

BEFORE THE NATIONAL GREEN TRIBUNAL (SZ) CHENNAI

MEMORANDUM OF APPLICATION
(Under Section 18(1) read with Sections 16 (h) of National Green Tribunal
Act, 2010)

Appeal No.14 of 2022

M. Yuvadeeban

...Appellant

Vs.

Department of Fisheries & Ors.

...Respondents

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Through
Yogeshwaran. A
Counsel for Appellant

BEFORE THE NATIONAL GREEN TRIBUNAL (SZ) CHENNAI**Appeal No. 14 of 2022**

M. Yuvadeeban

.... Appellant

Vs.

Department of Fisheries & Ors.

.... Respondents

Affidavit dated 20.02.2023 filed by the Appellant in response to the Counter Affidavit dated December, 2022 of the Fisheries Department, Documents filed by the Fisheries department on 09.01.2023 and the Status report of the Forest Department dated 25.02.2023 (Served on 08.02.2023)

I, M. Yuvadeeban, s/o Maragret Lawrence, aged about 26 years, B2, Ramaniyam Marvel, Seshadripuram, 1st main road, Velacherry, Chennai 42 do hereby solemnly affirm and sincerely state as follows:

1. I am the Appellant herein and aware of the facts and circumstances of the case and competent to swear the present affidavit.
2. I state that pursuant to the order of this Hon'ble Tribunal on 14.11.2022, the Appellant herein filed an affidavit dated 27.11.2022 along with documents (File-E) detailing the impact of the construction of training walls on the nesting of Olive Ridley turtles.
3. I state that subsequently, the Fisheries Department filed yet another counter affidavit dated December, 2022 along with voluminous annexures, further documents on 09.01.2023 and the Forest Department filed their status report dated 25.01.2023 that was served to my counsel on 08.02.2023. The present affidavit is filed in response to these reports and documents.

Response to the Status report of the Forest Dept dated 25.01.2023

4. The Forest department has stated that:
 - a. As per the new proposal, the training wall will be located in Alamparaikuppam, at about 500 m north to the Turtle nesting sites in Villupuram district. Hence it has very minimal impact on the nesting site in Villupuram.
 - b. No expertise/information is available on erosion and accretion of sand due to the proposed training wall at the newly proposed site in Alambaraikuppam.
 - c. Operation of lights in the fishing harbour and training wall area shall cause disorientation of female turtles approaching the coast.
 - d. The Conservator of Forest has reported that "one" turtle nesting has been reported in Alambaraikuppam, Thandumari amman koil, Velambur where the training wall is proposed
 - e. Turtle nesting is common along the coast of Chengapettu district.

5. Firstly, it is submitted that the report does not state which officer has filed the report for the PCCF. Secondly, the report does not even attempt to address the issue raised by this Hon'ble Tribunal.

6. It is submitted that the location of the training walls cannot be changed by the fisheries department by way of a statement before this Hon'ble Tribunal. It is clear that the respondent is now projecting the "new" site it has chosen as the location of the training walls. This can be done only based on conducting necessary studies (the existing reports contains chapters on the anticipated shoreline change for the location at Azhagankuppam, for which clearance has been obtained) and then obtaining fresh clearance from the MoEF&CC under the CRZ Notification for the proposal. The training walls are an integral part of the project and cannot be split from the rest of the project.

7. The PCCF's statement in the unnumbered para 1 and 2 is proof of three aspects
 - a. It reiterates that the site cleared in the impugned clearance for construction of training walls in Alagankuppam is a turtle nesting site. Maps and data have already been submitted by the forest department earlier.
 - b. Since the new site proposed is 500 meters away, it states that it will have minimal impact (not that there will be no impact) on turtle nesting in Villupuram, without even considering the impact of accretion and alteration of beach profile.
 - c. It does not address the impact of the training walls on the shoreline on the Alamparaikuppam side, which is also a turtle nesting ground and data has been filed by the forest department itself. The report clearly states that they do not have any expertise.

8. Unnumbered para 3 and 4 of the report talks about lights causing disorientation of turtles and that lights should be "fully restricted" and in para 4th paragraph states that the CCF, Chennai has stated that "one" turtle nesting has been reported at Alamparaikuppam, Tandumariamman kovil and Velambur where the training wall is proposed – this statement is both factually incorrect, contrary to the data filed by the DFO, Chengalpet and delightfully bereft of details. The report in the very next sentence states that turtle nesting is common along the coast of Chengalpet. The report also states that suitable mitigation measures should be taken by the fisheries department.

9. The report of the PCCF cannot be relied on to state that the training walls do not have any impact on the admitted turtle nesting grounds – the Alamparaikuppam coast and Alagankuppam coast.

Response to Counter Affidavit dated December 2022

10. I submit that I have read the affidavit filed by the Fisheries Department, the project proponent herein and deny the contents of the same, except to the extent expressly admitted hereunder.
11. I submit that in para 1 the respondent has stated that the location of the training wall can be shifted within the range of 500 meters and has subsequently filed a google earth imagery marking a site which is according to them 500 meters away from the originally proposed location for which clearance has been obtained. The same statement appears to reflect in the report of the forest department as well.
12. As submitted earlier, it is not the respondent's prerogative to shift the training walls wherever they want. The training wall is an integral part of the harbor project. The construction of training walls (breakwaters) have a severe impact on the shoreline – as seen from every harbor on the shore, the Chennai fishing harbor and its impact on the northern shoreline is an example. If the respondent is changing the location of the training walls, then the entire project profile changes – the area where dredging will be carried out will be different, the impact on littoral drift, the area subjected to erosion northward will change etc. The respondent has to once again apply and obtain clearances under the CRZ Notification, 2011 before any such change can be effected.
13. The contents of para 2 are denied as false and it is submitted that this Hon'ble Tribunal has taken judicial notice of the ill effects of hard structures like groynes and seawalls in its judgment in OA No. 4 of 2013 and these aspects have been addressed in the previous affidavits filed by the applicant and are not repeated herein. In fact, the EIA report dated June 2020 has only till 4.4.7 which deals with "socio economic development". The March 2021 report contains additional portions which were not present in the EIA submitted for public hearing and this itself is reason enough to quash the impugned clearance. In 4.9.1.4 the March 2021 EIA report does not talk about the groyne field area but about

deposit 200 meters away from the proposed training walls. The only hard structure e=reflected in 4.9.1.4 is the training walls and the 3 groynes referred to in his paragraph are nowhere mentioned. In fact, the only place in the EIA where it is mentioned is in the response to PH comments by the project proponent where they mention the 3 groynes. The 3 groynes mentioned are not part of the EIA study nor is it part of the clearance. The latest NCCR report is also evidence that this coast experiences erosion of more than 1 meter a year and harbors are prohibited on these stretches.

14. The contents of para 3 are denied as false and in light of available data, these assertions of the project proponent have no substance. Mitigation measures are valid when siting is otherwise legal and are adopted to minimize any possible remote impact that might occur. Mitigation measures are not a panacea for cases like the present – where clear damage is being caused to a biodiverse region.
15. The contents of para 4 are denied as false. It is submitted that the data regarding olive ridley nesting of these coasts is on record before this Hon'ble Tribunal and the attempt of the respondent project proponent – who has not only suppressed these facts in its EIA, to now contend that the forest department is not familiar with GPS tools and mobile phone GPS is not accurate is nothing but a futile attempt to cover up their illegality. I am advised to submit that the local level politics and pressure exerted by these vested interests on local inhabitants needs no elaboration. Fishing villages are split deeply across various caste, community and power lines. The letters ostensibly from Mr. Ponnivel and Mr. Umapathi pertains to the Villupuram side (Alagankuppam). It is a fact that the local turtle watchers have been under pressure from these vested interests and even on the Almaparai side, the persons who have been doing turtle walks for decades have been prohibited from doing so. In fact, turtle nesting data for this nesting season is not available due to this reason.

16. It is submitted that GPS accuracy on phones can be as close as 5m and it is incorrect to state that the GPS in commercial phones are not accurate. Further, the undated letters purported to be from the forest watchers Mr. Ponnivel and Mr. Umapathi are similar in content. In fact, the letters are identical when it comes to the portion about the site chosen for the training wall construction. It is clear that the said persons have merely signed letters written by someone else. The credibility of the same and the intention behind the collection of such letters by one Government department from the employees of another government department is questionable and the same ought to be rejected.
17. However, it is submitted that the changing of the location of the training walls does not take away the illegality in the siting of present project. The Alamparai coast is an active turtle nesting ground and nesting data has already been filed by the Forest department and the applicant has also filed data and google earth imagery marking the GPS data. This coast, which lies north of the proposed location, will erode away. The construction of groynes or seawalls, will compound the problem and armoring the coastline will cause erosion further northward and will lead to continuous construction of seawalls and groynes as has happened in the Chennai coastline north of the port and fishing harbor, all the way to the Ennore estuary. The Yedayanthittu estuary has rich seagrass beds and any dredging in the estuary will destroy the seagrass beds.
18. The contents of para 5 of the counter affidavit are denied and it is submitted that such allegations have been made earlier and have been suitably responded. The Hon'ble Supreme Court in Sterlite, Hanuman Laxman and other matters has made valuable observations regarding these aspects. The 1st Respondent in para 5 of the counter affidavit dated December 2022 has cited a news article in the vikatan reporter dated 29.11.2022 . It is submitted that the credentials of the Appellant herein are well-established and making such bald allegations on the basis of a news-report ought to be deprecated. The newspaper article is extremely speculative in nature and has no information about the alleged links of the Appellant with the resort in question. Further, the

article alludes to a NGO filing the present appeal, which in itself is inaccurate. The 1st respondent's plea to "check the credentials" of the Appellant at this stage is a desperate attempt to sidetrack from the main issue and they are put to strict proof of the same. The respondent is put to strict proof of these assertions and it is submitted that the law regarding making such allegations of malafide or fraud is clear – it has to be meticulously pleaded and proven to the hilt – such callous, bald assertions designed to prejudice albeit without substance ought to be deprecated.

19. The contents of para 6 are denied as false and has already been responded to in the previous affidavit of the respondent. These statements show the complete lack of awareness and knowledge of the respondent on these aspects.
20. In para 7, the respondent has admitted to the presence of seagrass meadows but contends that they are temporary and sparse. While these contentions are incorrect, it is submitted that seagrass beds by their very nature, like all components in nature, vary in extent and density depending on the season. This is the reason why the law classifies "seagrass beds" as CRZ 1A. If the area is destroyed by dredging etc. then these seagrass beds will be destroyed.
21. The contents of para 8 are denied as false. It is submitted that the 1st Respondent has relied in the example of the Dhamra port in Odisha as an example of a successful collaboration between the port establishment and a conservation organization. The same is false and several serious concerns about this port still remain.
22. In a paper titled **Threats to the nests of Olive Ridley Turtles (*Lepidochelys olivacea* Eschscholtz, 1829) in the world's largest sea turtle rookery at Gahirmatha, India: need for a solution**, (2020- Journal of Herpetology)- it has been observed that

*“the loss of nests by inundation and erosion accounted for 23% of the total nest loss by natural factors at Gahirmatha rookery (Fig.3) In recent years, significant temporal and spatial geomorphological changes in Gahirmatha have led to considerable changes in the nesting beach profile and an accelerated loss of nesting habitat (Prusty et al., 2007; Wildlife Institute of India, 2012; Behera et al., 2013). In the study area, the Segments used most for nesting, including the sand spit and the islets (Segments 1–3), have undergone conspicuous changes over time due to natural calamities, including cyclones and the interaction of oceanic forces and fluctuating riverine discharge (Prusty et al., 2007). **In addition, the construction of Dhamra Port near the Gahirmatha mass nesting site and the concomitant need for the dredging of ship channels are major, permanent intrusions**”.*

(Emphasis added)

23. It is submitted that in a critique to the EIA report of the Dhamra Port by Greenpeace, also point to serious omissions and shortcomings in the analysis of impacts. The dangers faced in the Odisha coast due to sea-erosion is also well known and reported widely. It is submitted that filing and relying on another project’s EIA report does not help the respondent in any manner. The ecological sensitivity of the subject site determines its legality.

24. The contents of para 9 -14 are bereft of merit and are denied as false. It is submitted that the attempt of the respondent to compare this site to another site and say that since permission was granted for that, let us also construct is bereft of merit. These contentions are repetitive and have been responded suitably in the previous affidavits and are not repeated once again.

Recent bird survey

25. It is further submitted that over December 2022 and January 2023 three bird surveys were conducted at Yedaiyanthittu estuary by Sutru Suzhal Kalvi Kazhagam, an environmental organization in Pondicherry. This was during

when migratory bird numbers were at their peak. Despite the disturbances caused due to filling up parts of the creek by harbor construction, 93 species of birds were seen of which 29 species are migratory and 4 are globally threatened. Among these the Asian open billed stork, Brown-headed gull, Lesser black-backed gull, Lesser sand-plover, Great crested tern, cattle egret were observed in their hundreds. The sandbars, salt marshes, and shallow waters were observed to be the most crucial bird foraging and roosting areas. Large patches of seagrass were also observed. Copy of this report is also annexed herewith.

26. It is therefore prayed that this Hon'ble Tribunal be pleased to record the above fact and set aside the Clearance granted to the 1st Respondent herein and render justice.

M. Juvay

|

Solemnly affirmed on this the
20th day of February, 2023 and
signed his name in my presence

BEFORE ME
Chethana V
(MADR/6108/18)
Chethana V
No. 14 Grindharan St.
Mylapore, ch-04

ADVOCATE : CHENNAI

சுற்றுச்சூழல் காப்போம்!

சூழல் நலம் பெறுவோம்!!

சுற்றுச்சூழல் கல்விக்கழகம்

அரசு பதிவு பெற்றது எண். 86/1996

1, முதல் தெரு, சாய் பாபா நகர், அரியாங்குப்பம், புதுச்சேரி - 605007. பேசி: 9629962973

19/01/2023

To Whomsoever It May Concern

On 24.12.2022, 01.01.2023 and 07.01.2023 three bird surveys were carried out by us at Yedaiyanthittu estuary. Surendhar. B, Umashankar Umi and Gauresh Naik did the bird count. Totally 93 bird species were recorded of which 29 are migratory and 4 are globally threatened. The complete eBird checklists and bird numbers are attached below.

Yedaiyanthittu mudflats, seagrasses, oyster reefs and sand bars are an important foraging and roosting grounds for a number of migratory and threatened bird species, among other biodiversity. This fragile coastal habitat needs protection from any further disturbances.

eBird checklist links:

<https://ebird.org/india/tripreport/94291>

<https://ebird.org/india/tripreport/98128>

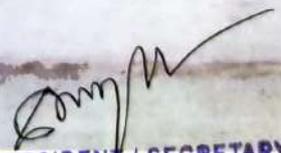
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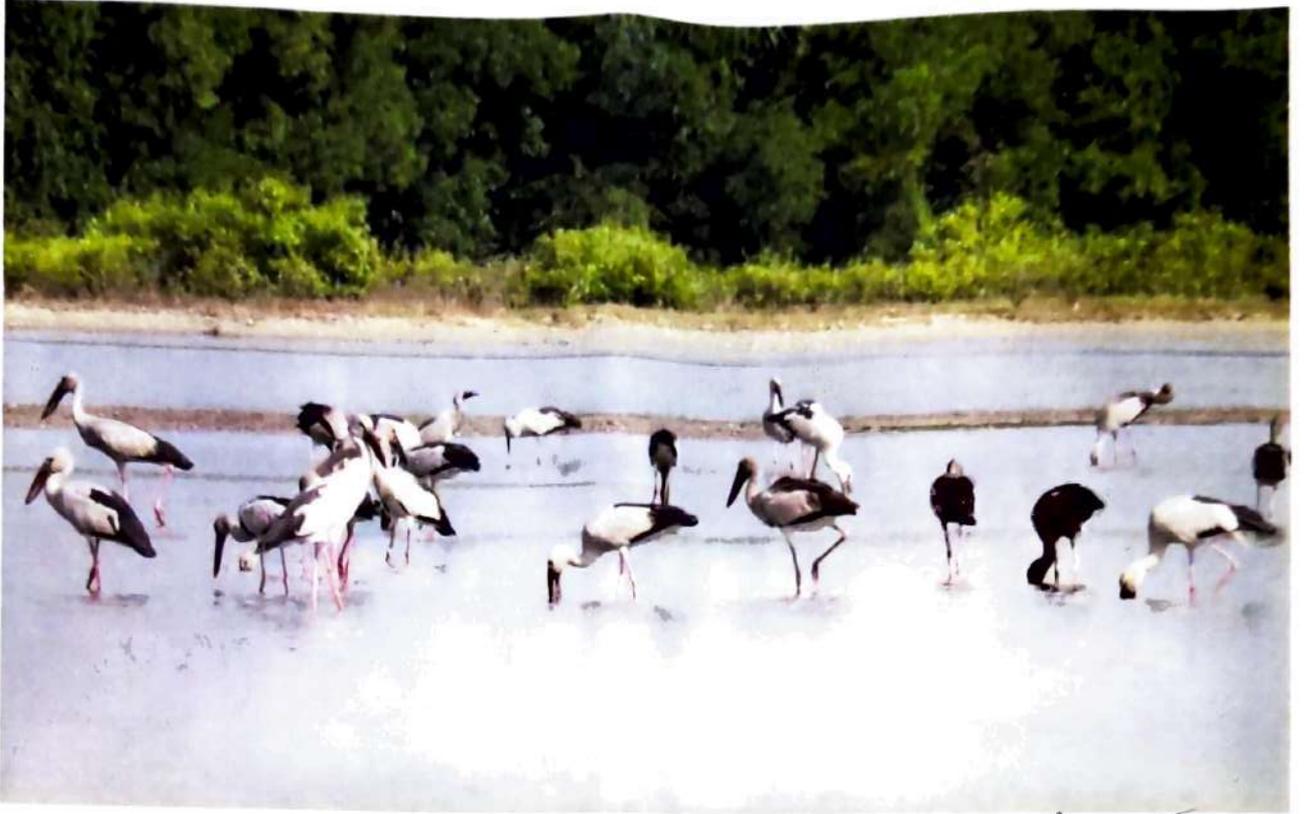
C.S. RAMANADAN
19/01/2023
PRESIDENT (SECRETARY)
SUTRU SOOZHAI KALVI KAZHAGAM
No:1, First Street, Sai Baba Nagar,
Ariyankuppam, Puducherry - 605 007.

