Assessment on coral reef and seagrass meadows within the 10km radius from the proposed groynes site in Keelavaippar coast, Gulf of Mannar

1. BACKGROUND

The Gulf of Mannar (GoM) located in the southeast coast of India extends from Rameswaram Island in the north to Kanyakumari in the south and is important coastal area. GoM has been declared as Marine Biosphere Reserve by Government of India in 1989, covering 10,500 km^2. Corals and coral reefs of Gulf of Mannar form an important ecosystem, which support a variety of commercial and ornamental faunal and floral species including fishery resources. The islands occur at an average distance of 8-10 km from the mainland. The 21 islands and the surrounding shallow water area covering 560 km^2 were declared as Marine National Park. Along with corals, luxuriant and patch seagrass meadows in GoM provide high biodiversity. The Tuticorin group of islands is located at the southern tip of the Gulf of Mannar Marine National Park which consists of four islands. Among them, two coral reef islands which occur closer to the proposed groynes location.

Proposed groynessites are located in Keelavipar coast and the project site comes within the Marine biosphere Reserve and about 2 Km away from the Marine National Park boundary. Tamil nadu fisheries department proposed to set up three groynes (Groynes - 1, Groynes - 2 and Groynes - 3) in Keelavaipar coast within 1 km proximity to the marine zone and these sites occurring in shore distance of 1 Km. Groynes - 1 would be covering a distance of 800 meter; Groynes - 2 covers a distance of 500 meter; and Groynes - 3 which is covering a distance of 100 meter towards marine zone. Project site is located in close proximity to the ecological sensitive habitats (Coral reef and seagrass meadows). Thus, coral reef and seagrass meadows baseline data collection is very much essential to find out the diversity of resources and distribution pattern in the nearby project location in order to take proper management measures. Hence, the present assessment was carried out to collect data on the diversity, distribution and abundance of marine biodiversity including ecologically sensitive habitats (corals and seagrass beds) and fish population in the sea area within 10 km radius from groynes site.

2. Methodology

The study area is divided into eight zones (Zone 1 to Zone 8) depending on horizontal distance from the shoreline (Fig. 1). Zones are further divided into equal spaced grids (G) of approximately 1 sq km each and totally 116 numbers of grids formed with in the 10 km radius. Zone 1 is located nearer to the groynes point which consist of G1 to G16; Zone 2 (G17 to G34); Zone 3 (G35 to G51) ; Zone 4 (G52 to G67) ; Zone 5 (G68 to G82) ; Zone 6 (G83 to G95) ; Zone 7 (G96 to G105) ; Zone 8 (G106 to G116), which was away from the groynes.

Fig. 1: Map showing the monitoring location in Keelavaipar Coast

The survey started with mapping of the proposed area, using manta tow technique (Done *et al.,* 1982) within 10 km radius area. The assessment involved SCUBA diving. Coral reef habitat sites were estimated by using the Line Intercept Transect (LIT) followed by standard monitoring protocol (English et al., 1997). Four to six line intercept transect (20 m) were laid on the benthic forms to assess the coral, algae, other fauna and abiotic percentage cover in the each grid. Coral recruitment density and coral health issues prevalence were assessed along the transect line.

Seagrass meadows were assessed by using 0.5 X 0.5 m^2 quadrats (Saito and Atobe, 1970) and seagrass cover and shoot density field data were collected from the grids. Quadrat number varies according to the availability of seagrass resources. The macro faunal communities were assessed using 1 X 1 m^2 quadrats following the method of English *et al*., (1997). Fish abundance and diversity was assessed using belt transect method (English et al. 1997). Length of each transect was 50 m and each transect was separated by 50 m gap. All the fishes encountered within 2.5 meters on both side.The mean seagrass cover and coral cover were calculated only for the observed grids respectively.The present assessment was carried out between 15th March 2017 and 25th March 2017. Three fishing villages (Sippikulam, Vipar and Periyasamipuram) were selected to study the fishery resources from the project site and fish landing data was collected during March 2016 to February 2017. A standard fish landing monitoring protocol were followed by Srinath et al., (2005).

Coordinates of each grid are given below

Zone - 1

Grid No.	Latitude	Longitude
1	8°56'44.12"N	78°12'7.50"E
2	8°57'2.58"N	78°12'27.97"E
3	8°57'24.42"N	78°12'50.72"E
4	8°57'47.66"N	78°13'17.24"E
5	8°58'9.91"N	78°13'45.46"E
6	8°58'32.68"N	78°14'15.09"E
7	8°58'55.05"N	78°14'46.19"E
8	8°59'19.82"N	78°15'16.54"E
9	8°59'41.66"N	78°15'48.81"E
10	9° 0'3.24"N	78°16'18.02"E
11	9° 0'23.13"N	78°16'45.34"E
12	9° 0'41.89"N	78°17'13.12"E
13	9° 1'1.01"N	78°17'40.26"E
14	9° 1'20.65"N	78°18'6.82"E
15	9° 1'42.31"N	78°18'34.84"E
16	9° 2'5.16"N	78°19'5.27"E

Zone – 2

Grid No.	Latitude	Longitude
17	9° 1'38.47"N	78°19'18.02"E
18	9° 1'16.84"N	78°18'50.40"E
19	9° 0'55.04"N	78°18'21.32"E
20	9° 0'33.99"N	78°17'55.01"E
21	9° 0'14.48"N	78°17'28.06"E
22	8°59'53.56"N	78°17'1.05"E
23	8°59'33.07"N	78°16'33.08"E
24	8°59'11.67"N	78°16'3.81"E
25	8°58'47.98"N	78°15'32.67"E
26	8°58'24.83"N	78°15'2.12"E
27	8°58'1.32"N	78°14'31.42"E
28	8°57'39.22"N	78°14'0.62"E
29	8°57'16.45"N	78°13'31.54"E
30	8°56'55.88"N	78°13'4.19"E
31	8°56'38.71"N	78°12'39.67"E
32	8°56'22.81"N	78°12'17.27"E
33	8°56'6.52"N	78°11'58.14"E
34	8°55'55.30"N	78°11'40.77"E

Zone – 3

Grid No.	Latitude	Longitude
35	8°55'39.21"N	78°12'12.78"E
36	8°55'53.68"N	78°12'33.19"E
37	8°56'9.44"N	78°12'54.79"E
38	8°56'28.18"N	78°13'19.13"E
39	8°56'49.13"N	78°13'47.63"E
40	8°57'9.43"N	78°14'15.77"E
41	8°57'32.93"N	78°14'47.55"E
42	8°57'56.60"N	78°15'20.10"E
43	8°58'18.17"N	78°15'50.01"E
44	8°58'40.39"N	78°16'20.67"E
45	8°59'2.96"N	78°16'51.28"E
46	8°59'23.42"N	78°17'18.62"E
47	8°59'41.41"N	78°17'45.52"E
48	9° 0'2.73"N	78°18'12.27"E
49	9° 0'21.90"N	78°18'38.94"E
50	9° 0'42.12"N	78°19'7.70"E
51	9° 1'3.16"N	78°19'32.90"E

Zone – 4

Grid No.	Latitude	Longitude
52	9° 0'11.07"N	78°19'26.62"E
53	8°59'50.17"N	78°18'57.72"E
54	8°59'29.08"N	78°18'30.14"E
55	8°59'10.26"N	78°18'3.29"E
56	8°58'50.18"N	78°17'36.01"E
57	8°58'31.04"N	78°17'8.99"E
58	8°58'9.43"N	78°16'39.01"E
59	8°57'47.22"N	78°16'8.63"E
60	8°57'24.28"N	78°15'36.98"E
61	8°57'1.07"N	78°15'4.81"E
62	8°56'37.49"N	78°14'34.88"E
63	8°56'15.89"N	78°14'4.69"E
64	8°55'55.69"N	78°13'35.73"E
65	8°55'37.61"N	78°13'12.00"E
66	8°55'22.10"N	78°12'49.54"E
67	8°55'7.97"N	78°12'28.74"E

Zone - 5

Grid No.	Latitude	Longitude
68	8°54'47.99"N	78°13'7.51"E
69	8°55'4.32"N	78°13'30.16"E
70	8°55'21.19"N	78°13'53.60"E
71	8°55'42.33"N	78°14'22.67"E
72	8°56'6.76"N	78°14'53.19"E
73	8°56'27.75"N	78°15'22.62"E
74	8°56'52.90"N	78°15'56.11"E
75	8°57'14.88"N	78°16'26.80"E
76	8°57'38.27"N	78°16'57.79"E
77	8°58'0.05"N	78°17'26.33"E
78	8°58'19.82"N	78°17'53.64"E
79	8°58'40.73"N	78°18'21.17"E
80	8°58'59.97"N	78°18'47.63"E
81	8°59'20.86"N	78°19'14.43"E
82	8°59'41.25"N	78°19'40.30"E

Zone – 6

Grid No.	Latitude	Longitude
83	8°58'51.54"N	78°19'31.90"E
84	8°58'31.30"N	78°19'4.84"E
85	8°58'8.79"N	78°18'37.75"E
86	8°57'49.75"N	78°18'12.48"E
87	8°57'29.02"N	78°17'45.52"E
88	8°57'6.27"N	78°17'16.10"E
89	8°56'42.61"N	78°16'46.20"E
90	8°56'18.68"N	78°16'15.31"E
91	8°55'52.30"N	78°15'42.62"E
92	8°55'29.42"N	78°15'12.30"E
93	8°55'6.39"N	78°14'43.24"E
94	8°54'44.26"N	78°14'14.20"E
95	8°54'29.83"N	78°13'49.59"E

Zone – 7

Grid no	Latitude	Longitude
96	8°54'31.85"N	78°15'2.17"E
97	8°54'54.71"N	78°15'31.92"E
98	8°55'19.40"N	78°16'1.88"E
99	8°55'45.47"N	78°16'35.30"E
100	8°56'8.55"N	78°17'5.22"E
101	8°56'33.11"N	78°17'35.45"E
102	8°56'56.87"N	78°18'4.89"E
103	8°57'15.99"N	78°18'30.22"E
104	8°57'37.07"N	78°18'56.34"E
105	8°57'59.28"N	78°19'21.05"E

Zone – 8

Grid No.	Latitude	Longitude
106	8°56'45.30"N	78°18'48.13"E
107	8°56'20.77"N	78°18'25.27"E
108	8°55'54.11"N	78°17'58.25"E
109	8°55'30.93"N	78°17'28.44"E
110	8°55'8.09"N	78°16'57.46"E
111	8°54'45.54"N	78°16'23.32"E
112	8°54'27.88"N	78°15'49.41"E

3. RESULT

ZONE -1

In zone-1, seagrass meadows were found in 12 grids; coral reef habitat was observed in two grids and reaming two grids was occupied with sand.

Seagrass habitat

In zone-1, scattered seagrass meadows were found and mean percentage cover was 14.55%. The maximum cover was observed in G 5 with 21.63 % followed by G 6 with 19.46 % respectively (Fig. 2). Totally five seagrass species were recorded, among them, *Thalassia hemprichii* and *Cymodocea serrulata* were the dominant species.

Mean shoot density was recorded as 136.78 m^{-2} and highest mean shoot density was found to be in *Thalassia hemprichii* and *Cymodocea serrulata* with 56.53 and 40.23 m^{-2} respectively (Fig. 3). Among the grids in zone 1, highest shoot density was recorded in G 5 and G 6 with the value of 207.49 and 191.77 m^{-2} respectively (Fig. 4 & Table 1).

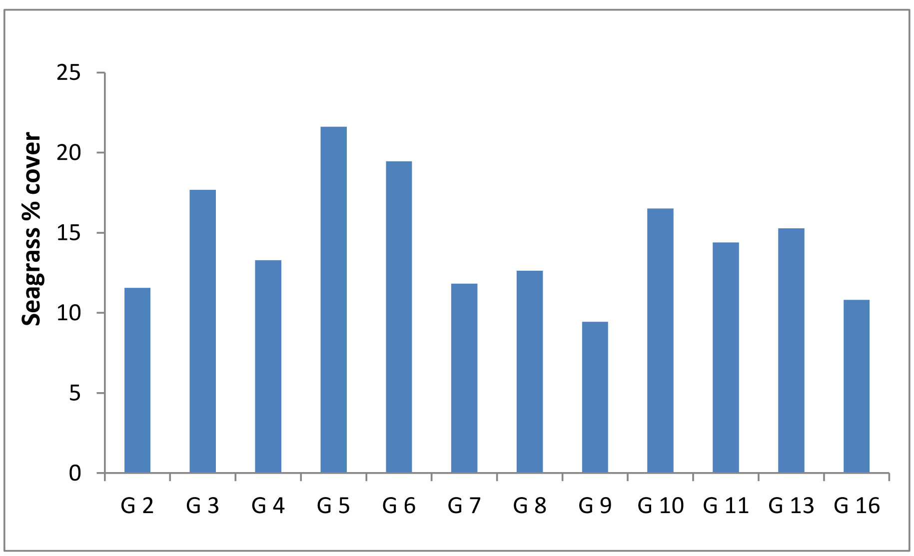

Fig.2. Seagrass percentage covers in Zone-1

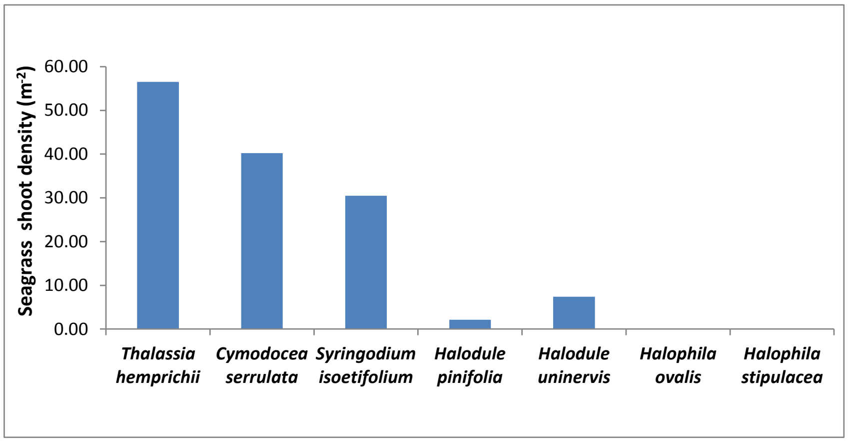

Fig.3. Mean species wise seagrass shoot density in Zone-1

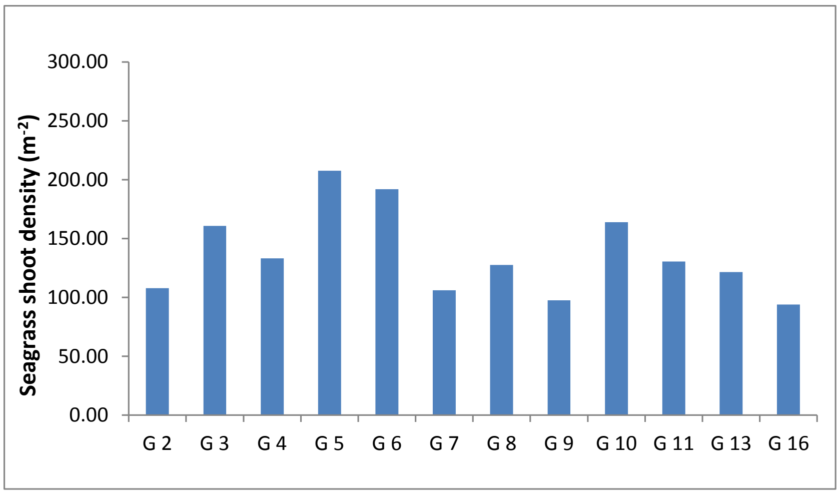

Fig.4. Mean species seagrass shoot density in Zone-1

Table 1: Seagrass species shoot density in Zone 1

	G 2	**G 3**	**G 4**	**G 5**	**G 6**	**G 7**	**G 8**	**G 9**	**G 10**	**G 11**	**G 13**	**G 16**
Thalassiahemprichii	42.36	71.36	54.26	89.67	74.52	42.67	49.72	38.27	63.72	56.94	56.27	38.58
Cymodoceaserrulata	31.58	42.61	33.29	58.64	58.65	33.83	36.83	29.61	46.18	36.28	49.62	25.61
Syringodiumisoetifolium	26.52	38.26	33.67	42.97	41.27	29.51	25.68	24.73	36.29	37.18	0.00	29.75
Halodulepinifolia	0	8.34	0	4.63	3.71	0	0	0	2.67	0	5.92	0
Haloduleuninervis	7.36	0.00	11.82	11.58	13.62	0.00	15.27	4.84	14.92	0.00	9.72	0.00
Halophilaovalis	0	0	0	0	0	0	0	0	0	0	0	0
Halophilastipulacea	0	0	0	0	0	0	0	0	0	0	0	0

Coral reef habitat

Inshore patchy coral reef habitats were found in this zone. Mean live coral was 7.15% and among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 77.94% (Fig. 5 & Table 2). The highest coral cover was observed in G 4 with 11.14% followed by 6.08% at G 7 respectively. A total of 4 hard coral species were observed and *Turninaria mesentrina* and *Porites lutea* were the most commonly observed coral species. Similarly low density of coral recruits was recorded with a mean value of 1.92 m^{-2} and density ranged between 1.52 and 2.24 m^{-2} in the observed grids (Table 3). Few coral health issues were observed in this zone and among the Coral health issue types, Macroalgae competition, Worm infestation and Sponge competition were observed with the mean prevalence of 1.02% (Table 3).

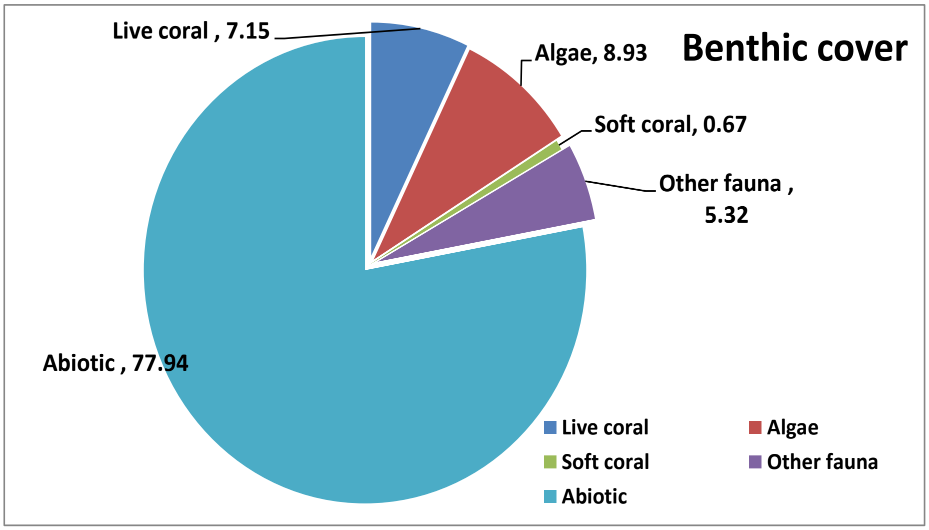

Fig. 5. Mean % cover of benthic community structures in Zone-1

Table 2: % cover of benthic community structures in Zone-1

Benthic categories	G 6	G 7	G 14
Live coral (%)	4.22	6.08	11.14
Algae (%)	9.25	11.36	6.18
Soft coral (%)	0	0.94	1.06
Other fauna (%)	2.69	4.11	9.15
Abiotic (%)	83.84	77.51	72.47

Table 3: Coral parameters in Zone-1

	G 6	G 7	G 14	Mean value
Coral species richness	3	4	4	4
Coral recruitment density (m^{-2})	1.52	1.99	2.24	1.92
Coral health issues (%)	0.86	1.02	1.18	1.02

Macrofaunal community

Five major macro faunal groups were observed in this zone. Mean density was 10.95 $5m^2$ and density ranged between 1.93 and 17.71 $5m^2$ (Fig. 6 & Table 4). Among the macro faunal community, Echinoderms were dominant with 5.645 m^2 followed by Molluscs with 1.52 $5m^2$. In the observed grids, greater density in G 5 with 17.71 followed by G 6 with 14.8 $5m^2$ (Fig. 7).

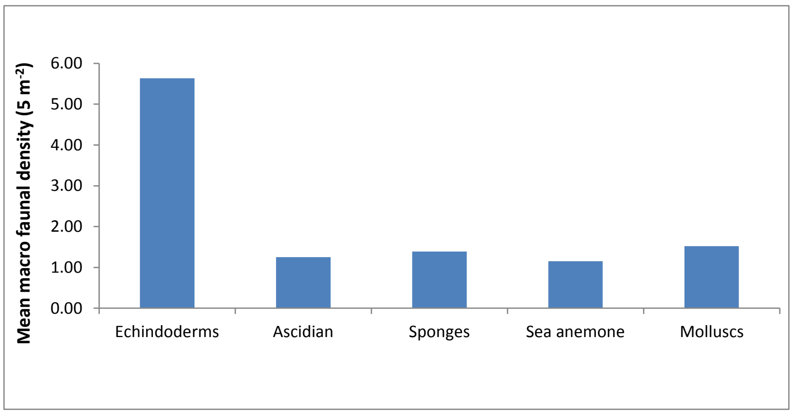

Fig. 6. Mean macro faunal group density in Zone-1

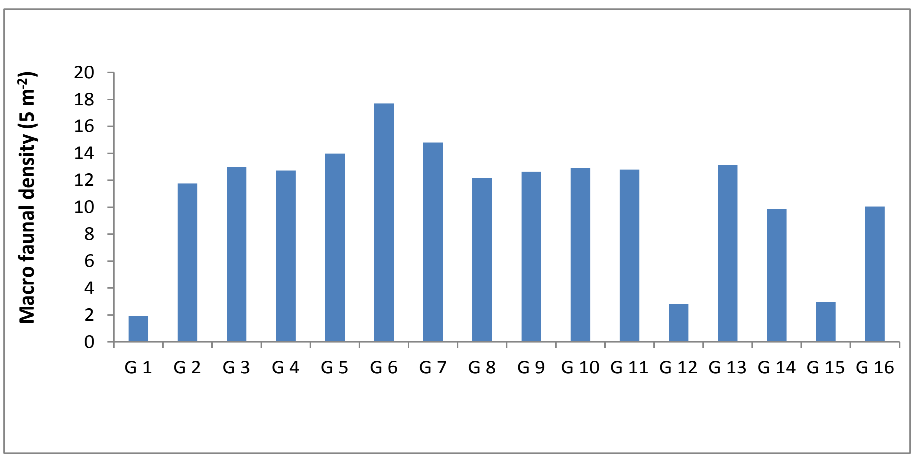

Fig. 7. Mean macro faunal density in Zone-1

Table 4: Total macro faunal group density in Zone-1

	G 1	G 2	G 3	G 4	G 5	G 6	G 7	G 8	G 9	G 10	G 11	G 12	G 13	G 14	G 15	G 16
Echindoderms	0.36	5.15	8.66	6.98	9.46	8.41	6.28	7.96	8.43	6.98	7.07	1.36	6.24	1.36	1.33	4.15
Ascidian	0	0.36	0.78	0.26	1.06	3.65	1.39	0.63	1.06	0.76	0.61	0.55	2.96	2.36	0.66	2.98
Sponges	0.21	1.09	1.02	1.56	0.88	1.36	2.63	1.35	0.39	1.66	1.39	0	1.63	5.09	0.34	1.63
Sea anemone	0	3.11	1.36	2.15	1.36	2.18	1.36	0.86	0.77	1.36	1.96	0	0.96	0.04	0	0.96
Molluscs	1.36	2.06	1.14	1.78	1.22	2.11	3.14	1.36	1.98	2.15	1.76	0.89	1.36	1.01	0.65	0.33

Fish community structure

A total of 1504 fish individuals were counted along the all observed grids in this zone. Among the 16 grids, the highest fish abundance was found to be in G 14 with 159 60/m^2 followed by G 6 with 143 60/m^2 respectively (Table 5). A total of 29 fish species were recorded in this Zone, among them, *Leiognathus splendens* and *Terapon puta* were the most dominant fishes with the mean abundance of 11.9 and 13.9 60/m^2 respectively. Among the grids, the maximum number of species was sighted in G 7 with 24 and low species richness was recorded in G 1 site as 5 numbers respectively (Table 6). Shannon diversty (H') value was ranged between 1.46 and 3.01 and with the mean value of 2.37during the survey period.

Table 5: Fish abundance in Zone-1

	G 1	G 2	G 3	G 4	G 5	G 6	G 7	G 8	G 9	G 10	G 11	G 12	G 13	G 14	G 15	G 16	Mean abundance
Stongylurastrongylura	0	12	15	10	18	11	8	13	0	6	10	0	13	10	0	16	8.9
Alepesdjedaba	0	0	2	3	5	3	2	8	3	0	3	0	5	3	0	5	2.6
*Sardinella*sp.	0	0	23	0	0	18	0	0	0	35	16	0	0	28	10	0	8.1
Upeneussulphurens	3	5	3	2	4	3	2	4	5	7	3	5	2	3	5	3	3.7
Lactoriacornuta	0	0	2	3	3	0	0	0	2	6	3	8	5	3	0	2	2.3
Sphyraenaobtusata	0	4	0	2	10	3	2	7	4	3	4	6	3	8	3	4	3.9
*Lutjanus*sp.	4	8	3	4	18	12	8	6	10	8	6	2	8	4	6	3	6.9
Plotosuslineatus	0	0	26	0	0	0	0	18	10	0	0	0	0	0	0	0	3.4
Mugilcephalus	0	0	5	0	0	0	8	0	0	4	0	0	6	5	0	3	1.9
Leiognathussplendens	10	3	24	6	16	26	10	6	18	20	6	12	8	10	6	10	11.9
Teraponputa	0	8	12	28	18	8	14	8	21	11	20	28	15	8	6	18	13.9
*Amphiprion*sp.	0	2	0	0	4	0	0	0	2	0	0	0	2	0	0	0	0.6
Hippocampus sp.	0	0	0	0	2	0	0	0	3	0	0	0	1	0	0	0	0.4
Siganusjavus	0	5	0	3	4	2	3	6	2	6	4	3	0	8	2	5	3.3
Caranxpara	0	0	0	0	3	0	5	0	0	4	0	0	3	0	0	0	0.9
Acanthuruslineatus	0	0	0	0	0	3	2	0	0	3	0	0	0	4	0	0	0.8
Balistoidesviridescens	0	2	0	0	0	2	1	3	0	0	3	0	0	3	2	0	1.0
*Chaetodon*sp.	0	0	0	0	0	8	3	0	0	0	0	2	0	5	0	3	1.3
Sargocentronrubrum	0	0	3	0	5	3	2	0	0	0	0	1	0	6	0	2	1.4
Bathygobiusladdi	0	0	2	0	0	2	3	3	0	0	2	0	0	2	0	0	0.9
Thalassomalunare	0	0	0	0	0	3	6	0	0	0	0	3	0	5	0	0	1.1
*Leiognathus*sp.	5	3	6	4	0	2	4	0	0	0	3	0	0	6	2	0	2.2
Paraupeneusindicus	2	6	5	3	2	2	3	0	5	2	3	0	0	4	5	2	2.8
Pempherisvanicolensis	0	0	0	5	0	8	9	0	0	0	0	0	0	5	0	0	1.7
Pomacanthus imperator	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0	0	0.6
Abudefdufsaxitalis	0	0	0	6	0	13	8	0	0	3	2	0	0	10	0	0	2.6
Scarusghibbus	0	3	0	0	0	6	5	0	3	4	0	0	0	6	2	0	1.8
Epinephelusmalabaricus	0	0	3	0	0	3	2	0	0	2	0	0	0	5	3	0	1.1
Scolopsisvosmeri	0	2	4	0	0	0	3	3	0	4	2	3	2	3	2	3	1.9
Total abundance (60 m^2)	24	63	138	79	112	143	116	85	88	128	90	73	73	159	54	79	1504.0

Table 6: Fish diversity indices in Zone-1

	No. of species (S)	**Diversity (H')**	**Species richness (D)**	**Eveness (J)**
G 1	5.00	1.46	1.26	0.91
G 2	13.00	2.41	2.90	0.94
G 3	16.00	2.37	3.04	0.85
G 4	13.00	2.18	2.75	0.85
G 5	14.00	2.35	2.76	0.89
G 6	22.00	2.74	4.23	0.89
G 7	24.00	2.97	4.84	0.93
G 8	12.00	2.33	2.48	0.94
G 9	13.00	2.23	2.68	0.87
G 10	17.00	2.45	3.30	0.86
G 11	16.00	2.46	3.33	0.89
G 12	11.00	1.95	2.33	0.81
G 13	13.00	2.31	2.80	0.90
G 14	25.00	3.01	4.74	0.94
G 15	13.00	2.42	3.01	0.94
G 16	14.00	2.32	2.98	0.88
Mean value =	15.06	2.37	3.09	0.89

ZONE -2

In zone-2, seagrass meadows were found in 17 grids and coral reef habitat was observed in one grid.

Seagrass habitat

In zone-2, seagrass meadows were found in dense and patchy manner and mean percentage cover was 37.20%. The maximum cover was observed in G 29 with 63.47 % followed by G 28 with 54.16 respectively (Fig. 8). A total of five seagrass species were recorded, among them, *Thalassia hemprichii* and *Cymodocea serrulata* were the dominant species.

Mean shoot density was recorded as 365.93 m^{-2} and highest mean shoot density was found to be in *Thalassia hemprichii* and *Cymodocea serrulata* with 151.27 and 98.26 m^{-2} respectively (Fig. 9). Among the grids in zone-2, highest shoot density was recorded in G 28 and G 32 with the value of 587.9 and 542.31 m^{-2} respectively (Fig. 10 & Table 7).

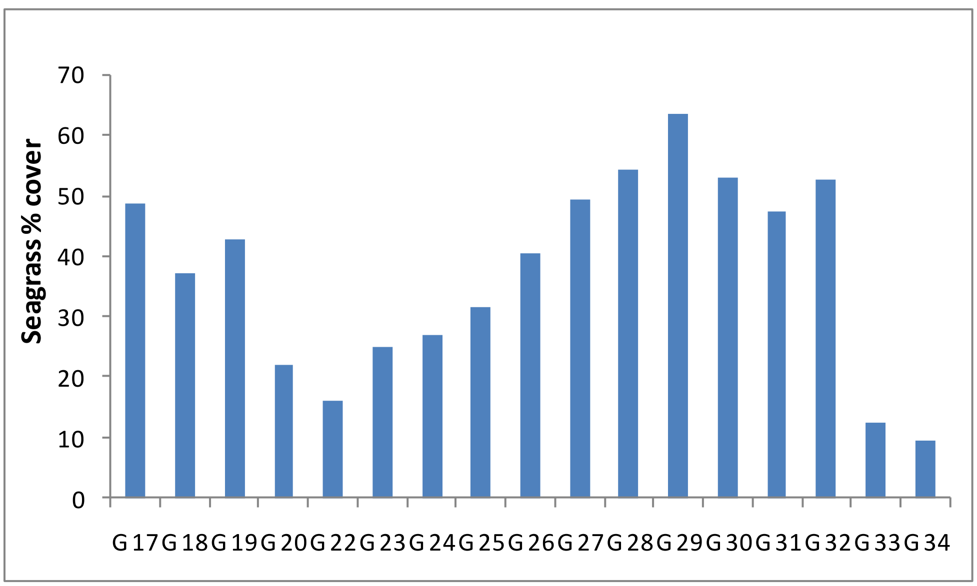

Fig.8. Seagrass percentage covers in Zone-2

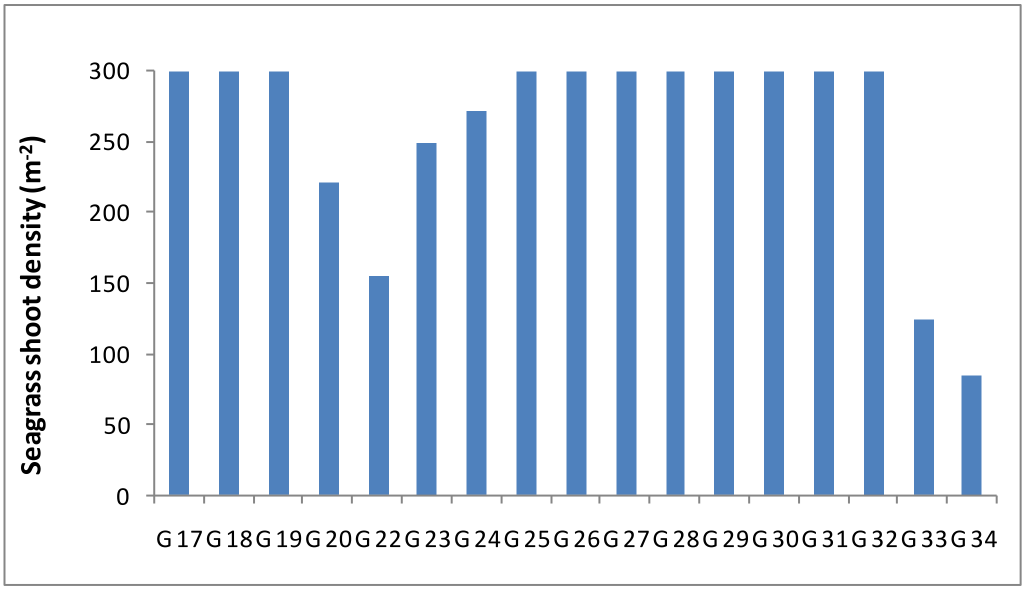

Fig.9. Mean species seagrass shoot density in Zone-2

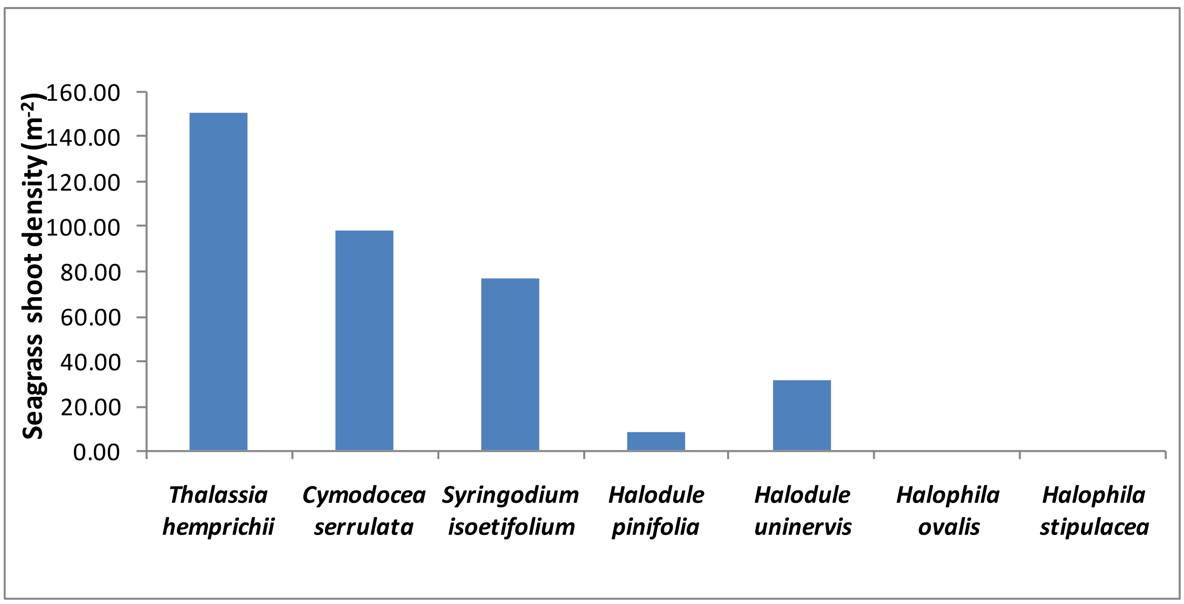

Fig.10. Mean species seagrass shoot density in Zone-2

Table 7: Seagrass species shoot density in Zone-2

	G 17	G 18	G 19	G 20	G 22	G 23	G 24	G 25	G 26
Thalassia hemprichii	192.67	161.27	186.24	89.85	62.98	105.86	109.51	127.31	168.34
Cymodocea serrulata	128.64	86.37	105.46	67.38	41.73	71.63	81.62	85.64	112.96
Syringodium isoetifolium	106.78	74.69	89.22	45.29	30.58	42.95	47.29	65.18	84.92
Halodule pinifolia	15.37	9.74	11.39	0.00	5.27	0.00	6.31	4.82	13.47
Halodule uninervis	41.95	29.69	35.21	18.64	13.69	27.84	26.81	29.37	28.67

	G 27	G 28	G 29	G 30	G 31	G 32	G 33	G 34
Thalassia hemprichii	208.67	217.34	236.82	211.43	186.39	219.44	51.68	35.74
Cymodocea serrulata	122.48	140.96	159.47	142.80	124.84	142.85	33.69	21.96
Syringodium isoetifolium	105.72	105.82	126.33	113.72	100.37	116.71	24.72	20.34
Halodule pinifolia	8.29	11.24	13.59	16.79	9.72	13.45	0.00	0.00
Halodule uninervis	35.95	44.27	51.69	45.95	39.51	49.86	13.83	5.82

Coral reef habitat

Few minor patches of coral reef habitat were found in this zone. Mean live coral was 14.61% and among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 63.76% (Fig. 11 & Table 8). The coral cover was observed in G 21 with 14.61 respectively. A total of 6 hard coral species were observed and *Turninaria mesentrina* and *Porites lutea* were the most commonly observed coral species. Similarly coral recruits were recorded with a mean value of 3.4 m^{-2} (Table 9). Few coral health issues were observed in this zone and among the Coral health issue types, Macroalgae competition, Worm infestation Sponge competition, Invertebrate gall, White syndrome and Fish predation were observed with the mean prevalence of 4.29% (Table 9).

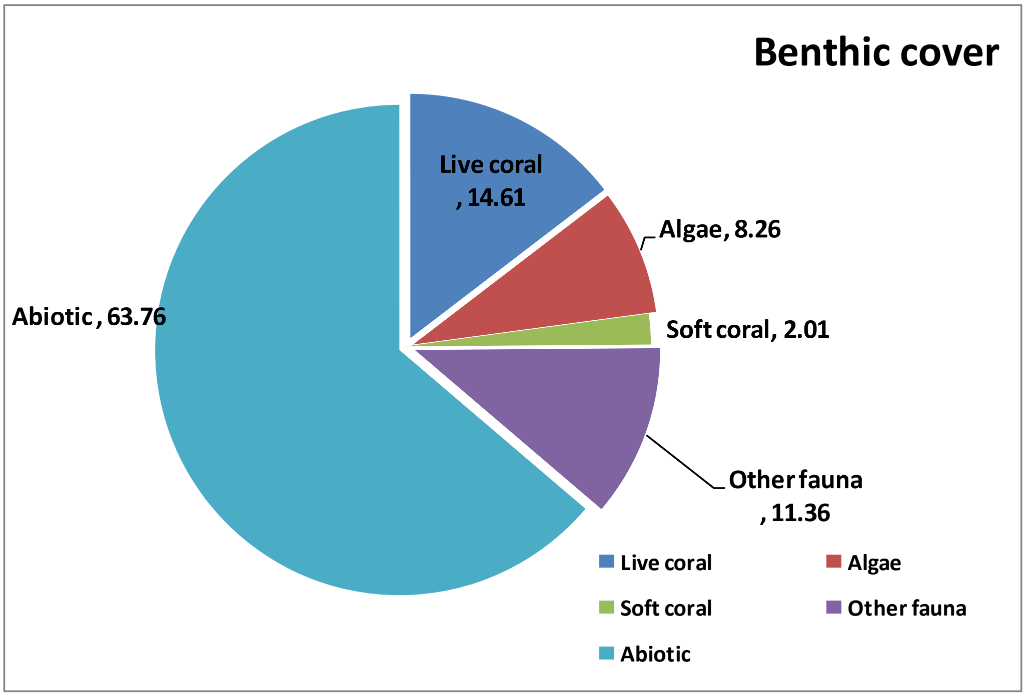

Fig.11. Mean % cover of benthic community structures in Zone-2

Table 8: % cover of benthic community structures in Zone-2

Benthic categories	G 21
Live coral (%)	14.61
Algae (%)	8.26
Soft coral (%)	2.01
Other fauna (%)	11.36
Abiotic (%)	63.76

Table 9: Coral parameters in Zone-2

	G 21
Coral species richness	6
Coral recruitment density (m^{-2})	3.4
Coral health issues (%)	4.29

Macrofaunal community

Five major macro faunal groups were observed in this zone. Mean density was 13.60 5m^2 and density ranged between 1.93 and 17.71 5m^2 (Fig. 12 & Table 10). Among the macro faunal community, Echinoderms were dominant with 23.09 5m^2 followed by Molluscs with 1.52 5m^2. In the observed grids, greater density was seen in G 29 with 23.09 5m^2 followed by G 28 with 20.33 5m^2 (Fig. 13).

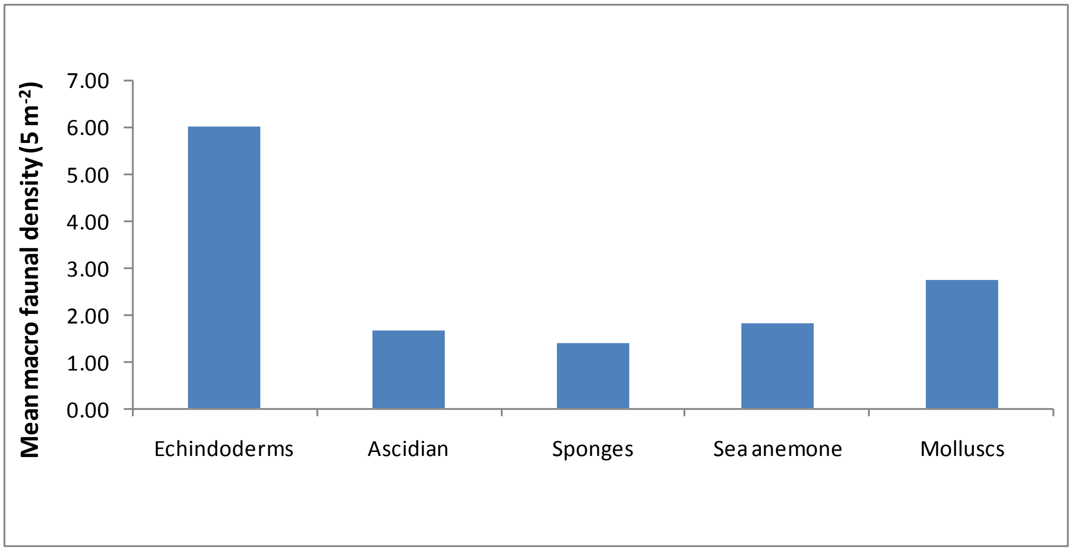

Fig.12. Mean macro faunal group density in Zone-2

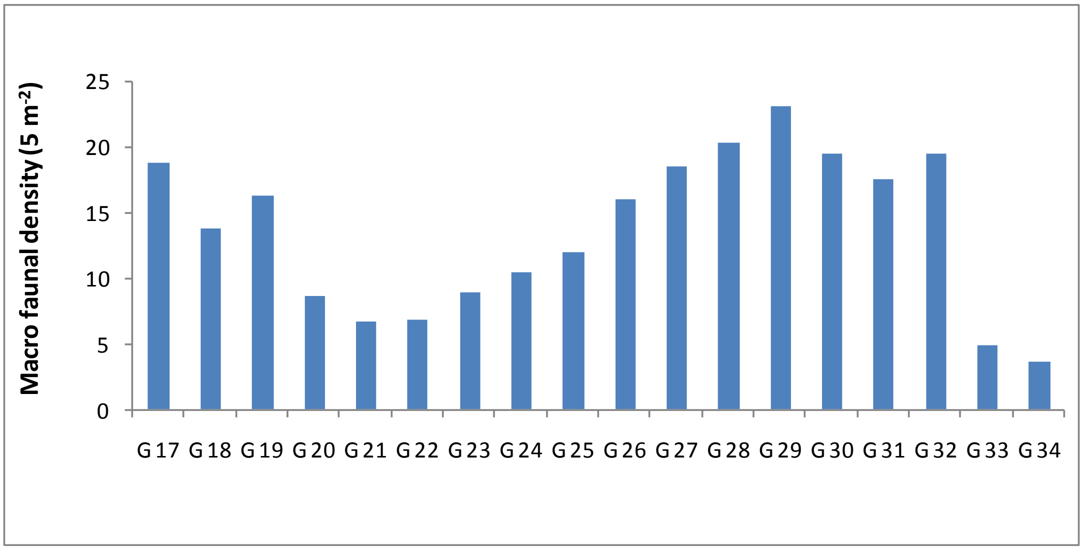

Fig.13. Mean macro faunal density in Zone-2

Table 10: Total macro faunal group density in Zone-2

	G 1	G 2	G 3	G 4	G 5	G 6	G 7	G 8	G 9	G 10	G 11	G 12	G 13	G 14	G 15	G 16
Echindoderms	0.36	5.15	8.66	6.98	9.46	8.41	6.28	7.96	8.43	6.98	7.07	1.36	6.24	1.36	1.33	4.15
Ascidian	0	0.36	0.78	0.26	1.06	3.65	1.39	0.63	1.06	0.76	0.61	0.55	2.96	2.36	0.66	2.98
Sponges	0.21	1.09	1.02	1.56	0.88	1.36	2.63	1.35	0.39	1.66	1.39	0	1.63	5.09	0.34	1.63
Sea anemone	0	3.11	1.36	2.15	1.36	2.18	1.36	0.86	0.77	1.36	1.96	0	0.96	0.04	0	0.96
Molluscs	1.36	2.06	1.14	1.78	1.22	2.11	3.14	1.36	1.98	2.15	1.76	0.89	1.36	1.01	0.65	0.33

Fish community structure

A total of 3147 fish individuals were counted along all the observed grids in this zone. Among the 21 grids, highest fish abundance was found to be in G 28 with 228 60/m^2 followed by G 26 with 221 60/m^2 respectively (Table 11). A total of 28 fish species were recorded in this Zone, among them, *Sardinella* Sp. and *Stongylura strongylura* were the most dominant fishes with the mean abundance of 23.05 and 18.24 60/m^2 respectively. Among the grids, the maximum number of species was sighted in G 21 with 20 numbers and low species richness was recorded in G 34 site with 8 numbers respectively (Table 12). Shannon diversty (H') value was ranged between 1.85 and 2.70 with the mean value of 2.22 during the survey period.

Table 11: Fish abundance in Zone-2

	G 17	G 18	G 19	G 20	G 21	G 22	G 23	G 24	G 25	G 26	G 27	G 28	G 29	G 30	G 31	G 32	G 33	G 34	Mean abundance
Stongylura strongylura	25	15	19	20	0	18	23	19	23	28	19	29	38	30	27	12	0	0	19.17
Alepes djedaba	10	16	23	18	0	0	0	16	10	26	18	26	18	20	18	0	0	10	12.72
Sardinella sp.	15	28	0	10	0	26	35	26	18	29	35	49	26	16	21	18	21	18	21.72
Upeneus sulphurens	14	12	9	12	5	16	18	10	14	18	8	14	16	19	6	8	0	0	11.06
Lactoria cornuta	4	0	0	0	3	0	4	0	5	9	2	4	2	8	13	0	0	0	3.00
Sphyraena obtusata	3	8	14	0	0	26	10	16	9	6	0	18	28	14	23	18	10	0	11.28
Lutjanus sp.	16	10	18	24	10	36	18	27	19	16	26	18	23	10	15	13	11	8	17.67
Plotosus lineatus	0	0	18	23	0	15	0	10	19	14	8	13	28	16	25	14	10	0	11.83
Mugil cephalus	6	0	8	3	8	12	10	16	8	6	3	8	4	10	8	16	6	10	7.89
Terapon puta	10	18	8	20	0	0	0	16	0	22	0	14	23	10	16	23	18	10	11.56
Amphiprion sp.	0	0	5	4	3	2	6	0	0	0	2	0	0	2	0	0	0	2	1.44
Hippocampus sp.	0	0	0	2	0	0	0	3	0	0	0	2	0	0	0	0	3	0	0.56
Siganus javus	4	3	6	5	2	6	2	8	0	15	0	8	6	0	0	8	16	18	5.94
Caranx para	0	8	0	12	0	14	0	0	0	8	0	0	6	0	2	3	5	2	3.33
Acanthurus lineatus	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0.28
Balistoides viridescens	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17
Chaetodon sp.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0.22
Sargocentron rubrum	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0.56
Bathygobius laddi	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11
Thalassoma lunare	0	0	0	0	4	0	0	0	0	0	0	5	0	0	0	0	0	0	0.50
Leiognathus sp.	0	0	8	0	10	0	0	0	0	9	0	0	0	12	0	8	0	0	2.61
Paraupeneus indicus	0	0	0	8	5	0	10	0	0	8	0	15	0	0	0	11	0	0	3.17
Pempheris vanicolensis	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	1.33
Pomacanthus imperator	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17
Abudefduf saxitalis	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	1.44
Scarus ghibbus	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0.56
Epinephelus malabaricus	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0.28
Scolopsis vosmeri	0	0	2	0	6	0	3	0	0	7	0	5	0	5	0	3	0	0	1.72
Total abundance (60 m2)	107	118	138	161	148	171	139	167	125	221	121	228	218	172	174	155	100	78	2741.00

Table 12: Fish diversity indices in Zone-2

	No. of species (S)	Diversity (H')	Species richness (D)	Eveness (J)
G 35	13	2.42	2.42	0.94
G 36	13	2.35	2.55	0.92
G 37	13	2.37	2.49	0.92
G 38	13	2.37	2.44	0.92
G 39	23	2.89	4.19	0.92
G 40	23	2.93	3.96	0.93
G 41	25	2.98	4.33	0.92
G 42	20	2.74	3.93	0.92
G 43	19	2.70	3.70	0.92
G 44	20	2.63	3.90	0.88
G 45	11	2.18	2.10	0.91
G 46	13	2.35	2.47	0.92
G 47	12	2.29	2.25	0.92
G 48	13	2.38	2.43	0.93
G 49	23	2.90	4.18	0.92
G 50	21	2.91	4.05	0.95
G 51	13	2.32	2.54	0.90
Mean value =	16.941	2.57	3.17	0.92

ZONE -3

In zone-3, seagrass meadows were observed in 15 grids and coral reef habitat was observed in 8 grids. Kariyachalli Island and surrounded reef were occurring in this island.

Seagrass habitat

In zone-3, patch and dense seagrass meadows were found and mean percentage cover was 37.22%. The maximum cover was observed in G 36 with 65.49 % followed by G 37 with 57.13 respectively (Fig. 14). A total of six seagrass species were recorded, among them, *Thalassia hemprichii* and *Cymodocea serrulata* were the dominant species.

Mean shoot density was recorded as 353.84 m-2 and highest mean shoot density was found to be in *Thalassia hemprichii* and *Cymodocea serrulata* with 144.69 and 91.99 m^{-2} respectively (Fig. 15). Among the grids in Zone 3, highest shoot density was recorded in G 36 and G 37 with the value of 631.99 and 565.5 m^{-2} respectively (Fig. 16 & Table 13).

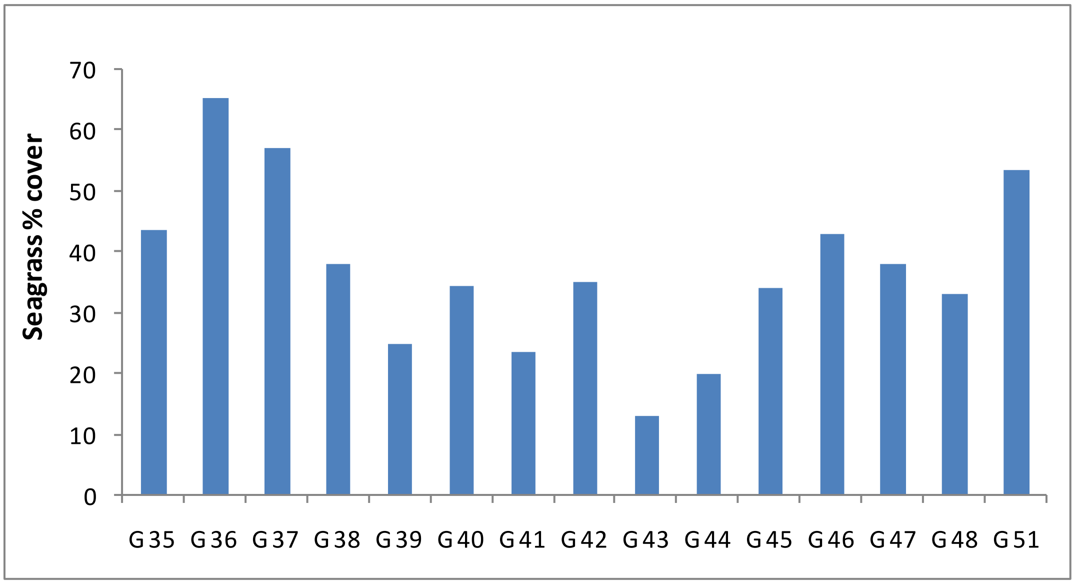

Fig.14. Seagrass percentage covers in Zone-3

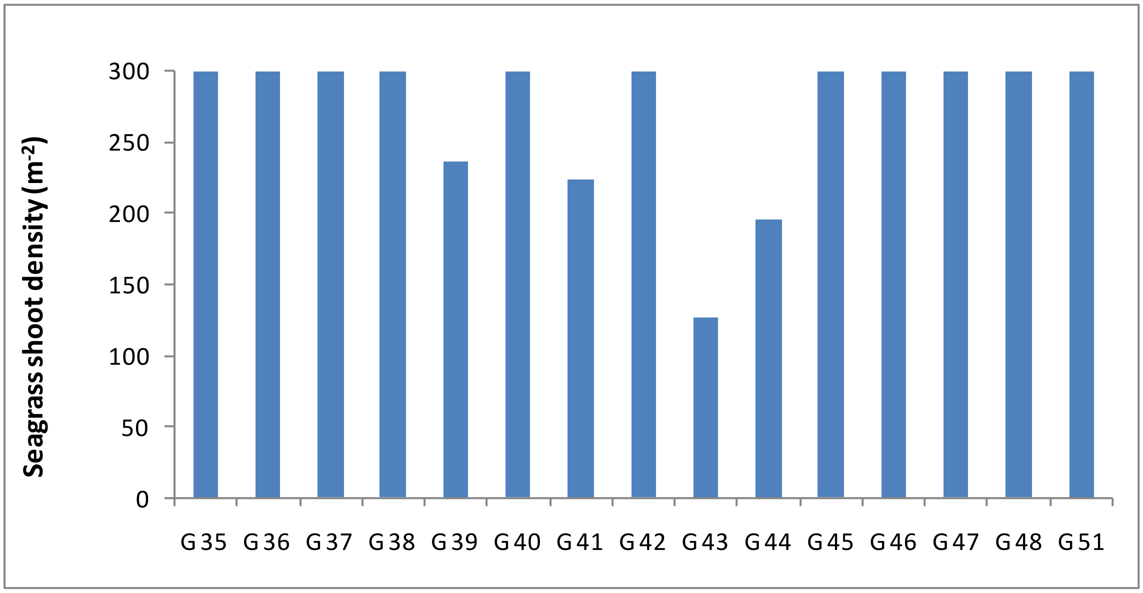

Fig.15. Mean species seagrass shoot density in Zone 3

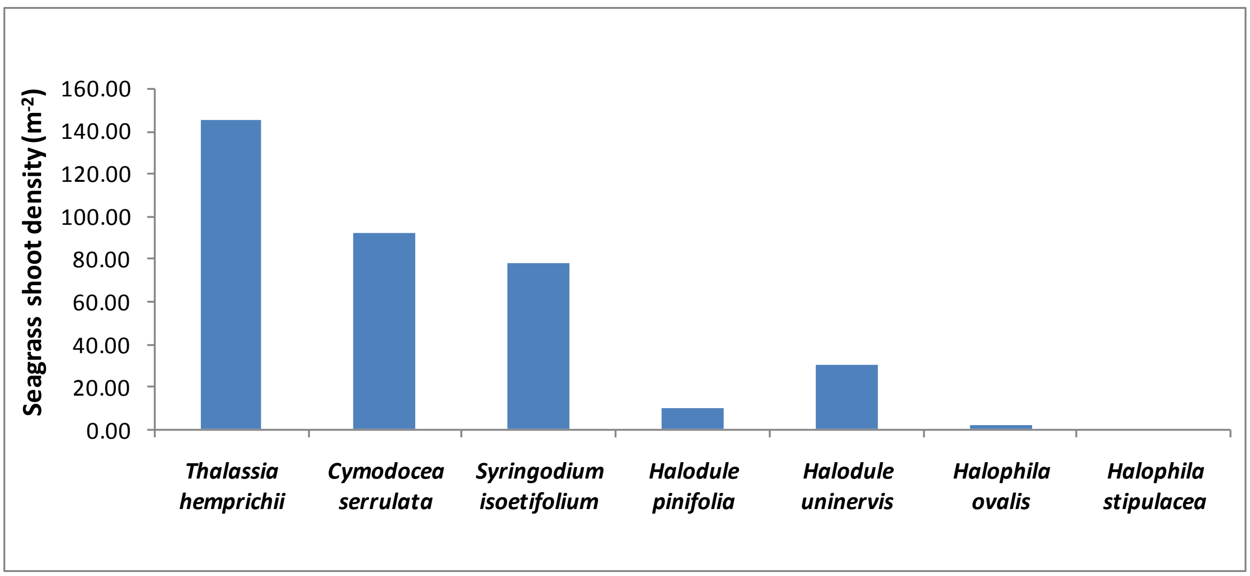

Fig.16. Mean species seagrass shoot denisty in Zone 3

Table 13: Seagrass species shoot density in Zone 3

	G 35	G 36	G 37	G 38	G 39	G 40	G 41	G 42	G 43
Thalassia hemprichii	183.47	254.96	231.85	142.63	97.62	132.54	90.51	138.26	51.68
Cymodocea serrulata	136.95	176.48	145.72	85.46	58.94	82.61	53.47	85.17	31.07
Syringodium isoetifolium	85.49	132.64	122.51	72.68	50.31	70.53	50.26	72.64	22.17
Halodule pinifolia	8.22	12.69	14.74	8.92	5.29	9.67	6.27	11.26	5.38
Halodule uninervis	39.47	55.22	50.68	31.56	18.47	32.49	18.57	24.63	16.62
Halophila ovalis	0	0	0	0	5.56	2.61	4.69	0	0

	G 44	G 45	G 46	G 47	G 48	G 51
Thalassia hemprichii	76.28	126.58	168.42	125.48	141.67	208.34
Cymodocea serrulata	49.16	86.42	105.26	73.19	83.16	126.85
Syringodium isoetifolium	45.17	76.19	89.43	85.42	75.98	109.46
Halodule pinifolia	6.22	8.33	16.24	8.61	11.49	15.72
Halodule uninervis	18.34	34.15	33.65	26.51	26.34	45..26
Halophila ovalis	0	3.11	0	0	4.82	0

Coral reef habitat

Patch and sparse coral cover were observed in this zone. Mean live coral was 21.53% and among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 62.66% (Fig. 17 & Table 14). The highest coral cover was observed in G 41 with 35.76% followed by 32.48% at G 50 respectively. A total of 11 hard coral species were observed *Acropora formosa, A.intermedia, A.cytherea, Favia pallida, Turbinaria mesenterina* and *Porites lutea* were the most commonly observed coral species. Similarly density of coral recruits was recorded with a mean value of 3.22 m^{-2} and density ranged between 1.6 and 4.98 m^{-2} in the observed grids (Table 15). Few coral health issues were observed in this zone and among the coral health issue types, Macroalgae competition, Sponge Competition, Invertebrate Gall, White syndrome, Growth Anomaly, Focal Bleaching, Worm infestation and Fish predation were observed with the mean prevalence of 3.43% (Table 15).

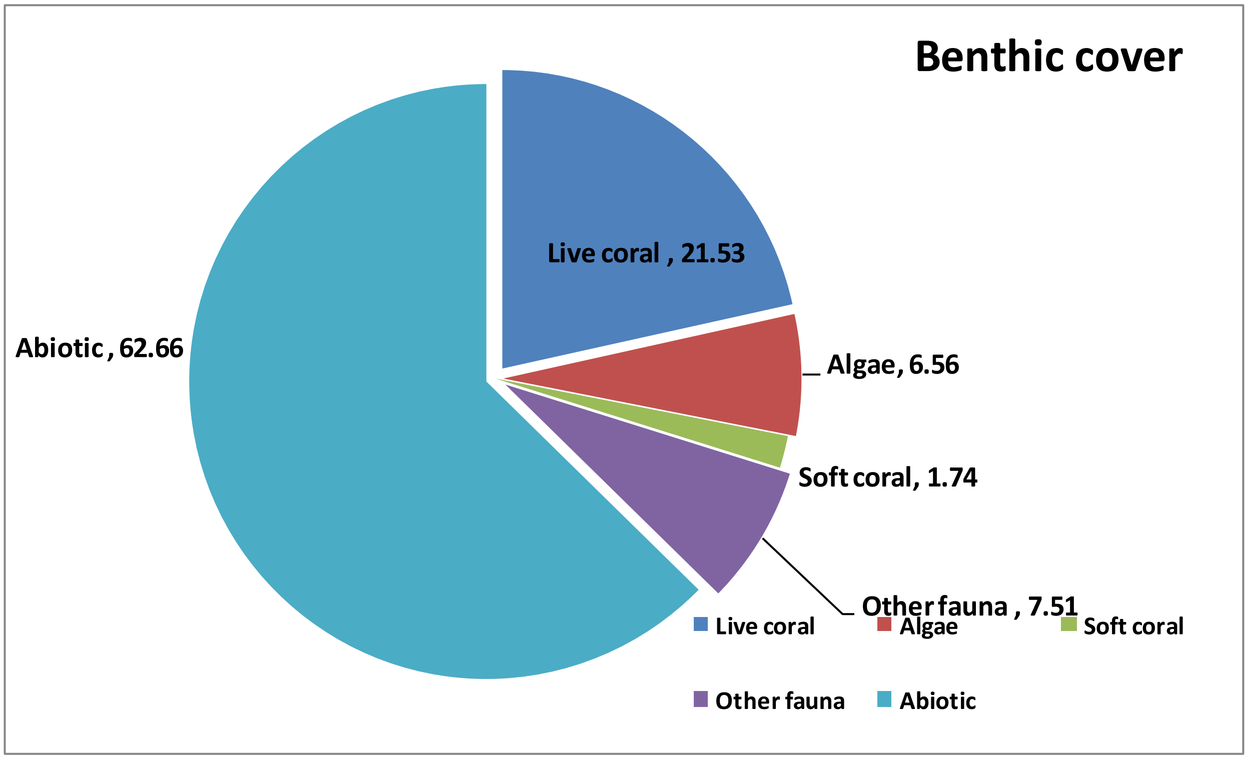

Fig.17. Mean % cover of benthic community structures in Zone 3

Table 14: % cover of benthic community structures in Zone 3

	G 39	G 40	G 41	G 42	G 43	G 44	G 49	G 50
Live coral (%)	17.36	21.48	35.76	10.09	13.48	18.11	23.47	32.48
Algae (%)	5.11	9.63	11.2	3.58	7.15	5.36	6.32	4.11
Soft coral (%)	2.48	1.36	0	1.89	3.11	1.78	1.33	1.98
Other fauana (%)	6.47	8.69	9.15	8.25	4.96	7.06	8.36	7.15
Abiotic (%)	68.58	58.84	43.89	76.19	71.3	67.69	60.52	54.28

Table 15: Coral parameters in Zone 3

	G 39	G 40	G 41	G 42	G 43	G 44	G 49	G 50
Coral species richness (no)	8	10	20	5	5	9	11	18
Coral recruitment density (m^{-2})	3.25	2.15	4.98	1.6	2.04	2.77	4.01	4.93
Coral health issues	5.12	3.07	4.78	2.36	2.11	2.36	3.48	4.15

Macro faunal community

Five major macro faunal groups were observed in this zone. Mean density was 15.88 $5m^2$ and density ranged between 7.29 and 23.2 $5m^2$ (Fig. 18 & Table 16). Among the macro faunal community, Echinoderms were dominant with 6.57 m^2 followed by Molluscs with 3.28 $5m^2$. In the grids, greater density is observed in G 36 with 23.2 followed by G 51 with 21.78 $5m^2$ respectively (Fig. 19).

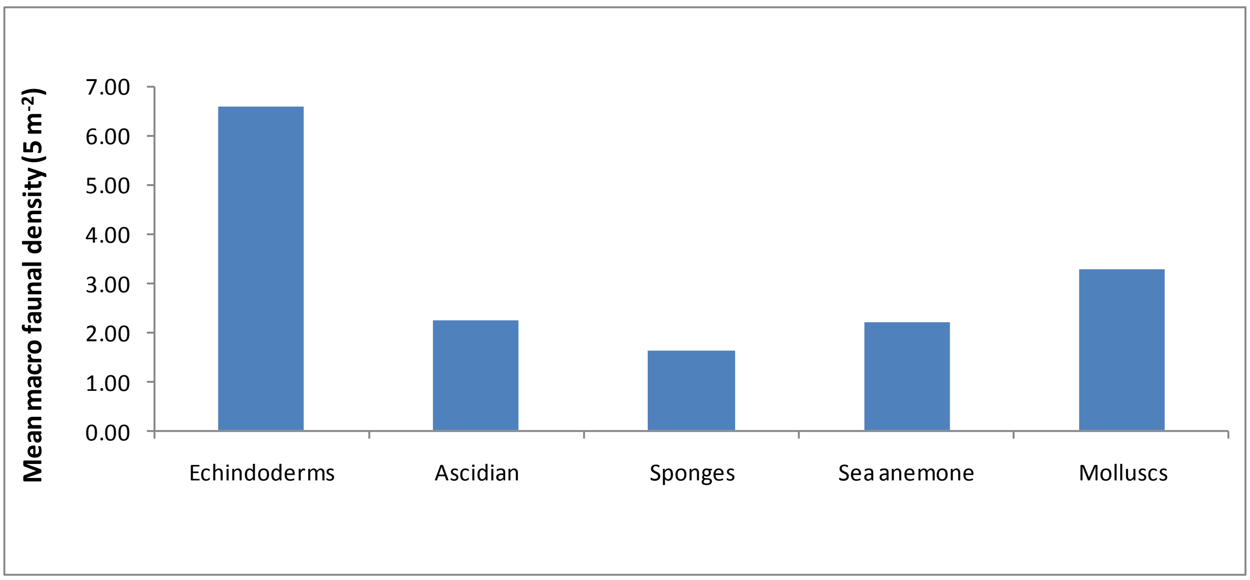

Fig.18. Mean macro faunal group density in Zone 3

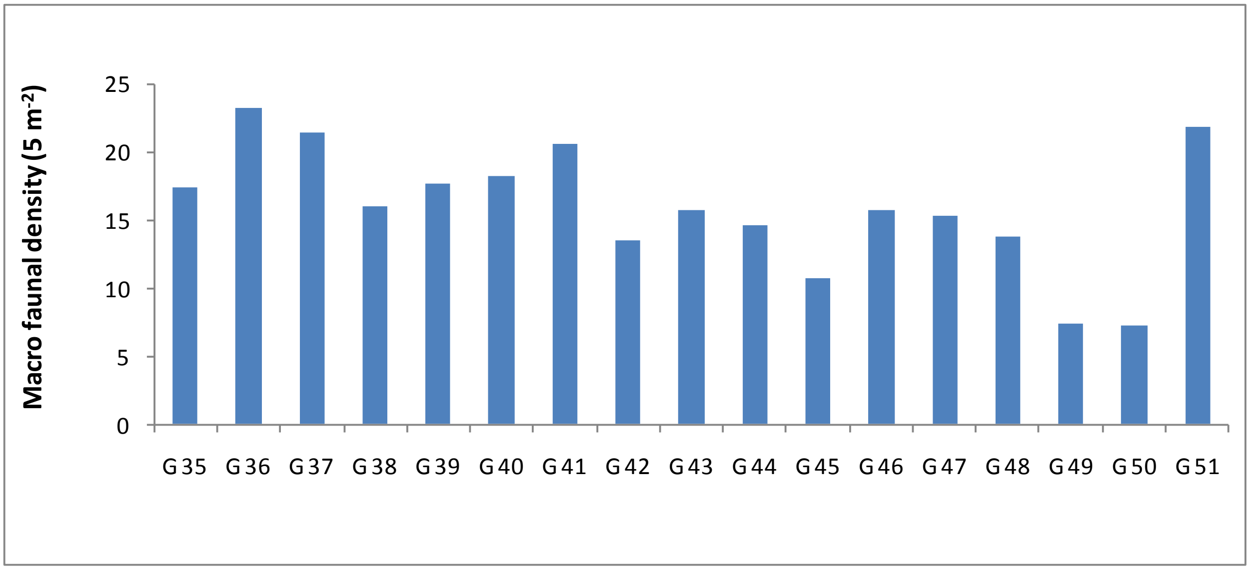

Fig.19. Mean macro faunal density in Zone 3

Table 16: Total macro faunal group density in Zone 3

	G 35	G 36	G 37	G 38	G 39	G 40	G 41	G 42	G 43	G 44	G 45	G 46	G 47	G 48	G 49	G 50	G 51
Echindoderms	6.25	9.68	9.11	8.15	6.25	7.05	6.95	6.25	3.11	4.72	5.96	7.18	8.96	6.81	1.02	1.93	12.36
Ascidian	1.47	2.36	1.36	1.36	3.59	2.98	4.96	1.36	2.36	3.85	1.02	1.36	0.89	0.63	3.48	3.11	1.75
Sponges	1.69	2.11	1.78	1.22	1.78	1.36	4.36	0.89	3.15	2.36	0.15	0	0.63	0.18	2.51	2.14	0.86
Sea anemone	2.78	3.44	2.11	3.15	2.36	1.63	1.36	1.65	1.98	1.48	1.22	3.69	3.98	2.98	0.11	0	3.56
Molluscs	5.14	5.61	6.98	2.15	3.68	5.15	2.98	3.26	5.14	2.14	2.36	3.41	0.88	3.21	0.25	0.11	3.25

Fish community structure

A total of 2564 fish individuals were counted along all the observed grids in this zone. Among the 17 grids, highest fish abundance was found to be in G 40 with 258 60/m^2 followed by G 41 with 255 60/m^2 respectively (Table 17). A total of 25 fish species were recorded in this Zone, among them, *Stongylura strongylura* and *Sardinella* Sp. were the most dominant fishes with the mean abundance of 15.94 and 15.65 60/m^2 respectively. Among the grids, the maximum number of species was sighted in G 41 with 25 and low species richness was recorded in G 45 site with 11 numbers respectively (Table 18). Shannon diversty (H') value was ranged between 2.18 and 2.98 with the mean value of 2.57 during the survey period.

Table 17: Fish abundance in Zone 3

	G 35	G 36	G 37	G 38	G 39	G 40	G 41	G 42	G 43	G 44	G 45	G 46	G 47	G 48	G 49	G 50	G 51	Mean abundance
Stongylura strongylura	19	13	23	18	0	26	13	15	18	26	23	19	26	16	0	0	16	15.94
Alepes djedaba	13	10	13	20	18	8	6	10	6	16	0	20	18	13	18	0	13	11.88
Sardinella sp.	10	26	16	18	26	15	28	6	10	0	20	12	6	16	20	12	25	15.65
Upeneus sulphurens	6	8	13	10	8	10	6	8	18	5	16	8	3	6	2	5	7	8.18
Lactoria cornuta	3	2	6	2	3	5	4	2	5	3	0	0	7	8	18	6	3	4.53
Sphyraena obtusata	8	5	3	0	0	18	10	8	6	15	6	13	18	10	16	13	8	9.24
Lutjanus sp.	21	6	10	18	8	24	13	23	14	8	20	14	20	31	10	6	8	14.94
Mugil cephalus	10	8	13	8	15	8	16	8	6	0	5	2	9	5	10	6	8	8.06
Terapon puta	22	10	13	14	6	10	4	5	9	13	6	10	8	13	11	0	0	9.06
Amphiprion sp.	0	5	0	3	2	0	4	0	0	3	0	0	0	3	0	0	2	1.29
Siganus javus	9	5	3	8	4	3	5	3	5	10	8	16	8	7	3	8	10	6.76
Caranx para	6	2	4	10	8	6	3	8	10	4	6	3	4	6	8	4	2	5.53
Acanthurus lineatus	0	0	0	0	5	8	10	0	2	0	0	0	0	0	3	5	0	1.94
Balistoides viridescens	0	0	0	0	4	0	2	0	0	3	0	0	0	0	2	3	0	0.82
Chaetodon sp.	0	0	0	0	2	5	13	5	3	2	0	0	0	0	12	16	0	3.41
Sargocentron rubrum	0	0	0	0	8	4	6	2	0	3	0	0	0	0	5	4	0	1.88
Bathygobius laddi	0	0	0	0	3	6	3	2	2	2	0	2	0	0	3	2	0	1.47
Thalassoma lunare	0	0	0	0	5	9	13	3	5	0	0	3	0	0	8	6	0	3.06
Leiognathus sp.	5	11	5	0	7	13	8	5	3	2	3	0	0	6	6	11	8	5.47
Paraupeneus indicus	10	0	0	4	9	12	16	3	2	3	4	6	6	0	18	6	0	5.82
Pempheris vanicolensis	0	0	0	0	20	28	13	2	0	2	0	0	0	0	6	8	0	4.65
Pomacanthus imperator	0	0	0	0	4	6	5	0	3	0	0	0	0	0	3	5	2	1.65
Abudefduf saxitalis	0	0	3	3	16	25	36	5	2	3	0	0	0	0	6	8	0	6.29
Scarus ghibbus	0	0	0	0	6	3	12	3	0	5	0	0	0	0	2	3	0	2.00
Epinephelus malabaricus	0	0	0	0	3	6	6	0	0	2	0	0	0	0	3	2	0	1.29

Total abundance (60 m2)	142	111	125	136	190	258	255	126	129	130	117	128	133	140	193	139	112	

Table 18: Fish diversity indicesin Zone 3

Sample	No. of species (S)	Diversity (H')	Species richness (D)	Eveness (J)
G 35	13	2.42	2.42	0.94
G 36	13	2.35	2.55	0.92
G 37	13	2.37	2.49	0.92
G 38	13	2.37	2.44	0.92
G 39	23	2.89	4.19	0.92
G 40	23	2.93	3.96	0.93
G 41	25	2.98	4.33	0.92
G 42	20	2.74	3.93	0.92
G 43	19	2.70	3.70	0.92
G 44	20	2.63	3.90	0.88
G 45	11	2.18	2.10	0.91
G 46	13	2.35	2.47	0.92
G 47	12	2.29	2.25	0.92
G 48	13	2.38	2.43	0.93
G 49	23	2.90	4.18	0.92
G 50	21	2.91	4.05	0.95
G 51	13	2.32	2.54	0.90
Mean value =	16.94	2.57	3.17	0.92

Zone -4

In zone-4, 7 grids were occupied by seagrass meadows; 6 grids were occupied by coral reef habitat and remaining 4 grids were occupied by sand. Southeast part of the kariyachalli Island occurring in this zone.

Seagrass habitat

In zone-4 also dense and sparse seagrass meadows were found with a mean percentage cover of 44.30%. The maximum cover was observed in G 65 with 68.32% followed by G 66 with 62.32% respectively (Fig. 20). A total of seven seagrass species were recorded, among them, *Cymodocea serrulata* and *Thalassia hemprichii* were the dominant species.

Mean shoot density was recorded as 396.84 m-2 and highest mean shoot density was found to be in *Cymodocea serrulata* and *Thalassia hemprichii* with 115.18 and 99.62 m^{-2} respectively (Fig. 21). Among the grids in Zone 4, highest shoot density was recorded in G 65 and G 66 with the value of 620.1 and 569.93 m^{-2} respectively (Fig. 22 & Table 19).

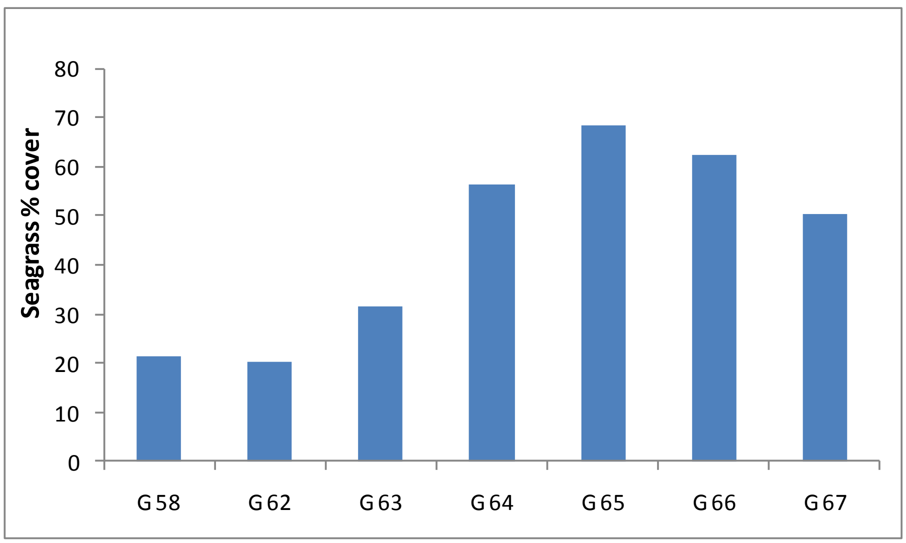

Fig.20. Seagrass percentage covers in Zone-4

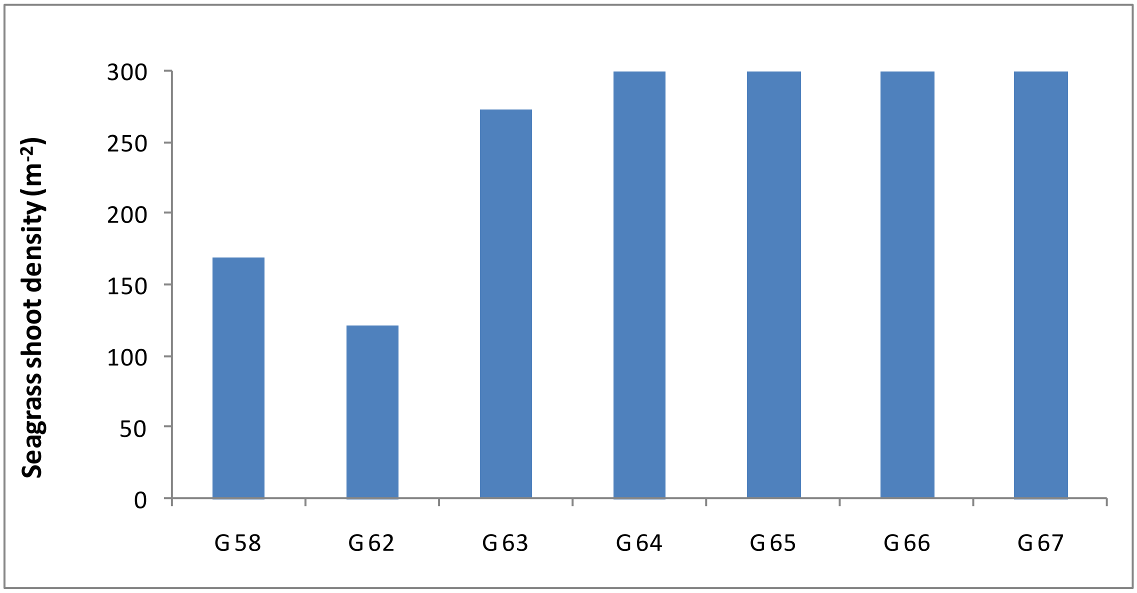

Fig.21. Mean species seagrass shoot density in Zone 4

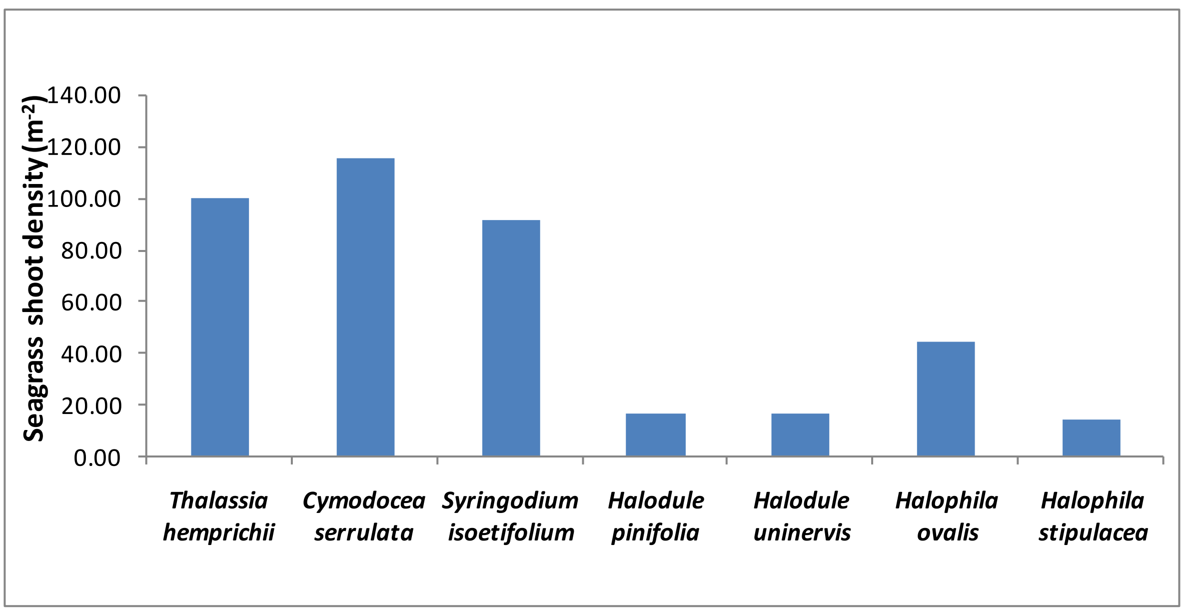

Fig22. Mean species seagrass shoot denisty in Zone 4

Table 19: Seagrass species shoot density in Zone 4

	G 58	G 62	G 63	G 64	G 65	G 66	G 67
Thalassia hemprichii	45.85	42.32	74.58	145.36	145.36	123.52	120.35
Cymodocea serrulata	45.65	52.47	65.39	156.85	175.32	175.32	135.25
Syringodium isoetifolium	65.85	15.85	52.69	37.58	147.55	145.98	175.32
Halodule pinifolia	0	0	26.32	28.35	35.21	12.69	10.25
Halodule uninervis	0	0	0	45.65	15.65	25.69	26.32
Halophila ovalis	12.58	11.52	54.69	58.65	85.32	58.21	28.65
Halophila stipulacea	0	0	0	35.98	15.69	28.52	17.54

Coral reef habitat

Dense and patch coral reef sites were observed. Mean live coral was 28.16% and among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 34.88% (Fig. 23 & Table 20). The highest coral cover was observed in G 61 with 46.38% followed by 33.62% at G 60 respectively. A total of 15 hard coral species were observed *Acropora intermedia, A. formosa, A.cyhterea, Montiopora digitata, Turbinaria peltata, Platgyra lamellina, Favia favus* and *Porites lutea* were the most commonly observed coral species. Similarly low density of coral recruits was recorded with a mean value of 3.85 m^{-2} and density ranged between 1.86 and 6.02 m^{-2} in the observed grids (Table 21). Few coral health issues were observed in this zone and among the coral health issue types, Macroalgae competition, Sponge Competition, Invetibrate Gall, White syndrome, Growth Anomaly, Focal Bleaching, Worm infestation and Fish predation were observed with the mean prevalence of 6.60% (Table 21).

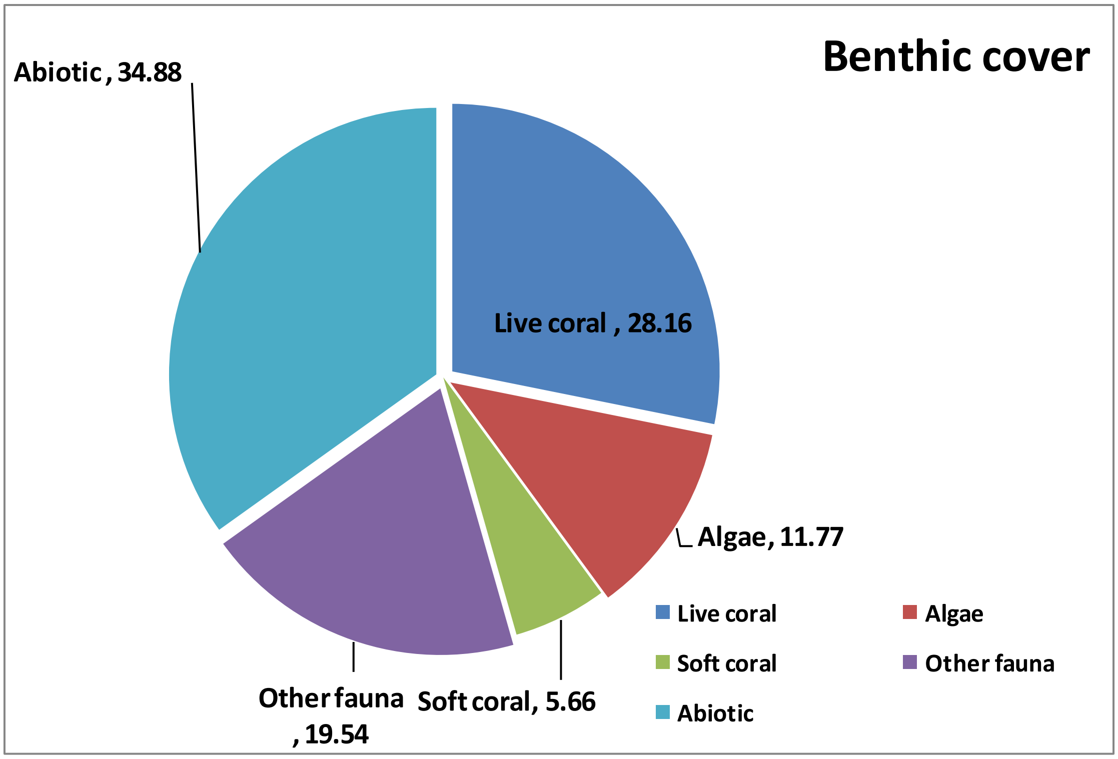

Fig.23. Mean % cover of benthic community structures in Zone 4

Table 20: % cover of benthic community structures in Zone 4

	G 53	G 55	G 56	G 60	G 61	G 62
Live coral (%)	28.15	16.09	13.47	33.62	46.38	31.24
Algae (%)	13.24	14.22	8.63	11.47	6.92	16.11
Soft coral (%)	4.11	2.98	0.91	13.28	9.68	2.98
Other fauana (%)	16.35	24.18	11.36	29.66	16.35	19.36
Abiotic (%)	38.15	42.53	65.63	11.97	20.67	30.31

Table 21: Coral parameters in Zone 4

	G 53	G 55	G 56	G 60	G 61	G 62
Coral species richness (no)	11	13	7	20	23	17
Coral recruitment density (m^{-2})	2.08	2.47	1.86	5.87	6.02	4.82
Coral health issues	2.36	1.98	0.76	9.64	13.21	11.65

Macrofaunal community

Five major macro faunal groups were observed in this zone. Mean density was 15.28 $5m^2$ and density ranged between 0.53 and 30.99 $5m^2$ (Fig. 24 & Table 22). Among the macro faunal community, Echinoderms were dominant with 6.04 $5m^2$ followed by Ascidian with 2.64 $5m^2$. Greater density was observed in G 65 with 30.99 followed by G 61 with 27.74 $5m^2$ respectively (Fig. 25).

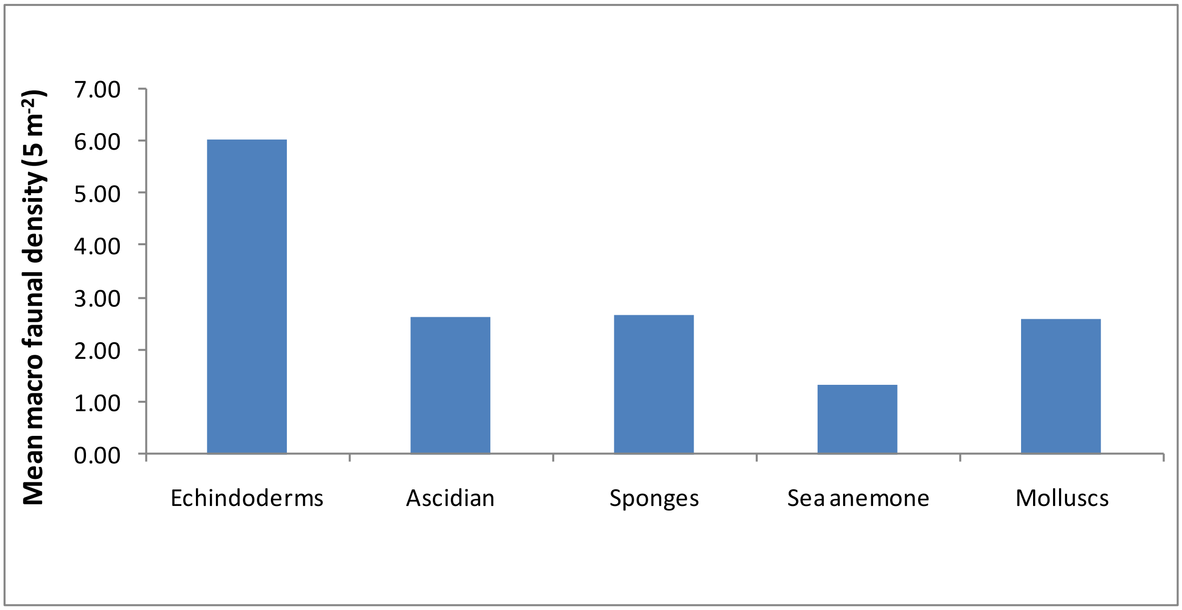

Fig.24. Mean macro faunal group density in Zone 4

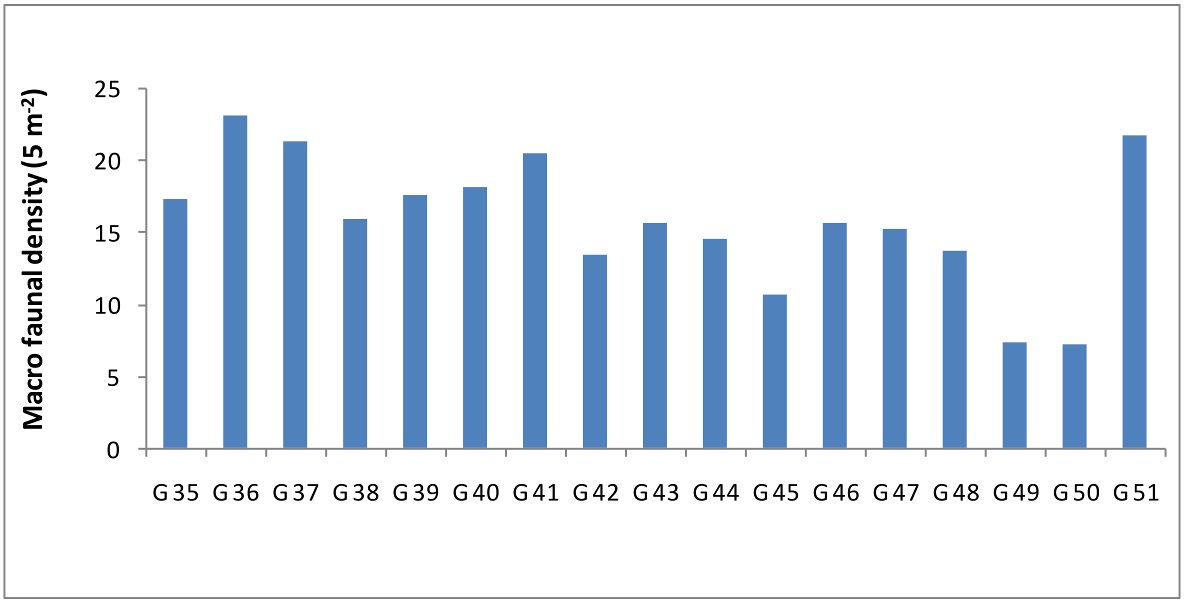

Fig.25 Mean macro faunal density in Zone 4

Table 22: Total macro faunal group density in Zone 4

	G 52	G 53	G 54	G 55	G 56	G 57	G 58	G 59	G 60	G 61	G 62	G 63	G 64	G 65	G 66	G 67
Echindoderms	0.36	3.15	0.68	2.04	1.05	0.59	5.98	0.31	2.01	4.25	6.15	9.86	15.24	17.62	13.59	13.75
Ascidian	1.01	3.65	0	3.15	3.22	0	1.25	0	5.98	7.92	4.25	2.72	2.99	2.14	1.86	2.15
Sponges	0.86	6.22	0.55	2.15	2.78	0	0.42	0	3.44	9.68	3.98	3.48	1.63	2.89	2.44	2.05
Sea anemone	0	0	0.86	0.44	0	0.9	3.25	0.22	0.12	0	1.09	1.36	2.99	5.98	2.56	1.36
Molluscs	1.52	3.48	2.14	1.96	0.36	1.63	1.89	0	1.98	5.89	5.63	3.65	1.89	2.36	3.65	3.77

Fish community structure

A total of 1579 fish individuals were counted from the grids of this zone. Among the 16 grids, highest fish abundance was found to be in G 62 with 221 60/m^2 followed by G 65 with 191 60/m^2 respectively. A total of 26 fish species were recorded in this zone, among them, *Lutjanus* Sp.and *Stongylura strongylura* were the most dominant fishes with the mean abundance of 10.06 and 8.63 60/m^2 respectively (Table 23). Among the grids, the maximum number of species was sighted in G 62 with 25 and low species richness was recorded in G 57 and G 59 sites with 4 numbers respectively (Table 24). Shannon diversty (H’) value was ranged between 1.21 and 3.03 with the mean value of 2.17 during the survey period.

