
	Porites lutea	-	16	-	78.42		
	Total	114	90	1349.9	1057.60	2.63	2.08
60-100	*Thais bufo*	40	37	1164.51	768.91		
	Thais rudolphi	17	23	390.70	527.98		
	Murex brunneus	12	-	425.70	-		
	Drupa konkanensis	7	-	71.84	-		
	Trochus radiatus	12	-	245.92	-		
	Turbo canaliculatus	16	8	201.28	174.88		
	Chiton tuberculatus	-	4	-	29.24		
	Modiolus metcalfei	4	-	19.68	-		
	Balanus amphitrite	11	28	24.56	122.64		
	Porites lutea	8	59	69.84	347.21		
	Total	127	159	2614.03	1970.86	1.79	1.79
Transect mean		85.67	91.00	1339.58	1099.83	1.70	1.65

– = Absent

Table 5 — Concentration of chlorophyll-*a*, count of phytoplankton and zooplankton and biomass of seaweeds in the seawater at Gopnath, Mahuva and Veraval

Parameter	Gopnath				Mahuva				Veraval			
	October		June		October		June		October		June	
	Low tide	High tide	Low tide	High tide	Low tide	High tide	Low tide	High tide	Low tide	High tide	Low tide	High tide
Chlorophyll-*a* (mg m^{-3})	0.57	0.97	1.31	2.25	1.70	2.70	1.40	2.87	11.90	13.84	13.21	15.58
Phytoplankton (No. l^{-1})	148	174	356	446	160	268	504	644	1054	1464	4246	7420
Seaweed (g fresh wt. m^{-2})	Rare		Rare		Rare		Rare		700		250	
Zooplankton dry weight (mg m^{-3})	328.2	521.4	455.8	563.1	612.1	832.2	795.6	1142.7	1029.8	1431.6	1031.0	2583.0

Table 6 — Similarity Index of species between Gopnath, Mahuva and Veraval

Transect	Similarity Index	
	October 1998	June 1999
Gopnath and Mahuva	44.44	42.85
Gopnath and Veraval	16.66	27.27
Mahuva and Veraval	43.24	28.571

these parameters were always low during low tide and high at high tide at all the stations. The concentration of chlorophyll-*a* as well as count of phytoplankton and zooplankton were more at Veraval as compared to Gopnath. The similarity index for three stations (Table 6) ndicates that Gopnath and Mahuva stations are more similar during October and June than Gopnath and Veraval; and Mahuva and Veraval ($p<0.01$, $r=1$ for all stations and seasons). However, during October the similarity index of Mahuva and Veraval was closer to that of Mahuva and Gopnath. None of these three stations showed very high degree of similarity as all the indices were below 45.

The extent to which benthic assemblages are affected by environmental disturbances is rather difficult to quantify because of lack of detailed knowledge on individual species responses to varying environmental stresses[18]. However, the present study reveals that the mean transect species diversity, numerical density and biomass were always low at Gopnath and they were many magnitude higher at Veraval. This directly correlates with the concentrations of chlrophyll-*a*, phytoplankton and zooplankton as well as biomass availability of seaweeds at these three stations ($P < 0.01$, $r=1$). The phytoplankton count at Gopnath is significantly low followed by its count at Mahuva during October. However the dry weight of zooplankton is comparatively high during the same period at these two places (Table 5). The low count of phytoplankton might be due to presence of high turbidity at Gopnath and Mahuva have inhibited photosynthesis and production of phytoplankton in that region. Since the high turbidity reduces the growth of phytoplankton, seaweeds and zooplankton (which are food for benthic fauna), the species diversity, numerical density and biomass of benthic macrofauna were low at Gopnath and high at Veraval. Even these parameters were higher at Mahuva than Gopnath where turbidity was higher than Mahuva. Similarity index also indicates that the fauna at Gopnath and Mahuva showed closer values where turbidity was very high and the index significantly differed at Veraval where turbidity was negligible. A number of species of benthos have been identified which have been found growing only in highly turbid sea water at Gopnath. Although, the numerical density and biomass availability are poor than fauna recorded in less turbid and clear seawater at Mahuva and Veraval respectively. The present study has identified some of the benthos which could be artificially cultivated even in the region where seawater is highly turbid. This will provide additional area for cultivation of such organisms and spare other areas for more productive uses.

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