மணிநீரும் மண்ணும் மலையும் அணிநிழற்
காடும் உடையது அரண்

- திருக்குறள்




PRESIDENT / SECRETARY
S. SOOZHAL KALVI KAZHAGAM
1st, First Street, Sai Baba Nagar,
Aranyakuppam, Puducherry - 605 007.



A handwritten signature in black ink, appearing to be 'Surya', written in a cursive style.

~~PRESIDENT / SECRETARY~~
SUTRU SOOZHAI KALVI KAZHAGAM
No:1, First Street, Sal Baba Nagar,
Ariyankuppam, Pudukcherry - 605 007.

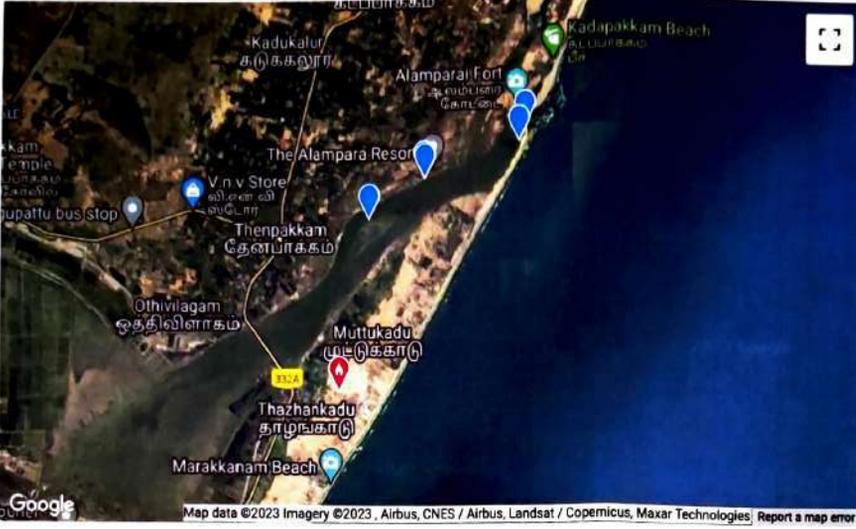
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My Trip Reports

Previous Next

Yedayanthittu Survey Day 1

24 Dec 2022 Link only



Tamil Nadu, India
Chengalpattu | Viluppuram
Surendhar Boobalan

75
Species observed

6
Checklists

Species observed

Show all details

- 8 Indian Spot-billed Duck *Anas poecilorhyncha* 2
- 49 Northern Pintail *Anas acuta* 2
- 4 Grey Francolin *Ortygornis pondicerianus* 2
- 1 Rock Pigeon (Blue Rock Pigeon) *Columba livia* 1
- 1 Eurasian Collared-Dove *Streptopelia decaocto* 1
- 14 Spotted Dove *Spilopelia chinensis* 3
- 1 Greater Coucal *Centropus sinensis* 1
- 2 Asian Koel *Eudynamis scolopaceus* 1
- 59 Asian Palm Swift *Cypsiurus balasiensis* 5
- 1 White-breasted Waterhen *Amaurornis phoenicurus* 1
- 3 Indian Thick-knee (Indian Stone-curlew) *Burhinus indicus* 2
- 5 Black-bellied Plover (Grey Plover) *Pluvialis squatarola* 1
- 13 Pacific Golden-Plover *Pluvialis fulva* 1


PRESIDENT / SECRETARY
SUTRU SOOZHAL KALVI KAZHAGAM 1/4
 No:1, First Street, Sai Pabe Nagar,
 Ariyankuppam, Puducherry - 605 007.

1/19/23, 11:24 AM

17	Red-wattled Lapwing	<i>Vanellus indicus</i>	3
96	Lesser Sand-Plover	<i>Charadrius mongolus</i>	1
10	Kentish Plover	<i>Charadrius alexandrinus</i>	1
19	Whimbrel	<i>Numenius phaeopus</i>	4
3	Eurasian Curlew	<i>Numenius arquata</i>	2
1	Sanderling	<i>Calidris alba</i>	1
1	Pin-tailed Snipe	<i>Gallinago stenura</i>	1
1	Terek Sandpiper	<i>Xenus cinereus</i>	1
8	Common Sandpiper	<i>Actitis hypoleucos</i>	2
4	Common Greenshank	<i>Tringa nebularia</i>	1
2	Wood Sandpiper	<i>Tringa glareola</i>	1
14	Common Redshank	<i>Tringa totanus</i>	1
1	Oriental Pratincole	<i>Glareola maldivarum</i>	1
1	Black-headed Gull	<i>Chroicocephalus ridibundus</i>	1
54	Brown-headed Gull	<i>Chroicocephalus brunnicephalus</i>	6
28	Lesser Black-backed Gull	<i>Larus fuscus</i>	1
6	Little Tern	<i>Sternula albifrons</i>	1
4	Gull-billed Tern	<i>Gelochelidon nilotica</i>	1
48	Caspian Tern	<i>Hydroprogne caspia</i>	5
2	Whiskered Tern	<i>Chlidonias hybrida</i>	1
1	Common Tern	<i>Sterna hirundo</i>	1
44	Great Crested Tern	<i>Thalasseus bergii</i>	3
205	Asian Openbill	<i>Anastomus oscitans</i>	3
1	Oriental Darter	<i>Anhinga melanogaster</i>	1
38	Little Cormorant	<i>Microcarbo niger</i>	3
2	Yellow Bittern	<i>Ixobrychus sinensis</i>	1
6	Grey Heron	<i>Ardea cinerea</i>	3
10	Great Egret	<i>Ardea alba</i>	5
1	Intermediate Egret	<i>Ardea intermedia</i>	1
79	Little Egret	<i>Egretta garzetta</i>	5

1	Western Reef-Heron (Western Reef-Egret)	<i>Egretta gularis</i>	1
518	Cattle Egret	<i>Bubulcus ibis</i>	4
30	Indian Pond-Heron	<i>Ardeola grayii</i>	5
2	Striated Heron (Little Heron)	<i>Butorides striata</i>	1
2	Black-crowned Night-Heron	<i>Nycticorax nycticorax</i>	1
31	Glossy Ibis	<i>Plegadis falcinellus</i>	2
10	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	2
2	Shikra	<i>Accipiter badius</i>	2
2	Spotted Owlet	<i>Athene brama</i>	1
11	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	3
4	Pied Kingfisher	<i>Ceryle rudis</i>	3
2	Asian Green Bee-eater	<i>Merops orientalis</i>	1
8	Blue-tailed Bee-eater	<i>Merops philippinus</i>	3
1	Indian Roller	<i>Coracias benghalensis</i>	1
5	Rose-ringed Parakeet	<i>Psittacula krameri</i>	2
1	Indian Golden Oriole	<i>Oriolus kundoo</i>	1
4	Black Drongo	<i>Dicurus macrocercus</i>	3
1	Rufous Treepie	<i>Dendrocitta vagabunda</i>	1
11	House Crow	<i>Corvus splendens</i>	2
18	Large-billed Crow	<i>Corvus macrorhynchos</i>	5
3	Jerdon's Bushlark	<i>Mirafra affinis</i>	2
2	Ashy Prinia	<i>Prinia socialis</i>	2
2	Plain Prinia	<i>Prinia inornata</i>	1
1	Zitting Cisticola	<i>Cisticola juncidis</i>	1
6	Blyth's Reed Warbler	<i>Acrocephalus dumetorum</i>	3
13	Barn Swallow	<i>Hirundo rustica</i>	4
3	Yellow-billed Babbler	<i>Argya affinis</i>	1
20	Common Myna	<i>Acridotheres tristis</i>	2
1	Oriental Magpie-Robin	<i>Copsychus saularis</i>	1
4	Purple-rumped Sunbird	<i>Leptocoma zeylonica</i>	3

1/19/23, 11:24 AM

3 **White-browed Wagtail (Large Pied Wagtail)** *Motacilla maderaspatensis* 2

2 **Paddyfield Pipit** *Anthus rufulus* 1

ADDITIONAL TAXA

135 **tern sp.** *Sterninae sp.* 1

1 **sunbird sp.** *Nectariniidae sp. (sunbird sp.)* 1


PRESIDENT SECRETARY
SUTRU SOOZHAI KALVI KAZHAGAM
No:1, First Street, Sal Baba Nagar,
Ariyankuppam, Puducherry - 605 007.

1/19/23, 11:24 AM

My Trip Reports

Previous Next

Yedyanthittu Survey Day 2

1 Jan 2023



Tamil Nadu, India
Chengalpattu | Viluppuram
Surendhar Boobalan

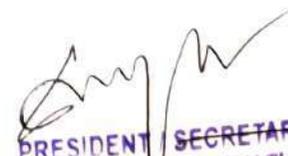
75
Species observed

4
Checklists

Species observed

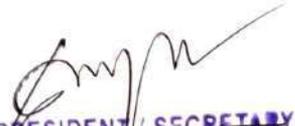
Show all details

- 1 Knob-billed Duck (Comb Duck) *Sarkidiornis melanotos* 1
- 5 Indian Spot-billed Duck *Anas poecilorhyncha* 2
- 23 Northern Pintail *Anas acuta* 1
- 5 Grey Francolin *Ortygornis pondicerianus* 2
- 2 Eurasian Collared-Dove *Streptopelia decaocto* 1
- 6 Spotted Dove *Spilopelia chinensis* 1
- 1 Greater Coucal *Centropus sinensis* 1
- 1 Asian Koel *Eudynamis scolopacea* 1
- 3 Common Hawk-Cuckoo *Hierococcyx varius* 2
- 83 Asian Palm Swift *Cypsiurus balasiensis* 3
- 1 White-breasted Waterhen *Amaurornis phoenicurus* 1
- 12 Black-winged Stilt *Himantopus himantopus* 2
- 2 Black-bellied Plover (Grey Plover) *Pluvialis squatarola* 1


PRESIDENT / SECRETARY
SUTRU SOOZHA / KALVI KAZHAGAM
No:1, First Street, Sai Baba Nagar,
Ariyankuppam, Puducherry - 605 007. 1/4

1/19/23, 11:24 AM

11	Red-wattled Lapwing	<i>Vanellus indicus</i>	3
57	Lesser Sand-Plover	<i>Charadrius mongolus</i>	1
7	Kentish Plover	<i>Charadrius alexandrinus</i>	1
14	Whimbrel	<i>Numenius phaeopus</i>	4
1	Eurasian Curlew	<i>Numenius arquata</i>	1
1	Sanderling	<i>Calidris alba</i>	1
1	Pin-tailed Snipe	<i>Gallinago stenura</i>	1
1	Common Sandpiper	<i>Actitis hypoleucos</i>	1
4	Common Greenshank	<i>Tringa nebularia</i>	2
1	Common Redshank	<i>Tringa totanus</i>	1
191	Brown-headed Gull	<i>Chroicocephalus brunnicephalus</i>	4
204	Lesser Black-backed Gull	<i>Larus fuscus</i>	1
3	Little Tern	<i>Sternula albifrons</i>	1
3	Gull-billed Tern	<i>Gelochelidon nilotica</i>	2
41	Caspian Tern	<i>Hydroprogne caspia</i>	3
5	Whiskered Tern	<i>Chlidonias hybrida</i>	1
139	Great Crested Tern	<i>Thalasseus bergii</i>	1
3	Lesser Crested Tern	<i>Thalasseus bengalensis</i>	1
263	Asian Openbill	<i>Anastomus oscitans</i>	3
3	Painted Stork	<i>Mycteria leucocephala</i>	1
44	Little Cormorant	<i>Microcarbo niger</i>	4
2	Great Cormorant	<i>Phalacrocorax carbo</i>	1
26	Indian Cormorant (Indian Shag)	<i>Phalacrocorax fuscicollis</i>	1
17	Grey Heron	<i>Ardea cinerea</i>	4
25	Great Egret	<i>Ardea alba</i>	1
40	Little Egret	<i>Egretta garzetta</i>	4
79	Cattle Egret	<i>Bubulcus ibis</i>	2
10	Indian Pond-Heron	<i>Ardeola grayii</i>	3
1	Striated Heron (Little Heron)	<i>Butorides striata</i>	1
5	Black-crowned Night-Heron	<i>Nycticorax nycticorax</i>	1


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1/19/23, 11:24 AM

1	Glossy Ibis <i>Plegadis falcinellus</i>	1
2	Black-headed Ibis <i>Threskiornis melanocephalus</i>	1
1	Shikra <i>Accipiter badius</i>	1
1	Brahminy Kite <i>Haliastur indus</i>	1
2	Eurasian Hoopoe <i>Upupa epops</i>	2
2	White-throated Kingfisher <i>Halcyon smyrnensis</i>	2
4	Pied Kingfisher <i>Ceryle rudis</i>	2
1	Asian Green Bee-eater <i>Merops orientalis</i>	1
6	Blue-tailed Bee-eater <i>Merops philippinus</i>	1
1	Indian Roller <i>Coracias benghalensis</i>	1
2	Black-rumped Flameback (Lesser Goldenbacked Woodpecker) <i>Dinopium benghalense</i>	1
6	Rose-ringed Parakeet <i>Psittacula krameri</i>	1
11	Indian Golden Oriole <i>Oriolus kundoo</i>	1
4	Black Drongo <i>Dicurus macrocercus</i>	2
5	Rufous Treepie <i>Dendrocitta vagabunda</i>	2
24	House Crow <i>Corvus splendens</i>	2
32	Large-billed Crow <i>Corvus macrorhynchos</i>	4
2	Jerdon's Bushlark <i>Mirafra affinis</i>	1
4	Common Tailorbird <i>Orthotomus sutorius</i>	2
5	Ashy Prinia <i>Prinia socialis</i>	2
4	Plain Prinia <i>Prinia inornata</i>	2
2	Zitting Cisticola <i>Cisticola juncidis</i>	1
7	Blyth's Reed Warbler <i>Acrocephalus dumetorum</i>	2
13	Barn Swallow <i>Hirundo rustica</i>	1
3	Red-vented Bulbul <i>Pycnonotus cafer</i>	1
6	White-browed Bulbul <i>Pycnonotus luteolus</i>	2
4	Yellow-billed Babbler <i>Argya affinis</i>	1
11	Common Myna <i>Acridotheres tristis</i>	3
1	Oriental Magpie-Robin <i>Copsychus saularis</i>	1