Table 23: Fish abundance in Zone-4

Fish abundance	G 52	G 53	G 54	G 55	G 56	G 57	G 58	G 59	G 60	G 61	G 62	G 63	G 64	G 65	G 66	G 67	Mean abundance
Stongylura strongylura	0	0	0	0	0	0	16	0	0	0	15	20	26	23	18	20	8.63
Alepes djedaba	0	0	0	0	0	0	3	0	0	0	8	8	10	13	15	10	4.19
Sardinella sp.	0	0	0	0	0	0	0	0	0	0	18	25	28	35	15	0	7.56
Upeneus sulphurens	0	3	0	0	0	3	7	0	0	0	10	12	8	0	6	4	3.31
Lactoria cornuta	0	0	0	0	0	0	3	4	0	0	3	3	5	0	0	0	1.13
Sphyraena obtusata	0	0	0	0	0	0	5	0	0	0	8	18	23	15	0	6	4.69
Lutjanus sp.	6	6	0	0	4	7	10	13	5	7	16	20	16	23	18	10	10.06
Mugil cephalus	0	0	8	0	0	0	5	0	0	0	7	16	12	18	0	6	4.50
Terapon puta	0	0	0	0	0	0	2	0	0	3	5	10	18	20	14	9	5.06
Amphiprion sp.	0	0	0	0	0	0	0	0	0	0	3	2	4	0	2	2	0.81
Siganus javus	3	0	8	0	0	3	8	0	0	0	4	8	12	10	6	5	4.19
Caranx para	5	0	6	0	0	0	6	5	0	0	2	10	15	19	5	3	4.75
Acanthurus lineatus	0	6	0	5	3	0	0	0	6	10	8	0	0	0	0	0	2.38
Balistoides viridescens	0	3	0	2	3	0	0	0	3	6	4	0	0	0	0	0	1.31
Chaetodon sp.	0	15	0	10	8	0	0	0	16	19	20	0	0	0	0	0	5.50
Sargocentron rubrum	0	6	0	3	5	0	0	0	7	9	10	0	0	0	0	0	2.50
Bathygobius laddi	0	3	0	0	0	0	0	0	3	5	0	3	0	0	0	0	0.88
Thalassoma lunare	0	7	3	5	3	0	0	0	4	8	5	0	0	0	0	0	2.19
Leiognathus sp.	3	5	0	2	4	3	6	3	9	13	6	0	5	10	5	8	5.13
Paraupeneus indicus	0	8	0	3	2	0	0	0	5	10	7	5	0	0	0	0	2.50
Pempheris vanicolensis	0	6	0	9	5	0	0	0	3	6	18	0	0	0	0	0	2.94
Pomacanthus imperator	0	3	0	0	2	0	0	0	0	2	3	0	0	0	0	0	0.63
Abudefduf saxitalis	0	26	0	13	10	0	0	0	18	26	20	0	0	0	0	0	7.06
Scarus ghibbus	5	8	6	4	3	0	0	0	6	14	10	0	0	0	0	0	3.50
Epinephelus malabaricus	0	5	0	2	6	0	0	0	3	5	8	0	0	5	2	5	2.56
Scolopsis vosmeri	0	0	0	2	0	0	0	0	2	0	3	5	0	0	0	0	0.75
Total abundance (60 m^2)	22	110	31	60	58	16	71	25	90	143	221	165	182	191	106	88	

Table 24: Fish diversity indices in Zone-4

Sample	No. of species (S)	Diversity (H')	Species richness (D)	Eveness (J)
G 35	13	2.42	2.42	0.94
G 36	13	2.35	2.55	0.92
G 37	13	2.37	2.49	0.92
G 38	13	2.37	2.44	0.92
G 39	23	2.89	4.19	0.92
G 40	23	2.93	3.96	0.93
G 41	25	2.98	4.33	0.92
G 42	20	2.74	3.93	0.92
G 43	19	2.70	3.70	0.92
G 44	20	2.63	3.90	0.88
G 45	11	2.18	2.10	0.91
G 46	13	2.35	2.47	0.92
G 47	12	2.29	2.25	0.92
G 48	13	2.38	2.43	0.93
G 49	23	2.90	4.18	0.92
G 50	21	2.91	4.05	0.95
G 51	13	2.32	2.54	0.90
Mean value =	16.94	2.57	3.17	0.92

ZONE -5

In this zone, totally 8 grids are dominated by seagrass meadows; 5 grids were occupied with reef habitat and 4 grids are represented as sandy bottom.

Seagrass habitat

In zone-5, the mean percentage cover of seagrass meadows was 29.02% with a patchy sparse cover. The maximum cover was observed in G 70 with 42.36% followed by G 68 with 41.25% respectively (Fig. 26). A total of seven seagrass species were recorded, among them, *Thalassia hemprichii* and *Cymodocea serrulata* were the dominant species.

Mean shoot density was recorded as 261.50 m^{-2} and highest mean shoot density was found to be in *Thalassia hemprichii* and *Cymodocea serrulata* with 89.91 and 59.26 m^{-2} respectively (Fig. 27). Among the grids in Zone-5, highest shoot density was recorded in G 70 and G 68 with the value of 389.26 and 362.03 m^{-2} respectively (Fig. 28 & Table 25).

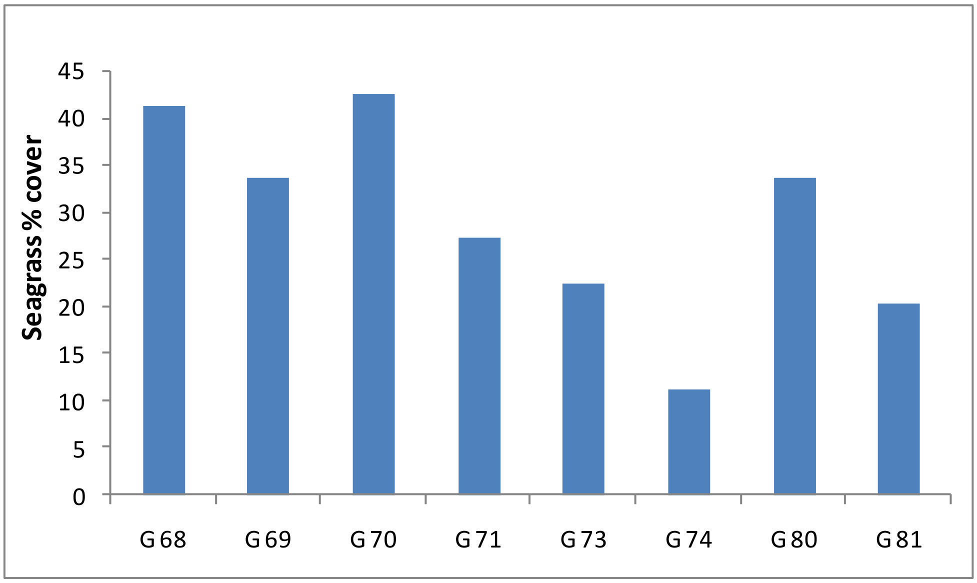

Fig.26. Seagrass percentage covers in Zone-5

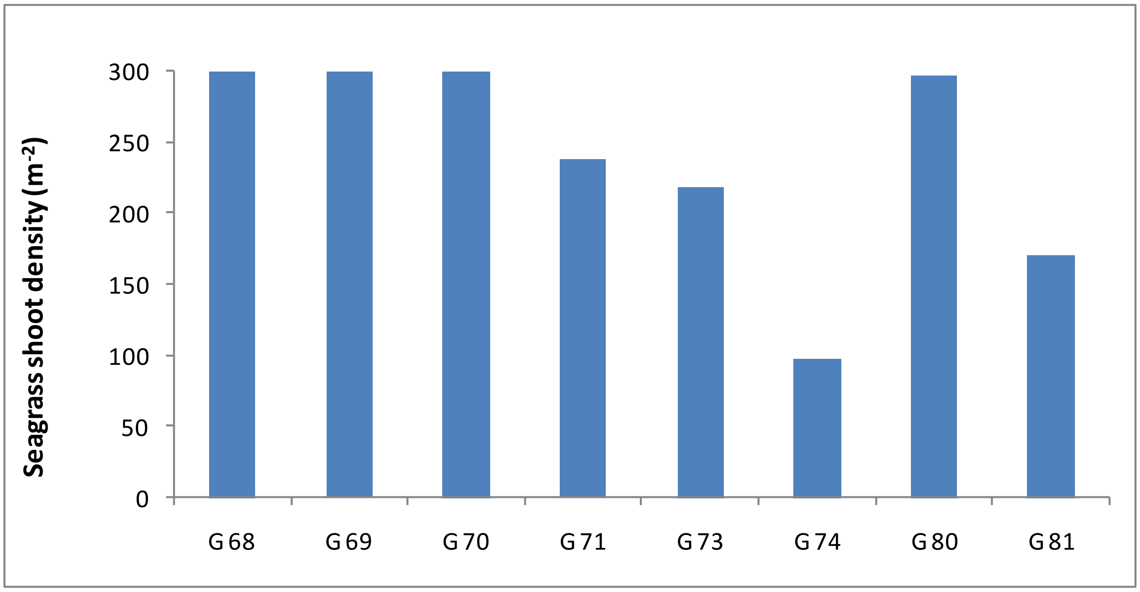

Fig.27. Mean species seagrass shoot density in Zone-5

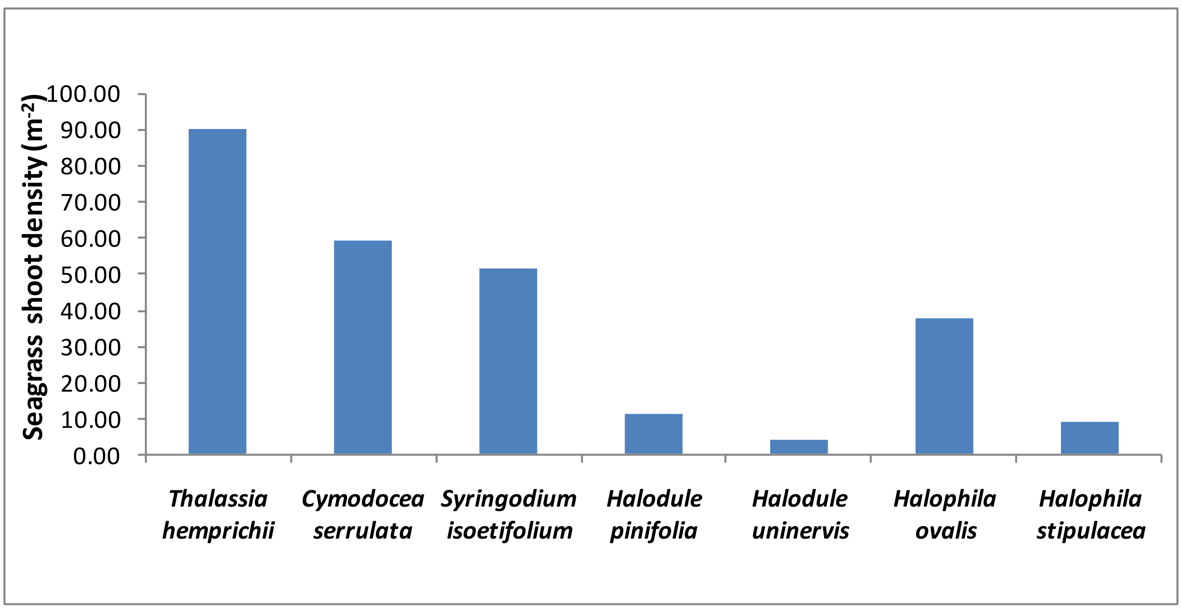

Fig.28. Mean species seagrass shoot density in Zone-5

Table 25: Seagrass species shoot density in Zone-5

	G 68	G 69	G 70	G 71	G 73	G 74	G 80	G 81
Thalassia hemprichii	125.32	86.52	145.75	75.65	65.85	45.32	142.32	32.54
Cymodocea serrulata	100.25	75.55	15.69	65.84	52.36	35.69	52.84	75.85
Syringodium isoetifolium	75.32	35.65	85.65	85.32	45.52	4.69	41.25	36.98
Halodule pinifolia	15.26	14.84	45.69	0	0	0	11.55	0
Halodule uninervis	0	15.65	14.68	0	0	0	0	0
Halophila ovalis	45.88	74.45	42.98	11.52	54.54	11.65	33.85	25.65
Halophila stipulacea	0	15.32	38.82	0	0	0	15.98	0

Coral reef habitat

The mean live coral cover of this zone was 26.3% and coral habitat was seen as few minor and dense patches. Among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 39.75% (Fig. 29 & Table 26). The highest coral cover was observed in G 74 with 36.92% followed by 31.59% at G 73 respectively. A total of 11 hard coral species were observed, among them *Acropora cytherea, Turbinaria peltata* and *Porites solida* was the commonly observed coral species. Similarly fair amount of coral recruit density was recorded with a mean value of 2.9 m^{-2} and density ranged between 1.02 and 4.63 m^{-2} in the observed grids (Table 27). Few coral health issues were observed in this zone and among the coral health issue types, Macroalgae competition, Sponge Competition, Invertebrate Gall, White syndrome, Growth Anomaly, Focal Bleaching, Worm infestation and Fish predation were observed with the mean prevalence of 6.58% (Table 27).

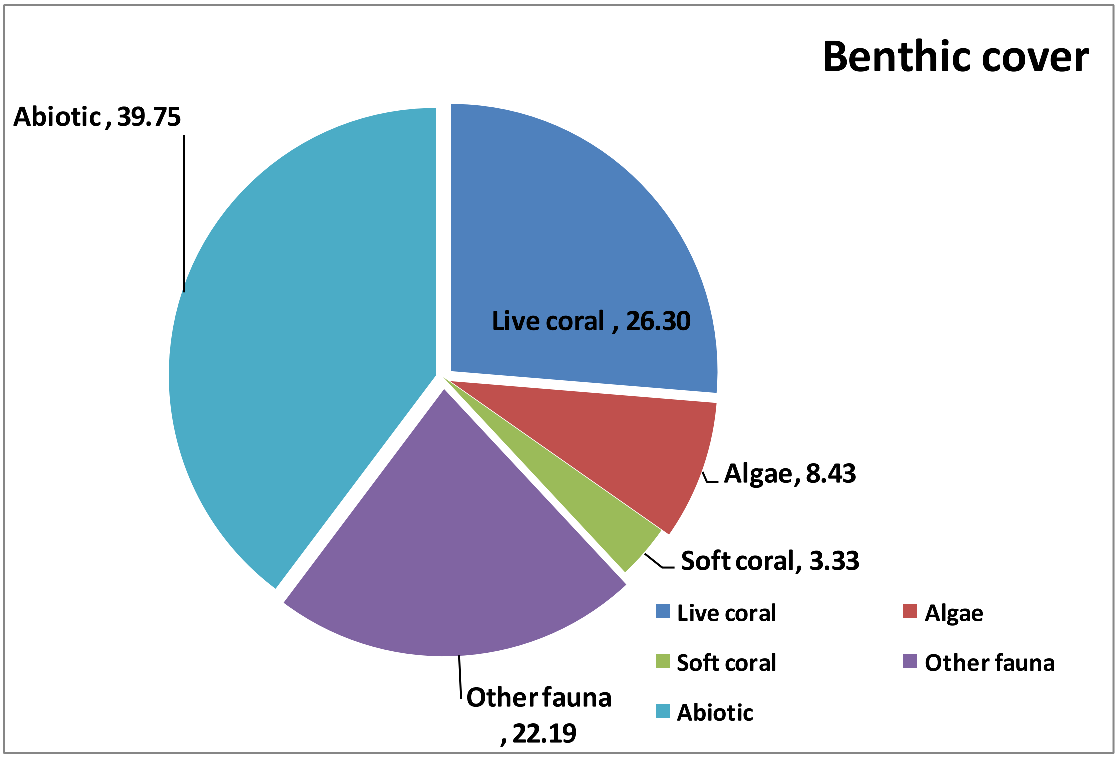

Fig.29. Mean % cover of benthic community structures in Zone-5

Table 26: % cover of benthic community structures in Zone-5

	G 73	G 74	G 75	G 76	G 78
Live coral (%)	31.59	36.92	21.96	27.08	13.96
Algae (%)	5.98	7.15	6.98	13.36	8.69
Soft coral (%)	1.68	6.48	4.89	0	3.59
Other fauana (%)	19.68	26.35	24.52	19.36	21.05
Abiotic (%)	41.07	23.1	41.65	40.2	52.71

Table 27: Coral parameters in Zone 5

	G 73	G 74	G 75	G 76	G 78
Coral species richness (no)	15	19	8	11	4
Coral recruitment density (m^{-2})	3.95	4.63	2.15	2.76	1.02
Coral health issues	11.36	13.25	4.26	2.77	1.27

Macrofaunal community

Five major macro faunal groups were observed in this zone. Mean density was 8.81 $5m^2$ and density ranged between 0.84 and 17.13 $5m^2$ (Fig. 30 & Table 28). Among the macro faunal community, Echinoderms were dominant with 3.66 $5m^2$ followed by Molluscs with 1.68 $5m^2$. In the observed grids, G 73 exhibits greater density with 17.13 followed by G 74 with 16.79 $5m^2$ (Fig. 31).

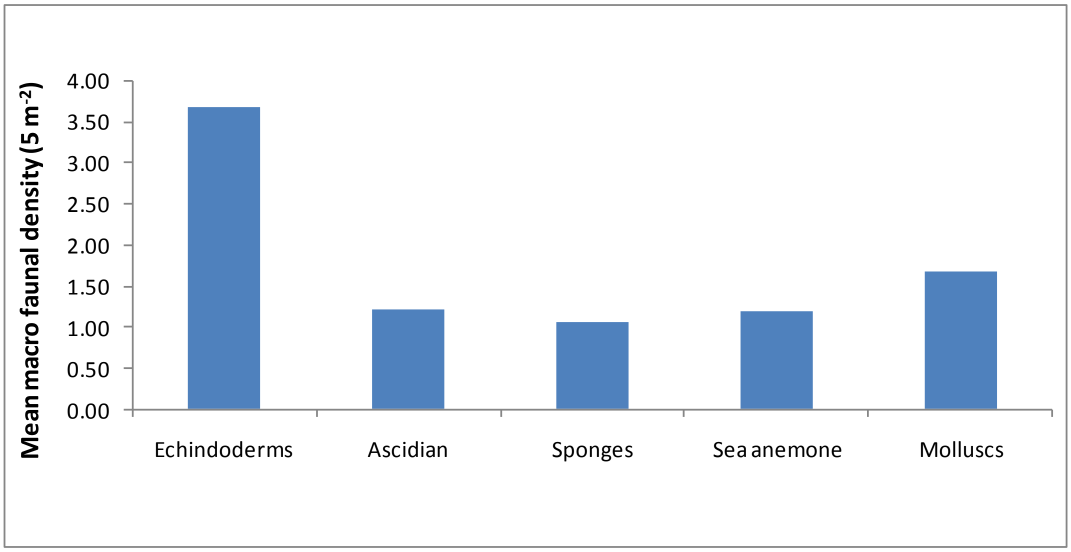

Fig.30. Mean macro faunal group density in Zone-5

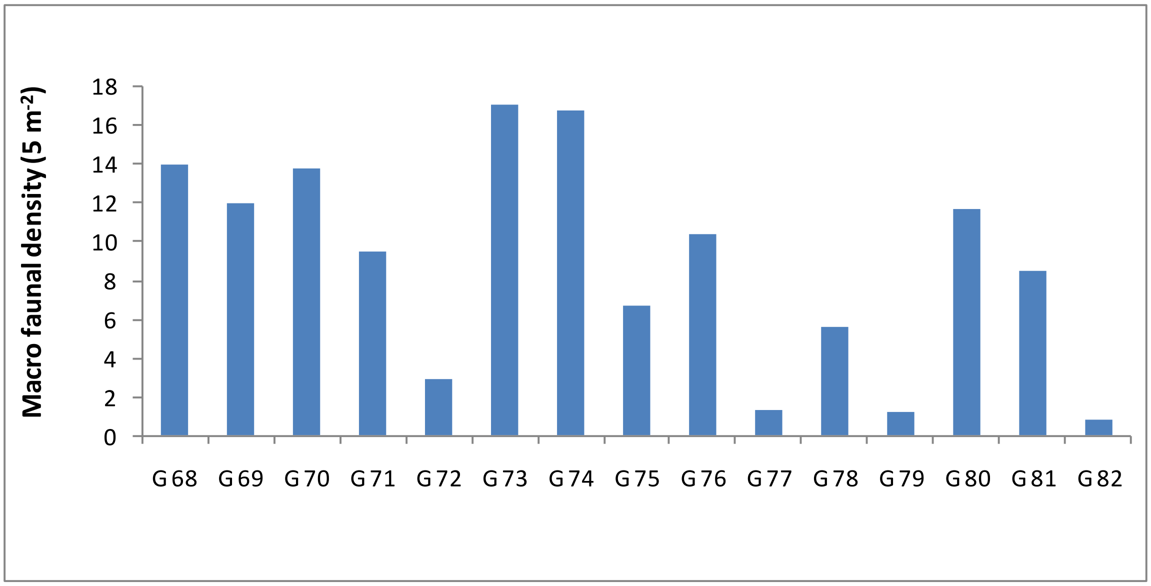

Fig.31. Mean macro faunal density in Zone-5

Table 28: Total macro faunal group density in Zone-5

Macro fauna no/ 5 m^2	G 68	G 69	G 70	G 71	G 72	G 73	G 74	G 75	G 76	G 77	G 78	G 79	G 80	G 81	G 82
Echindoderms	7.62	5.98	6.92	4.96	0.86	7.22	5.93	1.25	1.96	0.63	0.89	0.33	5.96	4.02	0.44
Ascidian	0.63	0.11	0.48	0.26	0	3.56	2.98	3.15	4.25	0	1.53	0.61	0.16	0.29	0.22
Sponges	0.47	0.88	0.16	0.31	0.91	2.05	3.11	1.36	2.51	0	2.98	0	0.81	0.41	0
Sea anemone	2.1	1.36	2.05	1.06	0	3.14	2.88	0.18	0	0.21	0	0.11	2.65	1.98	0.18
Molluscs	3.19	3.68	4.15	2.87	1.16	1.16	1.89	0.76	1.66	0.42	0.16	0.16	2.11	1.78	0

Fish community structure

A total of 1665 fish individuals were counted along all the observed grids in this zone. Among the 15 grids, highest fish abundance was found to be in G 73 with 203 60/m^2 followed by G 69 with 171 60/m^2 respectively (Table 29). Totally 25 fish species were recorded in this Zone, among them, *Sardinella* Sp. and *Lutjanus* Sp. were the most dominant fishes with the mean abundance of 11.20 and 11.0 60/m^2 respectively. Among the grids, the maximum number of species was sighted in G 73 with 25 and low species richness was recorded in G 82 with 4 numbers respectively (Table 30). Shannon diversty (H’) value was ranged between 1.36 and 3.04 with the mean value of 2.31 during the survey period.

Table 29: Fish abundance in Zone-5

	G 68	G 69	G 70	G 71	G 72	G 73	G 74	G 75	G 76	G 77	G 78	G 79	G 80	G 81	G 82	Mean abundance
Stongylura strongylura	16	22	19	23	0	15	8	0	0	0	5	0	6	10	0	8.27
Alepes djedaba	9	6	13	10	0	12	8	0	0	0	8	0	11	13	0	6.00
Sardinella sp.	20	26	23	16	0	10	0	0	0	0	18	0	20	35	0	11.20
Upeneus sulphurens	10	8	13	8	0	12	13	0	0	0	15	0	11	16	0	7.07
Lactoria cornuta	4	6	0	4	0	6	4	2	0	0	3	0	8	4	0	2.73
Sphyraena obtusata	19	26	16	11	0	16	10	0	0	0	5	0	16	18	0	9.13
Lutjanus sp.	23	18	20	16	6	6	16	0	0	4	16	5	10	15	10	11.00
Mugil cephalus	18	15	16	10	0	12	8	0	0	0	7	0	15	12	0	7.53
Terapon puta	15	9	13	5	0	6	5	0	0	2	5	0	10	13	0	5.53
Amphiprion sp.	0	2	0	3	0	2	0	0	0	0	3	0	3	2	0	1.00
Siganus javus	5	15	10	0	0	8	10	0	0	0	4	0	8	13	6	5.27
Caranx para	16	10	13	10	6	5	0	6	0	3	2	6	10	8	0	6.33
Acanthurus lineatus	0	0	0	0	0	8	5	2	5	0	0	0	0	0	0	1.33
Chaetodon sp.	0	0	0	0	0	10	16	8	10	0	6	0	0	0	0	3.33
Sargocentron rubrum	0	0	0	0	0	3	5	2	0	0	3	0	0	0	0	0.87
Bathygobius laddi	2	0	0	0	0	3	0	2	5	0	0	5	0	0	0	1.13
Thalassoma lunare	0	0	3	0	0	5	4	5	3	0	0	0	0	0	0	1.33
Leiognathus sp.	0	3	0	6	4	10	8	2	6	4	5	0	3	6	8	4.33
Paraupeneus indicus	4	0	0	3	0	6	3	4	8	0	3	4	0	0	0	2.33
Pempheris vanicolensis	0	0	0	0	0	16	13	5	6	0	10	0	0	0	0	3.33
Pomacanthus imperator	0	0	0	0	0	2	3	2	0	0	0	0	0	0	0	0.47
Abudefduf saxitalis	0	0	0	0	0	20	16	11	13	0	10	0	0	0	0	4.67
Scarus ghibbus	0	0	6	5	6	3	2	5	4	0	2	0	0	0	0	2.20
Epinephelus malabaricus	0	0	0	0	3	5	8	3	2	2	4	2	4	2	6	2.73
Scolopsis vosmeri	4	5	0	0	0	2	0	6	3	3	2	3	0	0	0	1.87

Total abundance (60 m2)	165	171	165	130	25	203	165	65	65	18	136	25	135	167	30	

Table 30: Fish diversity indicesin Zone-5

Sample	No. of species (S)	Diversity (H')	Species richness (D)	Eveness (J)
G 68	14	2.45	2.55	0.93
G 69	14	2.43	2.53	0.92
G 70	12	2.40	2.15	0.96
G 71	14	2.47	2.67	0.94
G 72	5	1.58	1.24	0.98
G 73	25	3.04	4.52	0.94
G 74	20	2.85	3.72	0.95
G 75	15	2.55	3.35	0.94
G 76	11	2.27	2.40	0.94
G 77	6	1.75	1.73	0.98
G 78	21	2.82	4.07	0.93
G 79	6	1.74	1.55	0.97
G 80	14	2.51	2.65	0.95
G 81	14	2.42	2.54	0.92
G 82	4	1.36	0.88	0.98
Mean value =	13	2.31	2.57	0.95

ZONE -6

In zone-6, seagrass meadows were found in 3 grids; coral reef habitats were observed in 5 grids and reaming 5 grids were occupied with sandy bottom.

Seagrass habitat

In zone-6, scattered seagrass meadows were found and mean percentage cover was 19.30%. The maximum cover was observed in G 83 with 22.32% followed by G 93 with 21.32% respectively (Fig. 32). A total of four seagrass species were recorded, among them, *Syringodium isoetifolium* and *Halophila ovalis* were the dominant species.

Mean shoot density was recorded as 205.76 m^{-2} and highest mean shoot density was found to be in *Syringodium isoetifolium* and *Halophila ovalis* with 55.41 and 54.32 m^{-2} respectively (Fig. 33). Among the grids in this zone, highest shoot density was recorded in G 93 and G 83 with the value of 227.1 and 219.39 m^{-2} respectively (Fig. 34 & Table 31).

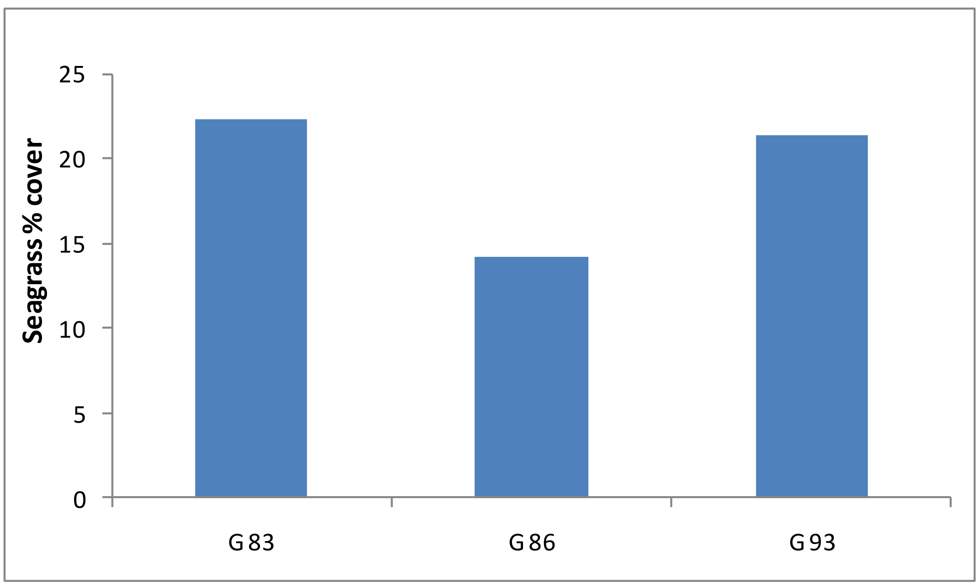

Fig.32. Seagrass percentage covers in Zone-6

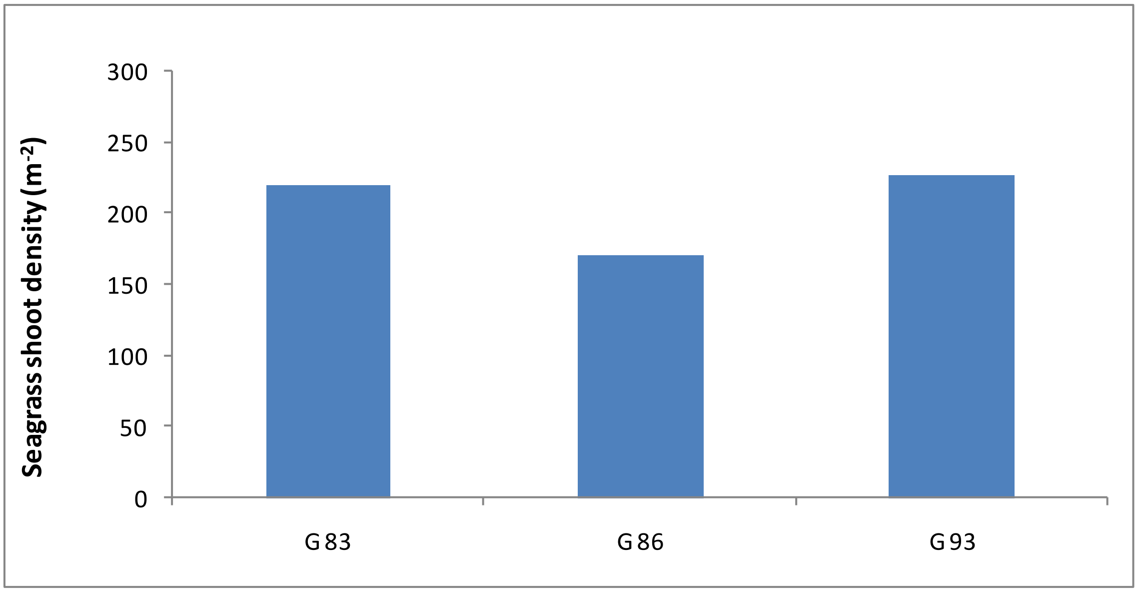

Fig.33. Mean species seagrass shoot density in Zone-6

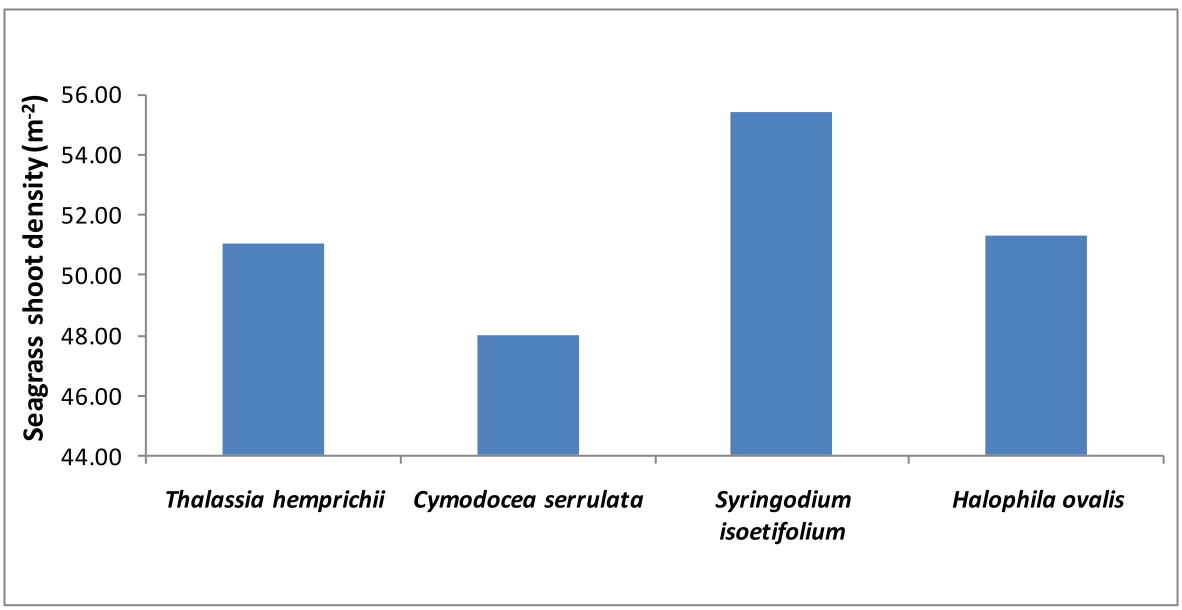

Fig.34. Mean species seagrass shoot density in Zone-6

Table 31: Seagrass species shoot density in Zone 6

	G 83	G 86	G 93
Thalassia hemprichii	65.98	41.25	45.85
Cymodocea serrulata	45.68	52.63	45.69
Syringodium isoetifolium	55.41	41.25	69.58
Halophila ovalis	52.32	35.65	65.98

Coral reef habitat

Few grids only coral reef patches were seen in this zone with a mean live coral of 16.61% and among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 46.45% (Fig. 35 & Table 32). The highest coral cover was observed in G 89 with 21.05% followed by 18.34% at G 92 respectively. A total of 6 hard coral species were observed, in which *Acropora formosa* and *Turbinaria mesnteria* are the most commonly observed species. Similarly low density of coral recruits was recorded with a mean value of 3.42 m^{-2} and density ranged between 2.63 and 4.11 m^{-2} in the observed grids (Table 33). Few coral health issues were observed in this zone and among the Coral health issue types, Macroalgae competition, Sponge Competition, Focal Bleaching, Worm infestation and Fish predation were observed with the mean prevalence of 4.35% (Table 33).

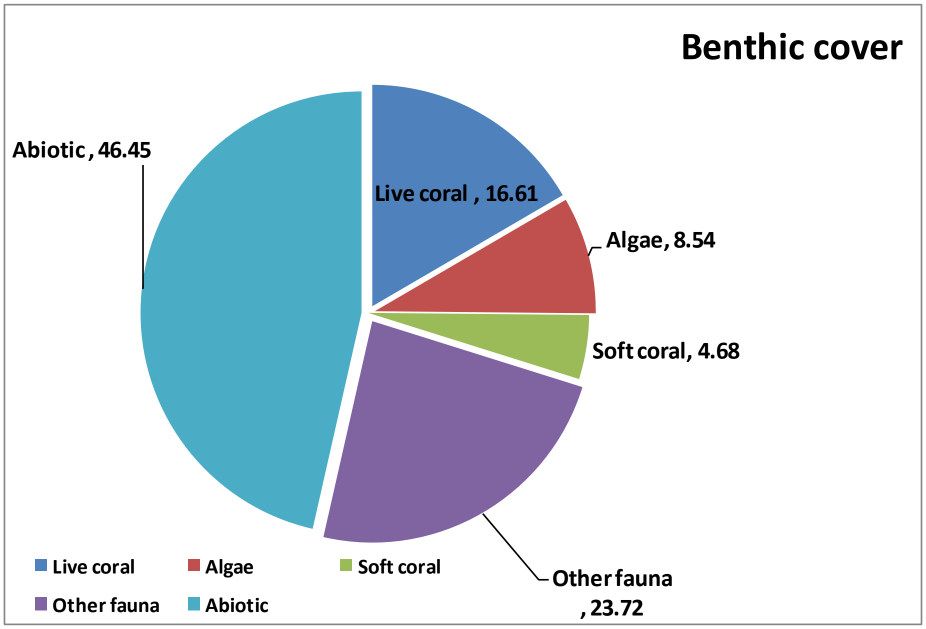

Fig.35. Mean % cover of benthic community structures in Zone-6

Table 32: % cover of benthic community structures in Zone-6

	G 85	G 89	G 90	G 92	G 94
Live coral (%)	13.48	21.05	16.96	18.34	13.21
Algae (%)	6.35	8.15	12.44	9.86	5.92
Soft coral (%)	1.98	3.11	5.48	6.47	6.35
Other fauana (%)	20.36	27.15	26.99	23.45	20.66
Abiotic (%)	57.83	40.54	38.13	41.88	53.86

Table 33: Coral parameters in Zone-6

	G 85	G 89	G 90	G 92	G 94
Coral species richness (no)	4	8	7	6	5
Coral recruitment density (m^{-2})	3.65	3.86	2.63	4.11	2.86
Coral health issues	3.99	5.36	4.44	4.06	3.89

Macrofaunal community

Five major macro faunal groups were observed in this zone. Mean density was 7.19 $5m^2$ and density ranged between 0.89 and 12.5 $5m^2$ (Fig. 36 & Table 34). Among the macro faunal community, Echinoderms were dominant with 2.00 $5m^2$ followed by Ascidian with 1.75 $5m^2$. In the grids, greater density was observed in G 83 with 12.5 followed by G 93 with 11.42 $5m^2$ (Fig. 37).

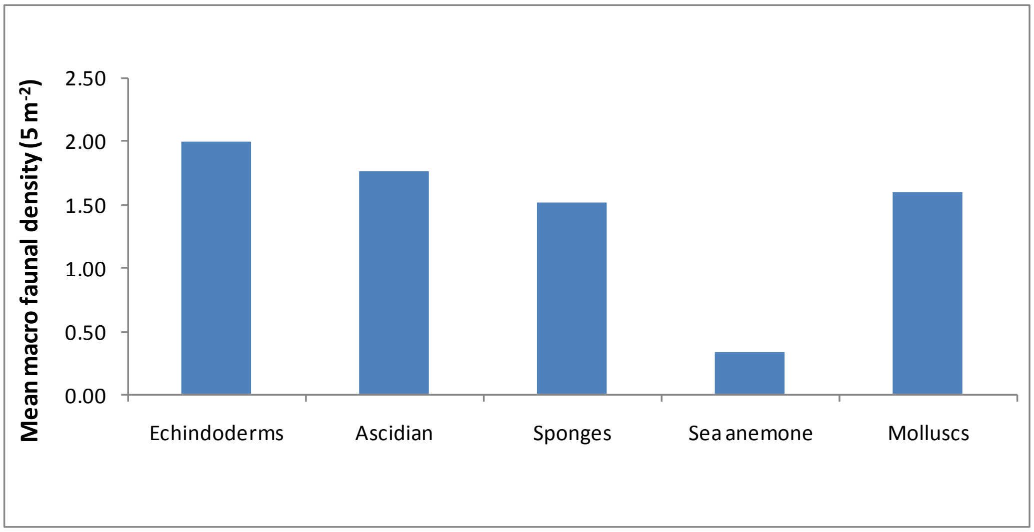

Fig.36. Mean macro faunal group density in Zone-6

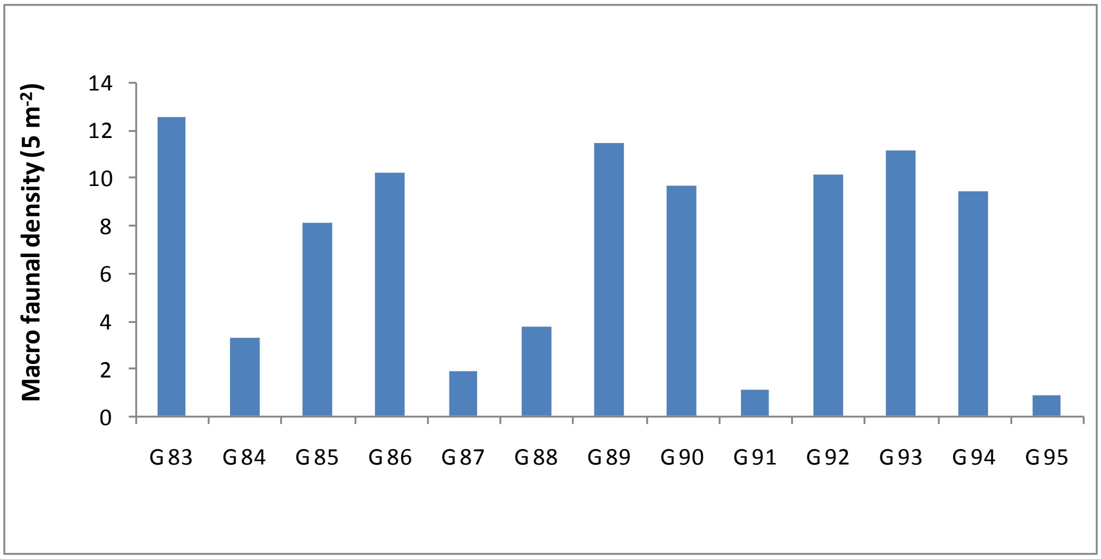

Fig.37. Mean macro faunal density in Zone-6

Table 34: Total macro faunal group density in Zone-6

Macro fauna no/ 5 m^2	G 83	G 84	G 85	G 86	G 87	G 88	G 89	G 90	G 91	G 92	G 93	G 94	G 95
Echinoderms	6.92	0.36	1.36	4.15	0.96	0.77	1.36	2.11	0.86	1.02	4.68	1.06	0.36
Ascidian	1.25	0	3.25	1.25	0	1.11	4.06	3.15	0.26	3.63	1.36	3.45	0
Sponges	0	1.02	2.15	0.69	0.78	0.28	3.47	2.99	0	2.86	2.1	2.92	0.32
Sea anemone	1.35	0.66	0	1.22	0.16	0	0.36	0	0	0.16	0.33	0.13	0
Molluscs	2.98	1.24	1.36	2.86	0	1.55	2.17	1.36	0	2.47	2.69	1.86	0.21

Fish community structure

A total of 729 fish individuals were counted along all the observed grids in this zone. Among the 13 grids, highest fish abundance was found to be in G 93 with 105 60/m^2 followed by G 83 with 102 60/m^2 respectively (Table 35). A total of 24 fish species were recorded in this zone, among them, *Lutjanus* Sp.and *Caranx para*were the most dominant fishes with the mean abundance of 5.85 and 4.31 60/m^2 respectively. Among the grids, the maximum number of species was sighted in G 83, G 86 and G 89 with 15 and low species richness was recorded in G 84 and 91 site with 4 numbers respectively (Table 36). Shannon diversty (H') value was ranged between 1.33 and 2.61 with the mean value of 2.18 during the survey period.

Table 35: Fish abundance in Zone-6

Fish abundance	G 83	G 84	G 85	G 86	G 87	G 88	G 89	G 90	G 91	G 92	G 93	G 94	G 95	Mean abundance
Stongylura strongylura	12	0	0	6	0	0	0	0	0	0	15	0	6	3.00
Alepes djedaba	3	0	0	4	0	0	0	0	0	0	10	0	0	1.31
Sardinella sp.	15	0	0	10	0	0	0	0	0	0	8	0	0	2.54
Upeneus sulphurens	6	0	0	4	0	8	0	0	0	0	10	0	0	2.15
Sphyraena obtusata	10	0	0	5	0	0	0	0	0	0	10	0	0	1.92
Lutjanus sp.	12	5	8	8	6	5	8	0	0	4	9	5	6	5.85
Mugil cephalus	8	0	0	5	0	0	3	0	0	0	10	0	0	2.00
Terapon puta	6	4	2	4	0	0	0	0	0	2	6	0	5	2.23
Amphiprion sp.	2	0	0	3	0	0	0	0	0	0	4	0	0	0.69
Siganus javus	6	0	10	2	0	0	0	0	0	0	2	0	0	1.54
Caranx para	10	0	0	5	5	3	7	6	0	3	8	6	3	4.31
Acanthurus lineatus	0	0	2	0	0	0	8	4	0	3	0	2	0	1.46
Chaetodon sp.	0	0	5	0	0	0	12	4	0	6	0	8	0	2.69
Sargocentron rubrum	0	0	3	0	0	0	6	0	0	3	0	6	0	1.38
Bathygobius laddi	5	0	0	0	0	0	2	3	0	6	0	2	0	1.38
Thalassoma lunare	0	0	5	0	0	0	5	4	0	8	0	3	0	1.92
Leiognathus sp.	0	2	3	4	8	4	3	5	3	5	0	3	4	3.38
Paraupeneus indicus	3	0	5	2	0	0	0	3	6	6	5	2	0	2.46
Pempheris vanicolensis	0	0	6	0	0	0	15	0	0	3	0	8	0	2.46
Pomacanthus imperator	0	0	0	0	0	0	5	5	0	2	0	4	0	1.23
Abudefduf saxitalis	0	0	10	0	0	0	11	9	0	8	0	6	0	3.38
Scarus ghibbus	0	0	4	3	5	3	3	2	3	4	0	3	5	2.69
Epinephelus malabaricus	2	5	2	2	5	2	4	2	5	2	5	2	3	3.15
Scolopsis vosmeri	2	0	2	0	2	0	2	1	0	0	3	0	0	0.92
Total abundance (60 m^2)	102	16	67	67	31	25	94	48	17	65	105	60	32	729.00

Table 36: Fish diversity indices in Zone-6

Sample	No. of species (S)	Diversity (H')	Species richness (D)	Eveness (J)
G 83	15	2.53	3.03	0.93
G 84	4	1.33	1.08	0.96
G 85	14	2.48	3.09	0.94
G 86	15	2.60	3.33	0.96
G 87	6	1.73	1.46	0.96
G 88	6	1.69	1.55	0.94
G 89	15	2.54	3.08	0.94
G 90	12	2.36	2.84	0.95
G 91	4	1.34	1.06	0.97
G 92	15	2.61	3.35	0.96
G 93	14	2.53	2.79	0.96
G 94	14	2.52	3.18	0.95
G 95	7	1.91	1.73	0.98
Mean value =	10.85	2.17	2.43	0.95

ZONE-7

In this zone, 2 grids were occupied by seagrass meadows, 4 grids were occupied by coral reef habitats and 5 grids by sandy bottom.

Seagrass habitat

In zone-7, scattered seagrass meadows were found and mean percentage cover was 11.84%. The maximum cover was observed in G 103 with 12.36% followed by G 98 with 11.32% respectively (Fig. 38). A total of five seagrass species were recorded, among them, *Halodule uninervis* and *Cymodocea serrulata* were the dominant species.

Mean shoot density was recorded as 130 m^{-2} and highest mean shoot density was found to be in *Halodule uninervis* and *Cymodocea serrulata* with 55.13 and 30.29 m^{-2} respectively (Fig. 39). Among the grids in this zone, highest shoot density was recorded in G 98 and G 103 with the value of 136.82 and 123.18 m^{-2} respectively (Fig. 40 & Table 37).

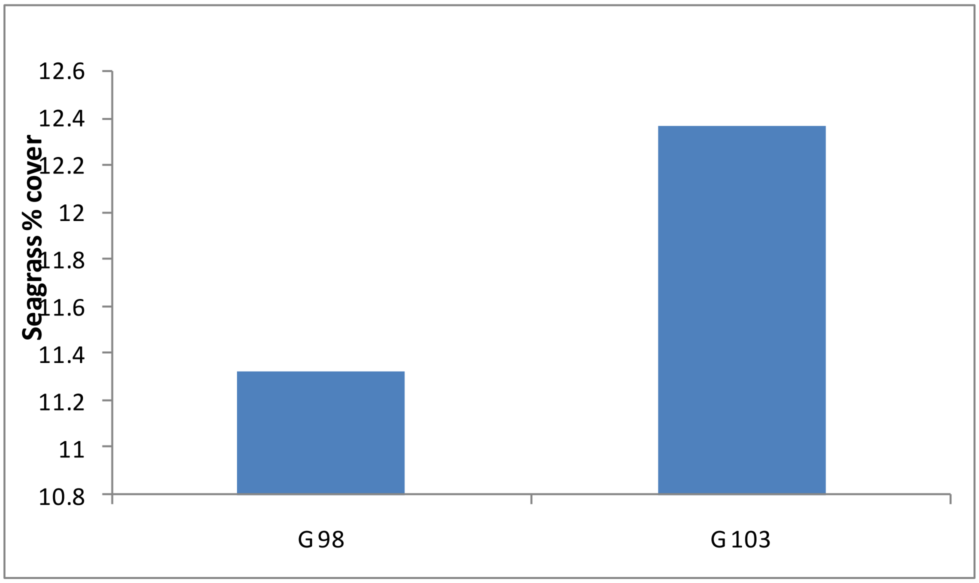

Fig.38. Seagrass percentage covers in Zone-7

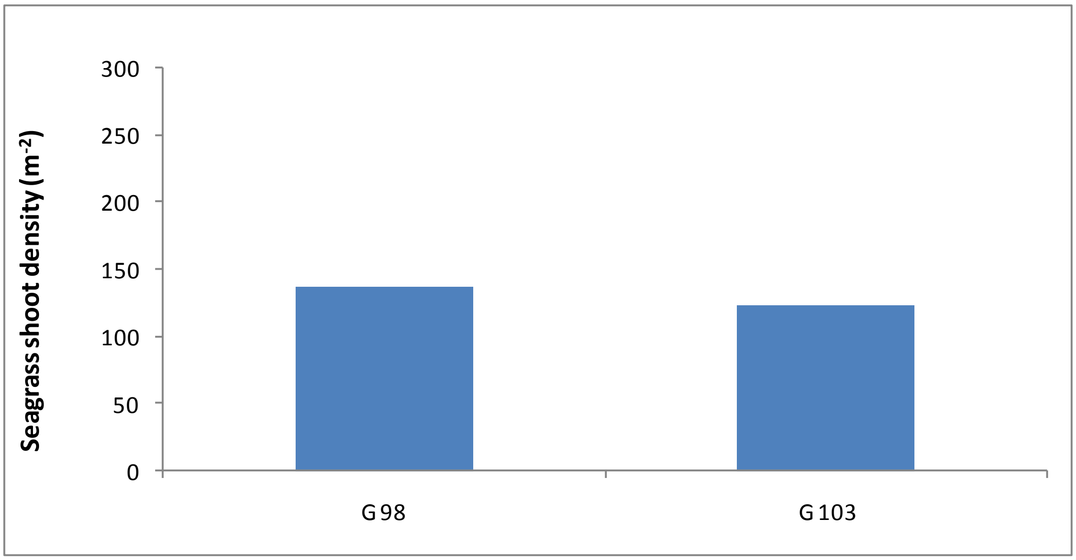

Fig.39. Mean species seagrass shoot density in Zone-7

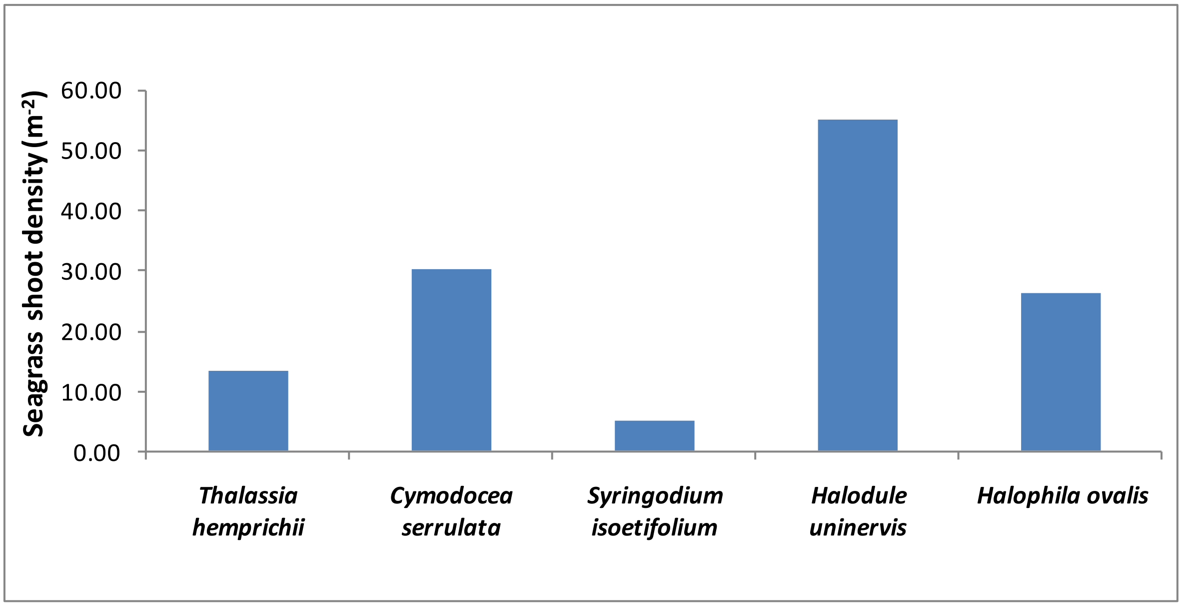

Fig.40. Mean species seagrass shoot density in Zone-7

Table 37: Seagrass species shoot density in Zone-7

	G 98	G 103
Thalassia hemprichii	11.25	15.36
Cymodocea serrulata	15.32	45.25
Syringodium isoetifolium	0	10.25
Halodule uninervis	110.25	0
Halophila ovalis	0	52.32

Coral reef habitat

Patchy sparse coral reef habitat was found in this zone. Mean live coral was 12.23% and among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 50.64% (Fig. 41 & Table 38). The highest coral cover was observed in G 104 with 19.77% followed by 11.42% at G 100 respectively. A total of 5 hard coral and 3 soft coral species were observed *Turninaria mesentrina*, *Suberorgia* and *Sacrophyton* were the most commonly observed coral species. Similarly low density of coral recruits was recorded with a mean value of 2.80 m^{-2} and density ranged between 1.96 and 3.78 m^{-2} in the observed grids (Table 39). Few coral health issues were observed in this zone and among the Coral health issue types, Macroalgae competition, Sponge Competition, Worm infestation, Invertibrate gall and Fish predation were observed with the mean prevalence of 1.77% (Table 39).

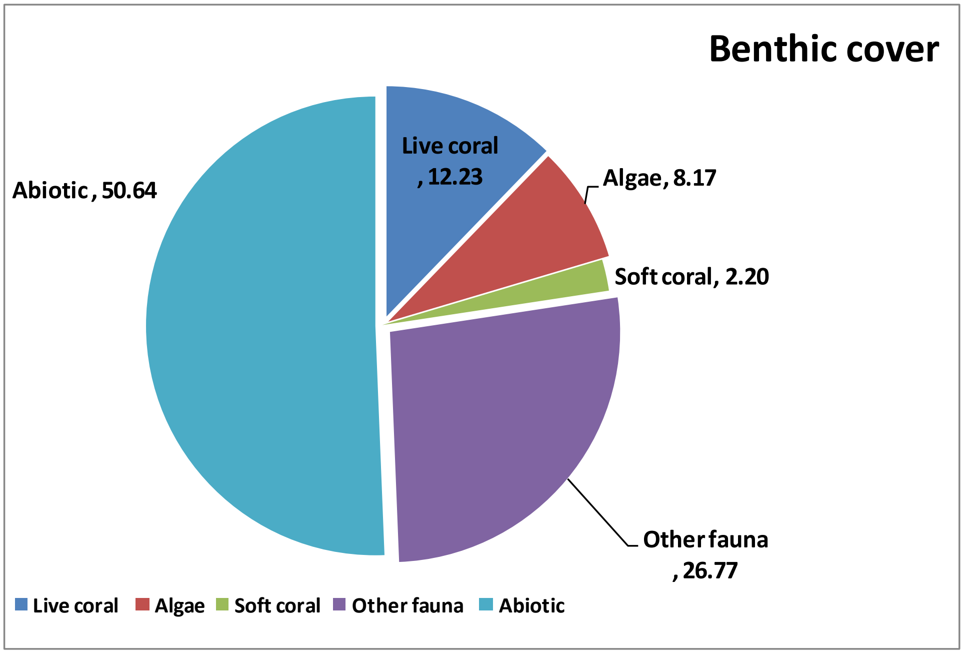

Fig.41. Mean % cover of benthic community structures in Zone-7

Table 38: % cover of benthic community structures in Zone-7

	G 98	G 100	G 102	G 104
Live coral (%)	9.78	11.42	7.96	19.77
Algae (%)	13.62	6.92	4.93	7.19
Soft coral (%)	2.63	2.11	1.41	2.66
Other fauana (%)	26.35	31.99	29.36	19.36
Abiotic (%)	47.62	47.56	56.34	51.02

Table 39: Coral parameters in Zone-7

	G 98	G 100	G 102	G 104
Coral species richness (no)	3	5	4	6
Coral recruitment density (m^{-2})	1.96	2.36	3.11	3.78
Coral health issues	1.89	2.15	1.36	1.66

Macrofaunal community

Five major macro faunal groups were observed in this zone. Mean density was 6.98 $5m^2$ and density ranged between 1.44 and 17.66 $5m^2$ (Fig. 42 & Table 40). Among the macro faunal community, Molluscs were dominant with 2.08 $5m^2$ followed by Sponge with 1.92 $5m^2$. In the observed grids, greater density in G 97 with 1.44 followed by G 98 with 15.88 $5m^2$ (Fig. 43).

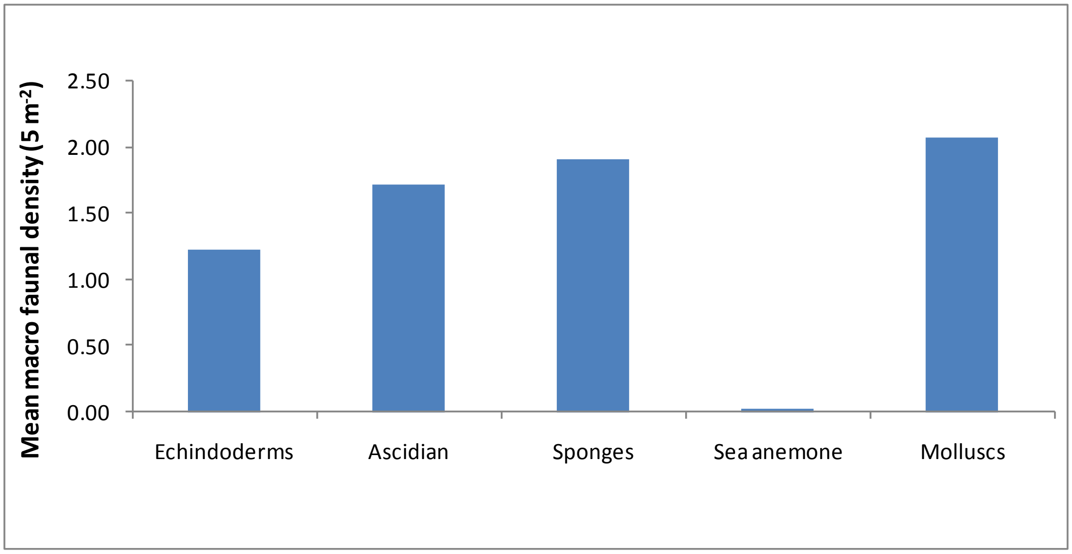

Fig.42. Mean macro faunal group density in Zone-7

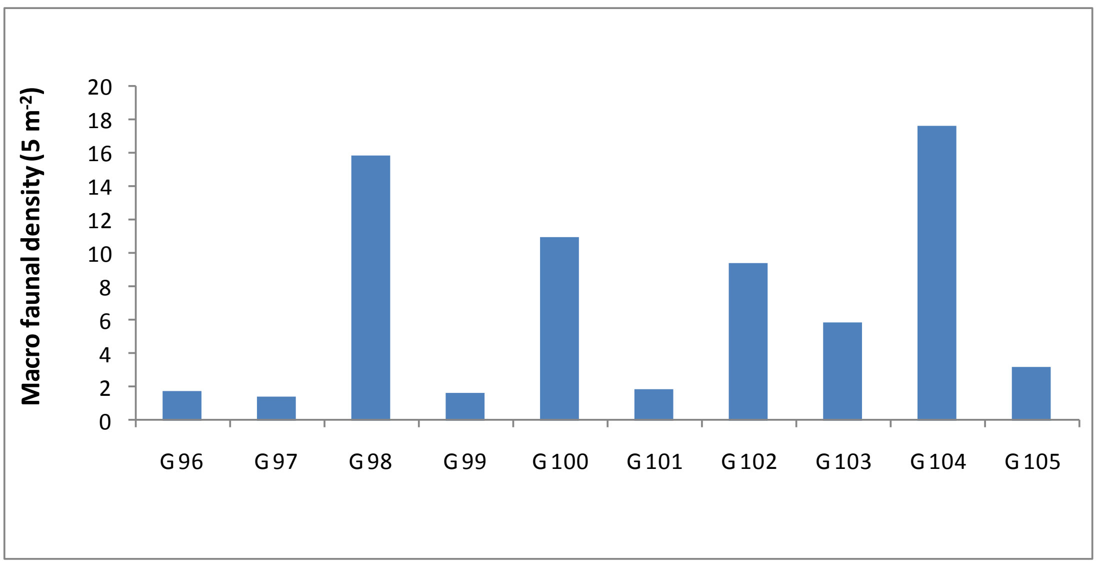

Fig.43. Mean macro faunal density in Zone-7

Table 40: Total macro faunal group density in Zone-7

Macro fauna no/ 5 m^2	G 96	G 97	G 98	G 99	G 100	G 101	G 102	G 103	G 104	G 105
Echindoderms	0.63	0.92	5.16	0.36	1.25	0.51	1.36	0.37	0.69	1.02
Ascidian	0	0.16	3.96	0.08	2.36	0.31	3.15	1.36	5.18	0.69
Sponges	0.11	0	2.47	0.16	4.25	0	2.8	2.45	6.91	0
Sea anemone	0	0	0.33	0	0	0	0	0	0	0
Molluscs	1.02	0.36	3.96	1.09	3.15	1.11	2.11	1.69	4.88	1.46

Fish community structure

A total of 451 fish individuals were counted along the observed grids in this zone. Among the 10 grids, highest fish abundance was found to be in G 98 with 92 60/m^2 followed by G 103,G 104 with 64 60/m^2 respectively (Table 41). A total of 24 fish species were recorded in this zone, among them, *Lutjanus* Sp.and *Leiognathus sp.* were the most dominant fishes with the mean abundance of 5.9 and 4.1 60/m^2 respectively. Among the grids, the maximum number of species was sighted in G 98 with 18 and low species richness was recorded in G 96, G 97 and G 105 site with 5 numbers respectively (Table 42). Shannon diversty (H') value was ranged between 1.51 and 2.76 with the mean value of 2.07 during the survey period.

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Table 41 Fish abundance in Zone-7

Fish abundance	G 96	G 97	G 98	G 99	G 100	G 101	G 102	G 103	G 104	G 105	Mean abundance
Stongylura strongylura	0	0	8	0	0	0	0	10	0	0	1.8
Alepes djedaba	0	0	3	0	0	0	0	5	0	0	0.8
Sardinella sp.	0	0	15	0	0	0	0	6	0	0	2.1
Upeneus sulphurens	0	0	5	0	0	4	0	3	0	4	1.6
Lactoria cornuta	0	0	3	0	0	0	0	4	0	0	0.7
Lutjanus sp.	8	10	5	6	3	8	5	6	6	2	5.9
Mugil cephalus	0	0	4	0	0	0	8	3	0	0	1.5
Terapon puta	0	0	0	3	0	0	0	5	0	0	0.8
Amphiprion sp.	0	0	3	0	0	0	0	3	0	0	0.6
Siganus javus	0	6	6	4	0	0	0	7	0	0	2.3
Caranx para	5	0	7	0	2	5	2	4	5	6	3.6
Acanthurus lineatus	0	0	5	0	3	0	2	0	8	0	1.8
Chaetodon sp.	0	0	6	0	5	0	3	0	3	0	1.7
Sargocentron rubrum	0	0	0	0	3	0	0	0	4	0	0.7
Bathygobius laddi	2	0	2	0	2	0	0	0	7	0	1.3
Thalassoma lunare	0	0	4	0	7	0	2	0	3	0	1.6
Leiognathus sp.	0	6	2	8	2	8	5	0	10	0	4.1
Paraupeneus indicus	5	0	3	3	5	0	3	5	5	5	3.4
Pempheris vanicolensis	0	0	0	0	8	0	8	0	3	0	1.9
Pomacanthus imperator	0	0	0	0	2	0	2	0	2	0	0.6
Abudefduf saxitalis	0	0	6	0	6	0	0	0	3	0	1.5
Scarus ghibbus	0	5	5	2	3	5	2	0	2	3	2.7
Epinephelus malabaricus	3	2	0	3	2	2	3	3	3	0	2.1
Scolopsis vosmeri	0	0	0	0	0	0	0	0	0	0	0
Total abundance (60 m^2)	23	29	92	29	53	32	45	64	64	20	451

Table 42: Fish diversity indices in Zone 7

Sample	No. of species (S)	Diversity (H')	Species richness (D)	Eveness (J)
G 96	5	1.51	1.28	0.94
G 97	5	1.51	1.19	0.94
G 98	18	2.76	3.76	0.95
G 99	7	1.84	1.78	0.95
G 100	14	2.51	3.27	0.95
G 101	6	1.71	1.44	0.95
G 102	12	2.34	2.89	0.94
G 103	13	2.49	2.89	0.97
G 104	14	2.52	3.13	0.95
G 105	5	1.54	1.34	0.96
Mean value	9.9	2.07	2.30	0.95

ZONE -8

This is last zone of the study area, in which 2 grinds were occupied by seagrass meadows and patch coral reef habitat were occurring two grids, while 5 grids were dominated by sandy bottom.

Seagrass habitat

In zone-8, scattered seagrass meadows were found and mean percentage cover was 13.75%. The maximum cover was observed in G 108 with 16.25% followed by G 110 with 11.25% respectively (Fig. 44). A total of four seagrass species were recorded, among them, *Halophila ovalis* and *Thalassia hemprichii* were the dominant species.

Mean shoot density was recorded as 137.48 m^{-2} and highest mean shoot density was found to be in *Halophila ovalis* and *Thalassia hemprichii* with 69.95 and 21.29 m^{-2} respectively (Fig. 45). In the grid highest shoot density was recorded in G 108 and G 110 with the value of 137.48 and 104.15 m^{-2} respectively (Fig. 46 & Table 43).

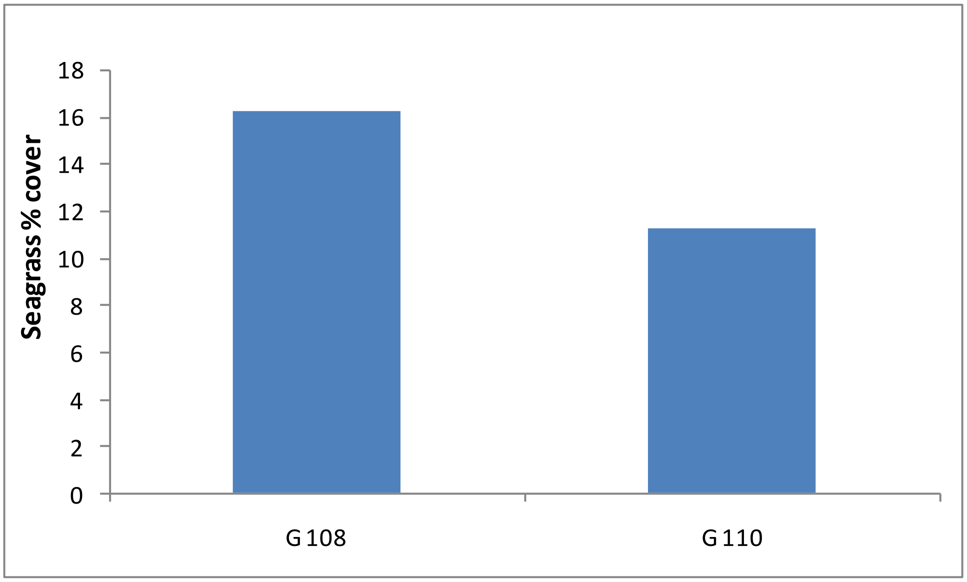

Fig.44. Seagrass percentage covers in Zone-8

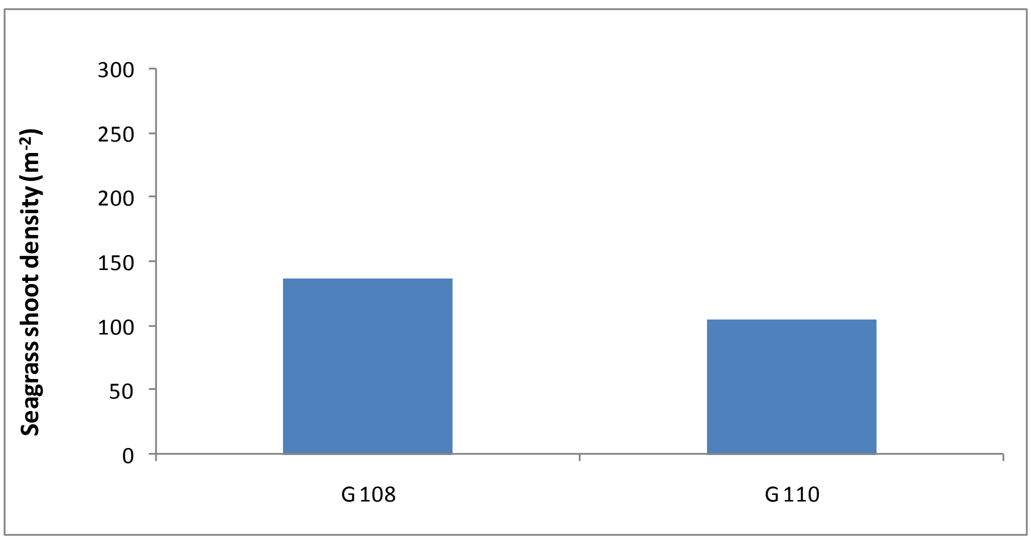

Fig.45. Mean species seagrass shoot density in Zone-8

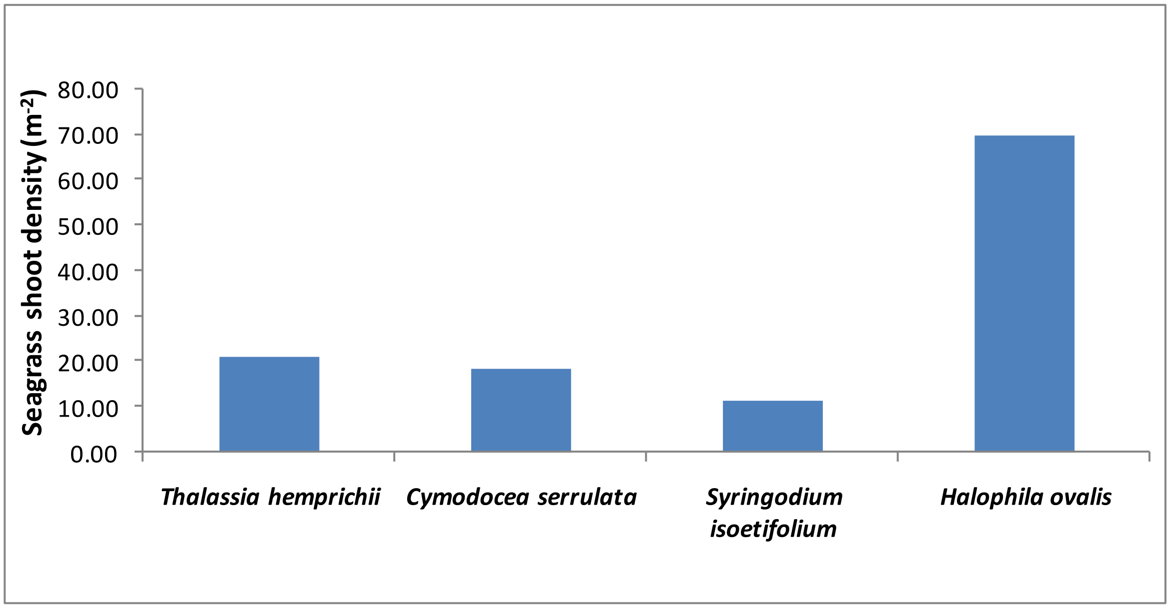

Fig.46. Mean species seagrass shoot denisty in Zone-8

Table 43: Seagrass species shoot density in Zone-8

	G 108	G 110
Thalassia hemprichii	25.32	17.25
Cymodocea serrulata	15.32	21.32
Syringodium isoetifolium	22.52	0
Halophila ovalis	74.32	65.58

Coral reef habitat

The mean live coral cover in this zone was 9.72% with poor occurrence of coral cover. Among the benthic community, abiotic (sand and rubbles) factor occupied maximum with a mean of 55.57% (Fig. 47 & Table 44). The highest coral cover was observed in G 110 with 13.19% followed by 6.25% at G 108 respectively. A total of 4 hard coral species were observed *Turninaria mesentrina* were the most commonly observed coral species. Similarly low density of coral recruits was recorded with a mean value of 2.06 m^{-2} and density ranged between 1.63 and 2.48 m^{-2} in the observed grids (Table 45). Few coral health issues were observed in this zone and among the coral health issue types, Macroalgae competition, Sponge Competition and Worm infestation were observed with the mean prevalence of 1.48% (Table 45).

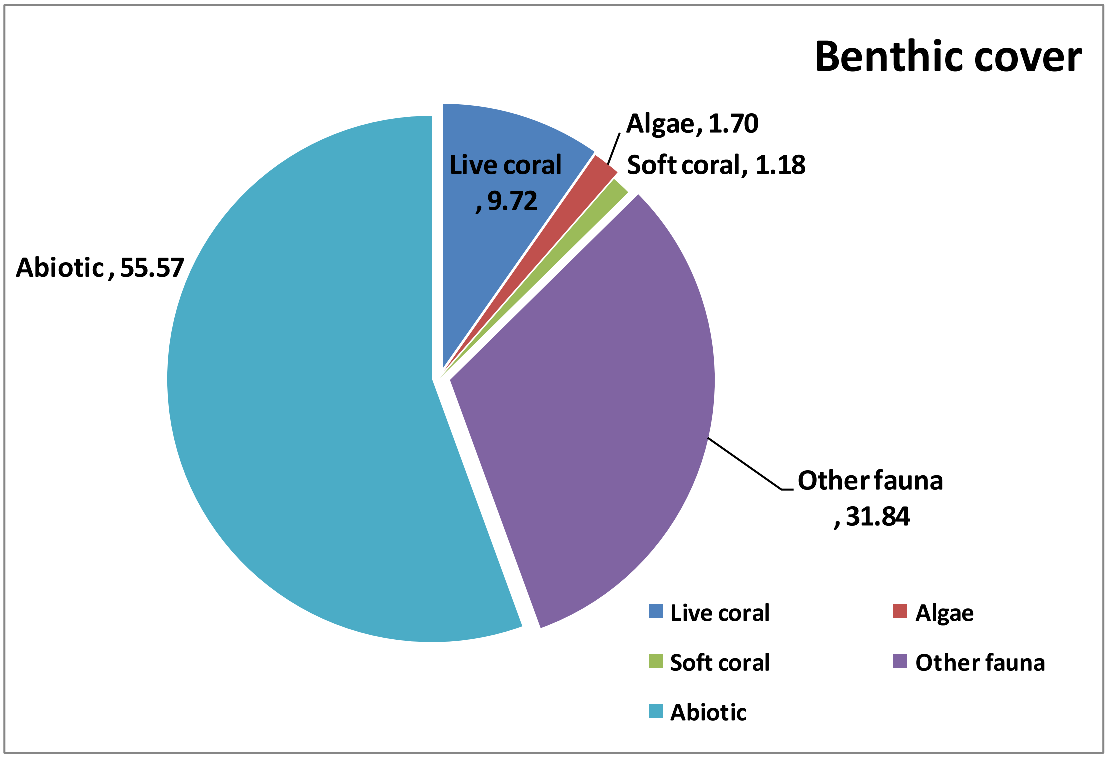

Fig.47. Mean % cover of benthic community structures in Zone-8

Table 44: % cover of benthic community structures in Zone-8

	G 108	G 110
Live coral (%)	6.25	13.19
Algae (%)	1.03	2.36
Soft coral (%)	2.36	0
Other fauana (%)	34.05	29.63
Abiotic (%)	56.31	54.82

Table 45: Coral parameters in Zone-8

	G 108	G 110
Coral species richness (no)	3	4
Coral recruitment density (m^{-2})	1.63	2.48
Coral health issues	1.22	1.74

Macrofaunal community

Four major macro faunal groups were observed in this zone. Mean density was 3.24 $5m^2$ and density ranged between 0.52 and 11.27 $5m^2$(Fig. 48 & Table 46). Among the macro faunal community, Echindoderms were dominant with 1.02 $5m^2$ followed by Sponge with 0.80 $5m^2$. In the observed grids, greater density in G 110 with 11.27 followed by G 108 with 6.99 $5m^2$ (Fig. 49).

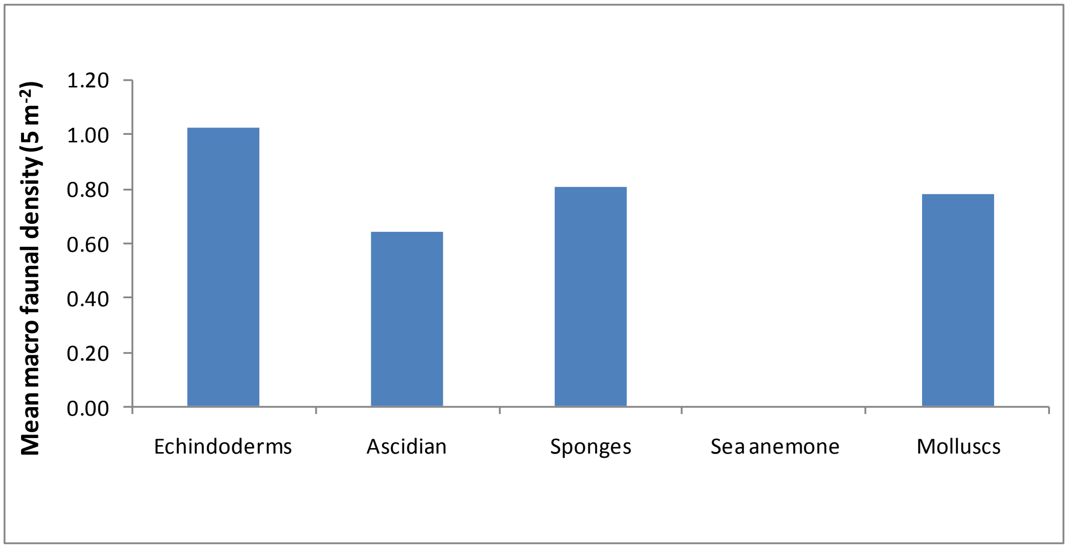

Fig.48. Mean macro faunal group density in Zone-8

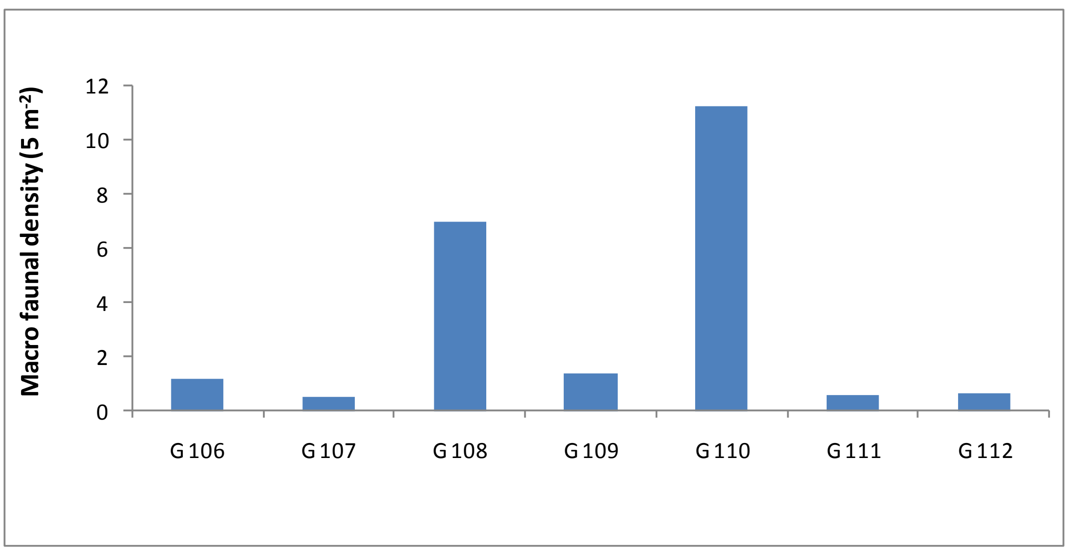

Fig.49. Mean macro faunal density in Zone-8

Table 46: Total macro faunal group density in Zone-8

Macro fauna no/ 5 m^2	G 106	G 107	G 108	G 109	G 110	G 111	G 112
Echindoderms	0.84	0.36	3.48	0.48	1.62	0.26	0.11
Ascidian	0.25	0	0	0.1	4.15	0	0
Sponges	0	0	1.36	0.68	3.15	0	0.42
Sea anemone	0	0	0	0	0	0	0
Molluscs	0.14	0.16	2.15	0.16	2.35	0.31	0.16

Fish community structure

A total of 391 fish individuals were counted in this zone. Among the 7 grids, highest fish abundance was found to be in G 110 with 124 60/m^2 followed by G 108 with 116 60/m^2 respectively (Table 47). A total of 26 fish species were recorded in this zone, among them, *Leiognathus sp* and *Epinephelus malabaricus* were the most dominant fishes with the mean abundance of 4.86 and 3.57 60/m^2 respectively. Among the grids, the maximum number of species was sighted in G 108 and G 110 with 23 and low species richness was recorded in G 106 and G 107 site with 5 numbers respectively (Table 48). Shannon diversty (H') value was ranged between 1.54 and 3.03 with the mean value of 2.18 during the survey period.

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Table 47 Fish abundance in Zone-8

Fish abundance	G 106	G 107	G 108	G 109	G 110	G 111	G 112	Mean abundance
Stongylura strongylura	0	0	10	0	8	0	0	2.57
Alepes djedaba	0	0	6	0	10	0	0	2.29
Sardinella sp.	0	0	8	0	13	0	0	3.00
Upeneus sulphurens	0	0	6	0	8	0	0	2.00
Lactoria cornuta	0	0	2	0	3	0	0	0.71
Sphyraena obtusata	0	0	8	0	5	0	0	1.86
Lutjanus sp.	5	8	7	3	4	0	8	5.00
Mugil cephalus	0	0	3	0	2	6	5	2.29
Terapon puta	0	0	5	2	3	3	0	1.86
Amphiprion sp.	0	0	2	0	0	0	0	0.29
Siganus javus	0	5	8	3	5	0	0	3.00
Caranx para	4	0	3	0	3	4	3	2.43
Acanthurus lineatus	0	0	6	0	5	0	6	2.43
Balistoides viridescens	0	0	3	0	0	0	0	0.43
Chaetodon sp.	0	0	8	0	8	0	2	2.57
Sargocentron rubrum	0	0	3	0	2	0	0	0.71
Bathygobius laddi	0	0	0	0	0	0	0	0.00
Thalassoma lunare	0	0	5	0	5	0	2	1.71
Leiognathus sp.	4	7	3	5	6	6	3	4.86
Paraupeneus indicus	2	0	7	2	3	0	5	2.71
Pempheris vanicolensis	0	0	3	0	4	0	3	1.43
Pomacanthus imperator	0	0	0	0	8	0	7	2.14
Abudefduf saxitalis	0	0	5	0	10	0	2	2.43
Scarus ghibbus	0	3	2	4	4	2	6	3.00
Epinephelus malabaricus	2	4	3	5	3	5	3	3.57
Scolopsis vosmeri	0	0	0	0	2	0	2	0.57
Total abundance (60 m2)	17	27	116	24	124	26	57	391.00

Table 48: Fish diversity indices in Zone-8

Sample	No. of species (S)	Diversity (H')	Species richness (D)	Eveness (J)
G 106	5.00	1.54	1.41	0.96
G 107	5.00	1.55	1.21	0.96
G 108	23.00	3.03	4.63	0.97
G 109	7.00	1.89	1.89	0.97
G 110	23.00	3.00	4.56	0.96
G 111	6.00	1.73	1.54	0.96
G 112	14.00	2.52	3.22	0.96
Mean value =	11.86	2.18	2.64	0.96

Fish landing data from three villages (Sippikulam, Vipar and Periyasamypuram) during March 2016 to February 2017

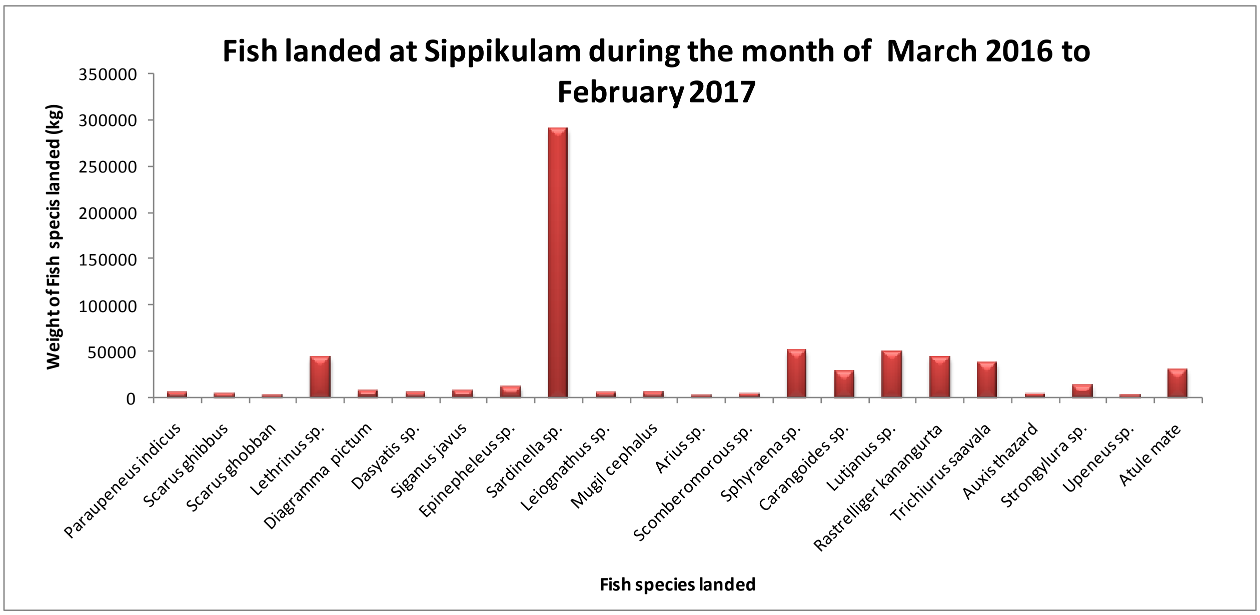
1. **Sippikulam**

Sippikulam village is considered as well known place for fish landing and village is located northern part of the Tuticorin coast 22Km away from Tuticorin town.It is situated on $09^0$59.893' N latitude and 078^0 14.998' S longitude along the coastline. This fishing village is one of the minor fish landing areas Fishing craft being operate in this village includes totally 35 fibre boats and 1 velllam. The major gears operated in this region are Sardine net, Mackerel net, Squid net, Skates net, and Crab net. The major fishery resources landed are Sardines, Scarids (Parrot fishes), Sweet lips, Cat fishes, Carangids, Leiognathids, etc. Fin fish species, *Sardinella*sp. was the most landed fishes in September, 2016 with highest catch about 35706 kg during the assessment period, Secondly, fair catch was recorded in *Sphyraena* sp. with yield of 11969 Kg during February 2017 and *Lutjanus* sp. was the third dominant catch fishes with 12314 Kg during the month of November 2016. A total of 22 commercially important fish species was recorded and total landing was recorded over the period of 12 months about 654845 kg and maximum catch yield was recorded during January 2017 with 77705 Kg respectively.

Details of fish landing at Sippikulam fishing village

Sl.No	Genus & Species	Total catch
1	*Paraupeneus indicus*	5227
2	*Scarus ghibbus*	4723
3	*Scarus ghobban*	2968
4	*Lethrinus* sp.	42950
5	*Diagramma pictum*	7115
6	*Dasyatis* sp.	5187
7	*Siganus javus*	7592
8	*Epinepheleus* sp.	11246
9	*Sardinella* sp.	289824
10	*Leiognathus* sp.	5134
11	*Mugil cephalus*	6325
12	*Arius* sp.	2413
13	*Scomberomorous* sp.	3848

14	*Sphyraena* sp.	50670
15	*Carangoides* sp.	28264
16	*Lutjanus* sp.	50027
17	*Rastrelliger kanangurta*	44095
18	*Trichiurus saavala*	37408
19	*Auxis thazard*	3401
20	*Strongylura* sp.	13106
21	*Upeneus* sp.	3256
22	*Atule mate*	30066
	Total catch	**654845**



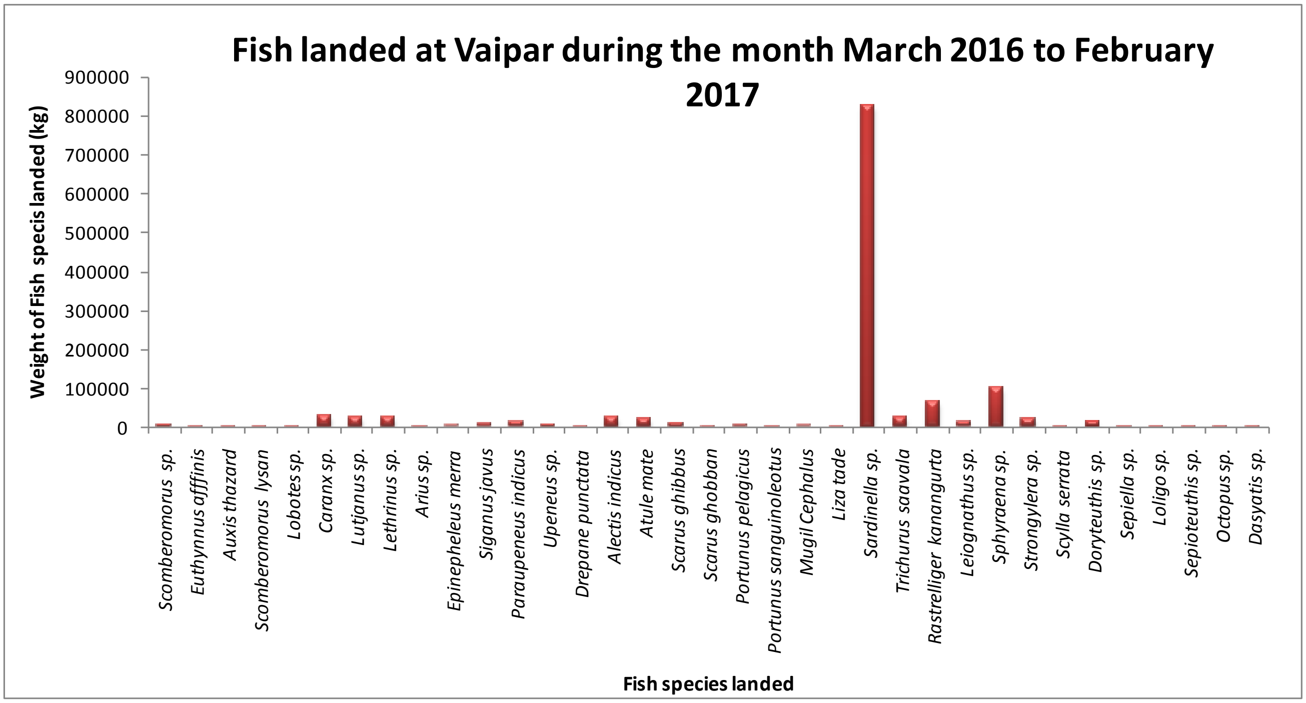
2. Vaipar

Vaipar (09^{0}00.067' N latitude and 078^{0} 15.081' Elongitude)is one among the major fishing village which are located nearer to the Sippikulam and 23 Km away from Tuticorin Town. Fishermen operating major crafts are 120 fibre boats and 5 vallams and important gears operated in this region are Sardine net, Mackerel net, Shrimp net, Squid net and Gill net. The major fishery resources of this village are Sardines, Carangids, Emperors, Seer fishes, Barracuda, Lobsters, Snappers,Squid,Cuttlefish and Crabs. Fisherman caught fishes during all seasons in a year and major fishes landed (fin fish and shell) were recorded between March 2016 and February 2017. Highest catch were recorded in *Sardinella* sp. with 107409 Kg during July 2016 followed by *Sphyraena* sp. yielded as 11962 Kg in September 2016 respectively. Comparatively low catch were observed in *Rastrelliger kanangurta*with 6443 kg during the month of September 2016. A total of 35 fin fish and shell fish species were recorded as landed fishes in this village. Total landing were recorded during March 2016 to February 2017 about 1282817 Kg and maximum catch was noticed during the month of July 2017 with a total of 139221Kg.

Details of fish landing at Vaipar fishing village

Sl.No	**Genus & Species**	**Total catch**
1	*Scomberomorus* sp.	6344
2	*Euthynnus afffinis*	3125
3	*Auxis thazard*	2867
4	*Scomberomorus lysan*	2007
5	*Lobotes* sp.	2180
6	*Caranx* sp.	28059
7	*Lutjanus* sp.	25136
8	*Lethrinus* sp.	25861
9	*Arius* sp.	1425
10	*Epinepheleus merra*	4718
11	*Siganus javus*	8170
12	*Paraupeneus indicus*	12226
13	*Upeneus* sp.	6780
14	*Drepane punctata*	1871
15	*Alectis indicus*	25985
16	*Atule mate*	20733
17	*Scarus ghibbus*	10381
18	*Scarus ghobban*	2657
19	*Portunus pelagicus*	4913
20	*Portunus sanguinoleotus*	3506
21	*Mugil Cephalus*	3817
22	*Liza tade*	2428
23	*Sardinella* sp.	824607
24	*Trichurus saavala*	24596
25	*Rastrelliger kanangurta*	64166
26	*Leiognathus* sp.	11633
27	*Sphyraena* sp.	99382
28	*Strongylera* sp.	21093
29	*Scylla serrata*	2542
30	*Doryteuthis* sp.	15563
31	*Sepiella* sp.	2377
32	*Loligo* sp.	3291

33	*Sepioteuthis* sp.	2987
34	*Octopus* sp.	2355
35	*Dasyatis* sp.	3037
	Total catch	**1282817**

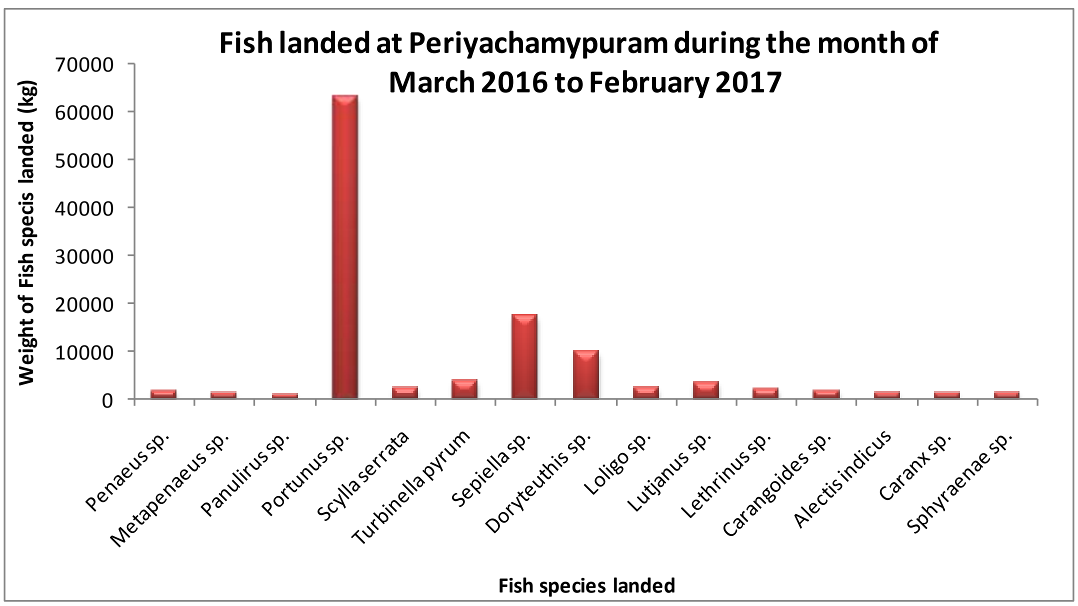


3. Periyachamypuram

Periyachamypuram (09^{0}03.003' N lat and 078^0 19.478' E longitude) is one of the minor fish landing areas in Tuticorin coastline. This fishing village has 40 fibre boats, 5 vallams and 5 Kattumarams. The major gears operated in this village are Crab net, Squid net, Shrimp net, Gill net. This fishing village is involved in traditional fishing practices. The major fishery resources of this village are Shrimps, Crabs, Lobsters and Carangids.Fishes caught in this region are widely seasonal and the major fishes caught in this region were recorded during the month of March2016 to February 2017. The major catch obtained for the crab species, *Portunus*sp.inFebruary 2017 with maximum of 7451 kg during the study period followed by squid, *Sepiella*sp. consider as second maximum landed fish with 1999kg during February 2017. A total of 15 fin fish and shell fish species were recorded as landed fishes in this village. Total landing were recorded during March2016 to February 2017 about 113687 kg and maximum catch was noticed during the month of November 2016 with a total of 13263 Kg.

Details of fish landing at Periyachamypuram fishing village

Sl.No	Genus & Species	Total catch
1	*Penaeus* sp.	1683
2	*Metapenaeus* sp.	1150
3	*Panulirus* sp.	976
4	*Portunus* sp.	63218
5	*Scylla serrata*	2226
6	*Turbinella pyrum*	3641
7	*Sepiella* sp.	17487
8	*Doryteuthis* sp.	9916
9	*Loligo* sp.	2460
10	*Lutjanus* sp.	3273
11	*Lethrinus* sp.	2089
12	*Carangoides* sp.	1815
13	*Alectis indicus*	1275
14	*Caranx* sp.	1148
15	*Sphyraenae* sp.	1330
	Total	**113687**



4. Executive summary

- Assessment was carried out in 10 km radius in the Keelavaipar coast and detailed underwater monitoring was carried out during March 2017.
- Two major ecological important ecosystems (coral reefs and seagrass meadows) were identified as predominated habitats in the study area.
- Based on the availability of corals and seagrass occurrence in the study area sampling size varies during the survey period.
- Eight horizontal zones located parallel to the shoreline which extended to marine zone and each zone further divided as grids (1 km^2).
- Seagrass distribution was predominately found between Zone 2 and 4. Highest mean percent cover of seagrass cover was found in Zone 4 (44.30%) followed by Zone 3 (37.22%) respectively.
- A total of 7 seagrass species were recorded and among the seagrass species, *Cymodocea serrulata* and *Thalassia hemprichii* were dominantly occupied in the study area.
- Highest shoot density were observed in Zone 2 with 365.9 m^{-2}whilst poor shoot density was observed in Zone 8 as 120.8 $m^{-2}$and comparatively low density were observed in Zone 1 with 136.7 m^{-2} .
- Patch and dense coral cover reef sites were found in the study area, highest coral cover was noticed in Zone 4 with 28.16% followed by Zone 5 with 26.30% respectively. Maximum coral species richness were recorded as 15 in Zone 5 and *Acropora cytherea*, *A. formosa, Turbinaria mesenterina* and *Porites lutea* were the most common species from the study area.
- Coral recruitment density, highest density was found in Zone 4 with 3.85 m^{-2} and poor density was found in Zone 1 with 1.92 m^{-2}.
- Coral health issues, high infestation was observed in Zone 4 with the mean prevalence of 6.60 % followed by 6.58% in Zone 5 during the assessment time.
- In macro fauna community, five major taxa were identified in the study area, among the groups, Echinoderms and molluscs were the predominated during the assessment. Faunal density varied between 3.24 5 m^{-2} and 15.88 5 $m^{-2.}$
- A total of 29 fish species were encountered in the study area and commonly observed fishes are Leiognathus *splendens, Terapon puta, Sardinella Sp., Stongylura strongylura, Lutjanus* Sp., *Caranx para, Leiognathus* sp. and *Epinephelus malabaricus*. Highest total of fish individual were counted in Zone 2 and followed by Zone 3 with 2741 and 2564 respectively. Shannon diversity index mean value was varied between 2.07 and 2.57 in the zones.
- Fish landing data has been analysed in three nearby villages (Vaipar, Sippikulam and periyasamypuram) and the data revealed that maximum landing was recorded in Vaipar

with the yield of 1282.817 tones/year followed by Sippikulam as 654.845 tones/year during the assessment period.

5. Key observations and Recommendations

- Patch seagrasses, less than 10% are observed near the groynes sites.
- Distance from the groynespoint to Marine National Park boundary is as follows: Groynes - 1 (1.66km); Groynes- 2 (1.97km); and Groynes- 3 (2.46Km).
- Kariyachalli Island is situated about 3.90km away from the Groynes - 1; 4.33km from the Groynes- 2; and 4.52km from the Groynes- 3.
- The average distance from the groynes site to the coral reef area in Kariyachalli Island is about 4.63km.
- Dense seagrass meadows are observed in 7.6 km distance from the groynes site and luxuriant coral diversity and cover has been recorded at Zone 4 of Grid 61 with a distance of about 4.86 km from groynes site.
- It is recommended that the length of the Groynes 1 and 2 may be reduced to minimize the impacts. Groynes – 1 may be reduced to 500m; and Groynes– 2 may be reduced to 200m.

6. Impact on Biodiversity

- The detailed underwater assessment in the project area to collect base line data on the Bio Diversity shows that less than 10% of seagrass patches are observed near the Groyne site and hence it is noted that there will be no significant impact on the Biodiversity due to the construction of Groyne.
- The project site is located at a distance of 4.63km from the nearby coral reef area in Kariachalli island and hence there will be no significant impact due to the project activities on the coral reefs and the associated Biodiversity.
- Since the project activities are proposed close to the shore where minimal biological resources are noted , the fish population will not be affected due to the activity of construction of Groyne.

- The study shows that there is no endangered marine life near the project site and hence there will not be any impact on the endangered organism due to the construction of Groyne.

7. References

1. Done, T.J., R.A. Kenchington and L.D.Zell (1982). Rapid, large area, reef resources survey using a manta board. Proceedings of the 4th International Coral Reef Symposium, Manila, Philippines, 2: 597-600.

2. English, S., Wilkinson, C., and Baker, V., (eds.) (1997) Survey manual for tropical Marine resources. Australian Institute of Marine Science, Townsville Australia. 390 p.

3. Saito, Y and Atobe S, 1970, Phytosociological study of intertidal marine algae. I. Usujiri Benten-Jima, Hokkaido. Bulletin of the Faculty of Fisheries, Hakkaido University., 21**:** 37–69.

4. Srinath, M., Kuriakose, S. and Mini, K.G. 2005. Methodology for estimation ofmarine fish landings in India. CMFRI spl. Publ, 86: 57.

Plate 1

Coral species near Kariyachalli Island

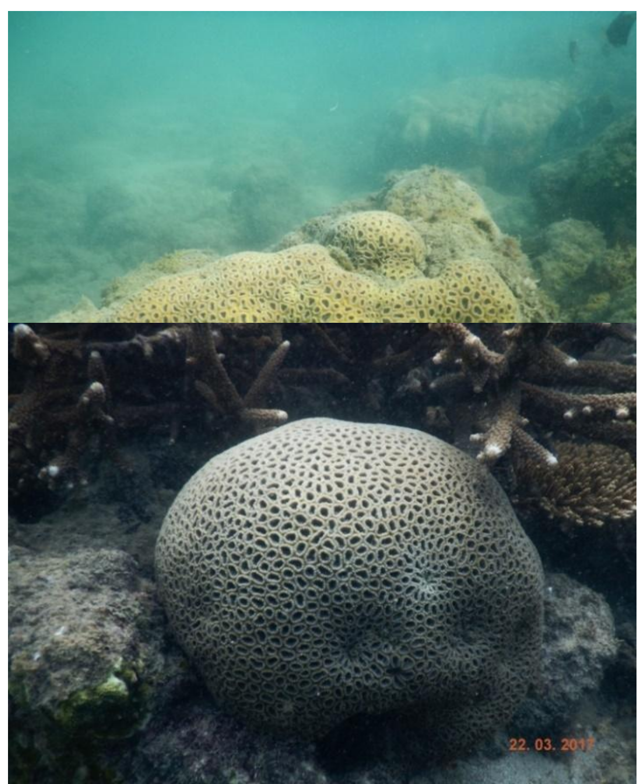


Plate 2

Dense seagrass area located about 7.6 Km from project site

Plate 3
Observed fishes in the coral area

Plate 4

Observed macro faunal community in the dense seagrass and coral area

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TUTICORIN -1.

Certificate Number	**0**	**0**	**0**	**8**	**2017 - 2018**	**Page**	**2**	of	**2**

RESULTS

SAMPLE: STONE.
[Source: Thattaparai].

Sl. No.	Test Description	Unit	Results
I.	**Physical Tests:**		
1	Crushing Strength	kg/cm^2	1070
2	Impact Value	Percent	25.9
3	Abrasion Value	Percent	19.2
4	Specific gravity	--	2.69
5	Soundness – 5 Cycles using Na_2SO_4 Solution	--	Passes the test
II.	**Chemical Tests:**		
1	Alumina (Al_2O_3)	Percent	11.30
2	Silica (SiO_2)	Percent	75.12
3	Lime as 'CaO'	Percent	0.89
4	Chloride as 'Cl'	Percent	NIL
5	Sulphate as 'SO_3'	Percent	0.04
6	Water – Moisture content	Percent	0.02

6 APR 2017

6/4/17
Senior Chemist.

Please Note: Any corrections in the certificate not attested shall invalid this certificate.

DEPARTMENT OF INDUSTRIES AND COMMERCE
REGIONAL TESTING LABORATORY
HARBOUR LINK ROAD
TUTICORIN -1.

TEST CERTIFICATE

Certificate No.: **0008 / 17-18** Date : 06.04.2017.

File No. : 301/A/2017 Sample Received on : 14.03.2017.

Lab No. : 10017 - 10027 / 2016-2017.

Issued To : ASSISTANT ENGINEER,
P.W.D. / W.R.O.,
SPECIAL PROJECT SECTION No. -II,
SRIVILLIPUTHUR.

Party's Letter No.: 03 / AE/ 2017/ C / Dated: 13.03.2017.

Sample Details : STONE.

Sample Mark : --.

Name of Work : Construction of Groyne at Keelavaippar Village in Vilathikulam Taluk of Thoothukudi District.

TEST RESULTS ENCLOSED

6 APR 2017

6/4/17

Senior Chemist.

- Any corrections in the certificate including Annexures not attested shall invalid this certificate.
- This certificate is issued for test conducted on the tendered samples only.
- This Report shall not be reproduced except in full without the written approval of the Laboratory.

Department of Ocean Engineering
Indian Institute of Technology Madras
Chennai 600 036, INDIA

Dr.-Ing. Dr. V. SUNDAR
Professor

7th April 2015

To
Er. P. Thanapalan, B.E.,
Executive Engineer PWD.,WRO
Special Project Division,
Virudhunagar – 626 001.

Sir,

Sub: CRZ – Construction of groyne at Keelavaippar Village, Vilathikulam Taluk, Thoothukudi District proposed by PWD/WRO., Special Project Division, Virudhunagar Division, Thoothukudi – Clearance under CRZ Notification 2011 requested – Reply to further details called for – regarding.

Ref: 1) Your letter No.07m/DB/C.340/2015/dt.25.03.2015.

2) Letter from Member Secretary, TNSCZMA & Director Department of Environment, Chennai R.C.No.P1/2031/2014, dated: 19.03.2015

With reference to exploring the possibility of soft measures in the case of the proposed groins at Keelavaippar village, the following points are to be noted.

It is observed that the beach width available during the months after the south-west monsoon is insufficient and unsafe for parking/berthing/landing of boats. A swell (long wave) that can propagate from the offshore can easily drag a parked/berthed boat into the offshore. In addition, during the monsoon period, it is found that the beach landing of small fishing boats poses severe threat in the loss of fish catch as well as the damages to the driving motor since the boat often experience the threat of slamming and green water (water overtopping). Thus, the local fishing community has made representation for providing a shelter region to preserve the beach width throughout the year and also, to make a tranquil nearshore region for safe beach landing of fishing boats. Keeping this main objective of the project and also, to avoid any significant impact on the neighbourhood shoreline, a groin field has been recommended. Since the application of geo-synthetic products including geo-textile tube for this location would be failure due to the possible anchorage of the boat on the structure and boat hitting might puncture the tube. The availability of suitable sand is a challenge. Further, skilled labor, lack of knowledge on the construction methodology and several other associated problems act against the soft measure for the present site. Availability of sufficient amount of rubble stones in the neighbourhood quarry qualify for rubble mound structures as it is cheaper. Hence, for this location, hard measure, i.e., groin field is recommended. The layout of the groins has been planned in detail by IIT Madras so as to minimize the impact on the adjoining shoreline.

Further, there is no possibility of annual artificial beach nourishment at this location due to non-availability of sediments and the maintenance cost of which would be beyond the cost benefit to the local society. Hence, the hard structures, rubble stone groins have been recommended.

Thanking you,

Yours sincerely,

(Dr. V.SUNDAR)

Tel : 044- 22574809/ 00 Fax : 044-22574809/ 4802/ 0545/ 0509 Mobile : 94440 49629
E-mail : vsundar@iitm.ac.in/ vallamsundar@gmail.com
Website: http://oec.iitm.ac.in/Facweb/vsundar/Division.html

Fwd: Email Alert From System Administrator of Online Submission and Monitoring of Wildlife Clearances Proposal(OSMWCP) portal

executive engineer special project [eespdvnr@gmail.com]

Sent: Thursday, March 15, 2018 7:29 PM

To: A Stephen Leo

---------- Forwarded message ----------
From: <monitoring-fc@nic.in>
Date: Thursday, March 15, 2018
Subject: Email Alert From System Administrator of Online Submission and Monitoring of Wildlife Clearances Proposal(OSMWCP) portal
To: eespdvnr@gmail.com
Cc: monitoring-fc@nic.in

This is to acknowledge that a proposal seeking prior approval of Central Government under the Forest (Conservation) Act 1980 as per the details given below has been successfully uploaded on the portal of the Ministry of Environment, Forests and Climate Change Government of India.

1. Proposal No.	:	FP/ TN/ Others/ 2363/ 2018
2. Proposal Name	:	Construction of Groyne at Keelavaippar village in Vilathikulam taluk of Thoothukudi District
3. Category of the Proposal	:	Others
4. Date of Submission	:	15/ 03/ 2018

5. Name of the Applicant with Contact Details

Name	: P
Mobile No.	: 9443570116
State	: Tamil Nadu
District	: Virudhunagar
Pincode	: 626001

6. Protected Area (ha.) : 2.374

The proposal will be examined by Wild Life Warden, Forest (Conservation) Act, 1980 to assess its completeness.

(System Administrator)

*** This is a system generated email, please do not reply. ***

REPORT ON
GEOTECHNICAL INVESTIGATION BY CONDUCTING BOREHOLE TEST IN SEA FOR THE CONSTRUCTION OF GROYNE AT KEELAVAIPPAR IN VILATHIKULAM TALUK OF THOOTHUKUDI DISTRICT

Prepared By

GEO MARINE
CONSULTANTS AND TECHNOCRATS
Consulting Through Knowledge

Geo Marine Consultants and Technocrats
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BORELOGS

PROJECT: GEOTECHNICAL INVESTIGATION BY CONDUCTING BOREHOLE TEST IN SEA FOR THE CONSTRUCTION OF GROYNE AT KEELAVAIPPAR IN VILATHIKULAM TALUK OF THOOTHUKUDI DISTRICT

BOREHOLE NO	BH - 1	Location	Keelavaippar
Ground Elevation		Soil Sampler Used	SPTs, UDSs & Rock Cores
Ground Water Table	3.30m LT/4.50m HT	Drilling Method	Rotary Rig
Inclination	Vertical	Drilling Commenced	10th March 2015
Depth of Boring, in meters	10.00	Drilling Completed	11th March 2015

Strata Description	Soil Classification	Soil Log	Depth from GL (m)	R.L of lower contact	Standard Penetration Test (SPT) 15 cm	15 cm	15 cm	N Value	Samples Type	No	Depth (m)	Ground Water Level	Remarks
Grayish Silty fine to medium loose Sand	SM		0.50	-0.50	1	2	4	6	SPT	1	0.00	3.30m LT/4.50m HT	
Brownish Silty stiff Clay with Sand	SC		1.60	-1.60	1	6	6	12	SPT	2	1.00		
Brownish Silty Sand	SM		2.80	-2.80	7	12	16	28	SPT	3	2.00		
Brownish Silty stiff Clay with Sand	SC		3.90	-3.90	3	7	8	15	SPT	4	3.00		
Brownish & Grayish Silty Clay	CI		6.80	-6.80	4	8	14	22	SPT	5	4.00		
					5	8	13	21	SPT	6	5.00		
					6	9	13	22	SPT	7	6.00		
Brownish & Grayish Silty Clayey Sand	SC		10.0	-10.0	8	20	41	61	SPT	8	7.00		
					10	22	43	65	SPT	9	8.00		
					12	30	46	76	SPT	10	9.00		
					12	33	50 Blows for 13 Cm	>100	SPT	11	10.00		

Borehole terminated at 10 m below Ground Level

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SUMMARY OF LABORATORY TESTS

PROJECT: GEOTECHNICAL INVESTIGATION BY CONDUCTING BOREHOLE TEST IN SEA FOR THE CONSTRUCTION OF GROYNE AT KEELAVAIPPAR IN VILATHIKULAM TALUK OF THOOTHUKUDI DISTRICT

S.No.	Borehole .No.	Lab Ref. No. (Given for testing)	Location of Samples Collected	Depth of Sample collected (From existing GL, in m)	SPT "N" Value	Natural Moisture Content (%)	Index Properties (%)			Specific Gravity	Gradation Properties (%)			B.I.S. Classification of soil
							Liquid Limit	Plastic Limit	Plasticity Index		Gravel	Sand	Silt & Clay	
1.	BH-1	BH-1/1	KEELAVAIPPAR	0	6	17.3					29	57	14	SM
2.		BH-1/2		1	12	18.3					3	46	51	SC
3.		BH-1/3		2	28	14.2					4	77	19	SM
4.		BH-1/4		3	15	22.1				2.67	4	44	52	SC
5.		BH-1/5		4	22	28.9					0	4	96	CI
6.		BH-1/6		5	21	30.4	46	21	25	2.7				CI
7.		BH-1/7		6	22	29.7					2	19	79	CI
8.		BH-1/8		7	61	23.0					3	50	47	SC
9.		BH-1/9		8	65	9.9				2.62	1	64	35	SC
10.		BH- 1 /10		9	76	15.0					4	55	41	SC
11.		BH-1 /11		10	>100	11.6					5	49	46	SC

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SBC CALCUTIONS

PROJECT: GEOTECHNICAL INVESTIGATION BY CONDUCTING BOREHOLE TEST IN SEA FOR THE CONSTRUCTION OF GROYNE AT KEELAVAIPPAR IN VILATHIKULAM TALUK OF THOOTHUKUDI DISTRICT

Foundation strata:	Silty fine to Medium Sand/ Silty Clay with Sand			
Structures				
Reference Borehole	BH-1	BH-1	BH-1	BH-1
Bed Level/Ground Level	0.000	0.000	0.000	0.000
Scour Level/Undisturbed GL	0.000	0.000	0.000	0.000
Foundation Level	-2.000	-2.000	-3.000	-3.000
Thickness of overburden soil, m	2.000	2.000	3.000	3.000
Depth of excavation required, m	2.000	2.000	3.000	3.000
Width of foundation, m	2.00	6.00	2.00	6.00
SPT value of the soil in the zone of influence	28	28	15	15
Angle of Internal friction, Degrees	31	31	0	0
Unit weight of over-burden soil, kN/Cu.m.	18.00	18.00	18.00	18.00
Length of foundation, m	2.00	6.00	2.00	6.00
Shear strength of soil, kN/Sq.m.	0	0	75	75
Bearing capacity factor Nc	33.34	33.34	5.14	5.140
Bearing capacity factor Nq	21.38	21.38	1.00	1.000
Bearing capacity factor Ny	27.53	27.53	0.00	0.000
Depth factor, dc	1.35	1.12	1.30	1.10
Depth factor, dq	1.18	1.06	1.15	1.05
Depth factor, dy	1.18	1.06	1.15	1.05
Shape Factor, sc	1.20	1.20	1.20	1.20
Shape Factor, sq	1.20	1.20	1.20	1.20
Shape Factor, sy	0.60	0.60	0.60	0.60
Inclination Factor, ic	1.00	1.00	1.00	1.00
Inclination Factor, iq	1.00	1.00	1.00	1.00
Inclination Factor, iy	1.00	1.00	1.00	1.00
Water Table Correction Factor, w	0.50	0.50	0.50	0.50
Ultimate Bearing Capacity, UBC1, kN/Sq.m.	0.00	0.00	601.38	508.86
Ultimate Bearing Capacity, UBC2, kN/sq.m.	483.05	434.68	33.12	30.24
Ultimate Bearing Capacity, UBC3, kN/Sq.m.	77.74	209.86	0.00	0.00
Ultimate Bearing Capacity, UBC, kN/Sq.m.	560.79	644.54	634.50	539.10
SBC with a factor of safety of 2.5, kN/Sq.m.	224.32	257.82	253.80	215.64

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This capacity is verified based on settlement criteria and calculations are provided below.			
For Isolated/Raft			
Refer, 9.2.3.2 I S 8009 Part 1 equation 11	=	$Si = \rho B (1 - \mu^2) I_s / Es$	
Net Bearing Capacity kN/m^2	=	200	kPa
Poissons ratio (0.3 to 0.5)	=	0.35	
Influence factor from Table 2 of I S 8009 P-1 for Square	=	0.95	
Elastic modulus of rock (assume as Sand Es From Bowels, Table 2.8)	=	20500	kN/m^2
Breadth of foundation	=	2.0	M
Depth of foundation	=	2.0	M
Depth Factor (Refer, Fig.12 of I S 8009 Part 1) For L/B = 1, D/SQRT(LB)= 1.5	=	1	
Si=200*2*(1-0.35^2)*0.95*1)/20500*1000	=	16.2659	Mm
Permissible Settlement		25	Mm
Allowable Pressure from settlements considerations		307.392	kN/m^2
SBC on shear failure criteria	=	224.32	kN/m^2
Hence, Allowable SBC	=	**200**	**kN/m^2**

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TEST GRAPHS

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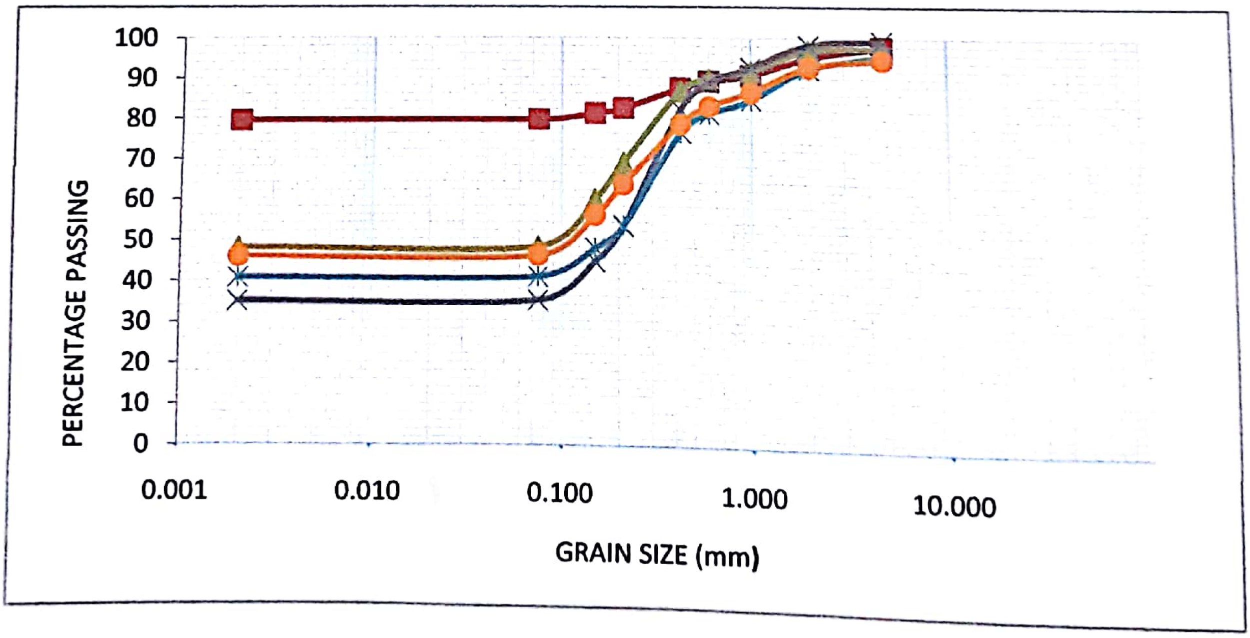
Symbol	Bore hole No	Depth (m):	Sample Type	IS	Gravel %	Sand %	Silt %	Clay %	Cu	Cc	D60 mm	D30 mm	D10 mm
	BH-1	6.00	SPT	CI	2	19	79						
	BH-1	7.00	SPT	SC	3	50	47						
	BH-1	8.00	SPT	SC	1	64	35						
	BH-1	9.00	SPT	SC	4	55	41						
	BH-1	10.00	SPT	SC	5	49	46						

Particle Size	CLAY	SILT	SAND			GRAVEL	
			F	M	C	F	C



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COMPREHENSIVE SHORELINE PROTECTION MANAGEMENT PLAN FOR ENTIRE TAMILNADU COAST

Report submitted to

Department of Environment

Govrnment of Tamil Nadu

By

Prof. V. Sundar

Prof. S.A. Sannasiraj

Department of Ocean Engineering

Indian Institute of Technology, Madras

March 2016

ACKNOWLEDGEMENTS

The investigators place on record, their sincere thanks to the Director, Department of Environment, and Government of Tamil Nadu for having entrusted this important task to them.

The investigators thank the officials and engineers of PWD, Government of Tamilnadu, NCSCM, Dr. J.K. Patterson Edward, Director,SuganthiDevadason Marine Research Institute, NIOT and Department of Fisheries for sharing their views on the preparation of the shoreline management plan for Tamilnadu coast.

The engineers of PWD extended their valuable support during the site visit, which is gratefully acknowledged.

The investigators also thank the continuous support by students and project staff of Department of Ocean Engineering, IIT Madras.

Prof. V. Sundar and Prof. S.A. Sannasiraj

EXECUTIVE SUMMARY

The Department of Environment had entrusted the task of preparation of comprehensive shoreline protection management plan/scheme for the entire coast of Tamil Nadu, on 29-12-2015, to Prof. V. Sundar and Prof. S.A. Sannasiraj, Department of Ocean Engineering, IIT Madras.

This report consists of eleven chapters with complete details on the shoreline management for the Tamilnadu coast. The project commenced with an Inception studies on the coastal features, basic environmental data, protection options and strategies. This has been followed by a comprehensive study on the works done in the past on the behaviour and problems along the Tamilnadu coast by different organizations with a plea for the need for protecting the coast. The historical data set available on the above aspect with different agencies were shared with IIT Madras by the department of Environment, Government of Tamilnadu.

In the present study, the stability of the coastal line of Tamil Nadu has been analyzed by dividing the entire coastline into number of stretches each of a length of about 5km which have been analyzed through satellite imageries. The assessment on the shoreline variations has been obtained using the Digital Shoreline Analysis System (DSAS). The DSAS computer software that computes statistics of the shoreline variations from multiple historic shoreline positions residing in a GIS environment, in which, the coastline is digitized for several years with the help of Google Earth with a resolution of 30 m and beach profile data from the PWD has been analyzed. The trend in the coast line variations obtained from the present study has been tabulated with the other data set obtained from Space Application Centre (SAC) and Public works department of Tamilnadu (PWD).

This is followed by the section dealing with the wave climate and longshore sediment transport rates by dividing the entire coast into four major divisions. Further, the applicability of monthly representative wave characteristics in computing the sediment transport has been addressed.

Tidal inlets along the coast and the associated problems have been addressed along with few tentative solutions and mitigation measures. This is followed by a presentation on the status of the fishing harbors, fish landing points and fish landing centers along the coast of Tamil Nadu.

The coast of Tamil Nadu is highly vulnerable to disasters that are perennial at least once a year like cyclone, storm surge or rare extreme events like the great Indian Ocean tsunami of

2004. The devastative effects of cyclones and tsunamis in the past has resulted in the loss of several lives and damage to private properties, infra structural facilities onshore and in the coastal regions. Through efficient pre-planned mitigation measures, loss of lives and property can be saved and environmental damage can be significantly reduced. Hence, the significance and the considerations of such events in the design of protection measures are briefed. This section also showcased the conceptual solutions suggested and submitted to PWD by Prof. Sundar, during the post Tsunami survey carried out during 2005.

Ecologically sensitive area is the one, needing special attention because of its landscape, special kind of eco-system or historical value. Hence, this section briefs about the ecologically sensitive areas along the coast of Tamil Nadu. The solution for these coasts should be provided with proper considerations in order to avoid any ecological imbalance to the system.

Coastal environment change under the influence of both natural and anthropogenic factors, and at temporal scales ranging from hours to decades and even longer. The coast line along Tamil Nadu that has experienced significant change between 2003 and 2016 has been identified through the shoreline analysis carried out using Google Earth imageries using GIS. Based on the analysis the vulnerability index has been assigned to each 5km stretch of coast. The field survey has been carried out in the locations which are highly vulnerable. The tentative solutions has been proposed to each of those location and the priority for the commencement of technical assessment followed by the execution of the work has been given based on vulnerability based on erosion and socio-economic aspects pertaining with the location.

Finally, conceptual protection measures to be considered under the shoreline management based on the problems faced by the coast and coastal communities have been addressed. The implementation of the proposed measures have to be carried out only after a detailed scientific study.

CONTENTS

LANDING CENTRES

FIGURES

TABLES

CHAPTER 1

COASTAL FEATURES, BASIC ENVIRONMENTAL DATA, PROTECTION OPTIONS AND STRATEGIES

1.1 INTRODUCTION

1.1.1 General

India has a long coastline of about 7500 km including its island territories, which consists of a variety of coastal habitats (areas) such as estuaries, mangroves, coral reefs, etc. These coastal areas and areas of endangered animals are considered as "critical habitats" as they are unique, fragile and exhibit high biodiversity supporting several coastal and marine plants and animals. By virtue of these habitats located in coastal areas, their high productivity and the services they offer, they are subjected to ecological pressure due to natural processes and human interventions. The combined pressure of natural processes and human activities cause changes in these critical habitats leading to deterioration and/or loss of these areas over the years. The coastal regions of India are densely populated and nearly 20% of the total population of India living in these regions. The maritime states of India is under enormous pressure in terms of maintaining its stability against the perennial erosion of coast, blocking of river mouths through sedimentation as well as against the extreme coastal hazards like cyclones, storm surges and tsunami. This calls for an in-depth assessment of the behavior of the shoreline which is dictated by the wave and sediment dynamics. On fulfilling this task, the next important task would be to plan for mitigation measures and implement them in such a way it does not transfer the problem to adjoining coast. **Such an exercise is taken up for the Tamilnadu coast, the details of which are presented in this report.**

Tamilnadu situated along the South-East of Peninsular India has a land area of nearly 1,30,000 Sq.Km and a coastline of nearly 1000 km. A major portion of this coastline, starts from Pulicat in the North and extends up to Kanyakumari in the south, along the east coast and on the west coast a length of about 40km of the coastline extends from Kanyakumari to Erayumanthurai. Estuaries of ecological importance, major and minor ports, fishing harbours, monuments of international heritage, tourist locations, pilgrimage centres, etc are located along the coastline of Tamilnadu. Considerable length of Tamilnadu coast is exposed to erosion and accretion, for instance, nearly 10 Km of coast north of Chennai harbour along the stretch of Royapuram has been eroding continuously since the development of the Chennai harbour which has been formed by a pair of breakwaters. Nearly 4,84,000 m^2 of coastal area is believed to have eroded along this coast over two decades. It is also a fact that about 2,25,000 m^2 of sand has deposited resulting in the advancement of the marina beach towards the sea. The erosion of beaches due to long shore transport has been observed from Pulicat up to Cuddalore. From Poompuhar to Nagapattinam, the effect of onshore-offshore movement during cyclone is seen apart from the littoral drift alongshore. The beaches along the Arabian Sea erode during south west monsoon months and subsequently recover during the non-monsoon months. The Tamilnadu state map is shown in **Fig.1.1.**

Fig. 1.1 Tamilnadu State Map

Therefore, while carrying out erosion control measures, it is imperative that the problems are analyzed systematically and appropriate management solutions are arrived to minimize damages if any. This is the major goal of the preparation of a comprehensive shoreline protection management plan / scheme. Realizing this, Director, department of Environment, Govt of Tamilnadu, vide: R.C No.P1/Appeal/4/2011 dated 29.12.2015 requested IIT Chennai to prepare Comprehensive shoreline protection management plan / Scheme for the entire coast of Tamil Nadu in compliance with the orders of Hon'ble NGT for the protection of the coast.

Indian Institute of Technology Chennai, IITM which spontaneously agreed to the task of planning for tsunami rehabilitation measures for Tamilnadu soon after the great Indian Ocean tsunami of 2004 readily accepted the request of Department of Environment, Government of Tamilnadu to carry out a detailed study which would also include a review of works as done till date by different agencies and to come out with a Comprehensive Shoreline Management Plan (SPM) for the entire coast of Tamilnadu. This would be a next higher level document on the Master Plan for Coastal Protection of TN coast which was prepared in 2005 as per the request of Public Works Department (PWD), Government of Tamilnadu as a part of tsunami rehabilitation. In the present investigation field measurements at vulnerable locations that are identified through a scientific approach would be supplemented to provide the solution.

The comprehensive SPM for the entire coast of Tamilnadu would cover the following.

- Identification of critically vulnerable coastal areas through vulnerability assessment
- Modeling studies, past significant data sources, literatures are the tools to be provided
- Management options including developing short term measures for protection of eroding areas based on behavioural studies
- Identification of hot-spot erosion sites on the areas furnished by the PWD & Fisheries department and fixing suitable protection measures – either soft or hard solutions.

The past experiences of IITM would supplement understanding the shoreline monitoring using remote sensing images by SAC, ISRO over the period from 2004-2009 and sediment cell approach by NCSCM. It would lead to the preparation of this comprehensive master plan after ascertaining the current conditions of the vulnerable coastal stretches through extensive field survey. A brief introduction to the morphology of the coast and the methodology to be adopted to achieve the goal of SPM are given below.

1.2 COASTAL FEATURES

1.2.1 Geology of the coastline

The entire coast of Tamil Nadu consists of alluvium and beach sands overlying sedimentary formation such as laterite, limestones, clay, and stones etc. The nature of the coastal belt is as detailed in **Table 1.1**

Table.1.1 Nature of Coast of Tamilnadu

Chennai to Marakkanam	Crystalline rocks overlaid by sedimentary and alluvial formation
Marakkanam to Coleroon mouth	Sand stone, shells, lime stone and clays
Coleroon to Ramanathapuram	Alluvial formation of beach sands and sand dunes that rest on crystalline rocks
Ramanathapuram to Kannyakumari	Alluvial formation of beach sands and sand dunes resting on crystalline rocks
Kannyakumari to Kollengode	Sand and rock

The coast of the Tamilnadu State contains some rare and Valuable minerals such as Illuminite, zircon, etc. These mainly occur along the Coast of Tirunelveli and Kanniyakumari district. There is also a Indian Rare earth factory at Manavalakurichi under the Control of Central Government in Kanyakumari district.The nature of coastline is generally classified as below(**Fig. 1.2**).

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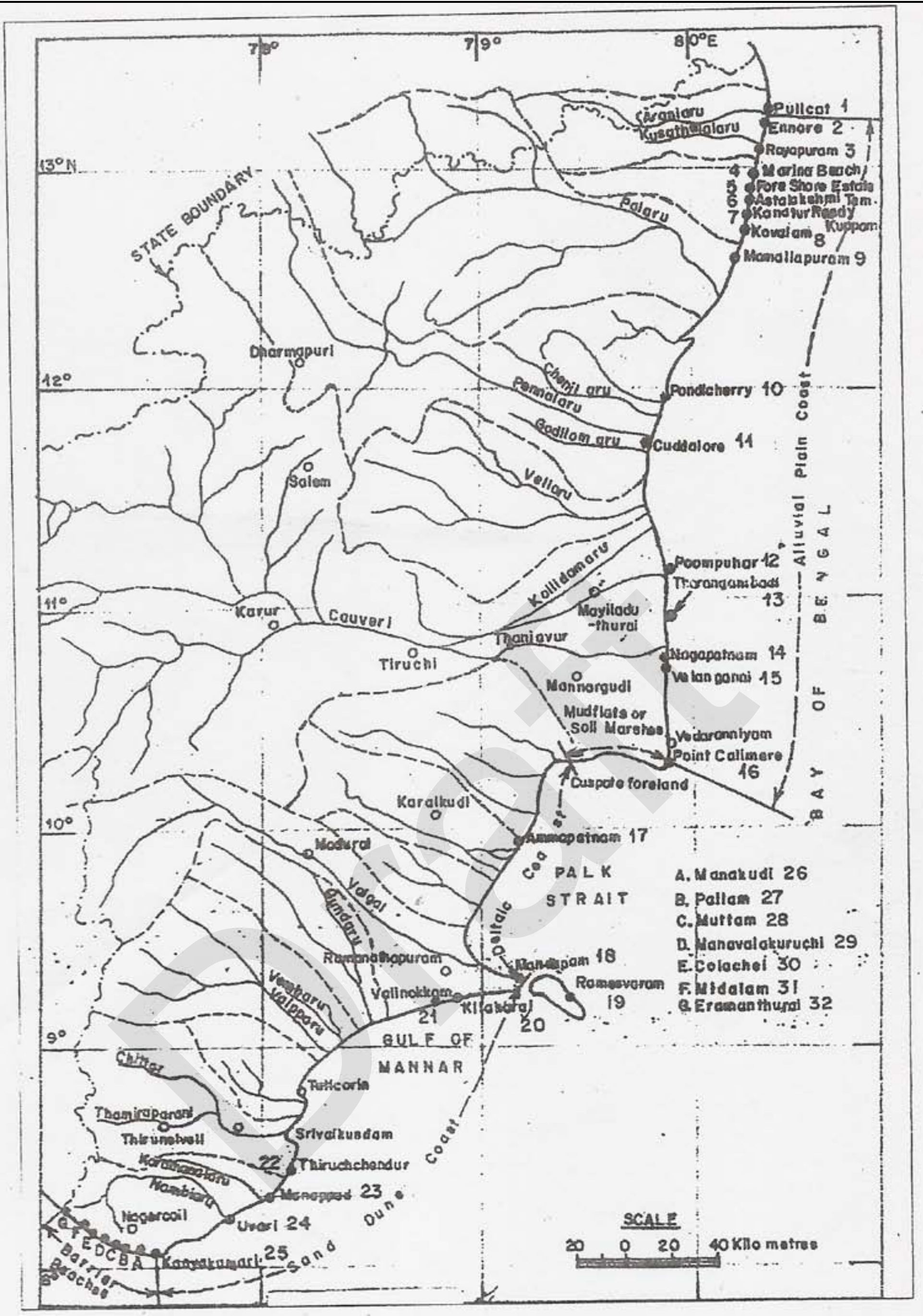
- Coastline from Pulicat to Vedaranyam-Alluvial
- Coastline from Vedaranyam to Mandapam-Deltaic
- Coastline from Mandapam to Kanniyakumari-Sand Dunes
- Coastline from Kanniyakumari to Nagerkoil Barrier Beach



MAP SHOWING THE COAST LINE OF TAMILNADU AND ITS CLASSIFICATION

Fig. 1.2. Map showing the coastline of Tamilnadu and its classification

1.2.2 Rivers and river mouths

There are 46 rivers draining into the sea along the coast of Tamilnadu as shown in **Fig.1.3.**The flooding of Tamilnadu during the unprecedented rain during the last week of Dec 2015 had created record and one of the probable reasons is improper draining of storm water into Bay of Bengal. The choking of river mouths had been a topic, in particular Cooum, Adyar, etc needs an in-depth investigation before finalizing the solution which could be a of scientifically examined pair of training walls. A few rivers needs to be carefully investigated as they are characterized by a number of mouths and conflicting of interests between the user agencies poses a big challenge needing a more careful planning. No piecewise solution will work to solve this decades old problem. Of the rivers of Tamilnadu, the following are the important ones, which need attention are given below.

- Pulicat
- Ennore
- Cooum
- Adayar
- Vellar
- Vellaiyar
- Punnakayal
- Thengapattinam

Fig.1.3 Rivers of Tamilnadu

1.3 BASIC ENVIRONMENTAL DATA

1.3.1 Wave climate

One of the main driving forces for the sediment transport along the coast that governs the stability of the shoreline is the wave characteristics and its estimation as close as possible to that occurring in the field is of paramount importance.The visually observed wave data for the period April 1974 to March 1984 has been analysed to arrive at the short term statistics, the details of which are reported by Sundar(1986). The wave characteristics (wave height, its period and its direction) along the Tamilnadu coast are influenced by the prevailing seasons, viz., South West monsoon, SW (June to sept), North East monsoon, NE (Oct to Dec) and Non monsoon, NM (Jan-May). The results on the wave characteristics are accordingly derived. The annual as well as the season wise wave scatter diagram are provided in **Tables1.2 to 1.5**. From the tables, it is seen that for the whole year, the most probable wave height ranges between 0.4m and 0.6m and the period ranges from 8s to 10s. The cumulative probability distribution of the wave climate (height, period and direction) according to the seasons are depicted in **Figs.1.4a to 1.4c**.The most probable wave height range during SW and NM Seasons is 0.4m to 0.6m, whereas, the said range for the NE season is higher to the extent of 1m to 1.2m. The most frequently occurring wave period ranges from 8 to 10 sec. The west coast is Vulnerable to both SW and NE monsoons. Although, the results on the average wave characteristics for the Tamilnadu coast are from the data collected during 1974 to 84, they would certainly be useful to describe the short term statistics which can be utilized for the prediction of sediment transport rate and its direction.Wave climate indicate that 90% of the waves approach the coast from SE direction and the remaining 10% from NE direction.

1.3.2 Wind

Hourly wind speed data from the Indian Meteorological Department, Govt. of India for the period 1974 to78 for Chennai harbour have been analysed by Sundar and Ananth (1988), the salient results on the season wise probability distribution of wind speed of which are provided in **Fig.1.5.** The results indicate the speed varies up to about 50 kmph and much higher when cyclone cross the coast.

Table. 1. 2. Percentage Frequency Of Occurrence Of Wave Heights And Wave Periods Off Chennai During April 1974 To March 1984

Wave height groups in (m)	Wave period groups in sec						
	4-6	6-8	8-10	10-12	12-14	14-16	Total
0.4-0.6	----	0.79	9.71	12.97	3.79	0.11	27.37
0.6-0.8	----	0.86	10.12	7.91	0.86	----	19.75
0.8-1.0	----	0.22	5.74	4.09	0.22	----	10.27
1.0-1.2	----	2.55	13.80	5.81	0.86	----	23.02
1.2-1.4	----	1.50	3.56	2.47	0.11	----	7.64
1.4-1.6	----	2.32	4.84	0.94	0.07	----	8.17

1.6-1.8	----	0.52	0.41	0.34	----	----	1.27
1.8-2.0	----	0.30	0.26	0.45	0.04	----	1.05
2.0-2.2	0.07	0.26	0.49	0.22	----	----	1.05
2.2-2.4	0.04	0.04	----	----	----	----	0.08
2.4-2.6	----	0.15	0.15	----	----	----	0.30
Total	0.11	9.51	49.08	35.20	5.95	0.11	100

Table. 1. 3. Percentage Frequency Of Occurrence Of Wave Heights And Wave Periods Off Chennai During South West Monsoon

Wave height groups in (m)	**Wave period groups in sec**					
	6-8	**8-10**	**10-12**	**12-14**	**14-16**	**Total**
0.4-0.6	0.11	10.13	13.29	8.06	0.22	31.81
0.6-0.8	0.44	9.91	8.39	1.74	----	20.48
0.8-1.0	----	6.54	7.08	0.33	----	13.95
1.0-1.2	0.98	14.38	6.75	1.09	----	23.20
1.2-1.4	0.65	3.38	1.53	----	----	5.56
1.4-1.6	0.65	2.61	0.65	0.11	----	4.02
1.6-1.8	0.22	----	0.22	----	----	0.44
1.8-2.0	----	----	----	----	----	----
2.0-2.2	----	0.33	0.22	----	----	0.55
Total	3.05	47.28	38.13	11.33	0.22	100

Table. 1. 4. Percentage Frequency Of Occurrence Of Wave Heights And Wave Periods Off Chennai During North East Monsoon

Wave height groups in (m)	**Wave period groups in sec**					
	4-6	**6-8**	**8-10**	**10-12**	**12-14**	**Total**
0.4-0.6	----	0.15	3.80	10.38	1.17	27.37
0.6-0.8	----	0.44	6.43	7.31	0.59	19.75
0.8-1.0	----	----	4.82	1.46	0.51	10.27
1.0-1.2	----	3.80	15.35	4.09	0.59	23.02
1.2-1.4	----	2.34	4.68	4.09	----	7.64

1.4-1.6	----	4.97	9.94	2.05	0.15	8.17
1.6-1.8	----	1.32	1.61	1.02	----	1.27
1.8-2.0	----	0.59	0.88	1.46	0.15	1.05
2.0-2.2	0.29	1.02	1.02	0.44	----	1.05
2.2-2.4	0.15	0.15	----	----	----	0.08
2.4-2.6	----	0.59	0.59	----	----	0.30
Total	0.44	15.37	49.12	32.3	2.8	100

Table. 1.5. Percentage Frequency Of Occurrence Of Wave Heights And Wave Periods Off Chennai During Non - Monsoon

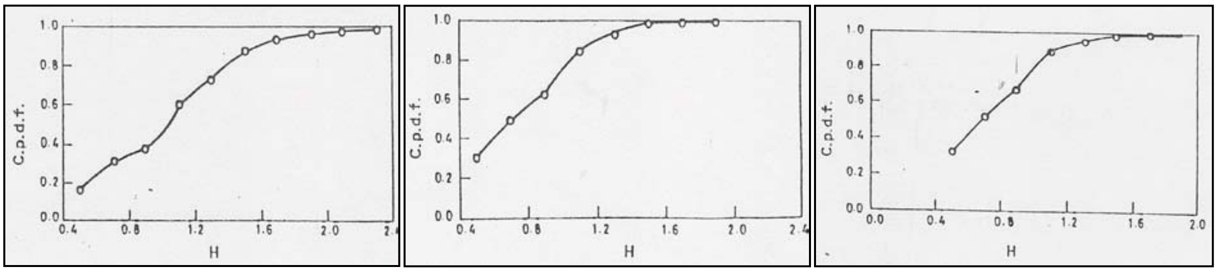
Wave height groups in (m)	Wave period groups in sec					
	6-8	**8-10**	**10-12**	**12-14**	**14-16**	**Total**
0.4-0.6	1.78	13.15	14.37	1.78	0.09	31.17
0.6-0.8	1.50	12.68	7.89	0.28	----	22.35
0.8-1.0	0.56	5.63	3.19	0.19	----	9.57
1.0-1.2	3.10	12.30	6.10	0.85	----	22.35
1.2-1.4	1.69	3.0	2.25	0.28	----	7.22
1.4-1.6	2.07	3.47	0.47	----	----	6.01
1.6-1.8	0.28	----	----	----	----	0.28
1.8-2.0	0.38	0.09	0.19	----	----	0.66
2.0-2.2	----	0.28	0.09	----	----	0.37
Total	11.36	50.60	34.55	3.38	0.09	100

1.3.3 Tides

The phenomenon of tide formation is due to attraction between Sun, Moon, Earth and other Celestial bodies. The average tidal range is about 1m, the effect of which, is not dominant along the Tamilnadu Coast compared to the other stretches of the coast of India.

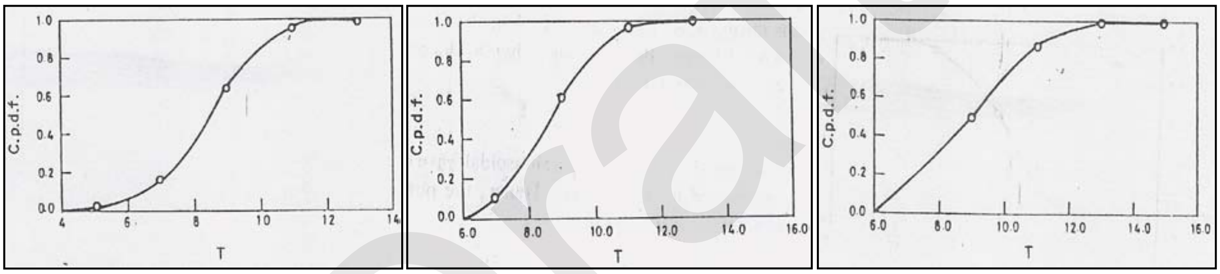
1.3.4 Currents

The currents off Tamilnadu coast varies up to about 1m/sec. The direction of the current varies with the seasons. The long shore current velocity which dictates the rate and direction of the littoral drift off the coast of Chennai have been calculated and found to vary upto about 0.75m/s and is in general directed towards north from Feb to September, while, during the other months the long shore current is directed towards south [Sundar(2002)].



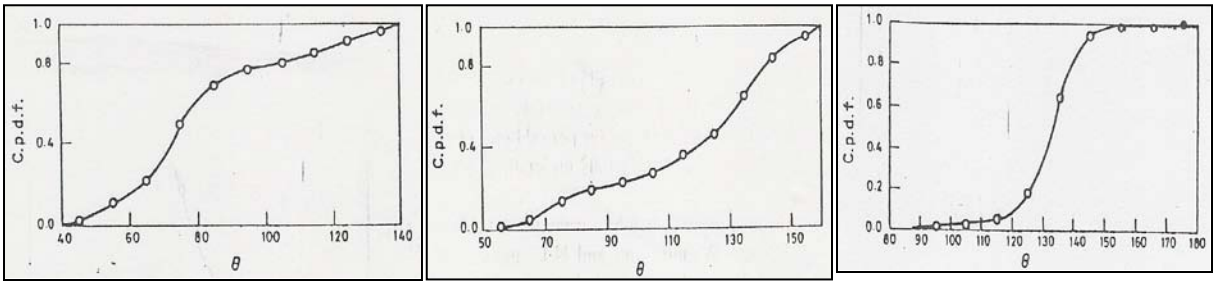
North East Monsoon Non - Monsoon South West

Fig. 1.4 a. Distribution of wave heights



North East Monsoon Non - Monsoon South West

Fig. 1.4 b. Distribution of wave periods



North East Monsoon Non - Monsoon South West

Fig. 1.4 c. Distribution of wave directions

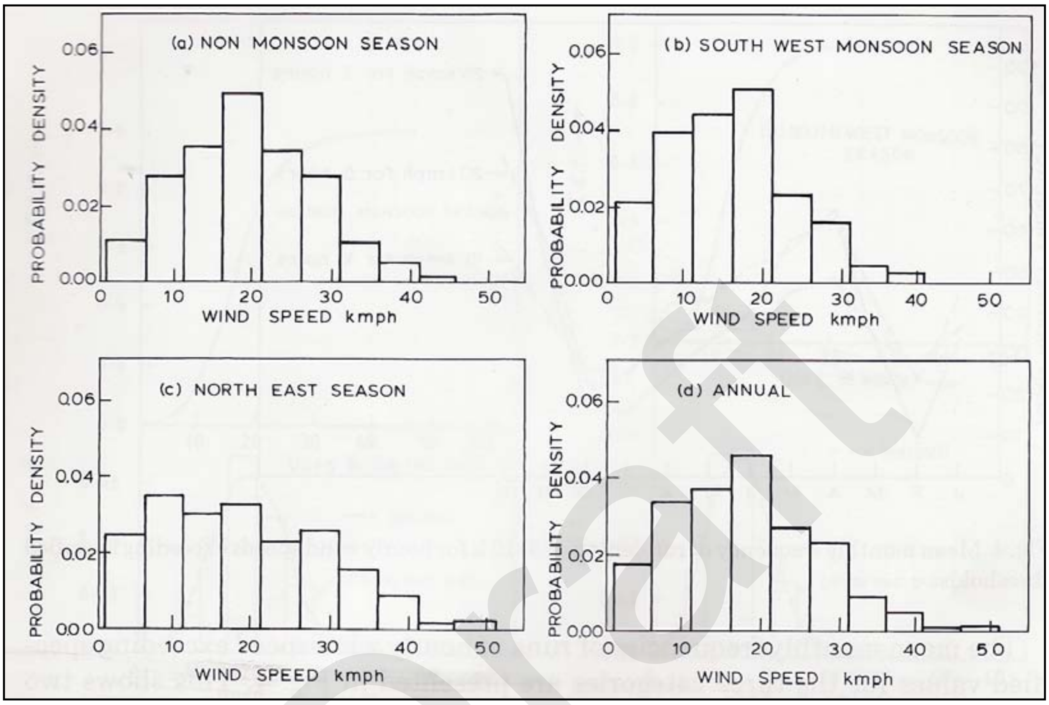


Fig. 1.5 Seasonal and annual distribution of hourly wind speeds for Chennai Harbor

1.3.5 Littoral drift (Erosion and accretion)

The wave induced sediment transport, 'littoral drift' takes place along the coast as well as normal to the shore, and however, the former mode of transport is predominant along the east coast of India in general and along the Tamilnadu coast in particular. The approximate rate of net littoral drift is $0.8*10^6$ m^3/ year along the Tamilnadu coast which is directed towards North. As we proceed northwards of Tamilnadu coast, the net drift reduces due to the interception of its movement by the breakwaters of Visakhapatnam and Paradeep ports. The said quantity is probably one of world's highest rates of sediment transport. The littoral drift can easily be calculated using empirical formulae. Some salient results on the monthly distribution of breaker angles, height and sediment transport rate along the Chennai coast have been discussed by Sundar (2002).

A coast is said to be eroding when the loss of sediments exceed the supply. Accretion is the process by which there is deposition of sediments. The shoreline is observed to be shifting land ward or towards the sea depending on a number of parameters like, prevailing wave climate, geomorphology, sediment characteristics, presence of natural or man-made obstructions, inlets, presence of outcrops, promontories or headlands. Along the Tamil Nadu coast, the erosion rate observed at Poompuhar, Tarangampadi, Nagapattinam, Mandapam,Manapadu, Ovari, Kanyakumari, Pallam, Manavalakurichi and Kolachel is about 0.15, 0.65, 1.8, 0.11, 0.25, 1.1, 0.86, 1.74, 0.60 and 1.2 m/yr respectively. (Kaliasundaram et al.,(1991). The P.W.D (2002) based on the continuous monitoring of the levels of the crest of berm have found that the stretch of the coast north of Chennai harbour is being eroded at an average rate of about 6.5m/year. The details of these results are reported in **Table 1.6**. The maximum rate of erosion along Tamil Nadu coast is about 6.6 m/yr near Royapuram, between Chennai and Ennore port (IHH Poondi, 2002). The accretion rate at Cuddalore, Point Calimere, Amma-pattinam, Kilakarai, Rameswaram, Tiruchendur, Manakudiand Muttam is observed to be about 2.98, 3.4, 0.72, 0.29,0.06, 0.33, 0.57 and 0.17 m/yr respectively.

Table 1.6 Rate of Erosion along the Tamilnadu Coast (PWD, Tamilnadu, 2002)

Accretion Erosion

Sl.No.	Location	Length in m	Accretion/ Erosion	Rate in m/year
1	Pulicate	0.71		3.20
2	Ennore	3.27		1.30
3	Royapuram	5.38		6.60
4	Marina	2.97		1.70
5	Foreshore	2.3		1.09
6	Elliot/Astalakshmi temple site	2.08		1.28
7	Kanathur	0.24		1.4
8	Kovalam	3.15		0.81
9	Mahabalipuram	5.45		.25
10	Piondicherry	1.19		0.15
11	Cuddalore(North)	1.538		8.00
11a	Cuddalore (south)	0.483		2.98
12	Poombuhar	1.905		0.65
13	Tranquebar	.76		1.80
14	Nagapattinam	4.27		0.11
15	Point Calimere	0.966		3.40
16	Ammapattinam	3.6		0.72
17	Keelakarai	2.9		0.29
18	Mandapam	2.19		0.25
19	Rameswaram	3.3		0.06
20	Tiruchendur	1.53		0.33
21	Manappadu	1.6		1.10
22	Uvari	2.6		0.86
23	Kanyakumari	0.7		1.74
24	Manakkudi	3.65		0.57
25	Pallam	2.6		0.93
26	Muttom	3.0		0.17
27	Manavalakurichi	3.5		0.60
28	Colachel	1.75		1.20
29	Midalam	2.5		0.84

1.3.6Cyclones and storms

The coast of the state has been hit by cyclonic storms about 30 times with disastrous effects from 1900 to 2004. The districts affected were Chennai, South Arcot district, Nagapattinam, Thanjavur, Ramanathapuram and Kanniyakumari. The storm surge ranging from 4 to 12 m have been experienced by the Tamilnadu coast.**Table.1.7** provides a list of vulnerable districts for cyclone wind and coastal/inland flooding. the tracks of cyclones along the North Tamilnadu coast during 1891-2007 as per the Indian Meteorological department is presented in **Fig. 1.6**.

The entire Indian coast can be categorized into 4 zones

- Very high risk zones (Surge height > 5m)
- High risk Zone (Surge height between 3 - 5m)
- Moderate risk zone (Surge height between 1.5 to 3m)
- Minimal risk zone (Surge height < 1.5m)

Tamilnadu coast between Pamban and Nagapattinam (~3 - 5m) falls under HRZ

Table 1.7. List of vulnerable districts for cyclone wind and coastal/inland flooding

Sl. No	District	Wind and cyclone	Coastal and inland flooding	No. of Cyclone (1800-1900)
1	Chennai	VH	FLZ	15
2	Podicherry	VH	FLZ	7
3	Tanjore	VH	FLZ	2
4	Cuddalore	VH	FLZ	2
5	Kanjeepuram	VH	-	
6	Thiruvallur	VH	-	
7	Thiruvanamalli	VH	-	
8	Villupuram	VH	-	
9	Ramanathapuram	VH	-	
10	Nagapattanam	VH	FLZ	6
11	Pudukottai	H	-	
12	Sivaganga	H	-	
13	Thuthukoodi	VH	FLZ	
14	Thirunelveli	VH	-	1
15	Kanyakumari	H	-	

Legend: M – Medium; H – High; VH – Very High; FLZ – Flood Zone

(Source: HPC Report, UNDP and NIDM)

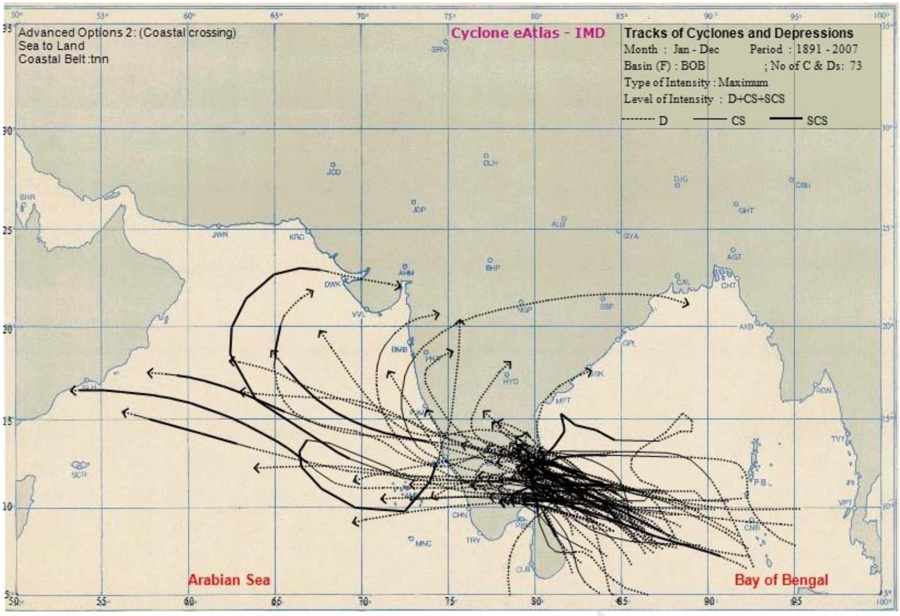


Fig. 1.6. Tracks of cyclones along the North Tamil Nadu Coast (1891 - 2007), IMD.

1.4 PORTS AND HARBOURS

A. Commercial: The commercial major and minor ports along the coast of Tamilnadu are given below.

Major ports

- Chennai
- Tuticorin
- Ennore

Minor ports

- Cuddalore
- Nagapattinam
- Valinokkam
- Pamban
- Rameswaram
- Kanniyakumari
- Colachal

B. Fishing :

- Chennai (Kasimedu) Fishing Harbour
- Cuddalore Fishing Harbour
- Nagapattinam Fishing Harbour

- Pazhayar Fishing Harbour
- Poompuhar Fishing Harbour
- Mallipattinam Fishing Harbour
- Thoothukudi Fishing Harbour
- Chinnamutton Fishing Harbour
- Colachel Fishing Harbour
- Muttom Fishing Harbour
- Thengapattinam Fishing Harbour

1.5 PILGRIMAGE AND TOURIST CENTERS

The most important tourist attractions and pilgrimage centres in Tamilnadu are located in

- Chennai
- Mahabalipuram
- Tharangampadi
- Velankanni
- Rameswaram
- Thiruchendur
- Uvari
- Kanniyakumari

1.6STRATEGY FOR COASTAL PROTECTION

Whenever erosion occurs, there are certain important guidelines to be followed. Coping erosion along a sandy coast is different from coping erosion along muddy coast, mangrove coast, and coast with clay or rock. The following are the suggested procedures:

- Verify if the erosion is temporary due to seasonal effect.
- Work out the cost of different alternatives. The costs should include not only maintenance, construction etc. but also in terms of loss of cultural values, impact on safety and the needs of the local public, etc.
- Fund/resources to combat erosion in a sustainable way.

Only after ascertaining the above basic resources and needs, proceed as follows.

- If fund / resources are available, then combat erosion permanently by proper planning.

- If enough funds or resources are unavailable, careful planning of temporary measures is essential.

1.7 REQUIREMENTS FOR A DETAILED EVALUATION FOR PROTECTION MEASURES

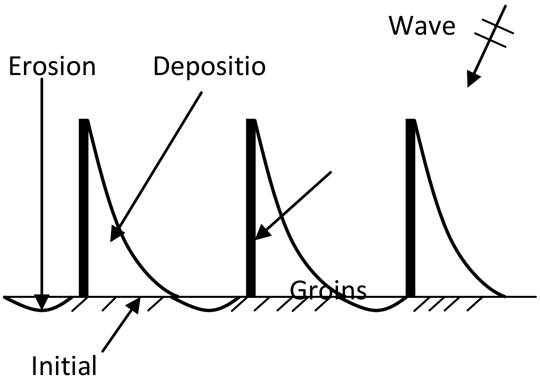
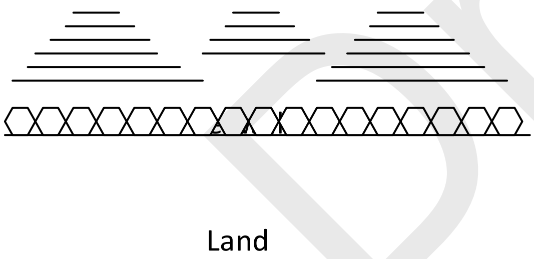
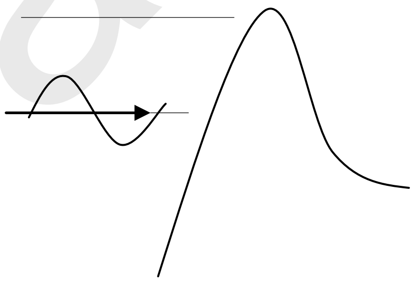
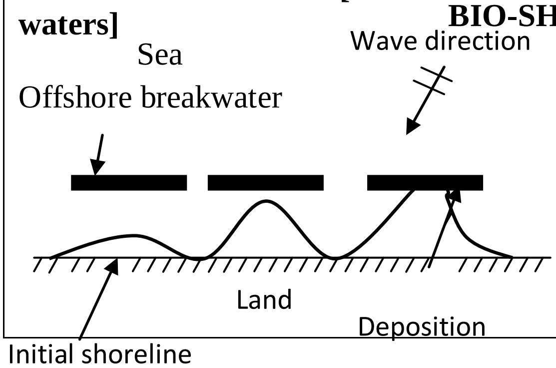
- Collection of seasonal field data and analyse the same critically
- Use old and new satellite imageries to assess the shoreline behaviour
- Use of G.I.S as a tool to map the coastal region of Tamilnadu. This would help in the planning process of coastal protection.
- A field visit along the coast.
- If erosion is observed continuously over a number of years, it is chronic erosion
- If a coast is stable over a long period, but subjected to occasional severe erosion (due to cyclone etc) and then recovers, it is called acute erosion.
- The effect of the recent tsunami on the shoreline should also be taken into account while detail planning is taken up. This can be accomplished using the techniques of remote sensing and G.I.S.

1.8COASTAL PROTECTION OPTIONS

1.8.1 General

Shorelines are constantly being changed by the interaction between wind, water and land. To protect the coast and properties, there are various methods which are discussed in **Table 1.8.**

Table 1.8. Remedial Measures for Coastal Erosion

HARD MEASURES	SOFT MEASURES
Normal to the shoreline [groins] 	Replenishment of coast with sand. At the landward side of the dune[A] At the seaward side of the dune, landward of the dune base [B] At the seaward side of the dune, seaward of the dune base [C]
Parallel to the shoretline on shore [seawalls] 	
Parallel to the shore[offshore break waters] 	**BIO-SHIELDS**

1.8.2 Artificial beach nourishment

Beach nourishment is an adaptation technology primarily used in response to shoreline erosion, although flood reduction benefits may also occur. It is a soft engineering approach to coastal protection which involves the artificial addition of sediment of suitable quality to a beach area that has a sediment deficit. Nourishment can also be referred to as beach recharge, beach fill, replenishment, re-nourishment and beach feeding.

Of all the several measures, the method of artificial nourishment deserves special mention due to the following merits:-

- It satisfies the basic need of the material demand and has all the characteristics of a natural beach.
- It increases the stability of not only the beach under protection but also the adjacent shore due to the supply of materials through longshore drift.
- More economical than massive structures as the materials for nourishment may be taken from offshore area and
- Development of the technique of dredging and sand pumping have popularised this method to effect economy.
- Sand dredged from a borrow site is deposited on the eroding shoreline

Dutch design method

- Perform coastal measurements (preferably for at least 10 years)
- Calculate the "loss of sand" in m^3/year per coastal section
- Add 40 % loss
- Multiply this quantity with a convenient lifetime (for example five years)
- Put this quantity somewhere on the beach between the low-water-minus- 1-meter line and the dune foot.

This method is simple and straightforward. It does not require mathematical models and wave (or wind) data, but need good quality measurements.

Placement of sand

Usually the dredged sand is dumped close inshore using split hopper dredger or pumping directly onto the beach using floating and/or submerged pipeline.

Borrow site

Sources of sand for beach nourishment can include upland sand deposits, estuaries, lagoons, inlets, sandy shoals dredged to clear channels for navigation and deposits in the near shore area. The most common source of sand used in nourishment projects is near shore deposits.

Drawbacks

- Once placed on the beach, the quality of sand is often sub-standard or even darker in color, despite assurances otherwise.
- Quality sand sources are becoming more difficult to locate. The problem will only get worse as sources are depleted and quality sand even more expensive.
- Dredging of sand often sucks sea turtles directly off the sea floor, killing them.
- Beach nourishment is a sudden, disruptive and unnatural process.
- It is expensive

In the Indian context, one successful project on artificial beach nourishment has been the coast north of the harbour of Puducherry that was implemented by IITM.

1.8.3 Application of Geo-synthetic products

Over the last few years, the field of geo-synthetic applications has expanded constantly, and their use, based on technical and economical advantages, compared to conventional building materials has increased steadily. They are used in coastal protection, agricultural waterway engineering, waterway engineering, railway construction, road and tunnel construction, waste management, as well as the construction of dams and slopes.

Geosynthetic is a generic term describing a product, at least one of whose components is made from a synthetic or natural polymer, in the form of a strip or a three dimensional structure, used in contact with soil and /or other materials in geotechnical and civil engineering applications. The development of geo-synthetic applications in geotechnical and hydraulic engineering has been very rapid. In the beginning the terms filter mats and woven geo-textiles were used for all water-permeable geo-synthetics, and the term membrane was used for all water-impermeable geo-synthetics. The classification as well as typical examples of geo-synthetics is presented in **Fig.1.7a** and **1.7b** respectively. Photos showing the application of geo-tubes for seawalls and groins are reported in the next section.

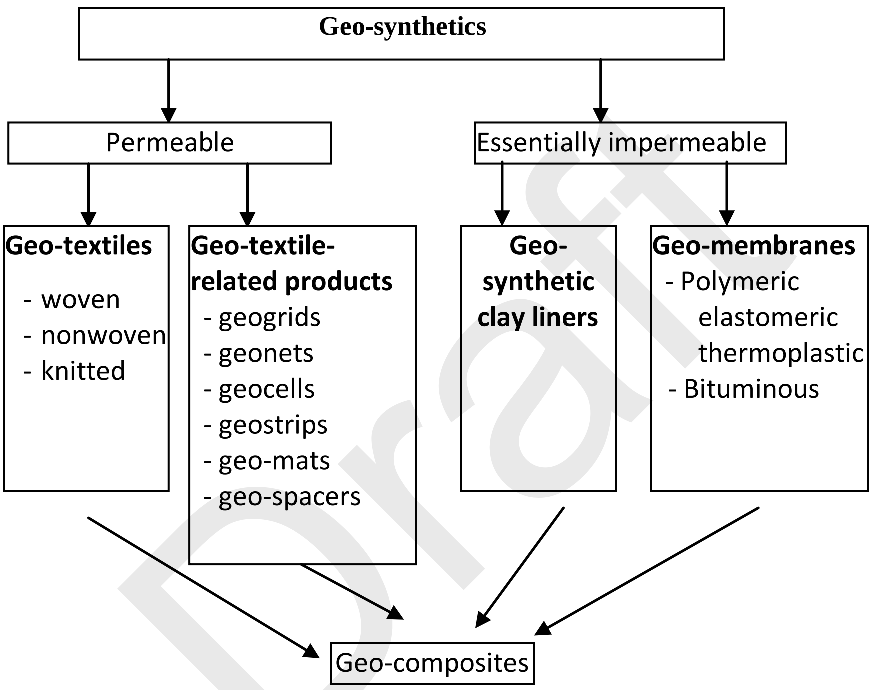


Fig. 1.7a Classification of Geo-synthetics

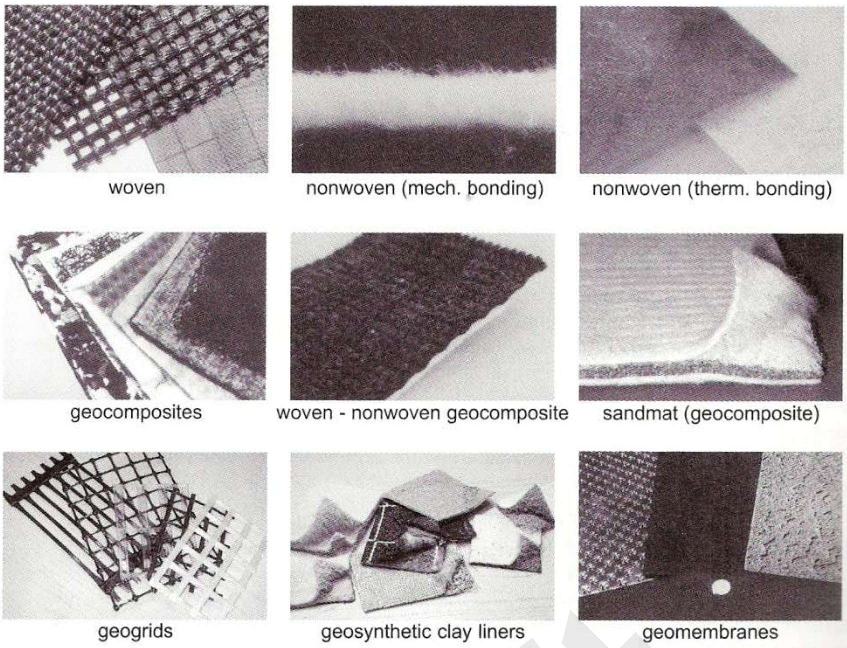


Fig.1.7b Examples of Geo-synthetics

- **Submerged Reefs**

Submerged reefs are man-made underwater structures which have been submerged into natural environment. These reefs are used due to their advantages such as reduction of wave energy reaching the shore in shallow water, providing marine habitat and enhancement of recreational benefits (diving, fishing and surfing). Geometry and design of the submerged reefs varies depending upon the main function of the structure and materials used. All kinds of materials such as concrete objects, steel structures, old wrecked cars, airplanes, military tanks, junked appliances, docks, old boats, ballistic missiles, decommissioned ships and obsolete oil rigs have been sunk and designated as submerged reefs. Reef units with different shapes and constructive characteristics can be used to produce submerged reefs. Reef units are made up of steel, reinforced or pre-stressed concrete, fibre glass or a variety of composite materials. Reef units are usually fabricated on land according to particular design specifications. Strength, stability of reef materials and construction are the physical principles involving factors such as material science, civil engineering and physical oceanography. There have been various variations in the shape, size and complexity of ref units used in submerged reefs throughout the world.

Alvarez et al. (2007) adopted technical solution of using geo-textile tubes, as low-crested structures which reduce the incident wave energy on the beach, by controlling the wave breaking process, to the required level that maintains the dynamic balance on the shoreline as shown in **Fig.1.8**. The Narrowneck Artificial Reef is located on the Gold Coast of Queensland, Australia (Jackson, 2004), approximately 2km north of Surfers Paradise implemented by Gold Coast City Council (GCCC).The design dimensions are 400m long (cross-shore), 175m wide (longshore), with the base of the reef positioned approximately 150m offshore (B/S ratio = 1.16). A view of the submerged reef as a coastal protection measure is shown in **Fig. 1.9**.

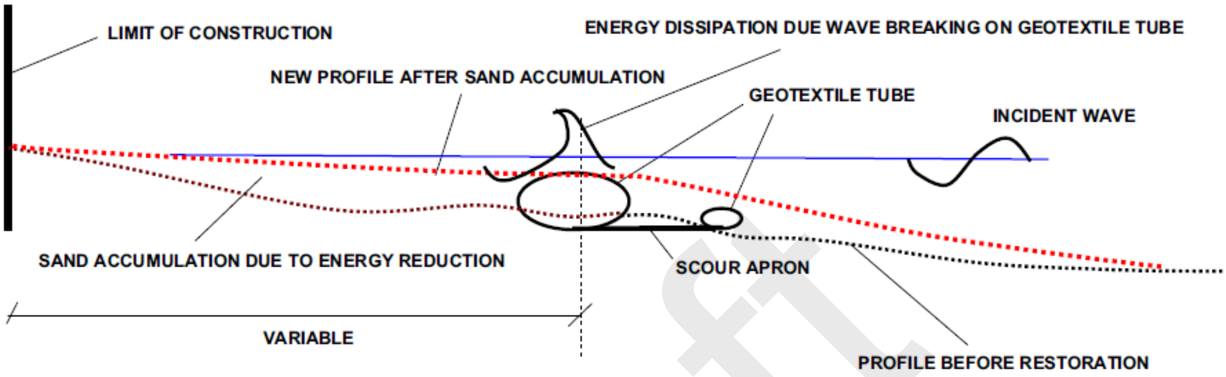


Fig.1.8. Schematic section of wave energy reduction (Alvarez, 2007).

Fig.1.9. A view showing the submerged reef as a coastal protection measure

1.8.4 Hard solution

- **General**

Unfortunately sustainable soft solution is always not possible. In such cases, the choice is either to face the problems or to shift them elsewhere, sometimes if there is a very important land to be protected and if further down the coast there are no important features, the following hard solutions can be used. The above stated shifting the zones of problems can be overcome if the protection measures are carefully planned out.

- **Seawalls and Bulkheads**

Seawalls and Bulkheads are structures placed parallel or nearly parallel to the shoreline to separate the land from water area. The primary purpose of a bulkhead is to retain or prevent sliding of the land, with a secondary purpose of affording protection to the back shore against damage by wave action. The most common and widespread coastal engineering tool for the protection of shoreline is the seawall as a hard measure. Varieties of seawalls / dikes constructed world- wide is shown in**Fig.1.10.** A typical concrete seawall cross-section is shown in **Fig.1.11.** A view of an existing concrete seawall is shown in **photo 1. Seawall protection is for all practical purposes an irreversible act because the beach in front of it is often removed.** A masonry/concrete seawall as shown in **Fig.1.12**, although very stable is expensive and difficult for implementation over long stretches of the coast affected by erosion**.** A seawall would not be more effective on coasts that experience predominant littoral drift, like the east coast of India. For example, the seawall along north of Chennai, Visakhapatnam and Paradeep ports have been suffering damages continuously. A strong toe for seawall is very essential as in the case of the seawall for a particular stretch, north of Chennai harbour shown in **Fig.1.13.**The section has withstood the effects of the tsunami 2004 and is still intact. In locations, where, large size natural rocks is scanty, gabions (wire net filled with stones of smaller size) as shown in F**ig.1.14** can be adopted. At locations of abundance of sand (near river mouths which may be dredged and Geo-bags or Geo-tubes can be adopted for seawalls or groins as can be seen in **Figs. 1.15a** (Island of Sylt) **and 1.15b**(Protecting the digha beach, west Bengal designed by IITM).

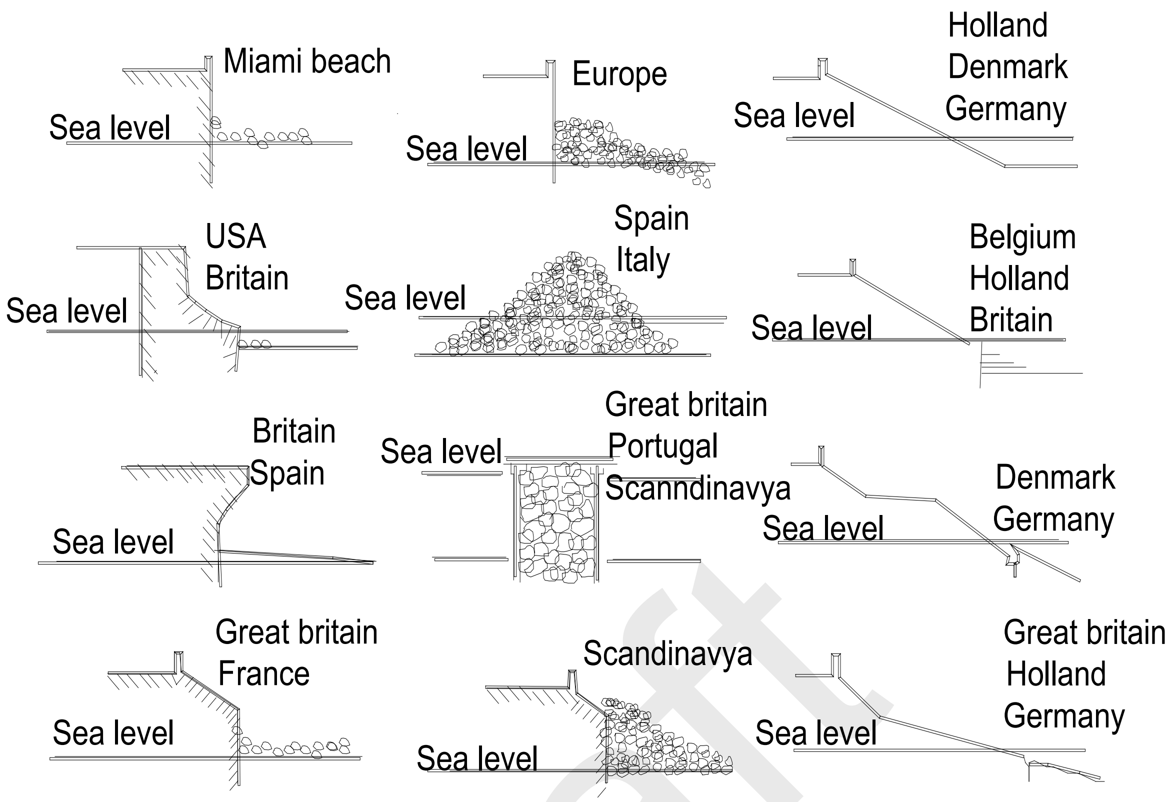


Fig.1.10 Varieties of seawalls / Dikes

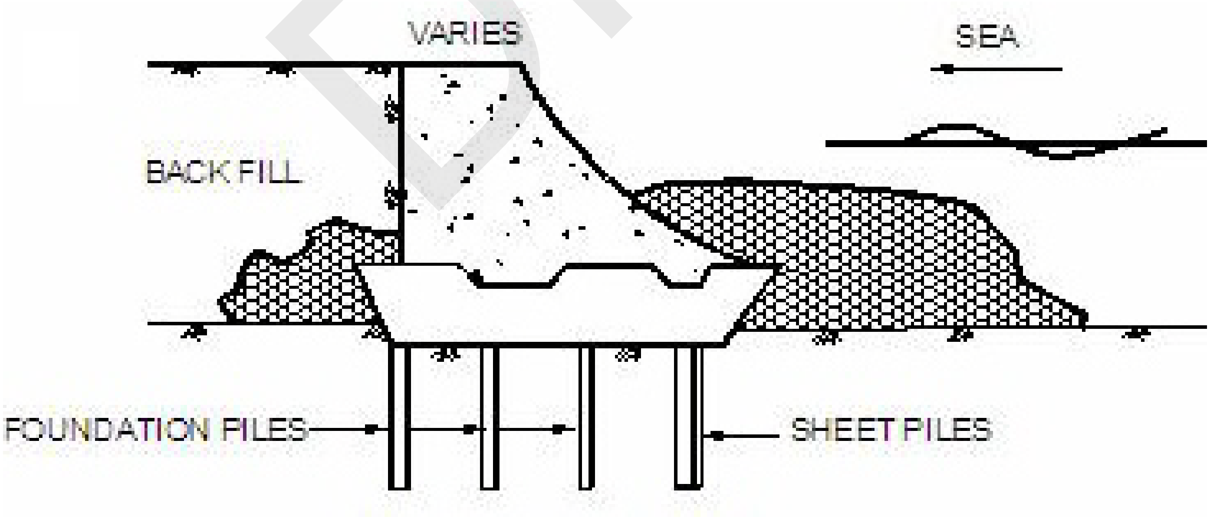
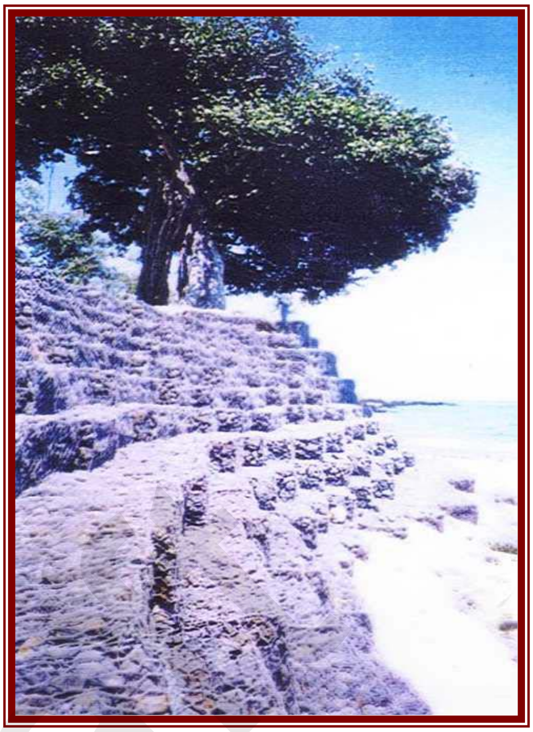


Fig.1.11 Typical cross section and photo of a concrete seawall

Fig. 1.12 View of a typical concrete seawall

Fig.1.13. Seawall with toe protection north of Ernavur

Fig.1.14 Use of Gabions



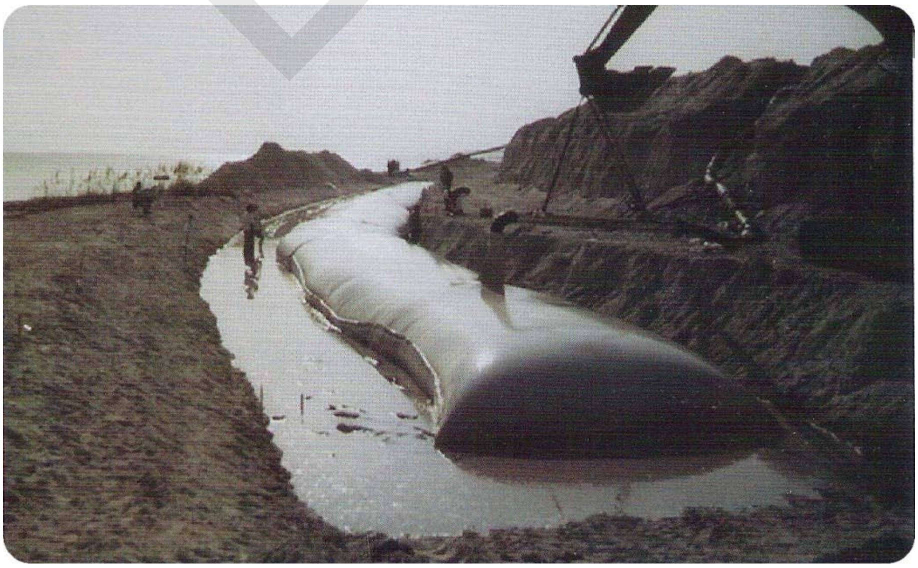


Fig.1.15a. Use of Geo-tubes to protect Island of Sylt, Germany

Fig.1.15b Use of Geo-tubes to protect Digha beach, West Bengal (IITM)

- **Single long groin**

When the long shore sediment transport threatens to cause a problem such as siltation of harbour entrance etc., a long groin can be constructed just slightly up drift from the harbour entrance or river mouth. Though, it prevents sediment movement, it can cause erosion on the other side. The different types of configurations of groins are shown in **Fig.1.16**.

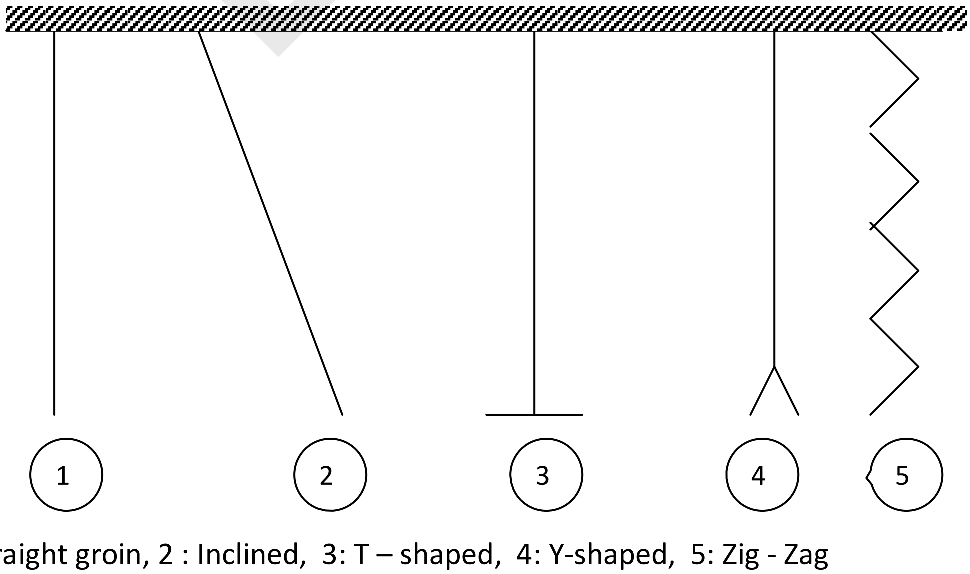


Fig. 1.16. Different configurations of groins

- **Series of groins**

Another way of using groins is to build a series of small groins (groin field) at shorter intervals along the affected coast. This will tend to stabilize the entire coast by keeping the sand trapped between them. Typical shoreline changes due to a single groin and that due to a groin field are projected in **Figs.1.17 and 1.18** respectively.The groin field has to be carefully designed and implemented. The effects of a groin field are clearly brought out through **Fig.1.19a.** Too small will produce offshore loss due to rip currents or seaward currents. Correct spacing will allow filling and overspill and too great a spacing will produce poor retention and scour. The oldest groin in the world in Vissingen, The Netherlands is shown in **Fig.1.19b**. The effect of the groin field as a protection measure protecting the west coast of Tamilandu (Kurumbunai, Vanyakudi villages, etc) designed by IITM is projected in **Fig.1.20**, while, that of a T-groin field protecting the shoreline of Narayanambalam, Kerala designed by IITM is shown in**Fig.1.21**. Sometimes unplanned groin works may still be an effective protection measure as in the case of the coast of Cyprus depicted in **Fig.1.22** Groin fields as a protection measure for Royapuram, Chennai and Kanyakumari district designed by IITM that have proven to be successful are shown in **Figs.1.23 and 1.24** respectively.