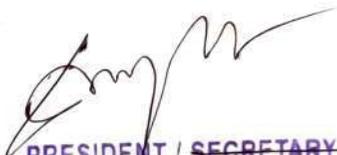
1/19/23, 11:24 AM

Yedayanthittu Survey Day 2 - eBird Trip Report

- 2 **Pied Bushchat** *Saxicola caprata* 1
- 1 **Purple-rumped Sunbird** *Leptocoma zeylonica* 1
- 3 **Paddyfield Pipit** *Anthus rufulus* 1

ADDITIONAL TAXA

- 35 **gull sp.** *Larinae sp.* 1
- 57 **tern sp.** *Sterninae sp.* 1
- 1 **Acrocephalus warbler sp.** *Acrocephalus sp.* 1



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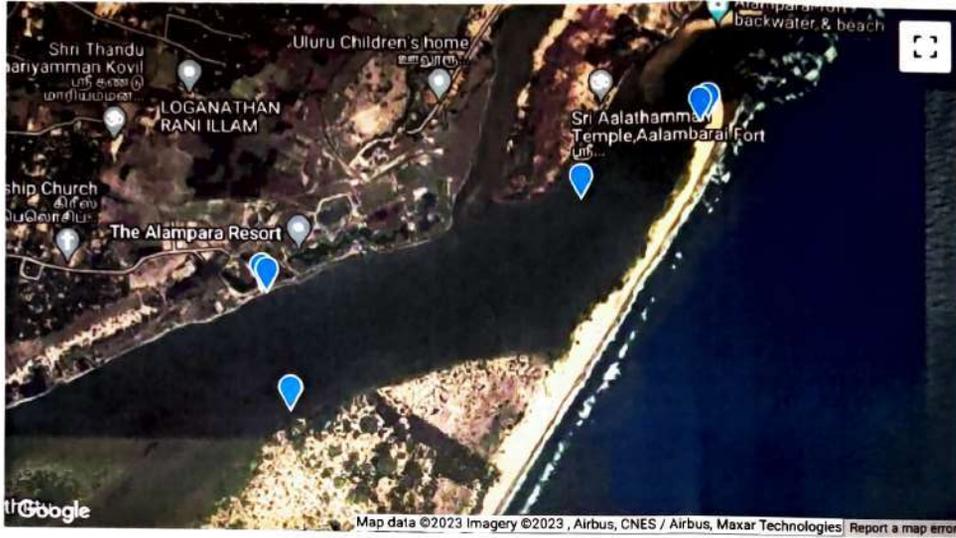
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My Trip Reports

Previous Next

Yedayanthittu Survey Day 3

7 Jan 2023 [Link only](#)



Tamil Nadu India
Chengalpattu Viluppuram
Surendhar Boobalan

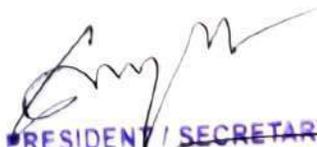
69
Species observed

Checklist

Species observed

Show all details

- 13 Indian Spot-billed Duck *Anas poecilorhyncha* 4
- 5 Grey Francolin *Ortygornis pondicerianus* 3
- 2 Eurasian Collared-Dove *Streptopelia decaocto* 1
- 4 Spotted Dove *Spilopelia chinensis* 2
- 1 Greater Coucal *Centropus sinensis* 1
- 2 Asian Koel *Eudynamys scolopaceus* 2
- 3 Common Hawk-Cuckoo *Hierococcyx varius* 2
- 35 Asian Palm Swift *Cypsiurus balasiensis* 3
- 3 Black-winged Stilt *Himantopus himantopus* 2
- 1 Black-bellied Plover (Grey Plover) *Pluvialis squatarola* 1
- 32 Pacific Golden-Plover *Pluvialis fulva* 1
- 5 Red-wattled Lapwing *Vanellus indicus* 2
- 97 Lesser Sand-Plover *Charadrius mongolus* 1


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1/19/23, 11:25 AM

2	Kentish Plover <i>Charadrius alexandrinus</i>	1
8	Whimbrel <i>Numenius phaeopus</i>	3
1	Pin-tailed Snipe <i>Gallinago stenura</i>	1
4	Common Sandpiper <i>Actitis hypoleucos</i>	3
4	Common Greenshank <i>Tringa nebularia</i>	2
1	Wood Sandpiper <i>Tringa glareola</i>	1
2	Common Redshank <i>Tringa totanus</i>	2
193	Brown-headed Gull <i>Chroicocephalus brunnicephalus</i>	4
82	Lesser Black-backed Gull <i>Larus fuscus</i>	3
1	Gull-billed Tern <i>Gelochelidon nilotica</i>	1
16	Caspian Tern <i>Hydroprogne caspia</i>	3
1	Whiskered Tern <i>Chlidonias hybrida</i>	1
205	Great Crested Tern <i>Thalasseus bergii</i>	2
3	Lesser Crested Tern <i>Thalasseus bengalensis</i>	1
327	Asian Openbill <i>Anastomus oscitans</i>	5
4	Painted Stork <i>Mycteria leucocephala</i>	1
32	Little Cormorant <i>Microcarbo niger</i>	3
2	Yellow Bittern <i>Ixobrychus sinensis</i>	1
22	Grey Heron <i>Ardea cinerea</i>	6
8	Great Egret <i>Ardea alba</i>	2
2	Intermediate Egret <i>Ardea intermedia</i>	2
85	Little Egret <i>Egretta garzetta</i>	5
427	Cattle Egret <i>Bubulcus ibis</i>	2
20	Indian Pond-Heron <i>Ardeola grayii</i>	4
9	Black-crowned Night-Heron <i>Nycticorax nycticorax</i>	1
2	Glossy Ibis <i>Plegadis falcinellus</i>	1
4	Black-headed Ibis <i>Threskiornis melanocephalus</i>	1
1	Spotted Owlet <i>Athene brama</i>	1
1	Eurasian Hoopoe <i>Upupa epops</i>	1
6	White-throated Kingfisher <i>Halcyon smyrnensis</i>	4

1/19/23, 11:25 AM

4	Pied Kingfisher <i>Ceryle rudis</i>	3
9	Asian Green Bee-eater <i>Merops orientalis</i>	1
4	Blue-tailed Bee-eater <i>Merops philippinus</i>	2
2	Black-rumped Flameback (Lesser Goldenbacked Woodpecker) <i>Dinopium benghalense</i>	1
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3	Rufous Treepie <i>Dendrocitta vagabunda</i>	2
26	House Crow <i>Corvus splendens</i>	3
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2	Common Tailorbird <i>Orthotomus sutorius</i>	2
4	Ashy Prinia <i>Prinia socialis</i>	1
2	Plain Prinia <i>Prinia inornata</i>	2
3	Zitting Cisticola <i>Cisticola juncidis</i>	2
9	Blyth's Reed Warbler <i>Acrocephalus dumetorum</i>	1
1	Red-vented Bulbul <i>Pycnonotus cafer</i>	1
2	White-browed Bulbul <i>Pycnonotus luteolus</i>	1
1	Common Myna <i>Acridotheres tristis</i>	1
1	Oriental Magpie-Robin <i>Copsychus saularis</i>	1
2	Pale-billed Flowerpecker <i>Dicaeum erythrorhynchos</i>	2
1	Purple-rumped Sunbird <i>Leptocoma zeylonica</i>	1
3	Purple Sunbird <i>Cinnyris asiaticus</i>	2
1	Western Yellow Wagtail <i>Motacilla flava</i>	1
1	White-browed Wagtail (Large Pied Wagtail) <i>Motacilla maderaspatensis</i>	1
1	Paddyfield Pipit <i>Anthus rufulus</i>	1
ADDITIONAL TAXA		
45	tern sp. <i>Sterninae sp.</i>	1

THE DHAMRA-CHANDBALI PORT EXPANSION PROJECT, ORISSA, INDIA

Critique of the Environmental Impact Assessment



By Dr. Paul Johnston & Dr. David Santillo
Greenpeace Research Laboratories,
School of Biosciences, University of Exeter
May 2007

GREENPEACE

The Dhamra-Chandbali Port Expansion Project, Orissa, India

Critique of the Environmental Impact Assessment

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1 Introduction

The Dhamra-Chandbali Port Project is far from being a simple expansion of the existing Dhamra fishing port, located some 4km upstream of the river and which can currently handle around 200 mechanised vessels, as well as some 300 traditional craft. By contrast, the proposal involves a large scale development to the north of the existing port, on the area between the existing high and low tide limits. Phase I, to be completed by 2009 will involve construction of 0.7 km of berth space with associated handling facilities for bulk and general cargoes. When fully realised, the project will provide for 13 berths of 18m depth, a dredged channel to this depth and a rail connection to the national rail network. This will make the facility the deepest water port in India, capable of handling vessels up to 180,000 deadweight tonnes.¹

The traffic potential is likely to be largely determined by the exploitation and export of mineral resources inland together with steel products, and the import of coal for coking and energy generation. It is possible that the port could also serve as an import point for crude oil, though the predominant cargo type is envisaged to be dry bulk.² The construction of the channel will involve the construction of constraining dikes and the construction (capital) dredging will require supplementation with periodic maintenance dredging.. It is projected that the dredged material will, in part, be used in reclamation of the tidal areas in which the facility will be located. The total “land take” is estimated at 9,200 acres exclusive of the intertidal area proposed, according to the EIA.

Overall, as noted in Chapter 15 of the Detailed Project Report, the development of the port facility is a key part of a wider policy in Orissa of moving from a predominantly agricultural economy towards increased industrialisation. The developers recognise that this development will have concomitant environmental impacts and these have been the subject of an Environmental Impact Assessment. This Assessment has been used as the basis for the Orissa Pollution Control Board issuing a “No Objection Certificate” to the proposed development. On the same basis, the Principal Secretary Environment & Forest to the Government of Orissa has given the project environmental clearance.

Clearly, this is a large scale development project, and the Environmental Impact Assessment prepared by Kirloskar Consultants Ltd is a key document underpinning the acceptance, in environmental terms, of the proposed development. Accordingly, the Assessment³ is worth considering in some detail; the remainder of the current document provides a critique of that Assessment.

2 Purpose of an Environmental Impact Assessment

Appendix II of the new EIA Notification issued in September 2006⁴ by the Ministry of Environment and Forests, Government of India, specifies several considerations to be taken into account by any EIA. While the 1997 EIA and grant of clearance predates this version of the EIA notification, these guidelines have remained relatively constant and are an indication of the basic requirements of a good EIA. Some of the considerations that are more relevant to this particular project, and which have been either neglected or inadequately addressed, are:

Land environment

1.5 Will the proposal involve alteration of natural drainage systems? (Give details on a contour map showing the natural drainage near the proposed project site)

1.6. What are the quantities of earthwork involved in the construction activity-cutting, filling, reclamation etc. (Give details of the quantities of earthwork involved, transport of fill materials from outside the site etc.)

1.8. Will the low lying areas & wetlands get altered? (Provide details of how low lying and wetlands are getting modified from the proposed activity)

Water environment

2.8. What would be the impact of the land use changes occurring due to the proposed project on the runoff characteristics (quantitative as well as qualitative) of the area in the post construction phase on a long term basis? Would it aggravate the problems of flooding or water logging in any way?

Fauna

4.1. Is there likely to be any displacement of fauna- both terrestrial and aquatic or creation of barriers for their movement? Provide the details.

4.2. Any direct or indirect impacts on the avifauna of the area? Provide details.

4.3. Prescribe measures such as corridors, fish ladders etc to mitigate adverse impacts on fauna.

Further, the European Community has defined and adopted legislation on the need for Environmental Impact Assessments as enshrined in the relevant council directive (Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, as amended by Council Directive 97/11/EC). Although not applicable in law to India, this Directive is nevertheless a useful benchmark against which to assess the content of EIAs and Environmental Impact Statements, including those which relate to projects outside the EU. It should be seen as defining the minimum standards required for EIAs globally.

The Directive states in Article 3:

The environmental impact assessment shall identify, describe and assess in an appropriate manner, in the light of each individual case and in accordance with Articles 4 to 11, the direct and indirect effects of a project on the following factors:

- human beings, fauna and flora;
- soil, water, air, climate and the landscape;
- material assets and the cultural heritage;
- the interaction between the factors

mentioned in the first, second and third indents.;

Moreover, Article 5 specifies:

The information to be provided by the developer in accordance with paragraph 1 shall include at least:

- *a description of the project comprising information on the site, design and size of the project,*
- *a description of the measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects,*
- *the data required to identify and assess the main effects which the project is likely to have on the environment,*
- *an outline of the main alternatives studied by the developer and an indication of the main reasons for his choice, taking into account the environmental effects,*
- *a non-technical summary of the information mentioned in the previous indents.*

ANNEX III INFORMATION REFERRED TO IN ARTICLE 5 (1)

1. Description of the project, including in particular:

- *a description of the physical characteristics of the whole project and the land-use requirements during the construction and operational phases,*
- *a description of the main characteristics of the production processes, for instance, nature and quantity of the materials used,*
- *an estimate, by type and quantity, of expected residues and emissions (water, air and soil pollution, noise, vibration,*

light, heat, radiation, etc.) resulting from the operation of the proposed project.

2. An outline of the main alternatives studied by the developer and an indication of the main reasons for this choice, taking into account the environmental effects.

3. A description of the aspects of the environment likely to be significantly affected by the proposed project, including, in particular, population, fauna, flora, soil, water, air, climatic factors, material assets, including the architectural and archaeological heritage, landscape and the inter-relationship between the above factors.

4. A description (1) of the likely significant effects of the proposed project on the environment resulting from:

- *the existence of the project,*
- *the use of natural resources,*
- *the emission of pollutants, the creation of nuisances and the elimination of waste, and the description by the developer of the forecasting methods used to assess the effects on the environment.*

5. A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment.

6. A non-technical summary of the information provided under the above headings.

7. An indication of any difficulties (technical deficiencies or lack of know-how)

encountered by the developer in compiling the required information.

(1) This description should cover the direct effects and any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the project.

The full text of the Directive may be accessed via: <http://eur-lex.europa.eu/LexUriServLexUriServ.do?uri=CELEX:31985L0337:EN:HTML>

Critically, following the production of numerous EIA/EIS documents of questionable quality, the Commission produced additional guidance which can be accessed via: <http://ec.europa.eu/environment/eia/eia-guidelines/g-review-full-text.pdf>

This document *inter alia* considers that a good EIS should contain:

- A clear structure with a logical sequence for example, describing, existing baseline conditions, predicted impacts (nature, extent and magnitude), scope for mitigation, agreed mitigation measures, significance of unavoidable/residual impacts for each environmental topic.
- A table of contents at the beginning of the document.
- A clear description of the development consent procedure and how EIA fits within it.
- Reads as a single document with appropriate cross-referencing.
- Is concise, comprehensive and objective.
- Is written in an impartial manner without bias.
- Includes a full description of the development proposals.

- Makes effective use of diagrams, illustrations, photographs and other graphics to support the text.
- Uses consistent terminology with a glossary.
- References all information sources used.
- Has a clear explanation of complex issues.
 - Contains a good description of the methods used for the studies of each environmental topic.
 - Covers each environmental topic in a way which is proportionate to its importance.
 - Provides evidence of good consultations.
 - Includes a clear discussion of alternatives.
 - Makes a commitment to mitigation (with a programme) and to monitoring.
 - Has a Non Technical Summary which does not contain technical jargon.

The Dhamra EIA can be broadly assessed using these metrics. Superficially, the Detailed Project Report and Environmental Assessments, taken together, appear to meet many of the Indian and European Community criteria given above. Upon more detailed consideration, however, a number of considerable shortfalls emerge, largely relating to the identification, prioritisation and analysis of likely impacts. In order to address the full extent and serious nature of these shortcomings it would be necessary largely to rewrite the EIA in order to provide a more balanced and holistic overview of the likely impacts, together with proposals for their mitigation.

3 Environmental Impacts of the Dhamra Port Project

Broadly, the environmental impacts of the Dhamra project fall into three categories:

Firstly, the construction phase of the project will lead to considerable physical disturbance of the environment and overall modification to the existing physical and ecological baseline conditions.

Secondly, the normal operation of the port will also create impacts due to the loading operations, shipping movements and ship-related activities such as refuelling, engineering and maintenance dredging.

Finally, impacts may result from non-routine events such as an oil or chemical spill, grounding, collision, or fire and/or explosion either on a vessel or on shore. Obviously the likelihood of such an event will be linked to the mix of activities carried out. For example, if oil, LPG or chemical cargo are being shipped through the port then the risks of a catastrophic incident will be higher as compared to those associated with the handling of largely inert cargoes.