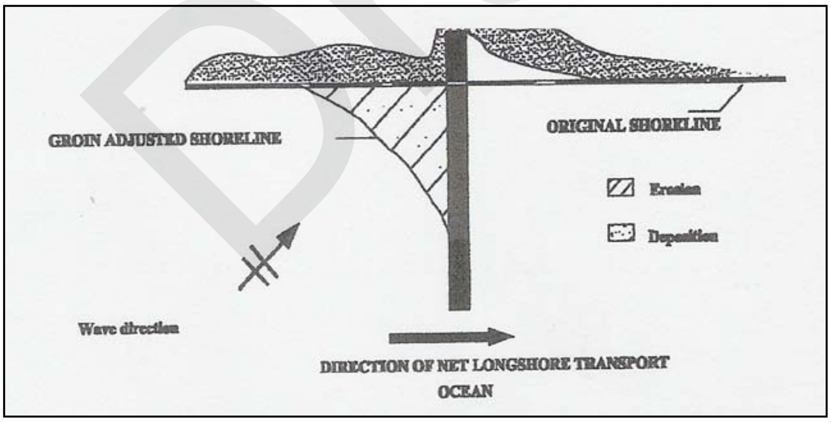


Fig. 1.17 Shoreline Configuration for Single Groin

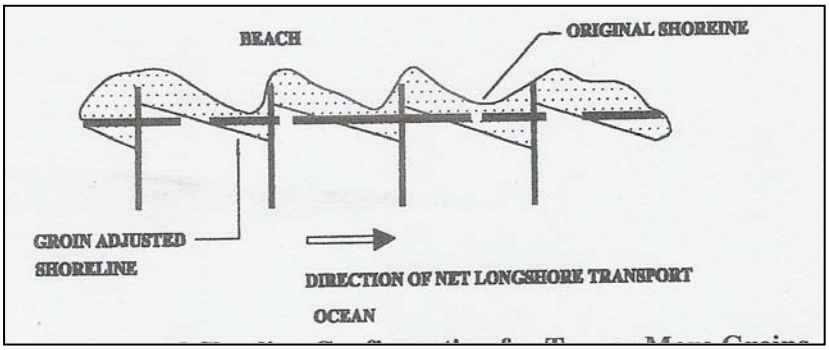


Fig. 1.18 Shoreline configurations for two or more Groins

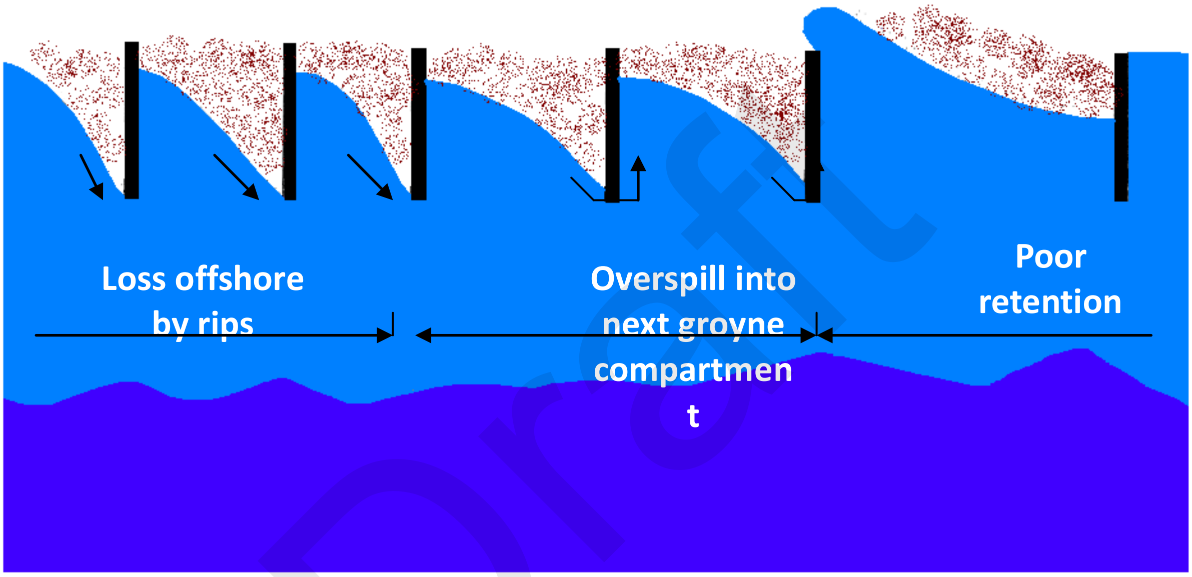


Fig.1.19a. Effects of groin field on the shoreline evolution

Fig.1.19b. Oldest groins (1503),Vvissingen, Netherlands

Fig.1.20. Groins field protecting the West coast of Tamilnadu

Fig.1.21. T-Gorin field protecting the coast of Narayanambalam, Kerala

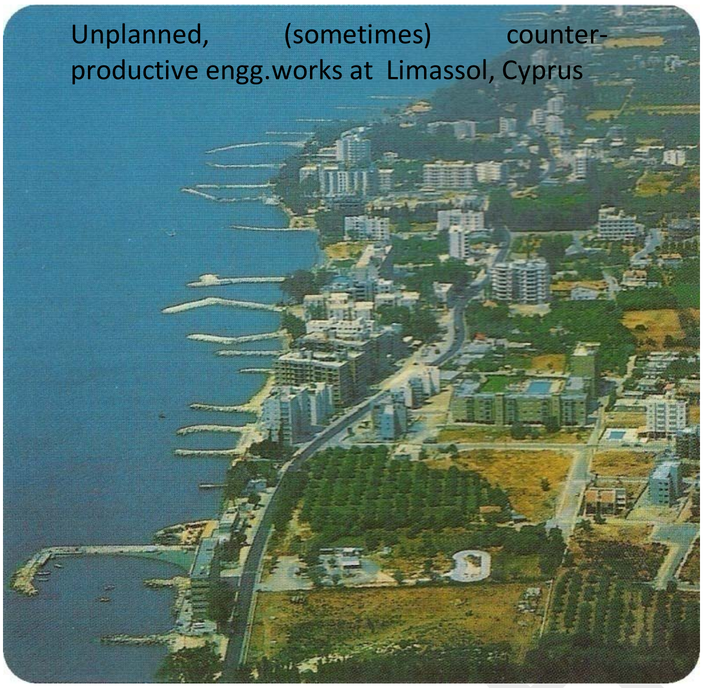


Fig.1.22. Groins as protection measures

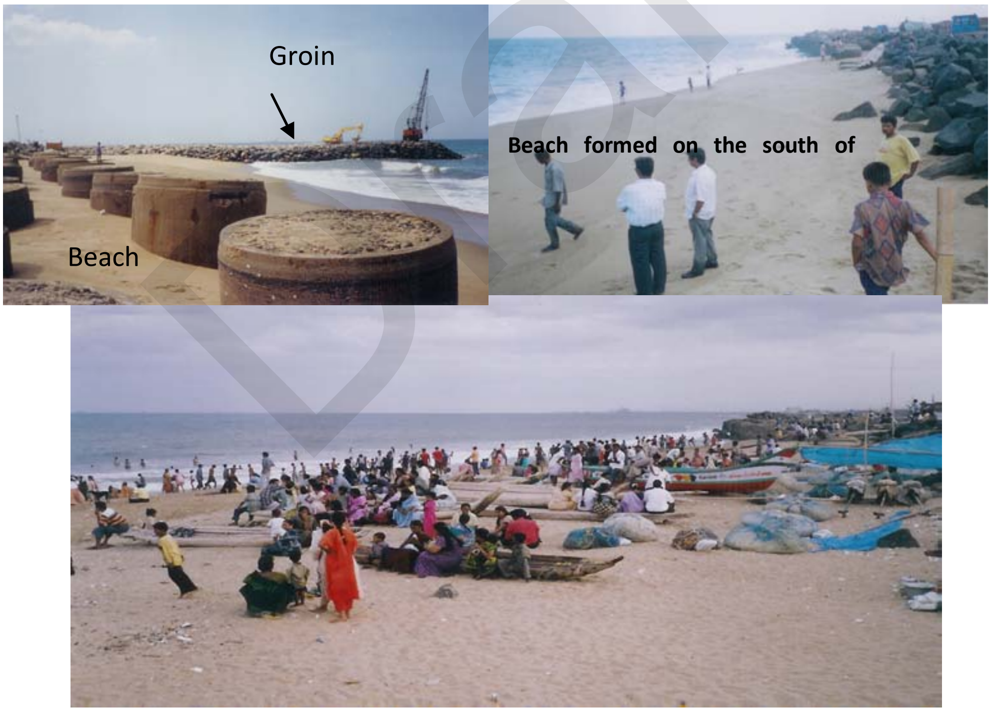


Fig.1.23. Effect of Groin field in winning the beach (Royapuram, Chennai)

Fig.1.24. Effect of groins as an effective coastal protection measure (Kanyakumari District)

- **Off shore Detached Breakwaters**

Offshore detached breakwaters are structures designed to protect the beach by dissipating the energy of the incoming waves. They restrict onshore and offshore transport of sand. Typical shoreline changes due to a single offshore breakwater and that due to a series of offshore detached breakwaters are projected in **Figs. 1.25and 1.26** respectively. Although, this measure is the most effective compared to all other hard measures, it is quite expensive and difficult to construct requiring special construction equipments.

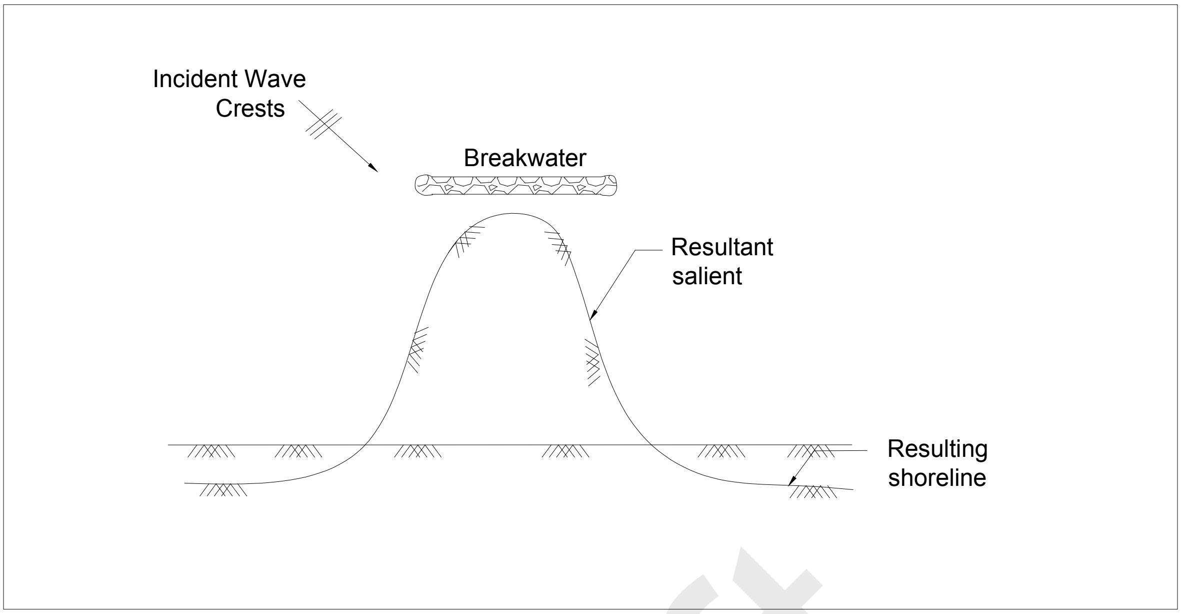


Fig. 1.25 Shoreline Evolution due to the presence of an Offshore Breakwater

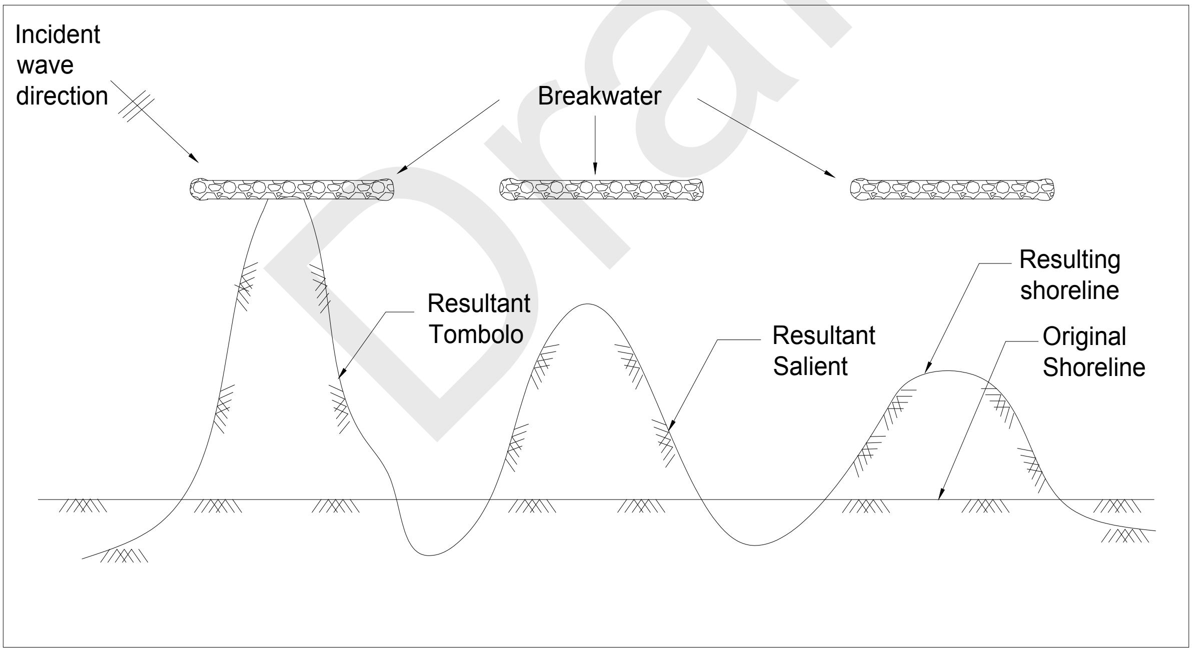


Fig. 1.26 Shoreline Evolution due to the presence of segmented Offshore Breakwaters

1.8.5 Plantations

The roots and stems of plants are natural traps for sand particles that would otherwise be carried away by wind, currents and waves. A flat beach is more favourable for such plantation. In addition marsh vegetation acts as a buffer against wave action and tsunami to some extent. **Vegetation** as a protection can both reduce loads and increase strength. Vegetation has a relatively large resistance to waves and currents, thus reducing the loads. Roots can increase the strength by protecting the grains on a micro scale or by reinforcing them. **Fig. 1.27**shows strength of vegetation with wave load. The outside plants are “front soldiers” and have to withstand a higher load than the inside plants. At the front, due to the high velocities, scour can also occur if the roots are not able to retain the soil. The effect can be that the outside plants are damaged or disappear. As long as the number of soldiers is large enough, the battle can still be won. Vegetation also influences the resistance against sliding. The roots clearly armour the soil, see **Fig.1.28** from CIRIA, 1992. Typical stretch of the coast protected by plantation is shown in **Fig. 1.29.**

Mangrove forests are the natural vegetation of many tropical coasts and tidal inlets; they form a highly productive ecosystem, a nursery for many marine species. Mangroves are essentially the root systems of trees and shrubs which thrive in the shallows of salt water areas (**Fig.1.30**). They provide an excellent safe habitat for small marine creatures.

Mangrove trees miraculously thrive in very dynamic circumstances. They can cope with salt water whereas most other plants cannot. Seedlings have little opportunity to settle, so mangroves are viviparous, giving birth to an almost complete tree in a capsule that can travel with the tide and can turn into an upright standing young tree within a few days.

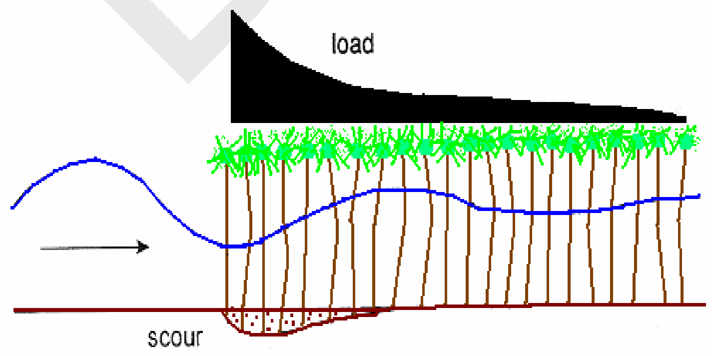
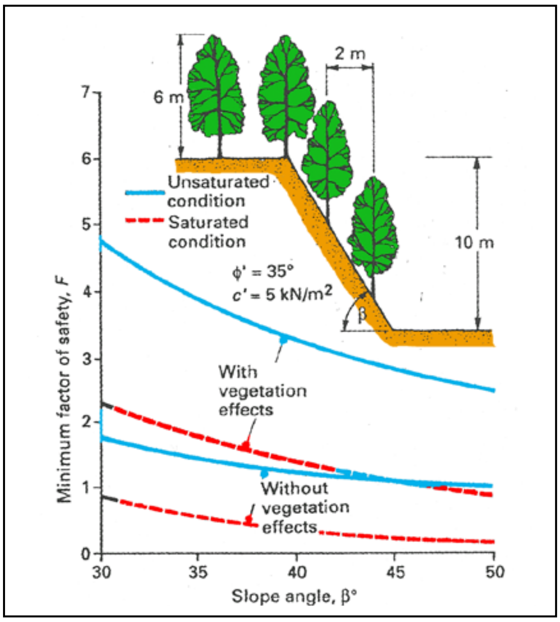


Fig.1.27 Load and Strength



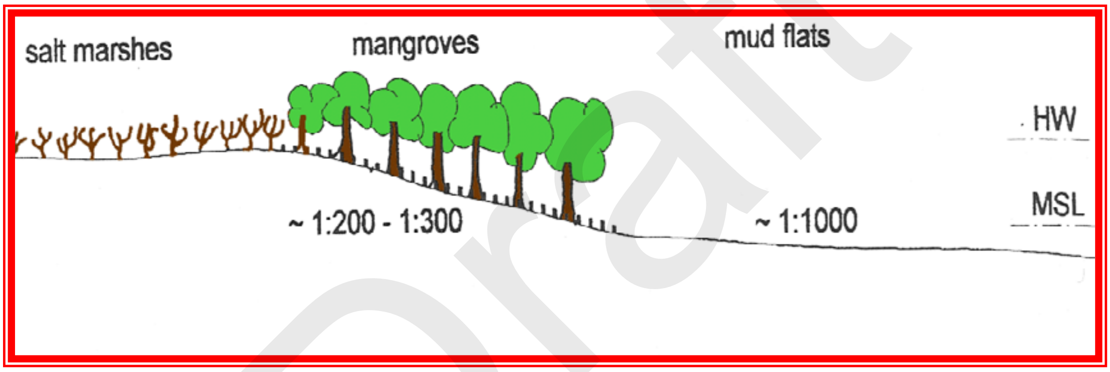


Fig. 1.28 Roots act as armour for the stem and reduces the scour Schiereck (2001)

Fig. 1.29. Plantations serving as coastal protection

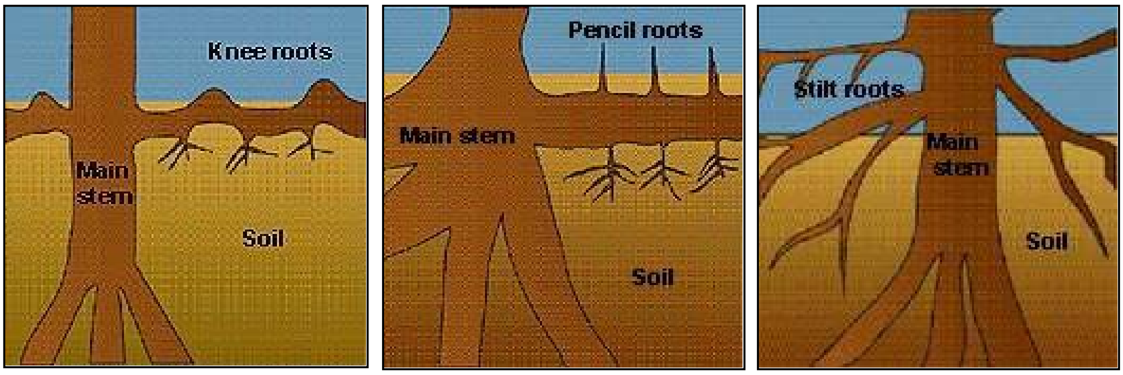
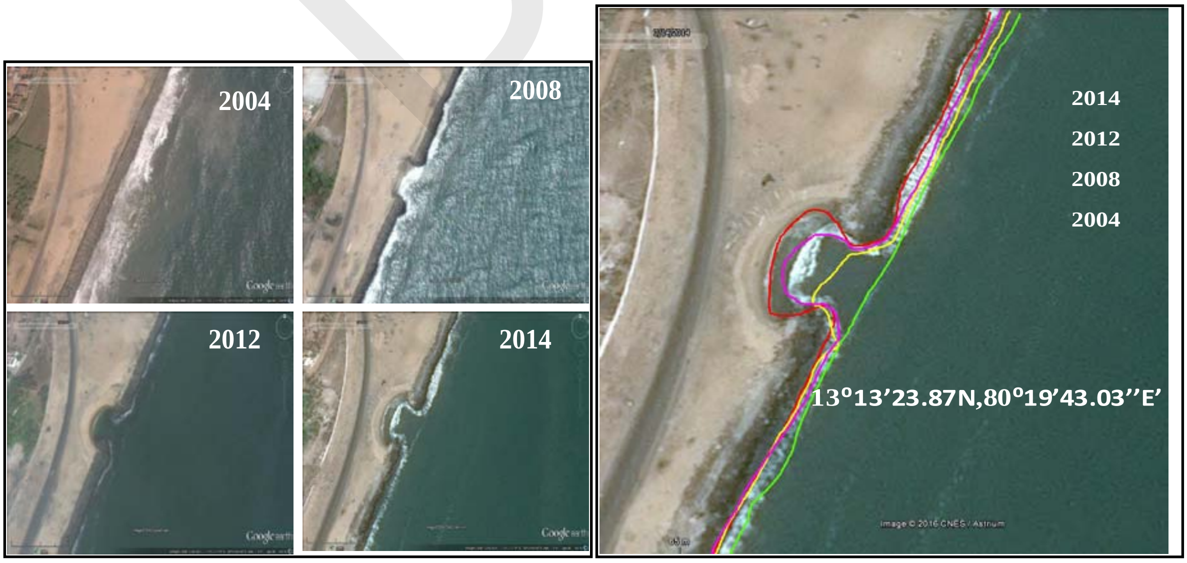


Fig.1.30. Different root systems of Mangroves that offer resistance to scour.

1.9 LONGTERM EFFECTS OF HARD STRUCTURES

Seawall has beena protection measure that has been adopted as a mitigation measure against coastal erosion over several stretches along the Indian coastline since the past several decades. Groin field has gained importance since early 2000.Both these structures if not carefully planned for, can result in serious problems in the vicinity of the terminal points.

The satellite imageries from 2004-2012 in an interval of 4 years are shown in **Fig.1.31a**.The seawall from north and from south terminating near (13^{o}13’23.87’’N,80^{o}19’43.03’’E) shows the initiation of erosion in between them in 2008, which is observed to penetrate landward with a continuous increase over the period. The super position of the shoreline (**Fig. 1.31b**) indicates that the stretch of beach of about 30m eroded over a length of about 25 m.



(a) **(b)**

Fig. 1.31a and 1.31b Shoreline behaviour near the termination of seawalls

Similar kind of scenario is observed at(13°20’00.40”N, 80°19’16.41”E)as shown **in Fig. 1.32a**.The superposition of the shoreline shown in **Fig. 1.32b** demonstrates a loss of beach of about 35m over a length of 125m.

Fig 1. 32a and b. Shoreline behaviour near the termination of seawalls

The groin field constructed north of Chennai harbor solved 5 decade problem of perennial erosion. It has been a general feeling that groins are expected to shift the zone of erosion further down drift side which is not the case if planned properly as can be seen in **Fig.1. 33a**. The superposition of shorelines **(Fig. 1.33b**) show that such problem does not arrives if a carefully designed seawall is constructed along the down drift of the last groin of the groin field. This indicates clearly irrespective of type of protection measure that is planned for, a stable coastline can be achieved if effects are put in an effective design, analysis, construction and follow up.

Fig. 1. 33a and 1. 33b. Behaviour of shoreline due to groin field off Chennai coast

Coastal erosion problems in many places of India such as Goa, Puri, and most recently in Kerala have been tried to solve using geo-textiles. New Zealand company ASR Limited (Amalgamate Solutions and Research) completed construction of Kovalam reef in February 2010 conducting extensive field studies, developing numerical and physical models, and performing exhaustive calibration and testing.

New Zealand company ASR Limited (Amalgamate Solutions and Research) half through monsoon season, Kovalam Multi-purpose reef is working to protect Lighthouse beach in Kovalam, India. The reef is 110m long, located about 10m away from the shoreline at Kovalam. Geo-textile bags filled with sand measuring about 30m in breadth were stacked on the seabed to build the soft reef. The laying of Kovalam reef is carried through preparation and moving of geo-mat to the reef location, which is followed by placement and sand filling of geo-mat at reef location.

A rubble mound seawall that is widely adopted along the coast will eventually have to be rehabilitated in constant intervals with bigger size stones as can be seen in**Fig.1.34.** In the event rehabilitationis not carried out, the cumulative damage can be even upto the disappearance of the seawall and the penetration of the shoreline into the landward side.

Fig.1.34. Seawall beyond ernavur experiencing toe erosion

1.10 LONGTERM EFFECTS OF SOFT STRUCTURES

1.10.1 Artificial beach nourishment

The benefits of the artificial beach nourishment has been discussed earlier. It is a flexible coastal management solution, in that it is reversible. It is very effective, eco-friendly, however, the sustainability of continuous bypassing of sand from the up-drift to the down-drift side becomes questionable. It is important to note that beach nourishment does not halt erosion, but simply provides sediment from an external source, upon which erosional forces will continue to act. In this sense, beach nourishment provides a sacrificial, rather than a fixed barrier against coastal erosion.As already stated, nourishment is not a permanent solution to shoreline erosion. Periodic re-nourishments, or 'top-ups', will be needed to maintain a scheme's effectiveness. This will require regular re-investment but can be viewed as a maintenance cost, such as those associated with hard engineered structures.

Depositing sediments onto beaches can generate a number of negative environmental effects, including direct burial of animals and organisms residing on the beach, lethal or damaging doses of water turbidity – cloudiness caused by agitation of sediments – and altered sediment compositions which may affect the types of animals which inhabit the area (Dean, 2002). As a result, projects must be designed with an understanding of, and concern for, the potential adverse consequences for the environment. Special consideration should be given to the impacts upon important or rare species resident in the coastal zone. Availability of funds dictate the sustainability of this measure. In the event of severe monsoon, while the coastal environment would be experiencing huge sediment transport rate, there could be power failure, leading to failure of pumping of sand. During this period the erosion on the down-drift side will continue with greater rates and also the efficiency of the pumps to handle the cumulative deposition of the sand may be less. In a nutshell, maintenance over a longer period of time is big challenge.

1.10.2 Geo-synthetic products

The geo-synthetic material over a period of exposure to direct sunlight or to the UV rays can become brittle and ultimately yield. The geo-tubes that considered as an alternative to hard structures can experience the above problem unless they are submerged below water in total. The filling of the tubes, placing them in position require skilled labor. Till date there are not many successful projects dealing with application of geo-synthetic products in marine environment. The laying of geo-tubes with a gap in between them, can result in strong run-down of flow in event of monsoon, resulting in scour and unequal settlement of the tubes, finally leading to its failure. Vandalism by piercing the geo-tubes would be a irreversible act as the sand will escape, in which case repair work becomes impossible.

Fig.1.35a Gaps between geo-tubes- vulnerable for scour/erosion

Fig.1.35bvandalism-punch ring of geo-tubes

1.11 IDENTIFICATION OF COASTAL STRETCHES VULNERABLE TO EROSION

1.11.1 Approach and methodology

DATA COLLECTION

A. Review of earlier Reports mentioned below has been carried out and a number of useful information have been included in this report.

- Master plan for coastal protection along Tamilnadu coast prepared by IIT Chennai in 2005
- Report on sediment cell prepared by the National Centre for Sustainable Coastal Management (NCSCM),
- ICZMP prepared by DHI and,
- Beach profiles of Tamil Nadu coast from ICMAM, Chennai

B. A brainstorming session with all the agencies involved in the coastal development and management was conducted in IIT Chennai on 23 Jan 2016, wherein all inputs discussed have been considered while preparing this report.

C. Collection of environmental data from various sources such as NIO wave Atlas, long term wave simulation done by IITM and Wave Watch III simulation have been done.

D.Run-up and inundation distance measured due to tsunami 2004 which were carried out by IITM and published in American Society of Civil Engineers, Jl of waterways is included in the section on extreme coastal events.

E. Storm surge data from published literature have been included.

FCollection of tide information from Indian Tide tables has been considered.

G. Collection of all publications, reports of IITM and other agencies. It is to be mentioned that IITM has carried out a detailed study on sediment transport rates and its direction, which in fact will be the basis for planning for soft or hard measures of coastal protection. This also will be the basis for the selection of type of hard structures. Only if it is felt absolutely essential, hard measures are considered while planning. Utmost importance is given for socio economic aspects of the coastal villages that need to be protected. Table 1 presents various coastal protection options.

H**.** Field collection of sediment samples

As IITM has been continuously involved in coastal protection design, it would be quite straightforward in identifying vulnerable location of erosion due to a wide variation in sediment characteristics. For only in vulnerable locations, sediment samples have been collected and the characteristics such as size distribution are drawn.

1.12 DATA ANALYSIS

- The first stage investigation was carried out through an analysis of satellite images and review of earlier reports. The vulnerable locations have beenprioritized.
- This was followed by a comprehensive survey of the coast to the vulnerable locations as identified from the analysis of Google satellite imageries by the two experts from IIT Chennai.
- This was followed by site visit to all the vulnerable locations and in addition, a few additional locations as suggested by the PWD officials were visited.
- During the site visits, the beach profiles, sediment size distribution, shoreline position were collected which is reported in this report. The socio economic aspects were discussed with the locals of the fishing villages.
- The above exercises were utilized to prepare this comprehensive Shoreline Management Plan for Tamilandu.

1.13 SUMMARY

The different stretches of the coast that need careful attention through the present study are identified and categorized into different priorities as well as different methods of mitigation measures mentioned below.

- Short term variation – No problem /Do nothing
- Soft measures (which include formation of sand dunes, Artificial beach nourishment, Buffer blocks, Vegetation, geo-synthetic products)
- Hard measures (Groin field, Seawall which may be of rehabilitating the existing ones or construction of new), offshore detached breakwaters.
- Combination of soft and hard measures

The recommendation of the study contains the vulnerable areas which require coastal protection measures along with the details of priority areas which need to be resolved immediately.

The plan is prepared after taking into consideration of various aspects such as the impact of coastal protection measures on ecology & environment, the effect on the adjacent areas, shifting of problems to other areas, social aspects, fishermen concerns, long term/ short term solutions, hard or soft solutions etc. It is to be mentioned that as this report is only a management plan, only the proposed conceptual protection measure is highlighted. For instance, only the measure like, seawall or groin field or offshore breakwaters or submerged reef will be mentioned and not the details like in the case of the most widely adopted hard structure like a seawall (without mentioning other details like crest elevation, sea front slope, etc) or in the case of groin field (without mentioning other details length, spacing, cross section, etc) are reported. This is because these are all site specific requiring detailed scientific investigations prior to arriving at the final decision. That is, prior to implementation of any suggested schemes, a detailed study including bathymetry measurement, site specific numerical modeling to ensure the proposed solution, site specific EIA study needs to be conducted.

A broadclassificationof coastal protection measures as per their priority are provided in **Table1.9**.

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Table 1.9. Coastal Protection Strategy: Priority classification and corresponding solution

Basic type of beach configuration		Evaluation factor (functions): Natural Environment	Space for growth of marine life	Space for recreation activities	Land conservation	Sea water purification	Landscaping efects	Disaster control functions
Basic sectional form	Natural sea shore type	Effective and suitable	Effective and suitable	Effective and suitable	Moderately effective and suitable	Effective and suitable	Effective and suitable	Moderately effective and suitable
	Offshore breakwater type	Moderately effective and suitable	Moderately effective and suitable	Effective and suitable	Moderately effective and suitable	Moderately effective and suitable	Effective and suitable	Moderately effective and suitable
	Submerged breakwater type	Of very limited effectiveness and not suitable	Moderately effective and suitable	Effective and suitable	Effective and suitable	Moderately effective and suitable	Effective and suitable	Effective and suitable
	Offshore breakwater type	Of very limited effectiveness and not suitable	Moderately effective and suitable	Effective and suitable	Effective and suitable	Of very limited effectiveness and not suitable	Of very limited effectiveness and not suitable	Effective and suitable
Basic plan form	Jetty type	Effective and suitable	Effective and suitable	Effective and suitable	Of very limited effectiveness and not suitable	Effective and suitable	Effective and suitable	Moderately effective and suitable
	Artificial reef type	Moderately effective and suitable	Moderately effective and suitable	Moderately effective and suitable	Effective and suitable	Moderately effective and suitable	Of very limited effectiveness and not suitable	Effective and suitable
	Offshore breakwater type	Moderately effective and suitable	Moderately effective and suitable	Moderately effective and suitable	Effective and suitable	Of very limited effectiveness and not suitable	Of very limited effectiveness and not suitable	Effective and suitable

● Effective and suitable ● Moderately effective and suitable
• Of very limited effectiveness and not suitable

CHAPTER 2
REVIEW OF PAST WORKS

2.1 GENERAL

Information about shoreline changes (erosion and accretion) available from existing data sources, which examines the causes and its effect on the environment, is used to explore ideas concerning a systematic approach to draw shoreline management plan for the Tamilnadu coast. Hence, a comprehensive review on the works done before for the coastal protection measures by different organizations are presented in this chapter. This chapter helps to address the information gaps and helps to determine the framework through avoiding the methodological inconsistencies.

2.2 SPACE APPLICATION CENTRE (ISRO)-SHORELINE CHANGE ATLAS OF THE INDIAN COAST (2014)

Shoreline change atlas has been undertaken by the Space Application Centre by (ISRO), Ahmedabad and Coastal Erosion Directorate of Central Water Commission (CWC) for the entire Indian Coast. This report comprises of six volumes and of which Tamil Nadu coast shoreline change details are mentioned in Shoreline Change Atlas of the Indian Coast Volume-4. This atlas comprises of shoreline change maps prepared using satellite data of 1989-1991 and 2004-2006 time frame on 1:25000 scale (one degree consists 8x8 rectangular grids and each rectangular grid is one topographic area of 1:25000 scale) for the entire coast. The maps show locations of erosion and accretion. It also incorporates the locations of stable coast. The data used, methodology, results, area under erosion and accretion and status of coastal erosion measures were briefly discussed. Primarily, the maps were prepared using IRS-P6 LISS 1V data and SPOT 1&2 Multispectral as well as IRS-1A and IRS-1B LISS II data for the duration 2004-06 and 1989-1991 respectively. The maps were rechecked using LANDSAT TM, ETM, and AWiFS and LISS IV data. The shore lengths and areas under erosion are evaluated for the main shoreline excluding creeks, river mouths and estuaries. The protection measures taken up by the maritime States and Union Territories were also mentioned in the report. Based on the shoreline change mapping the status of the Tamil Nadu coastline was given as a stretch of 281.56 km is under erosion, 514.11 km is under accretion and 29.25 km is under stable condition (excluding length of mouth of estuaries, rivers, creeks and their inner parts). From a detailed analysis, the summary of the results on the shoreline changes for the period 1989-91 and 2004-06 for the coast of Tamilnadu is projected in **Table 2.1**.From this study, the vulnerable stretches of the coast experiencing erosion and stretches protected with structures are tabulated in **Tables.2.2**and **2.3** respectively.

Table 2.1 Results of Shoreline change for 1989-91 and 2004-06 time frame for Tamilnadu and Puducherry coast.

S.No	Latitude	Longitude	Erosion Area(Sq.km)	Erosion Length(km)	Accretion Area(Sq.m)	Accretion Length(m)	Stable Length(km)
1	13°17'43.92"N	80°20'16.79"E	0	0	3.42	16.9	0
2	13°10'8.64"N	80°18'16.52"E	0.91	12.3	0.24	5.23	0
3	13° 0'4.14"N	80°15'23.39"E	0.12	4.36	0.21	12.9	0
4	12°56'56.82"N	80°15'16.52"E	0	0	0.9	14.1	0
5	12°47'12.77"N	80°15'1.61"E	0.98	5.29	0	0	0
6	12°46'15.40"N	80°14'35.96"E	0	0	1.46	13.2	0
7	12°39'52.07"N	80°12'15.27"E	0	0.2	0.36	5.67	5.92
8	12°37'36.82"N	80°11'33.76"E	0.16	6.65	0.09	3.55	0
9	12°26'0.25"N	80° 7'38.94"E	0.11	5.6	0.12	1.29	2.68
10	12°24'23.42"N	80° 5'3.27"E	0.13	4.74	0.01	1.38	0
11	12°15'57.88"N	80° 0'36.77"E	0.56	6.28	0.64	8.39	0
12	12°13'1.57"N	79°58'20.62"E	0	0	0.05	1.3	0
13	12° 9'33.04"N	79°55'59.72"E	0.78	14.8	0.01	0.22	0
14	12° 3'52.37"N	79°52'59.61"E	0.15	5.61	0.15	3.59	0
15	12° 0'34.62"N	79°51'17.58"E	0	0	0.06	4.03	0
16	11°59'29.31"N	79°50'58.04"E	0.68	3.15	0.13	6.94	0
17	11°49'3.15"N	79°48'0.92"E	0.43	10.1	0.01	0.43	0
18	11°38'19.40"N	79°45'40.94"E	0	0.22	0.75	8.95	0
19	11°32'59.43"N	79°45'27.04"E	0	0.16	1.45	16.8	0
20	11°22'55.82"N	79°48'48.84"E	0.53	6.9	2.32	21.3	0
21	11°20'59.42"N	79°48'47.93"E	0	0	2.05	13.4	0
22	11°14'40.82"N	79°50'20.81"E	0.46	7.37	0.12	1.64	0
23	11° 1'44.46"N	79°51'2.47"E	0.05	2.25	0.12	4.12	0
24	11° 0'3.99"N	79°51'2.37"E	0.02	0.45	0.91	12.4	12.7
25	10°51'7.91"N	79°50'53.64"E	0.77	8.22	0.47	11.5	0
26	10°40'54.73"N	79°50'37.24"E	0	0	0.86	22	0
27	10°35'43.59"N	79°50'6.98"E	0	0	0.43	10.1	1.47
28	10°24'0.07"N	79°50'52.30"E	0	0	0.78	2.05	0
29	10°16'49.84"N	79°19'1.13"E	0	0	0.94	6.35	0

30	10°14'4.51"N	79°15'48.35"E	0	0	0.78	11.2	0
31	10° 3'57.60"N	79°13'41.68"E	0.25	3.1	0.12	3.23	0
32	10° 2'16.75"N	79°15'57.60"E	0.25	3.1	0.12	3.23	0
33	9°58'47.67"N	79°11'49.86"E	0.24	8.2	0.19	5.81	0
34	9°56'9.33"N	79° 5'2.95"E	0.01	0.31	0	0	0
35	9°53'11.05"N	79° 6'54.99"E	0.14	4.51	0.22	6.01	0
36	9°44'37.45"N	79° 1'6.43"E	0.02	1.42	0.09	2.4	1.7
37	9°38'52.62"N	78°57'35.78"E	0.05	1.94	0.25	7.23	0
38	9°32'52.34"N	78°54'52.89"E	0.73	7.59	0.01	3.02	0
39	9°26'38.37"N	78°53'54.26"E	0.79	16.2	1.08	4	0
40	9°15'47.49"N	78°54'12.15"E	0.74	13.3	0.3	5.55	0
41	9°18'46.55"N	79° 0'47.96"E	0.45	7.13	1.77	16.3	0
42	9°16'47.47"N	79° 7'12.47"E	0.85	17.5	1.09	14.3	0
43	9°17'15.27"N	79°18'46.51"E	0.12	1.29	0.11	5.6	0
44	9°14'6.40"N	79°20'50.79"E	0.74	11.7	0.51	9.8	0
45	9°10'0.56"N	78°49'33.64"E	0.08	1.34	0	0	0
46	9°16'27.78"N	78°51'19.21"E	0.19	2.01	0	0	0
47	9°13'55.33"N	78°45'8.08"E	0.28	2.94	1.19	9.66	0
48	9°13'8.57"N	78°42'38.87"E	1.03	13.7	0.12	6.22	0
49	9° 8'54.60"N	78°32'24.69"E	0	0	2.1	14.6	0
50	9°10'11.05"N	78°26'35.82"E	0.05	1.34	0.01	2.97	0
51	9° 6'20.77"N	78°22'57.53"E	0	0	0.99	10.8	0
52	9° 3'44.94"N	78°19'17.35"E	0.01	0.63	0.57	9.96	0
53	8°59'59.97"N	78°15'15.18"E	0	0	0.04	1.12	0
54	8°59'10.31"N	78°13'39.61"E	0	0	2.06	12.3	0
55	8°51'42.45"N	78° 9'2.81"E	1.15	13.5	0.94	16	0
56	8°44'24.40"N	78° 8'18.24"E	0.07	1.42	1.41	6.35	0
57	8°33'30.93"N	78° 7'46.02"E	0	0	1.58	12.2	0
58	8°32'10.73"N	78° 6'59.47"E	0	0	0.07	2.25	0
59	8°29'46.26"N	78° 7'30.23"E	0.12	1.3	0.07	1.28	0
60	8°22'35.02"N	78° 3'22.65"E	0.06	2.54	0.93	12.7	0
61	8°21'48.02"N	78° 0'6.51"E	0.3	5.54	0.17	3.26	3.02
62	8°21'36.37"N	77°58'51.88"E	0.04	3.19	0.06	1.25	0
63	8°15'26.56"N	77°49'43.90"E	0	0	1.08	4	0
64	8°11'48.50"N	77°46'2.48"E	0.08	1.55	0.97	8.76	0
65	8°10'45.67"N	77°44'37.63"E	0.39	8.25	0.27	4.97	0
66	8° 9'15.27"N	77°34'44.90"E	0.01	0.4	0.46	6.93	0
67	8° 5'51.76"N	77°31'12.84"E	0.03	1.76	0.28	9.78	1.74
68	8° 5'45.83"N	77°30'6.39"E	0.32	0.53	0.53	9.24	0

69	8° 6'19.22"N	77°24'32.02"E	0.14	2.26	0.54	4.67	0
70	8° 7'55.02"N	77°18'22.84"E	0.07	3.58	0.3	6.12	0
71	8°15'14.47"N	77° 9'7.82"E	0.29	4.56	0.19	9.09	0
72	8°17'16.96"N	77° 6'44.78"E	0.14	3.94	0	0	0
73	8°17'14.41"N	77° 6'21.71"E	0.12	3.34	0.01	0.23	0
			17.19	**281.56**	**42.64**	**514.11**	**29.25**

Table 2.2 Vulnerable reaches of Tamilnadu

S. No	Location (Village/Taluk/District)	Latitude/Longitude		Length (m)
		From	To	
1	Royapuram fishing Harbour to Ennore (near Kosasthalayar estuary/Chennai & Thiruvallur Districts.	13° 13’50.28” N 80° 19’53.04” E	13° 13’50.28” N 80° 19’53.04” E	12500
2	Foreshore Estate, Chennai District.	13° 02’14.40” N 80° 16’49.32” E	13° 00’58.92” N 80° 16’39.60” E	3000
3	Mahabalipuram, Kancheepuram District.	12° 38’30.48” N 80° 12’16.92” E	12° 36’57.06” N 80° 11’58.02” E	2730
4	Kalpakkam (Sadras) to Oyyaiikuppam village, Kancheepuram District.	12° 37’1.2” N 80° 11’57.78” E	12° 29’12” N 80° 09’29.4” E	3000
5	Chinnakuppam	12° 26’54.8” N 80° 08’37.4” E	12° 26’58.26” N 80° 08’50.31” E	650
6	Devanampattinam Village/Cuddalore District.	11° 44’40.40” N 79° 47’16.60” E	-	420
7	Thazhanguda Village/Cuddalore District.	11° 46’08.10” N 79° 47’37.40” E	-	1570
8	Suba Uppalavadi Village/Cuddalore District.	11° 47’10.40” N 79° 47’40.40” E	-	210
9	Devanampattinam Village/Cuddalore District.	11° 44’40.40” N 79° 47’16.60” E	-	550
10	Thazhanguda Village/Cuddalore District.	11° 46’08.10” N 79° 47’37.40” E	-	800
11	Suba Uppalavadi Village/Cuddalore District.	11° 47’10.40” N 79° 47’40.40” E	-	450
12	Devanampattinam Village/Cuddalore District.	11° 44’40.40” N 79° 47’18.60” E	-	800
13	Thazhanguda	11° 46’08.10” N	-	800

	Village/Cuddalore District.	79° 47’37.40” E		
14	Thandhiriyankuppam to Chinnamudaliyar Chavadi in Vanur Taluk/Villupuram District.	11° 58’20.13” N 79° 50’41.95” E	11° 58’58.05” N 79° 50’54.08” E	1200
15	Chinnamudaliyar Chavadi to Bommaiyarpalayam in Vanur Taluk/Villupuram District.	11° 58’58.05” N 79° 50’54.08” E	11° 59’52.73” N 79° 51’16.66” E	1800
16	Sodanaikuppam, Vanur Taluk/Villupuram District.	-	-	736
17	Near Poombukar, Nagapattinam District.	11° 07’40” N 79° 51’33” E	11° 06’48” N 79° 51’12” E	1570
18	Akkaraipettai Village/ Nagapattinam District.	10° 74’ N 79° 85’ E	-	100
19	Kallar village/ Nagapattinam District.	10° 74’ N 79° 85’ E	-	700
20	Seruthur Village/ Nagapattinam District.	10° 68’ N 79° 85’ E	-	700
21	Sarnanthanpettai/ Nagapattinam District.	-	-	600
22	Palayar Village in Sirkali Taluk of Nagapattinam District.	11° 14’32” N 79° 51’58” E	-	1000
23	Thirumullaivasal Village in Sirkali Raluk, Nagapattinam District.	-	-	1700
24	Poombuhar Village in Sirkali Taluk of Nagapattinam District.	11° 08’17” N 79° 52’05” E	-	1810
25	Vanagirikuppam Village in Sirkali Taluk of Nagapattinam District.	11° 08’09” N 79° 52’05” E	-	1450
26	Kuttiyandiyur Village in Tharangambadi Taluk of Nagapattinam District.	11° 03’24” N 79° 51’37” E	-	600
27	Tharangambadi Village in Tharangambadi Taluk of Nagapattinam District.	11° 03’05” N 79° 51’35” E	-	2750
28	Chandrapadi Village in Tharangambadi Taluk of Nagapattinam District.	11° 03’00” N 79° 51’36” E	-	800

29	Keezhamanakudy Village/ agasteeswaram Taluk of Kanyakumari District.	08° 05.205’ N 77° 29.676’ E	08° 05.393’ N 77° 29.122’ E	950
30	Araiyanthoppu Village/ Vilavancode Taluk of Kanyakumari District.	08° 14.227’ N 77° 10.276’ E	08° 14.116’ N 77° 10.358’ E	250
31	Mullorthurai Village/ Vilavancode Taluk of Kanyakumari District.	08° 14.116’ N 77° 10.358’ E	08° 13.818’ N 77° 10.620’ E	745
32	Helan Colony Village/ Vilavancode Taluk of Kanyakumari District.	08° 12.859’ N 77° 11.682’ E	08° 12.822’ N 77° 11.745’ E	165
33	Kadiyapattinam Village/ Kalkulam Taluk of Kanyakumari District.	08° 07.660’ N 77° 18.540’ E	08° 07.647’ N 77° 18.605’ E	100
34	Neerodithurai to Erayumanthur River Mouth/ Vilavancode Taluk of Kanyakumari District.	08° 14.69’ N 77° 9.726’ E	08° 17.513’ N 77° 05.905’ E	4800
35	Kovalam Village/ agasteeswaram Taluk of Kanyakumari District.	08° 04.905’ N 77° 31.476’ E	08° 04.794’ N 77° 31.476’ E	136.2
36	Keezhamanakudy Village/ agasteeswaram Taluk of Kanyakumari District.	08° 05.306’ N 77° 29.161’ E	08° 05.232’ N 77° 29.136’ E	136.2
37	Melamanakudy Village/ Agasteeswaram Taluk of Kanyakumari District.	08° 05.242’ N 77° 28.416’ E	08° 05.374’ N 77° 29.316’ E	136.2

Table 2.3 Protected reaches of Tamilnadu

S. No	Location(Village/Taluk/ District)	Specification	Length (m)	Latitude-Longitude (from-to)	
1	Ennore (near Kosashalaiyar estuary) to Royapuram Fishing Harbour,Chennai,Thiruvallur district	RMS wall	10,617	13°14'03.07"N 80°19"59.19"E	13°08'3.68"N 80°17'53.67"E
2	Mahabalipuram (near Shore Temple), Kancheepuram Dt.	RMS wall	263	12°36'57.06"N 30°11'58.02"E	12°37'1.2"N 80°11'57.78"E
3	Sodhanaikuppam village, Vanur taluk,villupuram	RMS wall	946	11°57'22.73"N 79°50'31.54"E	11°57'45.99"N 79°50'31.54"E

4	Nadukuppam village, Vanur taluk, Villupuram	RMS wall	500	11°57'51.82"N 79°50'33.54"E	11°58'06.86"N 79°50'37.1"E
5	Devanamapattinam,Cuddalore district	RMS wall	800	11°45'12"N 79°47'27"E	11°44'36"N 79°47'23"E
6	Ariyanattu Theru, Nagapattinam district	RMS wall	400	_	_
7	Seruthur Village, Velankanni, Nagapattinam District	RMS wall	110	_	_
8	Poombukar, Nagapattinam District	RMS wall	750	11°08'45"N 79°51'32"E	11°08'25"N 79°51'33"E
9	Tharangambadi Nagapattinam district	RMS wall	1100	11°01'58"N 79°51'25"E	11°01'31"N 79°51'23"E
10	Nambuthalai, Thiruvadanai Taluk	RMS wall	405	09°17'18"N 79°19'14"E	09°17'35"N 79°19'30"E
11	Keezhakarai, Ramnad Taluk	RMS wall	180	09°13'45"N 79°47'25"E	09°13'45"N 78°47'19"E
12	Nagapattinam, Nagapattinam District	RMS wall	470	10°46'07"N 79°51'09"E	10°45'54"N 79°51'03"E
13	Nagapattinam, Nagapattinam District	RMS wall	1550	10°45'30"N 79°51'05"E	10°44'48"N 79°51'09"E
14	Kulasekarapattinam, Tiruchendur Taluk	RMS wall	400	8°23'34.9"N 78°03'27.08"E	Midpoint
15	Jevapuram, Tiruchendur Taluk,Thoothukudy Taluk	RMS wall	500	8°29'56.8"N 78°7'42.29"E	Midpoint
16	Collector's Bungalow, Trichendural, UK,Thoohukudy taluk	RMS wall	410	8°42'24.27"N 78°09'42.89"E	Midpoint
17	Thoothur, Kaniyakumari District	RMS wall	375	8°15'07"N 77°09'10"E	Midpoint
18	Christuraja kurusady at poothurai, Vilavancode taluk, Kaniyakumari District	RMS wall	130	8°15.22'N 77°09.063'E	8°1.5'225"N 77°09'065"E
19	Meelmidalam Vilavancode taluk, Kanniyakumari District	RMS wall	630	8°12'25"N 77°12'26"E	Midpoint
20	Keezhimidalam, Vilavancode taluk, Kanniyakumari District	RMS wall	775	8°13.818'N 77°1.0620'E	8°13.593'N 77°10.844'E

21	Erayumanthurai East, Vilavancode taluk, Kanniyakumari District	RMS wall	675	8°14.652'N 77°9.726'E	8°14.71'N 77°9.741'E
22	Erayumanthurai West, Vilavancode taluk, Kanniyakumari District	RMS wall	950	8°14'48"N 77°9'34"E	Midpoint
23	Enayam, Kanniyakumari District	RMS wall	900	8°13'13"N 77°11'03"E	Midpoint
24	Muloorthurai,Vilavancode taluk, Kanniyakumari District	RMS wall	520	8°12.176'N 77°12.889'E	8°11.976'N 77°13.157'E
25	Puthenthurai, Vilavancode taluk, Kanniyakumari District	RMS wall	570	8°5.38'N 76°26.35'E	8°5.14'N 77°25.52'E
26	Arayanthoppu, Vilavancode Taluk, Kanyakumari District	RMS wall	250	8°14.227'N 77°10.276'E	8°14.227'N 77°10.358'E
27	Ramanthurai, Vilavancode taluk,Kannyakumari District	RMS wall	310	8°13.818'N 77°10.620'E	8°13.593'N 77°10.844'E
28	Enayamputhanthurai, Vilavancod Taluk, Kanniyakumari District	RMS wall	70	8°10.405'N 77°15.097'E	8°10.364'N 77°15.320'E
29	Poothurai, Kanniyakumari Disrict	RMS wall	750	8°14'58"N 77°9'22"E	Midpoint
30	Kurumpanau Kalkulam Taluk, Kanniyakumari District	RMS wall	100	8°11.405'N 77°13.685'E	8°11.367'N 77°13.723'E
31	Vaniyakudi, Kalkulam taluk,Kanniyakumari District	RMS wall	312	8°30.878'N 77°14.112'E	8°10.751'N 77°14.258'E
32	Kodimunai, Kalkulam taluk, Kanniyakumari district	RMS wall	502 & 21.8	8°10.597'N 77°14.524'E& 8°10.604'N 77°14.415'E	8°10.563'N 77°14.622'E& 8°10.597'N 77°14.524'E
33	Kottilpadu, Kalkulam taluk, Kanniyakumari district	RMS wall	460	8°10.153'N 77°15.756'E	8°10.047'N 77°16.017'E
34	Mandaikattuputhoor, Kalkulam taluk, Kanniyakumari District	RMS wall	115	8°9.705'N 77°16.659'E	8°10.667'N 77°16.718'E
35	Chinnavilaithurai, Kalkulam taluk, Kanniyakumari district	RMS wall	120	8°8.682'N 77°18.076'E	8°8.604'N 77°18.150'E

36	Periavilaithurai, Kalkulam taluk, Kanniyakumari district	RMS wall	290 & 140	8°9.105'N 77°17.596'E& 8°9.156'N 77°558'E	8°9.019'N 77°17.131'E& 8°9.105'N 77°17.596'E
37	Kadiyapattinam, Kalkulam taluk, Kanniyakumari District	RMS wall	300	8°7.983'N 77°18.241'E	8°7.757'N 77°18.411'E
38	Maramadi, Kalkulam taluk, Kanniyakumari district	RMS wall	430	8°5.840'N 77°26.197'E	8°5.882'N 77°26.001'E
39	Rajakkamangalathurai, Agasteeswaram taluk, Kanniyakumari district	RMS wall	1100	8°6.775'N 77°23.023'E	8°6.934'N 77°22.446'E
40	Keezhamanakudi, Agasteeswaram taluk, Kanniyakumari district	RMS wall	950	8°5.215'N 77°29.627'E	8°5.395'N 77°31.600'E
41	Chinnamuttam, Kanniyakumari district	RMS wall	245	8°5'31"N 77°33'43"E	Midpoint
42	Pallamdurai,Agasteeswaram taluk,Kanniyakumari district	RMS wall	158	8°5.840'N 77°29.197'E	8°5.882'N 77°26.001'E
43	Melamanakudi, Agasteeswaram taluk, Kanniyakumari district	RMS wall	150	8°5.20'N 77°28.38'E	8°5.07'N 77°27.03'E
44	Kovalam, Agasteeswaram taluk,Kanniyakumari district	RMS wall	120	8°4.858'N 77°31.772'E	8°4.897'N 77°31.600'E
45	Vattakottai, Kanniyakumari district	RMS wall	150	8°7'30"N 77°33'57"E	Midpoint
46	Eraviputhenthurai,Kanniyakumari district	RMS wall	602	8°15'41"N 77°08'24"E	Midpoint
47	Chinnathurai, Kanniyakumari district	RMS wall	329	8°15'16"N 77°08'59"E	Midpoint
48	Marthandamthurai, Kanniyakumari district	RMS wall	500	8°16'50"N 77°06'49"E	Midpoint
49	Azhikal, Kanyakumari district	RMS wall	560	8°7'19"N 77°19'00"E	Midpoint
50	Vavathurai, Kanniyakumari district	RMS wall	149	8°4'55"N 77°33'08"E	Midpoint
51	Neerodithurai, Kanniyakumari district	RMS wall	1020	8°17'11"N 77°6'20"E	Midpoint
52	Vallavilaithurai, Kanniyakumari district	RMS wall	820	8°7'10"N 77°7'9"E	Midpoint

53	Periyakadu, Kanniyakumari district	RMS wall	200	8°6'42"N 77°23'15"E	Midpoint
54	Thiruvetriyur, Thiruvallur district	Groin	165	13°11'2.64"N 80°19'0.6"E	Backshore
55	Thiruvetriyur,Thiruvallur district	Groin	200	13°10'53.52"N 80°18'57.24"E	Backshore
56	Thiruvetriyur, Thiruvallur district	Groin	250	13°10'40.26"N 80°18'50.82"E	Backshore
57	Thiruvetriyur, Thiruvallur district	Groin	250	13°10'24.72"N 80°18'45.66"E	Backshore
58	Thiruvetriyur, Thiruvallur district	Groin	200	13°10'10.8"N 80°18'41.16"E	Backshore
59	Thiruvetriyur, Thiruvallur district	Groin	165	13°10'1.56"N 80°18'37.5"E	Backshore
60	Royapuram, Chennai district	Groin	245	13°9'15.48"N 80°18'38.66"E	Backshore
61	Royapuram, Chennai district	Groin	300	13°8'58.56"N 80°18'11.16"E	Backshore
62	Royapuram, Chennai district	Groin	300	13°8'41.52"N 80°18'2.58"E	Backshore
63	Royapuram, Chennai district	Groin	245	13°8'27.42"N 80°18'57.24"E	Backshore
64	Cooum North, Chennai district	Groin	140	13°4'7.50"N 80°17'22.68"E	Backshore
65	Cooum North, Chennai district	Groin	170	13°4'58.50"N 80°17'18.42"E	Backshore
66	Thanthiriyankuppam, Villupuram district	Groin	50	11°58'6.77"N 79°50'38.04"E	11°58'9.24'N 79°50'37.6"E
67	Thanthiriyankuppam, Villupuram district	Groin	375	11°58'9.24"N 79°50'37.56"E	11°58'20.13"N 79°50'41.95"E
68	Cuddalore Fishing harbour	South Groin	250	11°42'20"N 79°46'58"E	11°42'18"N 79°46'58"E
69	Dist between Groins		237		
70	Cuddalore Fishing harbor	North Groin	190	11°42'27"N 79°46'57"E	11°42'22"N 79°46'50"E
71	Fishing jetty	Jetty	270	11°42'28"N 79°46'46"E	11°42'27"N 79°46'55"E
72	Fishng harbour	Groin	105	10°45'53"N 79°51'05"E	10°45'53"N 79°51'08"E
73	Fishing harbour	Groin	140	10°45'52"N 79°51'05"E	10°45'53"N 79°51'08"E

74	Fishing jetty	Jetty	30	9°13'41"N 78°46'13"E	Onshore end
75	Fishing jetty	Jetty	70	9°16'49"N 79°18'56"E	9°16'48"N 79°18'54"E
76	Mandabam Fishing jetty, Ramanathapuram district	Jetty	30	9°16'18"N 79°18'55"E	9°16'17"N 79°7'55"E
77	At Kaduvaiyar & Kallar river	Training wall	650	–	–
78	Idinthakarai, Radhapuram taluk, Tirunelveli district	Groin	G-1 351 G-150 G-1 65 G-1 125	8°10'28"N 77°44'20.8"E 8°10'32.7"N 77°44'32"E 8°10'38.3"N 77°4'42.9"E 8°10'10.40"N 77°44'48"E	
79	Idinthakarai, Radhapuram taluk, Tirunelveli district	Groin	25	8°10'33"N 77°44'36"E	–
80	Threspuram, Thoothukudi taluk, Thoothukudi district	Groin	1310	8°48'55.4"N 78°09'47.6"E	–
81	Ratchagar Street, Aagasteewaram taluk, Kanniyakumari district	Groin	463	8°4.997'N 77°33.180'E	8°4.997'N 77°29.122'E
82	Melamanakudi, Agasteeswaram taluk, Kanniyakumari district	Groin	138	8°5'16"N 77°29'19"E	Backshore End
83	Keezha manakudi, Agasteewaram taluk, Kanniyakumari district	Groin	138	8°5'20"N 77°28'58"E	Backshore End
84	Arokyapuram, Agasteewaram taluk,Kanniyakumari district	Groin	G-12 390 G-2-3 296	8°4.997'N 77°33.180'E 8°7.265'N 71°33.590'E	8°7.050'N 77°33.770'E 8°7.200'N 71°33.698'E
85	Kovalam, Agasteeswaram taluk,Kanniyakumari district	Groin	265	8°4.905'N 77°31.476'E	8°4.794'N 77°31.512'E
86	Periyakadu, Agasteewaram taluk, Kanniyakumari district	Groin	G5 -6 320 G7-8 79	8°6.706'N 77°23.258'E 8°6.661'N 77°23.360'E	8°6.551'N 77°23.248'E 8°6.619'N 77°23.232'E

87	Vaniyakudi, Kalkulam taluk,Kanniyakumari District	Groin	G5-6 130 G7-8 110	8°11.091'N 77°13.933'E 8°10.751'N 77°14.259'E	8°10.676'N 77°14.232'E
88	Kurubanai, Kalkulam taluk, Kanniyakumari district	Groin	G1-2 160 G3-4 90	8°11.367'N 77°13.723'E 8°11.142'N 77°13.837'E	8°11.101'N 77°13.821'E 8°11.101'N 77°13.821'E
89	Symon colony, Kalkulm taluk, kanniyakumari district	Groin	G1-2 235 G3-4 110	8°10.642'N 77°14.336'E 8°10.532'N 77°14.658'E	8°10.531'N 77°14.324'E 8°10.469'N 77°14.649'E
90	Enayam East, Vilavancode taluk, Kanniyakumari district	Groin	216	8°13.022'N 77°11.286'E	8°12.933'N 77°11.243'E

2.3 DOCUMENTATION OF STRUCTURAL MEASURES ADOPTED FOR COASTAL ZONE PROTECTION AND MANAGEMENT IN THE SAARC REGION (2014)

In this report, the system of coastal protection adopted in SAARC countries has been identified.Various artificial structures have been constructed within the SAARC area. Land has been reclaimed to extend ports and provide associated industrial zones. Various sites have been proposed for future land reclamation projects. Coastal defense structures have been installed to prevent erosion and protect against flooding at vulnerable sites. Many ports, marinas, piers and other infrastructure have been created. Several individual structures have been placed in the SAARC area.In general, the coastal engineering solution can be differentiated as hard measures, soft measures and natural measures. Under hard measures, the constructions like Groins, breakwaters and seawalls form a major proportion as well as these are well understood protection measures. Under soft measures, the artificial beach nourishment plays a major role. Under natural measures, coastal vegetation forms a major role. Coastal structures like Groins, breakwaters and seawall are identified using Google Earth imageries. It is a useful tool to measure features like position on the earth surface (latitude and longitude) andlength of coastal structures. Of all the SAARC countries, predominant coastal structures are located in India, and Srilanka and, a few in Pakistan. Due to vast river delta along Bangladesh ocean front, there is no meaningful engineering structures along Bangladesh coast possible and hence, not accounted for in this report. The details of different coastal structures in India, Srilanka and Pakistan are included in this report. The total number of identified coastal structures for Tamilnadu state as per the report is given in **Tables 2.4 to 2.7.**The information is gathered to a maximum that is available in the public domain (worldwide web resources besides reports).

Table 2.4 Breakwater in Tamilnadu

S. No	Location(Village/Taluks/District)	Breakwater No	Length (m)	Latitude	Longitude
1	Kattupalli Port	1A	1100m	13°18'54.17"N	80°20'48.45"E
		1B	1100m	13°17'44.92"N	80°20'51.41"E
2	Ennore Port	2A	3000m	13°16'44.95"N	80°20'45.36"E
		2B	1000m	13°15'24.83"N	80°20'15.21"E
3	Chennai Port	3A	650m	13°08'1"N	80°17'56"E
		3B	1150m	13°07'21"N	80°17'56"E
		3C	1100m	13°06'50"N	80°18'E
		3D	3000m	13°05'17"N	80°17'44"E
4	Tuticorin Port	4A	3800m	8°45'14.26"N	78°11'37"E
		4B	4000m	8°45'51"N	78°11'54"E
5	TuticorinOld Harbour, Tuticorin	5A	750m	8°47'32"N	78°9'43"E
		5B	175m	8°47'46"N	78°9'43"E
6	Muttom Fishing Harbour	6A	800m, 150m	8° 7'18.53"N	77°19'2.81"E
7	Amanakkan	7A	340m	8° 7'16.63"N	77°33'38.68"E
		7B	276m	8° 7'2.77"N	77°33'33.55"E
8	Kanyakumari	8A	160m	8° 5'54.05"N	77°33'34.35"E
		8B	950m	8° 5'38.14"N	77°33'49.89"E

Table 2.5 Groynes in Tamilnadu

S. No	Location(Village/Taluk/ District)	Groynes No	Length (m)	Latitude	Longitude
1	Ramakrishna Nagar	1A	155m	13.184313° to 13.140618°	80.318116° to 80.300616°
		1B	165m		
		1C	200m		
		1D	225m		
		1E	180m		
		1F	180m		
		1G	250m		
		1H	260m		
		1I	300m		
		1J	260m		
2	ECR beach	2A	155m	11°58'20.36"N	79°50'41.92"E
		2B	90m	11°58'9.40"N	79°50'37.81"E
		2C	60m	11°57'52.12"N	79°50'33.99"E
		2D	40m	11°57'45.97"N	79°50'31.62"E
		2E	50m	11°57'29.92"N	79°50'27.26"E
		2F	40m	11°57'27.09"N	79°50'26.57"E
3		3A	130m	8°10'40.53"N	77°44'47.38"E
		3B	75m	8°10'38.86"N	77°44'43.87"E
		3C	75m	8°10'30.66"N	77°44'26.65"E
		3D	355m	8°10'26.99"N	77°44'12.82"E
4	Kanyakumari, Tamilnadu	4A	40m	8° 5'27.94"N	77°33'36.96"E
		4B	50m	8° 5'24.20"N	77°33'31.59"

S. No	Location(Village/Taluk/ District)	Groynes No	Length (m)	Latitude	Longitude
		4C	40m	8° 5'19.96"N,	77°33'24.01"E
		4D	70m	8° 5'16.56"N	77°33'18.92"E
		4E	70m	8° 5'11.04"N	77°33'15.07"E
		4F	255m	8° 4'54.19"N	77°31'28.43"E
5	Manakuday, Tamilnadu	5A	140m	8° 5'18.60"N	77°29'9.36"E
		5B	145m	8° 5'18.87"N	77°29'0.54"E
6	Periyakadu	6A	255m	8° 6'39.82"N77°23'14.85"E	
		6B			
7	Colachel	7A	135m	8°10'23.91"N	77°15'9.95"E

Table 2.6 Training wall in Tamilnadu

S. No	Location(Village/Taluk/ District)	Training wall No	Length (m)	Latitude	Longitude
1	Cuddalore	1A	190m	11°42'27.93"N	79°46'51.81"E
		1B	235m	11°42'20.50"N	79°46'50.93"E
2	Karaikkal beach	2A	230m	10°54'47.12"N	79°51'13.51"E
		2B	325m	10°54'53.17"N	79°51'11.69"E

Table 2.7 Seawall in Tamilnadu

S. No	Location(Village/Taluk/ District)	Seawall No	Length (m)	Latitude	Longitude
1	Tulsikuppam	1	2305m	13°13'51.28"N to 13°12'38.05"N	80°19'53.22"E to 80°19'26.83"E
2	Eranavarkuppam	2	2465m	13°12'29.23"N to 13°11'3.22"N	80°19'23.69"E to 80°19'1.13"E
3	Bengal beach	3	455m	11°58'6.80"N to 11°57'52.41"N	79°50'38.31"E to 79°50'33.71"E
4	Serenity beach	4A	505m	11°57'45.99"N to 11°57'30.06"N	79°50'31.70"E to 79°50'27.30"E
		4B	1055m	11°57'14.44"N to 11°56'41.59"N	79°50'24.03"E to 79°50'16.62"E
5	Pondicherrysea beach	5	900m	11°56'55.31"N to 11°56'25.77"N	79°50'18.32"E to 79°50'14.35"E
6	Pondicherry beach	6A	1805m	11°56'21.07"N to 11°55'24.87"N	79°50'13.38"E to 79°50'3.15"E
		6B	800m	11°55'22.71"N to 11°54'58.61"N	79°50'2.60"E to 79°49'53.11"E
7	Periavillai	7	290m	8° 6'45.77"N to 8° 6'36.47"N	77°33'27.22"E to 77°33'25.94"E

2.4 WAVE ATLAS OF THE INDIAN COAST, NATIONAL INSTITUTE OF OCEAN TECHNOLOGY, INDIA (2014)

(ISBN: 81-901338-4-5-Wave Atlas).

2.4.1 Wave Atlas of the Indian Coast

The majorobjective of Wave Atlas is to provide ready reference of wave in terms of wave climate and return period/ extreme values along the Indian coast. The present study is carried out utilizing the wave data simulated using MIKE21 spectral wave model. The model wind forcing is provided with ECMWF (European Centre for Medium-Range Weather Forecasting) analyzed wind data for the period 1998 to 2012.

The simulated wave data is available at every six hour at a grid resolution of 10x10 km covering the area, Long: 60-90DegE, Lat: 0-25DegN.

2.4.2 Model Setup

The MIKE 21 Spectral Wave Model (Mike-SW) developed by the Danish Hydraulic Institute, Denmark, is a new generation spectral wind-wave model based on unstructured meshes. The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. The model is based on the wave action balance equation (Komen et al., 1994 and Young, 1999). The discretization of the governing equation in geographical and spectral space is performed using cell-centered finite volume method. The details of the model equations and methods of solution are explained in MIKE-21 user manual (2011).

The bathymetry of the study area was prepared using the ETOPO1 (Earth Topography-1minute) in the open ocean above 250m depth and MIKE-CMAP for the shallow water. The model domain extends from the 40°S to 25°N and 30°E to 120°E. As part of this project numerical wave modeling is carried out and simulated the wave climate in the North Indian Ocean for a period of 15 years. These model results are validated with secondary wave measurements available at various research organizations. Apart from this NIOT has carried out wave measurements at selected locations and the validation exercise is continuing to assure the reliability of the simulated wave data.

2.4.3 Structure of the wave atlas

The wave atlas is envisaged to cater the requirement of coastal and offshore industry as a preliminary reference for initiating the engineering interventions. The Wave Atlas presents the detailed information on annual and monthly variability of various wave parameters in graphical and tabular form. Focusing on the variability along the coast line, locations at an interval of one degree at a water depth of 25m, covering the east and west coast of India is selected and presented separately. The rose vector plots (annual and monthly) along with joint distribution tables and monthly variability of significant wave height, average wave period and mean wave direction are presented for each locations.

2.5 OSCILLATIONS OF CREST OF BERM BASED ON SEGMENTATION OF THE COAST – PUBLIC WORKS DEPARTMENT (PWD)

The position of elevation of the crest of the berm and its distance from an established base line using chains and tapes as recommended by CERC of USA and as shown in **Fig 2.1** can serve as a useful tool to understand the oscillation of shorelines. The beach width in fact defines the geomorphology of a coast. There has been a systematic collection of such monthly variations by the Public Works Department, Government of Tamilnadu, India since 1978 at selected locations. The monthly movement of the crest of the berm from a fixed baseline in particular at locations experiencing severe changes in its configuration, were identified as the first task in this exercise. The observation stations were selected depending on field conditions in such a way that they will not be disturbed under normal environmental conditions and care was taken to locate them near permanent land marks such as existing structures, monuments, etc. The latitude and longitude of all these locations are mentioned in **Table 2.4** and the observations and the results of the analysis carried out through the present study are detailed in the next chapter.

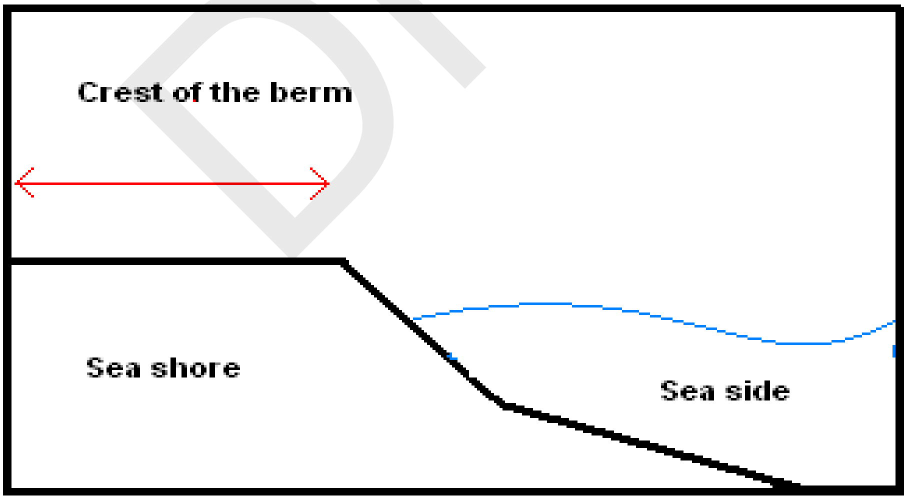


Fig 2.1Measurement of crest of the berm

Table. 2.8 Latitude and longitude of study locations along the Tamilnadu coast

Sl. No.	Name of Observation Site	Location	
		Latitude	Longitude
1.	Pulicat	13^0 25'	80^0 20'
2.	Ennore	13^0 13'	80^0 20'
3.	Royapuram	13^0 09’	80^0 18’
4.	Marina	13^0 03’	80^0 18’
5.	Foreshore Estate	13^0 02’	80^0 16’
6.	Besant nagar	13^0 00’	80^0 16’
7.	Kovalam	12^0 58’	80^0 16’
8.	Mahabalipuram	12^0 38’	80^0 12’
9.	Cuddalore	11^0 43'	79^0 47'
10	Port Novo	11^0 29'	79^0 47'
11	Poompuhar	11^0 13'	79^0 52'
12.	Tranquebar	11^0 03'	79^0 55'
13.	Nagapattinam	10^0 46’	79^0 51'
14.	Velankanni	10^0 45’	79^0 51'
15	Vedaranyam	10^0 22’	80^0 10’
16	Point Calimer	10^0 17’	79^0 53'
17	Ammapattinam	10^0 1'	79^0 13'
18	Rameswaram	9^0 17'	79^0 19'
19	Keelakkarai	9^0 14'	78^0 49'
20	Valinokkam	9^0 13'	78^0 46'

21	Thiruchendur	8^{0} 29’	78^{0} 7’
22	Manappadu	8^{0} 22'	78^{0} 4’
23	Periathalai	8^{0} 20’	77^{0} 57’
24	Idinthakarai	8^{0} 14’	77^{0} 47’
25	Kanyakumari	8^{0} 5’	77^{0} 30’
26	Manakkudi	8^{0} 8'	77^{0} 29’
27	Pallam	8^{0} 7’	77^{0} 24’
28	Muttam	8^{0} 8’	77^{0} 19’
29	Manavalakurichi	8^{0} 9'	77^{0} 18’
30	Colachel	8^{0} 11’	77^{0} 15’
31	Midalam	8^{0} 12'	77^{0} 13’
32	Erayumanthurai	8^{0} 13’	77^{0} 11’

(**Sl. no 1** to **25** are along east and **26** to **32** along west coast of Tamilnadu respectively)

2.6 NATIONAL STRATEGY FOR COASTAL PROTECTION – NATIONAL CENTRE FOR SUSTAINABLE COASTAL MANAGEMENT (NCSCM)

Sediments composed of mostly sand and silt originated from rivers and weathering move along the coast. Certain geomorphic features of the coast like river mouth, headland can block/restrict the movement of sediments further. Therefore, the length of coast from where sediments originate and up to which their movement is restricted is called a Primary (sediment) cell. Normally sediments do not cross the Primary cell boundaries except during extreme events like cyclones. The classification of cells for the Tamilnadu coast as arrived is projected in **Table. 2.5** and **Fig. 2.2**.

Primary cell is sub-divided in to sub-cells which is further divided in to Management Units. Understanding the functions within a sediment cell helps to identify the impacts of development or management and to take action to mitigate such impacts. It acts as a self-contained unit so that any development within the sediment cell will have a minimal impact on areas outside its boundaries.

Table 2.9 Classification of Sediment cell and its features

Classification	Extent	Features
Primary cell	10-100s of km	Major coastal landform (Headlands etc.), Major sediment sources (rivers etc.), Major sediment stores(beaches etc.), Major sediment sinks (offshore depositions)
Sub cell	10s of km	Coastal processes (Met-ocean factors), Coastal alignments (Swash, major & minor drift), Shoreline changes, Sediment budget etc.
Management units	100s of m to few kms	Change in land use land cover, upstream activities like dams etc., Sediment budget, Coastal activities like dredging, sand mining etc., Coastal structures (Groins etc.) and reclamation activities.

- **Primary cells in Tamilnadu**
    1. South of Ponneru river to south of Chennai port
    2. South of Chennai port to mouth of Palar river
    3. Mouth of Palar river to South of Coleroon river
    4. South of Coleroon river to Point Calimere
    5. Point Calimere to Dhanushkodi
    6. Dhanushkodi to Kaniyakumari

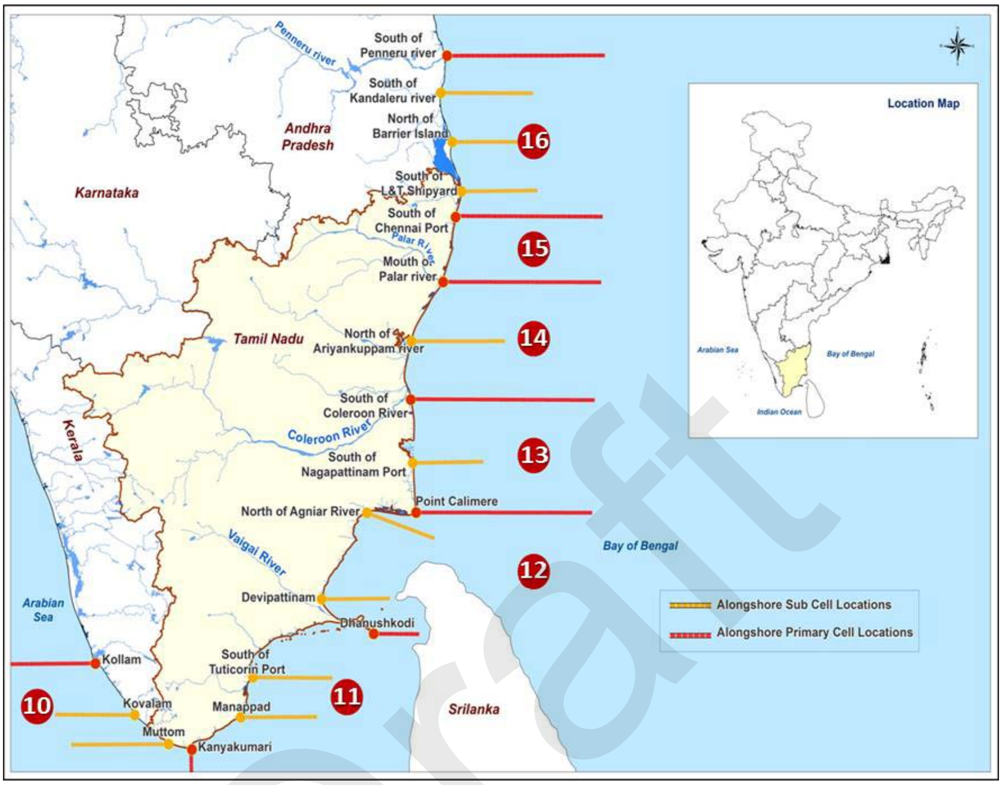


Fig 2.2 Primary cell and Sub cell along the coast of Tamilnadu (NCSCM)

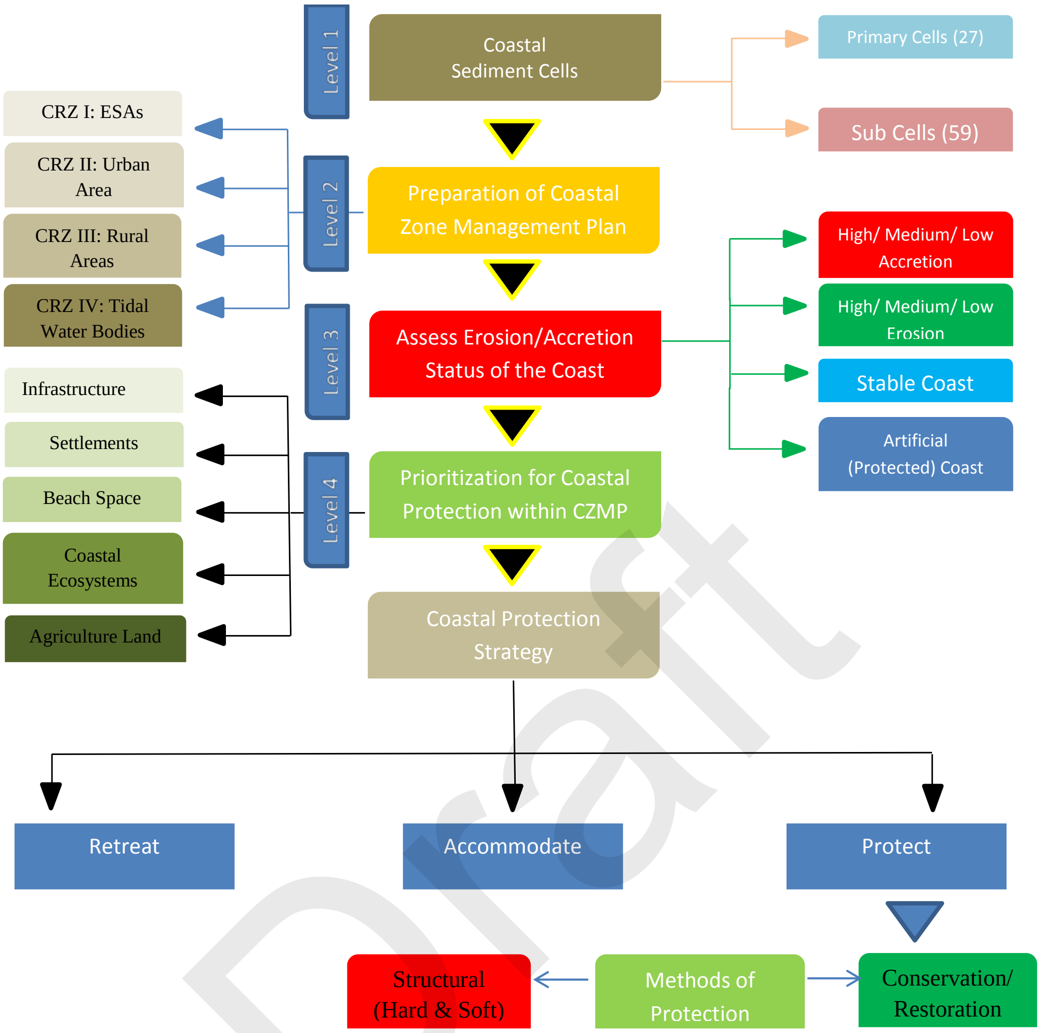


Fig 2.3 National Strategy for Coastal Protection (NCSCM)

2.7 PREPARATION OF INTEGRATED COASTAL ZONE MANAGEMENT PLAN AND COASTAL VULNERABILITY MAPS OF TAMILNADU – DHI (2013)

The management plan was prepared by DHI in collaboration with several local experts and premier institutes including NCSCM, ICMAM, NIOT, IRS, Anna University, IITs, Annamalai University, and TNAU etc. for sustainable management of the coastal areas of Tamil Nadu. The main aim of the Integrated Coastal Zone Management (ICZM) Plan is a holistic management of the Tamil Nadu Coast through better coordination of the developmental activities along the coast, enhancing socio-economic conditions of its population while keeping the natural resources and the environment healthy and capable of sustaining future generations.

The Government of Tamil Nadu with World Bank assistance has initiated the project "Preparation of an integrated coastal zone management plan and coastal vulnerability maps of Tamil Nadu", which was set against the backdrop of the 2004 tsunami and thus embarking on an Integrated Coastal Zone Management (ICZM) approach. ICZM is pursued to better coordinate the development along the coastal stretch targeting socioeconomic improvement for its population, while keeping the natural resources and the environment healthy and capable of sustaining future generations and also strengthening responses under emergency situations caused by extreme weather.

2.7.1 Action plan

The action plans has been developed based on a thorough analysis of the coastal baseline of Tamil Nadu through several in-depth studies and assessments carried out by the consultant in collaboration with local experts and premier institutes as mentioned above. The proposed action plan was presented in three components; (1) Decision Enabling Environment; (2) ICZM Demonstration Projects; and (3) Conservation & Rehabilitation – Pilot Projects.

2.8 SUMMARY

The relevant data sets from the reviewed reports had been used for complimenting/comparing/validating the present study, based on the requirement in the sub-sequent chapters.

CHAPTER 3
STABILITY OF SHORELINE THROUGH SATELLITE IMAGERY AND BEACH PROFILE

3.1 GENERAL

Shoreline change is considered as one of the most dynamic processes in the coastal area. Shoreline is subjected to continuous change due to natural causes and human interventions in coastal zone. Identifying the areas vulnerable for erosion and quantifying its extent is essential for coastal zone management. The evolution of coastal systems is controlled by various factors viz., morphology and geology of the catchment, the size of the catchment area, nature of sedimentation basin, climate leading to rainfall and river discharge at coastal zone, freshwater input and coastal hydrodynamics - waves, tides and currents (ChenthamilSelvan et al., 2013). Wind, waves and currents are natural driving forces that easily move the unconsolidated sand and soils in the coastal area, resulting in rapid changes in the position of the shoreline. The coastal systems have also been affected by several developmental activities such as ports, industries, aquaculture farming and other human intervention in the form of coastal defenses. Thus, it is not possible to ascertain the complex morphodynamic pattern of any coast by hydrodynamic modeling alone. Remote Sensing and Geographical Information System (GIS) techniques have been widely employed in various coastal morphodynamic studies as they are cost effective, reduce manual error and are useful in the absence of field surveys. The applications of remote sensing and GIS have proved particularly effective in delineation of coastal morphology and coastal landforms, detection of shoreline positions (ChenthamilSelvan et al., 2013). The location of the shoreline and its historical rate of change can provide important information for the design of coastal protection, plans for coastal development, and the calibration and verification of numerical models, etc.

The position of elevation of the crest of the berm and its distance from an established base line using chains and tapes as recommended by CERC of USA and can serve as a useful tool to understand the oscillation of shorelines. The beach width in fact defines the geomorphology of a coast.

3.2 SHORELINE DEMARCATION

3.2.1 General

In the present report the entire coastal line of Tamil Nadu has been analyzed by dividing the entire coastline into number of stretches with a length of around 5km each. The coastline is digitized for several years with the help of Google Earth with accuracy of 30 m resolution. The advantage in using google earth is that the updated and latest image available and a variety of supplementary data can be easily viewed on a feature of interest. Thereby existing coastal protection structures are located site specifically and demarcated. The instant availability of a wide range of historic images helps to enhance the accuracy and linearity in predicting the shoreline changes over the years.

3.2.2 Key points on shoreline analysis and its limitations

- To predict patterns of shoreline behavior using the derivation of historical rate of change trends as an indicator of future trends assuming continuity in the physical, natural or anthropogenic forcing which have forced the historical change observed at the site.
- The main advantage and reason for using historical maps is that they are able to provide a historic record that is not available from other data sources. Many potential errors however are associated with historical coastal maps and charts. Such errors may be associated with scale, datum changes, distortions from uneven shrinkage, stretching, creases, tears and folds, different surveying standards, different publication standards, and projection errors (Boak & Turner, 2005).
- The severity of these errors depends on the accuracy standards met by each map and the physical changes that have occurred since the publication of the map (Anders & Byrnes 1991).
- Uncertainty ranges (error bars) are smaller and the confidence of erosion rate data is greater when using long-term data rather than short-or medium-term data.
- The use of long-term data produces alongshore erosion rate profiles that are spatially smoother than short- or medium-term data
- The use of longer temporal spans acts to filter out short-term fluctuations (noise) from the long-term trend (signal).
- Forecasting guidance signifies the desirability of using data spanning duration at least twice as long as the projection interval. This demonstrates the importance of long

term data in defining construction setbacks. (Mark Crowell, Stephen P. Leatherman, Michael K. Buckley, 1993).

3.3 SHORELINE ASSESSMENT

3.3.1 General

The Digital Shoreline Analysis System (DSAS) is computer software that computes rate-of-change statistics from multiple historic shoreline positions residing in a GIS. It is used worldwide as a method for assessing shoreline change. It is useful for computing rates of change for just about any other boundary change problem that incorporates a clearly-identified feature position at discrete times. The software uses a reference baseline method as the starting point for transects that cross through a time series of shoreline positions. Output data include a variety of rate metrics including end-point and several regression methods like ordinary least square, weighted least squares, and least median of squares. The shoreline change rate was calculated by dividing the distance of shoreline movement by the time difference between the oldest and the most recent shoreline. End point rate (EPR) is a simple and popular approach adapted to calculate the shoreline change rates. Two shoreline dates is the minimal requirement for rate computation. Following equation is used for EPR calculation.

EPR (m/yr) = Distance between shorelines/Time difference between oldest and youngest shoreline

3.3.2 Shoreline analysis

Demarcating and assessing the shoreline for a given study area before going into the field has advantages that includes

- Promoting effective hypothesis for locating the vulnerable sites
- Aiding the selection and evaluating of the critically vulnerable sites
- Providing a baseline data on historic changes on shorelines

3.3.3 Steps involved in the present shoreline stability analysis through satellite imagery

- Shoreline of Tamilnadu is demarcated with the help of Google Earth based on the historical maps available which ranges over a period of 2004-2016.
- The coastal stretch is divided into 5 km so that the entire shoreline analysis is executed in around 1:5000 scale.

- Google earth have the updated and latest image available to the users and it is less time consuming.
- A variety of supplementary data can be easily viewed by clicking on a feature of interest in google earth and the mapping or the demarcation presented in Google Earth instantly makes the data presentation look professional with relatively little effort.
- The demarcated shorelines for different years of each stretch is superimposed for computing shoreline change rate using DSAS.
- The software uses a reference baseline method as the starting point for transects that cross through a time series of shoreline positions.
- The user supplies sequential shoreline vectors and a reference baseline as inputs and DSAS generates orthogonal transects from the baseline that intersect the shorelines.
- These transect-shoreline intersections provide the measurement locations used to estimate rates of change for the time series data.
- Calculations are performed using an external module included in the DSAS distribution that provides users the option of developing their own calculation modules.
- In addition to statistical outputs, DSAS automatically generates metadata when transect locations are created when rate calculations are performed.
- DSAS captures user-input variables and processing steps within the transect metadata file, providing automated recordkeeping of calculation parameters and settings used when generating transects and performing rate of change calculations
- The software presently works as an extension within ESRI's Arc Map application but an open-source, web-based application is currently being considered.
- Based on the accretion and erosion rate a vulnerability scale is defined which effective in channelizing the field study.

- Predictions were rechecked and compared with The Shoreline Change Analysis Atlas of the Indian Coast prepared by Space Application Centre (ISRO) and also with National Assessment of shoreline change for Tamilnadu coast prepared by National Centre for Sustainable Coastal Management (NCSCM).

3.3.4 Mapping the shoreline

Each 5km stretch is presented as plates numbered from 1to 180 in Annexure – 1, on 5 different mapping each portraying a significant data, which is used in this Comprehensive Shoreline Management study.

i. Present status of the shoreline including the physical features and man-made structures
ii. One decadal oscillation of shoreline profile
iii. Rate of shoreline change during last one decade
iv. Identification of vulnerability in terms of rate of shoreline erosion
v. Proposed structures

3.3.5 Vulnerability scale

The vulnerability scale is assigned based on the following criteria

1. Greater than 5m erosion
2. Erosion between 2m and 5m
3. Erosion between 0 and 2m
4. Accreting coast

3.4 OSCILLATIONS OF CREST OF BERM OF THE COAST

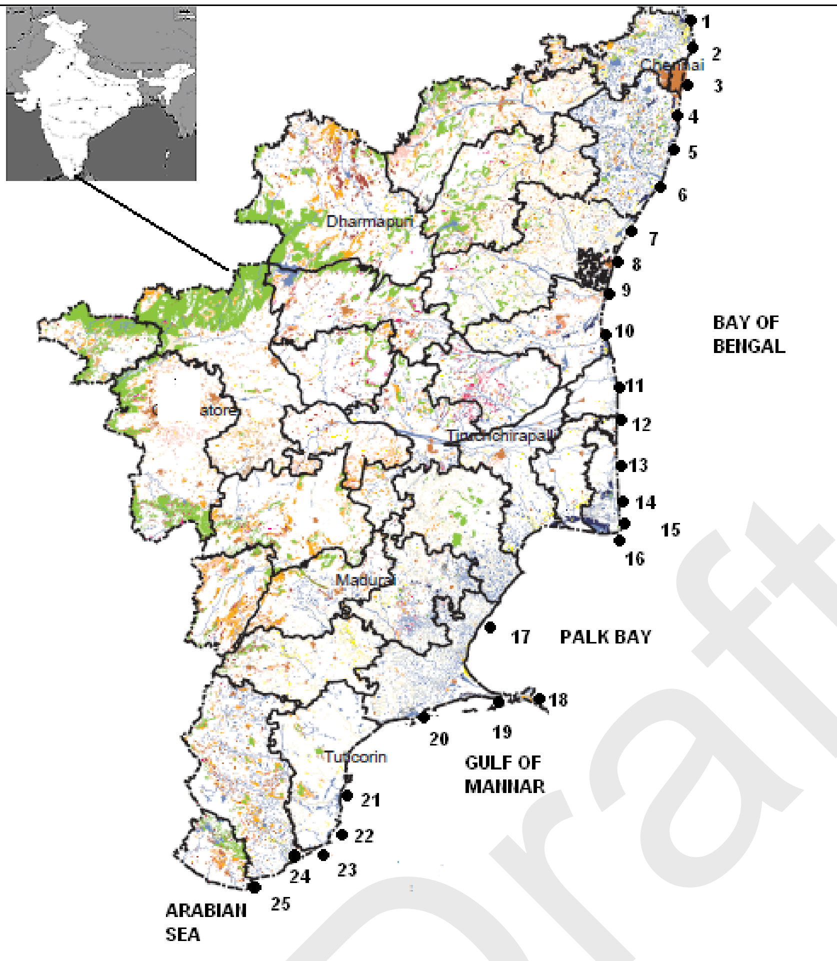
3.4.1 General

The monthly movement of the crest of the berm from a fixed baseline in particular at locations experiencing severe changes in its configuration, were identified through field data collection in this exercise. The observation stations were selected depending on field conditions in such a way that they will not be disturbed under normal environmental conditions and care was taken to locate them near permanent land marks such as existing structures, monuments, etc.

Out of the total length of Coastline of Tamilnadu about 60 km is along West coast of India bordering the Arabian Sea and the remaining portion is along East coast along the Bay of Bengal. In order to understand the physical process of sediment dynamics in detail, the entire coast has been divided into five segments along the east coast and one segment along the west coast. This was done based on the inclination of the coast with Geographic north and geomorphology. These are:

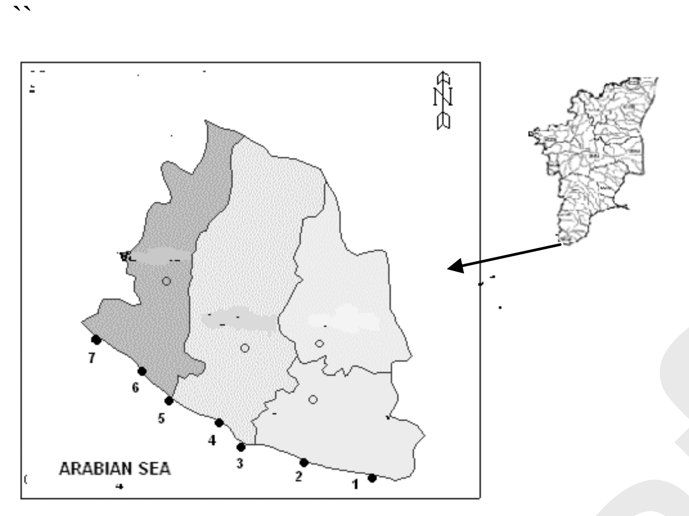
- Ennore to Cuddalore (inclined at about 15^o- with respect to North)
- Poompuhar to Point calimere (inclined at about 2^o- with respect to North)
- Palk strait (sheltered huge bay)
- Gulf of Mannar (sheltered, dominated by coral rocks)
- Thiruchendur to Kanniakumari (dominated by outcrops and inclined at about 62^o w.r.t North)
- West coast - Kannyakumari to Erayumanthurai (lying along the west coast)

The analysis on the behavior of the crest of berm has been carried out as per seasons, namely, South-West Monsoon (SW), North-East Monsoon (NE) and Non Monsoon (NM). The number of years of data varied with locations and ranged between 5 to 20 years.



Sl no	Site
1	Pulicat
2	Ennore
3	Royapuram
4	Marina-Chennai
5	Foreshore estate
6	Besant nagar
7	Kovalam
8	Mahabalipuram
9	Cuddalore
10	Port nova
11	Poompuhar
12	Tranquebar
13	Nagapattinam
14	Velankanni
15	Vedaranyam
16	Point Calimere
17	Ammapattinam
18	Rameswaram
19	Keelkarai
20	Valinokkam
21	Thiruchendur
22	Manappad
23	Periathalai
24	Idinthakarai
25	Kannyakumari

Fig 3.1a Sites in East coast of Tamil Nadu



Sl no	Site
1	Manakkudy
2	Pallam
3	Muttam
4	Manavalakurichy
5	Colachel
6	Enayam
7	Eraiyumanturai

Fig.3.1b West coast of Tamil Nadu

3.4.2 East coast of Tamilnadu

Ennore to Royapuram**1** ***(13^0 09'N, 80^0 18'E).***

Thetotal length of coastline along this stretch is about 15 km, inclined at about 15^o to the north starting from the Ennore creek and towards south. The beach slope in this stretch up to 6m depth is nearly 1:60. There are four observation points covering a distance of 3.2 km south of Ennore creek and 9 observation points covering a distance of 5.3km along the Royapuram coast north of Chennai major harbour. Most of the waves approach the coast from south east direction. The results on the variation of the beach width for this stretch of the coast in Fig.3.2a clearly show that the advancement of shoreline is about 175m towards the sea from 1983 to 1997. The commencement of the construction of the southern breakwater of the Ennore harbour from 1998 has resulted in an increase in the beach width that has gradually been built up to a width of about 275 m in 2005. Although, this proves a well known fact that the net littoral drift along the east coast of India is towards the North, the analysis shows the extent of beach that has formed due to the breakwater of Ennore acting as a littoral barrier.

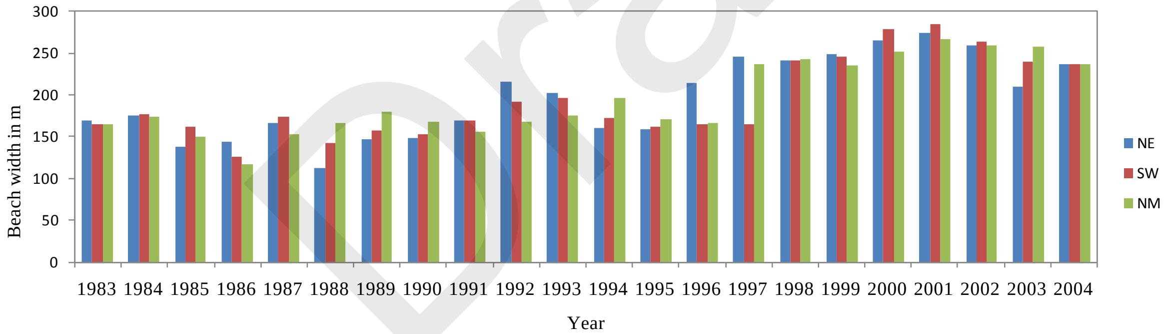


Fig 3.2a Beach width changes in Ennore coast

The coast of Royapuram is located on the south of Ennore. This stretch has been continuously undergoing severe erosion since the construction of the breakwaters of the Madras harbour in 1876 on its south. Initially the erosion was felt in 1 km stretch north of harbour. With the expansion of Chennai port and construction of fishing harbour in 1976, the impact of erosion was felt up to 6 km north of the harbour. There are nine observation stations covering 5.2km of coast. The analysis indicates that about 150m of beach width have been eroded in Royapuram in the past 25 years vide Fig. **3.2b** .

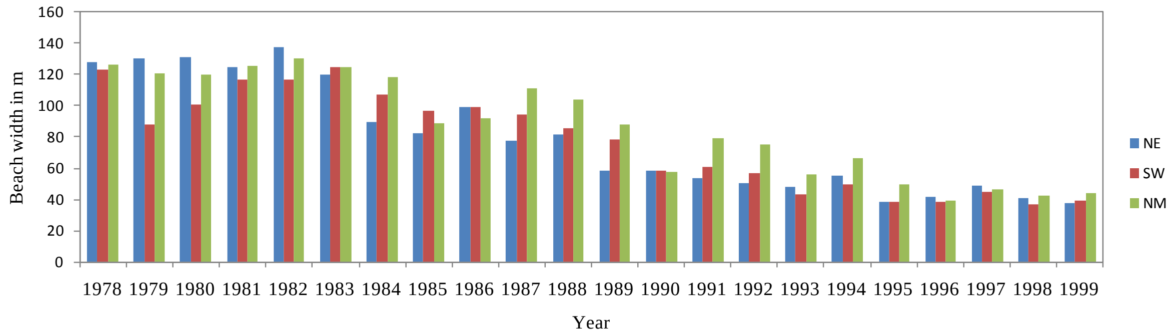


Fig 3.2b Beach width changes in Royapuram coast

Marina (13^0 03'N,80^0 18' E) to Kovalam (12^0 58'N, 80^0 16'E)

The total length of coastline along this stretch is about 35km and oriented at 14^oN. The rivers Cooum and Adayar meet the Bay of Bengal along this coast. Most of the waves approach the coast from south east direction. The beach slope in this stretch up to a 4m depth is nearly 1:75 along Marina, 1:100 along Foreshore estate to Besant nagar. The beach width along Marina located in the immediate south of Chennai harbour shows an advancement of shoreline which is felt up to the Foreshore estate. This effect is due to the construction and expansion activities of Chennai port breakwater. A groin of length 170m was completed on the south side of river Cooum on the south of Chennai harbour southern breakwater in the year 2001 and since then resulting in an accretion along this stretch of the coast.

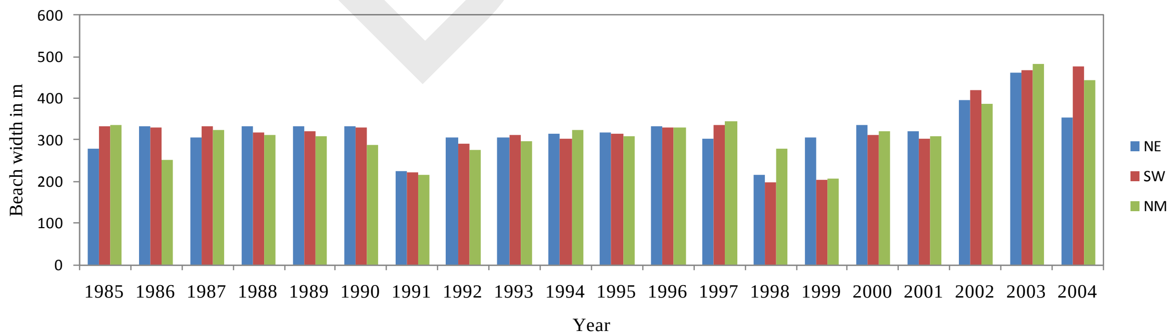


Fig 3.3a Beach width changes along Marina coast

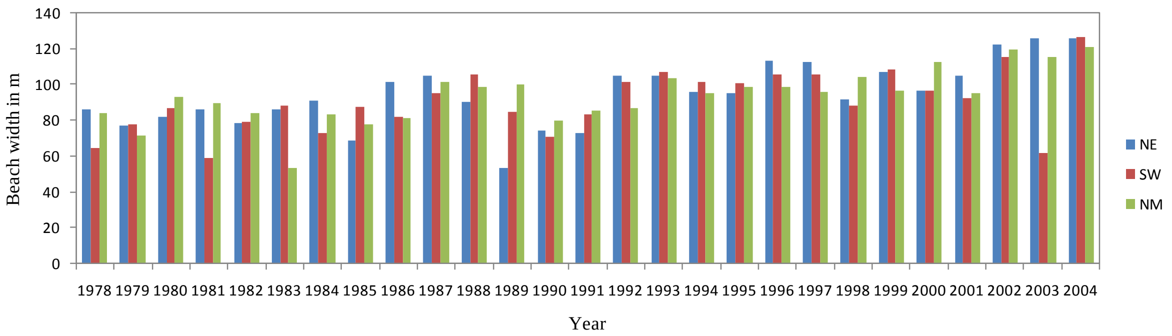


Fig 3.3b Beach width changes along Foreshore estate coast

The effect of accretion was noticed for a distance of 400m along the shore and the sand has bypassed the groin. The sand bar formation along the river mouth was observed to be migrating towards the north direction. From the analysis of observations on the variations in the beach width along this coast, it is found that the alongshore sediment transport is predominant(**Figs. 3.3a and 3.3b)** In general, the foregoing results show that the advancement of shoreline south of the mentioned obstruction and erosion on the north are dominant during the south west monsoon season, whereas, during the other seasons the effect is found to be less.

Kovalam (12^0 58' N, 80^0 16'E) to Cuddalore. (11^0 43' N, $79^0$47'E)

Thetotal length of coastline along this stretch is about 115km and oriented at 14^o to the north. Most of the waves approach the coast from south east direction. The beach slope in this stretch up to 4*m* depth is nearly 1:125 along Kovalam, 1:100 along Mahabalipuram coast. Three observation stations one each at Kovalam, Mahabalipuram and Cuddalore were considered, of which, Kovalam had 21 points covering a distance of 3150m, Mahabalipuram 26 points covering 5450m and Cuddalore 6 points covering a distance of 1718m. The coast of Kovalam is dominated by rock outcrops and jets into the ocean as a headland. Hence the discussion is based the behaviour of the beach width on south and north of this headland. The satellite imagery of this stretch of the coast is also discussed later in this part of the report. Erosion to an extent of about 20m on north side and accretion of about 30m on its south side are observed as can be seen in **Figs 3.4a** and**3.4b** respectively. This shows that natural obstructions also serve as littoral barriers leading to advancement of shoreline on its south anderosion on its north.

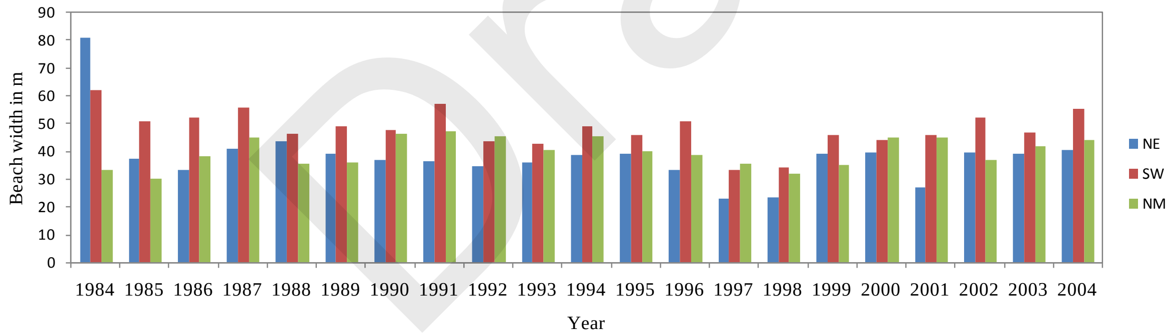


Fig 3.4aBeach width changes along Kovalam (north) coast

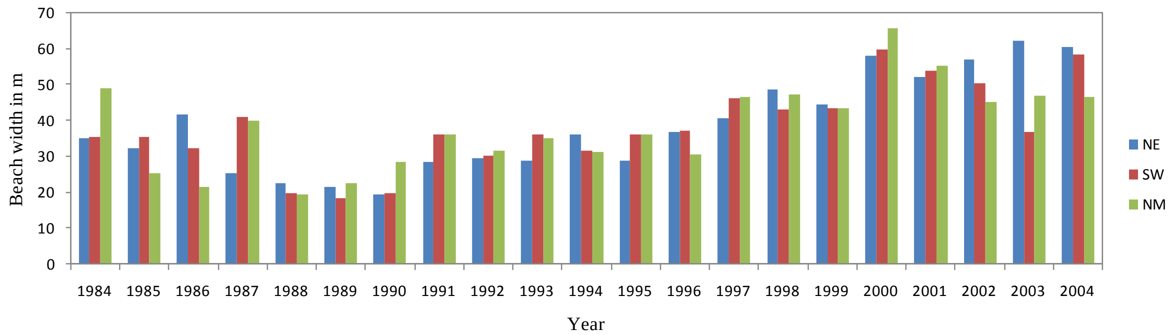


Fig 3.4b Beach width changes along Kovalam (south) coast

Along the coast of Mahabalipuram, a shore temple remains as a main tourist attraction. This temple was initially partly eroded and had been facing a severe threat from the onslaught of waves and resulting erosion. Hence, anti-sea erosion measures on a war footing was done in the mid 80's. The protection measure initially planned as two groins were joined which formed as a headland, the imagery of which is discussed. The measurements of the crest of berm elevation for about 20 years were undertaken. The season wise variations of the above parameter north and south of the mahabalipuram shore temple are shown in **Figs. 3.4c** and**3.4d** respectively. The results again demonstrate that the remedial measure jetting into the ocean has been serving as a littoral barrier leading to the advancement of the shoreline on its south and erosion on its north. The analysis of data indicates accretion of about 40m on southern side and erosion of about 20m on northern side.

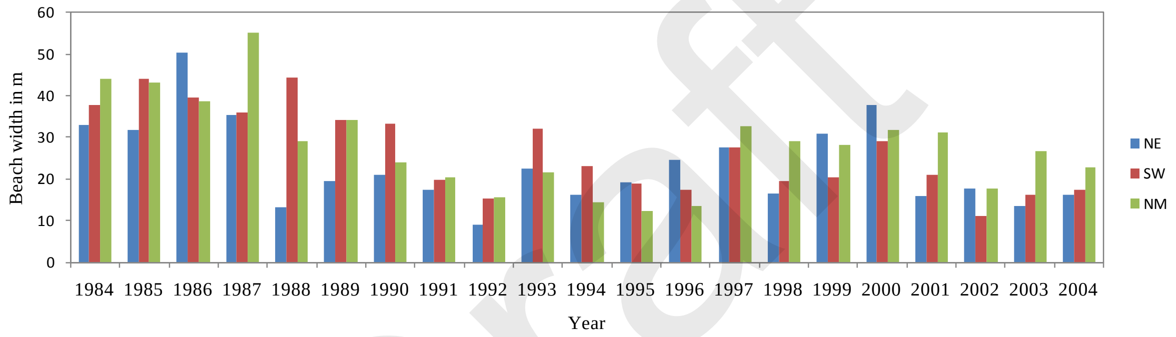


Fig3.4c Beach width changes along Mahabalipuram (north) coast

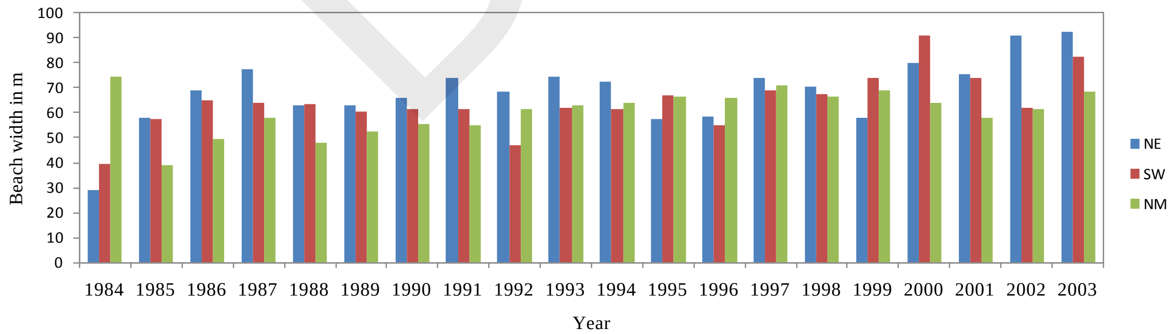


Fig 3.4d Beach width changes along Mahabalipuram (south) coast

Along the coast of Cuddalore two rivers join together in to Bay of Bengal. At the confluence region near the mouth of the rivers, a pair of training walls is constructed to facilitate smooth manoeuvring of vessels to the harbour located inside the river. The southern and northern training walls are 152m and 236m long respectively. The data available only at three points of observations covering a distance of about 180m on the south of the southern training wall were taken up for analysis, the results of which are projected in **Fig. 3.4d** . The results show the trapping of the sediments by the southern training wall and although observation points are not available on the north of the northern training wall, enough evidence is available to show the erosion of the shoreline, for example through satellite imagery discussed later.

Poompuhar (11^0 13'N, 79^{0}52'E) to Point calimere (10^0 17'N, 79^0 53'E)

Thetotal length of coastline along this stretch is about 115km and oriented at almost 180^o to the north. The beach slope in this stretch up to 10*m* depth is nearly 1:150 along Poompuhar, 1:450 along Nagapattinam near Velankanni. Data from four observation stations one each at Poompuhar, Tranquebar, Nagapattinam and Velankanni were available. Of this Poompuhar has 6 points covering a distance of 1550m. River Cauvery joins Bay of Bengal as a small stream at the northern end of this stretch. The river mouth is mostly closed during fair season**Fig 3.5a** Beach width changes along Cuddalore coastand gets opened during flood season indicating the dominance of alongshore transport during fair season forming sand bar. The average of the crest of berm elevations from the six observed points all of which are on the south of the mouth of the river measured from 1982 to 2000 has been plotted in **Fig.3.5b**. Except for a few oscillations during early 90's, the trend is observed to be advancement of the shoreline.

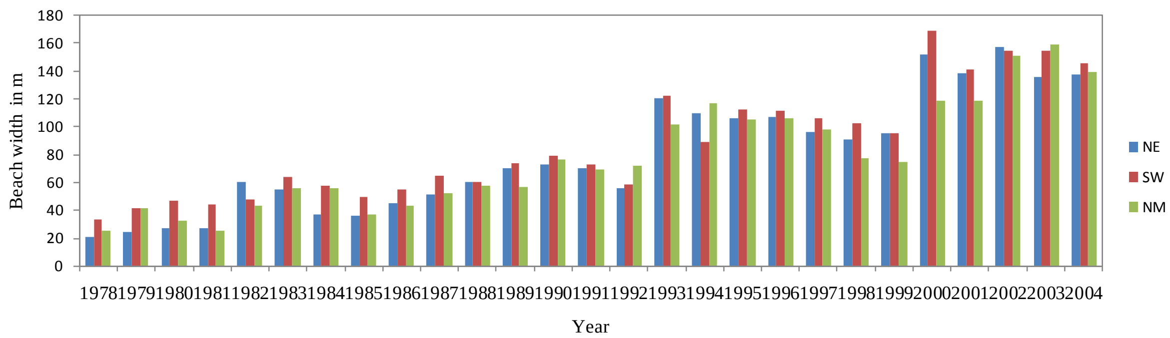


Fig 3.5a Beach width changes along Cuddalore coast

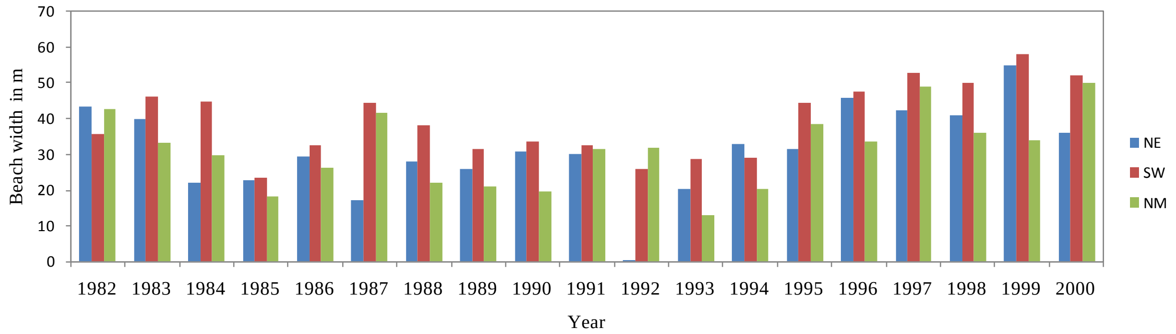


Fig 3.5b Beach width changes along Poompuhar coast

Tranquebar has 3 observation points covering a length of 760m. One observation points are on the southern side and two on the northern side of an existing ancient temple have been considered. Initially, an erosion trend was seen at all the points. The temple was almost eroded and subsequently anti sea erosion measures were executed in the form of rubble mound sea wall. At present, the location of the temple is acting like a barrier projecting slightly in to the sea. The north of the temple has been experiencing mild erosion and no beach is observed, while, beach is present on the southern side. A stretch of 1 km long coast on either side of the temple is protected by a rubble mound sea wall. Only the data on the southern side was analysed and the variation of the crest of berm elevation (average between the two stations) are plotted for the period 1978 to 2005 in **Fig.3.6a**. The beach width is seen to oscillate between 20m and 80m over the period of the study. This indicates that the dominance of the alongshore sediment has reduced compared to locations north of this stretch of the coast.

Along the coast of Nagapattinam, a minor port formed by a pair of breakwaters projecting in to the sea is located. There are three observation points covering a distance of 3000m north and two points covering 1270m south of the port. The analysis of data indicates an advancement of the shoreline of about 25m from 1995 onwards on the north, contrary, to the locations north of this stretch. The advancement of shoreline to an extent of about 15m from 1995 on the south of the port is observed which is similar to the locations north of this stretch of the coast. The beach although oscillates as per the seasons on both the sides of the Nagapatinam port as can be seen in **Figs.3.6b** and **3.6c** it is found to be stable. It is to be mentioned that the coast referred to herein is straight with no inclination to north and hence subjected to a wider sector of wave directions leading to littoral drift both towards north and south.

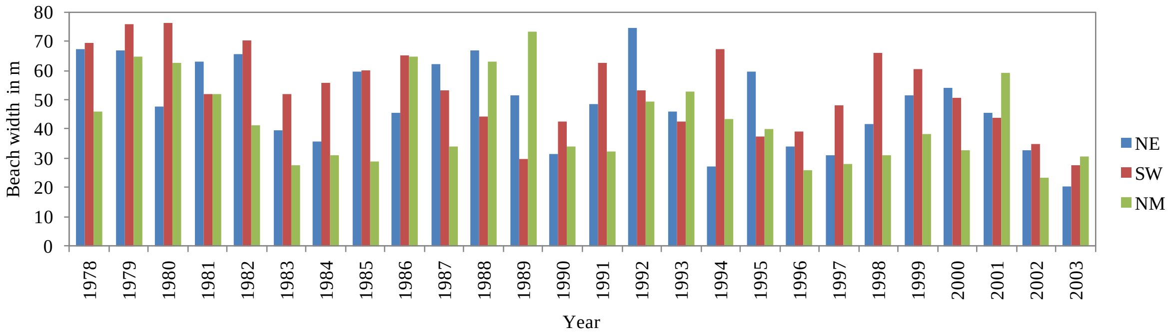


Fig 3.6aBeach width changes along Tranquebar coast

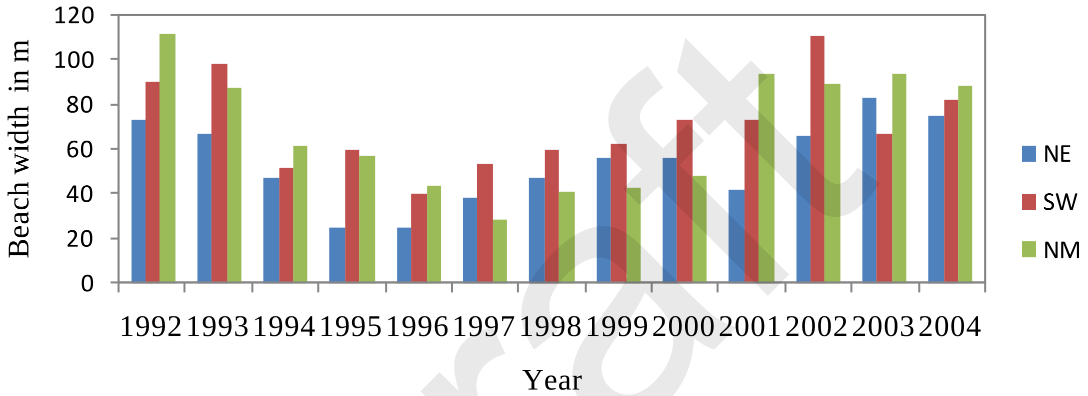


Fig 3.6b Beach width changes along Nagapattinam (north) coast

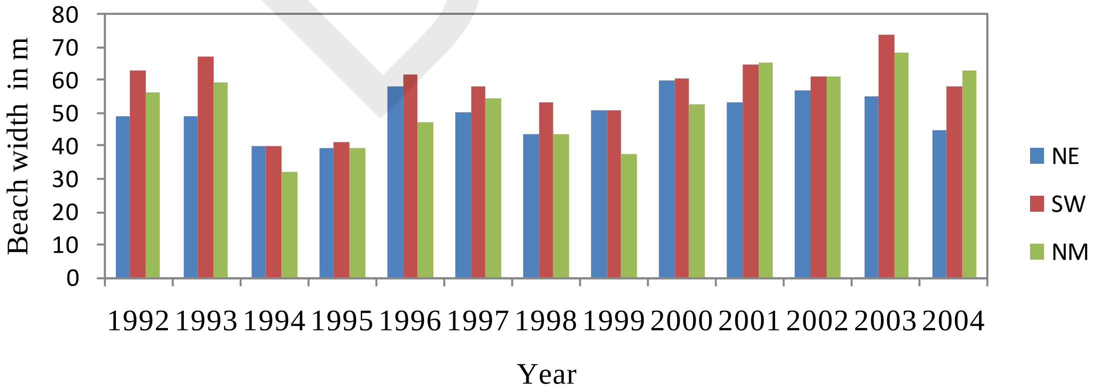


Fig 3.6c Beach width changes along Nagapattinam (south) coast

Further, it is found that the magnitude of accretion on the northern side is more compared to south, and hence is inferred that the net drift along this coast is towards south. This also clearly brings out an important phenomena that the net alongshore drift that is directed towards north along the east coast of Indian peninsula, is initiated around Nagapatinam. A satellite imagery showing this stretch of the coast being straight along with the locations of the temple, river Cauvery and the Nagapatinam port are shown in **Fig. 3.6d** .

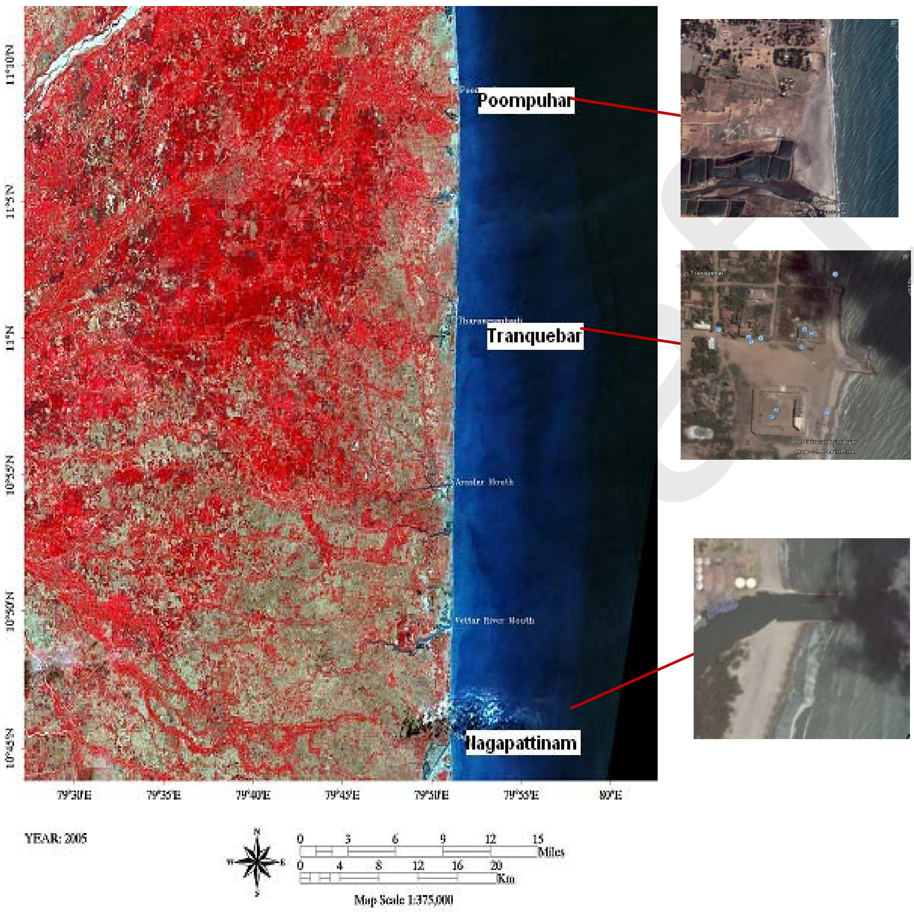


Fig 3.6dIRS-P6 (June-2005)

Further south of Nagapatinam, near Velankanni, the river Vellaiyar joins the east coast and available measured data for three points covering 1000m north and two points covering 549m south of river were collected. The beach on the north side indicates beach oscillation to an extent of about 10m over a decade as can be seen in **Fig. 3.6e** . The analysis of the data has indicated that the beach on the south stretch of Vellaiyar river mouth has been experiencing a mild advancement to an extent of about 15m as can be inferred from **Fig. 3.6f** . Furthermore, a significant erosion of the coast of about 70m close to the south side of the mouth during the year 2000 noticed is due to the heavy breach of the southern flank due to high floods in the river Vellaiyar. All these observations have clearly indicated that the net sediment transport directions have changed from north to south in this reach. The magnitude of littoral drift also reduces considerably along the reach at Velankanni. The results presented above show clearly that the net direction of littoral drift changes from North to south close to Nagapatinam,

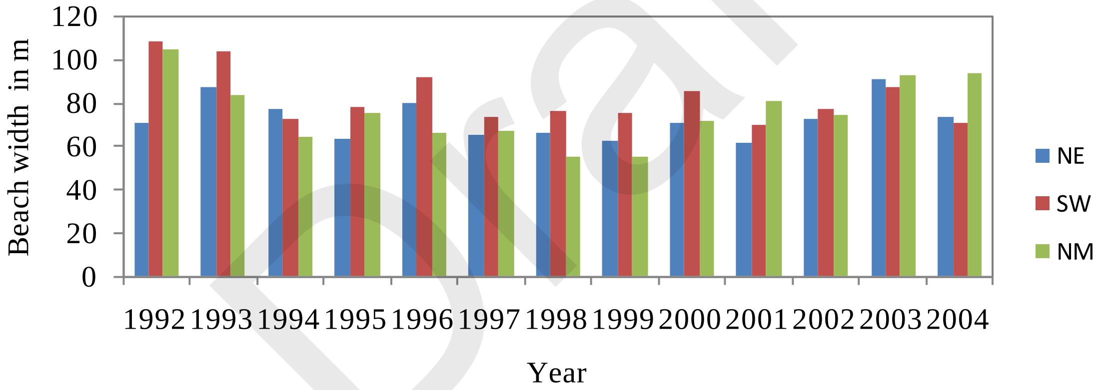


Fig 3.6eBeach width changes along Velankanni (north) coast

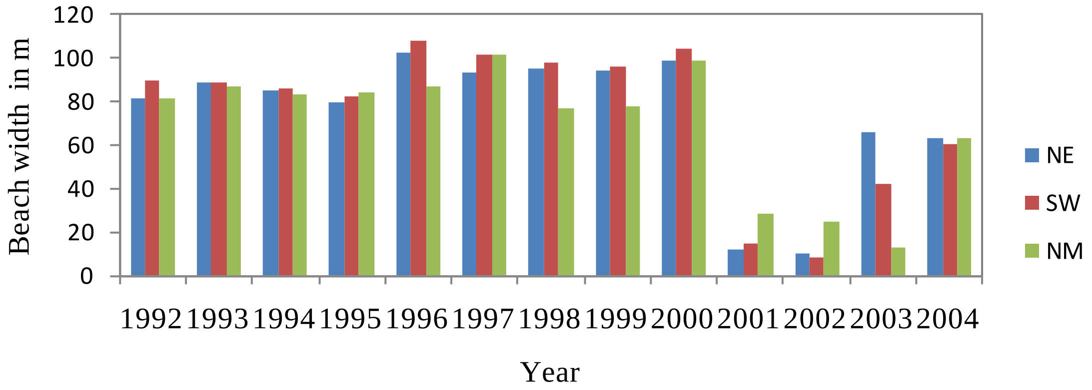


Fig 3.6f Beach width changes along Velankanni (south) coast

Point Calimere (Palk bay)

The coastline along the stretch extends east to west. This stretch has six observation points covering a distance of 800m. This coast does not experience any wave action as it is on the shadow region of SrilankanIsland. The beach slope in this stretch up to 2m depth is nearly 1:1000. The results of the beach width from 1978 to 2003 shown in **Fig. 3.7** .exhibit that a gradual advancement of the beach until 1994, and thereafter has stabilized.

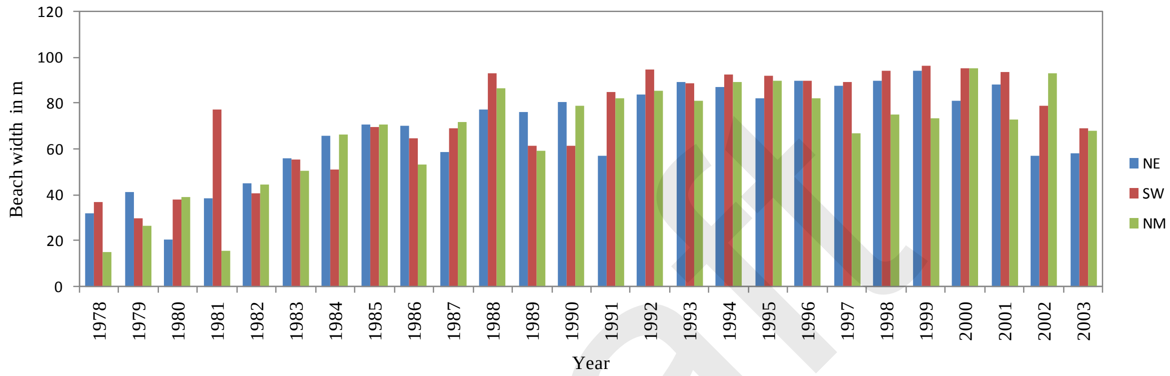


Fig 3.7 Beach width changes along Pt Calimere

Ammapattinam (10^0 1' N, 79^0 13' E).

The coastline is oriented 45^o north. This stretch has 15 points of observation covering a distance of 3700m. The beach slope in this stretch up to 2m depth is nearly 1:1000. As this stretch does not experience any wave action, the beach is almost stable as seen in **Fig. 3.8**

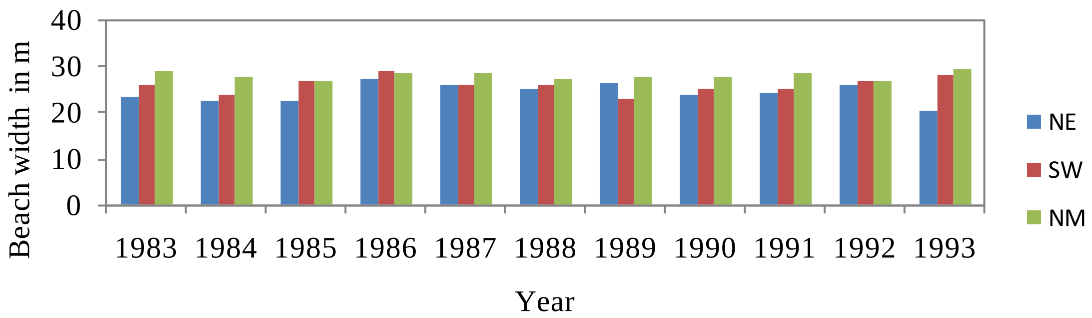


Fig3.8 Beach width changes along Ammapattinam coast

***Rameswaram* (9^{0}17′ N, 79^{0} 19′ E).**

The coastline along the stretch on the leeside of Island of Srilanka is a popular tourist destination The observation station has 13 points covering a distance of 3295m.This coast does not experience any wave action because of the presence of Srilanka. The beach slope in this stretch up to5m depth is nearly 1:600. The observation does not show any appreciable change **(Fig3.9)** and has stabilized.

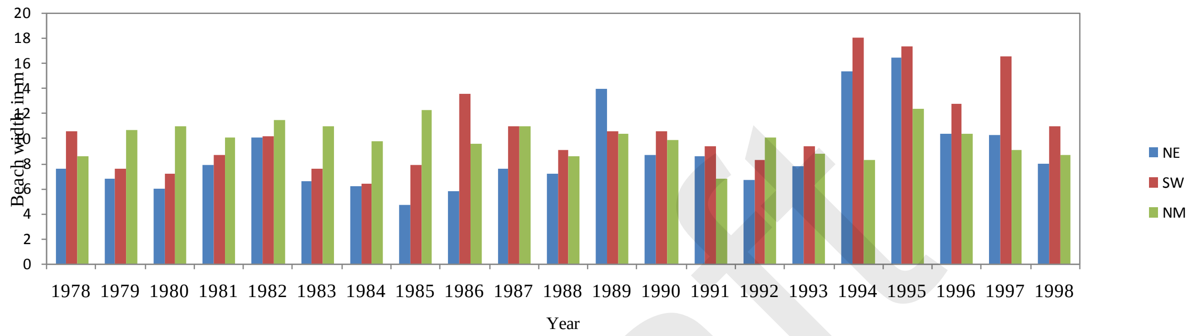


Fig 3.9 Beach width changes along Rameswaram coast

***Keelakarai* (9^{0} 14′ N, 78^{0} 49′ E).**

The coastline along the stretch is running about 75^{o} w.r.t North that has 8 observation stations covering a distance of 5140m.This coast does not experience any wave action. The beach slope in this stretch up to 2*m* depth is nearly 1:1500. The results of the measured beach width from 1978 to 1997 reported in **Fig.3.10** indicate that the beach is almost in stable equilibrium.

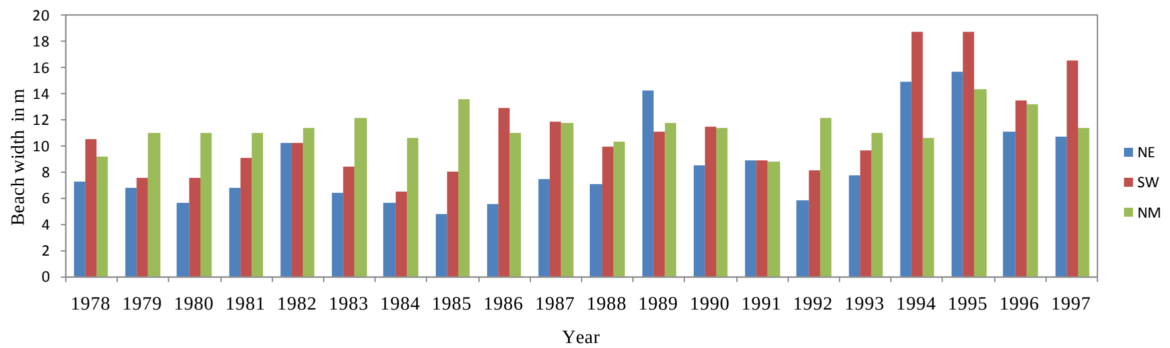


Fig 3.10 Beach width changes along Keelkarai coast

Thiruchendur (8^0 29' N,$78^0$7' E)

The coastline along this stretch is inclined at about 70^o w.r.t North and has 7 stations of observation spread over a distance of 1645m and is a popular pilgrimage spot. The coast does not experience wave action. The beach slope in this stretch up to 5m water depth is nearly 1:300 .There are a lot of discontinuous submerged outcrops at about 500m from the coast. Most of the waves experience premature breaking over these obstructions due to which no definite trend in the direction of littoral drift is observed along this stretch of the coast. The beach width is observed to vary from 40m to 60m over the period 1993 to 2001 as can be seen in **Fig 3.11**

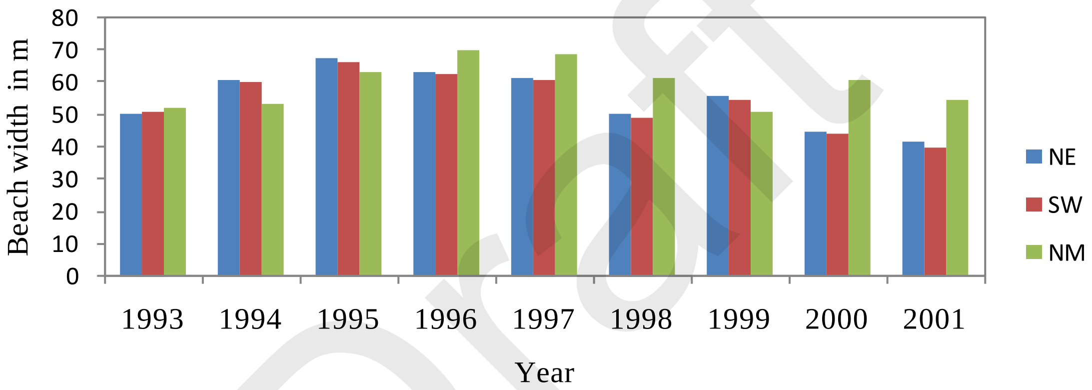


Fig 3.11Beach width changes along Thiruchendur coast

Manappadu (8^0 22' N 78^0 4' E).

The coastline is inclined at an angle 65^o w.r.t North with 8 measuring station spread over a distance of 1600m. Most of the waves approach the coast from south east direction. The coast has a bay like formation and a chain of discontinuous submerged rocks at a distance of about 100m from the coast. The beach slope in this stretch up to 10m depth is nearly 1:200. A beach of width 100m in front of an existing seawall is found. Further south of the existing seawall, the beach width from the available measured data shows that the beach width has been constantly increasing from 40m to about 110m over the period 1985 to 2004 as shown in **Fig 3.12**

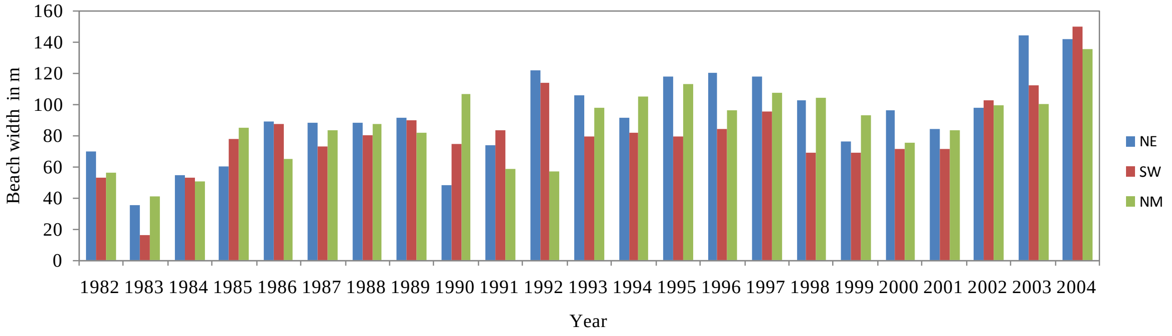


Fig 3.12 Beach width changes along Manappad coast

3.4.3 West Coast of Tamilnadu

General

The coast from Kannyakumari(8^0 4' N 77^0 33' E) to Eraiyummanthurai(8^0 13' N 77^0 11' E) along the west coast bordering Arabian Sea is about 50km long. It is oriented at an angle of 120^o w.r.t north. The foreshore slope in this stretch up to (-) 10m varies from 1/100 to 12/100. There are seven observation stations covering the entire west coast. The coast experiences both south west and north east monsoons. The data on beach width changes available from 1993 to 1998 from the observation stations have averaged and are discussed location wise below.

Manakkudi (8^0 8'N, 77^0 29'E)

There are 11 observation stations covering a distance of 3650 m. The analysis of beach width measurements indicate a beach width loss of about 20m after the south west monsoon which gets replenished during the onset of north east monsoon as is observed in **Fig 3.13**

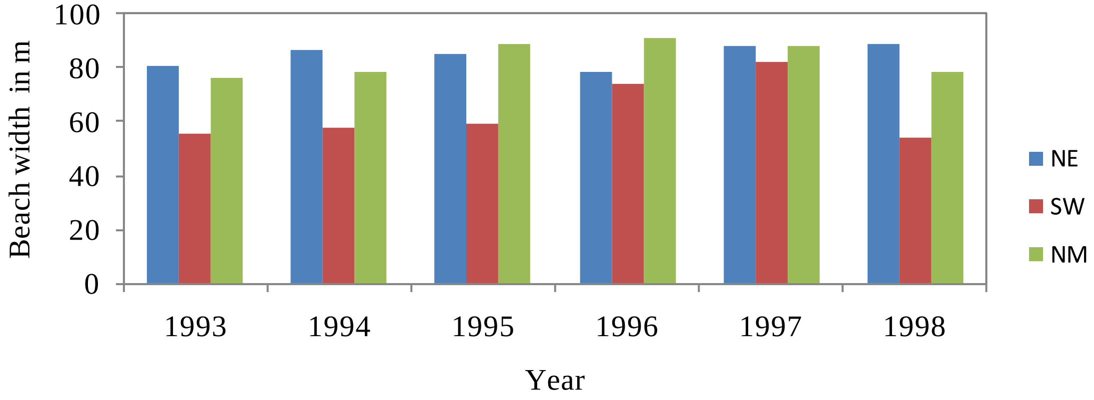


Fig 3.13 Beach width changes along Manakkudi coast

Pallam (8^0 8' N,77^0 29' E)

There are 10 observation stations covering a distance of 2600m. The analyses of beach width measurements indicate that the beach width loss of about 40m after south west monsoon that gets replenished during the north east monsoon as seen in **Fig 3.14**

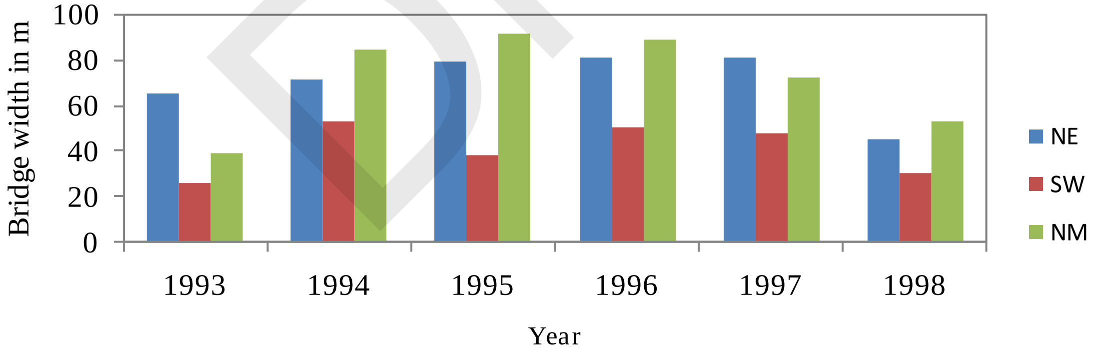


Fig 3.14 Beach width changes along Pallam coast

Muttam (8^0 8' N 77^0 19' E)

There are 19 observation stations stretching over a distance of 3000m. Rocky outcrops are seen along the coast. The analyses of beach width measurements shows a similar trend in variation as observed for the locations, Pallam and Manakudi with a width magnitude of about 15m as shown in **Fig.3.15**

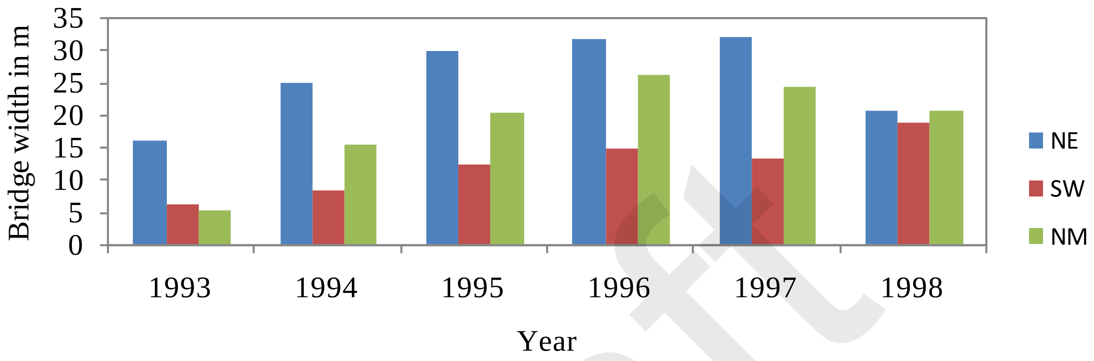


Fig 3.15 Beach width changes along Muttam coast

Manavalakurichy(8^0 9' N 77^0 18' E)

Along this coast there are 11 observation stations over a distance of 3500m. The analyses of beach width measurements indicate beach width loss of about 22m which gets replenished again as can be seen in **Fig 3.16**

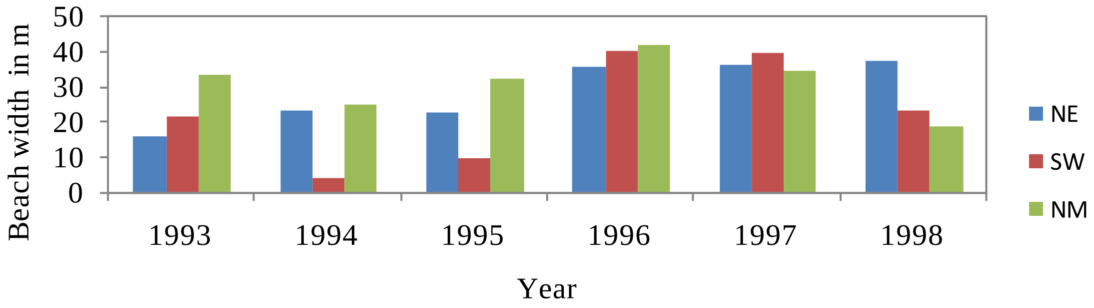


Fig 3.16 Beach width changes along Manavalakurichy coast

Colachel(8^0 11' N 77^0 15' E)

At this station there are 8 points over a distance of 1750m. The analyses of beach width measurements indicate beach width loss of about 40m and the trend in the variation in the beach width according the seasons is similar to the earlier locations as shown in **Fig 3.17**

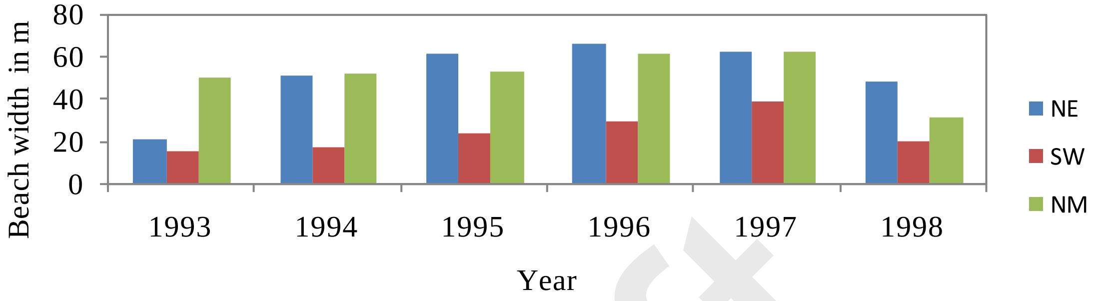


Fig 3.17 Beach width changes along Colachel coast

Midalam (8^0 12' N 77^0 13' E)

This stretch of the coast has 8 points spread over a distance of 2500m. The analyses of beach width measurements indicate beach width loss of about 50m after south west monsoon and after north east monsoon it is recovered **(Fig 3.18**).

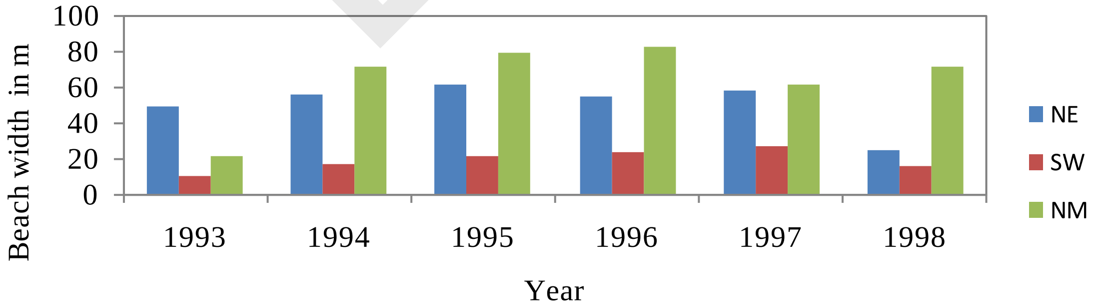


Fig 3.18 Beach width changes along Midalam coast

Eraiyummanthurai (8^0 13' N 77^0 11' E)

This is the last point of Tamilnadu coast and the river Tamaraparani meets the west coast along this point. The analyses of beach width measurements indicate beach width loss of about 40m after south west monsoon and after north east monsoon it is recovered **(Fig 3.19).**

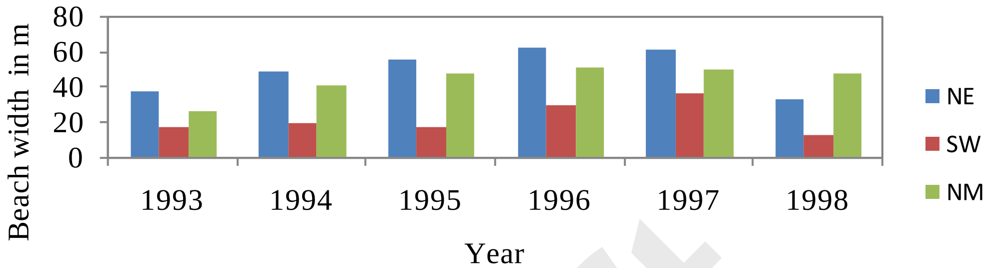


Fig 3.19 Beach width changes along Erayumanthurai coast

3.5 SUMMARY

The shoreline analysis based on the Google earth imageries are compared with SAC and PWD data set and presented in **Table 3.1**.

Table 3.1 Summarization and comparison of the present work with SAC and PWD

Places	Latitude	Longitude	PWD	SAC	IIT
Ennore to Royapuram coast	13°12'49.69"N to 13° 3'53.56"N	80°19'31.09"E to 80°17'16.81"E	Erosion	Erosion	Accretion/stable
Marina	13° 3'19.14"N	80°17'3.70"E	Accretion/stable	Accretion/stable	Accretion/stable
Foreshore estate	13° 1'27.10"N	80°16'43.84"E	Accretion/stable	Accretion/stable	Accretion/stable
Kovalam	12°47'25.18"N	80°15'8.33"E	Erosion	Erosion	Erosion
Mahabalipuram	12°37'8.99"N	80°11'54.53"E	Erosion	Erosion	Erosion/stable
Cuddalore	11°44'23.32"N	79°47'13.64"E	Accretion/stable	Erosion	Erosion
Poompuhar	11° 9'34.14"N	79°51'21.96"E	Erosion	Erosion	Erosion
Tranque bar	11° 1'43.26"N	79°51'20.96"E	Erosion	Erosion/stable	Erosion/stable
Nagapattinam	10°44'50.99"N	79°51'3.64"E	Erosion/stable	Accretion/stable	Erosion
Velankanni	10°40'29.30"N	79°51'11.81"E	Erosion	Accretion/stable	Erosion
Point Calimere	10°17'45.45"N	79°52'37.35"E	Accretion/stable	Accretion/stable	Accretion/stable
Ammapattinam	10° 0'49.21"N	79°13'54.33"E	Accretion/stable	Accretion/stable	Accretion/stable
Rameswaram	$9^0$17' N	79^0 19' E	Erosion	Erosion/stable	Erosion
Keelakarai	9°13'40.26"N	78°47'10.14"E	Erosion/stable	Erosion/stable	Erosion/stable

Places	Latitude	Longitude	PWD	SAC	IIT
Tiruchendur	8°29'40.89"N	78° 7'42.95"E	Erosion/stable	Accretion/stable	Erosion/stable
Manappad	8°22'16.79"N	78° 3'48.76"E	Accretion/stable	Accretion/stable	Accretion/stable
Manakkudy	8° 5'23.58"N	77°28'40.51"E	Accretion/stable	Accretion/stable	Erosion
Pallam	8° 5'53.60"N	77°25'58.59"E	Erosion/stable	Accretion/stable	Accretion/stable
Muttom	8° 7'26.60"N	77°18'50.65"E	Accretion/stable	Accretion/stable	Accretion/stable
Manavalakurichy	8° 8'44.64"N	77°18'3.11"E	Erosion/stable	Erosion/stable	Erosion
Colachel	8°10'21.16"N	77°15'16.54"E	Erosion/stable	Erosion/stable	Accretion/stable
Midalam	8°12'10.76"N	77°12'50.36"E	Erosion/stable	Erosion/stable	Erosion
Eraiyummanthurai	8°14'37.48"N	77° 9'47.83"E	Erosion/stable	Erosion/stable	Erosion

CHAPTER 4
WAVE CLIMATE AND LONGSHORE SEDIMENT TRANSPORT RATES

4.1 GENERAL

In the present report, the entire coastal stretch of Tamil Nadu has been divided into 4 major stretches based on the variation in shoreline orientation, nearshore slope, wave characteristics, coastal morphology etc., as given below.

- Chennai- Cuddalore stretch
- Poompuhar- Nagapattinam stretch
- Manappad-Kanyakumari stretch
- West coast of Tamil Nadu

4.2 WAVE CLIMATE

The offshore wave climate which is main driving force for longshore sediment transport has been simulated from the wind data from National Centre for Environmental Prediction (NCEP) for the year 2004 using the WAM model, of Komen et al (1994). In addition, the near shore wave climate was also derived for the different reaches as stated below.

The season wise wave climate for the different reaches as stated above in the form of wave rose diagrams are reported in **Fig.4.1 to 4.4**.

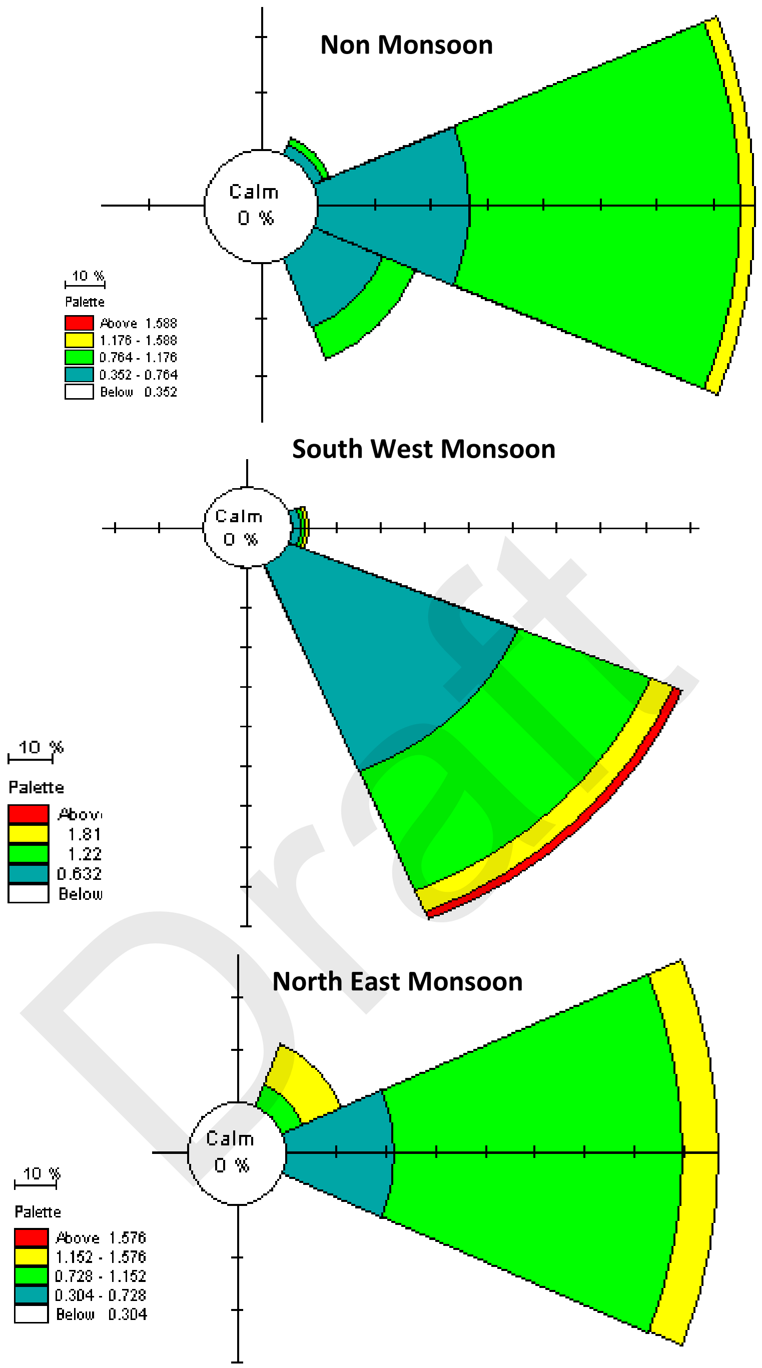


Fig. 4.1 The season wise wave climate for Chennai - Cuddalore stretch

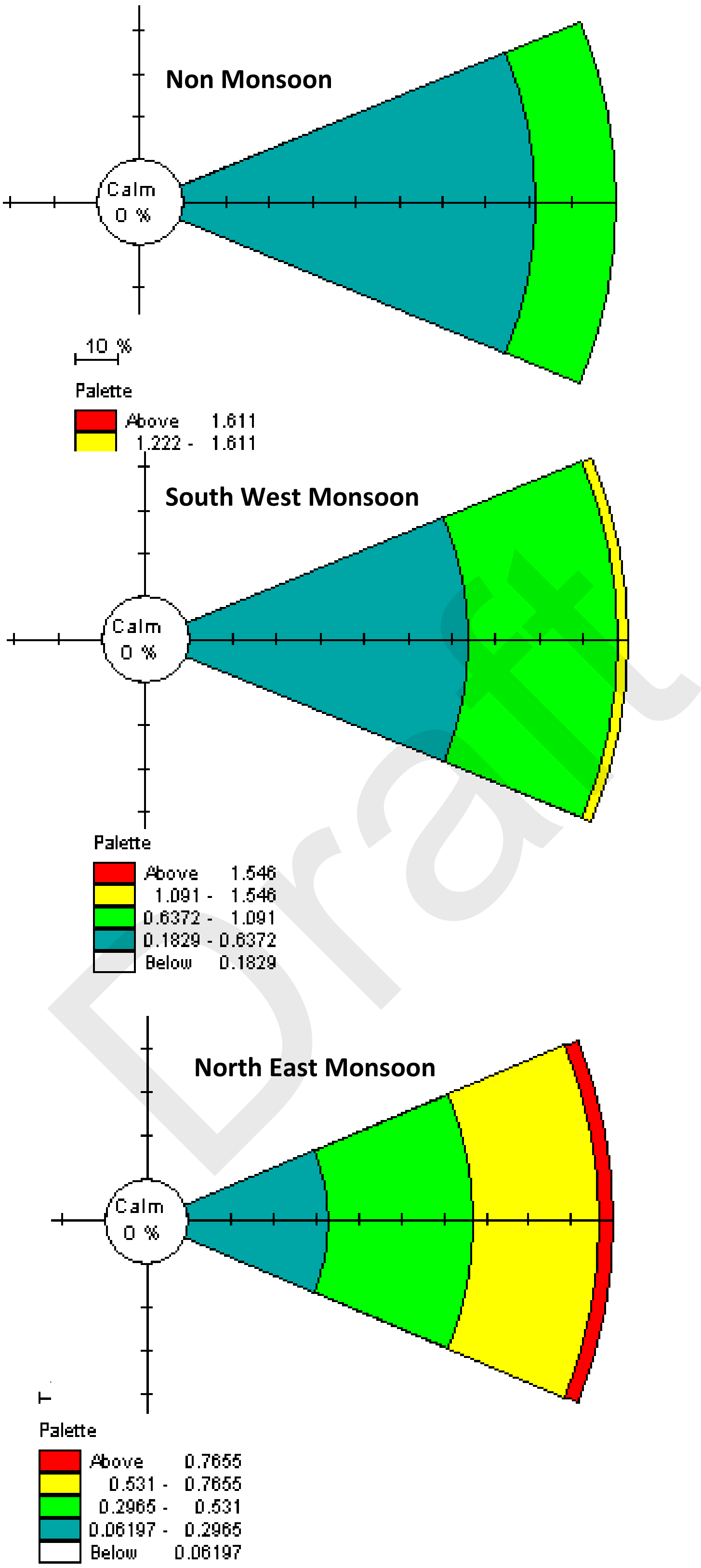


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Fig. 4.2 The season wise wave climate for Poompuhar – Nagapattinam stretch

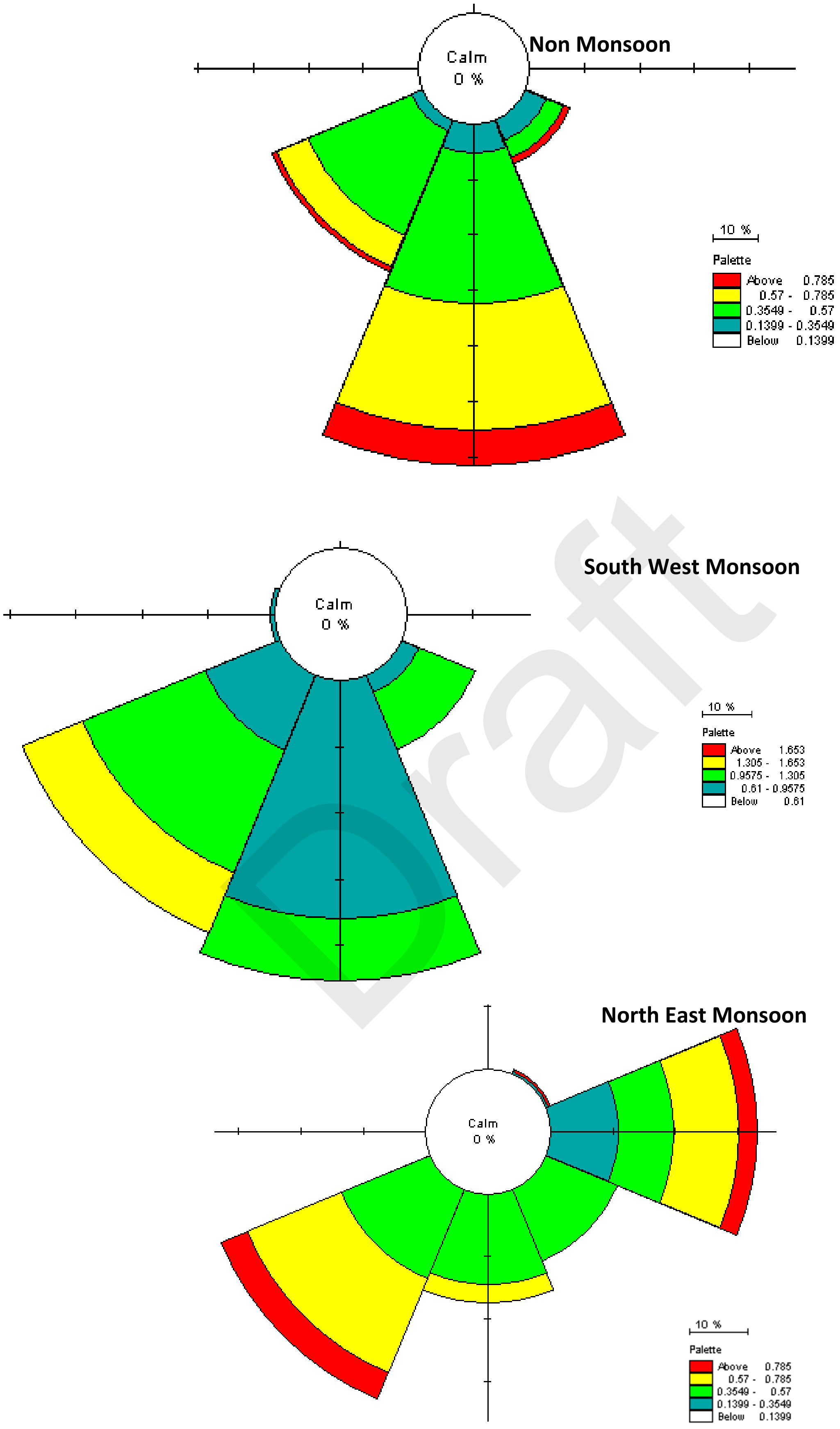


Fig. 4.3 The season wise wave climate for Manappad-Kanyakumari stretch

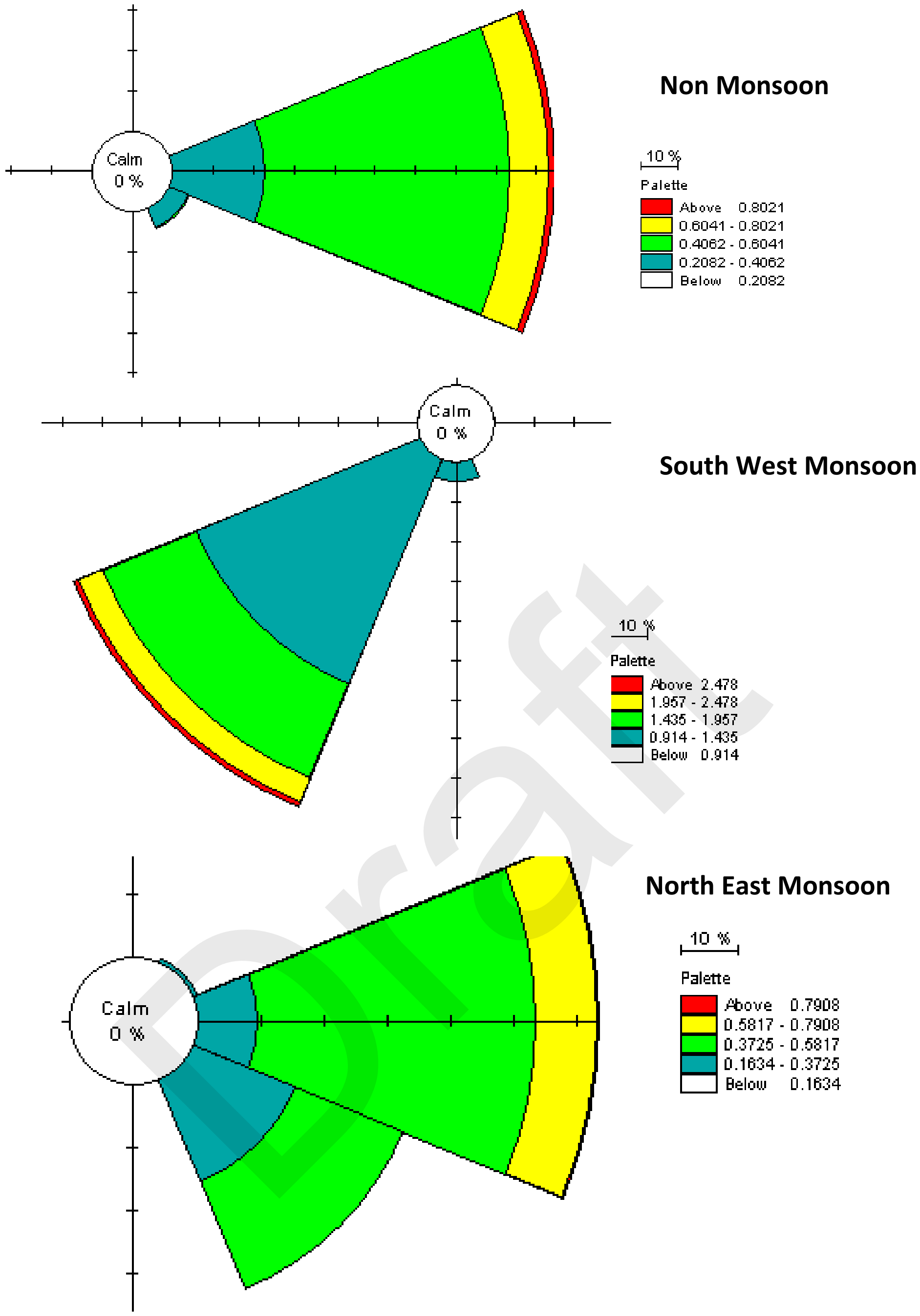


Fig. 4.4 The season wise wave climate for West coast of Tamil Nadu

Furthermore, the monthly representative wave characteristics for the above mentioned coastal stretches are presented in the Tables 1to4 The stretch of coast, Kanyakumari to Erayummanthurai was divided into two stretches, namely, Kanyakumari to Muttam and Muttam to Erayummanthurai for which the predicted average monthly wave characteristics are shown in Tables 4.4a and 4.4b respectively.

Table-4.1 Wave Climate (Chennai-Cuddalore)

Month	Wave Height (m)	Period (sec)	Angle deepwater (deg) w r t north
January	0.78	7	96.4
February	0.66	6	101.84
March	0.66	10	118.33
April	0.97	11	132.07
May	1.07	8	140.06
June	1.26	10	140.54
July	1.06	8	138.06
August	1.22	9	143.96
September	1.02	8	145.14
October	0.96	8.5	120.98
November	0.93	7	93.6
December	0.86	8	67.22

Table-4.2 Wave Climate (Poompuhar-Point Calimere)

Month	Wave Height (m)	Period (sec)	Angle deepwater (deg) w r t north
January	0.90	7.5	55
February	0.62	6	67
March	0.45	9.5	99
April	0.41	11	130
May	0.56	8	146
June	0.65	11	163
July	0.57	8	160

August	0.43	9	156
September	0.50	8	144
October	0.53	8	102
November	0.83	7	62
December	0.90	8.5	51

Table 4.3Wave Climate (Manappad-Kanyakumari)

Month	Wave Height (m)	Period (sec)	Angle deepwater (deg) w r t north
January	0.43	10	83
February	0.38	16	82
March	0.72	12	112
April	0.6	12	110
May	1.03	10	167
June	1.03	6	166
July	0.93	7	166
August	0.85	8	163
September	1.45	10	112
October	1.1	9	117
November	0.48	8	94
December	0.54	10	121

Table-4.4a Wave Climate (Kanyakumari-Muttam)

Month	Wave Height (m)	Period (sec)	Angle deepwater (deg) w r t north
January	0.89	7.5	77.4
February	0.75	6	82.84

March	0.75	9.5	99.33
April	1.11	11	113.07
May	1.22	8	121.06
June	1.44	11	121.54
July	1.21	8	119.06
August	1.39	9	124.96
September	1.16	8	126.14
October	1.09	8	101.98
November	1.06	7	74.6
December	0.98	8.5	48.22

Table 4.4b.Wave Climate (Colachel-Eraiyummanthurai)

Month	Wave Height (m)	Period (sec)	Angle deepwater (deg) w r t north
January	0.89	7.5	77.4
February	0.75	6	82.84
March	0.75	9.5	99.33
April	1.11	11	113.07
May	1.22	8	121.06
June	1.44	11	121.54
July	1.21	8	119.06
August	1.39	9	124.96
September	1.16	8	126.14
October	1.09	8	101.98
November	1.06	7	74.6
December	0.98	8.5	48.22

4.3 LONGSHORE SEDIMENT TRANSPORT

Different methods are available for the estimation of longshore sediment transport in the surf zone region. Many of the formulae proposed by earlier researchers were developed on the basis of experimental work or field conditions. Few methods are described below.

4.3.1 CERC (Shore protection Manual, 1984)

The empirical relationship between the longshore component of wave energy flux entering the surf zone and the immersed weight of sand moved with a non-dimensional coefficient '*K*' is termed as CERC formula

$$I_l = KP_l \tag{4.1}$$

I_1 - immersed weight transport rate (force/time),

K - dimensionless coefficient, and

P_1 the longshore energy flux (force/time).

As this method is based on the assumption that longshore transport rate, depends on the longshore component of energy flux in the surf zone. The longshore energy flux in the surf zone is approximated by assuming conservation of energy and evaluating the energy flux relation at the breaker line. Further, by assuming that the waves follow Rayleigh distribution, P_l is changed to P_{ls} and written as,

$$P_{ls} = \frac{\rho g}{16} H_{sb}^2 C_{gb} 2\alpha_b \tag{4.2}$$

Where,

ρ - mass density of water

g - acceleration due to gravity

H_{sb} - Significant wave height at breaker line

C_{gb} - wave group celerity at the breaker line, in shallow waters $C_g = C$, given by

$$C_{gb} = C_b = \sqrt{gd_b}$$

α_b - wave approach angle w.r.t shorenormal at the breaker line

The immersed weight transport rate I_l is given by

$$I_l = (\rho_s - \rho) g a' Q \tag{4.3}$$

Where,

ρ_s - mass density of sand;

a' - volume of solids/total volume, assumed as 0.6 for beach sands

Q - volume of sediment transport (m3/day or month or year)

By substituting for I_1 in CERC equation, we can get

$$Q = \frac{K}{(\rho_s - \rho)\,ga'} P_{ls} \qquad (4.4)$$

In the above equation, if 'K' taken as 0.39 or 0.4 – Then it is CERC methodand we need to useH_s,Whereas. if 'K' taken as 0.77 – Then it is KOMAR method, were we need to use H_{rms}. The estimation of sediment transport in the above formula depends on wave height and direction only.

4.3.2 Van Rijn (2001)

$$Q = 40\, K_{swell} K_{grain} K_{slope} (H_{sb})^3 \sin(2\theta_b) \qquad (4.5)$$

Where, Q - alongshore sediment transport (kg/s)

H_{sb}- Significant wave height at breaker line (m)

$\tan\beta$ - Slope

θ_b- Breaker angle (deg)

D_{50} - Effective size (mm)

T_P - Peak period

K_{swell}- Swell correction factor = $T_P/6$

D_{50} - Particle size (mm)

K_{grain} - Particle size correction factor = $0.20 / D_{50}$

K_{slope} - Slope correction factor = $(\tan\beta/0.01)^{0.5}$

A - $(1261440/\rho)X(K_{swell}K_{grain}K_{slope})(H_{s,br})^3 \sin(2\theta_b)$

4.3.3 Kamphuis formula

The formula of Kamphuis (2002) which considers all the important parameters like sediment grain size, bed slope for the calculation of the LST along different stretches of the coast.

$$Q_u = 6.4x10^4\, H^2_{sb}\, T_p^{1.5}\, m_b^{0.75}\, d_{50}^{-0.25}\, \sin^{0.6}(2\theta_b)\ m^3/year \qquad (4.6)$$

where, Qvol is the total immersed volume in m3/year,

H_{sb} - breaker wave height,

T_p - the peak wave period,

m_b - bottom slope up to two wave lengths offshore of the breaker line,

D_{50} - mean grain size and

θ_{br} - is the breaker angle with respect to shore normal.

4.3.4 Comparison of sediment transport from monthly representative wave climate and monthly sum of 3hourly wave characteristics

The net sediment transport computed from monthly representative wave characteristics and the monthly sum of 3hourly wave characteristics of the Chennai coast are presented in **Fig.4.5.** The result shows minimal variations between monthly and three hourly net sediment transport rate. The result shows minimal variations between monthly and three hourly net sediment transport rate. The annual net sediment transport computed from monthly representative wave characteristics and the monthly sum of 3hourly wave characteristics are 0.394 X 10^6 m^3 and 0.338 X 10^6 m^3 respectively. The investigation shows that, the net sediment transport is observed to higher to an extent of about 15%. This is due to the consideration of predominant monthly representative wave direction, whereas, wave action in the months of March and October, during which, the wave direction has a transition from north-west to south-east and vice versa.

Hence, the computation of sediment transport with monthly representative wave characteristics could be acceptable for the year without cyclonic events and if there is an extreme event, it needs to be considered in estimating the sediment transport.

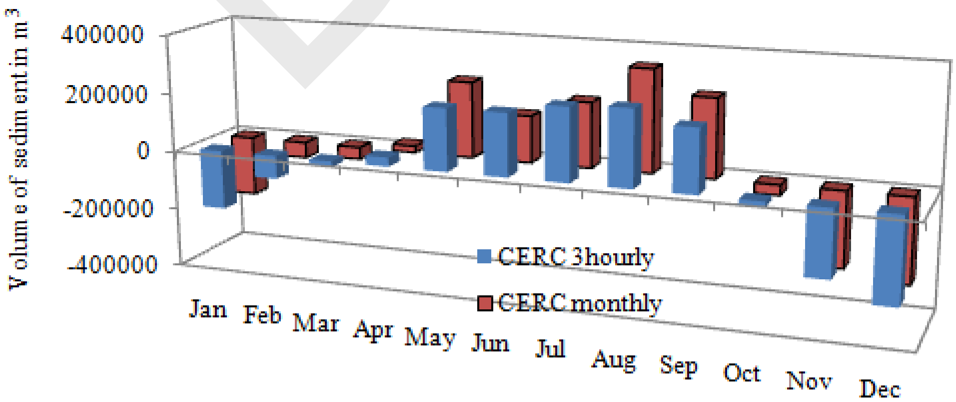


Fig. 4.5 The net sediment transport computed from monthly representative wave characteristics and the monthly sum of 3hourly wave characteristics for the Chennai coast during the year 2011

4.3.5 Sediment transport for the Tamil Nadu coast

The longshore sediment transport predicted at different coastal stretches along the Tamil Nadu coast has been estimated based on Van Rijn (2001). The direction and quantity of sediment transport depends on the wave breaker angle which depends on the orientation of coastline, wave climate and beach slopes etc. The orientation of coastline and the beach slope along different coastal stretches are projected in **Table 4.6 and 4.7** along East and West coast of India respectively. The breaker angle computed based on orientation of the coast and the beach slope using Snell's law is projected in **Figs. 4.6 to 4.9**

The longshore sediment transport for the different reaches of the coast of Tamil Nadu are and presented in the **Figs. 4.10(a) and (b)** for the East and West coast respectively. The monthly variations in the longshore sediment transport for the important coastal stretches are projected in Figs. 4.10 to 4.15.

Table 4.5 Salient features of the study area. (East coast)

Stretch	Lat& Long	Slope	Orientation of the coast w r t North
Ennore	13^0 13’ N 80^0 20’E	0.033	15
Royapuram	13^0 09’ N 80^0 18’E	0.027	15
Marina (Cooum)	13^0 03’ N 80^0 18’E	0.02	15
Cuddalore	$11^0$43’N $79^0$47’E	0.0067	19
Nagapattinam	10^0 46’ N79^0 51' E	0.009	0
Periathalai	8^0 20’ N 77^0 57’ E	0.0075	62
Idinthakarai	8^0 14’ N 77^0 47’ E	0.035	69

Table 4.6 Salient features of the study area.(West coast)

Stretch	Lat& Long	Slope	Orientation of the coast w r t North
Kanyakumari–Manakudy Reach -1	8^0 5' N 77^0 27'E	0.03	100
Manakudy-Muttam Reach -2	8^0 7' N 77^0 19'E	0.027	110
Muttam-Colachel Reach -3	8^0 10' N 77^0 14'E	0.06	120
Colachel- Thengapatnam Reach -4	$8^0$14'N $77^0$14'E	0.06 to 0.12	135

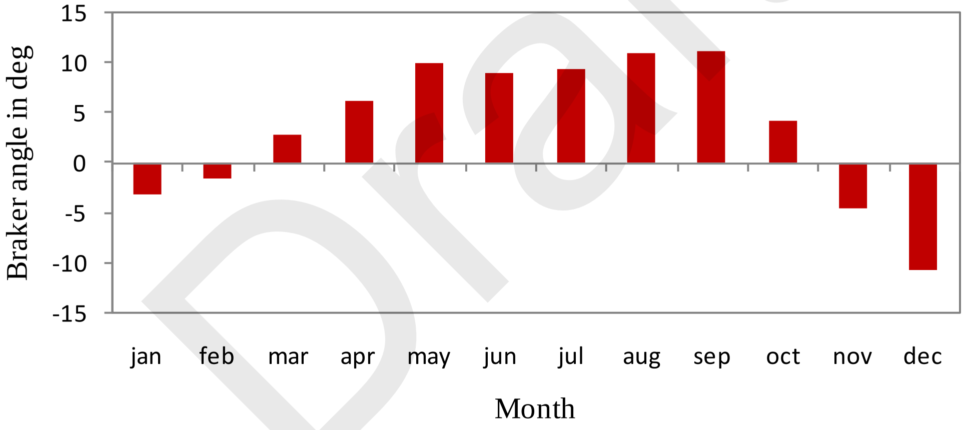


Fig 4.6 Breaker angle Chennai-Cuddalore stretch

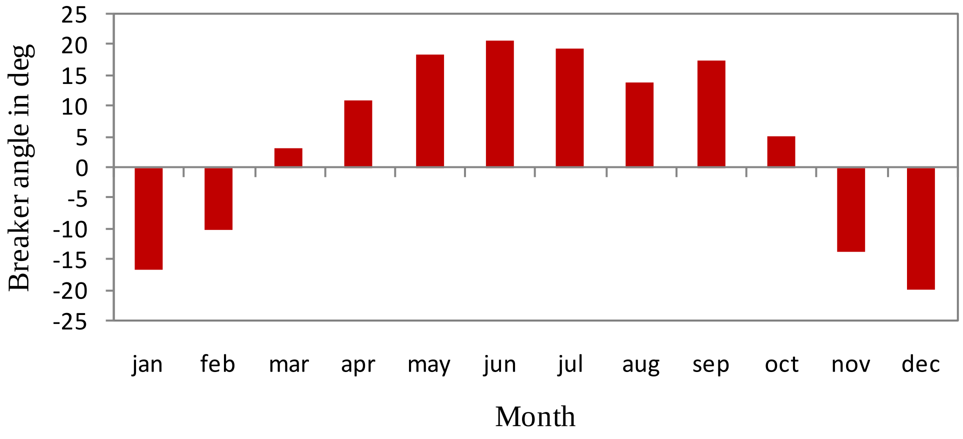


Fig 4.7 Breaker angle Poompuhar-Nagapattinam stretch

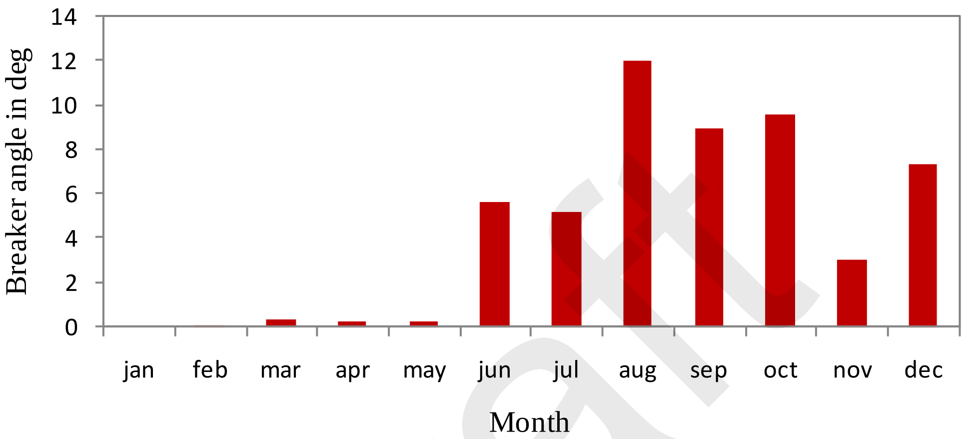


Fig 4.8 Breaker angle Periathali-Idinthakarai stretch

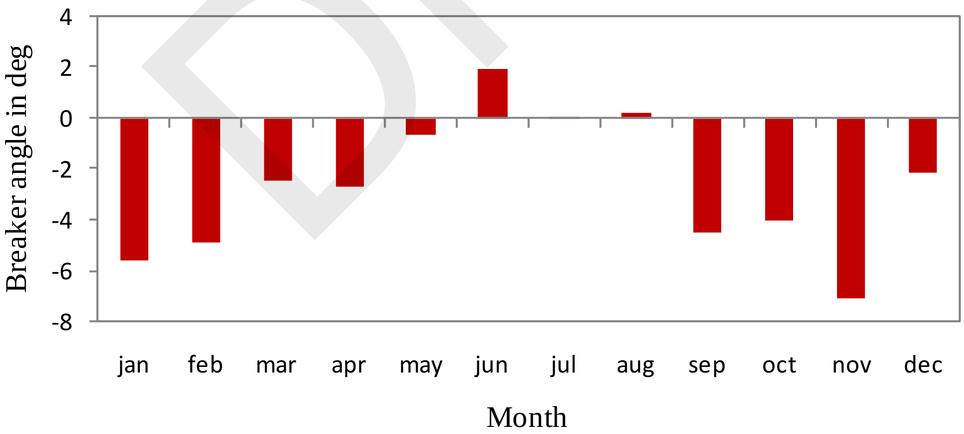


Fig 4.9 Breaker angle Kanyakumari-Eraiyumanthurai stretch

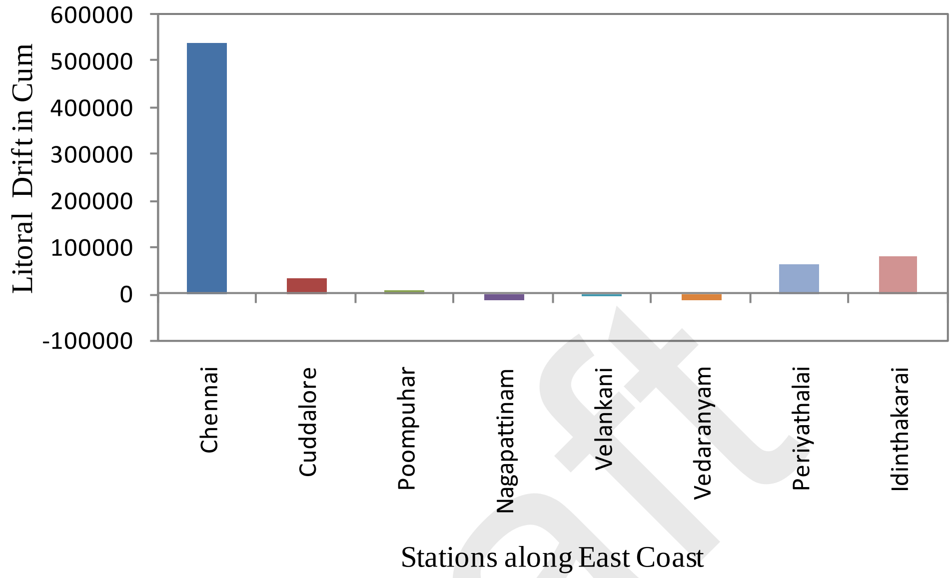


Fig 4.10(a) Estimation of littoral drift along east coast

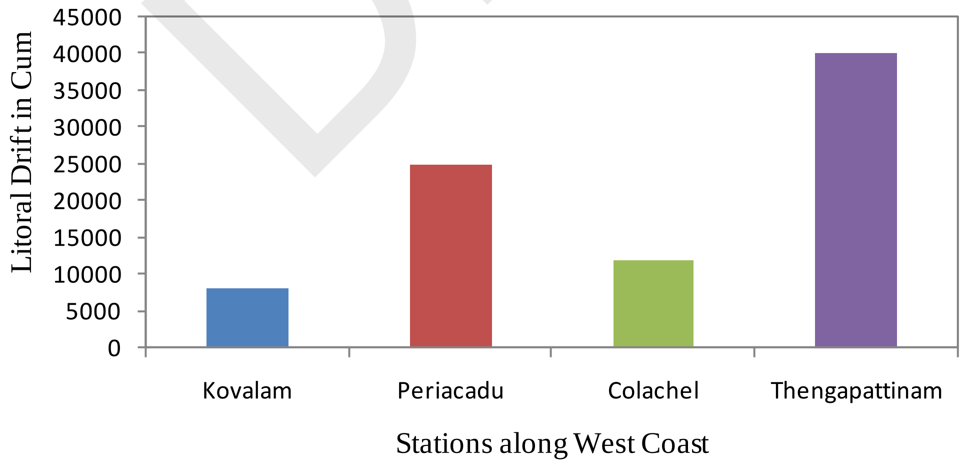


Fig 4.10(b) Estimation of littoral drift along west coast

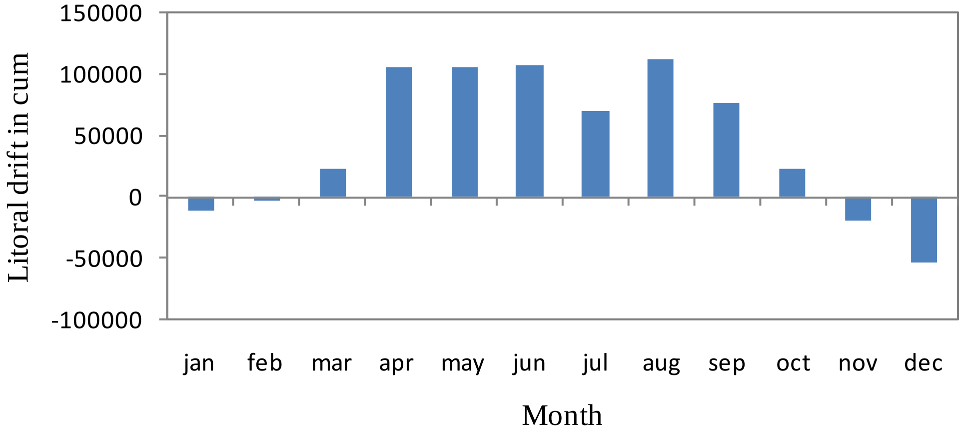


Fig 4.11 Sediment transport near Chennai

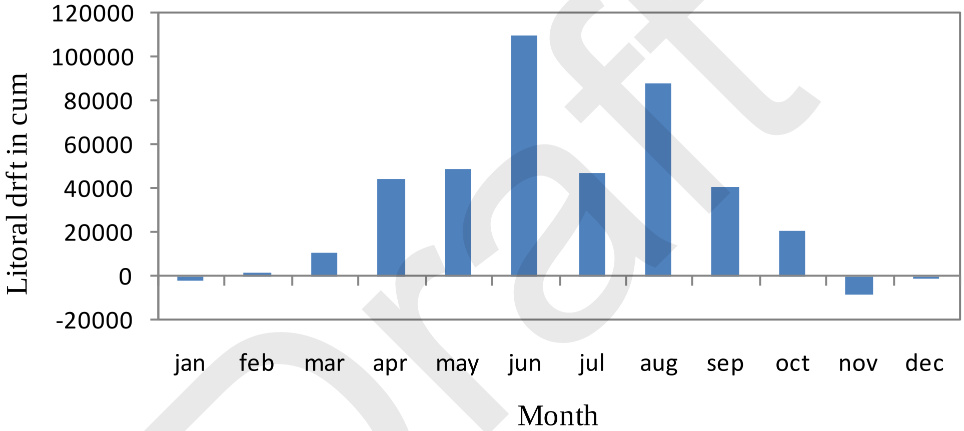


Fig 4.12 Sediment transport near Cuddalore

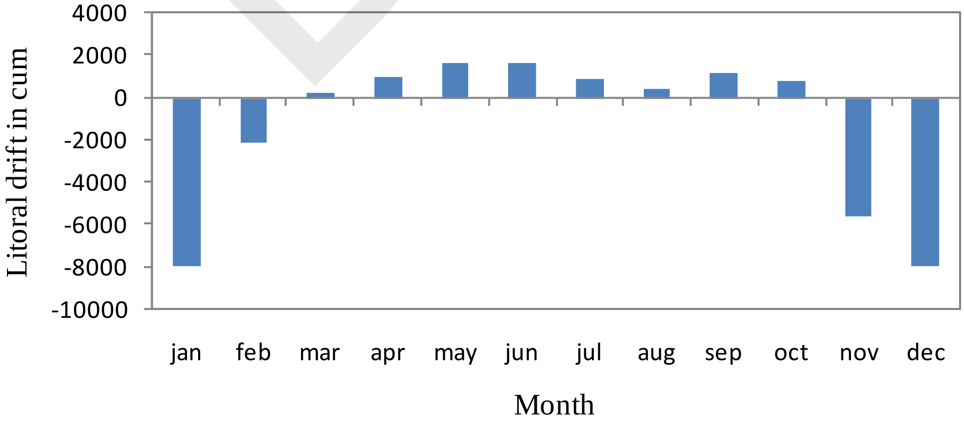


Fig 4.13 Sediment transport near Nagapattinam

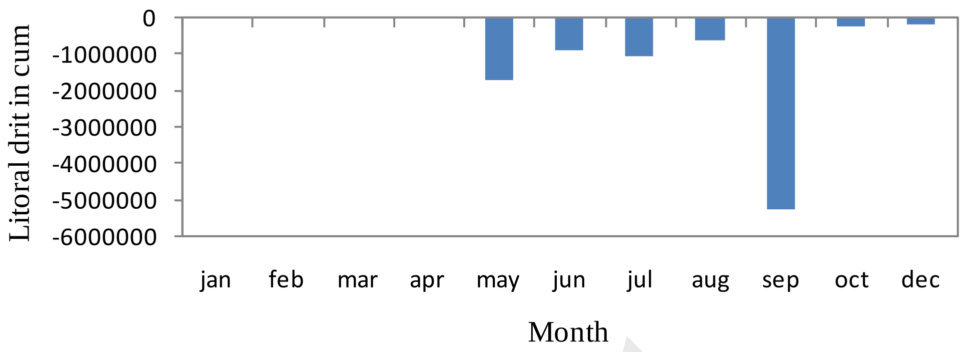


Fig 4.14 Sediment transport near Periathalai

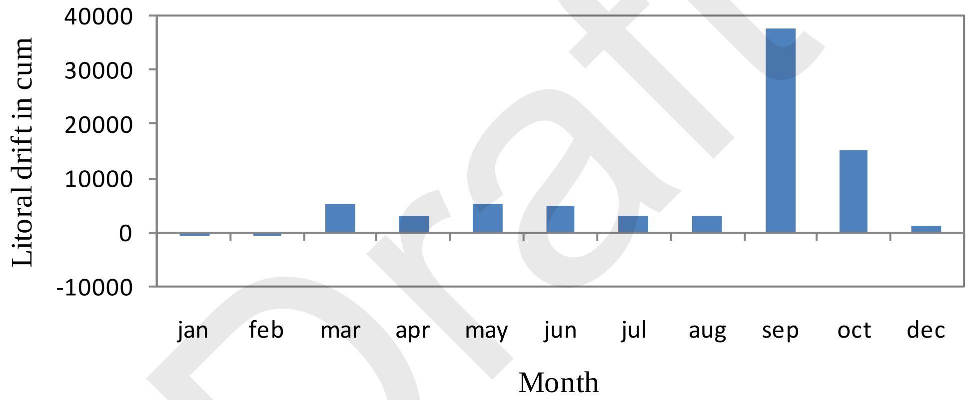


Fig 4.15 Sediment transport near Idinthakarai

4.4 SEDIMENT CELL

The longshore sediment transport and the shoreline management plan based on that normally covers an area along the coast described as a sediment Cell. A sediment cell is a section of the coastline in which the physical processes are relatively independent from the processes operating in the adjacent sediment cells. The boundary of a sediment cell generally coincides with larger estuaries or prominent headlands. In the other words, a sediment cell is defined as a stretch of coastline and its nearshore area within which the movement of coarse sediments is largely self-contained. Chapter 2 details about earlier works on the demarcation of sediment cell.