The indirect impacts of the development, by encouraging the development of infrastructure outside the immediate port area and increased exploitation of natural resources in the region as a whole, could extend over a wide area. Accordingly, it is questionable as to whether a study which considers in detail only issues within a 10km radius of the proposed development with more general treatment over a 20km radius is sufficient to capture the full impacts likely to flow from the development. This is particularly the case given the handling of bulk cargoes consisting of coal and iron ore, together with liquid and other specialty cargoes. In order to capture the full spectrum of external impacts of a

development of this scale, the detailed considerations should extend over a radius of at least 30km, particularly in respect of terrestrial transport impacts and impacts related to shipping operations.

i) Consistency of Information

The information presented in the Environmental Impact Assessment is not entirely consistent with that presented elsewhere in relation to the project. One illustration of this relates to the fundamental data on port capacity. In the Environmental Clearance Report ³, the port is described as providing for a draft of 14m. In the Detailed Project Report ² (2-7 to 2-11) the ultimate draft provided for is 16m while the Company website suggests that the capacity will be 18m. While this inconsistency might seem trivial at first, it has a large influence on the expected intensity of operations, since this will govern the size of ships entering the port. At 12m draft, the size of ship accommodated (Panamax size, around 60,000 deadweight tons) is very different to sizes accommodated at 16m draft (essentially small Capesize, too big for the Panama and Suez canals and of typically above 120,000) deadweight tonnes. The EIA (Section 2.4.3) notes that initial draft provided for will be 14m, with the intention to dredge to 16m or deeper in subsequent years to allow the passage of larger vessels. Assuming that the 18m figure (greater than 150,000 deadweight tonnes) is the latest development intention, this has potentially significant implications for the scale and extent of environmental impacts compared to the earlier figures and should be clarified explicitly by a supplementary environmental analysis. Moreover, the EIA

considers two options for the port's location, one on the Kanika Sands itself, and the other on the mainland, before discarding the mainland option in favour of Kanika Sands. The EIA then goes on to evaluate impacts on the basis of the port location on Kanika Sands. However, the project as it is currently being implemented locates the port on the mainland and not Kanika Sands. Such a fundamental discrepancy then calls into question the credibility of the entire EIA as a basis on which to gauge the environmental impacts of the project. (Fig 1, Pg 14)

Similar observations apply to the details given of likely operations at the port. The port is largely projected to handle bulk cargoes, principally coal and iron ore (Detailed Project Report Page 45). However, under Section 9.4 of this report, reference is made to liquid, fertiliser and container cargoes, tank farm facilities and LNG handling facilities, while under Section 8.1, crude and product liquid cargoes are referred to. The precise function of the port facilities is a matter of some importance, since the hazards involved in handling coal, steel and ores are quantitatively and qualitatively very different to the hazards involved in handling generalised mixed container cargoes. The potential hazards associated with crude and product petroleum/chemicals and LNG are potentially very serious indeed, and would require a very different degree of major incident preparedness (emergency plans) to provide health, safety and environmental protection both within the port and in the surrounding area. These further inconsistencies in the content of the report need to be rectified.

The standard of illustration in the document is very poor. Much could be gained by adding various maps and diagrams of the quality available on the developers' website.

ii) Hazard/risk analysis and Emergency Plan

The possibility of a much wider spectrum of activities taking place as development progresses (as noted above) essentially means that the risk assessment carried out and reported in Chapter 6 of the Environmental Impact Assessment is seriously deficient. It considers the major hazard to arise from fire/explosion associated with the storage of fuel oil and diesel oil on the site and the possibility of oil spillage. The maximum credible hazard analysis needs to be re-evaluated to take account of the possibility that chemicals such as pesticides and specialty chemicals may be present in containerised cargo likely to be handled at the facility.

There is one key omission from the hazard/risk analysis undertaken. Given that a significant element of the bulk cargo is projected to be coal, little analysis of the risks associated with this cargo has been made. Bulk coal can ignite spontaneously as a result of oxidation reactions taking place. In addition, the evolution of methane gas in cargo spaces is a potential explosion hazard. Such events, particularly those taking place on board a vessel, can be extremely challenging to bring under control. Given that this is such a well known problem with such cargoes^{5, 6} the fact that the EIA does not address it must be regarded as a serious inadequacy.

Fertiliser cargoes and stockpiles can also ignite spontaneously and when burning give off toxic fumes. A recent fire of this type took place off Spain in February 2007.⁷ Ammonium nitrate is particularly hazardous. Once again, the failure to consider the potential hazards associated with this cargo group must be considered a serious deficiency of the EIA.

The Environmental Assessment and the Detailed Project Report do not consider the impacts of cyclones in the area. These could have significant impacts upon port operation and safety. Depressions and cyclonic storms are only enumerated for the years between 1891 and 1991. Accordingly, the report does not cover the highly damaging storm event of 29th October 1999, with winds of more than 250 Kph, tidal waves rising 7 metres (normal tidal height is 4.75 m above chart datum in the area) and torrential rains. An estimated 10,000 people were killed and many buildings destroyed.⁸ A similar event took place in 1971 and, in general, such high intensity storms appear to have an approximate return period of around fifty years, as do major flooding events. Moreover, the intensity of such events may well increase in the future as a result of climate change. Accordingly the omission of any analysis of the impacts of these events upon port operations, together with the lack of an analysis of how the development might affect the severity of the impacts of such events, constitutes a fatal flaw.

A number of events could take place as a result of an intense cyclone, each of which require analysis and accommodation in the emergency plan proposed for the development:

- i) foundering/grounding/collision of vessels in, or in the vicinity of, the port.
- ii) loss of hazardous cargo (chemicals, petroleum products) from both ship and shore areas
- iii) breach of onshore storage containment of bunker oil of LNG

These important potential events are not currently considered in the documentation. The potential impacts of the loss of pesticides carried as part of containerised general cargoes upon fisheries and aquatic resources could be severe and effectively irreversible. A modelling exercise carried out for the English Channel (between the UK and France) suggested that a spill of only 10 tonnes of the organophosphate pesticide pirimiphos ethyl could result in significant contamination over an area of 10,000 square kilometres⁹. If a substantial chemical spill was carried inland in Orissa on a tidal surge, significant impacts could extend to freshwater aquatic resources.

iii) Potential Ecological Impacts

The Baseline Environmental Status presented under Chapter 3 of the EIA should be a key informational element of the overall assessment. Far from being a considered and well structured evaluation, however, it is arguably the weakest element of the information presented. The baseline evaluation restricts itself to detailed study within a 10km radius and lesser consideration of issues within 20km of the development. These distances seem somewhat arbitrary. In approaching the study in this way, the greater part of Bhitarkanika Conservation Area is omitted from consideration. Indeed, a very significant proportion of the mangrove

resources in the Conservation area lie within 25km of the proposed development site. Some lie even closer; for example, the mangroves on the island (Kalibhanj Dian, part of Bhitarkanika Sanctuary) due south of the existing Dhamra fishing port and the particularly rich mangrove assemblage found on the Kanika Sands on a relatively newly formed island. While this area was sampled as one of the four limited sampling sites, its unique vegetation is only mentioned briefly (Page 3-81). Moreover, the Gahirmatha Marine Sanctuary, a globally highly important Olive Ridley turtle nesting area, is also excluded from in-depth consideration, despite lying partly within a 20km radius of the proposed development, with the main nesting beaches less than 15 km. from the port.

In addition, it is inevitable that the port will increase shipping movements in the area and this will inevitably cause increased traffic through offshore areas used by the turtles. This has not been considered within the supporting documentation for the proposed development. While noise has been considered to some degree in the environmental assessment, one key source of noise impacts appears not to have been considered at all. Construction will require piling of the site in order to secure a firm foundation, and this will inevitably lead to high ambient noise levels for some time during construction. Port operation and shipping will also create underwater noise, elevated well above background (and almost certainly above noise levels associated with the more limited fishing activities in the port as it currently exists). Turtles are known to be sensitive to noise¹⁰, although their precise responses to

increased noise levels remain largely conjectural. Even so, elevated noise may well deter adults from nesting sites and could also lead to other modified behaviour. This needs to be more closely examined. Impacts on aquatic fauna have not been considered at all. Cetaceans are also known to be affected by increased noise levels due to shipping traffic^{11,12}. and the waters off the port site are known to harbour several species of dolphins. These aspects need to be examined for the EIA to have any scientific credibility in relation to these potential impacts.

In addition, the EIA does not consider in detail the impacts of the development on the ecological systems which are going to be obliterated by the reclamation and building in the intertidal area. This is a matter of considerable concern. The EIA suggests, on the basis of the map included between Pages 3-72 and 3-73, that in the area to be occupied by the port development, mangrove coverage is sparse or the area is scattered shrub/swampland with only dense mangrove to the north of the area in question. This does not appear to be based upon direct observation. None of the sampling sites addressed this area, which could again be construed as a form of systematic bias in the way the assessment was carried out. Indeed, images posted on the development company website (<http://www.dhamraport.com/images/006.jpg>) clearly show the existence of significant mangrove cover along the coast. This mangrove cover undoubtedly has considerable value in protecting against the impact of storms¹³, but this role is not considered in the EIA.

The impact analysis in relation to the mangroves seems to be predicated upon the fact that no endangered species of mangrove are present in the development area and, therefore, that any impacts will be minimal. Given the ecological value of mangrove as a biological assemblage, and the particular richness of the mangroves in the area, this is an entirely incorrect basis upon which to assess the impacts. In fact, consideration of impacts in terms of endangered species is a common thematic throughout the ecological section of the EIA. Even if it was defensible simply to assess potential impact on this basis, it then begs the question as to why the endangered species and systems present in areas immediately adjacent to the development area (especially turtles) have not been considered.

The port site is an extensive intertidal mudflat zone, and such areas typically sustain a diversity of fish, crustacean, amphibian and reptile species. Development of the port site, as per the latest plans available, will require extensive engineering (landfilling) of the site in order to raise the level, thereby destroying this habitat. The EIA has not dealt with this angle at all. There is in fact no mention of the amount of earth filling that will be undertaken or its impacts, even though this is a basic requirement for the preparation of the port.

On Page 4-11, the assessment asserts that there is little inshore fishing activity in the area and the waters are not considered to be significant spawning or nursery areas. This statement suggests that insufficient baseline survey work has been done in the

area, since estuaries, together with mangroves, tend to be highly important as both spawning and nursery areas. This important aspect needs to be clarified.

Accordingly, the baseline study overall can be regarded as highly inadequate with respect to consideration of true ecological conditions and it is difficult to understand how the Dhamra project could have been approved without detailed consideration of the areas and aspects identified above. The problems are compounded by the facts that the baseline study is predicated upon information obtained from only four sampling sites, as detailed in Section 3.8.5.2., and that many of the supporting references are somewhat old. None of the sites sampled address the baseline situation in the Reserve or Sanctuary areas. Indeed the exclusion of consideration of these areas can be construed as a form of bias in the document.

The process descriptions for port-side operations are, in some respects, quite detailed, particularly in relation to handling systems, rail interfaces and similar. Despite describing these processes, however, the EIA signally fails to take account of potential impacts of these operations upon the wider environment. Similarly, there is a tendency in the document to describe regulatory conditions which apply without describing in detail how these are going to be met.

One further important area which has been neglected in the EIA relates to the impacts of dredging activities during the construction phase and subsequently as part of the maintenance dredging program.

Although the statement that current sediments are largely unpolluted may be

defensible, no baseline data seem to be presented to support this conclusion and no impact is attributed to the current Dhamra port. It is unlikely that historical and ongoing port and related activities in the area have had no impact on levels of contaminants in the local environment. In addition, the analysis of potential for smothering effects and negative impacts of sediment plume formation is extremely superficial. Given the large scale of both capital and maintenance works, the analysis of this needs to be considerably expanded such that the EIA can present a realistic picture of current and likely future impacts.

The estuarine system on which the current Dhamra port operates is a depositional area, as attested by the presence of mangroves, the presence of the Kanika sands and the deltaic nature of the country. Any mobilisation of sediment in these areas will inevitably impact upon sediment dynamics in areas external to the study area. Long term physical modification of benthic communities can take place as a result of dredging and disposal, even of clean sediments.¹⁴

Moreover, even if it can be shown to be of relatively minor importance now, sediment contamination is an issue of potential future importance. As shipping operations intensify in the area, the levels of contamination will inevitably increase.¹⁵ In addition to metal contamination, a variety of important organic contaminants can also be generated by shipping activity. These contaminants can be mobilised into the wider environment via dredging and dumping activities. No detailed consideration of this is included in the EIA, nor of methods to mitigate the impacts or to

handle the dredge spoils generated in a responsible manner.¹⁶ It is worth noting, in this regard, that India is not party to the London Convention (1972) or its 1996 Protocol, both of which provide for the prevention of marine pollution from the dumping of wastes, including dredge spoils. The extent to which permitting regimes in India provide for similar degrees of impact assessment and precautionary environmental protection is therefore unclear.

Ship operations can also lead to a further significant ecological impact. Discharge of ballast waters can lead to the introduction of alien species,¹⁷ and/or to the release of substantial quantities of ballast water treatment chemicals. The distribution of alien species in ballast water is a serious problem globally, and the Dhamra port project could lead to significantly greater likelihood of damaging invasions of this kind, on a local or regional level. Once again, the EIA does not consider this issue, nor options for treatment or responsible handling of ballast waters which could reduce the risk of introduction of alien species by this means.

Overall, therefore, the poor quality of ecological information comprehensively undermines the EIA. As a particularly egregious example, and one which suggests that the author(s) have little expertise in certain areas, Table 3.27 purports to be a list of endangered species in the study area. Reference to the text on page 3-92 suggests that these are marine zooplankton. It is of some concern, therefore, that each specific name appears to be erroneously spelled, and that in any case, even if these errors

are corrected, each species listed is actually found in freshwater, not seawater. Moreover, the references cited in support of such assertions date back to the 1970s and 1980s. The errors of nomenclature also

extend to other areas of the text.

In short, the level of detail implied by the volume of text coverage of ecological analysis and impacts obscures the fact that this section of the EIA is seriously flawed.

4. Conclusions and Recommendations

Consideration of the Dhamra Port EIS and Detailed Project Report indicate some extremely serious omissions and shortcomings in the analysis of impacts. These conspire to undermine fatally the analysis, suggesting in turn that the decision to permit the development may be seriously misguided. The most important problems relate to:

- i) failure to describe fully the baseline ecological conditions (Bhitharkanika, Gahirmatha)
- ii) failure to identify fully the potential ecological impacts
- iii) failure to consider potential extreme weather events and impacts of climate change.

Overall, while many of the issue areas addressed by the report apparently conform

superficially to the requirements of an Indian EIA and perhaps even an EU EIA/EIS, in practice, the level of evidential support and analysis in these documents fall well short of the required standards and of the quality necessary to support an informed and reliable judgment on the suitability and acceptability of the development.

Accordingly, given the national importance of the Bhitharkanika Reserve and the global importance of the Gahirmatha turtle breeding beaches, there is a need for the assessment to be repeated and reworked completely in order to accommodate the issues identified above in a suitably comprehensive manner.

The documents would also benefit from substantial restructuring, correct prioritisation of issue areas, and proportionate analysis based upon this prioritisation.



Fig.1: Map showing discrepancy between port site chosen by the EIA and the one currently being developed.