CHAPTER 5
TIDAL INLETS ALONG THE TAMILNDAU COAST

5.1 GENERAL

Inlets provide both man and nature with a means of access between the ocean and a bay (or lagoon or creek). Successful engineering of inlets requires knowledge of water and sediment movement in and adjacent to the inlet. Tidal inlets are commonly used as navigation channel for fishing and other small vessels. It is vital to keep the mouth of such inlets open and free from sand bar formations. Further, the tidal ingress enhances flushing, thus enhancing the water quality. The formation of sand bars due to the dominance of the alongshore sediment transport in the vicinity of the mouth of the inlet as well as the sediment brought in by the inlets are responsible for degradation of the smooth flushing of tidal inlets. The dynamics of tidal inlets is rarely a subject of systematic study due to the complexities involved. Hydrodynamic conditions at tidal inlets can vary from a relatively simple ebb-and-flood tidal system to a very complex one in which tide, wind stress, freshwater influx, and wind waves (4- to 25-s periods) have significant forcing effects on the system (CEM, 2006). Flow enters the bay (or lagoon) through a constricted entrance (**Fig 5.1**Schematic diagram of flood and ebb currents outside an inlet (O'Brien 1969)). Entrance occurs after flow has traversed over a shallow region where the flow pattern may be very complex due to the combined interaction of the tidal-generated current, currents due to waves breaking on the shallow shoal areas, wind-stress currents, and currents approaching the inlet due to wave breaking on adjacent beaches.

The inlet acts to interrupt long shore current, which either reinforces or interferes with tidal currents, dependent on the tidal cycle. Also, the complicated two-dimensional flow pattern is further confounded because currents transverse to the coast tend to influence the propagation of waves, in some cases blocking them and causing them to break. The inlet has a complex shoal pattern that would cause odd refraction patterns and breaking regions, even if tidal flows were weak (**Fig. 5.2)**Typical ebb-tidal delta morphology (Hayes 1980)). Final complications are structures such as jetties, which cause wave diffraction patterns and reflections.

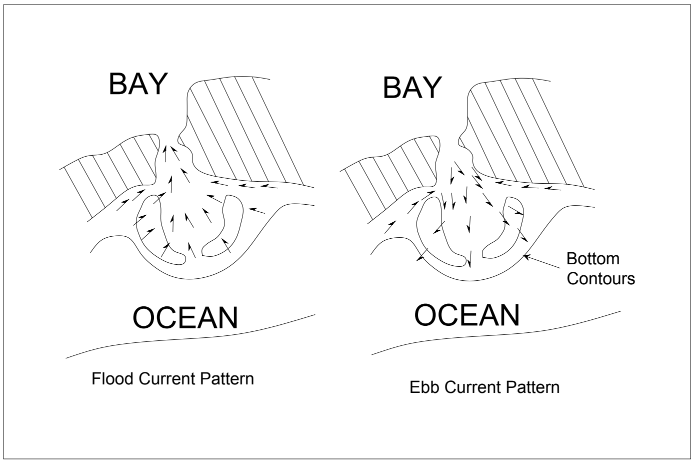


Fig.5.1.Schematic diagram of flood and ebb currents outside an inlet (O'Brien 1969)

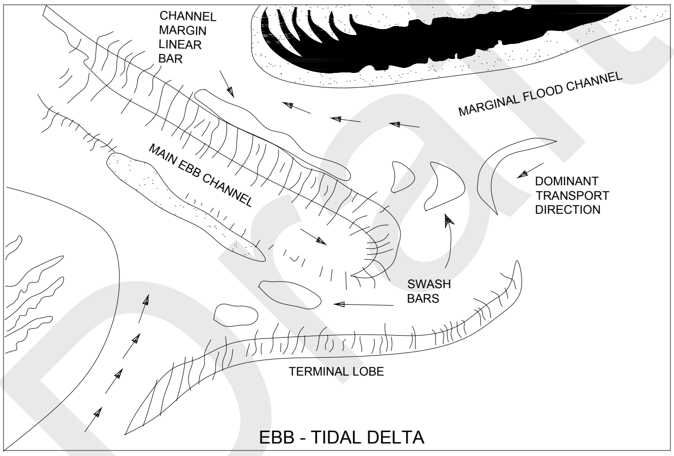


Fig. 5.2.Typical ebb-tidal delta morphology (Hayes‘1980)

5.2 INLETSALONG TAMILNADU COAST

There are 29 rivers draining into the sea and 4 lakes and 1 lagoons connected to the sea along the coast of Tamilnadu had been tabulated in **Table.5.1**.A few of the most important inlets are detailed below.

5.2.1 Ennore (Lat 13°14.101'N, Lon 80°19.998'E)

This is the estuary lying north of Chennai along the mouth of Kosasthalayar. Typical images representing the seasonal variations on inlet dynamics at Ennorecreekis presented in**Fig. 5.3.**

It is inferred that the mouth is open during the non-monsoon period and as the monsoon approaches the siltation increases and chokes the mouth. This scenario has enhanced due to the construction of Ennore port and also polluted due to discharge from thermal plants.

(a) March 2011 (b) May 2011 (c) January 2012

Fig.5.3 Effects of seasonal variations on inlet dynamics at Ennore creek

5.2.2 Cooum (Lat 13°3.998'N, Lon 80°17.351'E)

This estuary is situated south of Chennai harbour. Once upon a time it was a breeding ground for migratory birds. But due to low inflow and construction of harbour it has been choked and it has also become a drainage carrier. Two training walls were constructed both on northern and southern side of the river mouth. From the **Fig. 5.4** it is inferred that though siltation is considerably reduced near the mouth still the problem exist. An in-depth study is need of the hour.

(a) February 2001 (b) May 2001 (c) July 2001

(d) February 2005 (e) May 2005 (f) December 2005

(g) April 2014 (h) July 2014 (i) November 2014

(j) January 2015 (k) April 2015 (l) July 2015

Fig. 5.4 Effects of seasonal variations on inlet dynamics at Cooum river mouth

5.2.3 Adyar (Lat 13°0.779'N, Lon 80°16.641'E)

This lies along the Bay of Bengal and it is a famous sanctuary for pelicans, turtles etc. Now due to meager flow the mouth is partially closed. Efforts are on now to dredge the river. Typical images representing the seasonal variations on inlet dynamics at the Adyar inlet is shown in **Fig.5.5**. From the above figure, it is inferred that the mouth is closing during the non-monsoon period and south-west monsoon and during the north-east monsoon there is reduction in siltation. An in-depth study is need of the hour.

(a) February 2005 (b) May 2005 (c)December 2005

(d) January 2013 (e) May 2013 (f) July 2013



(g) April 2014 (h) June 2014 (i) November 2014

Fig.5.5 Effects of seasonal variations on inlet dynamics at Adyarestuary

5.2.4 Vellaiyar (Lat 10°40.683'N, Lon 79°51.203'E)

This lies in Nagapattinam district and the famous Velankanni shrine is situated by the side of river mouth. A typical view of the inlet is shown in the **Fig. 5.6**.

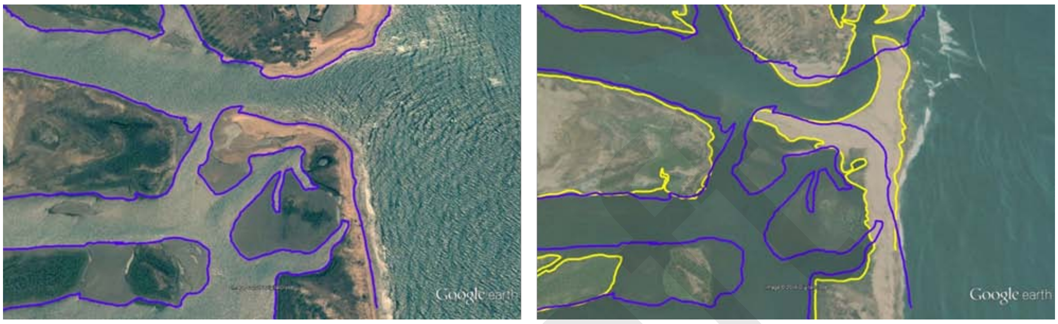
Fig.5.6 Typical view of inlet at Vellar River mouth

5.2.5 Punnakayal (Lat 8°38.425'N, Lon 78° 7.680'E,Lat 8°39.032'N, Lon 78°7.663'E)

This is the estuary of Tamaraparani situated along Bay of Bengal near Thiruchendur. Typical images representing the seasonal variations on inlets at Punnakayal is shown in **Fig. 5.7(a) and (b)**.This river has two inlet connected to the Bay of Bengal as shown in the earlier figure. The closure of the mouth deprives the fisherman performing their fishing operation. This area is referred for study to Institute of Hydraulics and Hydrology, Poondi by the Fisheries Department. Training this inlet would be a challenge as the mouths are not stationary and keep oscillating.

(a) February 2005 (b) July 2005

Fig. 5.7(a) Effects of seasonal variations on inlet dynamics at Northern Inlet of Punnakayal River



(a) February 2005 (b) July 2005

Fig. 5.7(b) Effects of seasonal variations on inlet dynamics at Southern Inlet of Punnakayal River

5.2.6 Thengapattinam (Lat 8°14.476'N, Lon 77°9.967'E)

This is situated along west coast of Arabian Sea and the river Pazhayar of Kodayar system meets Arabian Sea. Typical images representing the seasonal variations on inlet dynamics at Punnakayal river mouth is shown in **Fig. 5.8**.A fishing harbor at the mouth constructed by the Tamilnadu fisheries department has resulted in the closure of the mouth due to the misalignment of the longer breakwater, which is opened towards the east and the sediment transport which happens to be westerly has found its way into the mouth, thereby closing it. This proves beyond doubt that the direction of the littoral drift is extremely important in the planning of harbors, training walls or for that matter any type of shore connected structure.

Fig.5.8.Thengapattinam before and after construction of fishing harbour

Table5.1Rivers draining into the sea along the coast of Tamilnadu

SL No	Inlets	Latitude	Longitude	Training wall	Recommendation
1	Pulicat	13°25'53.72"N	80°19'24.73"E	-	Priority I
2	Kosasthalaiyar river	13°14'4.31"N	80°19'54.62"E	-	Priority I
3	Cooum	13° 4'2.11"N	80°17'23.75"E	✓	Priority I
4	Adyar	13°0'48.20"N	80°16'37.16"E	-	Priority I
5	Muttukadu backwaters	12°48'11.19"N	80°14'55.45"E	-	Priority I
		12°34'34.44"N	80°11'4.39"E	-	
6	Kalpakkam backwaters	12°30'34.91"N	80° 9'43.22"E	-	Priority III
7	Palar	12°27'50.11"N	80° 9'8.68"E	-	WW
8	Odiyur lake	12°18'57.18"N	80° 2'30.42"E	-	WW
9	Kaliveli lake	12°15'40.85"N	80° 0'39.72"E	-	WW
10	Thengaithittu estuary	11°54'20.78"N	79°49'46.23"E	✓	---

SL No	Inlets	Latitude	Longitude	Training wall	Recommendation
11	Chunnambar river	11°52'33.01"N	79°49'17.90"E	-	---
12	Malataru	11°49'58.16"N	79°48'24.69"E	-	Soft solution
13	Then pennai river	11°49'58.16"N	79°48'24.69"E	-	Soft solution
		11°46'17.77"N	79°47'40.12"E	-	---
		11°45'11.46"N	79°47'23.30"E	-	---
14	Gadilam	11°44'10.53"N	79°47'9.14"E	-	Soft solution
		11°42'22.53"N	79°46'49.61"E	✓	
15	Vellar	11°30'10.74"N	79°46'43.45"E	✓	
16	Uppanar	11°27'39.12"N	79°47'46.87"E	-	WW
		11°14'42.52"N	79°50'47.99"E	-	WW
		11° 1'10.92"N	79°51'20.52"E	-	WW
17	Kollidam	11°21'37.33"N	79°49'48.36"E	✓	Soft solution
18	Kaveri	11° 8'12.65"N	79°51'28.46"E	✓	
19	Manjalaru	11° 5'12.36"N	79°51'24.99"E	-	WW
20	Araslar river	10°54'49.27"N	79°51'13.45"E	✓	
21	T.R Patnam river	10°53'8.60"N	79°51'7.68"E	-	Soft solution
22	Kaveri-Vettar river	10°49'33.54"N	79°51'6.24"E	✓	
23	Kaduvaiyar	10°45'51.97"N	79°51'5.15"E	✓	
24	Vellaiyar	10°40'40.31"N	79°51'12.59"E	-	WW

SL No	Inlets	Latitude	Longitude	Training wall	Recommendation
25	Kodiyakadu	10°16'35.45"N	79°44'24.19"E	-	Do nothing
26	Muthupet lagoon	10°18'40.95"N	79°31'12.69"E	-	Do nothing
27	Agni river	10°17'39.09"N	79°22'5.48"E	-	Do nothing
		10°17'9.98"N	79°20'55.20"E	-	
28	Chinnamanai mangroves	10°15'55.25"N	79°18'26.52"E	-	Do nothing
29	Ambli river	10°12'56.68"N	79°16'53.60"E	-	Do nothing
30	Embakkottai	9°54'39.63"N	79° 8'47.21"E	-	
31	Vellar	10° 3'12.64"N	79°15'6.75"E	-	Do nothing
32	Bambar	9°51'39.42"N	79° 7'25.89"E	-	Do nothing
		9°50'13.03"N	79° 6'23.16"E	-	
33	Uppur river	9°38'42.41"N	78°57'55.63"E		Do nothing
		9°38'21.05"N	78°57'43.21"E		Do nothing
34	Vaigai	9°20'42.98"N	78°59'58.29"E	-	WW
35	Gundur river	9° 7'41.70"N	78°29'1.74"E	-	Do nothing
		9° 4'47.17"N	78°22'7.13"E		
36	Vaippar river	9° 0'15.84"N	78°16'7.40"E	-	Do nothing

SL No	Inlets	Latitude	Longitude	Training wall	Recommendation
37	Thamiraparani (Punnaikayal)	8°40'26.20"N	78° 7'57.52"E	-	Do nothing
		8°39'46.71"N	78° 7'49.62"E		
		8°38'52.03"N	78° 7'36.22"E		
		8°38'25.89"N	78° 7'35.76"E	✓	
38	Karumeni	8°22'48.71"N	78° 3'29.49"E	-	Priority II
39	Thottavilai	8°14'21.87"N	77°48'3.49"E	-	Soft solution
40	Manakudy lake	8° 5'18.37"N	77°29'6.74"E	✓	
41	Thamiraparani (Thengapatinam)	8°14'14.78"N	77°10'7.97"E	✓	

Priority I – Needs to be mitigated immediately, followed by priority II &III.

WW- Wait and watch the behavior of shoreline before going for a solution.

Do nothing

Soft solution- In depth study needs to be done before proposing a solution.

Site specific solution has to be analyzed (Beach nourishment, Artificial reef etc.)

5.3 GENERAL RECOMMENDATIONS

The alongshore sediment transport is predominant for the east coast of Tamil Nadu, which is directing towards north, adding to this the inference from most of the inlets shown above has a common phenomenon, that, closure and opening on inlets depends on the seasonal climatic variations. Hence, a common strategy of constructing a pair of training walls at mouth region can be conceptually suggested. However, specific inlets like Cooum, the issue have not been solved with simple pair of training walls. Hence, a detailed site specific study is required for individual cases.

An effort can be put in considering the dredging of river mouth and use the dredged soil to fill geo-tubes that may be considered to serve as training walls. This also needs a detailed investigation prior to its implementation

CHAPTER 6
FISHING HARBORS, FISH LANDING POINTS AND FISH LANDING CENTRES

6.1 INTRODUCTION

The fisheries sector has been recognized as a powerful income and employment generator as it stimulates growth of a number of subsidiary industries and is a source of cheap and nutritious food, at the same time it is an instrument of livelihood for a large section of economically backward population of the country. More than 6 million fishers in the country depend on fisheries and aquaculture for their livelihood. Indian fisheries being the third largest producer of fish in the world and second in inland fish production (FAO 1998) is an important component of the global fisheries. India’s share in the world production of fish has increased from 3.2% in 1981 to 4.5% at present. Fishery sector occupies an important place in the socio-economic development of the country.

6.2 FISHING HARBORS

Aportis a location on a coast or shore containing one or more harbors where ships can dock and transfer people or cargo to or from land. Port locations are selected to optimize access to land and navigable water, for commercial demand, and for shelter from wind and waves. Ports with deeper water are rarer, but can handle larger, more economical ships. The locations of the fishing port along the coast of Tamilnadu is given in **Table 6.1** and indicated in **Fig.6.1.**

Table 6.1 Fishing harbors along the coast of Tamilnadu

Sl.no	District	Fishing Port	Latitude	Longitude
(1)	Chennai	(1) Chennai (Kasimedu) Fishing Harbour	13^{0}07’50”N	80^{0}17’50”E
(2)	Cuddalore	(1) Cuddalore Fishing Harbour	11^{0}42’52”N	79^{0}46’31”E
(3)	Nagapattinam	(1)Nagapattinam Fishing Harbour	10^{0}45’39”N	79^{0}50’59”E
		(1) Pazhayar Fishing Harbour	11^{0}21’32”N	79^{0}49’25”E
		(2) Poompuhar Fishing Harbour	11^{0}08’55”N	79^{0}51’22”E

(4)	Thanjavur	(1) Mallipattinam Fishing Harbour	10^{0}16’37”N	79^{0}19’09”E
(5)	Thoothukudi	(1) Thoothukudi Fishing Harbour	08^{0}47’41”N	78^{0}09’36”E
(6)	Kanniyakumari	(1) Chinnamutton Fishing Harbour	08^{0}05’45”N	77^{0}33’48”E
		(2) Colachel Fishing Harbour	08^{0}10’23”N	77^{0}14’56”E
		(3) Muttom Fishing Harbour	08^{0}07’29”N	77^{0}19’51”E
		(3) Thengapattinam Fishing Harbour	08^{0}14’23”N	77^{0}10’08”E

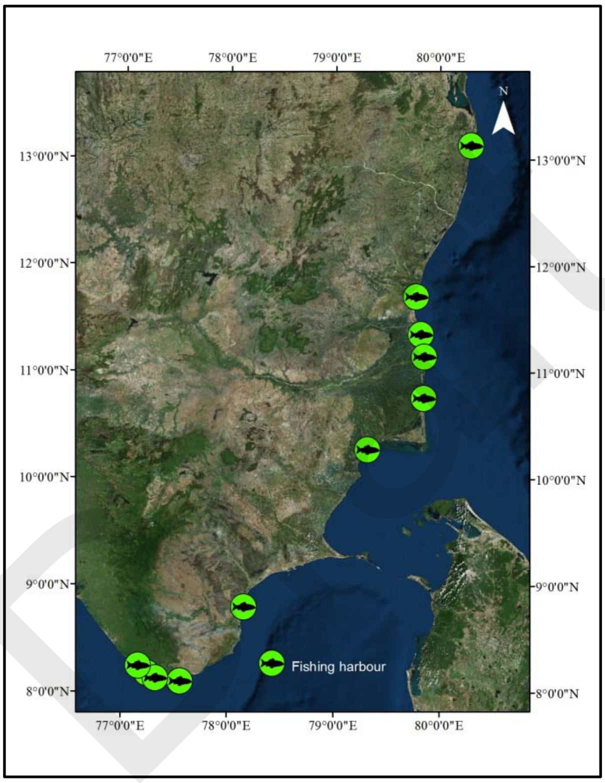


Fig 6.1 Location of fishing port along Tamilnadu coast

Tamil Nadu government has notified the Fish Landing Centres/Jetties as detailed in **Table 6.2 (Fig.6.2)** which are in operation as Fish Landing Centres, while, the Fish landing points in operation are detailed in **Table 6.3 (Fig.6.3)**.

Table 6.2 Fish landing centers along the coast of Tamilnadu

S no	District	Fish Landing Centres	Latitude	Longitude
(1)	Thiruvallur	(1)Pulicat	13^{0}25’11”N	80^{0}19’06”E
		(2)Periyamangodu	13^{0}29’15”N	80^{0}12’21”E

S no	District	Fish Landing Centres	Latitude	Longitude
		(3) Annamalaichery	13^{0}27’26”N	80^{0}15’49”E
		(4)EnnoreMugathuvarakuppam	13^{0}13’36”N	80^{0}19’19”E
(2)	Kancheepuram	(1)KadalorePeriyaKuppam	12^{0}26’41”N	80^{0}08’33”E
(3)	Villupuram	(1)Ekkiyarkuppam	12^{0}10’56”N	79^{0}57’41”E
(4)	Cuddalore	(1)Annankoil (Parangipettai)	11^{0}30’07”N	79^{0}46’18”E
		(2)Mudasalodai	11^{0}29’02”N	79^{0}46’29”E
		(3)M.G.R. Thittu	11^{0}28’05”N	79^{0}46’47”E
		(4)Samiarpettai	11^{0}32’59”N	79^{0}45’34”E
(5)	Nagapattinam	(1)Thirumullaivasal	11^{0}14’41”N	79^{0}50’35”E
		(2)Nagoorpattinacheri	10^{0}48’46”N	79^{0}50’21”E
		(3)Arucottuthurai	10^{0}23’30”N	79^{0}51’12”E
		(4)Seruthur	10^{0}40’20”N	79^{0}51’12”E
(6)	Thanjavur	(1)Sethubavachatram	10^{0}14’49”N	79^{0}16’54”E
(7)	Pudukottai	(1)Kottaipattinam	09^{0}58’52”N	79^{0}12’09”E
		(2)Jagathapattinam	09^{0}57’43”N	79^{0}11’08”E
		(3)Muthukuda	09^{0}52’12”N	79^{0}07”05”E
		(4)R. Pudhupattinam	09^{0}54’34”N	79^{0}08’38”E
(8)	Ramanathapuram	(1)Thirupalaikudi North	09^{0}32’58”N	78^{0}55’09”E
		(2)Devipattinam	09^{0}28’38”N	78^{0}53’55”E
		(3)Rochmanager	09^{0}05’38”N	78^{0}23’11”E
		(4)Keelakarai	09^{0}13’39”N	78^{0}47’09”E
		(5)Thondi	09^{0}44’37”N	79^{0}01’19”E
		(6)Mandapam North	09^{0}17’09”N	79^{0}09’31”E
		(7)Mandapam South	09^{0}16’38”N	79^{0}09’19”E
		(8)Rameshwaram	09^{0}16’51”N	79^{0}18’54”E

S no	District	Fish Landing Centres	Latitude	Longitude
(9)	Thoothukudi Location	(1)Tharuvaikulam	08^{0}53’16”N	78^{0}10’29”E
		(2)Thirespuram	08^{0}49’00”N	78^{0}09’49”E
		(3)Periyathalai	08^{0}20’01”N	77^{0}58’21”E
		(4)Punnakkayal	08^{0}38’13”N	78^{0}07’17”E
		(5)Veerapandianpattinam	08^{0}31’08”N	78^{0}07’22”E
(10)	Tirunelveli	(1)Uvari	08^{0}16’29”N	77^{0}53’24”E
(11)	Kanniyakumari	(1)Simon colony	08^{0}10’33”N	77^{0}14’39”E
		(2)Kurumbanai	08^{0}11’17”N	77^{0}13’48”E
		(3)Enayamputhenthurai	08^{0}13’31”N	77^{0}10’53”E

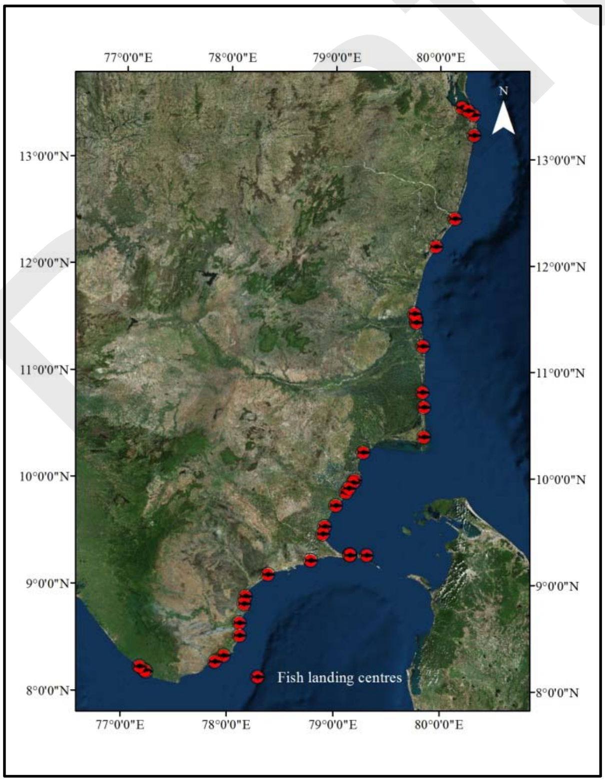


Fig 6.2 Location of fish landing centres along Tamilnadu coast

Table 6.3 Fish landing points along the coast of Tamilnadu

Sno	District	Fishing Port	Latitude	Longitude
(1)	Thiruvallur	(1)Arambakkam	13^{0}33’23”N	80^{0}05’08”E
		(2)Ennorekuppam	13^{0}13’42”N	80^{0}18’54”E
		(3)Thazankuppam	13^{0}13’34”N	80^{0}19’19”E
		(4)KathivakkamPeriakuppam	13^{0}12’30”N	80^{0}19’06”E
		(5)KathivakkamChinnakuppam	13^{0}12’30”N	80^{0}19’03”E
		(6) Ernavoorkuppam	13^{0}12’07”N	80^{0}18’57”E
		(7)Indira Gandhi Kuppam	13^{0}12’07”N	80^{0}18’57”E
		(8)Kasikoilkuppam	13^{0}09’56”N	80^{0}18’25”E
		(9)Kasivishalakshikuppam	13^{0}09’56”N	80^{0}18’25”E
		(10)KasiviswanatharkoilKuppam	13^{0}09’47”N	80^{0}18’19”E
		(11)Palagaithottikuppam	13^{0}09’54”N	80^{0}18’18”E
		(12)Thiruvottiyurkuppam	13^{0}09’47”N	80^{0}18’19”E
		(13)Ondikuppam	13^{0}07’53”N	80^{0}17’54”E
		(14)Thiruchinnankuppam	13^{0}09’01”N	80^{0}18’02”E
		(15)LakshmipuramOdaikuppam	13^{0}07’36”N	80^{0}17’46”E
		(16)NallathanneerOdaikuppam	13^{0}07’57”N	80^{0}17’47”E
(2)	Chennai	(1)Mattankuppam	13^{0}03’30”N	80^{0}17’10”E
		(2)Ayothikuppam	13^{0}03’06”N	80^{0}17’03”E
		(3)Nadukuppam	13^{0}02’50”N	80^{0}16’56”E
		(4)Nochikuppam	13^{0}02’16”N	80^{0}16’51”E
		(5)Mullimanagar	13^{0}01’33”N	80^{0}16’44”E
		(6)Srinivasapuram	13^{0}01’08”N	80^{0}16’42”E
		(7)Orurkuppam	13^{0}00’15”N	80^{0}16’27”E

		(8)Odaikuppam	12^{0}59’44”N	80^{0}16’19”E
		(9)Thiruvanmiyur Kuppam	12^{0}59’04”N	80^{0}16’09”E
(3)	Kancheepuram	(1)Kottivakkam	12^{0}58’05”N	80^{0}15’55”E
		(2)Palavakkam	12^{0}57’37”N	80^{0}15’50”E
		(3)ChinnaNeelankarai	12^{0}57’13”N	80^{0}15’45”E
		(4)PeriyaNeelankarai	12^{0}56’28”N	80^{0}15’36”E
		(5)Chinnandikuppam	12^{0}56’03”N	80^{0}15’32”E
		(6)Injampakkam	12^{0}55’11”N	80^{0}15’25”E
		(7)Panaiyurkuppam	12^{0}53’16”N	80^{0}15’10”E
		(8)Nainarkuppam	12^{0}52’27”N	80^{0}15’04”E
		(9)Kanathur Reddy Kuppam	12^{0}51’08”N	80^{0}14’55”E
		(10)EgatturKarikattukuppam	12^{0}49’13”N	80^{0}14’51”E
		(11)Kovalamkuppam	12^{0}47’26”N	80^{0}15’05”E
		(12)Chemacherry	12^{0}46’33”N	80^{0}15’10”E
		(13)Pudhukalpakkam	12^{0}43’49”N	80^{0}14’13”E
		(14)Nemmelikuppam	12^{0}43’03”N	80^{0}13’56”E
		(15)Soolerikattukuppam	12^{0}42’17”N	80^{0}13’40”E
		(16)Pattipulam	12^{0}41’15”N	80^{0}13’18”E
		(17)PuduNemeliKuppam	12^{0}39’32”N	80^{0}12’41”E
		(18)Salavankuppam	12^{0}39’12”N	80^{0}12’33”E
		(19)Devaneri	12^{0}39’05”N	80^{0}12’30”E
		(20)Mamallapuram	12^{0}37’11”N	80^{0}11’55”E
		(21)Venpursham	12^{0}35’50”N	80^{0}11’27”E
		(22)Kokilamedu	12^{0}35’36”N	80^{0}11’22”E
		(23)Umarikuppam	12^{0}31’42”N	80^{0}10’01”E
		(24)Meyyurkuppam	12^{0}31’45”N	80^{0}10’02”E

		(25)Sathurangapattinam	12^{0}31’23”N	80^{0}09’55”E
		(26)PudhupattinamKuppam	12^{0}29’24”N	80^{0}09’32”E
		(27)Uyyalikuppam	12^{0}29’14”N	80^{0}09’31”E
		(28)KadaloreChinnaKuppam	12^{0}26’55”N	80^{0}08’42”E
		(29)Kadalore Ali Kuppam	12^{0}26’28”N	80^{0}08’24”E
		(30)Angalammankuppam	12^{0}25’42”N	80^{0}07’51”E
		(31)Pazhayanadukuppam	12^{0}25’25”N	80^{0}07’39”E
		(32)Pudhunadukuppam	12^{0}24’59”N	80^{0}07’22”E
		(33)PerunThuravuKuppam	12^{0}22’33”N	80^{0}05’24”E
		(34)Paramankeni	12^{0}20’57”N	80^{0}04’05”E
		(35)MudaliyarKuppam	12^{0}18’35”N	80^{0}02’19”E
		(36)PanaiyurChinnakuppam	12^{0}18’26”N	80^{0}02’13”E
		(37)PanaiyurPeriyaKuppam	12^{0}17’58”N	80^{0}01’54”E
		(38)Alambaraikuppam	12^{0}16’01”N	80^{0}00’44”E
		(39)Kadappakkam	12^{0}16’16”N	80^{0}00’59”E
		(1)Muttukaduazhagankuppam	12^{0}14’23”N	79^{0}59’54”E
		(2)Vasavankuppam	12^{0}13’35”N	79^{0}59’24”E
		(3)Kaippanikuppam	12^{0}12’58”N	79^{0}58’59”E
		(4)MandavaiPudukuppam	12^{0}09’44”N	79^{0}56’52”E
		(5)Komuttichavadikuppam	12^{0}08’02”N	79^{0}55’44”E
(4)	Villupuram	(6)Anumandhaikuppam	12^{0}07’11”N	79^{0}55’13”E
		(7)Chettinagar	12^{0}06’00”N	79^{0}54’25”E
		(8)KoonimeduKuppam	12^{0}05’17”N	79^{0}53’59”E
		(9)Nochikuppam	12^{0}04’30”N	79^{0}53’30”E
		(10)Mudaliarkuppam	12^{0}03’48”N	79^{0}53’04”E
		(11)Anichankuppam	12^{0}03’30”N	79^{0}52’54”E

		(12)Pudhukuppam	$12^0$03'06"N	$79^0$52'42"E
		(13)Pillaichavadi	$12^0$00'19"N	$79^0$51'25"E
		(14)Bommaiyarpalyam	$11^0$59'36"N	$79^0$51'08"E
		(15)Chinnamudaliarchavadi	$11^0$58'36"N	$79^0$50'44"E
		(16)Thandhirayankuppam	$11^0$58'15"N	$79^0$50'40"E
		(17)Nadukuppam	$11^0$57'50"N	$79^0$50'32"E
		(18)Sodhanaikuppam	$11^0$57'28"N	$79^0$50'26"E
(5)	Cuddalore	(1)Thazahankuda	$11^0$46'00"N	$79^0$47'34"E
		(2)Devanampattinam	$11^0$44'40"N	$79^0$47'17"E
		(3)Sothikuppam	$11^0$41'15"N	$79^0$46'26"E
		(4)Sonaankuppam	$11^0$43'13"N	$79^0$46'55"E
		(5)Rajappettai	$11^0$40'55"N	$79^0$46'21"E
		(6)Chitrappettai	$11^0$38'55"N	$79^0$45'51"E
		(7)Pudhukuppam	$11^0$31'37"N	$79^0$45'57"E
		(8)Pudhupettai	$11^0$30'52"N	$79^0$46'03"E
		(9)Killai	$11^0$25'55"N	$79^0$46'58"E
6)	Nagapattinam	(1) Madavamedu	11°19'56"N	79°50'11"E
		(2) Kottaimedu	11°19'22"N	79°50'05"E
		(3) Koozhaiyar	11°17'32"N	79°50'13"E
		(4) Thoduvai	11°16'23"N	79°50'19"E
		(5) Keezhamoovarkarai	11°12'54"N	79°51'01"E
		(6) Chavadikuppam	11°12'30"N	79°51'03"E
		(7) Naickerkuppam	11°11'26"N	79°50'57"E
		(8) Madathukuppam	11°10'59"N	79°51'03"E

		(9) Pudukuppam	11°10’05”N	79°50’51”E
		(10) Vanagiri	11°07’50”N	79°51’26”E
		(11) Chinnangudi	11°05’35”N	79°51’22”E
		(12) Thazhampettai	11°04’54”N	79°51’11”E
		(13) Pudhupettai	11°04’07”N	79°51’11”E
		(14) Perumalpettai	11°03’33”N	79°51’19”E
		(15) Bommayanpettai (Vellakoil)	11°03’08”N	79°51’19”E
		(16) Kuttiyandiyur	11°02’40”N	79°51’16”E
		(17) Tharangampadi	11°01’55”N	79°51’15”E
		(18) Chandrappadi	10°59’55”N	79°51’09”E
		(19) Chinnorpettai	10°59’09”N	79°51’09”E
		(20) ChinnaMedu	11°06’16”N	79°51’24”E
		(21) ChinnaKottaimedu	11°18’22”N	79°50’12”E
		(22) Samanthanpettai	10°47’41”N	79°50’42”E
		(23) Nambiarnagar	10°46’41”N	79°50’52”E
		(24) Velankanni	10°40’55”N	79°50’37”E
		(25) Kameswaram	10°37’23”N	79°51’05”E
		(26) Vilunthamavadi	10°35’35”N	79°50’03”E
		(27) Vanavanmadevi	10°32’04”N	79°50’27”E
		(28) Vellapallam	10°30’40”N	79°49’52”E
		(29) Pushpavanam	10°27’33”N	79°50’54”E
		(30) Kodiyakarai	10°17’04”N	79°49’27”E

		(31) Seruthalaikadu	10°23’02”N	79°43’31”E
7)	Thiruvarur	(1) Muttupettai	10°24’01”N	79°30’02”E
8)	Thanjavur	(1) Ganesapuram	10°08’27”N	79°13’44”E
		(2) Chinnamalai	10°16’20”N	79°18’46”E
		(3) Gandhi Nagar	10°19’32”N	79°23’35”E
		(4) Maravakadu	10°21’33”N	79°26’20”E
		(5) Vallavanpattinam	10°09’02”N	79°13’52”E
		(6) AnnanagarPudhutheru	10°09’57”N	79°14’19”E
		(7) Somanathanpattinam	10°09’25”N	79°14’20”E
		(8) Sembiyanmadevipattinam	10°08’16”N	79°13’44”E
		(9) Karaiyurtheru	10°19’51”N	79°23’40”E
		(10) Senthalaivayal	10°11’12”N	79°14’53”E
		(11) Thambikottai	10°22’55”N	79°29’02”E
		(12) Kazhumanguda	10°14’36”N	79°16’36”E
		(13) Kollukadu	10°17’40”N	79°20’48”E
		(14) Karanguda	10°14’14”N	79°16’15”E
		(15) Sambaipattinam	10°13’31”N	79°15’59”E
		(16) Mandhiripattinam	10°10’14”N	79°14’14”E
		(17) Adaikkadevan	10°11’40”N	79°15’37”E
		(18) Pilayarthidal	10°15’35”N	79°17’38”E
		(19) Eripurakkarai	10°19’09”N	79°22’50”E
		(20) Keelathottam	10°17’55”N	79°21’53”E

		(21) Velivayal	10°17’14”N	79°20’30”E
		(22) Subbamachatram	10°09’10”N	79°14’15”E
		(23) Puthupattinam	10°17’09”N	79°20’03”E
(9)	Pudukottai	(1) Kattumavadi	10°07’49”N	79°13’45”E
		(2) Prathabiramanpattinam	10°06’08”N	79°13’38”E
		(3) Krishnajipattinam	10°05’55”N	79°13’35”E
		(4) VadakkuAmapattinam	10°02’55”N	79°15’04”E
		(5) Seetharampattinam	10°04’34”N	79°14’07”E
		(6) Keelakudiyiruppu	10°02’18”N	79°15’57”E
		(7) Ponagaram	10°01’39”N	79°14’44”E
		(8) Ayyampattinam	09°57’34”N	79°10’57”E
		(9) Muthanenthal	09°57’18”N	79°10’42”E
		(10) Anthoniyarpuram	10°01’23”N	79°14’27”E
		(11) Pudhukkudi north	09°59’49”N	79°13’01”E
		(12) Pudhukkudi south	09°59’34”N	79°12’47”E
(10)	Ramanathapuram	(1) Pathanendal	09°30’55”N	78°54’50”E
		(2) Pamban	09°16’56”N	79°12’32”E
		(3) Olaikuda	09°19’04”N	79°19’52”E
		(4) Kundhukal	09°15’35”N	79°13’27”E
		(5) Mukuntharayarchatram	09°11’57”N	79°22’54”E
		(6) Dhanushkodi	09°11’13”N	79°24’50”E
		(7) Chinnapalam	09°16’22”N	79°12’55”E

		(8) Thangachimadam	09°17'28"N	79°14'57"E
		(9) Theerthaandathanam	09°49'32"N	79°05'22"E
		(10) Pasipattinam	09°48'42"N	79°04'49"E
		(11) Dhamotharanpattinam	09°47'33"N	79°04'07"E
		(12) Narendhal	09°46'13"N	79°02'54"E
		(13) M.R. Pattinam	09°45'48"N	79°02'14"E
		(14) Nambuthalai	09°43'30"N	79°00'30"E
		(15) Pudhupattinam	09°40'49"N	78°58'34"E
		(16)Karankadu	09°38'47"N	78°57'30"E
		(17) Mullimanai	09°39'27"N	78°58'15"E
		(18) Morepannai	09°36'37"N	78°56'09"E
		(19) Devipattinam North	09°28'38"N	78°53'55"E
		(20) Devipattinam South	09°28'22"N	78°53'58"E
		(21) Palanivalasai	09°25'25"N	78°55'34"E
		(22)Mudiveeranpattinam	09°26'03"N	78°55'10"E
		(23) Pudhuvalasaichathiram	09°23'49"N	78°56'43"E
		(24) Athankarai	09°20'54"N	78°59'31"E
		(25) Valasapatinam (P.V.Pattinam)	09°46'02"N	79°02'39"E
		(26) Pudukkudi	09°22'19"N	78°57'34"E
		(27) Panaikulam	09°22'29"N	78°57'18"E
		(28) Alagankulam	09°21'46"N	78°58'12"E
		(29) Kalimankundu	09°15'24"N	78°52'28"E

		(30) Munaikadu	09°17’13”N	79°07’57”E
		(31) Vedhalai	09°15’48”N	79°06’13”E
(11)	Thoothukudi	(1) Vembar	09°04’35”N	78°21’54”E
		(2) Keezhavaippar	08°59’44”N	78°15’16”E
		(3) Sippikulam	08°59’38”N	78°15’08”E
		(4) Pattinamaruthur	08°55’21”N	78°11’09”E
		(5) Vellapatti	09°06’50”N	78°25’00”E
		(6) Palayakayal	08°40’15”N	78°06’11”E
		(7) KombuthuraiMadhakoil	08°34’50”N	78°08’12”E
		(8) Amalinagar	08°29’20”N	78°07’27”E
		(9) Alanthalai	08°27’51”N	78°05’59”E
		(10) Kulasekarappattinam	08°23’39”N	78°03’28”E
		(11) Manappadu	08°22’39”N	78°03’29”E
		(12) Kallamozhi	08°26’37”N	78°04’58”E
		(13) Jeevanagar	08°30’07”N	78°07’33”E
		(14) Singhithurai	08°34’07”N	78°08’04”E
		(15) Ratchanyapuram	08°40’14”N	78°06’10”E
		(16) New Harbour	08°44’38”N	78°10’15”E
		(17) Iniconagar	08°47’23”N	78°09’40”E
		(18) Thalamuthunagar	08°50’03”N	78°09’55”E
		(19) Perisamypuram	09°02’41”N	78°19’36”E
(12)	Tirunelveli	(1) Kooduthalai	08°17’55”N	77°55’41”E

		(2) Koottappanai	08°17'24"N	77°54'32"E
		(3) Kootapuli	08°08'48"N	77°36'06"E
		(4) Idinthakarai	08°10'42"N	77°44'47"E
		(5) Koothanguzhi	08°12'54"N	77°46'47"E
		(6) Perumanai	08°09'32"N	77°38'49"E
		(7) Thommayarpuram (Muddukuli)	08°11'32"N	77°45'41"E
(13)	Kanniyakumari	(1) Arokiyapuram	08°07'09"N	77°33'31"E
		(2) Chinnamuttom	08°05'45"N	77°33'33"E
		(3) Kanyakumari	08°05'10"N	77°33'13"E
		(4) Puthugramam (Vavuthurai)	08°04'53"N	77°33'05"E
		(5) Kovalam	08°04'53"N	77°31'30"E
		(6) Keezhamanakudi	08°05'32"N	77°29'44"E
		(7) MelaManakudi	08°05'24"N	77°30'11"E
		(8) Pallam	08°05'55"N	77°25'56"E
		(9) Puthenthurai	08°06'03"N	77°25'21"E
		(10) Kesavanputhenthurai	08°06'19"N	77°24'22"E
		(11) Pozhikkarai	08°06'22"N	77°24'13"E
		(12) Periyakadu	08°06'37"N	77°23'18"E
		(13) RajakkamangalamThurai	08°06'53"N	77°22'42"E
		(14) Azhikkal	08°07'31"N	77°20'20"E
		(15) Keezhamuttom	08°07'29"N	77°19'52"E
		(16) Melamuttom	08°07'24"N	77°19'03"E

		(17) Keezhakadiapattinam	08°07’45”N	77°18’26”E
		(18) Melakadiapattinam	08°08’07”N	77°18’17”E
		(19) Chinnavilai	08°08’48”N	77°18’04”E
		(20) Periavilai	08°09’08”N	77°17’37”E
		(21) PuthurMandaikadu	08°09’41”N	77°16’42”E
		(22) Kottilpadu	08°10’11”N	77°15’49”E
		(23) Kodimunai	08°10’38”N	77°14’22”E
		(24) Vaniyakudi	08°10’53”N	77°14’05”E
		(25) Melakurumpanai	08°11’17”N	77°13’48”E
		(26) Midalam (Naduthurai)	08°12’10”N	77°12’55”E
		(27) Melmidalam	08°12’25”N	77°12’26”E
		(28) Enayam	08°13’01”N	77°11’23”E
		(29) EnayamChinnathurai	08°13’12”N	77°11’03”E
		(30) Ramanthurai	08°13’43”N	77°10’44”E
		(31) Mulloorthurai	08°13’57”N	77°10’31”E
		(32) Erayumanthurai	08°14’42”N	77°09’43”E
		(33) Poothurai	08°15’24”N	77°08’51”E
		(34) Thoothur	08°15’29”N	77°08’44”E
		(35) EzhudesanChinnathurai	08°15’47”N	77°08’17”E
		(36) Eraviputhenthurai	08°15’53”N	77°08’06”E
		(37) Vallavilai	08°16’44”N	77°06’57”E
		(38) Marthandamthurai	08°17’06”N	77°06’29”E

		(39) Neerodi	08°17’20”N	77°06’08”E

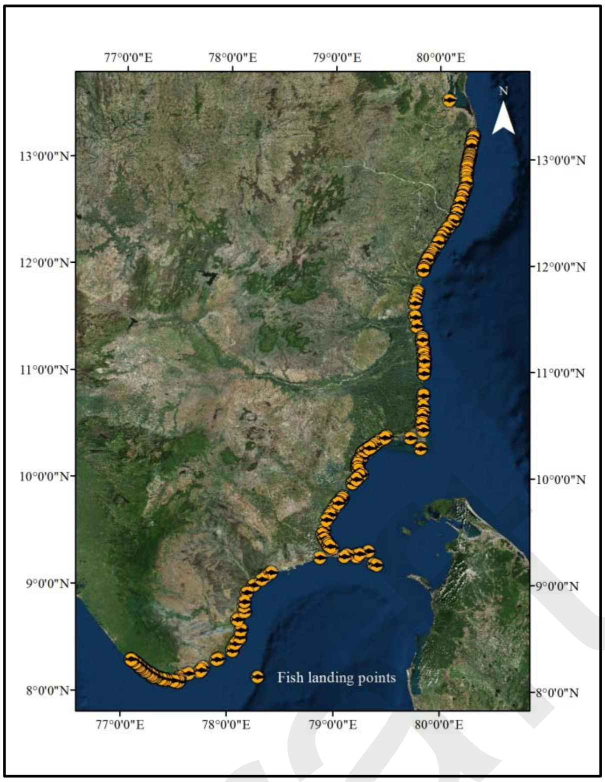


Fig 6.3 Location of fish landing points

There are 11 fishing harbours, 36 fish landing centres and about 254 fish landing points along the coast of Tamilnadu according to the details provided by department of fisheries, which are projected in **Table 6.4** and superposed over the map of Tamilnadu as shown in **Fig 6.4.**

Table 6.4 List of Fishing port, Fish Landing Centre and Fish Landing Points in Tamilnadu

SI. No.	Name of District	Name of Fishing Port	Name of Fishing Landing Centre’s	No. of Fish Landing Points	Total (Nos)	Remarks
1.	Thiruvallur	--------	1.Pulicate 2.Periyamangodu 3.Annamalaichery 4.Ennore Mugathuvarakuppam	16	20	
2.	Chennai	1.Chennai (Kasimedu)	-----	9	10	

SI. No.	Name of District	Name of Fishing Port	Name of Fishing Landing Centre's	No. of Fish Landing Points	Total (Nos)	Remarks
3.	Kancheepuram	-----	1.Kadalore Periyakuppam	39	40	
4.	Villupuram	-----	1.Ekkiyarkuppam	18	19	
5.	Cuddalore	1.Cuddalore	1.Annankoil (Parangipettai) 2.Mudasalodai 3.MGR Thittu 4.Samiyarpettai	9	14	
6.	Nagapattinam	1.Nagapattinam 2.Pazhayar 3.Poompuhar	1.Thirumullaivasal 2.Nagoorpattinacheri 3.Arcottuthurai 4.Seruthur	31	38	
7.	Thiruvarur	-----	----------	1	1	
8.	Thanjavur	1.Mallipattinam	1.Sethubavachatram	23	25	
9.	Pudukottai	-----	1.Kottaipattinam 2.Jagathapattinam 3.Muthukuda 4.R.Pudhupattinam	12	16	
10.	Ramanathapuram	-----	1.Thirupalaikudi North 2.Devipattinam 3.Roachmanagar 4.Keelakarai 5.Thondi 6.Mandapam North 7.Mandapam South 8.Rameshwaram	31	39	
11.	Thoothukudi	1.Thoothukudi	1.Thavaikulam 2.Thireshpuram	19	25	

SI. No.	Name of District	Name of Fishing Port	Name of Fishing Landing Centre's	No. of Fish Landing Points	Total (Nos)	Remarks
			3.Periyathalai 4.Punnakayal 5.Veerapandianpattinam			
12.	Tirunelveli	----	1.Uvari	7	8	
13.	Kanniyakumari	1.Chinnamuttom 2.Colachel 3.Muttom 4.Thengapattinam	1.Simon Colony 2.Kurumbanai 3.Enayam Puthenthurai	39	46	
	Total	**11**	**36**	**254**	**301**	

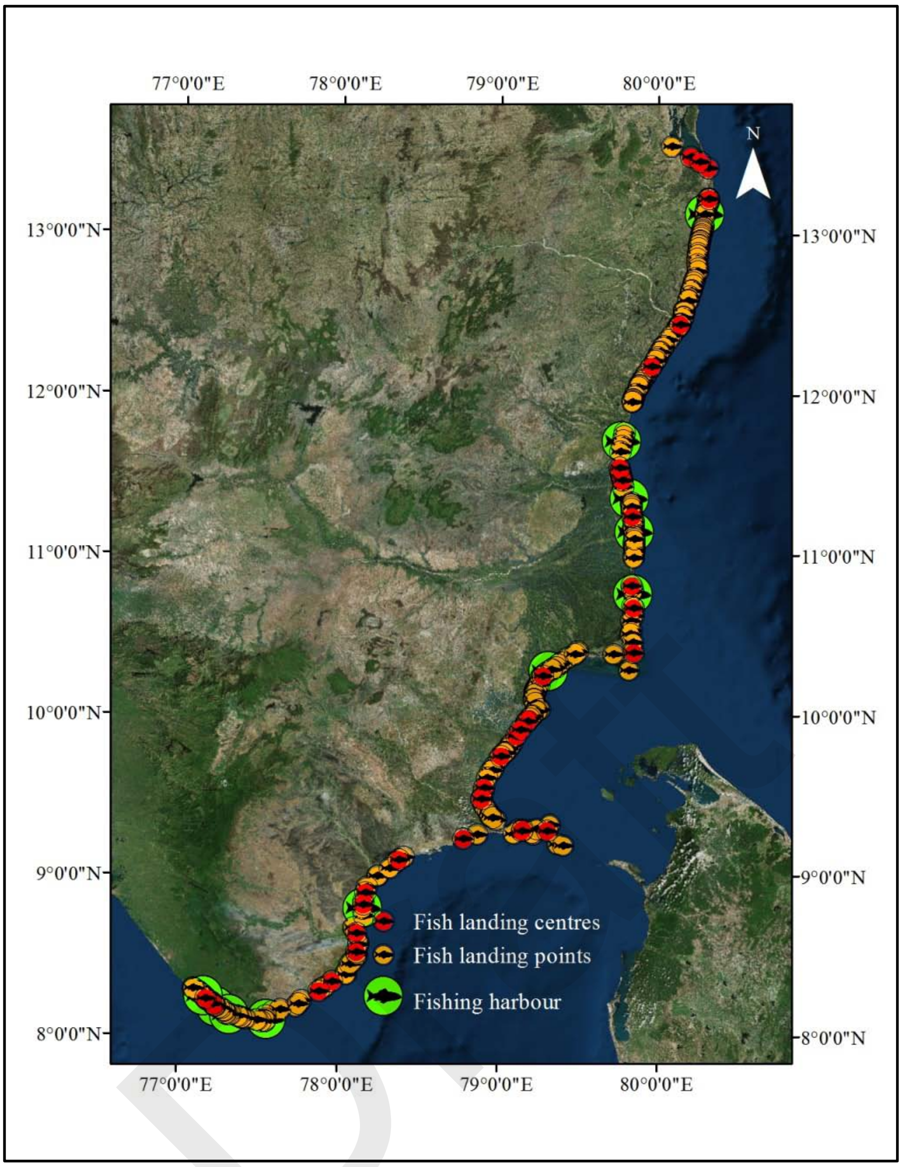


Fig 6.4 List of Fishing port, Fish Landing Centre and Fish Landing Points in Tamilnadu

6.3 STUDIES CARRIED OUT BY IIT MADRAS FOR KANYAKUMARI COAST

Background and justification for development

The livelihood of the villages along the coast of Tamil Nadu has been fishing. Hence there has been an ever increasing demand for fish landing centres along this stretch of the coast from Neerodyup to Ratchakar Street near the tip of Indian peninsula. Realizing this growing importance and urgent need, the department of Fisheries, Govt. of Tamil Nadu(vide: letter from Executive Engineer, Fishing harbour Project division, Nagercoil No: Lr. No. DO/146

M/C.6 (A)/2013 dated 12.8.2013) requested the Department of Ocean Engineering, IIT Madras to examine and to bring out a feasibility report.

The total population of Kanyakumari district is 16, 76,034 comprising 8, 32,269 male and 8, 4, 3765 female consisting of 3, 76,499 households (2001 census). Out of the total population 5, 82,107 live in rural and 10, 93,927 in urban areas of the district. The entire stretch of the coast starting from Neerody, about 10km west of Thengapattanam fishing harbour up to Ratchakar Street near the tip of Indian peninsula covering a stretch of about 72km, of which, 12km lie along the east coast of Tamil Nadu is being considered for development. The length of the coastline is about 72km, of which 12km is along the east coast and the rest of 60 km along the west coast of India.

The stretch of the coast along the Kanyakumari district of Tamil Nadu has 42 marine fishing villages with a total population of 2, 01,955 of which about 50% are actively engaged in fishing which has been their main livelihood. It is to be mentioned that there are 11,179 fishing craft comprising 1,785 mechanized fishing vessels, 3,823 vallams and 5,571 catamarans are operating along the coastal belt of the Kanyakumari district and thereby gets the distinction of having the second highest number of fishing crafts among the 13 coastal districts of the Tamil NaduState.

Till date, landing of fishing vessels are in progress at about 45 locations along the Kanyakumari coast.The Arabian Sea off Kanyakumari district is generally rough throughout the year. Although the stretch of the coast is about 72km, there is only one fishing harbour at Chinnamuttom providing landing and berthing facilities for about 250 MFVs. In the absence of any fish landing centres, along the coast, nearly 1500 MFVs belonging to the district in order earn their livelihood; migrate to the coastal waters of the maritime states of Kerala, Karnataka, Maharashtra and as far as Gujarat. In such a process, the fishermen face a lot of problems leading to clashes, damages to boats, nets and other properties at their alien fishing centres. This has become a regular feature almost year after year during their migration for fishing. Some of the boats also operate from Rameswaram and Mandapam fishing centres. When the fishermen return to their native villages during off-season they used to anchor the boats in the open sea and due to heavy waves and currents the MFVs get damaged or lost.

There have been continuous requests and representations from the fishermen and their representatives for the provision of new beach landing centres as well as improving the existing ones in order to handle the 1500 MFVs which also has been on the increasing trend. The above said requirements are urgently needed in order to protect the interest of the different sections of persons engaged in fishing particularly those engaged in fishing using traditional crafts. To ensure their demands and to ascertain their requirements for Beach Landing and marketing, a Walk through survey was conducted on 27-08-2013 with the officials of the Fisheries department and the Fishing Harbour project division of the district along with fishermen and their representatives.

On 21-09-2013, the District Collector, Kanyakumari district organized a meeting with the representatives of the coastal villages and officials of Fisheries department during which the problems and the difficulties of the fishing folks in landing their vallams and cattamarans in their respective villages that have been experiencing erosion were highlighted. Finally, it was decided to restore the coast and provide beach landing facilities along the affected villages. To ease the planning and execution, the villages are clubbed into packages and they are listed in the enclosed **Table.1.** The planning for the development of fish landing centres will be carried out broadly under two categories, viz., **(1)Development of fish landing centres in gaps of existing coastal protection measures and (2) Conversion of existing coastal protection measures to fish landing centres with possibility for further expansion.**

To ascertain the feasibility for these marine works, the Fisheries department, Govt. of Tamil Nadu engaged the services of Ocean Engineering Department in IIT Madras. The professors from Ocean Engineering Department of IIT Madras, Prof. S.A.Sannasiraj and Prof.V.Sundar visited these coastal villages thrice on 27.9.2013, 4.10.2013, 20.11.2013. It is believed that this report will just discuss on the feasibility of the proposed fish landing centres at selected locations. Based on the feasibility report thus submitted by IIT Madras, an appropriate qualified agency will be identified to carry out the detailed studies for all the proposed locations. The Chief Engineer, Fishing Harbour Project Circle, Chennai and The Director, Central Institute of Coastal Engineering for Fishery (CICEF), Bangalore visited these sites on 26.11.2013. Seeing the site reality the Director, CICEF insisted to get the detailed project report based on the feasibility report from IIT Madras and expressed an immediate need of these works to safeguard the interests of coastal villages of Kanyakumari district.

The coastal stretch of Kanyakumari district is enriched by fishing hamlets. However, the developments to facilitate the fishing activities have been varied on a wider scale. For example, the coast on the western side of Thengapattanam harbour does not have any protected beach landing facilities even though the numbers of fishing villages are so many and also, during most of the seasons, they could not land the fishing vessels on their own soil. This needs greater attention. Similarly, on the east of Thengapattanam harbour, the developmental activities have been discrete in the sense that either the present coastal structures such as seawalls/ groins do not meet the requirements of safe beach landing of fishing vessels or the coast is bare beach without any protection against monsoon waves. By considering the above aspects, the developmental activities have been packaged under three major classifications.

Package I: Western side of Thengapattanam harbour from Neerody to Erayumanthurai.

Package II: Eastern side of Thengapattanam harbour up to Arokkiyapuram, wherein, the beach does not have any safe beach landing facility

Package III: Eastern side of Thengapattanam harbour up to Arokkiyapuram wherein, the existing coastal structure needs modification to facilitate enhanced beach landing.

Since the coastal features vary widely along the Kanyakumari district, the **Package II** has been classified further into four sub-divisions. The details of the different packages are provided in **Table 6.5**.

Table: 6.5 Development of the fish landing centres along the Kanyakumari district

Sl.No.	Package No	Name of Work	Fishing Villages / hamlets to be covered
Development of fish landing centres in gaps of existing coastal protection measures			
1	I	Protection works to restore the coast to facilitate the berthing of fishing vessels/crafts from **Neerody to Erayumanthurai**with shore connected structures serving as littoral barriers inThengapattanam.	▪ Neerody. ▪ Marthandamthurai. ▪ Vallavilai. ▪ Thatheyupuram. ▪ Edappadu ▪ Eraviputhenthurai. ▪ Chinnathurai. ▪ Thoothoor. ▪ Karunyapuram. ▪ Poothurai. ▪ Erayumanthurai.

2	**II.1**	Protection works to restore the coast to facilitate the berthing of fishing vessels/crafts from **Mulloorthurai to Simon Colony** – withshoreconnectedstructuresserving as littoral barriers inColachel.	o Mulloorthurai. o Ramanthurai. o Helen nagar. o Melmidalam. o Midalam.
3	**II.2**	Protection works to restore the coast to facilitate the berthing of fishing vessels/crafts from **Kottilpadu to kadiapattinam**–breakwaters of Muttom as barriers.	• Kottilpadu. • Pudur. • Kadiyapattanam.
4	**II.3**	Protection works to restore the coast to facilitate the berthing of fishing vessels/crafts from **Periyakadu to Annainagar** – training walls at Manakkudy as barriers.	o Pozhikarai. o KesavanPuthenthurai o Puthenthurai. o Pallamthurai. o Annainagar.
Conversion of existing coastal protection measures to fish landing centers with possibility for further expansion			
5	**III**	Conversion of existing Groins to Breakwater creating a basin with tranquility to berth fishing vessels in Kanyakumari district	❖ Enayamputhenthurai. ❖ Enayam. ❖ Kurumpanai. ❖ Vaniyakudi. ❖ Kodimunai. ❖ Simon colony. ❖ Periyakadu. ❖ Keezhamanakudy. ❖ Kovalam. ❖ Kanyakumari. ❖ Arokkiyapuram.

6.0 RECOMMENDATION BASED ON RECONNAISSANCE SURVEY

It is strongly felt that a similar exercise for the other coastal districts need to be carried out having the plan prepared by the department of Fisheries serving as the base materials.

CHAPTER 7
EXTREME EVENTS

7.0 INTRODUCTION

The coast of Tamil Nadu is highly vulnerable to disasters that are perennial at least once a year like cyclone, storm surge or rare extreme events like the great Indian Ocean tsunami of 2004. The devastative effects of cyclones and tsunamis in the past has resulted in the loss of several lives and damage to private properties, infra structural facilities onshore and in the coastal regions. The spatial distribution of a catastrophic event like the 2004 great Indian Ocean tsunami and its impact is of vital importance in recovery stages in case of emergency and in the planning for mitigation measures. Through efficient pre-planned mitigation measures, loss of lives and property can be saved and environmental damage can be significantly reduced.

7.1 TSUNAMI

7.1.1 General

Tsunamis have been occurring in all the major oceans of the world. However, this phenomenon is frequently seen in the Pacific basin, an area surrounded by volcanic island arcs, mountain chains and subduction zones, as it is the most geologically active area on the planet. The amount of activity in this region makes it much more susceptible to submarine faulting and subsequent tsunami events, whereas the Indian and Atlantic oceans are far less geologically active, with some exceptions, and therefore the occurrence of tsunamis is rare. Ninety tsunamis were recorded in the pacific since 1900 [every one decade see one major devastating tsunami]. Tsunamis are not entirely unknown in India. **Table 7.1** shows the details of tsunami occurrences in India and the authenticity of the data provided in this table is uncertain (Sannasiraj and Sundar, 2005).

Table 7.1: Tsunamis Recorded In India (NIO, Goa, India)

Date	Cause	Impact
326 B.C.	Unknown	Unknown. Noted from the history Alexander the Great
April-May 1008	Earthquake along Iranian coast	Unknown
31 Dec 1881	A 7.9 Richter scale earthquake beneath Car Nicobar	Entire east coast of India and Andaman & Nicobar Islands; 1m tsunamis were recorded at Chennai.
27 Aug. 1883	Explosion of the Krakatoa Volcano in Indonesia	East coast of India was affected; 1.5m tsunamis at Chennai; 0.6m at Nagapattinam; 0.2m at Arden
26 June 1941	A 8.1 Richter scale earthquake in the Andaman archipelago at 12.9°N, 92.5°E.	East coast of India was affected with 0.75 to 1.25m tsunamis. Some damages were reported.
27 Nov. 1945	A 8.5 Richter scale earthquake at a distance of about 100km south of Karachi	West coast of India from north to Karwar was affected; 12m tsunami was felt at Kandla.
26 Dec 2004	A 9.1 Richter scale earthquake at Sumatra coast	East coast of India, Andaman & Nicobar islands, Laksdweep islands, Kerala coast were recorded 1-7m tsunami. 9700 people lost their lives and 6000 people were reported to be missing. Minor damages to coastal and harbour structures.

7.1.2 Indian Ocean Tsunami

On 26 Dec 2004, 7:58:53 am local time, an earthquake occurred off the West Coast of northern Sumatra, Indonesia. The epicenter was located under seawater. This is the fourth largest earthquake in the world since 1900. The earthquake generated tsunamis, which swept across the Indian Ocean within hours. Over 200,000 lost their lives in this disaster. Areas near to the epicenter in Indonesia, especially Aceh, were devastated by the earthquake and tsunamis. The tsunamis also affected Phuket and surrounding areas in Thailand, Penang in Malaysia, Sri Lanka, India, and places as far as Somalia in Africa

Following the Tsunami wave attack along Indian coast on December 26th of 2004, the Department of Ocean Engineering, IITM took steps in collecting the data of time of occurrence of waves, run-up, inundation level and their and their geographical locations for 38 places were surveyed, are given **Table 7.2**.

Table7. 2: Survey Stations along Northern Tamilnadu Coast (Sannasiraj and Sundar, 2005)

No.	Name of the place	Latitude (N)	Longitude (E)	Inundation (m)	Run-up (m)	Time of struck
1	KatupalliKupam	13.18'24.4"	80.20'48.7"	300-500		A - 8:45 C-10.45
2	Ennore Creek	13.13'56.9"	80.19'51.7"	500		
3	Netukuppam	13.13'54.4"	80.19'47.8"			A - 8:50
4	Chinnakuppam	13.12'35.3"	80.19'20.2"	500	3.08	
5	Ondikuppam	13.09'14.7"	80.18'17.4"		3.81	A* - 9:00
6	Marina beach, Chennai	13.02'24.9"	80.16'47.5"		2.23	A - 9.00
7	Light House, Chennai	13.02'04.9"	80.16'43.1"	700	2.27	A - 8.55
8	Fore Shore Estate	13.02'04.9"	80.16'35.3"	400	4.51	A - 9.00
9	Besant Nagar Beach	12.59'47.0"	80.16'14.2"	200	2.76	A - 9.00 C*
10	Thiruvanmiyur	12.58'36.4"	80.16'0.7"	100	3.65	
11	Kottivakam	12.59'51.6"	80.15'48.1"	300	4.85	A - 9.00
12	Injambakkam	12.54'40.4"	80.15'19.0"		3.2	
13	Mutukadu	12.49'53.8"	80.14'51.0"		4.1	A – 9.00 C*
14	Kovalam	12.47'22.6"	80.15'10.1"		5.71	
15	Venpurushan, Mahabalipuram	12.35'53.5"	80.11'26.8"	500	5.74	
16	Periyakuppam	12.26'42.8"	80.8'35.3"	700	5.67	A - 10:30 C*
17	Perunthuravu	12.22'38.9"	80.05'31.3"		4.59	
18	Alambarai	12.16'16.2"	80.01'00.8"		4.75	
19	KizhapettaiKuppam	12.08'00.4"	79.55'44.9"		3.29	A - 8:45 B* D- 11.30
20	Periyakalapetkuppam	12.01'51.6"	79.52'05.2"	300-500	5.79/6.93	A* – 8.45 D-9.30
21	Thalangkuda, Cuddalore	11.46'00.1"	79.47'34.3"	IR- 500m, 1500	3.66/9.08	A – 8.45
22	Silver Beach, Thevanampattinam, Cudalore	11.44'22.6"	79.47'09.1"	1000	7.55/11.25	

No.	Name of the place	Latitude (N)	Longitude (E)	Inundation (m)	Run-up (m)	Time of struck
23	Tamil Nadu Maritime Board, Port office, Cuddalore, Tamil Nadu Petrochem Ltd.	11.42'27.8"	79.46'30.0"	142	2.76	A - 8.45 B – 9.00
24	Annankovil	11.30'15.1"	79.46'13.5"	1500	11.12	
25	Parankipettai, Centre for Biological sciences	11.29'27.7"	79.45'55.6"		2.32	A - 9:00 B* C
26	ThirumullaiVasal	11.14'31.0"	79.50'37.4"	700	5.22	A* - 9:00
27	Poompuhar	11.08'36.1"	79.51'24.5"	100	5.72	
28	Tharangambadi Village	11.01'48.1"	79.51'21.1"		4.61	B* - 9.00
29	Tharangambadi, Near cross	11.01'32.3"	79.51'22.8"		8.56	A – 8.50
30	Karaikal Beach	10.54'49.1"	79.51'05.01"	IR 500m, 1000	4.48	9:00
31	Nagore	10.49'21.4"	79.51'03.6"	1000	5.81 /6.5	A - 9:10 B* - 9.30
32	Aryanatutheru, Nagapatnam	10.46'08.8"	79.51'00.5"	IR 500m, 1000	4.68	
33	Nagapatnam Port	10.45'47.4"	79.50'57.4"	300	4.59	A - 9:30 B*- 9.35 R 500m
34	Akkaraipettai	10.44'34.5"	79.50'58.2"	IR100m,	4.02	A - 9:15
35	Kallar Village	10.44'21.1"	79.50'57.2"	1500	4.3	A - 9:15
36	Velankanni Church	10.40'48.4"	79.51'10.0"	500	4.9	
37	Arukattudurai, 10km from point calimere	10.23'38.4"	79.52'01.3"		6	A - 8:30
38	Athirampattinam	10.19'18.3"	79.23'49.7"	300	4.48	

*Note: IR – Initial receding, R – Receding, A - First wave, B – Second wave, C – Third wave, D – Fourth wave; * The most destructive wave*

7.1.3 Case study – groin field and sediment under tsunami

The impact of the construction of the coastal structures (man-made problem) on the shoreline changes on the northern side of the Chennai port after its construction. It is estimated that 500meters of beach has been lost on the between 1876 and 1975 and another 200 meters between1978 and 1995. A permanent solution for the coastal erosion problem, ten numbers of shore-connected straight rubble mound groins in the two severely affected stretches (stretchI and II) shown in **Fig. 7.1** were proposed. The length and the spacing between groins were designed based on the recommendations of Shore Protection Manual [SPM(1984)], the details of which are projected in **Figs. 7.2a and 7.2b**.

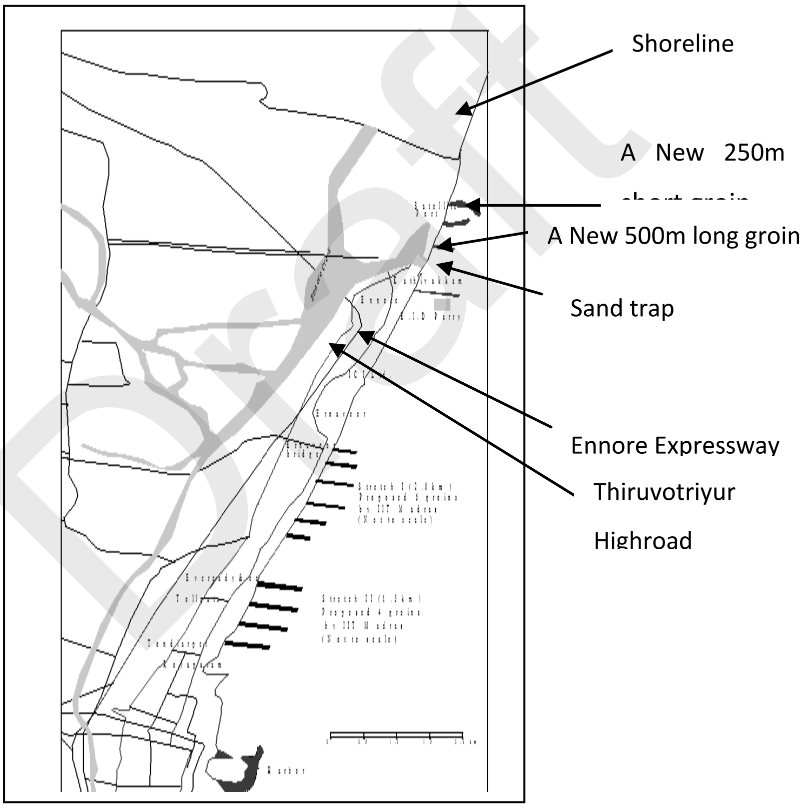


Fig. 7.1 Layout of the Study Area

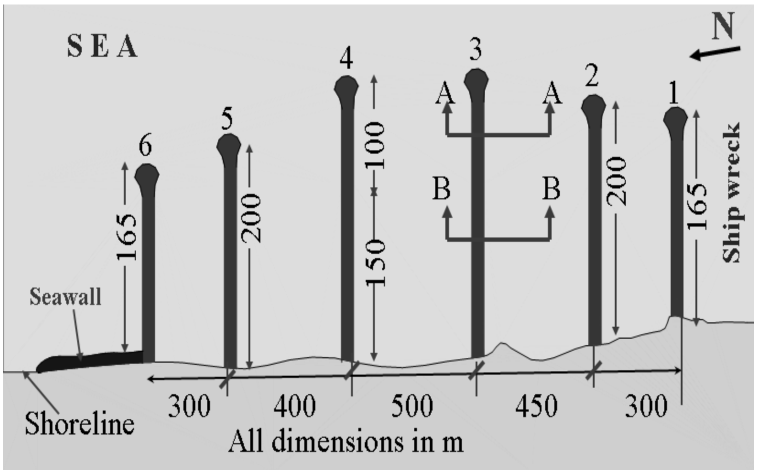


Fig. 7.2a Layout of Groin Field for Stretch I

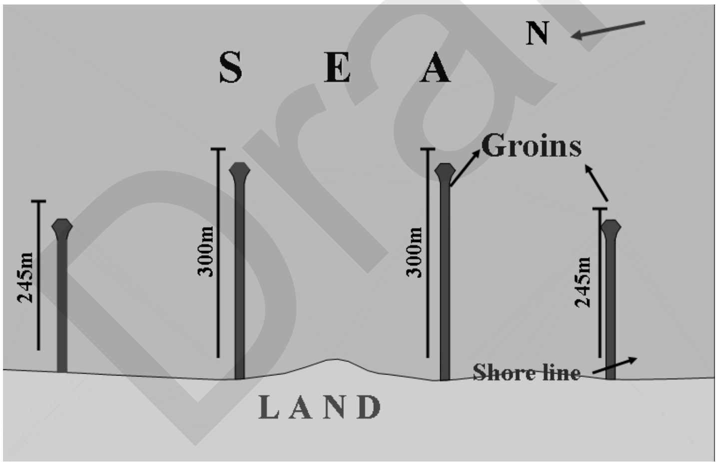


Fig. 7.2b Layout of Groin Field for Stretch II

The construction of the proposed groin field started in May 2004. Immediate shoreline advancement on the south of the executed groin has been substantiating the most favorable choice and design of the suggested remedial measure. The approximate beach widths formed due to the groins 6 and 5 as reported by **Sundar (2005)** are shown in **Fig. 7.3**. The area of the beach obtained through continuous monitoring for the different periods are shown in **Table.7.3**. It is to be mentioned here that all the groins in stretch 1 are nearing completion which has clearly indicated, that stretch of the coast and the road has been saved from any further damage. This is evident from that fact that the groin field not only withstood the dynamics of the 2004 tsunami, but also has helped to a very great in reducing the inundation and damage on the landward side of this stretch of coast. The shoreline advancement due to the groin field (6 groins) in stretch 1 after the tsunami in Dec'04 proves the effectiveness of the proposed groin field not only in preventing further erosion, but also has enhanced the formation of beach.

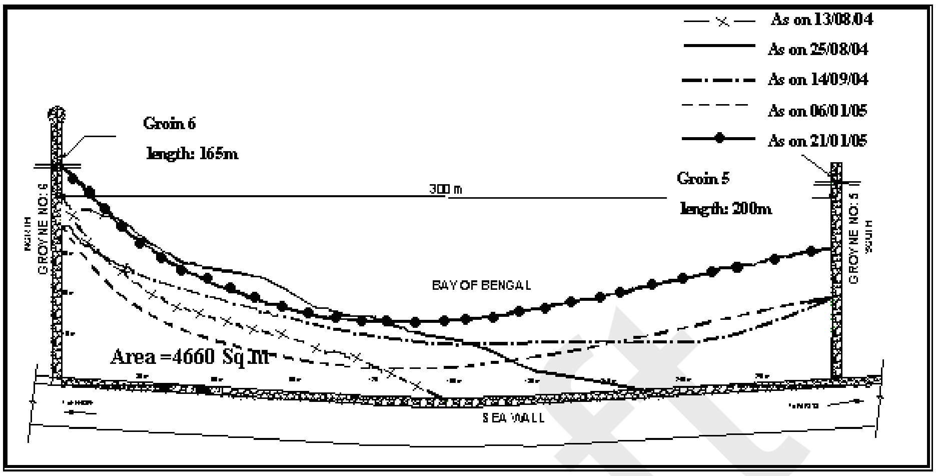


Fig.7.3 Shore Line Advance In Between Groins 5 and 6 for Different Periods (Sundar 2005)

Table 7.3 Area of Beach in Between Groins 5 and 6.

Date of Measurement	Area in m^2
Work commenced in May 2004	
13 Aug '04	3700
25 Aug'04	6970
14 Sep'04	8800
Post Tsunami	
06 Jan'05	4660
21 Jan'05	10450

7.2 CYCLONES AND STORMSURGES

Atmospheric disturbances in the form of regions of low pressure over tropical oceans sometimes intensify and develop into nearly circular low-pressure areas surrounded by regions of extremely strong winds. These wind systems do not stay stationary, but move over the ocean surface and are referred to as the tropical cyclones. They are also commonly known as 'cyclonic storms' or 'storms'.

These storms are large vortices in the atmosphere extending from 100 to 1000 km in the horizontal direction with strong winds spiralling around a central low-pressure area, called the eye of the cyclone. The wind speed is zero at the centre of the eye, increases radialy to a maximum value and then decays slowly towards the storm periphery. When these wind systems approach a coast from the ocean, the onshore winds to the right of the storm path in the northern hemisphere of the earth (to the left of the storm path in the southern hemisphere) force the water towards the coast causing a rapid rise in the sea level, while the offshore winds to the left of the storm path force the water away from the shore causing a decrease in the sea level. This rapid sea level rise in the near shore region observed during a storm is known as the storm surge. In the storm induced sea level variations near the coast, sometimes three stages, viz. a fore runner, a main surge and resurgence, are observed. The forerunner is a gradual rise of sea level near the coast observed before the arrival of an approaching storm when it is relatively far from the coast. The forerunner, if present, serves as an indicator of an approaching storm. When the storm approaches close to the coast, the sea level rise that we observe is the main surge. The resurgence follows the main surge after the storm crosses the coast and enters the land. In this stage, the sea level near the coast oscillates depending on shelf geometry and the storm induced flow, and finally returns to the normal state. The surges along with high waves induced by storm, flood the low lying areas and coastal marshes, increase the salinity of water in the estuaries, bays and aquifers along the coast and also erode the shore line.

The North Indian Ocean (the Bay of Bengal and the Arabian Sea) is one of the favored ocean basins for the formation of cyclonic storms. In the Bay of Bengal alone more than 400 cyclonic storms of various intensities were reported to have been generated between the years 1891 and 1990, and during these storms the coastal regions surrounding this ocean basin have frequently experienced surges of different magnitudes. The impacts of these storms are more pronounced in the states located on the East Coast of India, namely West Bengal, Orissa, Andhra Pradesh and Tamil Nadu.

The coastline is susceptible to severe cyclonic storms during Northeast monsoon. This area was subjected to 26 storms and 26 severe storms in the last 100 years. It is also seen that 8 out of 42 depressions, 9 out of 26 storms and 11 out of 26 severe storms in the area have their tracks on are very close to Chennai coast.

It was reported by Chennai Port trust that a severe cyclone occurred on 12.11.1984 which generated significant wave height of 6.0 m with a maximum wave height of 9.10 m. In the year 2010 cyclone naming JAL has crossed Chennai coast in October 2010. The net effect of cyclones on the coast is erosion and flooding. The details of damages on coastal stretch is shown below In **Figs. 7.4a** and **b.**

Fig. 7.4 (a) Cyclonic waves lashing the coast

Fig. 7.4(b) Erosion of seawall due to cyclonic waves

In recent past we had two major cyclones namely, Thane and Nilam in Dec 2011 and Nov 2012, respectively, which made land fall south of Chennai.

The prediction of sea state and its severity during a cyclone that usually occurs in deep Ocean along with its effect as it propagates towards the coast is of paramount importance. The said information is needed not only for the preparedness for evacuating the coastal community but also dictates the design of coastal structures. It forms the design basis for all types of marine structures in particular along the coastal zone, since the effect of both storm surge and storm waves could significantly influence the design.

7.2.1 Wave climate off the Tamil Nadu coast during Thane cyclone

The measurement campaign off Chennai coast has captured the wave climate during the passage of the Thane with its landfall at about 130km south of Chennai at 0730hrs on 30 Dec 2011 has been reported by **(Anand et al., 2015)**. The integrated wave characteristics such as significant wave height (H_s), mean wave period (T_m) and mean wave direction (θ_m) have been derived from the directional spectra that were deduced from buoy and directional tide gauges.

The variation of H_s, T_m and θ_m at different locations along the Chennai coast, during the period 14-31 December 2011 is depicted in **Fig.7.5**.

A typical contour plot of wave height obtained from WAM over the entire Bay of Bengal at 0600 hours 29th December 2011 is projected in **Fig. 7.6.** The measured wave characteristics, H_s, T_m and θ_m at off Chennai coast in 20m water depth are compared with that simulated through WAM are projected in **Fig. 7.7**.

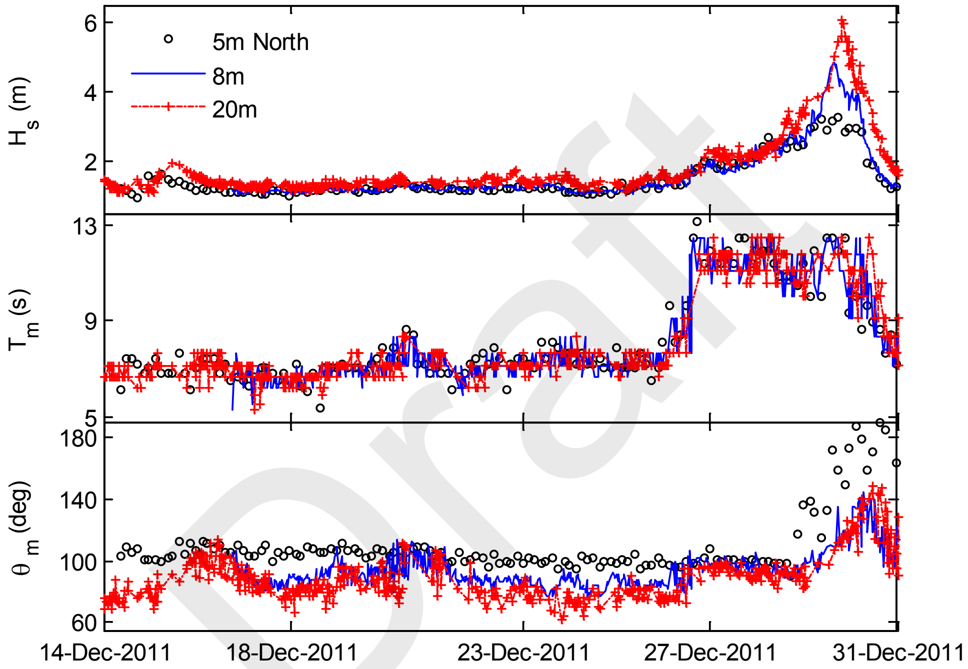


Fig.7.5 Measured H_s, T_m and θ_m, during 14th to 31st Dec, 2011 at the study area

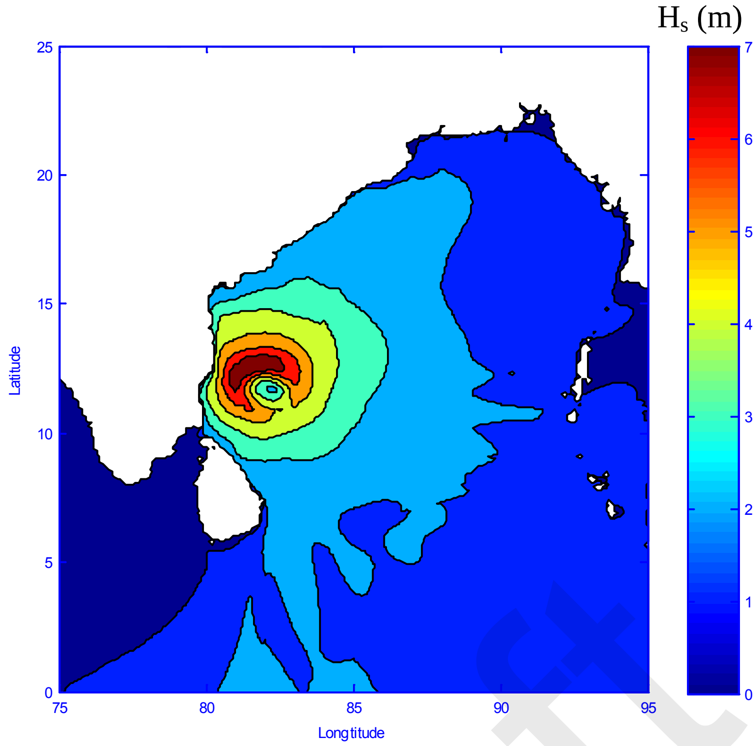


Fig. 7.6 Typical significant wave height contour (6:00 am, 29th 12 2011) obtained from WAM

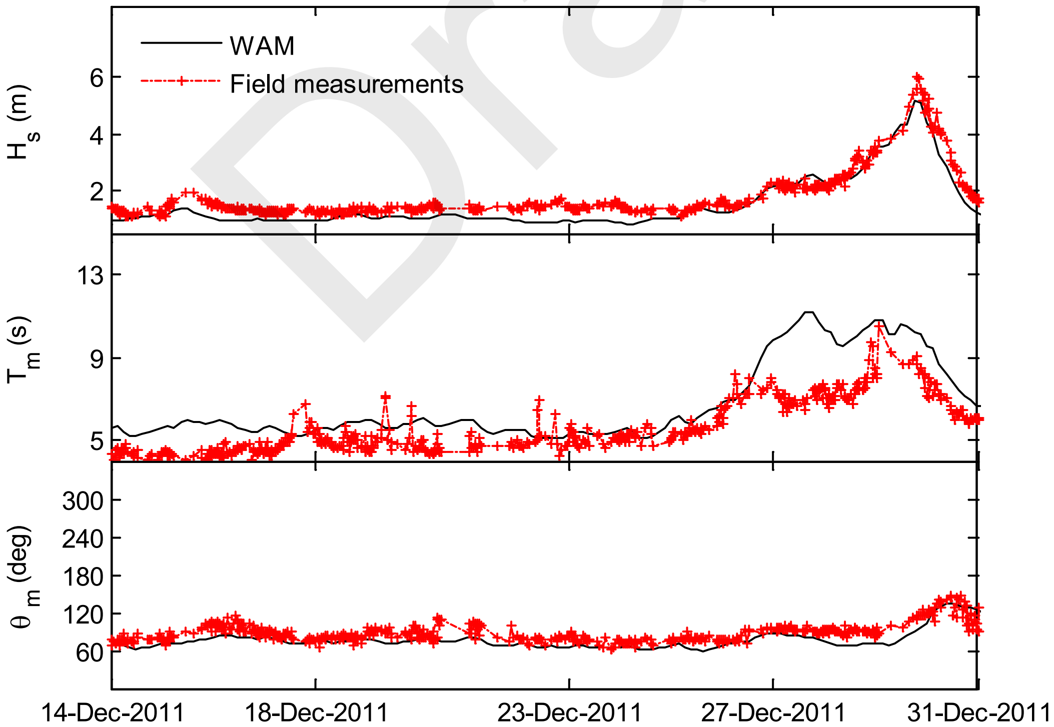


Fig. 7.7 Comparison of results from WAM with field measurements in 20m water depth at off Chennai coast during Thane cyclone

7.2.2 Prolongation study

In the recorded history of Bay of Bengal and Indian Ocean, the cyclone which occurred during October 1999 is one of the most intense one with an adjective of ‘Super’ cyclone. According to the records, it is said that the maximum wind speed that sustained during this cyclone was about 250 to 260 km/h (IMD, Super cyclone in 1999), that crossed Orissa coast near Paradip on the east coast of India on 29th Oct 1999, and it lead to a huge loss of human life and properties. Since WAM has proven to be in good agreement with the measurements during the Thane cyclone, the prediction of extreme wave heights with the maximum wind speed of super cyclone is considered herein as a case study. The wind speed of the super cyclone is used to upscale the Thane cyclone’s wind field, while the track of Thane has been kept the same. The evolution of wave height, period and direction off the Chennai coast is presented in **Fig. 7.8** that shows an appreciable increase in the wave height and period. The predicted H_s is about 12m associated with a wave period of 13s, which should be borne in mind while planning for the development along east coast of India. The above stated parametric study pertains to the coast of Chennai. Similar, studies need to be done for individual sites based on the requirements.