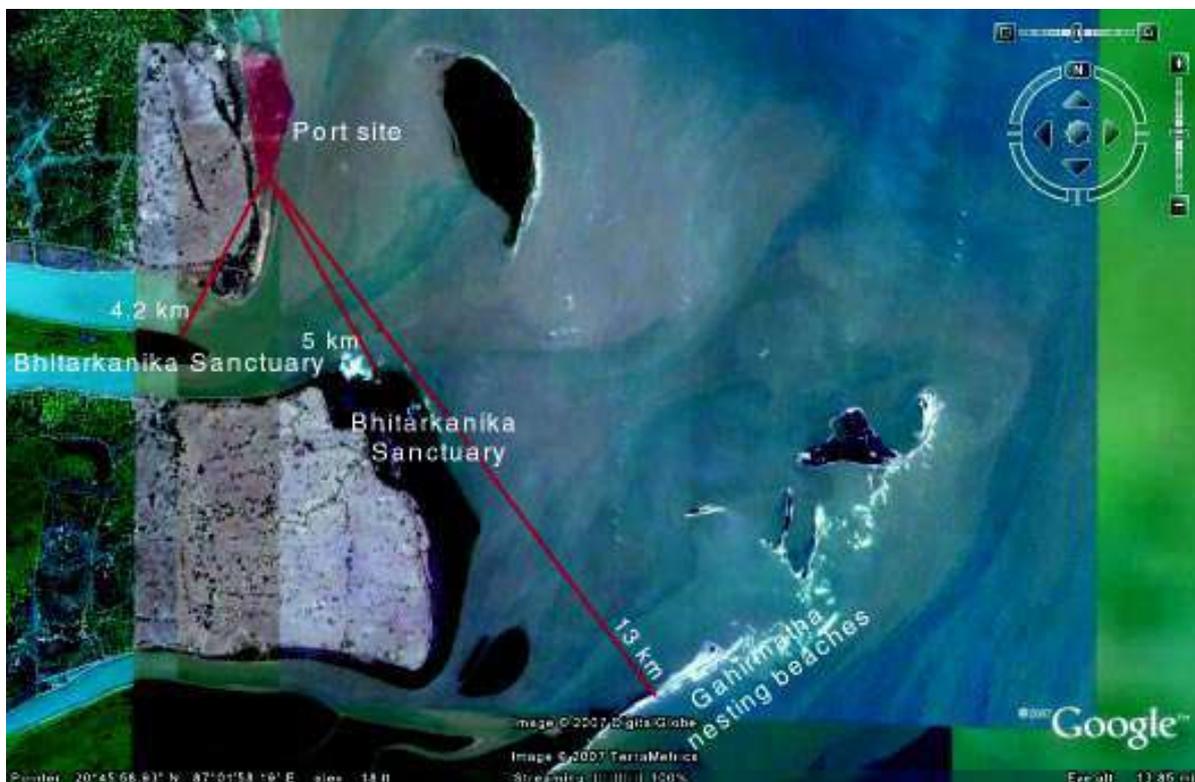


Fig.2: Map showing distances between port site and Bhitarkanika and Gahirmatha Sanctuaries.

5. References

1. The Dhamra Port Company Ltd. URL: www.dhamraport.com/
2. Dhamra-Chanbali Port : Detailed Project Report. International Seaports Pte Ltd. p 37
3. Environment Clearance for Dhamra Port Expansion Project: Summary of Submissions/Correspondence. Prepared by Kirloska Consultants Ltd for International Seaports PTE Ltd. 1997.
4. <http://envfor.nic.in/legis/eia/eia-2006.htm>
5. Understanding self ignition of coal, A literature study elaborated in cooperation of Deutsche Monat Technologie GmbH (DMT) and the Federal Institute for Materials Research and Testing (BAM). Work Package 2000
<http://www.coalfire.caf.dlr.de/media/download/results/StudyWP2410a6.pdf>
6. Marine Safety Agency (UK) Code of Safe Practice for solid bulk cargoes (BC Code) : 1996 Amendment, Carriage of Coal Cargoes. Marine Guidance Note MGN 60 (M) 12pp publ. DETR
[http://www.nepia.com/fin/modules/Library/assets/industrynews/documents carriage%20of%20coal%20mgn60.pdf](http://www.nepia.com/fin/modules/Library/assets/industrynews/documents/carriage%20of%20coal%20mgn60.pdf)
7. European Commission Monitoring and Information Centre, Daily Monitoring and Alert Service (MIC Daily) 21 February 2007.
<http://dmaweb1.jrc.it/MIC/MICdailyreports/2007-02-21%20MIC%20Daily.doc>
8. Chittibabu, P., Dube, S.K., Macnabb, J.B., Murty, T.S., Rao, A.D., Mohanty, U.C. & Sinha, P.C. (2004). Mitigation of flooding and cyclone hazard in Orissa, India. *Natural Hazards*. **31**: 455-485.
9. Johnston, P. Marquardt, S. Keys, J. & Jewell, T. (1997) Shipping and handling of pesticide cargoes: The need for change. *J.CIWEM* 11 (3): 157-163.
10. Samuel, Y., Morreale, S.J., Clark, C.W., Greene, C.H., Richmond, M.E., (2005) Underwater low frequency noise in a coastal sea turtle habitat. *Journal of the Acoustical Society of America*, 117 (3): Part 1465-1472
11. Soto, N.A., Johnson, M., Madsen, P.T., Tyack, P.L., Bocconcelli, A. & Borsani, J.F. (2006) Does intense ship noise disrupt foraging in deep-diving Cuvier's Beaked Whales (*Ziphius cavirostrus*)? *Marine Mammal Science* 22(3): 690-699.
12. Southall, B.L. (2005) Final Report of the International Symposium 'Shipping Noise and Marine Mammals: A Forum for Science, Management and Technology', Technical Report, NOAA Fisheries Acoustics Program.]
13. Badola, R., Hussain, S.A., (2005) Valuing ecosystem functions; an empirical study on the storm protection function of Bharkanika mangrove ecosystem, India. *Environmental Conservation* 32 (1): 85-92.
14. Salomons, W. & Forstner U., (1984) *Metals in the Hydrocycle*. Publ. Springer Verlag, Berlin, 350pp.
15. Newell, R.C., Seiderer, L.J., & Hitchcock, D.R., (1998) The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and Marine Biology: An Annual Review* 36: 127-178
16. Lee, C.W. (2003) A review of environmentally improved techniques for dredging contaminated mud. Technical Note 3/2003 Publ, Fill Management Division, GEO Hong Kong http://www.cedd.gov.hk/eng/publications/geo_spr_tn_report/tn/tn3_2003.pdf
17. Bax, N., Williamson, A., Aguero, M., Gonzalez, E. & Geeves, W. (2003) Marine invasive alien species: A threat to global biodiversity. *Marine Policy* 27: 313-323

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DHAMRA PORT: HOW ENVIRONMENTAL REGULATORY FAILURE FUELS CORPORATE IRREVERENCE

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The site of the proposed Dhamra port project is located on the eastern Indian coast of Orissa, north of the River Dhamra and is about 13 km away from the Nasi group of islands, the Gahirmatha Marine Sanctuary and the Bhitarkanika National Park. How diligent are the 'due diligence' practices outlined for the port developers? The environmental regulatory framework sets the country's priorities towards the environment and only provides a signal for companies to follow. The controversies over the Dhamra port area result from lacunae in the environmental laws, litigation processes and in the nature of engagement over environmental decision-making in the country.

Flexible priorities

The Wild Life Protection Act, 1972, is revered by many as one of the most stringent of conservation laws. Under the WLPA, areas can be set aside to declare Wildlife Sanctuaries and National Parks. Prior to the declaration of the Gahirmatha Wildlife Sanctuary, the earlier draft map of the GMS comprised of a region measuring 65 km in length, and 10 km in width (seaward distance). This included the Wheeler islands (site of the present DRDO missile testing range) as well as the site of the proposed Dhamra port. However the Government in its letter No. 11693 dated 20th June 1997 requested that these areas be excluded. This was promptly attended to and executed by the Forest Department. Ironically, there is no evidence to show that any consultation took place with local fisherfolk on conservation measures or fishing restrictions in the GMS area prior to its declaration. This was one of the first compromises of the environment, well within the letter of the law but against its spirit of conservation.

Assessments of environmental impacts

The original project proponent was International Seaports Private Limited (ISPL) which signed a concession agreement with the Government of Orissa on 2 April 1998 to expand and develop the 'minor' port of Dhamra. As required by law, ISPL hired a private consulting firm, Kirloskar Consultants Ltd to conduct an Environmental Impact Assessment in October 1997 (Dhamra Port Company Limited, 2006).

It is important to note here that Dhamra is a 'minor' port governed under the Indian Ports Act, 1908. The term 'minor' only denotes those ports that are under the administration of the State Government, while 'major' ports are administered by the Central Government. This distinction has an important significance for the application of environmental regulations on ports. Minor ports are exempt from the environmental clearance process under the Environmental Impact Assessment (EIA) Notification of 1994. In reality however, most minor ports are much larger in scale and costs (Sekhsaria, 2002; Sridhar & Parthasarathy, 2003). Though exempt from the above process, 'minor' port projects are still required to conduct an EIA and seek environmental clearance under another law – the Coastal Regulation Zone (CRZ) Notification, 1991 as it falls within the coastal regulation zone. However, unlike the EIA Notification, the CRZ Notification does not require public hearings as part of the clearance process (Sridhar, 2001; Sridhar & Parthasarathy, 2003). These lacunae in the environmental legislation did not allow local coastal communities living in the vicinity or fisherfolk using these waters an opportunity to express their viewpoints and participate in the environmental decision-making process. In India, several faults with the EIA reports prepared by consultants have come to light only through public hearings and the availability of reports through the public hearing related procedures where these reports are kept in local district offices, as per the EIA Notification, 1994. The Kirloskar EIA did not go through any scrutiny by the larger public at that time.

The second gap in the environment clearance came from an amendment on 9 July 1997 to the CRZ Notification which transferred environmental clearance of port projects from the Ministry of Environment and Forests (MoEF) to the Ministry of Surface Transport (MoST). In fact, both of the above gaps made the environmental clearance 'easier' for state governments and the project proponents (Sekhsaria, 2005). This amendment was challenged on many grounds by the Wildlife Protection Society of India, in the Delhi High Court and the case is pending till date. The MoST granted environmental clearance to the project in January 2000. Essentially, the Ministry which has a primary mandate towards the growth of shipping and ports in the country had granted clearance to a project which would benefit it. This reflects a grave conflict of interest. Though the 1997 amendment was reversed

by another amendment to the CRZ in August 2000, the earlier clearances held good. DPCL, the current proponents of the port, repeatedly state that they have all statutory clearances; however the above issues enable us to evaluate the true value of these assessments and clearances.

The clearance by the MoST was challenged vide a petition filed by the Orissa Beach Protection Council filed with the National Environment Appellate Authority (NEAA), a body set up by the government under the National Environment Appellate Authority Act, 1997 to review appeals and grievances with respect to environmental clearances under the Environment Protection Act, 1986. The petition challenged the Dhamra port environmental clearance on only two grounds – firstly, that the project site was a marine turtle nesting area and secondly that it was also ecological sensitive and falls under the CRZ-I(i) category in the Orissa Coastal Zone Management Plan (CZMP) making it a “no development zone.” The NEAA was considered to be a defunct body for several years and environmentalists worth their salt hesitated approaching this authority until recently (T. Mohan, pers comm.). The NEAA upheld the port’s clearance as the petitioner had not provided adequate papers including nesting data or data on turtle behaviour and ecology, causing the NEAA to conclude that the site was not a nesting ground. The NEAA overlooked the fact that the area was not included as a CRZ-I(i) category in the Orissa CZMP. Virtually no coastal state in India has an accurate, revised and finalised CZMP as per the guidelines provided by the MoEF in the CRZ Notification or in the conditional clearance letter issued by the MoEF. According to the CRZ Notification, areas such as mudflats and fish breeding grounds are supposed to be included in CRZ I(i) category but this was not done in the CMZP and never corrected despite the MoEF’s conditions. The NEAA also did not consider other issues, such as turtle congregations offshore, impacts of oils spills, ship traffic, dredging, port lighting on turtles, impacts on the ecology of the Bhitarkanika system and the port site itself, as these issues were not raised by the petition.

The environmental clearance for the port has also been challenged in the Orissa High Court by a petition by Wildlife Society of Orissa and others in 2000 which is still pending. There are many other instances of conservation oversight. According to a manual on Eco (Turtle) Friendly Coastal Development, no ports, harbours and jetties should be planned within a range of 25 km from any important nesting and congregating site (Choudhury et al. 2003). No doubt, the contents of this manual were long forgotten even if recognised.

Change of proponents and project details

In October 2004, Larson and Turbo (L&T) one of the share holders in ISPL took over as sole stakeholder and then assigned and subrogated all its rights and obligations to Dhamra Port Company Limited (DPCL), a 50:50 venture with Tata Steel which achieved full closure in May 2005. (Manoj, 2005; Dhamra Port Company Limited, 2006).

The 1998 and 2005 port site: from apples to oranges

When the project proponent changed, the site and scale of the project also changed significantly from the one proposed in the EIA of 1997. The site shifted from the Kanika sand bank island to the mainland coast (Table 1). As part of oft repeated environmental ‘due diligence’ requirements, during the assigning and subrogating of rights and obligations from ISPL to DPCL, the latter would have deemed it necessary to have re-applied for environmental clearance with a fresh EIA of its own accord.

The EIA Notification, 1994 requires that there should not be any change in the dimensions of the project once it has been accorded clearance. But with the regulatory and monitoring body, the MoEF, itself failing to do so, it is of little surprise that the company chose to pay short shrift to these significant details.

Many experts unanimously agree that the Kirloskar EIA study was inadequate and incomplete and had poor baseline ecological data, very little references to turtles, a poor Hazard Analysis and Risk Assessment. It has not taken into account impacts oils spills, lighting of the port, continuous dredging and ship movement (Johnston & Santillo, 2007; Sridhar et al., 2005). To date there have been no impact studies on ancillary and downstream projects as a result of port which are a ship building yard, a steel plant, and a port-based fertilizer plant.

Many experts and NGOs are of the view that the Kirloskar EIA of 1997 is no longer valid, now that the dimensions of the project are totally changed under the new proponent. Rightfully, they have called for a fresh Environmental Impact Assessment and clearance. The Tatas and DPCL have refused to conduct a fresh EIA, or consider alternate sites. The same has been highlighted and stressed by campaigns, several letters to DPCL/ Tatas by various experts, press statement and campaigns by NGOs.

Table 1. Comparison of 1997 and 2005 Port Details

Port Details	ISPL EIA (1997)	Dhamra Port Company Limited (2005)
Location	On Kanika Sand Banks Island ⁶	On mainland
Land Area	<ul style="list-style-type: none"> • 1200 acres on main land for port Area • 5000 acres for industrial park • 3000 acres for rail road alignment 	<ul style="list-style-type: none"> • 4013 acres for Port • 3000 acres for rail road Ancillary Industries • Ship building yard • Steel plant • Port-based fertilizer plant
Channel Length	7 Km	18 km
Depth	14 m	18 m
Dredging	50 million tonnes	60 million tonnes for phase I (2 berths)
Maintenance Dredging	2.2 Million tonnes/year	No details available
Max Vessel Size	120,000 DWT	180,000 DWT
Cargo Handling /yr	25 Million tons/year	83 million tons/year
No. of Berths	2	13 (Two in Phase I)

Source: (International Seaports Pte. Ltd 1997, International Seaports Pte. Ltd 1998, DPCL 2006)

(<https://www.iotn.org/wp-content/uploads/2015/12/08-9-1.jpg>)

In public statements to counter this issue and criticism, the Tatas and DPCL rely on and repeatedly emphasise NEAA's final judgement upholding the environmental clearance. This is doubly misleading. Firstly, the NEAA judgement itself was born out of a poorly argued petition. But more importantly, the petition was focused on the original location and scale as mentioned in the 1997 EIA report. The campaigns against Dhamra port are vocal and hard to ignore. Yet both the regional and central offices of the MoEF and their colleagues with the Departments of Environment or Forests in Orissa choose to demonstrate complacency over a major breach in the regulatory process for this project. DPCL chants on about possessing all requisite clearances, but no government authority has pointed out what is obvious to all else. The present port project is totally different from the earlier one proposed by ISPL and actually has no EIA and no environmental clearance.

More greenwash

The Tatas and DPCL have also approached many NGOs, individual experts, and institutions for research studies on possible impacts of the port and mitigation options, but have refused to agree to halt project related activities till the findings of these studies emerge. Abandoning the current site was also not an option they were willing to consider (Anon., 2004; Sahgal, 2005). Many NGOs, institutions and individual experts refused to engage any further because of this stand taken by the company. The insistence on continuing work on the port while impact studies were even on is against the spirit of the precautionary principle – an established principle of international environmental law. The principle basically put the onus of burden of proof of no/minimum impact on the proponent and till such time that is achieved, considers no development as the best option. It is this principle which is also supposed to have guided the EIA Notification.