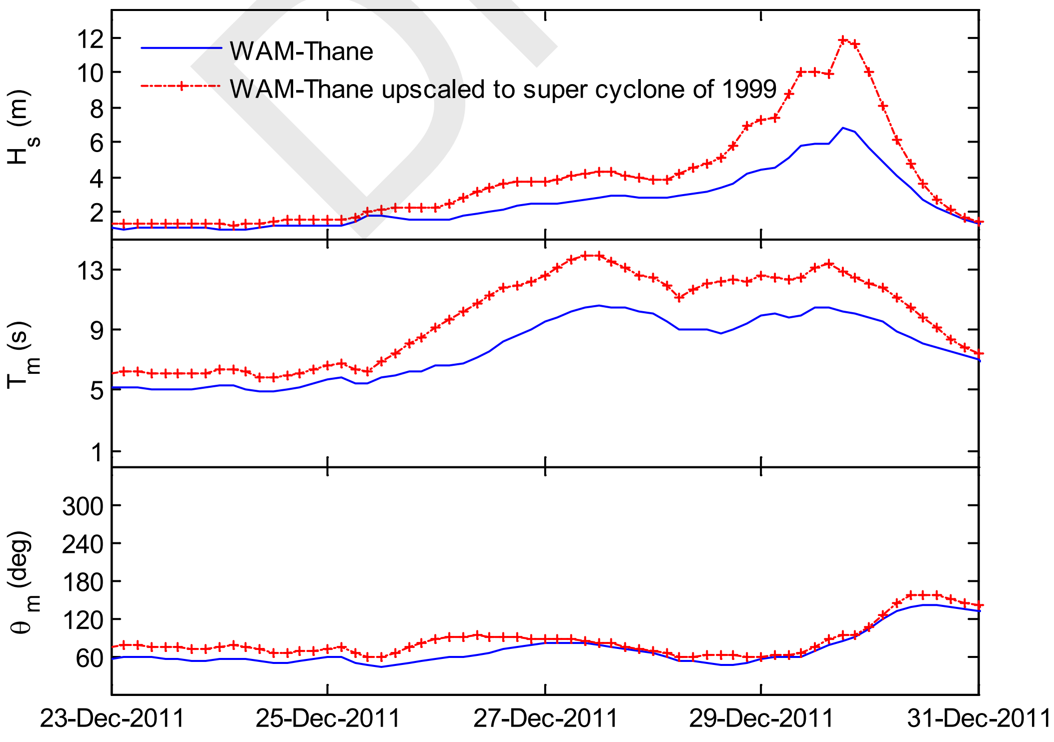


Fig.7.8 Comparison of Thane wave characteristics with Predicted wave characteristics of up-scaled winds of Thane to super cyclone of 1999 at off Chennai coast

Points to be considered during field measurements

During Thane cyclone, all the data buoys installed from Pudhucherri (11.87 N, 79.84 E) to Ennore (13.25N, 80.35E) had failed. The one installed in 20m water depth at the north Chennai groin field by ICMAM has survived and they made direct relay of the field data in their official website during the occurrence of Thane cyclone.

This suggests that in order to capture extreme wave characteristics in particular during cyclones, it would be preferable to install wave rider buoys around 20m water depth on the east coast of India.

7.3 CONCEPTUAL SOLUTIONS

The coast of Tamilnadu was visited and a general survey was carried out by Prof. V.Sundar, Department of Ocean engineering, I.I.T.Madras during Feb-March 2005 in order to assess the vulnerable areas being affected by the perennial problem of erosion along with the consideration of the effect of the tsunami 2004 and a detailed report have been submitted to Public works department, Govt of Tamil Nadu. The coastal region of the state is divided into three stretches namely, Chennai, Madurai and Trichy, accordingly the suitable conceptual protection measures for each of the regions are given as projected in **Table.7.4.**

Table. 7.4 Summary of the protection measures for Tamil Nadu coast

Name of the location	Name of the Region	Solution	Priority / Ranking
Kaatupallikuppam	Chennai	Plantations & Nourishment	**
Ennore creek	Chennai	Groins	***
Ennore – Ernavoorkuppam	Chennai	Groin field	***
Masthankoilkupam	Chennai	Replenishment of Existing seawall	***
North of Royapuram fishing harbor	Chennai	Replenishment of Existing seawall	**
Cooum River	Chennai	Training walls	**
Adyar river	Chennai	Dredging + plantations	*
Besant Nagar	Chennai	No intervention	
Kovalam	Chennai	Plantations	**
Devaneri	Chennai	Seawall	***

Mammalapuram	Chennai	Plantations	*
Meyyurkuppam	Chennai	Groin field + Seawall	***
Oyyalikuppam	Chennai	Groin field	***
Chinnakuppam	Chennai	Training walls	**
Sodhanaikuppam	Chennai	Groin field	**
Thanthiriyankuppam	Chennai	Groin field + plantations	**
Mudaliarkuppam	Chennai	Plantations	*
Thazhanguda to Devanampattinam	Chennai	Training walls + Groin field + Seawall	***
Singarathoppu	Chennai	Shifting of Dwelling units + Plantations	***
Pudukuppam, Parangipettai	Chennai	Buffer blocks + plantations	**
Neerodi to Erayumanthurai	Madurai	Groin field	*
Enayam to Muttam	Madurai	Groin field	**
Vaniyakudi	Madurai	Groin	*
Colachel jetty	Madurai	Pair of Groins	***
Kottilpadu	Madurai	Seawall + plantations	***
Kadiyapattanam	Madurai	Training walls	*
Keezhamuttam	Madurai	Replenishment of Existing seawall	*
Pozhikarai to MezhaManakudithur ai	Madurai	Groin field	***
Keezhamanakudithur ai	Madurai	Groin field + Training walls	***
Ratchagar street	Madurai	Extension of existing groins	*
Vaavuthurai	Madurai	Seawall	*
Kootupuli	Madurai	No intervention	-
Perumanal	Madurai	No intervention	-
Idinthakarai	Madurai	Groin field	***
Koothankuli	Madurai	Pair of groins	**
Aalanthalai	Madurai	Groin field	***
Punnakayal	Madurai	Training walls	**
Threspuram	Madurai	Pair of groins	***
Devipattanam to Nambuthalai	Madurai	Plantations + monitoring of coastline	*
Nagoor to Keechankuppam	Trichy	Training walls + T-shaped groin field	***
Velankanni	Trichy	Dredging + Nourishment + plantaions+ Buffer blocks	***
Vellapallam	Trichy	Training walls	*
Tharangampadi	Trichy	Replenishment of existing groins + groin	***

		field + Plantations	
Poombuhar	Trichy	Rehabilitation of existing seawall + plantations	***
Vaanagirikuppam	Trichy	Seawall + groin field + Plantations	**
Pudukuppam	Trichy	Plantations	*
Palayur	Trichy	Dunes with revetments or Geotubes +	**
Thirumullaivasal	Trichy	Dredging + Nourishment + Training walls	***

* Least Priority; ** Moderate Priority;*******High Priority

CHAPTER 8

ECOLOGICALLY SENSITIVE AREAS

8.1 INTRODUCTION

Ecologically sensitive area is the one, needs special protection because of its landscape, wildlife, special kind of eco-system or historical value. Coastal zone is a dynamic area with many cyclic processes owing to a variety of resources and habitats. Coastal plains and seas include the most taxonomically rich and productive ecosystems on the earth. Mangroves forests are over 20 times more productive than the average open ocean. Estuaries, salt marshes and coral reefs are 5 to 15 times higher. These enhanced rates of primary production result in an abundance of other life forms including species of commercial importance. Although occupying only 8% of the total surface, ecologically important areas account for 20-25% of global plant growth. (Ramesh et al 2008). The ecologically sensitive areas are included under CRZ-I, where no activity is allowed. The ecologically sensitive areas along the Tamilnadu coast are,

- Pulicat lake
- Pichavaram
- Vedaranyam, Muthupettai
- Palk Bay
- Gulf of Mannar

8.2 PULICAT LAKE

Pulicat lagoon, also called as lake of the Palar Basin, is the second largest lagoon on the east coast of India. The Pulicat lake is situated between 13°20’ and 13°40’N lat. and 80°14’ to 80°15’E **(as shown in Fig.8.1)** long with its narrow (1–1.5 km) opening into the Bay of Bengal through the south-eastern margin near the Pulicat town which is 70 km north of Chennai.

Pulicat Lake is one of the good productive ecosystems in India. Several researchers have been reported the biodiversity details from this area. Chacko*et al*. (1953) have given the first exhaustive account of the biodiversity of the Pulicat Lake and it has been classical benchmark for the biodiversity of the Pulicat Lake for a long time (Sanjeeva Raj, 1997, 2003, 2006).

Fig.8.1 Location of Pulicat Lake

According to the Forest Department records, Pulicat lake is Birds Sanctury, lying along the Tamil Nady-Andhra Presesh part; part extending to Chengalpattu district of Tamil Nadu. The sanctuary has an area of 321 Km^2 with 108 Km^2 of National Park area. About 60 to 80 thousand water birds, belonging to about 50 species visit the lake, every winter. Today, about 78-80 species of water birds are counted during the winter, on this lake. There are several ecological problems that these migrant birds are facing on the northern Pulicat Lake, chief among them is the lack of water for a longer duration.

8.2.1 Ecological crises facing the Pulicat Lake

Impact of lake-mouth closure

The inlet opening of the lake is a major determining factor for the hydrology, biodiversity and fisheries in this lake, tends to get narrower and shallower during the post-monsoon months (January to September), chiefly due to the accretion of sand, resulting in the formation of a sand-bar across the inlet. As a result, the impact of the ebb (low) and flood (high) tides in the lake tends to be feeble. This has major consequences on the biodiversity and fisheries in this lake. If the sand-bar closes up the lake-mouth completely, as it happened during some severe summers, the lake water gets impounded, gets subjected to evaporation and reaches hyper saline levels. (Thirunavukkarasu*et al*. 2011)

8.3 PICHAVARAM

Pichavaram is situated in the southeast coast of India in the Tamil Nadu State. It is located at about 225 km south of Chennai and 5 km north east of Chidambaram, Cuddalore district, Tamil Nadu, between latitude 11°20' to 11°30' north and longitudes 79°45' to 79°55' east, and the location map is shown in **Fig 8.2**.

Fig 8.2 Location of Pichavaram

In Tamil Nadu, mangroves are well developed in Pichavaram. The Pichavaram mangrove wetland has 51 islets and the total area of the Vellar-Pichavaram-Coleroon estuarine complex is 2335.5 ha of which only 241 ha. is occupied by dense mangrove vegetation. Nearly 593 ha, of this wetland is occupied by helophytic vegetation like Suaeda, 262.5 ha. by barren mud flats and 1238.50 ha., by barren high saline soil. Of this, the mangrove wetland occupies only 1100 ha., comprising the entire mangrove vegetation located in the middle portion of the Vellar-Pichavaram-Coleroon wetland which has been declared on 15th December 1987 as a reserved forest by the Department of Forest, Government of Tamil Nadu (Planning Commission, New Delhi, Report, 2008)

The changes in the forest cover of the Pichavaram mangrove wetland was due to various reasons and causes. In the interior region of the mangrove wetland the degradation is mainly due to stagnation of tidal water in the trough shaped area whereas in the peripheral region degradation is due to a combination of stagnant tidal water and heavy grazing.

8.3.1 Advantages of Mangroves

- Network system of roots traps the sediments - stability of the shore, as shown in **Figs. 8.3** and **8.4**
- Nutrient and metal sinks
- Breeding and nursery grounds
- Source of wood, poles, firewood, charcoal, honey, medicines, fodder, etc

Figure 8.3 Typical view of mangroves along with their root system

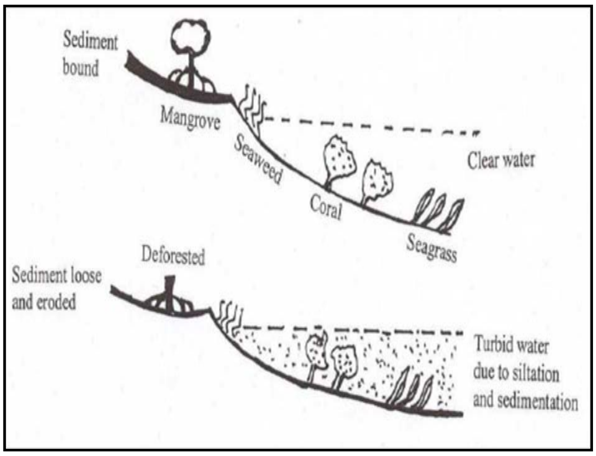


Fig 8.4 Schematic diagram representing the sediment dynamics with and without mangroves

8.4. VEDARANYAM, MUTHUPETTAI

It is one of the coastal blocks in Thanjavur district. It falls within the co-ordinates of 10°15’-10°22’N and 79°45’–79°52’E as shown in **Fig 8.5.** Vedaranyam is one of the six major Wildlife Sanctuaries and also an important coastal wetland in Tamilnadu. Vedaranyam is the one of the major wintering grounds for migratory birds from North India, Europe, Asia and Africa. The number of reservoirs formed here for making salt,serve as feeding grounds for the migratory birds and to the resident bird population.

Muthupet mangrove swamp is in close association with the coastal wetlands of Vedaranyam spreading an area of approximately 6,800ha. out of which 77.20 ha. Is occupied by well grown mangrove and the remaining area is covered by poorly grown mangroves. Mangrove zone of the forest is restricted to the edges of the brackishwater lagoon where the true mangrove species are distributed in varying degree of abundance. *Avicennia marina* is the most common and abundant species.

Fig 8.5 Location map of Vedaranyam,Muthupettai

8.5 PALK BAY

Palk Bay is situated in the southeast coast of India in the Tamil Nadu State. Though Palk Bay is not having any conservation sttaus, The ecologically sensitive habitat, the seagrass beds are distributed densely between Athiramapattinam and Pamban, covering three coastal districts namely Thanjavur, Puthukoattai and Ramanathapuram with the coastal length of about 170 Km. Recent (2014-2015) surveys by SDMRI indicates that about 209 Km2 area is covered with largely dense seagrass beds, however this area is not having any conservation status. It is located between latitude 9°20' to 10°17' north and longitudes 78°59' to 79°20' east and the location map is shown in **Fig. 8.6**. In the entire Palk bay region the sea grass population has been seen from shoreline to a distance of about 8 km perpendicular to the shore. This will act as a natural buffer to certain extent in the occurrence of any extreme events.

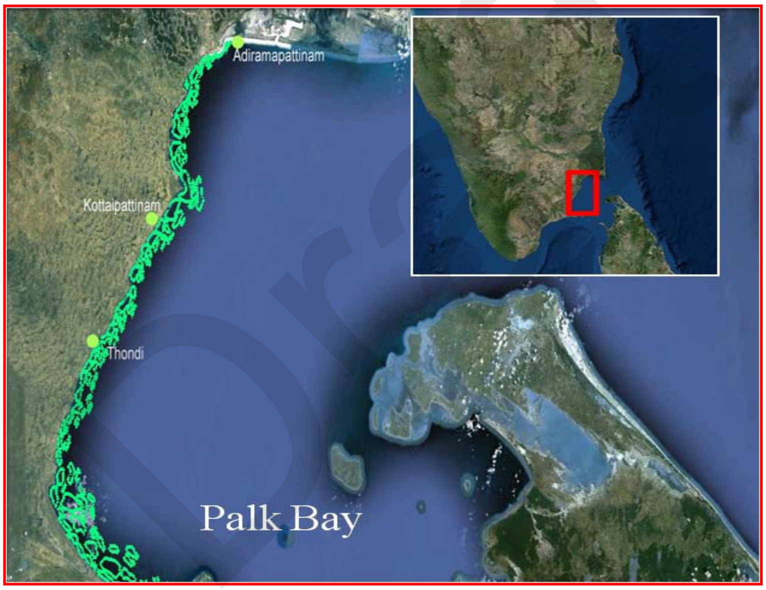


Fig. 8.6 Location and sea grass distribution along Palk Bay(Source: Patterson)

8.6 GULF OF MANNAR

Gulf of Mannar lies in between India and Srilanka and it is one of the biologically richest coastal regions of India. Gulf of Mannar covers approximately an area of 10,500 sq.km between Rameswaram and Kanyakumari, and extending between 8° 35' N - 9° 25' N latitude and 78°08' E - 79° 30' E longitude and this entire area was declared by the Government of India in 1989 by Gulf of Mannar Marine Boisphere Reserve. The location map is shown in **Fig. 8.7**.

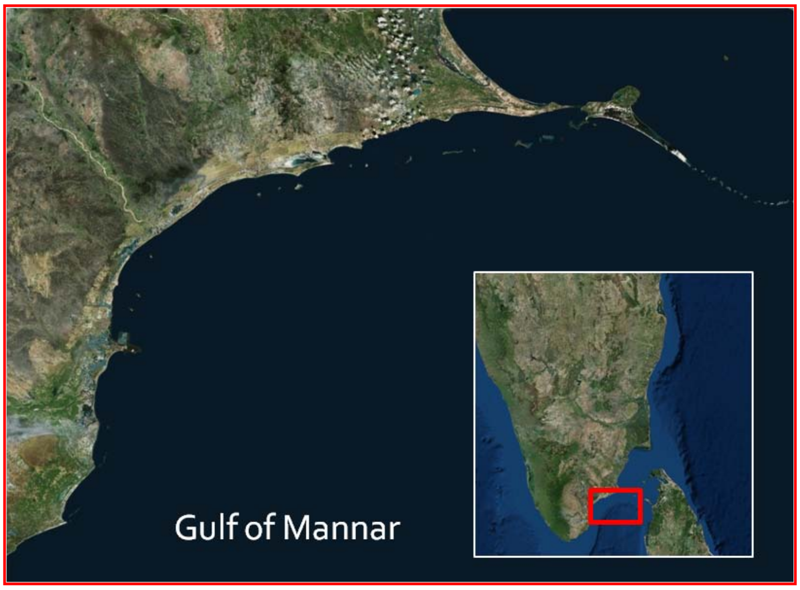


Figure 8.7 Location of Gulf of mannar

The Gulf of Mannar Marine National Park declarded in 1986 by the Government of Tamil Nadu, covering the 21 islands and the surrounding shallow coastal waters with 560 Km2 area for the core zone of the Biosphere Reserve. The Gulf of Mannar is one of the four major coral reef areas in India and the reefs are distributed around the 21 islands. The total coastal length of Biosphere Reserve between Rameswaram and Kaniyakumari is 364.9 Km covering four districts, namely part of Ramnathapuram, Tuticorin, Tirunelveli and part of Kaniyakumari. The Marine National Park has 160 km long coast between Rameswaram and Tuticorin which is shown in **Fig 8.8.**

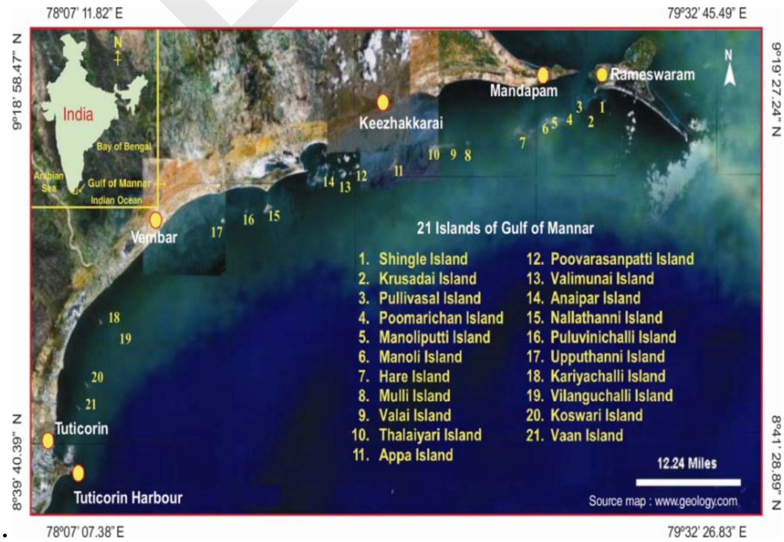


Fig 8.8 Islands of Gulf of Mannar (Source: Patterson)

There are also several coastal lagoons making up the biosphere that serve as marine fisheries. These fisheries, both shellfish and fin fish are important to the livelihood of over 100,000 small scale fisher folk. The trees, fauna, and lagoons are spread across the islets and coastal land areas. Most of the animals are aquatic or reside primarily in the water, but there are some that live on land. The seagrass and coral reef distribution pattern along the Gulf of Mannar is shown in **Fig. 8.9**

Fig 8.9 Sea grass and Coral reefs distribution pattern in Gulf of Mannar (Source: Patterson)

8.7 SUMMARY

The solution for these coasts should be provided with proper considerations in order to avoid any ecological imbalance to the system.

CHAPTER 9
IDENTIFICATION OF VULNERABLE SITES

9.1 GENERAL

Coastal environment change under the influence of both natural and anthropogenic factors, and at temporal scales ranging from hours to decades and even longer. Short term changes are induced by storm events and long term changes are due to the factors like sea level variation and changes in sediment supply (Gomez et.al. 2014). The coastal erosion and inundation causes threat to human populations, activities and infrastructure, especially within the context of a changing climate and increasing coastal populations. Maps became more and more common because of the ever greater participation of geologists, geotechnical engineers, hydrologists, and other experts and also they were able to provide required data for the adequate identification of the danger or hazard zones, according to the area of influence of the natural phenomena. Computer science tools such as geographic information systems (GIS) have facilitated this type of identification and analysis. This type of study or analysis of risk has increasingly been presented with the intention of contributing data on threats or risk to physical and territorial planning specialists as an ingredient of the decision making process (Kumar et.al., 2010).

9.1.1 Objectives

Specific objectives supporting the main aim include

- To statistically evaluate the movement of the shoreline in a specified time period based on shoreline analysis at every 5km discussed in the chapter 3.
- To identify the shoreline that has experienced significant change between 2003 and 2016 and inferring the status of vulnerability of the coastline to erosion and coastal flooding.

A quantitative analysis of the shoreline change over the spatial and temporal scale is represented in the following **Table 9.1**

Table 9.1 A quantitative analysis of the shoreline change over the spatial and temporal scale

Place and location		Latitude		Year		Erosion		Average Erosion (in m/year)	Accretion		Average Accretion (in m/year)
		From	To	From	To	Spatial Average Erosion (in m)	Length of coast (in m)		Spatial Average Accretion (in m)	Length of coast (in m)	
Pulicat	Pulicat	13° 26' 42.00" N	13° 24' 00.00" N	2004	2014	-7.8	2500	-0.8	3.5	2500	0.4
Kattupalli	1- 5km Karungali	13° 23' 42.00" N	13° 21' 10.80" N	2004	2015	-11.1	3000	-1	14.9	2000	1.4
	North of Kattupalli	13° 21' 10.80" N	13° 18' 28.80" N	2004	2015	-89.1	4050	-8.1	0	0	0
	South of Kattupalli	13° 18' 28.80" N	13° 15' 45.00" N	2004	2015	0	0	0	150.8	2000	13.7
	Puzhithivakkam	13° 15' 45.00" N	13° 12' 36.00" N	2004	2015	-48.6	1600	-4.4	40.5	3400	3.7
Chennai Port	Bharath Nagar	13° 12' 36.00" N	13° 09' 54.00" N	2004	2015	-9.2	3450	-0.8	10.2	1550	0.9
	North of Port	13° 09' 54.00" N	13° 07' 48.00" N	2004	2015	-9.5	1400	-0.9	20.4	2250	1.9
	South of Port	13° 07' 48.00" N	13° 05' 13.20" N	2004	2015	-7.4	200	-0.7	13	450	1.2
	Triplicane	13° 05' 13.20" N	13° 02' 20.40" N	2004	2015	-5.5	1800	-0.5	16.5	3200	1.5
	Adyar	13° 02' 20.40" N	12° 56' 52.80" N	2004	2015	-9.5	1650	-0.9	12.3	3650	1.1
Thiruvanmiyur to Kovalam	Adyar to Karapakkam	12° 58' 58.80" N	12° 56' 27.60" N	2004	2016	-2.4	1100	-0.2	9.6	3900	0.8
	Karapakkam to Kanathur	12° 56' 27.60" N	12° 53' 49.20" N	2004	2016	-6	1600	-0.5	9.1	3400	0.8
	Kanathur to Kanathur Reddikuppam	12° 53' 49.20" N	12° 51' 18.00" N	2004	2016	-5.2	3000	-0.4	8.5	2000	0.7
	Kanathur Reddikuppam to Muthukadu	12° 51' 18.00" N	12° 48' 18.00" N	2004	2016	-4.1	1150	-0.3	17.9	3850	1.5
	Muthukadu to Kovalam	12° 48' 18.00" N	12° 45' 39.60" N	2004	2016	-25.6	2250	-2.1	22.8	2950	1.9
Kovalam to Kokilamedu	Vadanemmeli to Perur	12° 45' 39.60" N	12° 43' 04.80" N	2003	2014	-6.7	3150	-0.6	5.3	1850	0.5

	Perur to Pattipulam	12° 43' 04.80" N	12° 40' 30.00" N	2003	2014	-16.5	3900	-1.5	9.6	1100	0.9
	Pattipulam to Mahabalipuram	12° 40' 30.00" N	12° 37' 55.20" N	2003	2014	-8	4350	-0.7	1.3	650	0.1
	Mahabalipuram to Kokilamedu	12° 37' 55.20" N	12° 35' 16.80" N	2003	2014	-12.3	4550	-1.1	3.4	450	0.3
	Kokilamedu to Edaiyur	12° 35' 16.80" N	12° 33' 07.20" N	2003	2014	-28.3	3700	-2.6	12.2	3000	1.1
Edaiyur to Magaiyur	Edaiyur to Kalpakkam	12° 33' 07.20" N	12° 30' 14.40" N	2003	2015	-7.1	1900	-0.6	6.7	3100	0.6
	Kalpakkam to Meiyur	12° 30' 14.40" N	12° 27' 39.60" N	2003	2015	-57.7	2950	-4.8	13.8	2050	1.2
	Meiyur to Kadalur Periya Kuppam	12° 27' 39.60" N	12° 25' 22.80" N	2003	2015	-36.6	4800	-3.1	10.1	200	0.8
	Kadalur Periya Kuppam to Kadalur	12° 25' 22.80" N	12° 23' 09.60" N	2003	2015	-23.9	4850	-2	1.1	150	0.1
	Kadalur to Mugaiyur	12° 23' 09.60" N	12° 21' 18.00" N	2003	2015	-13.8	3500	-1.2	3.8	1500	0.3
Paramankeni to Ekkiar Kuppam	Paramankeni to Odiyur	12° 21' 18.00" N	12° 19' 04.80" N	2005	2015	-12.1	3700	-1.2	6.6	1300	0.7
	Odiyur to Edaikazhinadu	12° 19' 04.80" N	12° 48' 00.00" N	2005	2015	-18.5	4900	-1.9	4.6	100	0.5
	Edaikazhinadu to Muttukadu	12° 48' 00.00" N	12° 14' 27.60" N	2005	2015	-33.5	4300	-3.4	40.8	700	4.1
	Muttukadu to Naipenikuppam	12° 14' 27.60" N	12° 12' 18.00" N	2005	2015	-22.7	5000	-2.3	0	0	0
	Naipenikuppam to Ekkiarkuppam	12° 12' 18.00" N	12° 09' 54.00" N	2005	2015	-21.5	4750	-2.2	5.5	250	0.6
Kazhikuppam to Bommayapalayam	Kazhikuppam to Mandavi	12° 09' 54.00" N	12° 07' 30.00" N	2005	2014	-15.6	3500	-1.7	10.4	1500	1.2
	Mandavi to Koonimedu	12° 07' 30.00" N	12° 05' 13.20" N	2005	2014	-9.6	1600	-1.1	16.2	3400	1.8
	Koonimedu to Kalapet	12° 05' 13.20" N	12° 02' 52.80" N	2005	2014	-5.7	2100	-0.6	9.6	2900	1.1
	Kalapet to Bommayapalayam	12° 02' 52.80" N	12° 00' 25.20" N	2005	2014	-7.2	1300	-0.8	24.8	3700	2.8
	Bommayapalayam to Kottakuppam	12° 00' 25.20" N	11° 57' 46.80" N	2005	2014	-11.1	1400	-1.2	25.5	3800	2.8
Muthialpet to Manjakuppam	Kottakuppam to Duppuypet	11° 57' 46.80" N	11° 55' 08.40" N	2005	2014	0	0	0	36.5	5000	4.1
	Duppuypet to Pooranankuppam	11° 55' 08.40" N	11° 52' 48.00" N	2005	2014	-6.7	1350	-0.7	20.5	3650	2.3
	Pooranankuppam to Adalimedu	11° 52' 48.00" N	11° 50' 09.60" N	2005	2014	-4.8	500	-0.5	14.3	4500	1.6
	Adalimedu to Moorthikuppam	11° 50' 09.60" N	11° 47' 24.00" N	2005	2014	0	0	0	16.8	5000	1.9

	Moorthikuppam to Devanampattinam	11° 47' 24.00" N	11° 44' 42.00" N	2005	2014	-6	400	-0.7	17.6	4650	2
Manjakuppam to Parangipettai	Devanampattinam to Akkarai Gori	11° 44' 42.00" N	11° 41' 56.40" N	2003	2014	-36.2	4150	-3.3	28.4	850	2.6
	Akkarai Gori to Sangolikuppam	11° 41' 56.40" N	11° 39' 21.60" N	2003	2014	-22.9	4550	-2.1	5.4	450	0.5
	Sangolikuppam to Thammanam Petai	11° 39' 21.60" N	11° 36' 28.80" N	2003	2014	-21.9	5000	-2	0	0	0
	Thammanam Petai to Poochimedu	11° 36' 28.80" N	11° 33' 43.20" N	2003	2014	-11.8	2650	-1.1	10.1	2350	0.9
	Poochimedu to Chinnur	11° 33' 43.20" N	11° 31' 08.40" N	2003	2014	-5.7	300	-0.5	12.4	4750	1.1
Parangipettai to Pudupattinam	Puthupettai to M.G.R. Thittu Old	11° 31' 08.40" N	11° 28' 51.60" N	2003	2014	-95.5	1850	-8.7	28.6	3150	2.6
	Killai R.F.	11° 28' 51.60" N	11° 26' 42.00" N	2003	2014	-60.7	5000	-5.5	0	0	0
	Thandavarayancholanganpettai	11° 26' 42.00" N	11° 24' 10.80" N	2003	2014	-45.4	4550	-4.1	9.5	450	0.9
	Kodiyampalayam	11° 24' 10.80" N	11° 20' 31.20" N	2003	2014	-88	3300	-8	63.6	2050	5.8
Sirkazhi	Pazhaiyar	11°21'30" N	11°18'30" N	2003	2014	-40.48	4900	-3.68	8.69	150	0.79
	Kooliyar	11°18'30" N	11°16'00" N	2003	2014	-3.52	1300	-0.32	11.77	3750	1.07
	Thirumullaivasal	11°16'00" N	11°13'30" N	2003	2014	-12.43	1400	-1.13	14.74	3100	1.34
Mayiladuduthurai	Keezhamoovarkarai	11°13'30" N	11°10'30" N	2003	2015	-14.52	3900	-1.21	6.12	1100	0.51
	Pompuhar	11°10'30" N	11°08'00" N	2003	2015	-38.76	3350	-3.23	9.96	650	0.83
	Vanagiri	11°08'00" N	11°05'30" N	2003	2015	-32.88	4600	-2.74	9.84	200	0.82
	Veepanchery	11°05'30" N	11°02'30" N	2003	2015	-11.52	4450	-0.96	6.84	200	0.57
	Tharanganpadi	11°02'30" N	11°01'30" N	2003	2015	-13.92	2300	-1.16	17.4	1050	1.45
Dharmapruam	Chandripady	11°01'30" N	10°57'30" N	2006	2012	-4.2	3250	-0.7	3.48	1800	0.58
	Akkampettai	10°57'30" N	10°54'30" N	2006	2012	-2.52	1750	-0.42	4.02	3050	0.67

	Ammal Chattiram	10°54'30" N	10°52'00" N	2006	2012	-5.52	3100	-0.92	3	1250	0.5
	Thethi nagar	10°52'00" N	10°48'00" N	2006	2012	-13.44	2450	-2.24	22.86	3300	3.81
Nagapattinam	Annai nagar	10°48'00" N	10°45'30" N	2006	2014	-15.44	2550	-1.93	16.96	1850	2.12
	North poigainallur	10°45'30" N	10°42'30" N	2006	2014	-21.28	4550	-2.66	9.92	500	1.24
	Velankani	10°42'30" N	10°40'00" N	2006	2014	-20.64	4400	-2.58	4.16	300	0.52
	Prathanmaramapuram	10°40'00" N	10°37'30" N	2006	2014	-12.88	2200	-1.61	10.48	2800	1.31
	Vizhunthamavadi	10°37'30" N	10°35'00" N	2006	2014	-4.32	300	-0.54	14.72	3800	1.84
Vedaranyam	Vettaikaranirappu	10°35'00" N	10°32'00" N	2006	2014	-2.56	400	-0.32	15.12	4250	1.89
	Vellapallam	10°32'00" N	10°28'30" N	2006	2014	0	0	0	26.88	4600	3.36
	Pushavanam	10°28'30" N	10°27'00" N	2006	2014	-6.4	2050	-0.8	6	2850	0.75
	Periyakutharai	10°27'00" N	10°24'00" N	2006	2014	-10	3000	-1.25	4.16	1600	0.52
	Arucottuthurai	10°24'00" N	10°21'30" N	2006	2014	-4.56	950	-0.57	14.08	3750	1.76
Kodiyakadu	Agathiyampalli	10°21'30" N	10°19'00" N	2003	2014	-44.33	3450	-4.03	15.07	1400	1.37
	Kodiyakarai sanctuary	10°19'00" N	10°17'00" N	2003	2014	-90.86	2050	-8.26	100.87	2100	9.17
	Kodiyakkari	10°17'00" N	10°16'30" N	2003	2014	-27.28	1200	-2.48	17.38	3750	1.58
	Pachanathikulam	10°16'30" N	10°16'30" N	2003	2014	-13.75	2050	-1.25	22	2950	2
	Kodiyakadu	10°16'30" N	10°16'30" N	2003	2014	-19.69	1900	-1.79	5.17	700	0.47
Muthupet	Voimedu	10°16'30" N	10°17'30" N	2003	2014	-18.7	3200	-1.7	8.58	550	0.78
	Thulaiyapattinam	10°17'30" N	10°17'30" N	2003	2014	-27.5	4200	-2.5	8.36	600	0.76
	Muthupet R.F	10°17'30" N	10°18'30" N	2003	2014	-23.54	4200	-2.14	7.26	800	0.66
	Thuraikkadu	10°18'30" N	10°18'30" N	2003	2014	-18.7	1200	-1.7	6.93	1350	0.63

	Pudukkottigam	10°18'30" N	10°19'00" N	2003	2014	-41.91	4400	-3.81	21.45	1300	1.95
Pattukkottai	Thambikottai	10°19'00" N	10°19'00" N	2005	2014	-10.89	2600	-1.21	9.27	1250	1.03
	Thamarankottai South	10°19'00" N	10°19'00" N	2005	2014	-18.18	3900	-2.02	2.07	50	0.23
	Erippurakkarai	10°19'00" N	10°18'00" N	2005	2014	-11.79	3850	-1.31	18.72	800	2.08
	Pudupattinam	10°18'00" N	10°17'00" N	2005	2014	-9.81	3450	-1.09	14.49	350	1.61
	Palliodiaivayal	10°17'00" N	10°15'30" N	2005	2014	-11.79	4400	-1.31	28.35	100	3.15
Kattumavadi	Nayagathivayal	10°15'30" N	10°13'30" N	2005	2012	28	200	4	17.5	3900	2.5
	Villunivayal	10°13'30" N	10°11'30" N	2005	2012	-9.1	100	-1.3	49	4400	7
	Manthiripattinam	10°11'30" N	10°09'30" N	2005	2012	-19.6	1000	-2.8	38.29	4100	5.47
	Ravuttanvayal	10°09'30" N	10°06'30" N	2005	2012	-9.94	100	-1.42	43.75	5100	6.25
Manamelkudi	Subramanyapuram	10°06'30" N	10°04'30" N	2005	2013	0	0	0	68	1200	8.5
	Vadakkuammapattinam	10°04'30" N	10°02'30" N	2005	2013	-12.16	500	-1.52	63.44	4100	7.93
	Avadaiyarpattinam	10°02'30" N	10°00'30" N	2005	2013	-7.68	3200	-0.96	4.64	1700	0.58
	Vannichipattinam	10°00'30" N	09°58'30" N	2005	2013	-8.96	3900	-1.12	5.36	1000	0.67
	Ayyampattinam	09°58'30" N	09°56'30" N	2005	2013	-5.44	2300	-0.68	4.56	2800	0.57
Devakottai	Sannathi	09°56'30" N	09°54'30" N	2005	2015	-6.2	3400	-0.62	3.7	1250	0.37
	Nattanipurshakudi	09°54'30" N	09°51'30" N	2005	2015	-7.1	2650	-0.71	64.7	2350	6.47
	Maragur	09°51'30" N	09°49'30" N	2005	2015	-16.7	2700	-1.67	33.1	2250	3.31
	Pasi pattinam	09°49'30" N	09°47'30" N	2005	2015	-10.1	3400	-1.01	4.2	1600	0.42
	Thondi	09°47'30" N	09°44'30" N	2005	2015	-7.9	3850	-0.79	10.1	3400	1.01
Thiruppalikudi	Nambuthali	09°44'30" N	09°42'30" N	2005	2014	-4.41	3450	-0.49	5.04	1000	0.56
	Pudupattinam	09°42'30" N	09°44'00" N	2005	2014	-6.48	3850	-0.72	6.3	1000	0.7
	Karankadu	09°44'00" N	09°37'30" N	2005	2014	-	4150	-1.27	4.05	650	0.45

						11.43					
	Uppur	09^{0}37'30" N	09^{0}35'30" N	2005	2014	-13.23	4400	-1.47	7.38	200	0.82
	Valamavur	09^{0}35'30" N	09^{0}32'30" N	2005	2014	-16.92	3900	-1.88	13.14	450	1.46
	Pathanendai	09^{0}32'30" N	09^{0}30'00" N	2005	2014	-18.09	4550	-2.01	6.75	450	0.75
	Devipattinam	09^{0}30'00" N	09^{0}28'00" N	2005	2014	-6.3	2650	-0.7	4.86	1700	0.54
Ramanathapuram	Ilanthaikuttam	09^{0}28'00" N	09^{0}26'00" N	2005	2014	-5.31	1400	-0.59	11.43	2650	1.27
	Palanivalsai	09^{0}26'00" N	09^{0}23'30" N	2005	2014	0	0	0	17.82	5000	1.98
	Puduvalasai	09^{0}23'30" N	09^{0}21'30" N	2005	2014	-2.07	800	-0.23	7.83	4150	0.87
	Atrangarai	09^{0}21'30" N	09^{0}20'00" N	2005	2014	-11.52	1700	-1.28	12.06	3350	1.34
	Uchipulai	09^{0}20'00" N	09^{0}18'30" N	2005	2014	-3.87	650	-0.43	7.83	3600	0.87
Mandapam	Irumeni	09^{0}18'30" N	09^{0}17'30" N	2010	2013	-12.69	4400	-4.23	2.16	600	0.72
	Sattakkonvalasai	09^{0}17'30" N	09^{0}17'30" N	2010	2013	-19.59	4800	-6.53	1.68	200	0.56
	Mandapam	09^{0}17'30" N	09^{0}17'00" N	2010	2013	-5.64	3750	-1.88	3.12	2000	1.04
Pamban	Thangachimadam	9°16'28.05"N	9°17'28.21"N	2013	2014	-23.82	5300	-23.82	37.81	1600	37.81
	Sambaivillage	9°17'28.21"N	9°19'19.77"N	2013	2014	-13.3	6050	-13.3	2.93	1000	2.93
	Olakkadu village	9°19'19.77"N	9°18'50.62"N	2008	2012	-8.64	5050	-2.16	0	0	0
Rameshwaram	Rameshwaram	9°18'50.62"N	9°16'52.15"N	2008	2012	-3.72	2000	-0.93	6.32	3000	1.58
	Rameshwaram	9°16'52.15"N	9°14'3.35"N	2008	2012	-9.92	5600	-2.48	3.4	400	0.85
	Rameshwaram	9°14'3.35"N	9°12'46.71"N	2009	2010	-2.93	1000	-2.93	7.88	4050	7.88
Dhanushkodi	Dhanushkodi	9°12'46.71"N	9°10'58.83"N	2009	2010	-4.65	550	-4.65	22.22	4450	22.22
	Dhanushkodi	9°10'58.83"N	9°10'51.11"N	2009	2010	-21.9	4150	-21.9	21.73	3750	21.73
Pamban	Mukundaryar chathiram	9°10'51.11"N	9°12'54.01"N	2009	2010	-3.76	5750	-3.76	2.51	1900	2.51

	Natarajpuram	9°12'54.01"N	9°15'34.41"N	2010	2012	-18.88	3700	-9.44	9.9	1350	4.95
	Tharavaithoppu	9°15'34.41"N	9°14'44.65"N	2013	2014	-3.83	5150	-3.83	2.4	1450	2.4
	Pamban	9°14'44.65"N	9°16'28.05"N	2013	2014	-9.47	7050	-9.47	0	0	0
Mandapam to pudumnadam	Mandapam	9°16'56.46"N	9°16'36.94"N	2010	2014	-6.8	4450	-1.7	0.76	250	0.2
	Koorappalli	9°16'36.94"N	9°16'1.00"N	2010	2014	-5.4	4550	-1.4	1.76	250	0.4
	Sattakkonvalasai	9°16'1.00"N	9°15'39.82"N	2010	2014	-4.92	2500	-1.2	7.24	2500	1.8
	Nochiyurani	9°15'39.82"N	9°16'5.52"N	2010	2014	-8.968	4850	-2.2	6.96	500	1.7
	Pudumadam	9°16'5.52"N	9°16'25.51"N	2006	2014	-20.8	2400	-2.6	5.6	700	0.7
Pudumadam to keelakarai	Thalaithoppu	9°16'25.51"N	9°16'7.34"N	2005	2014	-9.9	3700	-1.1	4.95	1150	0.6
	South kudi irruppu	9°16'7.34"N	9°15'3.77"N	2009	2014	-10.5	4750	-2.1	26.45	100	5.3
	Sethu karai	9°15'3.77"N	9°15'6.93"N	2005	2014	-24.58	3850	-2.7	9.54	1200	1.1
	Sengalanooradai	9°15'6.93"N	9°14'14.28"N	2004	2014	22.3	3850	2.2	17.4	500	1.7
	Keelakarai	9°14'14.28"N	9°13'25.88"N	2005	2014	-13.86	1100	-1.5	43.29	650	4.8
Keelakarai to Mookaiyur	Ervadi	9°13'25.88"N	9°12'38.99"N	2005	2014	-14.94	1650	-1.7	9.18	1650	1
	Anpunagar	9°12'38.99"N	9°11'41.42"N	2010	2014	-8.4	3800	-2.1	17.68	1400	4.4
	Valinokkam	9°11'41.42"N	9°10'43.35"N	2010	2014	-14.4	2950	-3.6	11.08	550	2.8
	Periakulam	9°10'43.35"N	9° 8'0.88"N	2005	2014	-37.8	7600	-4.2	19.98	2350	2.2
	Mookaiyur	9° 8'0.88"N	9° 7'38.88"N	2005	2014	-17.82	3450	-2	12.51	1100	1.4
Mookaiyur to kannirajpuram	Periyanayagi puram	9° 7'38.88"N	9° 7'12.67"N	2003	2014	-9.57	1400	-0.9	7.48	1900	0.7
	Kannirajpuram	9° 7'12.67"N	9° 6'1.34"N	2003	2014	-5.39	250	-0.5	10.89	3150	1
Vembar	Vembar	9° 6'1.34"N	9° 4'32.99"N	2003	2015	-14.04	3650	-1.2	7.08	200	0.6
Pachaiyapuram	Pachaiyapuram	9° 4'32.99"N	9° 3'3.44"N	2003	2014	-5.28	800	-0.5	12.1	3350	1.1

Keelavaipar	Keelavaipar	9° 3'3.44"N	9° 0'37.05"N	2009	2015	-6.48	4150	-1.1	4.8	3250	0.8
Veppalodai	Veppalodai	9° 0'37.05"N	8°58'7.35"N	2009	2014	-17	6700	-3.4	3.695	1000	0.7
Pattanamrthor	Pattanamaruthor	8°58'7.35"N	8°54'57.74"N	2007	2015	-4.72	650	-0.6	9.76	6250	1.2
Pattanamrthor to inigo nagar	Vellaipatti village	8°54'57.74"N	8°51'26.54"N	2005	2014	-11.7	7650	-1.3	44.64	1100	5
	Inigo nagar	8°51'26.54"N	8°47'22.47"N	2005	2014	-11.52	3750	-1.3	185.67	1800	20.6
Muttayyapuram	Muttayyapuram	8°47'22.47"N	8°43'40.67"N	2005	2015	-56.7	5450	-5.7	23.4	5600	2.3
Muttayyapuram to mangalavadi	Punnaikayal	8°43'40.67"N	8°37'18.55"N	2005	2014	-25.47	9900	-2.8	23.31	5850	2.6
	Mangalavadi	8°37'18.55"N	8°33'9.15"N	2005	2014	-12.24	2750	-1.4	3.33	900	0.4
Tiruchendur	Tiruchendur	8°33'9.15"N	8°29'17.62"N	2007	2013	-28.8	5700	-4.8	9.96	4750	1.7
Alanthali	Aalanthalai	8°29'17.62"N	8°27'21.05"N	2007	2015	-11.04	1950	-1.4	7.68	2950	1
Kulasekharapatanam	Kulasekharapatnam	8°27'21.05"N	8°23'43.13"N	2005	2015	-16.8	3400	-1.7	12	4350	1.2
Pudukudiyeatru	Pudukudiyeatru	8°23'43.13"N	8°22'1.87"N	2005	2013	-7.92	700	-1	19.6	3150	2.5
Pudikudiyeatru to Periyathalai	Periyathalai	8°22'1.87"N	8°19'54.34"N	2011	2015	-13.36	5400	-3.3	8.8	4550	2.2
	Periyathalai	8°19'54.34"N	8°17'50.78"N	2009	2015	-34.8	4300	-5.8	23.52	2350	3.9
Uvari	Uvari	8°17'50.78"N	8°16'10.79"N	2005	2014	-25.92	1550	-2.9	24.57	4350	2.7
Navaladi	Navaladi	8°16'10.79"N	8°14'59.44"N	2004	2014	-3.7	400	-0.4	9	5600	0.9
Kuthenkuly melur	Kuthenkuly melur	8°14'59.44"N	8°12'2.83"N	2004	2016	-8.4	1350	-0.7	20.028	7050	1.7
Idinthakarai	Idinthakarai	8°12'2.83"N	8°10'25.38"N	2003	2016	-8.06	2700	-0.6	8.32	3100	0.6
Idanthakarai to Puthugramam	Perumanal	8°10'25.38"N	8° 9'31.90"N	2006	2016	-37.5	5450	-3.8	37	3550	3.7
	Vattakkottai	8° 9'31.90"N	8° 7'37.41"N	2006	2016	-14.1	6350	-1.4	10.9	3100	1.1
	Pudhugramam	8° 7'37.41"N	8° 4'42.61"N	2006	2016	-29	600	-2.9	7.6	150	0.8
Thengamputhoor	Thengamputhoor	8° 4'42.61"N	8° 5'27.41"N	2006	2011	-27.16	7450	-5.4	4.25	200	0.9

Chinavilai	Periyakadu	8° 5'27.41"N	8° 6'45.91"N	2005	2016	-15.18	6350	-1.4	16.17	3650	1.5
	Chinnavilai	8° 6'45.91"N	8° 8'38.43"N	2005	2016	-15.04	5550	-1.4	11.77	3350	1.1
Melmidalam	Melmidalam	8° 8'38.43"N	8°12'34.80"N	2002	2015	-25.11	9150	-1.9	29.77	3950	2.3
Neerody	Neerody	8°12'34.80"N	8°17'41.35"N	2002	2016	-26.04	12650	-1.9	35.14	2650	2.5

9.1.2 Identifying the vulnerable coast

The quality of shoreline being exposed to the natural disasters, environmental changes and anthropogenic activities is termed as the vulnerability of shoreline or the coast. Based on the erosion rate the vulnerability scale is assigned

1. Greater than 5m/yr erosion
2. Erosion between 2m/yr and 5m/yr
3. Erosion between 0 and 2m/yr
4. Accreting coast

Among the above category the coast which falls under the category 1 and 2 is considered as the most vulnerable reaches identified and tabulated in **Table 9.2** .Based on the above study the sites are selected for the field survey and are tabulated in **Table 9.3**

Table 9.2 Vulnerable reaches of Tamilnadu

Places	Latitude		Length of coast in (m)
	From	To	
Vulnerability scale:1			
North of Kattupalli	13° 21' 10.80" N	13° 18' 28.80" N	4050
Puthupettai to M.G.R. Thittu Old	11° 31' 08.40" N	11° 28' 51.60" N	1850
Killai R.F.	11° 28' 51.60" N	11° 26' 42.00" N	5000
Kodiyampalayam	11° 24' 10.80" N	11° 20' 31.20" N	3300
Kodiyakarai sanctuary	10^{0}19'00" N	10^{0}17'00" N	2050
Sambaivillage	9°17'28.21"N	9°19'19.77"N	6050
Thangachimadam	9°16'28.05"N	9°17'28.21"N	5300
Dhanushkodi	9°10'58.83"N	9°10'51.11"N	4150
Natarajpuram	9°12'54.01"N	9°15'34.41"N	3700
Pamban	9°14'44.65"N	9°16'28.05"N	7050
Muttayyapuram	8°47'22.47" N	8°43'40.67"N	5450
Periathalai	8°19'54.34"N	8°17'50.78"N	4300
Thengamputhoor	8° 4'42.61"N	8° 5'27.41"N	7450
Vulnerability scale:2			
Puzhithivakkam	13° 15' 45.00" N	13° 12' 36.00" N	1600
Muthukadu to Kovalam	12° 48' 18.00" N	12° 45' 39.60" N	2250
Kokilamedu to Edaiyur	12° 35' 16.80" N	12° 33' 07.20" N	3700
Kalpakkam to Meiyur	12° 30' 14.40" N	12° 27' 39.60" N	2950
Meiyur to Kadalur Periya Kuppam	12° 27' 39.60" N	12° 25' 22.80" N	4800
Kadalur Periya Kuppam to Kadalur	12° 25' 22.80" N	12° 23' 09.60" N	4850
Edaikazhinadu to Muttukadu	12° 48' 00.00" N	12° 14' 27.60" N	4300

Muttukadu to Naipenikuppam	12° 14' 27.60" N	12° 12' 18.00" N	5000
Naipenikuppam to Ekkiarkuppam	12° 12' 18.00" N	12° 09' 54.00" N	4750
Devanampattinam to Akkarai Gori	11° 44' 42.00" N	11° 41' 56.40" N	4150
Akkarai Gori to Sangolikuppam	11° 41' 56.40" N	11° 39' 21.60" N	4550
Sangolikuppam to Thammanam Petai	11° 39' 21.60" N	11° 36' 28.80" N	5000
Thandavarayancholanganpettai	11° 26' 42.00" N	11° 24' 10.80" N	4550
Pazhaiyar	11° 21' 11.52" N	11° 18' 34.56" N	4850
Perunthottam	11° 13' 20.28" N	11° 10' 34.68" N	5850
Pompuhar	11°10'30" N	11°08'00" N	3350
Vanagiri	11°08'00" N	11°05'30" N	4600
Tharanganpadi	11°02'30" N	11°01'30" N	2300
Thethi nagar	10°52'00" N	10°48'00" N	2450
North poigainallur	10°45'30" N	10°42'30" N	4550
Velankanni	10°42'30" N	10°40'00" N	4400
Agathiyampalli	10°21'30" N	10°19'00" N	3450
Thamarankottai South	10°19'00" N	10°19'00" N	3900
Kodiyakkari	10°17'00" N	10°16'30" N	1200
Thulaiyapattinam	10°17'30" N	10°17'30" N	600
Muthupet R.F	10°17'30" N	10°18'30" N	800
Pudukkottigam	10°18'30" N	10°19'00" N	1300
Nayagathivayal	10°15'30" N	10°13'30" N	200
Manthiripattinam	10°11'30" N	10°09'30" N	1000
Pathanendai	09°32'30" N	09°30'00" N	4550
Olakkadu village	9°19'19.77"N	9°18'50.62"N	5050
Rameshwaram	9°16'52.15"N	9°14'3.35"N	5600
Rameshwaram	9°14'3.35"N	9°12'46.71"N	1000
Dhanushkodi	9°12'46.71"N	9°10'58.83"N	550
Mukundaryar chathiram	9°10'51.11"N	9°12'54.01"N	5750
Tharavaithoppu	9°15'34.41"N	9°14'44.65"N	5150
Irumeni	09°18'30" N	09°17'30" N	4400
Sattakkonvalasai	09°17'30" N	09°17'30" N	4800
Mandapam	09°17'30" N	09°17'00" N	3750
Pudumadam	9°16'5.52"N	9°16'25.51"N	2400
South kudi irruppu	9°16'7.34"N	9°15'3.77"N	4750
Nochiyurani	9°15'39.82"N	9°16'5.52"N	4850
Sethu karai	9°15'3.77"N	9°15'6.93"N	3850
Sengalanooradai	9°15'6.93"N	9°14'14.28"N	3850
Anpunagar	9°12'38.99"N	9°11'41.42"N	3800
Valinokkam	9°11'41.42"N	9°10'43.35"N	2950
Periakulam	9°10'43.35"N	9° 8'0.88"N	7600
Mookaiyur	9° 8'0.88"N	9° 7'38.88"N	3450
Veppalodai	9° 0'37.05"N	8°58'7.35"N	6700

Punnaikayal	8°43'40.67"N	8°37'18.55"N	9900
Tiruchendur	8°33'9.15"N	8°29'17.62"N	5700
Periyathalai	8°22'1.87"N	8°19'54.34"N	5400
Uvari	8°17'50.78"N	8°16'10.79"N	1550
Perumanal	8°10'25.38"N	8° 9'31.90"N	5450
Pudhugramam	8° 7'37.41"N	8° 4'42.61"N	600

Table 9.3 Sites selected for surveying

S.No	Places	Latitude	Longitude
1	Nettukuppam	13°13'42.40"	80°19'50.12"
2	Tharankuppam	13°13'24.03"	80°19'43.13"
3	Kovalam	12°47'24.9"	80°15'12.10"
4	Kokilamedu	12°19'46.08"	80°2'42.42"
5	Bommayapalayam	11°59'36.24"	79°51'7.92"
6	Thandayarkuppam	11°58'9.06"	79°50'38.04"
7	Devanampatinam	11°42'44.82"	79°46'51.12"
8	Sangolikuppam	11°38'16.68"	79°45'47.10"
9	Periyakuppam	11°36'27.42"	79°45'29.46"
10	Pettodai	11°35'52.44"	79°45'27.42"
11	Keelaiyur	11°09'22.25"	79°51'21.28"
12	Tharangambadi	11°01'32.83"	79°51'23.04"
13	Samanthapettai	10°47'54.8"	79°51'1.81"
14	Nambiyar nagar	10°46'50.48"	79°51'2.74"
15	Kallar river	10°44'34.27"	79°51'4.33"
16	Velankanni church	10°38'35.4"	79°51'14.6"
17	Rameswaram	9°15'40.69"	79°4'10.18"
18	Dhanushkodi	9°10'13.93"	79°25'36.87"
19	Inigo nagar	8°47'9.96"	78°9'45.22"
20	Rajkahnna nagar	8°30'27.68"	78°7'33.56"
21	Kulasekarapatinam	8°24'38.27"	78°3'47.38"
22	Periyathalai	8°19'27.15"	77°57'29.63"
23	Uvari	8°17'5.81"	77°54'0.35"
24	Vallavilai	8°16'32.59"	77°7'13.22"
25	Edappadu	8°16'12.36"	77°7'40.98"
26	Eraviputhamthurai	8°16'5.20"	77°7'57.25"
27	Chinnathurai	8°15'46.02"	77° 8'17.10"
28	Helan colony	8°12'50.87"	77°11'42.40"
29	Mandaikadu	8°9'43.96"	77°16'36.40"

30	Perumanal	8°9'32.34"	77°38'49.68"
31	Chothuvalai	8°5'37.90"	77°27'16.24"
32	Melamanakudi	8°5'22.63"	77°28'48.43"
33	Kovalam	8°4'54.34"	77°31'28.60"

CHAPTER 10
COASTAL SURVEY

10.1 GENERAL

Although the vulnerable locations, i.e., zones of perennial erosion, river mouth closures, need for preserving flora and fauna, ports and harbours, etc can be derived to a certain degree of accuracy, a coastal survey at least with minimum instruments to assess the ongoing stability of the shoreline, activities along the coast, the probable impact of future activities on the adjoining shoreline, its behaviour during extreme events will be very important for an effective SPMP. In this chapter, the details of such an exercise carried out during Jan and Feb 2016 are presented and discussed in part1, whereas, part 2 provides the results from the analysis of beach profiles taken over the past few years.

10.2 MEASUREMENT AND ANALYSIS OF BEACH PROFILES

The measurement and analysis of the beach profiles and sediment grain size at the vulnerable locations based on the coastal survey during mid-Jan 2016 to Feb 2016 are discussed in this **part.**

Ernavur (Nettukuppam 13°13’42.40”N80°19’50.12”E)

The stretch of the coast of Nettukuppam is shown in **Fig.10.1a.** A clear view of the northern region of Nettukuppam that is continued as a seawall on the sea front is shown in **Fig.10.1b.** The conventional seawall to be given due to densely populated region. The conventional seawall with a crest elevation of +5.2m is recommended to avoid storm-surge overtopping when the surge occurrence coincides with high tide, the overtopping and erosion leading the damage to the seawall could be high. Erosion in Nettukuppam is shown in **Fig.10.1c.**

Solution suggested: *A groin field designed through detailed scientific studies with existing bathymetry and shoreline morphology would serve the purpose. The existing seawall needs a careful examination and at locations of distress, it has to be rehabilitated.*

Fig.10.1a Mouth region of Nettukuppam

Fig.10.1b North region of Nettukuppam

Fig.10.1c Erosion in Nettukuppam in 2012.

Tharankuppam (13°13'24.03"N 80°19'43.13"E)

The stretch of the coast off Tharankuppam is shown in **Fig.10.2**.The gap between two seawall ends has resulted in erosion, the details of which has been discussed earlier. A perfect road is also available up to this beach, which may be quite suitable for the development of a fish landing centre and also prevent further coastal erosion.The gap between the tips of the seawalls can be utilised for developing the stretch into small fish landing centre by providing a pair of training walls.

Solution suggested: *A pair of groins designed through detailed scientific studies with existing bathymetry and shoreline morphology could be the solution.*

Fig.10.2 Mouth region of Tharankuppam

Kovalam(12°47′24.9″N 80°15′12.1″E)

The stretch of the coast off Kovalam is shown in **Fig. 10.3a**.A bay like formation, from north of the above location has formed and this formation as per the local public appears to be eroding since 2007 at a rate of about 5m/year. This bay formation is likely due to the outcrops on its south acting as a natural littoral barrier. As regard to the coastal protection, it is suggested to tame the waves and the sediment transport by providing groins as tentatively shown in the above figure. The solution suggested can proveto serve as an efficient coastal protection as well as allow the local fishermen to use the bay on the legsideto the southern groin as a mini harbour. A perfect road is also available up to this beach, which may be quite suitable for the development of a fish landing centre and also prevent further coastal erosion. However, this needs further assessment as regard to the Cost – Benefit analysis. A detailed numerical modelling is absolutely essential to conclude the protection measure.

Sediment samples have been collected along the beach, the results from the sieve analysis is shown in **Fig.10.3b**, whereas, the variation of the beach slope along this stretch of the coast is shown in **Fig. 10.3c.**

Solution suggested: *A field of short groins designed through detailed scientific studies with existing bathymetry and shoreline morphology would serve the purpose. It is recommended to provide a pair of training walls for training the mouth of Mutukadu backwater.*

Fig.10.3a Beach profile Left (North) of yellow temple

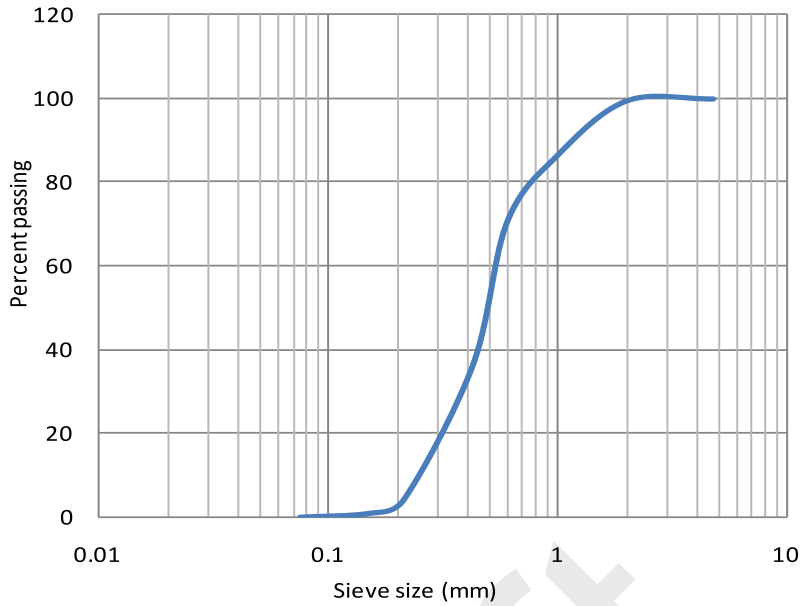


Fig.10.3b Grain size distribution along Kovalam

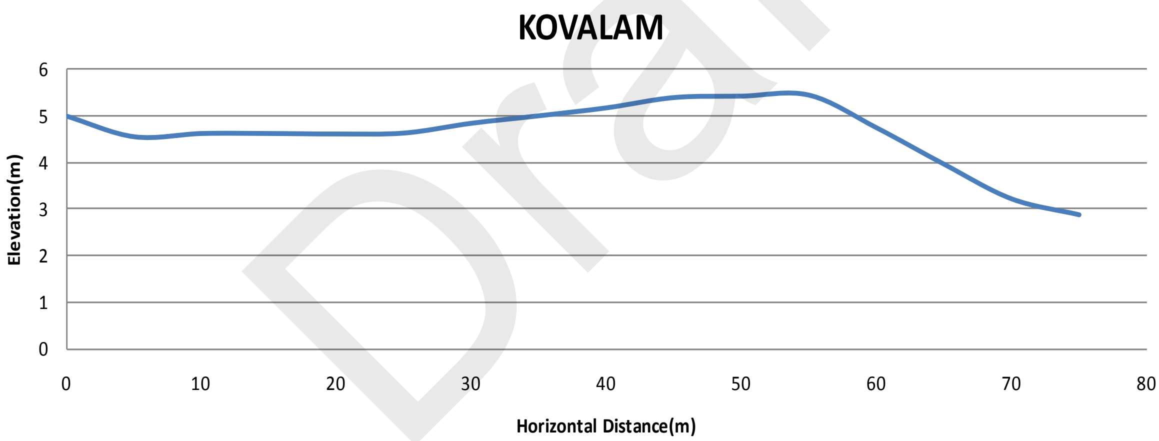


Fig.10.3c Beach profilealong Kovalam

Kokilamedu (12° 19.768'N80° 2.707'E)

This stretch of the coast on the north shown in **Fig.10.4a** although experiences erosion to the tune of 5m/yr as it is presently inhabited only by about 800 people, as many of them have moved to safer place, for instance, to Edaikkadu. The protection measure can be considered under the phase II of the highly vulnerable locations. Only in the event the local public express anxiety, should this stretch be taken up for protection. A groin field of short groins could be planned for this stretch so that the pockets in between the groins filled with sand due to littoral drift can be used for landing small fishing boats.The south of the stretch of the coast is shown in **Fig. 10.4b**. The Sediment collected along the beach, the results of which from the sieve analysis is shown in **Fig.10.4c**, whereas, the variation of the beach slope along this stretch of the coast is shown in **Fig. 10.4d.**

Solution suggested: *A groin field designed through detailed scientific studies with existing bathymetry and shoreline morphology would serve the purpose. However, this could be taken up under priority II or III since along this stretch of the coast, there is no habitation due to resettlement.*

Fig.10.4a Beach profileNorth of Kokilamedu

Fig.10.4b Beach profile South of Kokilamedu

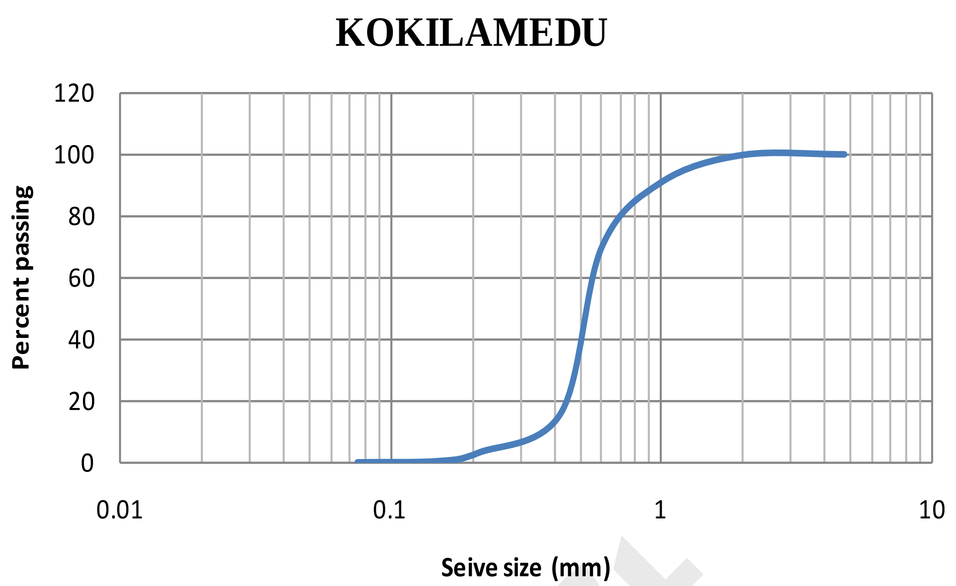


Fig.10.4c Grain size distribution along Kokilamedu

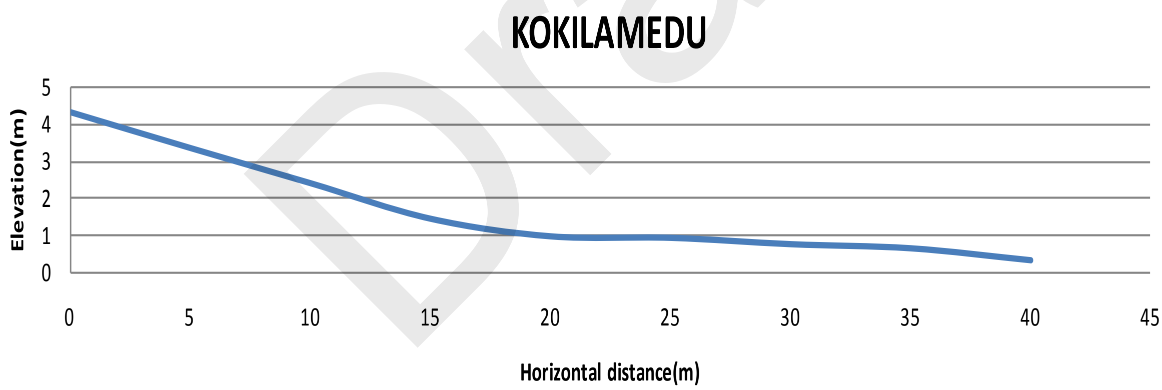


Fig.10.4d Beach profilealongKokilamedu

Edaikkadu

Although the rate of erosion is 6m/yr, as this stretch is not inhabited, at present protection measure need not be considered as several other stretches can be given priority.

Bommayapalayam(11° 59.604'N 79° 51.132'E)

This stretch of the coast has been experiencing erosion at a rate of 5m/yr over a length of about 3.5km. As the longshore drift is dominant along this stretch, a carefully designed groin field could be a solution. The beach formed in between the groins could be used the landing of fishing boats.Slightly south of this location groin field has proved to be very effective in protecting the coast as well as resulting in beach formation. Unfortunately, without any design principles or concepts, Palmyra trees have been driven into the sea bed **(Fig.10.5a)**, which in fact is bound to accelerate scour particularly during the down wash of the waves from the beach towards the Sea. The beach on the north of the measurement point exhibits a much flatter beach as can be seen in **Fig. 10.5b**. The beach profile in the south is observed to be steeper. The practice of driving logs of wood into the seabed parallel to the shoreline should be avoided and instead, the Palmyra trees could be tried normal to the shoreline and placed as close as possible in two rows as they can act as groins. An example of such a protection adopted in the Baltic Sea as a semi-permanent measure is seen in **Fig. 10.5c**. Sediment samples have been collected along the beach, the results from the sieve analysis is shown in **Fig.10.5d**, whereas, the variation of the beach slope along this stretch of the coast is shown in **Fig. 10.5e.**

Solution suggested: *A series of short transition groins after critical investigation is recommended as the alongshore drift along this stretch can be trapped and the lost beach could be won.*

Fig.10.5a Beach profileSouth of Bommayapalayam

Fig.10.5b Beach profile north of Bommayapalayam

Fig.10.5c Two rows of wooden logs driven into the seabed normal to the shoreline act as groin field.

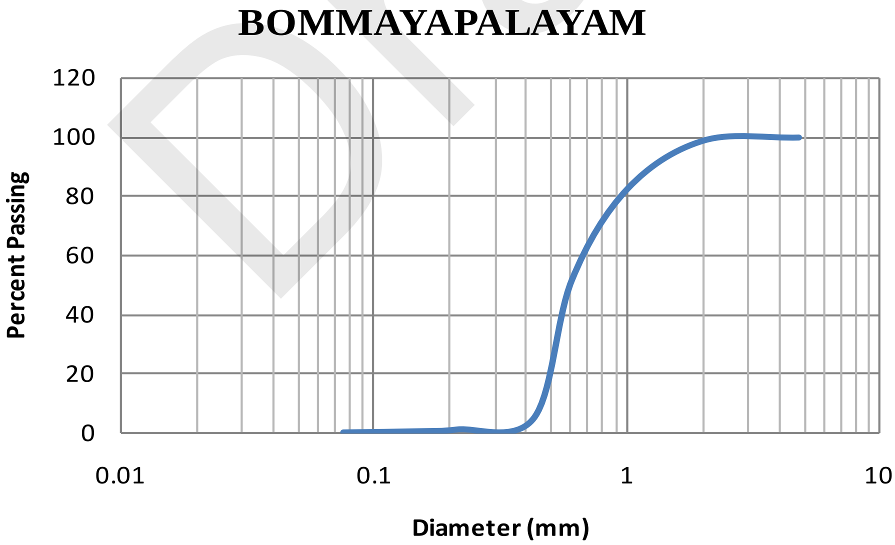


Fig.10.5d Grain size distribution along Bommayapalayam

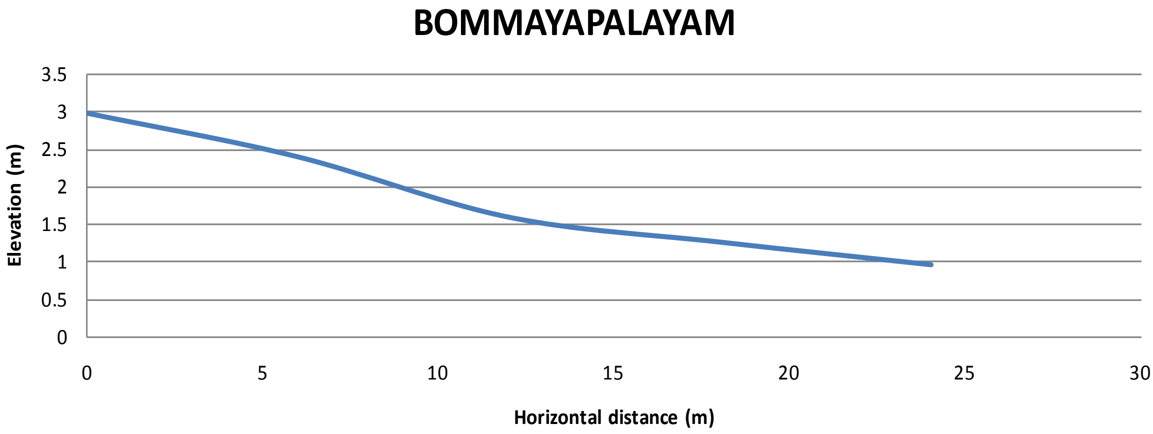


Fig.10.5e Beach profilealong Bommayapalayam

Thandarayarkuppam(11° 58.151'N 79° 50.634'E)

A stretch of about 3.5km north of this village (muthialpet, mudaliarchavadi, bommayapalyam) is densely populated. During the post tsunami period the damages near this village was heavy as reported Sundar (2005) in his report on protection measures for Tamilnadu coast soon after tsunami of 2004. Two long groins along with two short groins have been laid. The basis for the design of this groin field is unknown. In spite of erosion caused at certain pockets and only during certain months, beaches have been formed in between the groins, however they are irregular. As the heads of the groins have not been completed, they are in distress and likely to be sacrificed to the ocean waves. The head of the groins have almost vanished, but groin is intact and problem is aggravated by the neighbouring Palmyra tree trunks that have been laid as possible protection measure. The trunk of the groin is intact as can be seen in **Fig. 10.6.**The grain size as well as the beach slope is similar to that observed at Bommarayapalayam. As the layout of the groin field was improperly fixed and executed, we observe the inefficiency of the groins in giving us a good beach.

Solution suggested: *The solution to this problem is to immediately take up rehabilitation of the groins in distress and also carry out a scientific study to assess its effectiveness and arrive at a solution that could protect the coast as well as accelerate the formation of beach. The lengths and spacing between groins will only be given after a detailed scientific study.*

Fig.10.6 Trunk of the groin

Devanampattinam(11° 42.747'N 79° 46.852'E)

The beach slope is very flat as can be in **Figs. 10.7a** and **10.7b.**This location less inhabited experiences erosion and advancement of shoreline. This is due to the northern breakwater of the cuddaloreport, which port is an open roadstead (anchorage) Port situated at the confluence of the rivers Uppanar and Paravanar. This stretch of the coast has been experiencing severe erosion as a perineal problem as well as suffered severe problem during the tsunami 2004. a few pictures of the damages suffered are shown in **Fig. 10.7c**. The shoreline keep oscillating due to the variation in the direction of littoral drift. Sediment samples have been collected along the beach, the results from the sieve analysis is shown in **Fig.10.7d**, whereas, the variation of the beach slope along this stretch of the coast is shown in **Fig. 10.7e.** This stretch of the coast experiences flooding during extreme coastal events and as such the priority for coastal protection may be low. This stretch also includes **Akkavai.**

Solution suggested: *Coastal bund with geo textile tube as core layer beyond 50 m from the shoreline could be the solution.*

Fig.10.7a Beach profile North of Devanampattinam

Fig.10.7b Beach profile south of Devanampattinam

Fig.10.7c Damages along the coast of Devanampattinam

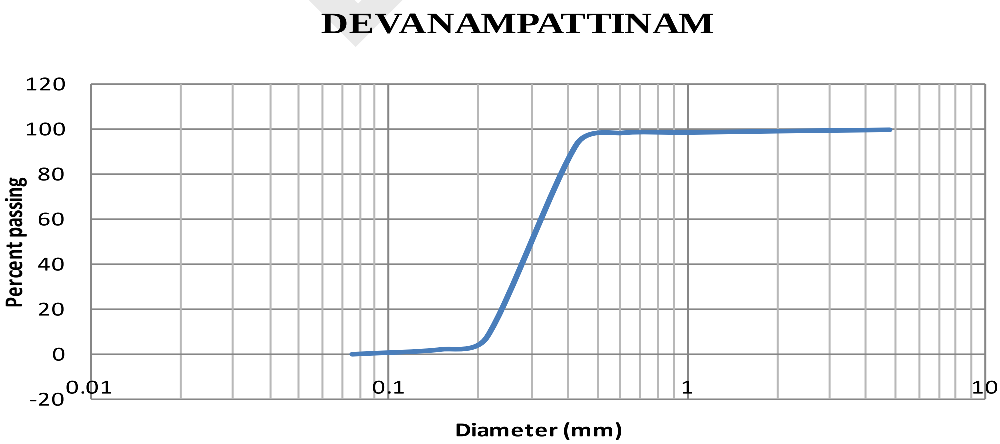


Fig.10.7d Grain size distribution along Devanampattinam

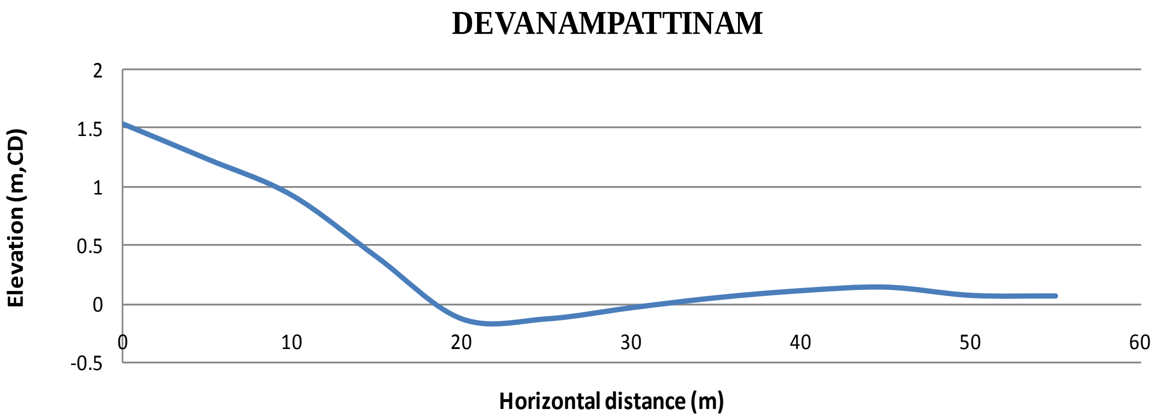


Fig.10.7e Beach profile along Devanampattinam

Sangolikuppam(11° 38.278'N 79° 45.785'E)

Although, beach formation is observed in Jan 2016 (non-monsoon season), this stretch of the coast has been experiencing erosion to an extent of 5m per year. An unused offshore jetty to the observation point does not act as a littoral barrier as it is supported on piles, thus, allowing free passage of sediments alongshore. Views of the beach along the north and south of the measurement location are projected in **Figs.10.8a**and **10.8b** respectively.

Fig.10.8a Beach profile north of Sangolikuppam

Fig.10.8b Beach profile south of Sangolikuppam

. Sediment samples have been collected along the beach along Chittharapettai close to Sangolikuppam, the results from the sieve analysis is shown in **Fig.10.8c** , whereas, the variation of the beach slope along this stretch of the coast is shown in **Fig. 10.8d.**

Solution suggested: *It is believed that considerable inundation during monsoon upto a distance of about 1km is a bit common. A soft solution like geo-textile tube/ containers on the backshore could be adopted, so that the beach front could be effectively been used for beach landing of fishing vessels.*

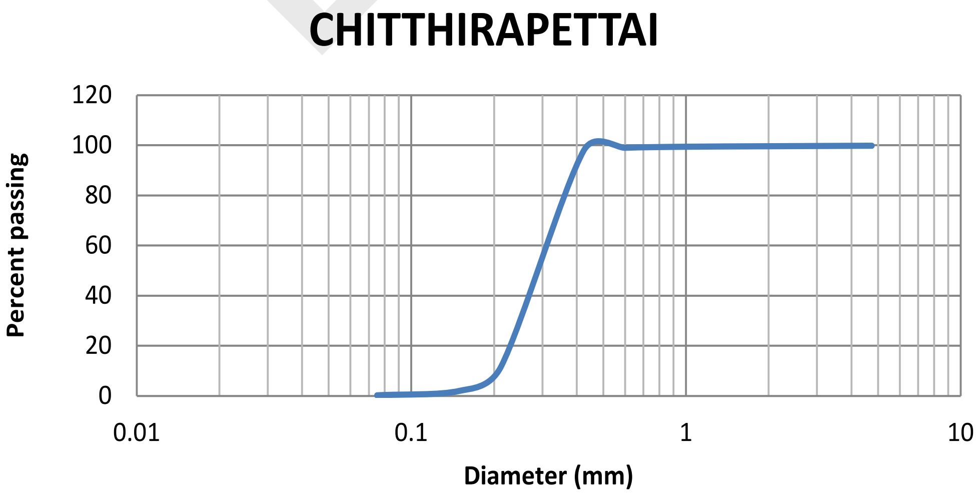


Fig.10.8c Grain size distribution along Chittharapettai

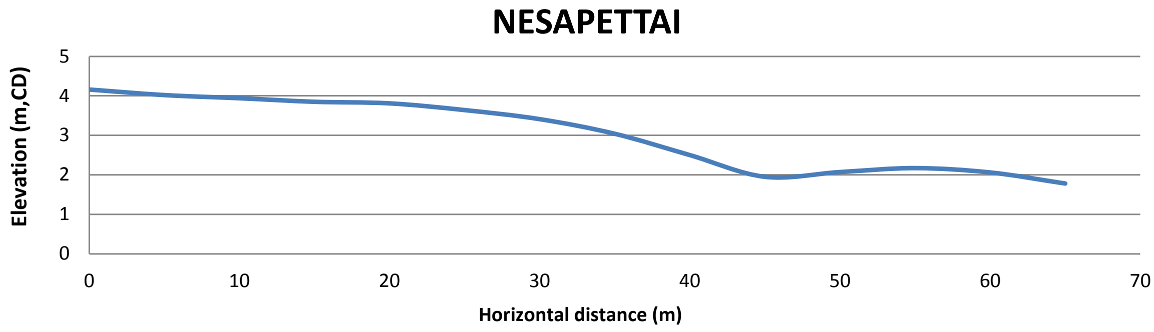


Fig.10.8d Beach profilealongChittharapettai

Periyakuppam(11° 36.457'N 79° 45.491'E)

This stretch of the coast with flat beach as seen in **Figs. 10.9a** and **10.9b** is very badly affected by erosion. Buildings and an existing fishing jetty have been demolished due to erosion and flood beach as can be seen in **Figs.10.9c** and **10.9d.**

Flat seawall and groins or a flat seawall may be enough. A picture showing the IITM team carrying out the survey is projected in **Fig. 10.9e.**

Solution suggested: *Flat seawall (either hard or soft solution) with proper toe protection may be considered to avoid water inundation during severe monsoon. In addition, a series of short groins would provide as erosion prevention measure.*

Fig.10.9a Beach profile north of Periyakuppam

Fig.10.9b Beach profilesouth of Periyakuppam

Fig.10.9c Demolished buildings

Fig.10.9d Demolished buildings

Fig.10.9e Site inspection (12 Jan 2016)

Sediment samples have been collected along the beach along Periyakuppam close to Sangolikuppam, the results from the sieve analysis is shown in **Fig.10.9f**, whereas, the variation of the beach slope along this stretch of the coast is shown in **Fig. 10.9g.**

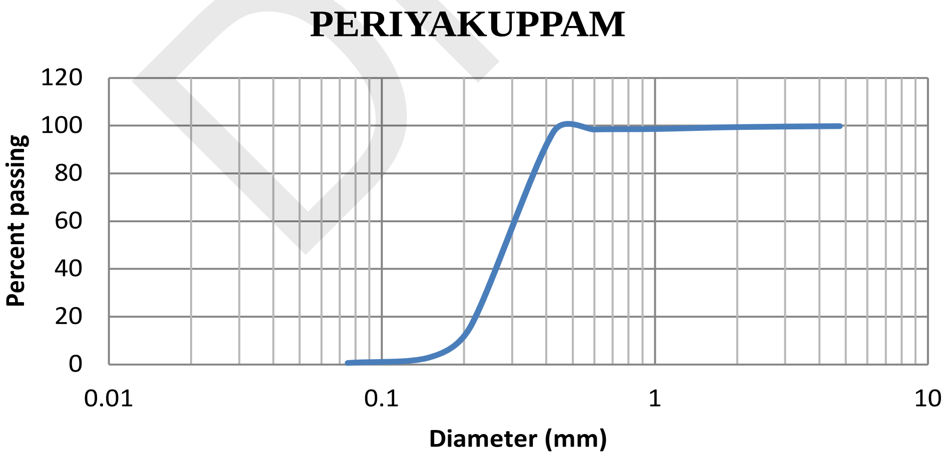


Fig.10.9f Grain size distribution along Periyakuppam

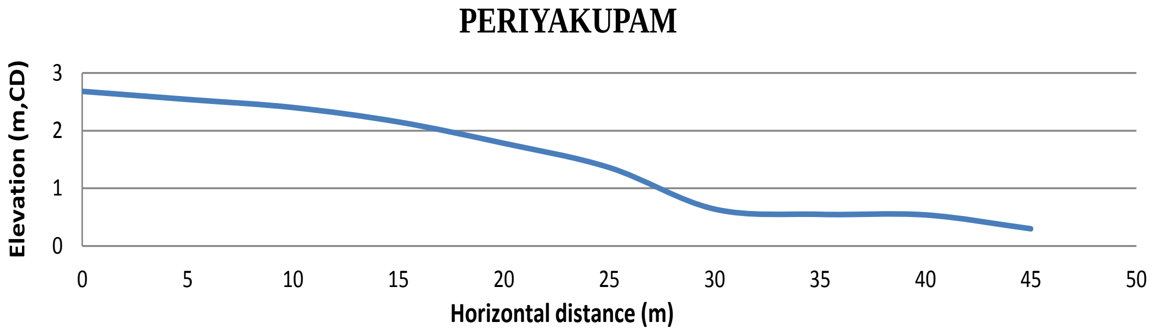


Fig.10.9g Beach profilealongPeriyakuppam

Pettodai(11° 35.874'N 79° 45.457'E)

On either side of location (North and South), significant erosion and damages to buildings as seen in **Figs. 10.10a** and **10.10b** remain a threat to the coastal community (highly inhabited) and in the event of an extreme coastal hazard, the threat can be manifold and hence protection measure to this stretch is essential.

Solution suggested: *A flat Seawall is preferred for this stretch of the coast and is given top priority. The toe of the seawall should be wide enough to reduce wave run-up.*

Fig.10.10a Beach profile North of Pettodai

Fig.10.10b Beach profileSouth of Pettodai

Sediment samples have been collected along the beach along Pettodai close to Sangolikuppam, the results from the sieve analysis is shown in **Fig.10.10c**, whereas, the variation of the beach slope along this stretch of the coast is shown in **Fig. 10.10d.**

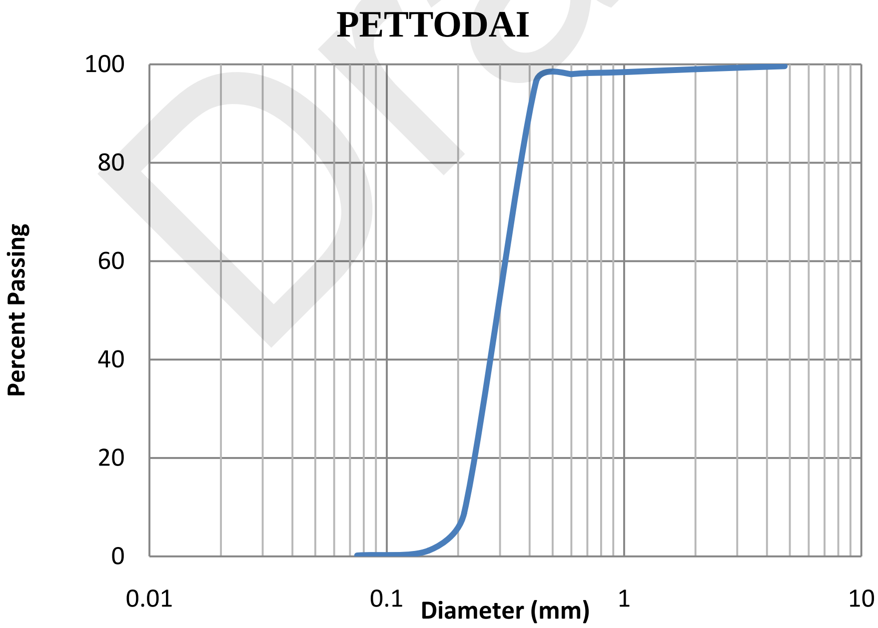


Fig.10.10c Grain size distribution along Pettodai

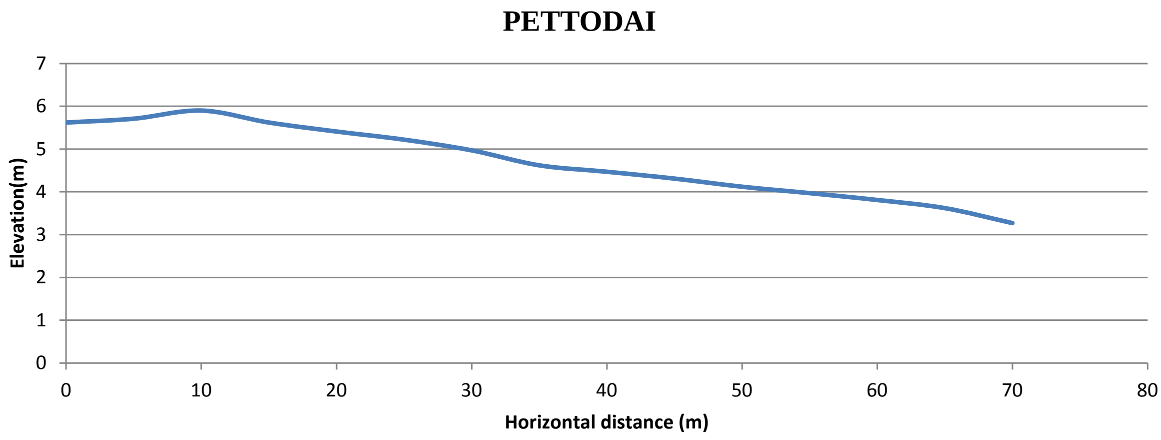


Fig.10.10d Beach profilealongPettodai

Keelaiyur (North of Poompuhar fishing harbour)(11°09'22.25"N 79°51'21.28"E)

The newly constructed northern breakwater of Poompuhar fishing harbour has resulted erosion to an extent of about more than 5m/year **(Fig.10.11a)** . The erosion is found to occur over an extent of 1km. The measured beach profile along the eroding area as well as the grain size distribution are projected in **Fig.10.11b** and **10.11c** respectively. Since there is no habitation along this stretch of this coast, a seawall that could prevent further loss of land and this measure could be considered only after the completion of first two priorities suggested in this report.

During the construction of the fishing harbour, the storm water drainage channel has been diverted on the north of northern breakwater. This might be properly trained to avoid inland inundation. This should be taken as a part of the fishing harbour development.

Solution suggested: *The storm water drainage should be properly diverted into sea to avoid flooding inland.*

Fig.10.11a View of the eroding shoreline on the north of northern breakwater of Poompuhar fishing harbour. Photo also shows the diverted drainage channel behind the harbour.

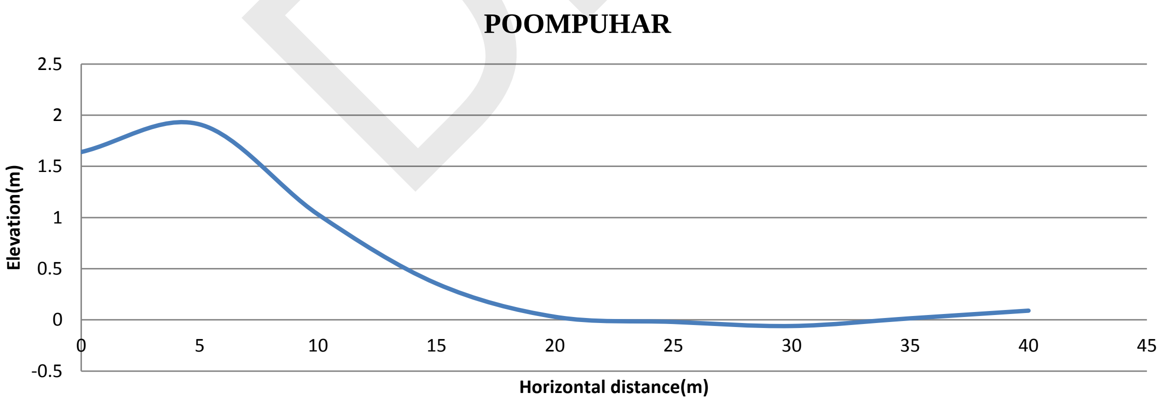


Fig.10.11b Measured beach profile for the south of the fort along the coast.

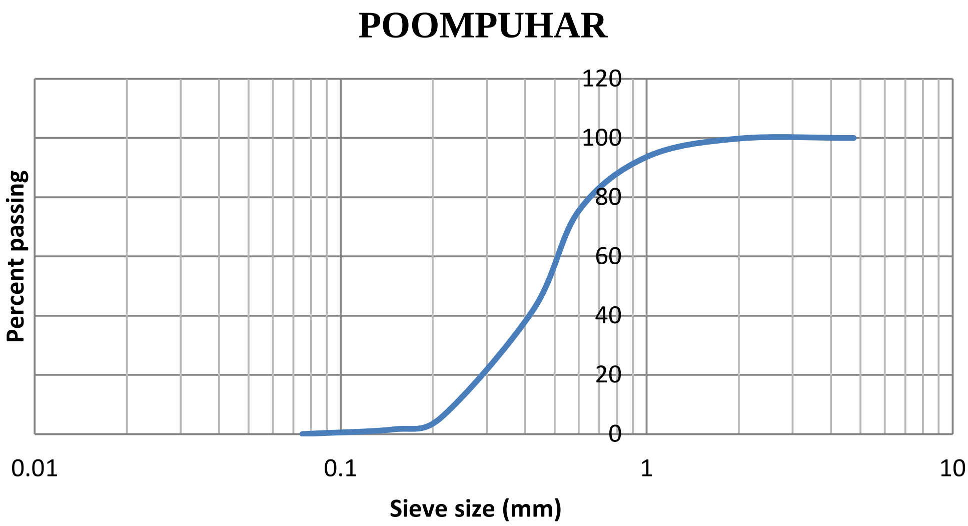


Fig.10.11c Measured grain size distribution for the south of the fort along the coast

Cauvery river confluence region (south of Poompuhar fishing harbour)

A pair of training walls has been constructed at the mouth of Cauvery in-fall **(Fig 10.12a)**. There are five groins along with seawall has been constructed on the north and south of mouth without any scientific studies. A view of a groin on the south of Cauvery confluence point is shown in **Fig.10.12c**. On the north of the mouth and behind the seawall, the available space is best suitable for plantations so that Department of Environment could consider this site for the said purpose **(Fig.10.12b)**.