In most instances, many State CZMPs classify port areas and their limits as CRZ-II by default even though they may be ecologically sensitive sites warranting a CRZ-I classification (Bhaskar 2007). Furthermore, in most states zoning of areas into CRZ categories in the CZMP process lacked a well planned and participatory exercise and hence did not produce a robust scientific document to guide development along the coast (Menon & Sridhar, 2007). Thus many areas along the coast that should have ideally been CRZ-I(i) and hence protected, are sites for development projects. The Dhamra port is an illustrative example in this regard as the current project site is known to harbour ecologically significant biodiversity and was recently found to be an important habitat for the endangered horseshoe crab making it a fit case for a CRZ-I(i) classification (Dutta, 2007; Anon., 2008). This would have made it impossible for the port to be located in the site. Finally the Supreme Court appointed Central Empowered Committee (CEC) in its directions on a petition filed before it, through its July 2004 report to the Supreme Court states: "The present site (Dhamra port) will seriously impact Gahirmatha's nesting turtles and could lead to the beach being abandoned by the marine creatures. It is therefore necessary that an alternative site is located for this port". The recommendation is yet to be acted upon by the State Government or by the Supreme Court.

Conclusion

Matters are still pending in the Orissa High Court challenging the development of the port. The question of the legal validity of the environmental clearance remains a very valid one. The Tatas and DPCL meanwhile carry on with their priorities. The construction of Dhamra Port cannot wait for the dust to settle on environmental matters. The Dhamra case is not an isolated event of mere corporate irreverence towards the environment. It is closely intertwined with the regulatory environment which at present is designed to fail, with its gaps in legal text, poor implementation and monitoring framework besides other systemic issues such as corruption. Little succour is found in an already strained judicial system which is reluctant to intervene when a contentious project has already started, particularly when it is considered a 'development' project. The Dhamra case poses many fundamental challenges. Is it possible to expect an integrated and meaningful operation of the regulatory framework? What is required to

integrate legislation, clearance procedures, implementation and compliance mechanisms and development planning? The regulator needs to demonstrate that environment protection is a social norm. Only then will corporate behaviour adapt itself to respecting and following environmental norms.

Literature cited

- Anonymous. 2004. *Minutes of meetings of Mr. Prasad, Tata Group of Companies with Coastal Marine Programme members, ATREE. 25th November 2004, Bangalore.*
- Anonymous. 2008. *Horseshoe crabs vanishing from coast: Survey. The New Indian Express, 11th August. (Available from <https://www.newindpress.com/> (<https://www.newindpress.com/>))*
- Bhaskar, G.U. 2007. *Infrastructure Development and Environment-Existing Law and Policy. (Available: <https://www.nlsenlaw.org/> (<https://www.nlsenlaw.org/land/articles/infrastructure-development-and-environment-existing-law-and-policy>))*
- Choudhury, B.C., B. Pandav, B. Tripathy & H.A. Andrews. 2003. *Sea turtle conservation: Eco (turtle) friendly coastal development. GOI UNDP Project Manual. Centre for Herpetology/Madras Crocodile Bank Trust, Tamil Nadu, India.*
- Dhamra Port Company Limited. 2006. (Available from <https://www.dhamraport.com/> (<https://www.dhamraport.com/>))
- Dutta, S.K. 2007. *Biodiversity Assessment of Dhamra Port Site and Surrounding Areas, Orissa. Greenpeace India, Bangalore. 38pp. (Available: <https://www.greenpeace.org/> (<https://www.greenpeace.org/raw/content/india/press/reports/greenpeace-biodiversity.pdf>))*
- Johnston, P. & D. Santillo. 2007. *The Dhamra-Chandbali Port: Critique of the Environmental Impact Assessment. Greenpeace India, Bangalore. 15pp. (Available: <https://www.greenpeace.org/> (<https://www.greenpeace.org/raw/content/india/press/reports/critique-of-the-environmental.pdf>))*
- International Seaports Pvt. Ltd. 1997. *Environment Impact Assessment for Dhamra Port Expansion Project, prepared by Kirloskar Consultants Ltd., International Seaports Pvt. Ltd.*
- International Seaports Pvt. Ltd. 1998. *Dhamra-Chandbali Port : Detailed Project Report. International Seaports Pvt. Ltd.*
- Manoj, P. 2005. *Financial closure of Dhamra port project by May, The Hindu Business Line, 23 February.*
- Menon, M. & A. Sridhar. 2007. *An appraisal of coastal regulation law in tsunami-affected mainland India. In: Report on ecological and social impact assessments post-tsunami in mainland India; Submitted to UNDP. Post-Tsunami Environment Initiative. 105-149 p.*
- Sahgal, B. 2005. *Record notes of discussion held on 14/12/04 to discuss various issues related to Dhamra port and Study related to spatial distribution of sea turtles. Message to: Kartik Shanker. 1 January 2005. Personal communication.*
- Sekhsaria, P. *Minor ports, major trouble. 2002. The Hindu Business Line, 27 July.*
- Sekhsaria, P. 2005. *The Dhamra Port in Orissa. Indian Ocean Turtle Newsletter. 1:14-16.*
- Sridhar, A. 2001. *Portending Threats, Deccan Herald, 27 July.*
- Sridhar, A., & M. Parthasarathy. 2003. *An account of the environmental and legal implications of minor port development in India. Submitted to ODAF and Oxfam (India) Trust. 103pp.*

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Disappearing beaches: From humans to Olive Ridleys, none spared in Odisha

Sea erosion threatens 318 villages in six coastal districts of Ganjam, Puri, Kendrapara, Balasore, Jagatsinghpur and Bhadrak



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Though Odisha typically has a pro-gradation coast due to the disposal of sediment and discharge from Mahanadi river, it is now turning into a hotspot of coastal erosion. (Photo | EPS)

By Hemant Kumar Rout

Express News Service

BHUBANESWAR: Jaga Rao of Ramayapatna village in Odisha's Ganjam district used to be a happy man. Like many other traditional fishermen of the region, every morning, he loved setting out into the Bay of Bengal where landing fish was never a problem. Now it is a never-ending struggle with the sea.

The Bay of Bengal has advanced more than 600 metre into his village, located under Chikiti block, gobbling up hundreds of acres of farmland and more than 100 dwelling units. Rao lost his house to the marauding sea but cannot leave Ramayapatna as fishing sustains his five-member family.

Five hundred metres from the new shoreline, he currently lives in the house of another villager who left for Andhra Pradesh in search of work. “The monsoon season brings fear. No one knows when the hungry sea will devour this house too,” he says.

Rao is caught between the devil and the deep sea.

Though Odisha typically has a pro-gradation coast due to the disposal of sediment and discharge from Mahanadi river, it is now turning into a hotspot of coastal erosion with climate change doubling down the impact. The conversion process is rampant in hotspots like Boxipalli and Podampeta in Ganjam district, Baliapanda, Chadrabhaga beach in Puri district, Pentha and Satabhaya in Kendrapara and Chandipur beach and Subarnarekha estuary in Balasore.

At least four villages in Ganjam district face extreme coastal erosion. Podampeta under Ganjam block is now a ghost village as nearly 450 families have already been relocated to a nearby habitation.

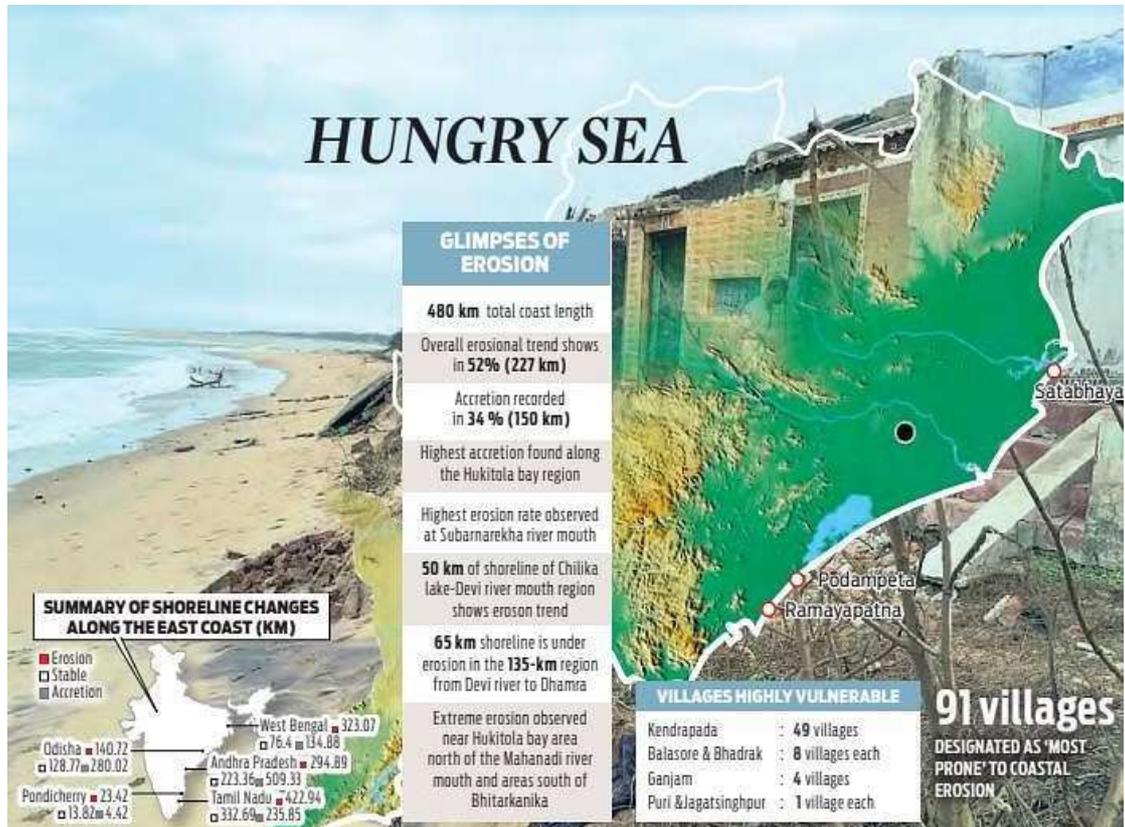
Spectre over six districts

A happy hunting ground for natural calamities, Odisha faces the threat of tropical cyclones like no other. Add to it the misery of vanishing landmasses. State’s Forest, Environment and Climate Change assessed sea erosion threats in 318 villages of six coastal districts - Ganjam, Puri, Kendrapara, Balasore, Jagatsinghpur and Bhadrak. While 91 villages are designated ‘most prone,’ 85 villages are ‘prone’ to sea erosion. With 49 villages facing the charging sea, Kendrapara is the worst hit. Eight each in Balasore and Bhadrak districts, four in Ganjam and one each in Puri and Jagatsinghpur districts are vulnerable to coastal erosion.

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In Kendrapara district, Satabhaya panchayat under Rajnagar block stands testimony to the erosion as the sea has swallowed it. The panchayat having a cluster of 16 seaside villages has been reduced to a few hamlets by now.

The Subarnarekha river in Balasore district has already swallowed about 75 per cent of Badakhanpur village and its neighbouring Sanakhanpur. Of more than 120 families, only fifty hold on to their dwelling units while the rest have shifted base to neighbouring villages. The ferocious nature has redrawn the map of over 40 villages in Bhogarai, Jaleswar, Baliapal, Remuna and Sadar blocks in the coastal district.



According to a global study conducted by 11 researchers from six universities, almost the entire Gopalpur shoreline experienced erosion between 2010 and 2020 and the construction of Gopalpur port markedly impacted the shoreline dynamics. Of the 480 km sea coast of Odisha, erosion trend has surfaced across 227 km, accretion recorded in 150 km while coast character remains unchanged over the rest.

Professor of Geography department at FM University Manoranjan Mishra said most ports on the east coast have shown a pattern of erosion and deposition, 52 per cent Odisha coastline faces erosion at one stretch or other. Construction of breakwater perpendicular to the coastline prevented the uniform distribution of littoral sediments in all cases, he said.

Coastal infrastructure

With the Odisha government contemplating construction of 14 more ports, researchers warn such infrastructure could potentially impact its fragile coastal system. Resilience of the coastal landforms is compromised due to the construction of onshore and offshore coastal infrastructures in order to meet the growing demand for economic activities.

Previous studies too had observed a similar trend of erosion and accretion along the eastern coast. The northern part of Paradip port experiences intense erosion due to the construction of a rigid engineering structure (sea wall). The southern part of the port also had signs of erosion. Although accretion pattern was witnessed along Dhamra port from 1990 to 2000, drastic erosion was observed after the port area development in 2007.

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Meanwhile, closer to Ramayapatna, erosion has impacted nesting of Olive Ridley turtles. The impact was so high that turtles for the first time in 30 years changed their nesting site from the Rushikulya rookery to a nearby Island, south of Rushikulya river, said secretary of Rushikulya Sea Turtle Protection Committee Rabindranath Sahu. Earlier, the marine turtles used to lay eggs on the 5 km beach from Purunabandha to Podampeta, north of the river mouth.

While state government had relocated residents from Satabhaya and Podampeta and laid geo-synthetic walls along the Satabhaya coast as part of protection measures, the Ganjam seaside villages have long been demanding a protection wall.

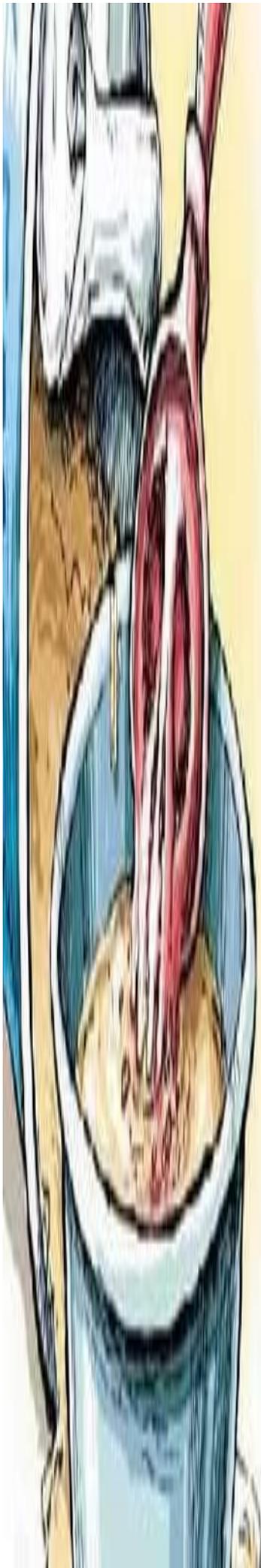
Superintendent engineer, Berhampur Irrigation division Jayadeep Panda said as per recommendations made by National Institute of Oceanography (NIO), a 3.4 metre sea wall along the 1200 metre stretch covering Ramayapatna will be built at a cost of ` 23 crore. "Work will start by next month and it will provide protection to the villages south of Rushikulya. The Podampeta stretch will be taken up in the next phase," he said.

"The best way forward is to protect salt marshes and mud flats in the coastal regions. Besides, mangrove protection and rejuvenation must be focussed. Similarly, it is critical to create soft structure instead of hard structures to fend off

the impact of erosion,” said PCCF and Project Director, Integrated Coastal Zone Management Project Susanta Nanda.

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Threats to the nests of Olive Ridley Turtles (*Lepidochelys olivacea* Eschscholtz, 1829) in the world's largest sea turtle rookery at Gahirmatha, India: need for a solution

Satyanarjan Behera^{1,*} and Hinrich Kaiser²

Abstract. We report on a preliminary study of threats to olive ridley turtle (*Lepidochelys olivacea*) nesting beaches at their largest rookery in Gahirmatha, Odisha State, India during the 2012 season. We found a total of 1223 olive ridley nests, of which nearly two thirds had been destroyed by inundation and depredation. Likewise, two thirds of turtle landings, as indicated by their tracks, did not lead to nest establishment. The nest encounter rate (nests per km) was highest on beaches of isolated islets in the northern part of the rookery. Nesting frequency was 25.4 ± 6.7 nests/km with 18.5 ± 4.8 destroyed nests/km. The Gahirmatha sea turtle rookery needs continuous monitoring throughout the year to determine levels of nesting activity, non-nesting crawls, and predation threats, and we advocate for the establishment of a fence to minimize the impact of terrestrial predators on the nesting beach.

Keywords. Gahirmatha rookery, Nesting, Inundation, Nest, Olive ridley turtle, *Lepidochelys olivacea*, Predation

Introduction

Nesting beaches of marine turtles are ephemeral and subject to destruction by natural processes (e.g., submersion, erosion), and in addition they can be made inhospitable to turtles' egg-laying needs by the activities of humans and their domestic animals (e.g., Fish et al., 2005; Tripathy and Rajasekhar, 2009; Fuentes et al., 2010; Whytlaw et al., 2013). Furthermore, large numbers of olive ridley nests may be predated upon by native predators (e.g. Silas et al., 1984; Blamires, 1999). This invariably leads to a significant reduction in the numbers of turtle nests, laid eggs, and hatchlings.

Olive ridley turtles are found nearly circumglobally in tropical oceans (Reichert, 1993; Turtle Taxonomy Working Group, 2017). Out of the four sea turtle

species reported to occur along the coast of Odisha State, India³ (*Chelonia mydas*, *Dermochelys coriacea*, *Eretmochelys imbricata*, *Lepidochelys olivacea*), only the latter has been confirmed to nest (Dash and Kar, 1990; Pandav and Choudhury, 2000; Shanker et al., 2004; Tripathy, 2008; Tripathy and Rajasekhar, 2009). *Lepidochelys olivacea* is listed as Vulnerable (VU) by the IUCN (Abreu-Grobois and Plotkin, 2008), and its trade is forbidden by its listing as a CITES Appendix I species (Turtle Taxonomy Working Group, 2017). It is also legally protected throughout India by its inclusion in Schedule I of the Wild Life (Protection) Act, 1972 (Government of India, 1972). As a consequence, the protection and preservation of its nesting habitats must be a priority for wildlife conservation managers.

Lepidochelys olivacea is a vulnerable species throughout most of its range because of habitat loss, incidental capture in gill nets, and illegal local trade in meat (e.g., Pandav and Choudhury, 2000; Behera et al., 2016). In addition, there exists high predation

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³ Until the 2011 passage of the *Orissa (Alteration of Name) Bill, 2010* and the *Constitution (113th Amendment) Bill, 2010*, the name of this state was Orissa.

pressure on its eggs from feral pigs, dogs, monitor lizards (*Varanus* spp.), and indigenous harvest at several locations in other parts of the world (e.g., Whiting et al., 2007; Chatto and Baker, 2008). Especially feral dogs (*Canis familiaris*) and wild pigs (*Sus scrofa*) are known to cause considerable damage to nests of leatherback, green, hawksbill, and olive ridley turtles (e.g., Bhaskar, 1993; Whytlaw et al., 2013; Engeman et al., 2019; Nordberg et al. 2019). It has also been determined that the predation risk on solitary nests is higher than for arribada nesters (e.g., Costa Rica: Eckrich and Owens, 1995) and that the position of a nest on a nesting beach influences its survival rate (Whitmore and Dutton, 1985; Eckert, 1987; Behera et al., 2018).

The 480-km-long Odisha coastline harbours three mass nesting beaches (Gahirmatha, Devi, Rushikulya). Each year, olive ridleys arrive in the area during October, followed by mating in shallow coastal waters and nesting from January–May. With an estimated annual nesting of 100,000–500,000 turtles during arribadas, Gahirmatha is the world's largest known nesting aggregation of olive ridleys (Dash and Kar, 1990; Behera, 2012). Moreover, sporadic nesting by olive ridleys has been observed year-round at these and other localities along the Odisha coast (Dash and Kar, 1990; Tripathy, 2008; see also additional references in Tripathy et al. 2008) and these nests are reproductively highly effective and need to be protected in natural condition.

Studies on the population dynamics and reproductive biology of olive ridleys at Gahirmatha have indicated that a large percentage of the eggs laid during each nesting season are destroyed (Dash and Kar, 1990; Behera et al., 2015). Indeed, it has been documented that heavy beach erosion and predation on eggs may lead to high levels of destruction of olive ridley eggs on nesting beaches (Valverde et al., 2012; Behera et al., 2013), but quantitative information on olive ridley nest predation is anecdotal. It has generally been accepted that high predation pressure at accessible mainland sites can play an important role in the adaptive selection of islands and isolated beaches by sea turtles for nesting (e.g., Hendrickson, 1958; Carr et al., 1974). Nests of olive ridleys, in particular, are frequently depredated by dogs (*Canis familiaris*), jackals (*C. aureus*) and hyenas (*Hyaena hyaena*) along the Andhra Pradesh Coast (Tripathy et al., 2003). The aim of this study was to identify and quantify the main threats to solitary nesting of olive ridleys at Gahirmatha and determine possible solutions.

Materials and Methods

Study site.—The study was carried out along the ca. 35 km of coastline known as Gahirmatha, a significant sea turtle rookery on the Odisha coast of India that lies between the mouths of the Dhamra and Barunei Rivers⁴ (20.5049°N, 86.7602°E in the south to 20.7233°N, 87.0701°E in the north; Fig. 1). The beach forms the eastern boundary of Bhitarkanika National Park. The coastline is part of the extensive delta system produced by the Brahmani River estuary, and it is locally intercepted by two tributaries, the Maipura and Baunsagada Rivers. In addition to mainland beaches, there is a long sand spit of over 4 km length extending into the mouth of the Maipura and there is some isolated beach area on two small sandy islets, Nasi-I (Segment 2) and Nasi-II⁵ (Segment 1; Fig. 1). She-oak (*Casuarina* spp.) has been planted on a massive scale as an erosion control measure along the mainland beach and along the spit. Extensive native mangrove forests are present behind the *Casuarina* (see Reddy et al., 2007; Upadhyay et al., 2008). Thus, the mainland beach is flanked primarily by *Casuarina* trees and mangroves. The lowest elevations of the nesting beach are open and covered in sand. Above this open area, several low, herbaceous, and salt-resistant plants grow, including psammophytes (or sand binders) such as *Ipomea pescaprae*, *Launea sarmentosa*, *Gisekia pharnacoides*, and *Spinifex littoreus* (Behera, 2012).

We divided the study area into seven segments of similar length along the shoreline to allow systematic monitoring (Fig. 1). These include opportunities for both island and mainland nesting by olive ridleys. Two of these segments, assigned to cover Nasi-I and Nasi-II to the east of the Maipura, are very short on account of the islets' shortened shoreline (Fig. 1). However, over the past two decades, most nesting has occurred on the islets (Behera et al., 2018), with only sporadic or solitary nesting occurring along the rest of the coastline. The breeding season of olive ridley turtles in Odisha is from

⁴ The names of rivers in this area may be confusing because some of the area is a river delta. Names are not correctly presented on Google Maps, where the river in the north is called the Baitarani River and the one in the south the Brahmani River. We list these main geographical features by names used and known locally.

⁵ Nasi-II used to be called Wheeler Island but is now known as Abdul Kalam Island, which is the name used on Google Maps.

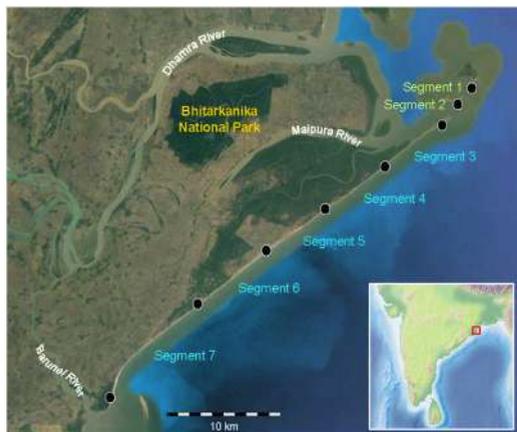


Figure 1. Map of the olive ridley (*Lepidochelys olivacea*) rookery at Gahirmatha Beach on the coast of Odisha State, India, showing its location in India (red square in the inset), as well as its division into seven Segments for the purposes of this study. Segments 1 and 2 are two small islets (Nasi-II and Nasi-I, respectively). Black dots demarcate the northern and southern extent of each Segment, with the exception of the islets, where a single dot denotes the entire beach. Map by Mark O'Shea.

November–May, during which mating, egg-laying, and hatching take place (Behera et al., 2010).

Beach profiling.—To characterize the available area for nesting, beach profiling (to obtain a measurement of available nesting beach width) was executed on a fortnightly basis from January–May following standard procedures (Cooper et al., 2000). Permanent GPS points were marked along the high tide line (HTL) on both the seaward and estuarine sides at 100-m increments. These points were marked with a handheld GPS (Garmin 72, Garmin Ltd., Olathe, Kansas, USA) for subsequent monitoring. Beach width was measured perpendicular from HTL to the permanent landmark. The average nesting beach width was calculated as the arithmetic mean of beach width measurements at each landmark. Following the calculations of average beach width for each of the seven nesting segments, the total available nesting beach area (average beach width x total beach length) could be estimated.

Surveys.—Data were obtained from January–May 2012 with three people surveying the beach every morning to identify nesting crawls and count identifiable nests. Nests were characterized by the presence of a nest

pit and could be located by following nesting crawls. In contrast, non-nesting crawls lack a nest pit and the turtle likely returned back to sea without nesting. For nests that were determined to have been predated, the species of predator was identified by direct sighting or indirectly from footprints and faeces near the degraded nests (Menon, 2014). Identified nests were flagged and also monitored at night.

Results

During the olive ridley breeding season in 2012, we identified 1223 solitary nests at Gahirmatha. Tidal inundation and predation destroyed 749 (61%) of these nests. All nests in Segments 2–5 were destroyed or lost during the study period (Table 1). The nest density (nest/km) was highest in Segments 1 and 2 on Nasi-II and Nasi-I, respectively, followed by Segment 7, the southernmost mainland beach segment. The mean \pm SD nest encounter rate (a measure of estimated nest density) was 25.4 ± 6.7 nests/km and it was 18.5 ± 4.8 nests/km for destroyed nests. During this survey, the average beach width was 52.3 ± 7.8 m.

A total of 3642 crawls produced 2419 non-nesting crawls (66%), with successful nest establishment resulting from only one third (34%) of turtle landings. Numerous non-nesting crawls were observed in each survey segment, except for Segment 5 where only very few were recorded. The average beach width during the study was 49 ± 7.2 m and 62 ± 11.5 m in Segments 1 and 2 respectively on both islands during the course of study. On the mainland beach the smallest beach widths were 13 ± 3.2 m and 19 ± 5.6 m in Segments 4 and 5, followed by the highest in Segments 6 and 7 (Fig. 2).

A total of 285 nests (mean = 69 ± 21) per segment were destroyed by inundation, 267 (27 ± 8.9) were depredated by feral dogs, 114 (23 ± 7.1) by wild pigs, 53 (15 ± 3.4) by jackals, 17 (3 ± 1.7) by hyenas, and 13 (2 ± 0.8) by water monitors (*Varanus salvator*). Stranded turtles were also scavenged by these animals. Nest predators were directly observed 31 times and indirectly recorded near depredated nesting pits through their footprints 53 times. Predation data were not normally distributed, given that all seven segments had different lengths, dissimilar beach widths, disparate probabilities of nest occupancy, and therefore it was likely that predation pressures would be different. Results of a Kruskal-Wallis test showed that there were highly significant differences in predation pressure among segments ($n = 464$, mean rate = 14, Kruskal-Wallis $P < 0.001$).

Table 1. Beach parameters for seven demarcated Segments at Gahirmatha, an olive ridley (*Lepidochelys olivacea*) nesting rookery in Odisha State, India. (a) Beach width, (b) nest density, (c) ratio of false crawls to successful nesting attempts, (d) rate of inundation and (e) rate of predation on olive ridley turtles during 2012 breeding season in.

Segment Number	Beach width (m)	Nest density (per km)	Ratio of false crawls to successful nesting attempts (%)	Rate of inundation (per km)	Rate of predation (per km)
1	49	48.1	57	18.3	15.3
2	62	61.8	53	30.6	31.2
3	32	9.0	24	1	8
4	13	3.8	20	0	3.8
5	19	3.7	23	0	2.9
6	84	8.2	21	0.3	4.2
7	107	43.3	42	0	13.2
Overall	52.3	25.4	34	7.1	11.2

Discussion

Erosion and inundation.—The loss of nests by inundation and erosion accounted for 23% of the total nest loss by natural factors at Gahirmatha rookery (Fig. 3). In recent years, significant temporal and spatial geomorphological changes in Gahirmatha have led to considerable changes in the nesting beach profile and an accelerated loss of nesting habitat (Prusty et al., 2007; Wildlife Institute of India, 2012; Behera et al., 2013). In the study area, the Segments used most for nesting, including the sand spit and the islets (Segments 1–3), have undergone conspicuous changes over time due to natural calamities, including cyclones and the interaction of oceanic forces and fluctuating riverine discharge (Prusty et al., 2007). In addition, the construction of Dhamra Port near the Gahirmatha mass nesting site and the concomitant need for the dredging of ship channels are major, permanent intrusions. Plans for the construction of additional ports in the area, including in protected areas, will doubtlessly have further significant and permanent negative impact on the rookery (Senapati, 2013). Furthermore, sea level rise as a consequence of climate change and the resulting dynamic coastal processes pose another threat to these nesting beaches (National Research Council, 1990; Leatherman et al., 2000; Garcia et al., 2015; Grases et al., 2020).

A large sand spit in Segment 1 (Nasi-II islet), where mass nesting occurred at Gahirmatha, was inundated by several high tides during March 2012, which likely affected the incubation success of the nests. Nests deposited on shifting beaches are more susceptible

to damage due to erosion, and the natural and human impacts listed above appear to degrade what was for some time a stable nesting habitat. It has been reported that beach erosion caused the loss of 40–60% of leatherback turtle (*Dermodochelys coriacea*) nests on beaches in Suriname (Whitmore and Dutton, 1985), and similar losses have been reported for olive ridleys (Mortimer, 1981; Dash and Kar, 1990; Andrews et al., 2003; Behera et al., 2018). Erosion at Gahirmatha began in the 1970s with the planting of *Casuarina equisetifolia* along the Odisha coast, which was planted to avoid land-side erosion but appears to have promoted beach-side erosion. However, coastal industrial developments

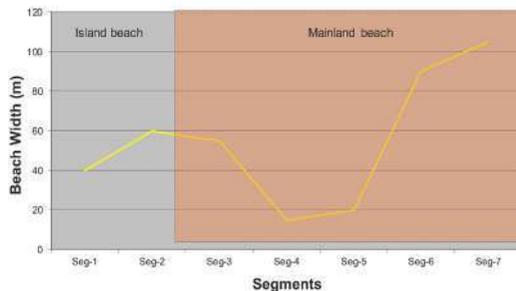


Figure 2. Availability of nesting beach area at the Gahirmatha rookery on the coast of Odisha State, India, during the 2012 nesting season. Segments 1 and 2 are island beaches and Segments 3–7 are on the mainland (Fig. 1). Segments 4 and 5 have less beach area available, which is reflected in the reduced number of nests observed.



Figure 3. (A) Olive ridley (*Lepidochelys olivacea*) eggs in a destroyed nest, exposed by the combined action of natural erosion and wind, photographed at Segment 1 (Nasi-II) of the Gahirmatha rookery on the coast of Odisha State, India. The photograph is taken in a landwards direction, showing planted *Casuarina* trees in the background. (B) Accumulation of beach debris at Segment 3, with *Casuarina* trees in the background. This obstacle can be found in nearly all mainland Segments at Gahirmatha. Photos by Satyaranjan Behera.

have at least equally affected the nesting turtles along the Odisha coast (Behera and Tripathy, 2014). Due to limited nesting beach availability in Segment 1 of Nasi-II (Abdul Kalam Island), turtles may be shifting their nesting activity to nearby beaches. This is largely because of beach exchange, which is part of a complex phenomenon that olive ridleys use to colonise new areas or move to other beaches altogether (Valverde et al., 1998; Tripathy and Pandav, 2008).

Reduction in nesting beach area.—As observed during earlier studies between 2009 and 2012, the nesting decline at Gahirmatha likely parallels the decline in beach nesting areas availability (Behera et al., 2015). This study showed that there may be insufficient average beach area available for sea turtle nesting, with the exception of the 900-m island beach (Segment 1) connected to Nasi-II (Behera et al., 2015, 2018). Although there was some apparently suitable beach available in the northern mainland part of Gahirmatha, nesting was not found and only few non-nesting crawls were observed. Sand in this area is mixed with clay

and a muddier area is present along this stretch. Olive ridleys prefer to nest in medium, coarse, or fine sand (Rubio, 2009) and with regard to the bathymetry profile, sea turtles prefer to congregate in water between 5–30 m in depth prior to approaching a nesting beach (Mishra et al., 2011). Thus, this area may be of only limited use to olive ridleys for nesting. This reflects the reality that while the east coast of Odisha generally has suitable environmental conditions for olive ridley nesting, nesting opportunities may be spotty in parts. Beyond Gahirmatha's famous arribada areas (Segments 1 and 2), olive ridleys apparently prefer to nest in the southern portion of the beach (Segments 5–7), as evidenced by the highest levels of sporadic and solitary nesting there (Fig. 2; Behera et al., 2013). Should a permanent reduction of suitable beach habitat push the beach area below an unknown threshold, olive ridleys may move away from Gahirmatha and seek other suitable beaches.