Solution suggested: *An effect can be put in considering the concepts of dredging the river mouth using the dredged spoil to fill geo-textile tubes that may be considered to serve as training walls. A detailed scientific study is required prior to implementation.*

Fig.10.12a View of the pair of training walls at Cauvery confluence point

Fig.10.12b View of the location suitable for plantation which is behind the seawall

Fig.10.12c View of a groin on the south of Cauvery confluence point

Tharangambadi (Tranquebar) (11°01’32.83’’N, 79°51’23.04’’E)

Tharangambadi is a historically important site having a Fort museum and Masilanathar temple on the shore. The shoreline had advanced into the land in the past decades and swallowed the part of the temple and few historically important buildings. The remnants of the buildings in the nearshore witness the severity of the erosion in this location. There is a single groin constructed at the foot step of the main shrine of the temple which extends about 100m into the sea. In addition, the seawall that has been constructed from the temple site towards north for a stretch of about 1km in 2007-2008 is found to be stable without any maintenance for the past several years. However, there is no sand movement in front of the seawall as well as on either side of the existing groin in front of the temple and on either side of the existing remnants of an old building serving as a littoral barrier. However, the coastline south of the Fort museum is carved in for about 100m into the land. Views of the remnants of existing building acting as a littoral barrier, the existing groin in front of the Masilanathar temple and the Fort museum, existing seawall and the remnants of the building on the south of the Masilanathar temple, existing seawall on the north of the

Masilanathartemple and shoreline intrusion on the south of Fort museum up to Uppanaar river mouth are all shown in **Figs.10.13a**, **10.13b**, **10.13c**, **10.13d**, **10.13e** and **10.13f**respectively.The variation of measured beach profile and grain size distribution for south of the fort area of the coast are shown in **Figs.10.13g** and **10.13h** respectively.

Solution suggested: *In order to save the Fort museum and also regain stability of unprotected stretch including the stretch of Uppanar river mouth, seawall and revetment are recommended. A short training wall at the Uppanar river mouth may be considered as a last priority after monitoring the shoreline.*

Fig.10.13a View of the remnants of existing building that act as littoral barrier in front of the Fort museum in Tharangambadi

Fig.10.13b View of the existing groin in front of the Masilanathar temple in Tharangambadi

Fig.10.13c View of the Fort museum showing the shoreline erosion reaches its boundary

Fig.10.13d View of the existing seawall and the remnants of the building on the south of the Masilanathar temple in Tharangambadi

Fig.10.13e View of the existing seawall on the north of the Masilanathar temple in Tharangambadi

Fig.10.13f View of the shoreline intrusion on the south of Fort museum uptoUppanaar river mouth

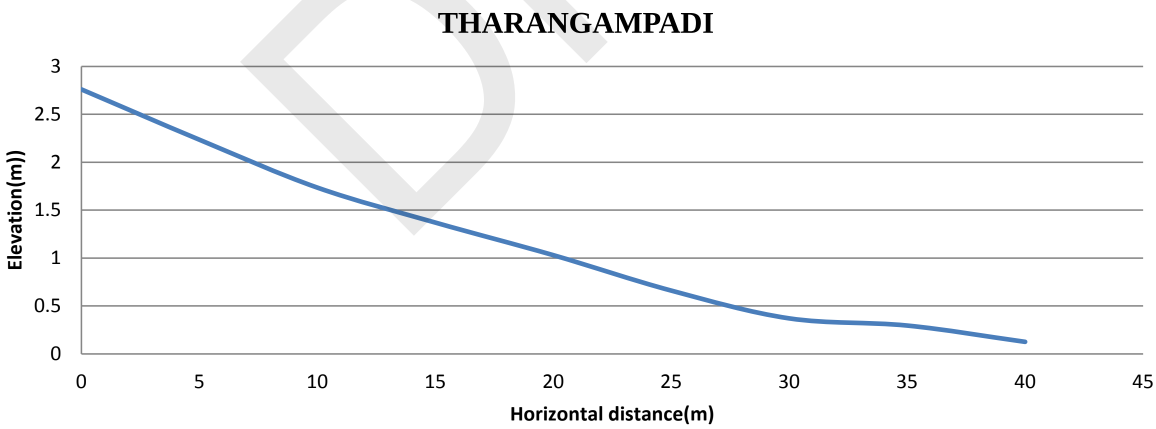


Fig.10.13g Measured beach profile for the south of the fort along the coast.

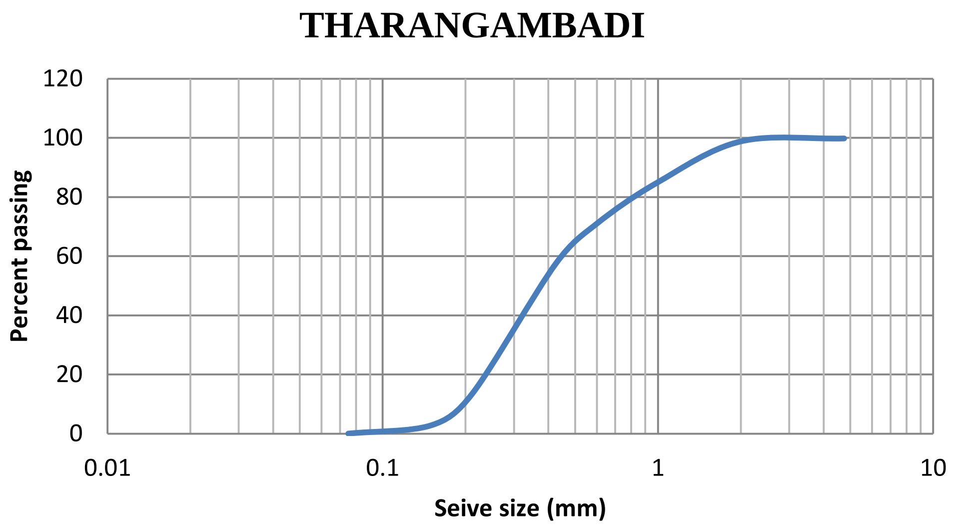


Fig.10.13h Measured grain size distribution for the south of the fort along the coast

Samanthanpettai (10°47'54.8"N, 79°51'1.81"E)

Samanthanpettai is an another fishing village with a flat beach front. The northern and southern coastal stretch of Samanthanpettai are Fig **10.14a** and **10.14b** respectively. The measured beach profile along the north and south of this stretch of the coast is shown inFigs.**10.14c** and **10.14d** respectively. The grain size distribution for this stretch is shown in Fig. **10.14e**. There are about one hundred boats landing on the beach. There are many dwelling units located about 100m from the shoreline landwards. Due to the flat topography of 150m wide corridor on its immediate southern side, the surge makes it into the land and inundates the entire habitat from all possible directions.

Solution suggested: *A coastal bund using soft structures to prevent water ingress is an immediate mitigation measure with* ***the first priority****. Further, a series of T-groins for a stretch of 600m might prevent the loss of beach width over the years. The latter may be considered under* ***priority 3.***

Fig.10.14a Samanthanpettai southern coastal stretch

Fig. 10.14b Samanthanpettai northern coastal stretch

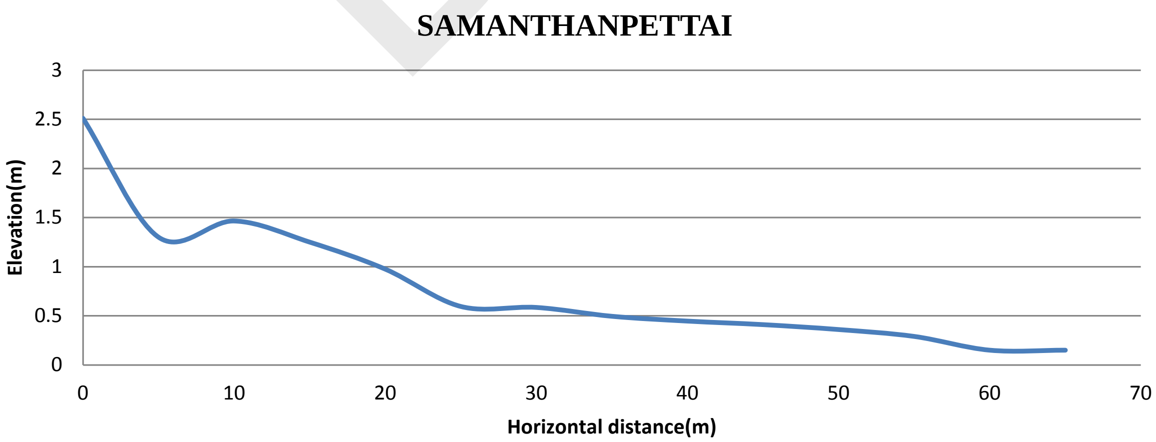


Fig. 10.14c Measured beach profile north of Samanthanpettai

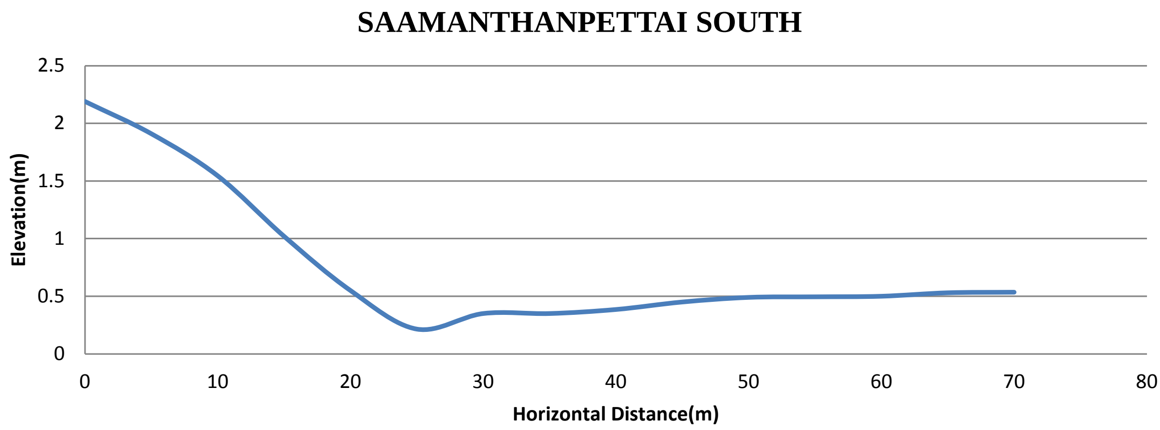


Fig. 10.14d Measured beach profile south of Samanthanpettai

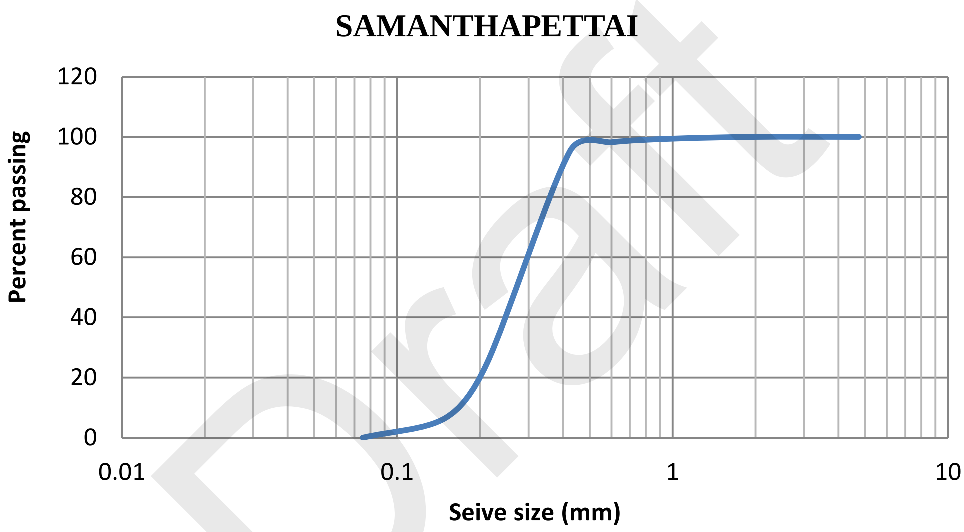


Fig.10.14e Grain size distribution near Samanthanpettai

Nambiyar nager (10⁰46’50.48’’N, 79⁰51’2.74’’E)

There are several boats parked along the coast is shown in Fig **10.15a**. The length of stretch of coast along the Nambiyarnagar is about 800m. This stretch had suffered huge damage during the tsunami. This is a part of the stretch of 6km from Kadavayar river to Nagore that was damaged heavily during the Tsunami for which groin filed was recommended in 2005. At present, for combating the perennial erosion alone, a transition T-groin field in this densely populated coastal villages would function well and the beaches formed in between the groins could serve as a useful shelter for landing the boats on the beaches. This coastal stretch is further extended on its north with: a beach front for about 500m long; and dense vegetation for a length of 600m. For this stretch **'do nothing'** could probably be a solution. Beyond this point northwards, we have the Samanthapettai village that covers a stretch of 600m. The measured beach profile and grain size distribution for this stretch are shown in Figs. **10.15b** and **10.15c** respectively.

Solution suggested: *Can adopt wait and watch strategy before venturing into an engineering mitigation measure.*

Fig.10.15a Nambiyarnagar coastal stretch.

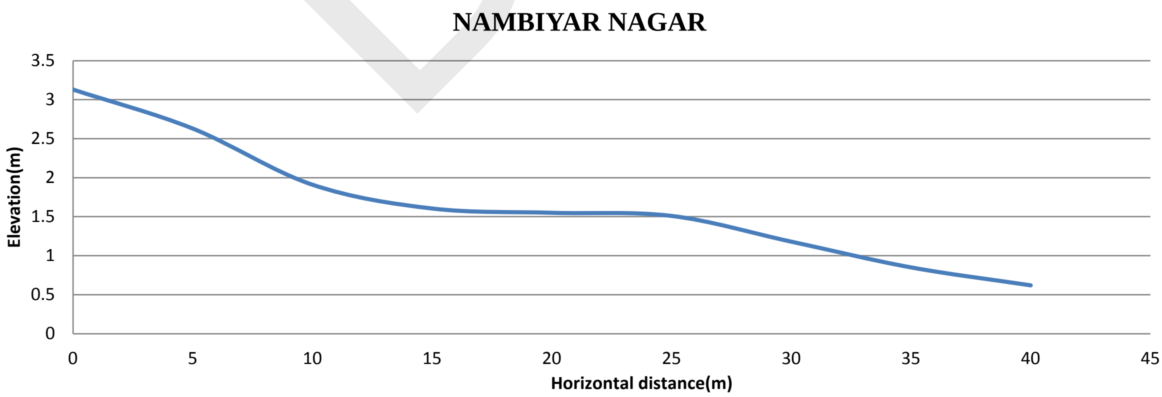


Fig.10.15b Beach profile near Nambiyar Nagar

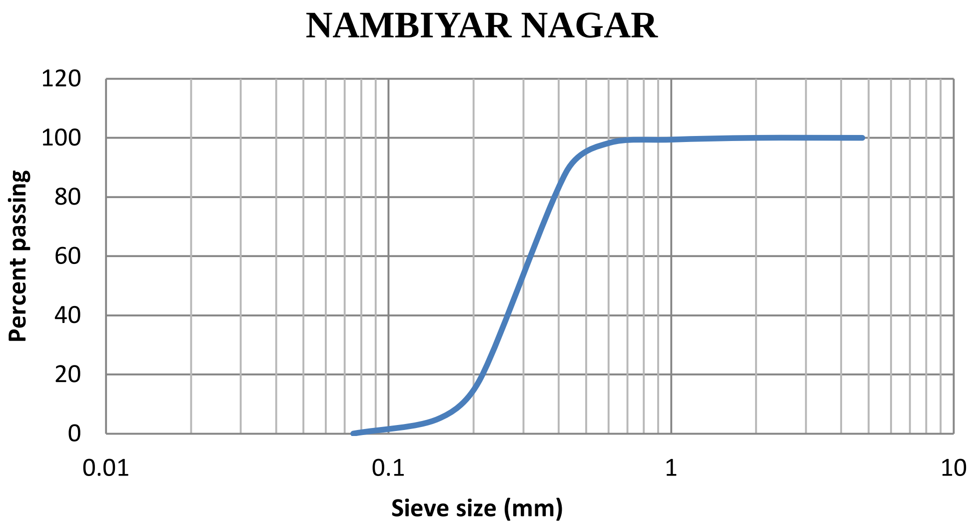


Fig.10.15c Grain size distribution near Nambiyarnagar

Kallar river mouth (10°44'34.27"N 79°51'4.33"E)

A view of the Kallar river mouth along with partly exposed bank protection is shown in Fig **10.16a**. A clear view of the bank protection on the northern bank of Kallarriver that is continued as a seawall on the sea front is shown in Fig **10.16b**. In between Kallar and Kaduvaiyar, conventional seawall to be given due to densely populated region. The conventional seawall with a crest elevation of +4.3m is recommended to avoid storm-surge overtopping when the surge occurrence coincides with high tide, the overtopping and erosion leading the damage to the seawall could be high. The existing seawall needs a careful examination and at locations of distress, it has to be rehabilitated. The training wall on the Kallar river mouth may be considered and the decision of which depends on the performance of the present revetment at the river mouth. The dredging needs to be carried out as a first step in order to minimise or avoid upland flooding and the training works is necessary only if the dredging is not sufficient to keep the mouth open.

Solution suggested: *An effect can be put in considering the concepts of dredging the river mouth using the dredged spoil to fill geo-textile tubes that may be considered to serve as training walls. A detailed scientific study is required prior to implementation.*

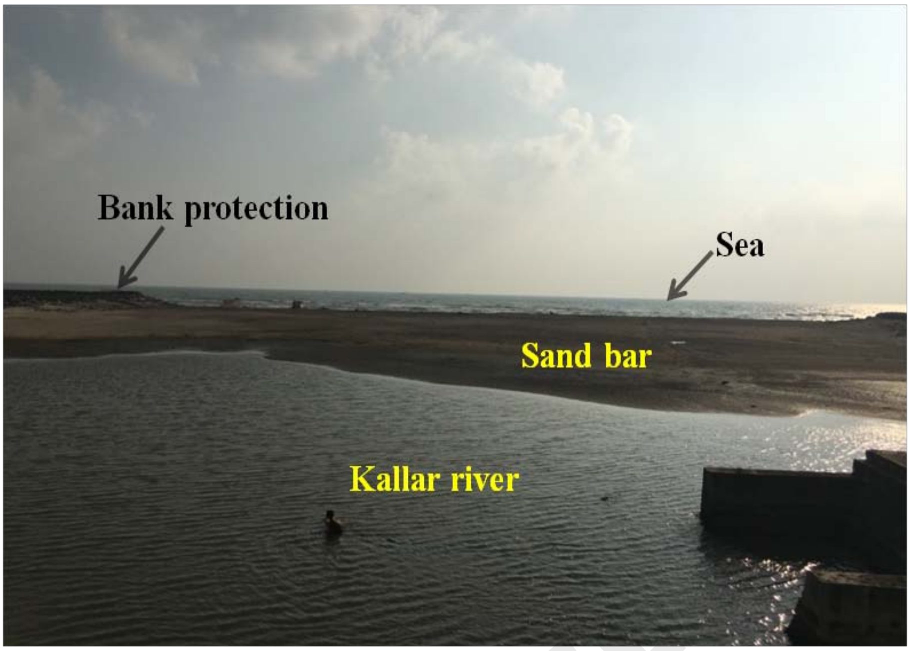


Fig.10.16a View of Kallar river mouth from upstream

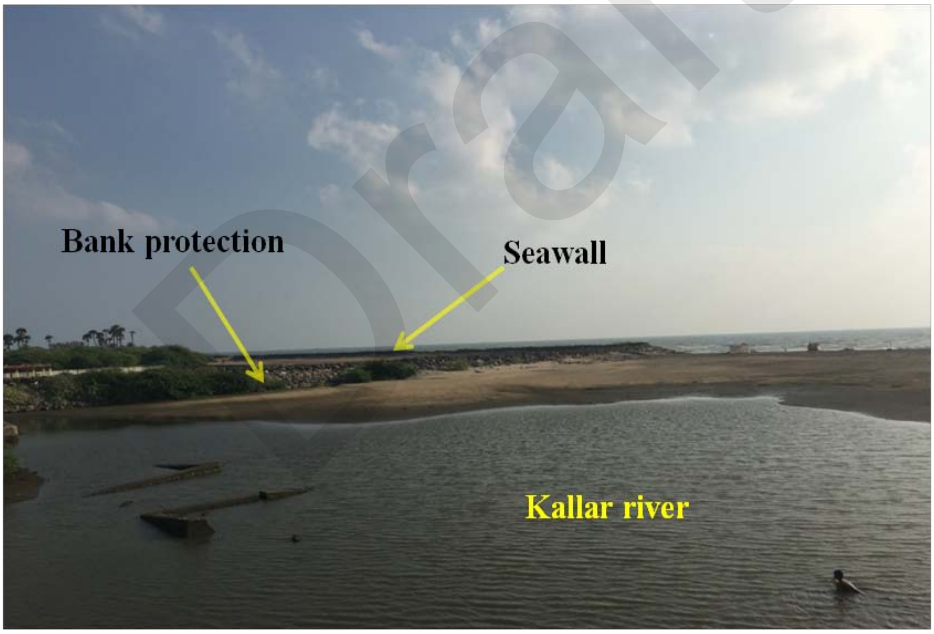


Fig.10.16b View of Kallar river mouth along with the seawall in front of the beach on the north of the mouth

Velankanni church (10°38'35.4"N 79°51'14.6"E)

The stretch of coast on the north of the vellar river mouth is characterised by its flat beach which attracts the tourists on a regular basis .This stretch of the coast although affected badly during the tsunami 2004 has been quite stable with a occasional oscillation. A view of coastal stretch towards south along the southern Velankanni shoreline is shown in**Fig. 10.17a**. Beach needs to be conserved and any hard structure should be avoided.

The Vellaiyar river mouth requires a pair of training walls. Further, the river needs to be dredged and the dredged spoil either can be used to nourish the beach on the north or can be used to fill geo-textile tube which could probably run parallel to shoreline to serve as a protection against possible erosion, the schematic representation of which is shown in **Fig.10.17b**. **This site could be taken up as third priority**. The beach slope and grain size distribution are shown in **Fig. 10.17c** and **10.17d** respectively.

Solution suggested: *It is recommended to dredge the river mouth Vellar and nourish the beach on its northern side. This could be one time solution provided a sand dune along with plantation is implemented. In order to consider also the extreme events like cyclone and tsunami, buffer blocks on the landward side of the dune could be planned for (***Fig.10.17e***).*

Fig. 10.17a View of coastal stretch towards south along the southern Velankanni shoreline.

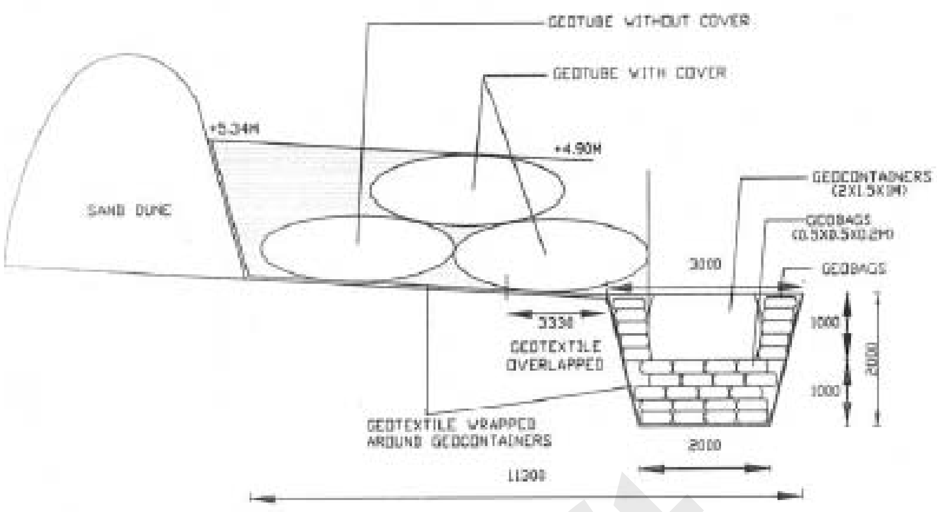


Fig.10.17b. Typical cross- section of geo-textile tube (not to be implemented as it is)

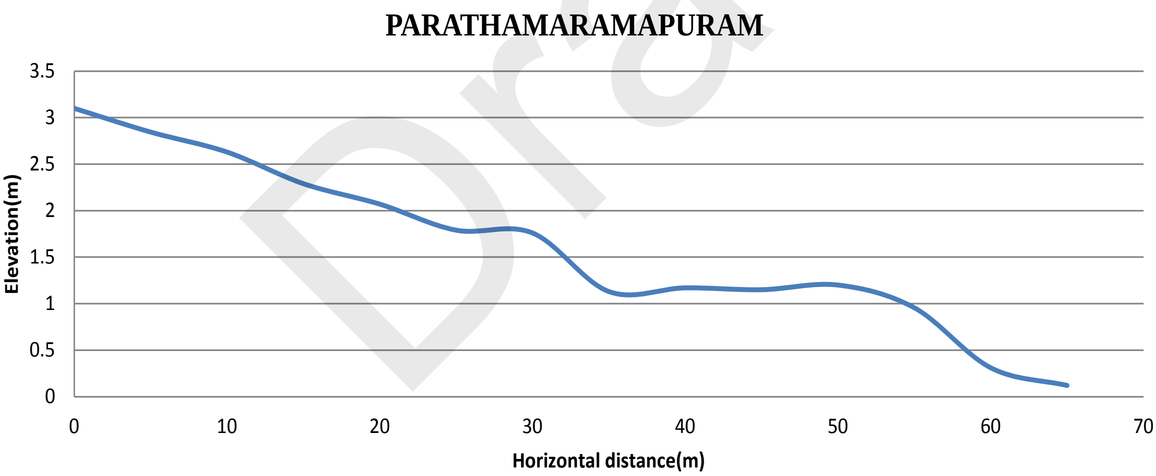


Fig.10.17c Beach profile near Prathabaramapuram

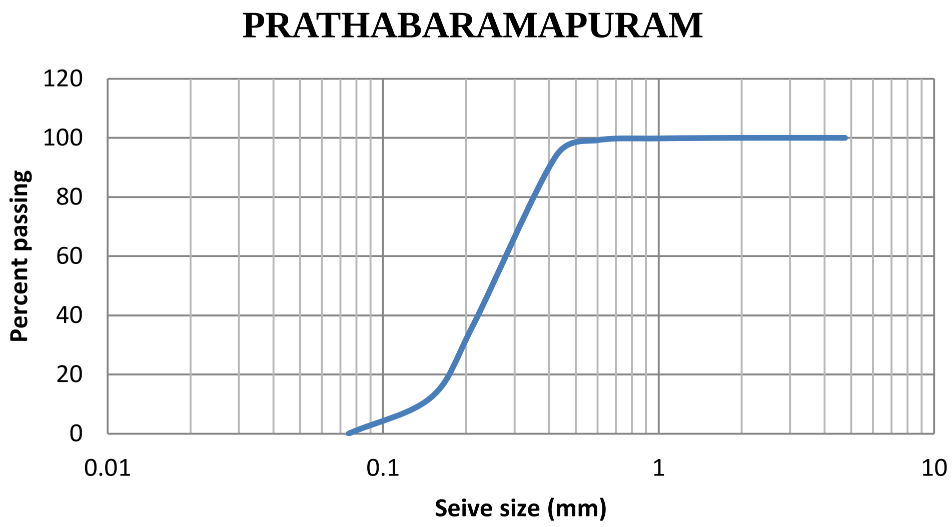


Fig.10.17d Grain size distribution near Prathabaramapuram

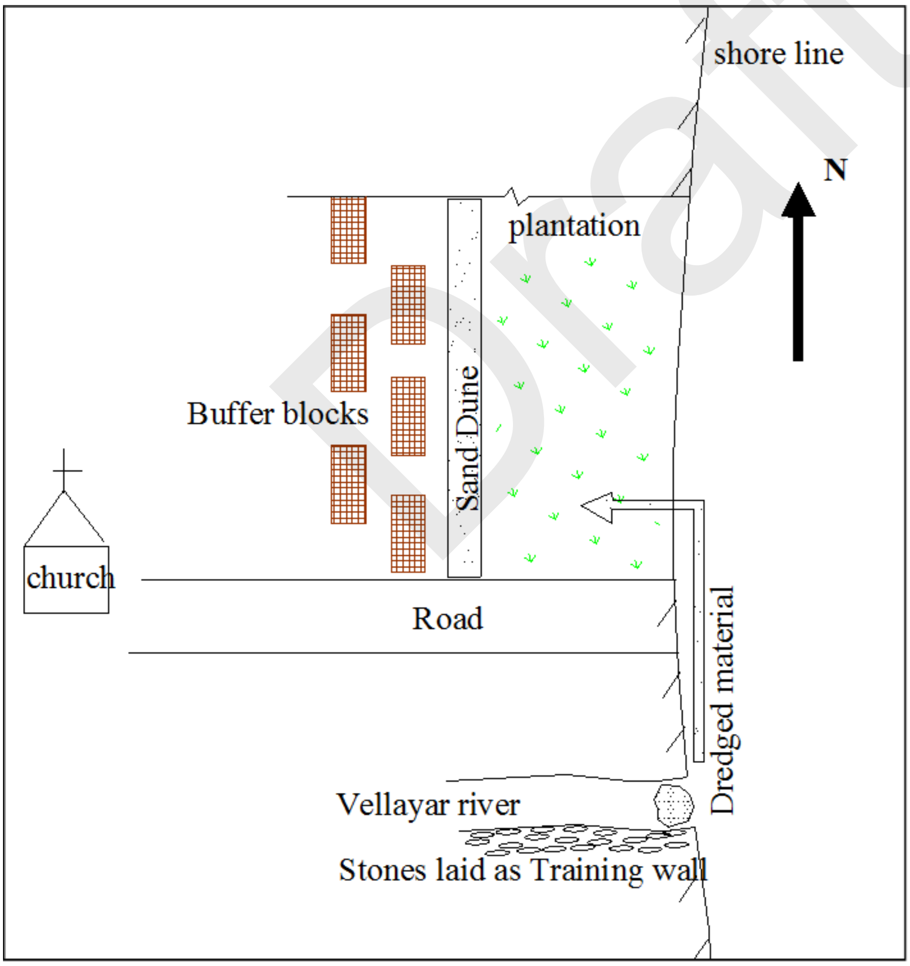


Fig.10.17e Schematic representation of solution to include extreme events

SeeniappaDharga, Rameswaram (9^o 15' 40.69'' N ,79^o 4' 10.18'' E)

This stretch of the coast in Rameswaram has been experiencing erosion over a length of 2.00 km. Roads connecting the coastal villages sacrificed to the waves as can be seen in **Figs. 10.18a** and**10.18b.**

Solution suggested:*Flat seawall (either hard or soft solution) with proper toe protection may be considered to avoid water inundation during severe monsoon. This has to be under priority 1.*

Fig.10.18a Damage of coastal road along SeeniappaDharga in Rameswaram

Fig.10.18b. Damage of coastal road along SeeniappaDharga in Rameswaram

Dhanushkodi (9^{o} 10'13.93"N, 79^{o}25'36.87")

A road of length of about 5km has laid using gabion box as protection measure on this continuously vanishing stretch of the coast. The protection measure is likely to be damaged over time particularly during monsoon seasons. The gabions of 0.5m height adopted as shown in **Fig.10.19a** will not be sufficient enough to resist during extreme events. Further, the percolation of storm water in between the road and gabions is likely result in scour, thereby leading to its failure. Similarly, along the coast, the gap between the gabion seawall and the road **(Fig.10.19b)** also not protected with filter layer is bound to result in failure. In order to protect a proper filter layer need to be designed and implemented. This needs to be carried prior to the onset of next monsoon. .

Solution suggested: Proper filter layer in between the road and the heel of the seawall need to be immediately done. The height of the seawall need to be raised. This could be taken up under priority 1.

Fig.10.19a. Gabions adopted for protecting the road.

Fig.10.19b. Gabions adopted for protecting the road.

Inigo Nagar, Tuticorin (8°47'9.96"N,78°9'45.22"E)

The damaged coastal stretch at Inigo Nagar is shown in **Fig.10.20a** and **Fig.10.20b** respectively. The northern coastal stretch of Tuticorin port has been experiencing very severe erosion of the order more than 5m/year in the last one decade. A Hindu temple is under threat of being sacrificed into the sea. And, at present, there is only a narrow stretch of land of width about 10m to 15m separating the backwaters from the sea. If further erosion continues, the sea would extend upto the land for about 1km inland. This would result in the change in the biodiversity in this region. To avoid such a threat, a soft structure solution can be considered for a stretch of about 1km.

Solution suggested: *A soft structure solution may be designed following detailed scientific study. This can also be taken up as a site for scientific testing of new methods of implementation of soft measures.*

Fig.10.20a Coastal stretch at Inigo Nagar

Fig.10.20b Inigonagar damaged coastal stretch

Rajkhannanagar, Veerapandipatnampanchayat (8°30'27.68"N, 78°7'33.56"E)

The coastal stretch just north of Tiruchendur temple has been experiencing severe erosion over the past decades. This is due to the effect of downstream erosion with the obstruction as the shore temple on its south. Since, there is no immediate threat to the habitation on this slushy shore width. Hence, it is highly recommended to provide soft measures such as plantation or environmental friendly solutions with an immediate effect. This would also train the drain mouth on its south.

Solution suggested: *Soft measures such as plantation or environmental friendly alternative solutions –groins may be considered. Even though, it is not threatening at this stage, a proper immediate measure is required due to the vicinity of rel*
igious location.

Kulasekarapatnam(8°24'38.31"N, 78° 3'47.67"E)

The View of Northern and Southern coastal stretch along Kulasekarapatinam village is shown in **Fig.10.21a** and **Fig.10.21b** respectively. This stretch of the coast of about 600m is experiencing perennial erosion due to its coastal morphology, being located on the north of the Manapad coastal stretch dominated by rocky strata. The average rate of erosion is of the order of 4m/year for the last one decade. However, this stretch has no habitation in its vicinity. However, in order to avoid further loss, this stretch of the coast is ideal for plantation as possible mitigation measure. Before doing so detailed investigation on the site is necessary. The beach profile and the grain size distribution along the coast of Kulasekarapatinamis shown in **Fig.10.21c** and **Fig.10.21d** respectively.

Solution suggested: *This site is ideal for plantation. A pilot stage implementation of plantation is highly recommended.*

Fig.10.21a View of Northern coastal stretch along Kulasekarapatinam

Fig.10.21b View of Southern coastal stretch along Kulasekarapatinam village

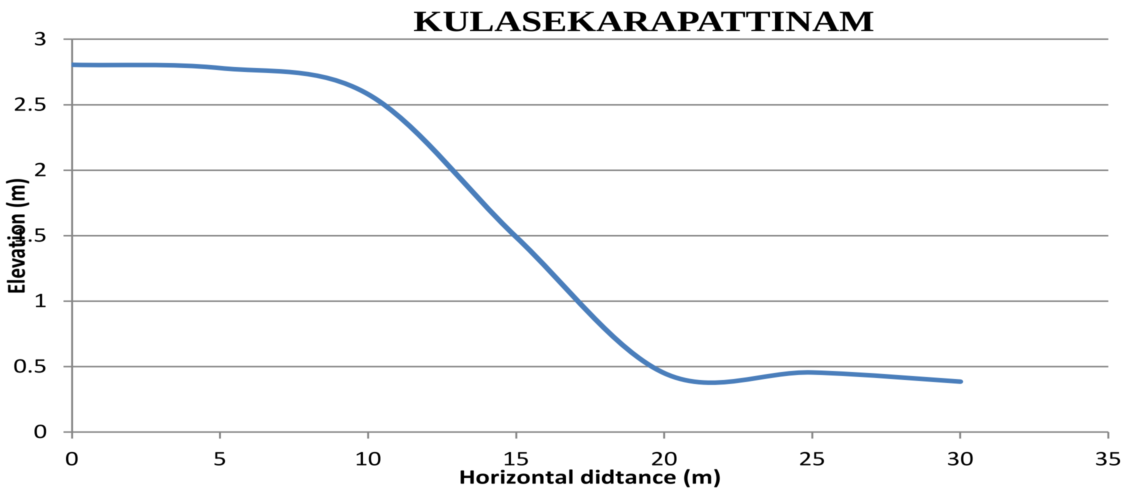


Fig.10.21c Beach profile near Kulasekarapatinam

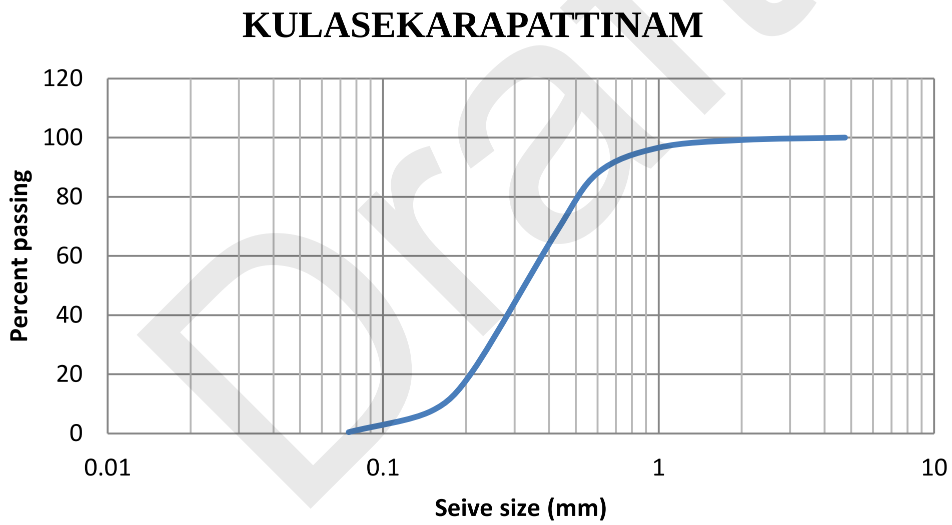


Fig.10.21d Grain size distribution along the coast of Kulasekarapatinam

Periyathalai(8°19'27.15''N, 77°57'29.63''E)

This stretch of the coast has been experiencing continuous erosion and threatening the villages along the coast. There are several fishing vessels that adopt beach landing facility as shown in **Fig.10.22**. Hence , it is worth considering a groin field.

Solution suggested: *The straight forward solution would be a series of groins as pockets in between them could serve as shelters for the fishing boats in addition to serving as beach protection.*

Fig.10.22. Fishing vessels adopting beach landing facility

Uvari(8°17'5.81"N, 77°54'0.35"E)

This is area of perennial erosion, which has been mitigated to a certain extent (Fig.10.23).

Solution suggested: *A groin field has already been constructed to take care of the problem and hence no action is needed as of now*.

Fig.10.23. Mitigation measure for erosion in Uvari

Vallavilai(8°16'32.59"N,77°7'13.24"E)

The coastal road connecting number of villages had suffered severe damages resulting in disconnection between villages has been experiencing continuous ingress of waves as reported by the PWD officials and local public. Although beach formation is observed during fair weather season, it is reported to be seasonal lasting for few months. This only indicates that the sand is being transported along beach and groin field will be effective in addition to the seawall being constructed. The length of this coastal stretch is 1.6km covering the neighbourhood localities. Due to its nature of impact, it is classified as Priority I. The erosion upto the berm is shown in **Fig.10.24a**, whereas, the damages to the coastal road is shown in **Fig.10.24b**. The view of the partial loss of road width is shown in **Fig.10.24c.** The beach profile along the coast of Vallavilai is shown in **Fig.10.24d**.

Solution suggested: *The western coastal stretch of Tamilnadu has been subjected to perennial erosion and groins have proved to be effective solution along this stretch. Hence, a series of short transition groins after critical investigation is recommended. Further, seawall is recommended to protect the coastal road.*

Fig.10.24a Erosion up to the berm

Fig.10.24b Damages to the coastal road

Fig.10.24c View of the partial loss of road width

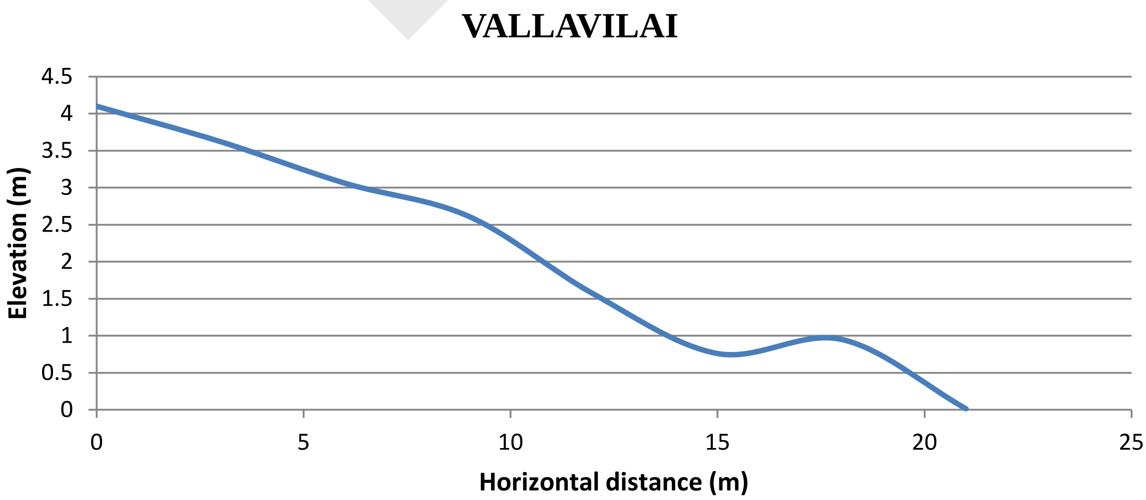


Fig.10.24d Beach profile near Vallavilai

Edappadu(8°16'12.36"N,77°7'40.98"E)

The stretch of road between Vallavilai and Edappadu remain as only one road which is running along west coast of Tamilnadu that is being threatened by erosion. The damages to coastal road in Edappadu region is shown in **Fig.10.25a**. At several stretches, half width of the road has been sacrificed to waves. The grain size distribution along the coast of Edappadu is shown in **Fig.10.25b**.

Solution suggested: *Seawall is recommended to protect the coastal road. The soft solution can be considered to implement on the back shore.*

Fig.10.25a Edappadu coastal stretch showing the damages to the coastal road

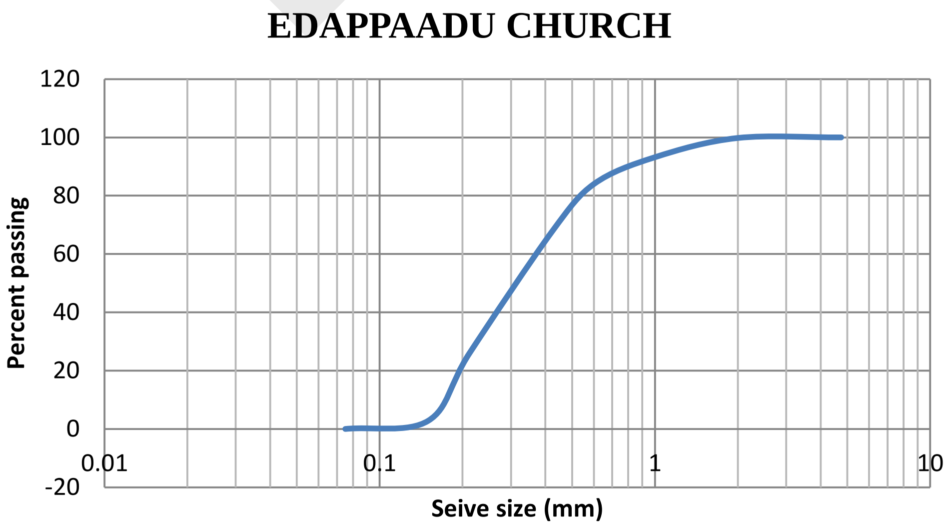


Fig.10.25b Grain size distribution for Edappadu

***Eraviputhamthurai**(8°16'5.20"N,77°7'57.25"E)*

The location ***8°16'5.20"N,77°7'57.25"E***is the starting point of this coastal stretch. The severe erosion at Eraviputhamthurai coastal stretch is shown in **Fig.10.26**This stretch is completely residential area on either side of the coastal road with few houses situated very close to coast. People were found to be highly agitated and were frustrated and have been expressing, inspite of this stretch of this coast that was to be protected as per the report of IITM in 2005, nothing has happened.

Solution suggested: *A series of short transition groins after systematic scientific study is recommended. Further, seawall is recommended at some stretches.*

Fig.10.26 Severe erosion at Eraviputhamthurai coastal stretch

Chinnathurai(8°15'46.02"N, 77° 8'17.10"E)

Damages of the many houses have shown the severity of the shoreline erosion. Few houses were fully sacrificed to the sea in the recent past. The existing seawall is not effective during rough monsoon season leading to significant overtopping during monsoon. Three short groins proposed by IIT Madras for the purposes of fish landing centre at Thoothoor has proved to be successful **(Fig.10.27a)** in protecting the beach in between them and on its upstream. This only proves again that this area is the zone of active sediment transport along the shore. Hence, groin field can be considered as effective coastal protection measure along this stretch. The damaged seawall along coast of Chinnathurai is shown in **Fig.10.27b**. The partially functional coastal road abutting seawall and view of Thoothoor groin on the east is shown in **Fig.10.27c** and **Fig.10.27d** respectively.

Solution suggested: *Due to the effectiveness of the groins on its south (east), a series of short groins after detailed scientific study is recommended.*

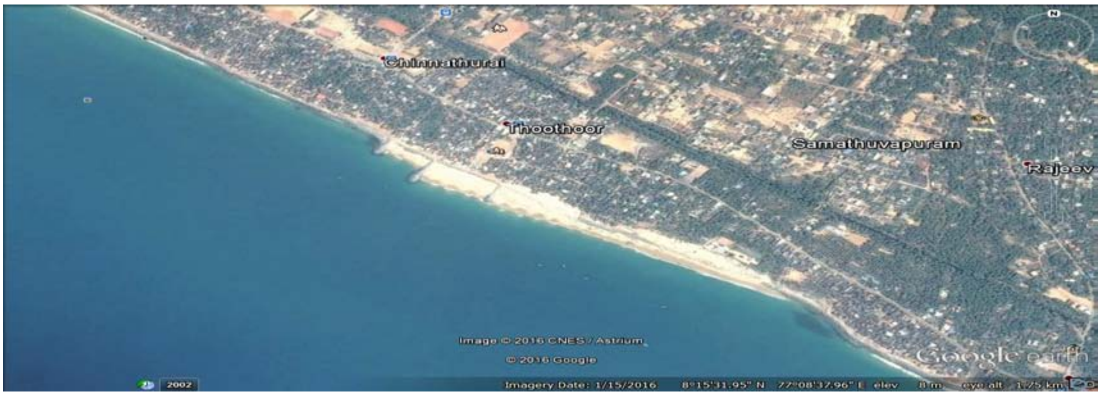


Fig.10.27a Google image showing the effectiveness of the groins at Thoothoor

Fig.10.27b Damaged seawall

Fig.10.27c Partially functional coastal road abutting the seawall

Fig.10.27d View of Thoothoor groin on the east

***Helan colony** (8°12'50.87"N,77°11'42.40"E)*

Nearly 400m stretch of the coast has been suffering the damages. Few houses are in danger and the village coastal road has damaged in full. The local people have been demanding for the implementation of the groin field between Inayam and Muttom, which was suggested in 2005 by IIT Madras after Tsunami. The western side of this stretch has been protected by seawalls and has been serving its purpose. This stretch of the coast can either be protected by groin field as suggested by IIT Madras in 2005 report or a flat seawall as being adopted by PWD. The damaged coastal road is shown in **Fig.10.28a**. During the fair weather season, the beach width is shown in **Fig.10.28b**, whereas the wave scouring the building foundation is shown in **Fig.10.28c**.

Solution suggested: *A series of short transition groins for the entire stretch along with flat seawall at some stretches can be considered.*

Fig.10.28a View of damaged coastal road

Fig.10.28b View of beach width during fair weather season

Fig.10.28c Wave scouring the building foundation

MandaikaduPudur (8°9'43.96"N,77°16'36.40"E)

A famous temple and a church along the coastal stretch of MandaikaduPudur are importance pilgrimage centres and have been densely populated along this 850m long coastal stretch. It is beneficial to the public, in particular a large number of pilgrimages, to protect the coast by retaining the sand being lost to sea. During severe weather season, the wave ingress into the land and hence, the habitation which is at the level of +5m above mean sea level are under threat of being collapsed. The stretch of the coast of Mandaikadu is shown in **Fig.10.29a** and **Fig.10.29b**. During fair weather season, about 20m beach width is normally available. T-groins would be effective in this stretch and one smaller stretch within this groin field may be created for boat-beach landing facility. The variation of the beach slope along this stretch of the coast is shown in **Fig.10.29c,** whereas the Sediment collected along the beach, the results of which from the sieve analysis is shown in **Fig.10.29d**.

Solution suggested: *T-groins would be effective in this stretch and one smaller stretch within this groin field may be created for boat-beach landing facility. The higher elevated land topography is need to be protected using geo-textile tubes.*

Fig.10.29a Erosion along the western end coast of Mandaikadu

Fig.10.29b MandaikaduPudur coastal stretch showing the severity of the coastal berm erosion

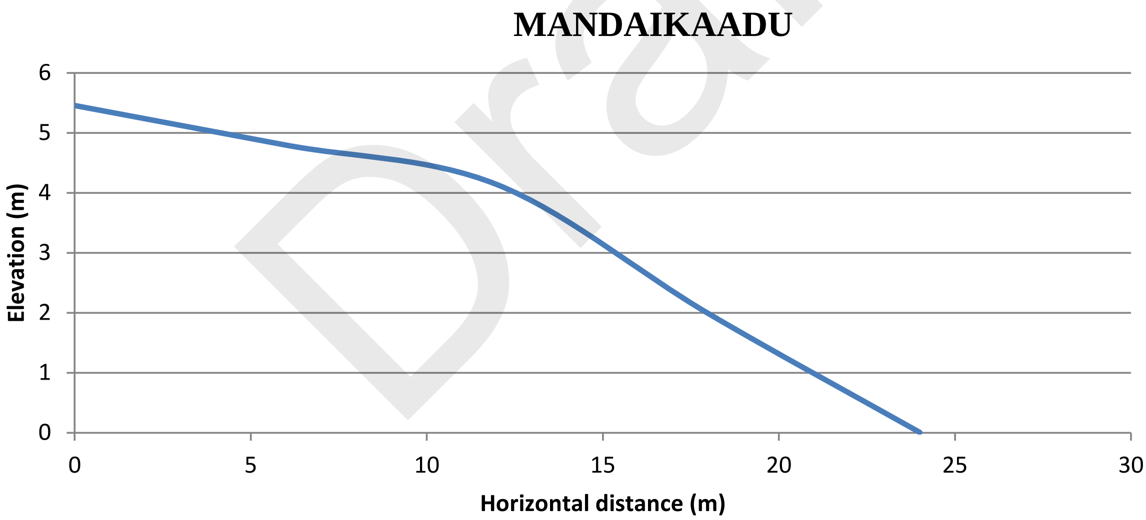


Fig.10.29c Beach profile for Mandaikadu

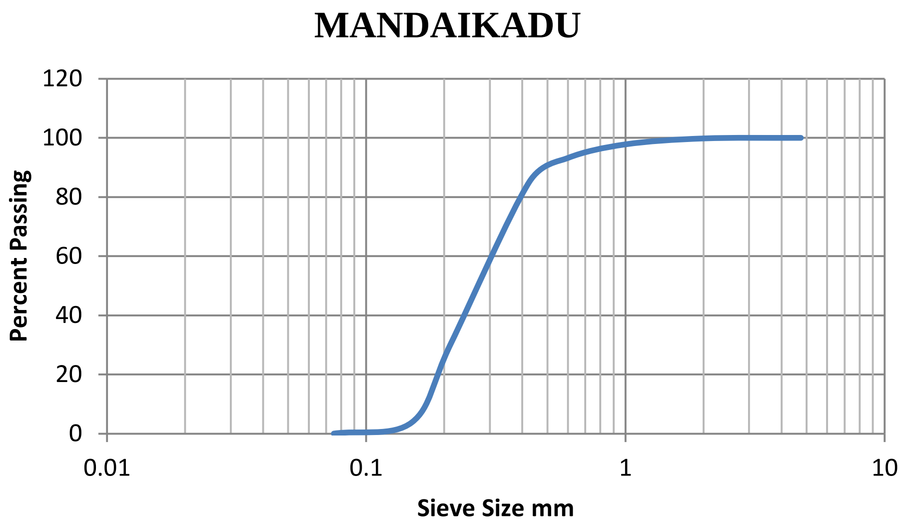


Fig.10.29d Grain size distribution along the western end of Mandaikadu

Perumanal(8°9'32.34"N,77°38'49.68"E)

The view of the North and South groin at Perumanal is shown in **Fig.10.30a** and **Fig.10.30b** respectively. The fisheries department has constructed two groins in 2015 with an idea of gap between groins as a boat landing facility. The net littoral movement along this stretch is in general balanced. And, thus it is not expected any severe adverse impact. If the fish landing requirements demand, one of the groin may be bend to form as a fully protected basin. The beach profile along the coast of Perumanal is shown in **Fig.10.30c**. And the grain size distribution for Perumanal is shown in **Fig.10.30d**.

Solution suggested: *A pair of groins has been constructed recently and one of which may be extended to form a fish landing facility.*

Fig.10.30a View of the North groin at Perumanal

Fig.10.30b View of the South groin at Perumanal

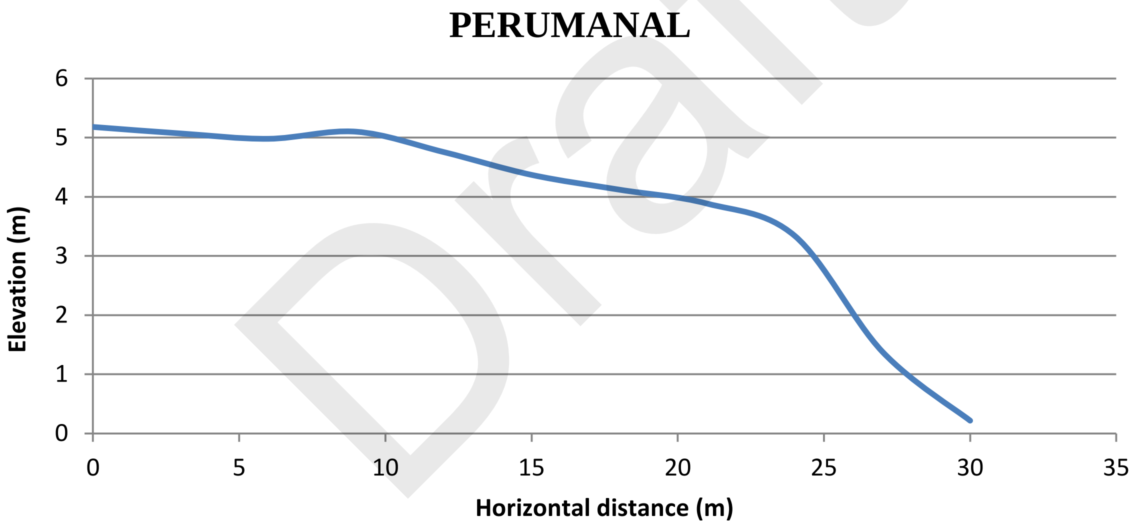


Fig.10.30c Beach profile near Perumanal

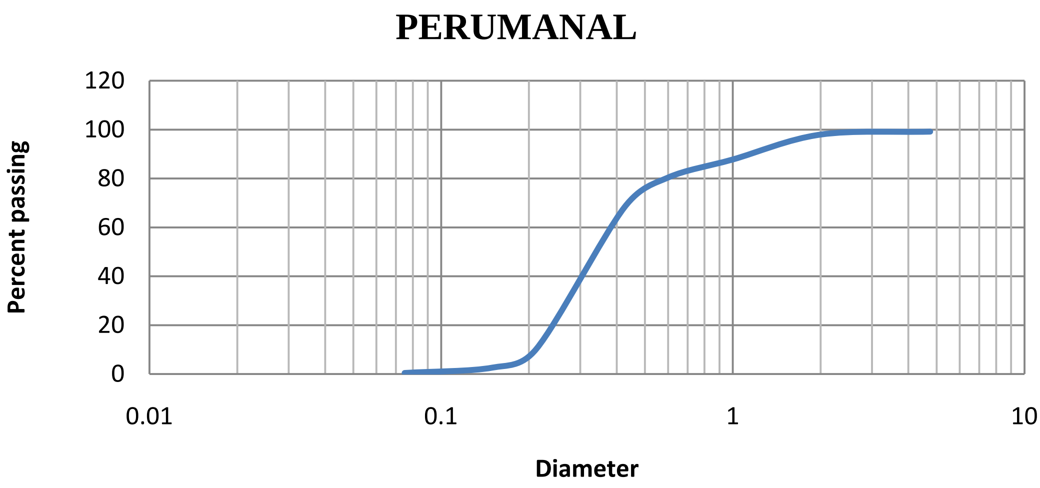


Fig.10.30d Grain size distribution at Perumanal

Chothuvalai beach &Mukilankudiyuruppu *(8°5'37.90"N,77°31'16.31"E)*

The existing coastal road at certain locations damaged severely to an extent of loss of 50% of beach width. Public transport has been stopped for the last 3 years along this road. This stretch of 1km needs immediate protection with geotextile tube running parallel to the coast to serve as a seawall over which plantation can serve as additional protection. This not only save beach and also beautify the tourist beach. It is believed that this stretch was fronted by casuarinas plantations which have been sacrificed to sea over the years. The erosion of road in Chothuvalai Beach is shown in **Fig.10.31a** and **Fig.10.31b** respectively. The beach profile along this coast is shown in **Fig.10.31c,**whereasthe results of grain size distribution from the sieve analysis is shown in **Fig.10.31d**.

Solution suggested: *Soft solution using plantations on the geo-textile tubes to protect the coastal road with proper deep toe protection is suggested. The beach may be left to oscillate between different seasons.*

Fig.10.31a Erosion of road in Chothuvalai Beach

Fib.10.31b Chothuvalai tourism beach showing the coastal road is being eroded

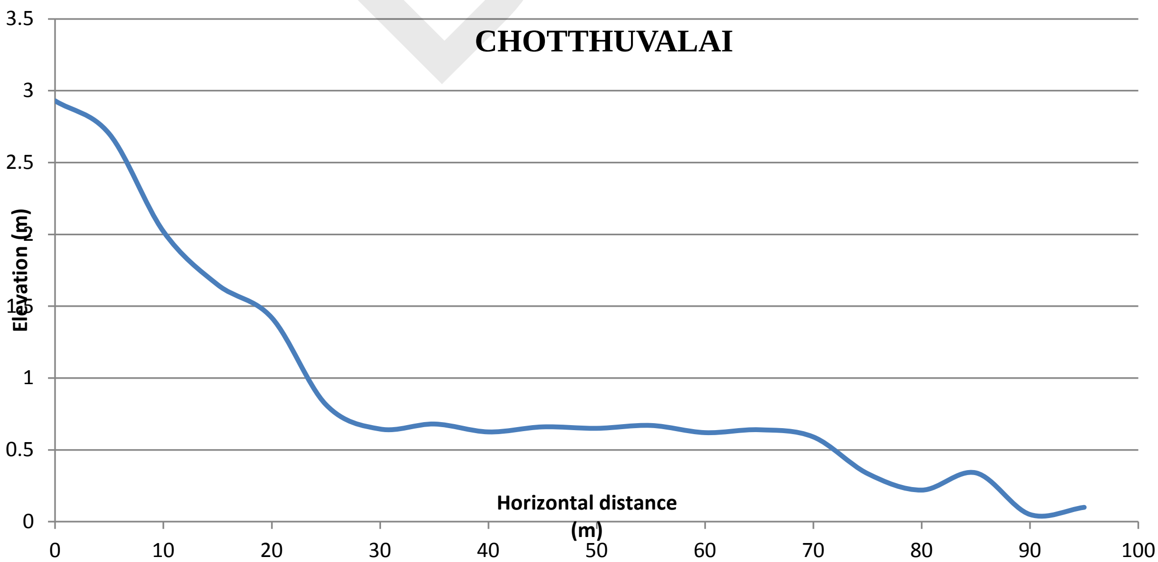


Fig.10.31c Beach profile for chothuvalai beach

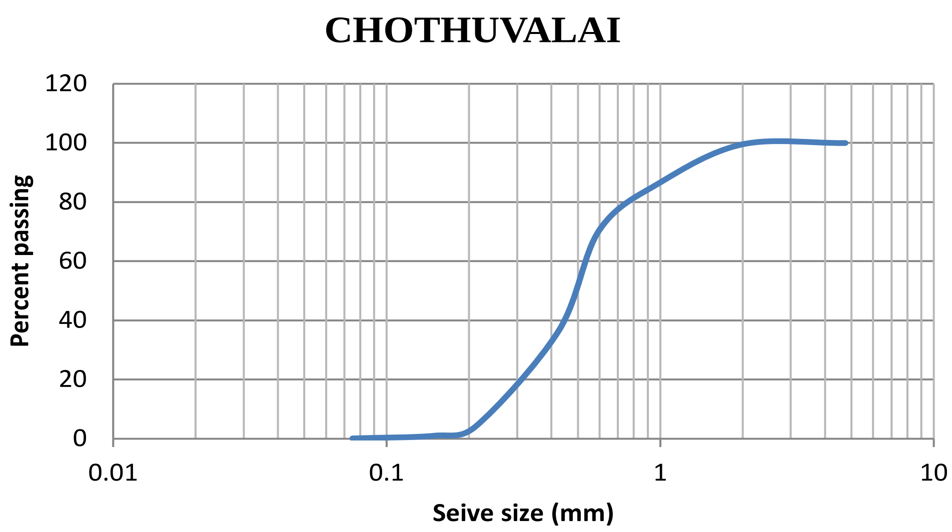


Fig.10.31d Grain size distribution near Chothuvalai beach

***Melamanakudi** (8°5'31.63"N,77°32'48.43"E)*

The river mouth joining to sea to Manakudilake has been protected from mouth closure by a pair of training walls. Due to dominant westerly littoral movement along this stretch, the sediment bypasses the eastern training wall and blocks the mouth of the river during most of the year. This has to be rectified by dredging the river mouth in between the training walls. By doing so, necessary tidal prism would prevail to keep the mouth open throughout the year by maintaining sufficient current flow. Alternatively, the eastern training wall may be considered to increase its length in addition to the dredging. The erosion of soil near Melamanakudi is shown in **Fig.10.32a**. The damages seawall and building is shown in **Fig.10.32b**.

Due to this pair of training walls, the downstream coastal stretch of 1.2km long along Melamanakudi village has been suffering severe erosion resulting many shore buildings sacrificed to the sea. The seawall that was constructed in the past decades had been completely washed away at many locations. A series of groin is the best solution in this littoral dominant location. The view of the Melamanakudi river mouth closure during March 2016 is shown in **Fig.10.32c**. The beach profile and the grain size distribution along the coast of Melamanakudiis shown in **Fig.10.32d** and **Fig.10.32e** respectively.

Solution suggested: *A series of transition groins on the north of northern training wall is recommended. It is strongly suggested to dredge the river mouth in between the training walls and the dredged spoil should be deposited in between the proposed groins.*

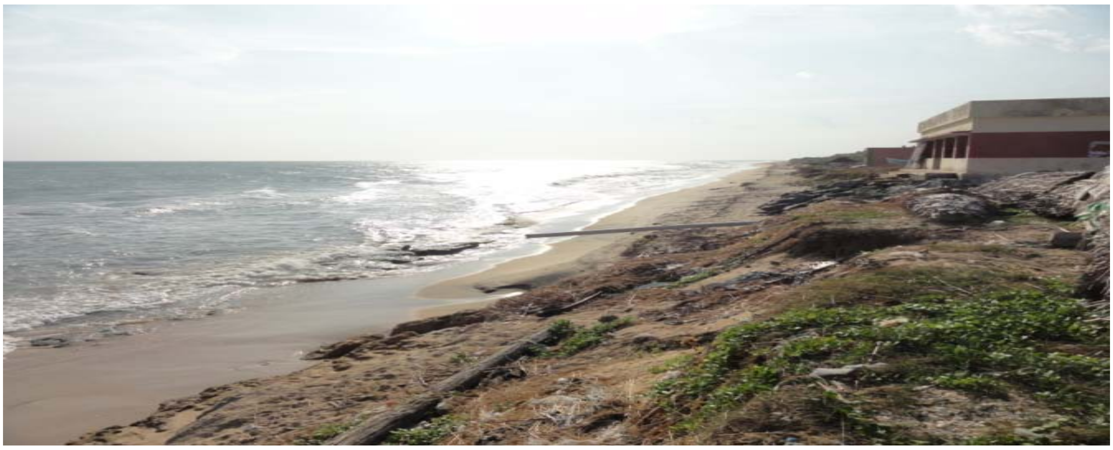


Fig.10.32a Erosion of soil near Melamanakudi

Fig.10.32b Melamanakudi coast showing the damaged seawall and the collapse of building

Fig.10.32c View of the Melamanakudi river mouth closure during March 2016.

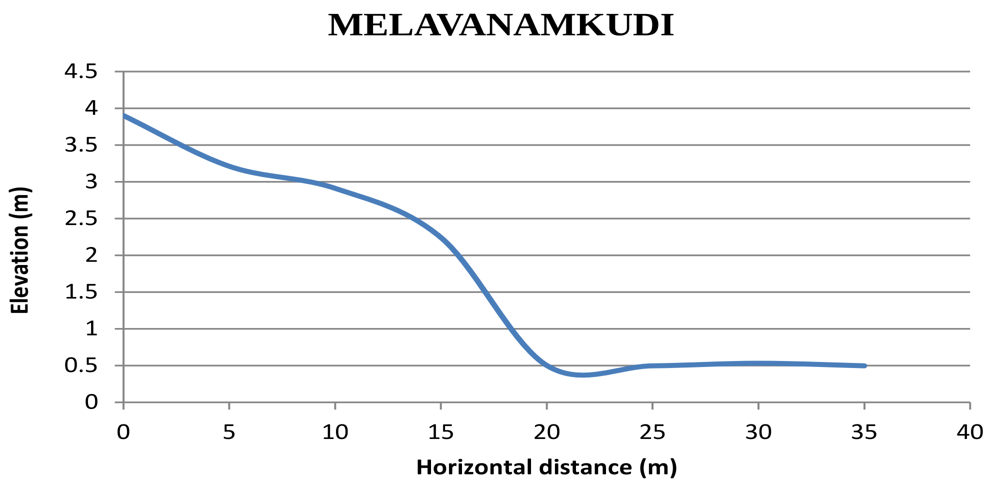


Fig.10.32d Beach profile near Melamanakudi

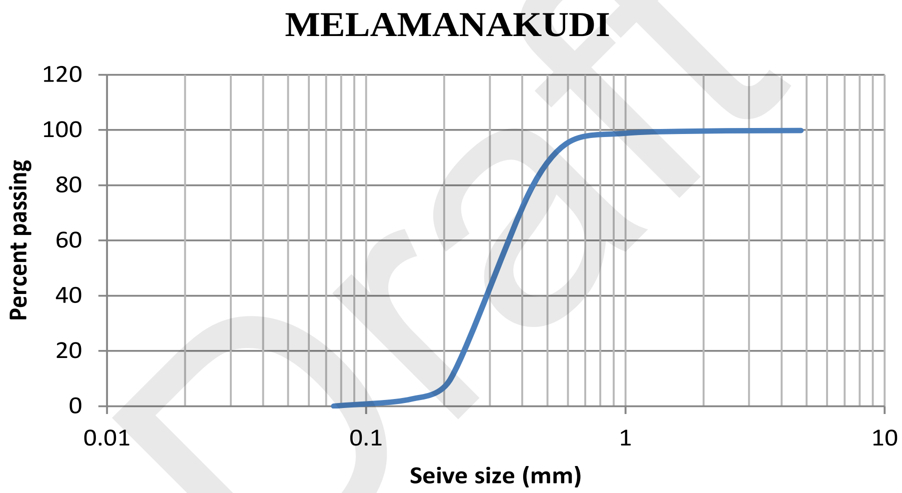


Fig.10.32e Grain size distribution along the coast of Melamanakudi

***Kovalam** (8°4'54.34"N,77°33'33.60"E)*

A long groin along the coastal stretch of Kovalam village, just west of the Kanyakumari, has been constructed in 2003 to create a safe fish landing facility on its east. However, the downstream of this groin has shown severe erosion over the years due to scarcity of sediment movement. The erosion at downstream coastal stretch of Koavalam is shown in **Fig.10.33a**.The entire stretch of coastal road connecting upto Kanyakumari has been lost to the sea. In addition, several houses had been sacrificed to the sea. This 500m long coastal stretch, downstream of Kovalam groin should be protected using a transition groin.field such that the downstream of the last groin should not be affected. The view of upstream accretion and subsequent beach landing is shown in **Fig.10.33b**.

The beach profile along the coast of Kovalam region is shown in **Fig.10.33c**, whereas the soil is collected along the beach, the results from which the sieve analysis is shown in **Fig.10.33d** respectively.

Solution suggested: *A transition groin field is required to mitigate erosion on the north of the existing groin. Further, an additional groin may be constructed on its south to create safe fish landing facility.*

Fig.10.33a Erosion at downstream coastal stretch of Kovalam groin

Fig.10.33b View of upstream accretion and subsequent beach landing

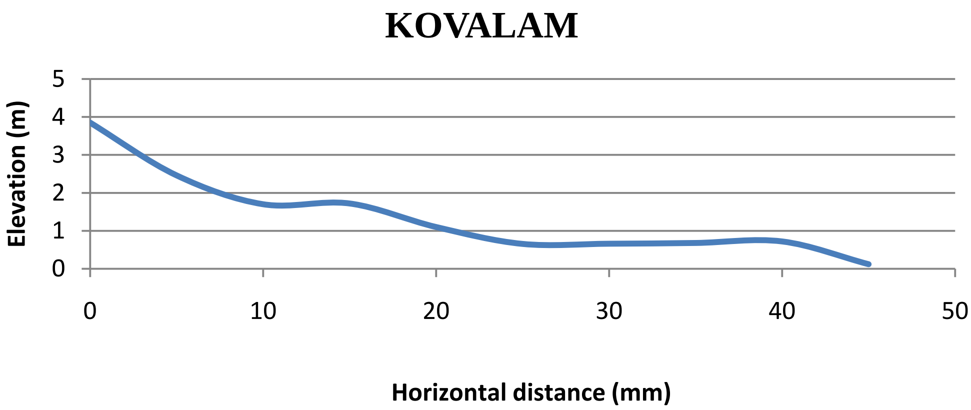


Fig.10.33c Beach profile along the coast of Kovalam

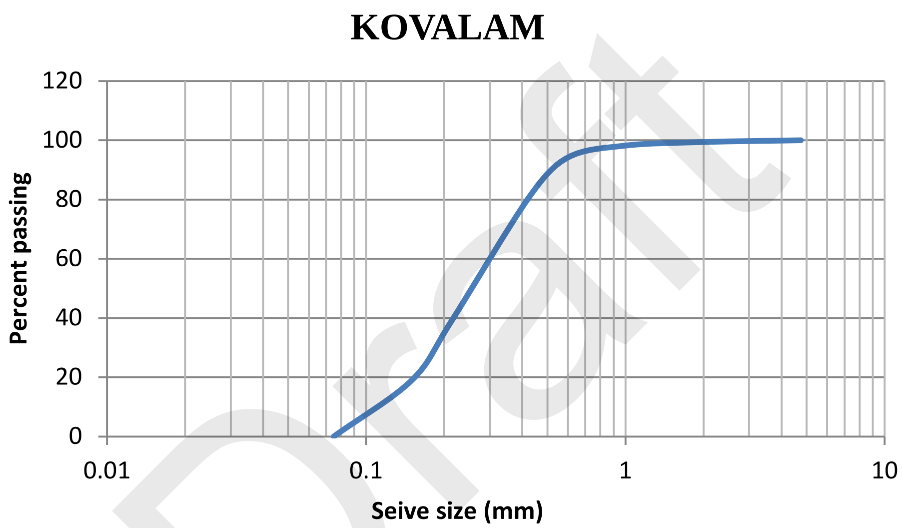


Fig.10.33d Grain size distribution for Kovalam

CHAPTER 11
SHORELINE MANAGEMENT PLAN

11.1 GENERAL

There exists an indispensable requirement for sustainable development and preservation of natural resources in the coastal zone. There are several examples that unplanned, uncoordinated and uncontrolled developments in the fragile coastal zone which havelead to destruction of natural resources as well as unsuccessful development. The coastline may be viewed as a series of inter-linked physical systems, consisting of both offshore and onshore elements. Sediments move around the coast by waves and currents in a series of linked systems. The sediments move from sediment source areas such as eroding cliffs and rivers to sea bed by coastal processes to sediment sinks such as beaches, estuaries or offshore sinks. Along a particular coastal stretch, these processes bring linked changes, i.e., changes in one part may lead to adjustment in other parts. This is the background for the development of the concept of integrated shoreline management plan.

11.2 NEED FOR SHORELINE MANAGEMENT PLAN (SMP)

- The purpose of Shoreline Management Planning is to identify the resources and assets in the coastal area at present and foresee in the future and, through that minimize negative consequences from the interaction between the various interests, i.e., tourist and economical development, coastal protection, natural dynamics etc.

- The aim of a Shoreline Management Plan is to provide the basis for the implementation of overall sustainable shoreline strategies – a management strategy – for a well defined region and to set the frame work for the future management of conflicts in the coastal area.

- The plan shall be based on a strategic assessment of conditions within the plan area rather than detailed studies of individual sites. To implement the plan, detailed scientific study is a must.

- All types of coasts cannot be treated equally for management/regulatory measures. Hence, natural geographic segmentation of coast with self-contained sedimentation processes assumes importance for management of coastal environment.
- Hence, a Shoreline Management Plan normally covers an area along the coast where either a need for shore protection emerges or the plan of industrial/ tourism development. The first and foremost information to be collected is to identify a constrained region within which any impact due to such developments might occur. This region is described as a sediment cell. A sediment cell is a section of the coastline in which the physical processes are relatively independent from processes operating in adjacent sediment cells.

11.3 SHORELINE MANAGEMENT PLAN

Experiences have shown that management is necessary to prevent large sections and possibly all of the shoreline from becoming congested with land based uses, thereby, making it more vulnerable to coastal hazard and coastal pollution. It may also lead to loss of space for public use including settlement, fishery and recreational related activities. Management of the shoreline will provide an opportunity for optimum uses for the maximum number of people and less impact of hazards.

Shoreline Management Plan (SMP) sets out the strategy for the protection of the coastal communities and the resource for a specified segment of the coast. Shoreline management involves large-scale and longer-term strategic planning in order to reduce risks to people and the developed and natural environments from coastal flooding and erosion. SMPs are also intended to provide information to support the preparation of development plan policies and action plans by concerned coastal protection departments and local planning authorities in determining planning applications in the coastal zone.

11.4 COASTAL REGULATION ZONE REGULATION

The Coastal Regulation Zone (CRZ) regulation has been introduced in 1991 which intends to regulate land use practices, so that, destruction of coastal ecosystems are controlled. These regulations are to be followed to any coast that needs protection/development.

11.5 MANAGEMENT ISSUES

Thedevelopmental activities of the coast and the coastal hinterland should bewithin the act of CRZ regulations. Such issues normally bring the restrictions of setback lines and hence, dictating the terms for the development activities being allotted on the seaside of CRZ regulationsetout lines. In addition, special restrictions should include in the vicinity of very active morphological features such as river mouths, tidal inlets, sand spits and barrier islands before considering the implementation of the solutions/ development activities.

Flowcharts, **Fig.11.1** to **Fig.11.4** depict the sequence of considerations to be undertaken before planning any coastal related activity that would exploit shoreline of any nature. While considering SMP, the following classification is made in the initial framework (Fig.11.1).

I. Morphologically important regions
   a. Inlet

II. Regions that need of Developmental activities
   a. Highly populated
   b. Tourism and Recreation
   c. Industrial sector
   d. Socio-economic aspects

III. Ecologically sensitive regions

Among the above regions, it is required to go through various natural and man-made developmental activities (existing and being planned), before planning for any activities as part of the SMP. **Fig.11.2** to **Fig.11.4**present the detailed step-by-step procedure before arriving at a SMP solution by considering natural, engineering and environmental aspects.

11.6APPROACH FOR COASTAL PROTECTION MEASURE

Typical Scientific approach needs to be followed for any coastal project with systematic studiesas described in thenext sub-sections hereunder. Prior to any activity along the coast, top priority need to given for protecting the coast against erosion through a comprehensive scientific study and also ensure that any such developments does not lead to instability in adjoining shoreline.

11.6.1 Reconnaissance survey

It is essential for the identification of the problem and possible solution based on the severity of the problem from a detailed reconnaissance survey. This includes preliminary investigations of the site, such as orientation of the coast, brainstorming with coastal habitants, behavior of the shoreline with the presence and absence of the coast in the neighborhood. The primary sediment cell into which the project site falls and the coastal/sediment dynamics of the cell, like source and sinks present in it are to be examined. The priority needs to be given based on the physical and socio-economic aspects.

Bathymetry

For any numerical study along the coast, shallow water bathymetry is the most important component and should be measured atleast to an extent of twice the surf width(this may vary

11.6.2 Field measurements

with the requirement), along with the mapping of shoreline and the beach profile variations from the upper berm.

Wave climate and tidal variations

Annual field measured or the simulated wave data with proper validation, near to the site is required along with the tidal level variations and current speed, based on its magnitude.

Sediment characteristics

The sediment sample at different locations of the site needs to be collected and the analysis on the grain size distribution and the specific gravity are to be arrived, which will be used in the modeling part.

11.6.3 Design of structure/system

The structural parameters (example –for a groin, top level, top width, side slopes, toe width, toe thickness, weight and thickness of armour layer, under layer, core etc.,) are to be designed.

If it is a soft measure or an integrated structure made either with soft or hard measure, needs to be analyzed for its combined performance.

11.6.4 Numerical modeling

Near shore wave modeling with the presence of proposed structure and its effects needs to be studies first, which will be followed by the sediment transport rate and shoreline modeling with the presence of the structure.

The field measurements will be used in the modeling as input or for validation according to the requirements.

11.6.5 Physical modeling

The stability of the designed structure needs to be tested with scaled models of the structures in a wave tank, based on the requirement.

11.6.6 Post monitoring program

The environment monitoring program during the stage wise construction and annual monitoring after the construction to find the seasonal variation exhibited by the coast with the suggested solution, which may be useful for the validation purposes.

11.7 SUMMARY

SMP in general should fulfill basically the following measures.

- provides, the desired and sustainable protection to the coast.
- Should have an acceptable limit and recreational feature.
- Should be cost effective, easy to implement with minimum maintenances

The agencies (private or Government) involved in the different activities should interact and planning of the development of the coast, should be undertaken through detailed discussions. This should ensure, that the activity of one of the department should not hinder the activities of any other department along the coast. In other words, most of the solutions, require consensus and well coordinated SMP and/or ICZMP (Integrated Coastal Zone Management Plan) .

(Prof. V. Sundar) **(Prof. S.A. Sannasiraj)**

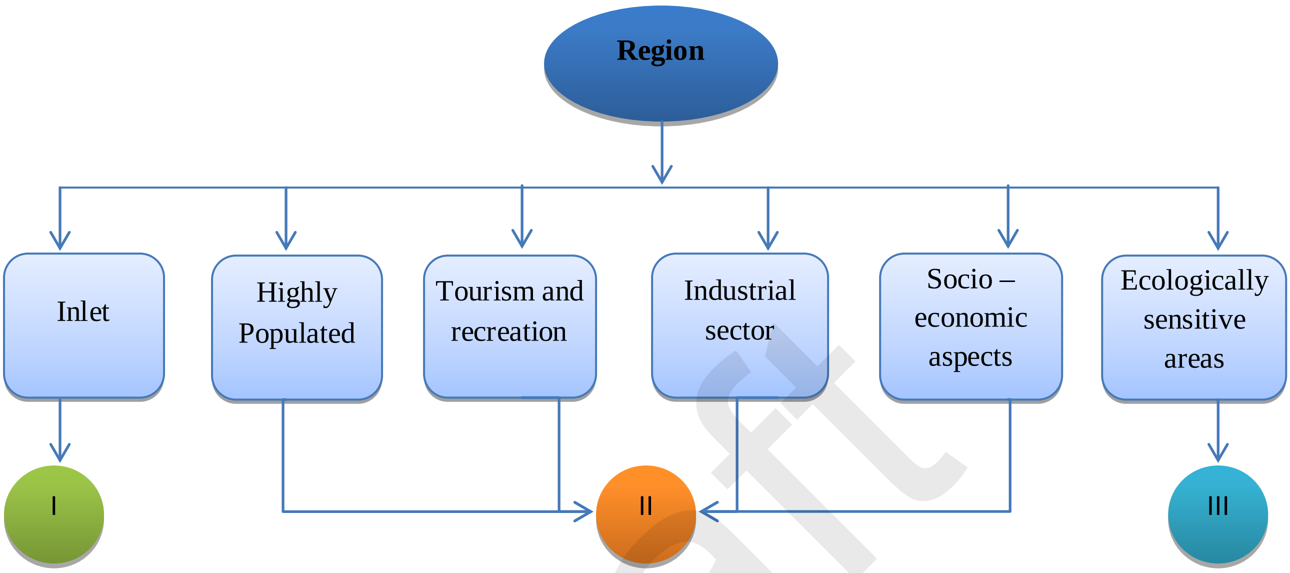


Fig.11.1. Classification of coastal regions for SMP

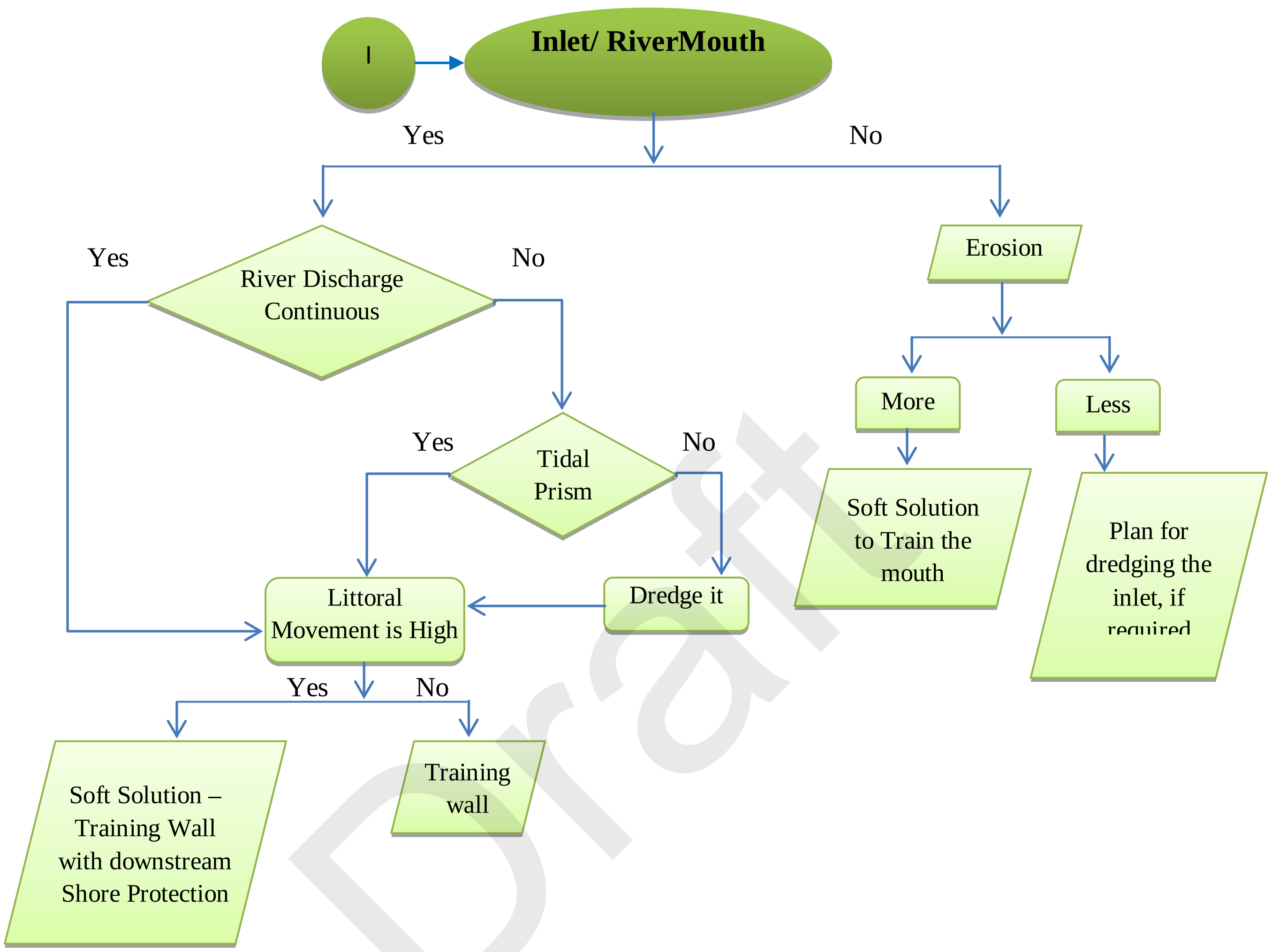


Fig.11.2. Sequence of SMP to be followed for an inlet/ river mouth

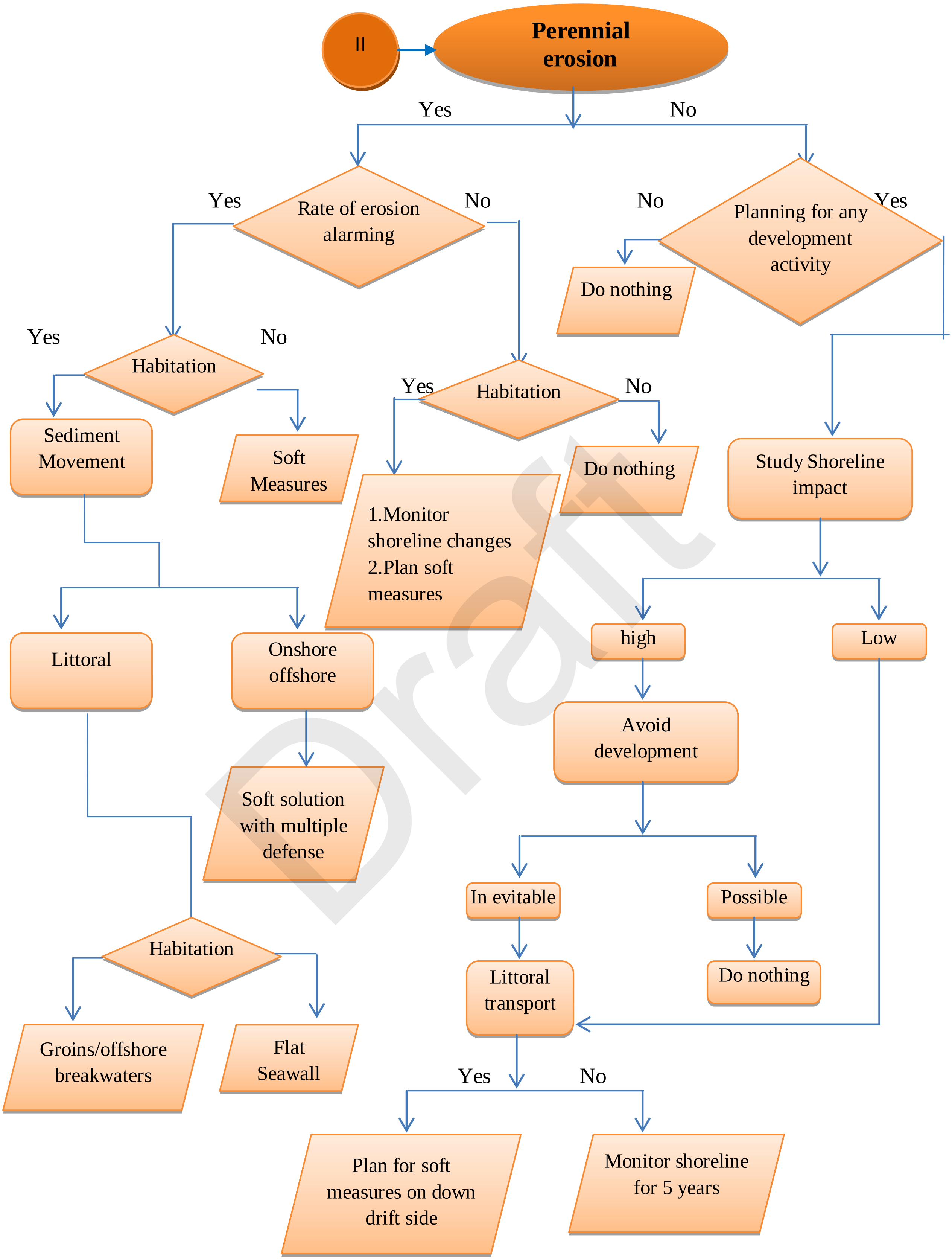


Fig.11.3. Sequence of SMP to be followed for a developmental activity along a coastal sector

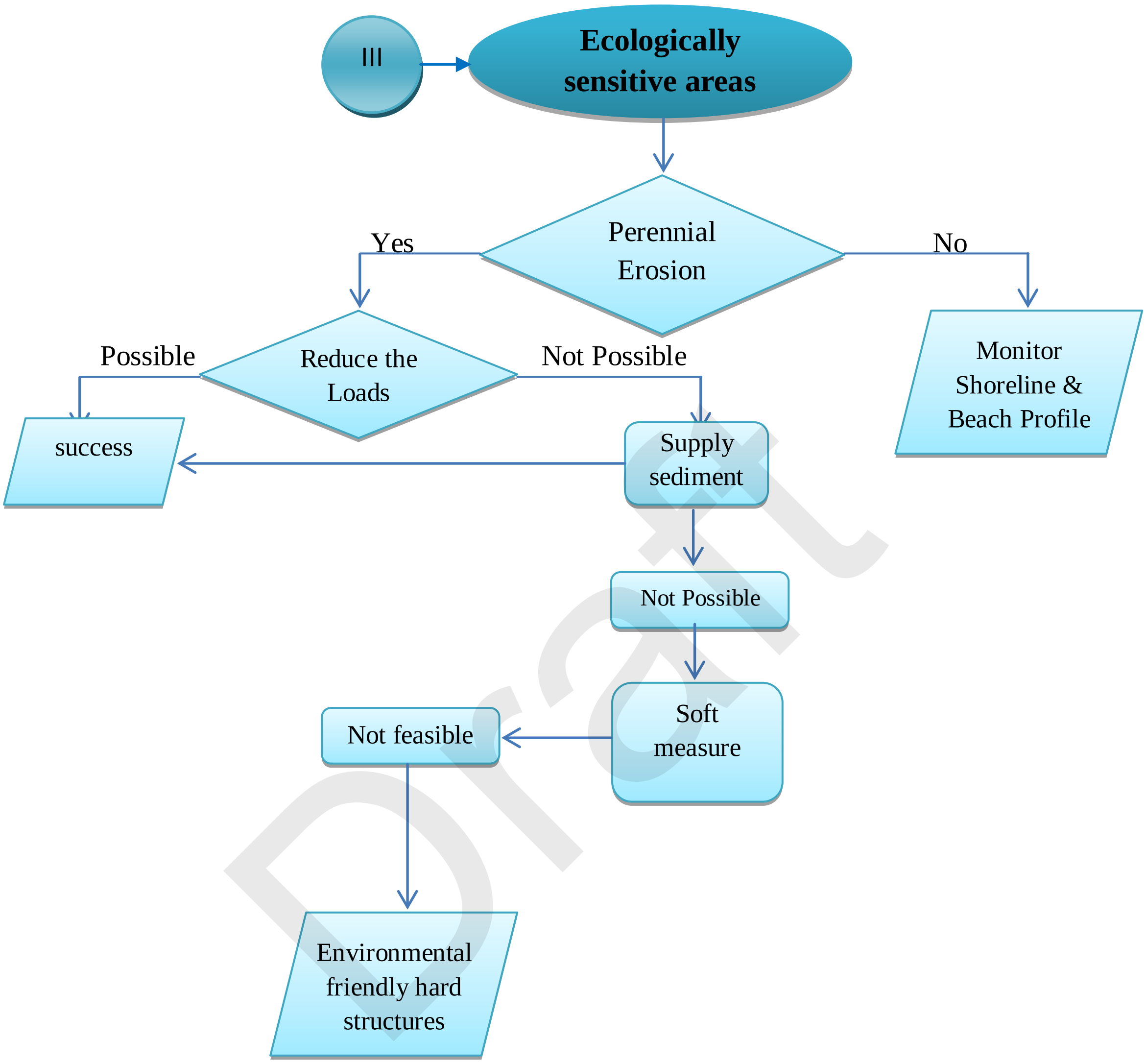


Fig.11.4. Sequence of SMP to be followed for an ecologically sensitive regions

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