Storms and tides.—With the breeding season of olive ridleys in Odisha extending from November–May, nest loss is affected by the tropical storm season, which in this area coincides with the sea turtle nesting season (Garcia et al., 2003). In the course of this study, beach availability for nesting was quite low for Segments 1–5, while it was higher for Segments 6 and 7. High tides during this time tended to cover most nesting beaches in Gahirmatha. For example, high tides covered Segment 1 and 2 beaches due to their low elevation and width. Nesting beaches in Segments 3–5 also became inundated during high tides because the beach is low and narrow, and water can reach the tree line or mangrove vegetation. In many places, tidal mud deposited on the surf zone of the beach may prevent turtles to successfully emerge and nest. This appears to push more turtles to nesting in the southern section (Segments 6 and 7), where conditions may be more favourable (Fig. 2). Mrosovsky (1983) found that leatherback turtles tended to nest closer to the high tide line, where nests were easily inundated by seawater, and this was also reported for olive ridleys in Australia by Whiting et al. (2007). At Gahirmatha, we observed some olive ridley nests deposited within 1 m of the high tide line, and these were subsequently destroyed by incoming tidal seawater. In some cases, clutches were laid within 1 m of the spring high-water line.

Predation.—Predation is a major cause of sea turtle nest losses in many beaches of the world (Fowler, 1979; Cornelius, 1986). In addition, Tripathy et al. (2003) reported that almost all solitary turtle nests were destroyed in Andhra Pradesh, and those were destroyed mostly by animals. Our study documents that

at Gahirmatha, olive ridleys prefer to position their nests in locations without vegetation cover, a strategy that was previously documented for Green turtles (*Chelonia mydas*) at Tortuguero, Costa Rica (Bjorndal and Bolten, 1992). As a consequence, these nests may be easier to locate by predators. We found that of the destroyed nests not impacted by erosion or inundation, over 80% were predated by feral dogs, wild pigs, jackals, hyenas, and water monitor lizards (Fig. 3A). There were significant differences in predation levels among beach Segments. Feral dogs were found in Segments 1 and 2 (islets) and these dogs have remained on Abdul Kalam Island. Dogs often follow the crawl marks of turtles and spot the actual nesting sites, then sometimes prey on the nests. Additionally, ghost crabs (Decapoda: Ocypodinae) burrow into turtle nests and consume a few eggs, with the crab's burrow becoming a conduit for bacteria that grow on the eggs and can destroy embryos (Eckrich and Owens, 1995). Crab burrows may also release a turtle egg scent, which can lead to secondary predation by mammals. We observed ghost crabs near olive ridley nests at Gahirmatha but did not attempt to quantify crab predation due to its small scale and the fact that nests reached by crabs were almost always secondarily depredated by larger predators; opened and destroyed nests, of course, attract all manner of scavengers, including ghost crabs. The many tracks of non-nesting crawls we observed, when turtles returned to the water without nesting, might be a response to predator avoidance, with the presence of predators on nesting beaches altering the behaviour of females planning to nest (Santos et al., 2016).

Human activities and pollution.—In addition to the factors listed above, human activities have also dramatically increased the pressure on these sea turtles. This includes rendering the habitat unsuitable for nesting turtles, such as by the establishment of *Casuarina* trees close to the beach, by port construction, through the increase of predatory human commensals (feral mammals), or by agents of pollution (e.g., chemicals, discarded fishing gear). Construction and the resulting alteration of local currents, along with natural storm events, now lead to the establishment of debris piles (Fig. 3B), some of which are difficult for turtles to surmount or circumvent. Some turtles hurt by human activities float and are deposited onto the beach or die from injury after leaving the water, which may bring additional land-based predators to the beach.

Management proposal.—The present study indicates that many factors, both natural and human-caused, impact

the ability of turtles to nest at Gahirmatha. Whereas beach inundation and erosion are the leading natural causes of severe nest loss at Gahirmatha, predation by human commensal species is the most significant other problem. Large scale environmental impacts by the human population, including port construction and the establishment of *Casuarina* trees, promote the impact of the former, and the encroachment of human habitations promotes the latter. We propose to limit predator intrusion into the nesting beach by the establishment of wire fencing along the vegetation line. This would not only protect the more isolated arribada sites but would also help maintain sporadic or solitary nests along the Gahirmatha coast. In addition, turtle carcasses and excessive accumulations of debris should be eliminated from the beaches to facilitate turtle movement and to reduce predator attraction and predation risk on nests and live individuals. The Gahirmatha sea turtle rookery should be continuously monitored to determine nesting activity, non-nesting crawls, and predation stress, and these data should be provided to and used by wildlife managers in real time to implement proper management strategies and mitigate the nest loss by olive ridley sea turtles.

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References

- Abreu-Grobois, A., Plotkin, P. [IUCN SSC Marine Turtle Specialist Group] (2008): *Lepidochelys olivacea*. The IUCN Red List of Threatened Species 2008: e.T11534A3292503. Available from: www.iucnredlist.org. Accessed on 23 April 2020.
- Andrews, H., Choudhury, B.C., Pandav, B., Tripathy, B. (2003): Sea Turtle Conservation: Eco (Turtle) Friendly Coastal Development. Mammalapuram, Tamil Nadu, India Centre for Herpetology, Madras Crocodile Bank Trust. 45 pp.
- Behera, S. (2012): Ecology and distribution patterns of olive ridley sea turtles *Lepidochelys olivacea* at Gahirmatha rookery of Orissa Coast, India. Unpublished PhD dissertation, North Orissa University, Odisha, India.
- Behera, S., Tripathy, B. (2014): Review of current developmental activities and their possible impact on olive ridley sea turtles along the Odisha coast of India. *Testudo* 8: 38–55.
- Behera, S., Tripathy, B., Choudhury, B.C., Sivakumar, K. (2010): Behaviour of Olive Ridley Turtles (*Lepidochelys olivacea*) prior

- to arribada at Gahirmatha, Orissa, India. *Herpetology Notes* **3**: 273–274.
- Behera, S., Tripathy, B., Sivakumar, K., Choudhury, B.C. (2013): A case study on olive ridley (*Lepidochelys olivacea*) solitary nests in Gahirmatha rookery, Odisha, India. *Testudo* **7**: 49–60.
- Behera, S., Tripathy, B., Choudhury, B.C. (2015): World's largest olive ridley turtles *Lepidochelys olivacea* nesting grounds: Gahirmatha rookery now un-certain for arribada in future, East-Coast of India. *Herpetological Bulletin* **130**: 18–20.
- Behera, S., Tripathy, B., Sivakumar, K., Choudhury, B.C., Pandav, B. (2016): Fisheries impact on breeding of olive ridley turtles (*Lepidochelys olivacea*) along the Gahirmatha coast, Bay of Bengal, Odisha, India. *Herpetological Journal* **26**: 93–98.
- Behera, S., Tripathy, B., Sivakumar, K., Choudhury, B.C., Dutta, S.K., Pandav, B. (2018): Nesting space dynamics and its relationship with the arribada of olive ridley turtles at Gahirmatha rookery, East Coast of India. *Journal of Herpetology* **52**: 381–386.
- Bhaskar, S. (1993): The status and ecology of sea turtle in the Andaman and Nicobar Islands. Centre for Herpetology Publication ST 1/93. Mamallapuram, Tamil Nadu, India, Centre for Herpetology, Madras Crocodile Bank Trust. 37 pp.
- Bjorndal, K.A., Bolten, A.B. (1992): Spatial distribution of Green Turtle (*Chelonia mydas*) nests at Tortuguero, Costa Rica. *Copeia* **1992**: 45–53.
- Blamires, S.J. (1999): Quantifying the impact of predation on sea turtle nests by varanids at Fog Bay. Unpublished MSc Thesis, Northern Territory University, Darwin, Northern Territory, Australia. 148 pp.
- Carr, A.F., Ross, P., Carr, S. (1974): Interesting behavior of the green turtle, *Chelonia mydas* at a mid-ocean island breeding ground. *Copeia* **1974**: 703–706.
- Chatto, R., Baker, B. (2008): The Distribution and Status of Marine Turtle Nesting in the Northern Territory. Palmerston, Northern Territory, Australia, Parks and Wildlife Service of the Northern Territory. 309 pp.
- Cooper, N.J., Leggett, D.J., Lowe, J.P. (2000): Beach-profile measurement, theory and analysis: practical guidance and applied case studies. *Water and Environment Journal* **14**: 79–88.
- Cornelius, S.E. (1986): The Sea turtles of Santa Rosa National Park. San José, Costa Rica, Fundación de Parques Nacionales. 64 pp.
- Dash, M.C., Kar, C.S. (1990): The Turtle Paradise Gahirmatha: an Ecological Analysis and Conservation Strategy. New Delhi, India, Interprint Press. 295 pp.
- Eckert, K.L. (1987): Environmental unpredictability and leatherback sea turtle (*Dermodochelys coriacea*) nest loss. *Herpetologica* **43**: 315–323.
- Eckrich, C.E., Owens, D.W. (1995): Solitary versus arribada nesting in olive ridley sea turtles (*Lepidochelys olivacea*): a test of the predator-satiation hypothesis. *Herpetologica* **51**: 349–354.
- Engeman, R.M., Byrd, R.W., Dozier, J., McAlister, M.A., Edens, J.O., Kierepka, E.M., Smyser, T.J., Myers, N. (2019): Feral swine harming insular sea turtle reproduction: the origin, impacts, behavior and elimination of an invasive species. *Acta Oecologica* **99**(103442): 1–8.
- Fish, M.R., Cote, I.M., Gill, J.A., Jones, A.P., Renshoff, S., Watkinson, A.R. (2005): Predicting the impact of sea-level rise on Caribbean sea turtle nesting habitat. *Conservation Biology* **19**: 482–491.
- Fowler, L. (1979): Hatching success and nest predation in the green sea turtle *Chelonia mydas* at Tortuguero Costa Rica. *Ecology* **60**: 946–955.
- Fuentes, M., Limpus, C.J., Hamann, M., Dawson, J. (2010): Potential impacts of projected sea level rise on sea turtle rookeries. *Aquatic Conservation Marine and Freshwater Ecosystems* **20**: 132–139.
- García, A., Ceballos, G., Adaya, R. (2003): Intensive beach management as an improved sea turtle conservation strategy in Mexico. *Biological Conservation* **111**: 253–261.
- García, Y.C., Ramírez-Herrera, M.T., Delgado-Trejo, C., Legorreta-Paulin, G., Corona, N. (2015): Modeling sea-level change, inundation scenarios, and their effect on the Colola Beach Reserve – a nesting-habitat of the black sea turtle, Michoacán, Mexico. *Geofísica Internacional* **54**(1): 179–190.
- Government of India (1972): Wild Life (Protection) Act, 1972. In: India Code, unpaginated. Government of India, Delhi, India. Available at https://indiacode.nic.in/handle/123456789/1726?view_type=browse&sam_handle=123456789/1362. Accessed on 25 April 2020.
- Grases, A., Gracia, V., García-León, M., Jue, L.-Y., Sierra, J.P. (2020) Coastal flooding and erosion under a changing climate: implications at a low-lying coast (Ebro Delta). *Water* **12**(346): 1–26.
- Hendrickson, J.R. (1958): The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. *Proceedings of Zoological Society of London* **130**: 455–535.
- Leatherman, S.P., Zhang, K., Douglas, B.C. (2000): Sea level rise shown to drive coastal erosion. *Eos* **81**(6): 55–57.
- Menon, V. (2014): Indian Mammals: a Field Guide. Gurugram, Haryana, India, Hachette India Publishing. 528 pp.
- Mishra, R.K., Marale, S.M., Mishra, S., Naik, S. (2011): Olive ridley sea turtle movement in relation to oceanographic parameters in India. *International Journal of Environmental Protection* **1**: 49–54.
- Mortimer, J.A. (1981): Reproductive ecology of the green turtle, *Chelonia mydas* at Ascension Island. Unpublished PhD Thesis, University of Florida, Gainesville, Florida, USA.
- Mrosovsky, N. (1983): Ecology and nest-site selection of leatherback turtles *Dermodochelys coriacea*. *Biological Conservation* **26**: 47–56.
- National Research Council (1990): Decline of Sea Turtles: Cause and Prevention. Washington, D.C., USA, National Academy Press. 259 pp.
- Nordberg, E.J., Macdonald, S., Zimny, G., Hoskins, A., Zimny, A., Somaweera, R., Ferguson, J., Perry, J. (2019): An evaluation of nest predator impacts and the efficacy of plastic meshing on marine turtle nests on the western Cape York Peninsula, Australia. *Biological Conservation* **238**(108201): 1–8.
- Pandav, B., Choudhury, B.C. (2000): Conservation and management of olive ridley sea turtle (*Lepidochelys olivacea*) in Orissa. Project Final Report, Wildlife Institute of India, Dehradun.
- Prusty, G., Dash, S., Singh, M.P. (2007): Spatio-temporal analysis

- of multi-date IRS imageries for sea turtle habitat dynamics characterisation at Gahirmatha coast, India. *International Journal of Remote Sensing* **28**: 871–883.
- Reddy, C.S., Pattanaik, C., Murthy, M.S.R. (2007): Assessment and monitoring of mangroves of Bhitarkanika Wildlife Sanctuary, Orissa, India using remote sensing and GIS. *Current Science* **92**: 1409–1415.
- Reichert, H.A. (1993): Synopsis of biological data on the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz, 1829) in the western Atlantic. NOAA Technical Memorandum NMFS-SEFSC-336. 76 pp.
- Rubio, M. (2009): Nesting beach characteristics of endangered sea turtles in Las Perlas Archipelago, Panama. Unpublished MSc Thesis, Heriot-Watt University, Edinburgh, Scotland.
- Santos, R.G., Pinheiro, H.T., Martins, A.S., Riul, P., Bruno, S.C., Janzen, F.J., Ioannou, C.C. (2016): The anti-predator role of within-nest emergence synchrony in sea turtle hatchlings. *Proceedings of Royal Society B* **283**: 20160697.
- Senapati, A. (2013): Olive ridley sea turtles may be extinct in ten years in Orissa. In: Proceedings of the Thirtieth Annual Symposium on Sea Turtle Biology and Conservation, NOAA Technical Memorandum NMFS-SEFSC-640, p. 72–73.
- Blumenthal, J., Panagopolou, A., Rees, A.F., Eds., Miami, Florida, USA, National Marine Fisheries Service.
- Shanker, K., Pandav, B., Choudhury, B.C. (2004): An assessment of the olive ridley turtle (*Lepidochelys olivacea*) nesting population in Orissa, India. *Biological Conservation* **115**(1):149–160.
- Silas, E.G., Rajagopalan, M., Dan, S.S., Fernando, A.B. (1984): Observations on the mass nesting and immediate postmass nesting influxes of the olive ridley *Lepidochelys olivacea* at Gahirmatha, Orissa –1984 season. *CMFRI Bulletin* **35**: 76–82.
- Tripathy, B. (2008): An assessment of solitary and arribada nesting of olive ridley sea turtles (*Lepidochelys olivacea*) at the Rushikulya rookery of Orissa, India. *Asiatic Herpetological Research* **11**: 134–140.
- Tripathy, B., Pandav, B. (2008): Beach fidelity and interesting movements of olive ridley turtles (*Lepidochelys olivacea*) at Rushikulya, India. *Herpetological Conservation and Biology* **3**: 40–45.
- Tripathy, B., Rajasekhar, P.S. (2009): Natural and anthropogenic threats to olive ridley sea turtles (*Lepidochelys olivacea*) at the Rushikulya rookery of Orissa coast, India. *Indian Journal of Marine Sciences* **38**: 439–443.
- Tripathy, B., Shankar, K., Choudhury, B.C. (2003): Important nesting habitats of olive ridley turtles *Lepidochelys olivacea* along the Andhra Pradesh coast of eastern India. *Oryx* **37**: 454–463.
- Tripathy, B., Kumar, R.S., Choudhury, B.C., Sivakumar, K., Nayak, A.K. (2008): Compilation of Research Information on Biological and Behavioural Aspects of Olive Ridley Turtles along the Orissa Coast of India – a Bibliographical Review for Identifying Gap Areas of Research. Dehra Dun, Uttarakhand, India, Wildlife Institute of India.
- Turtle Taxonomy Working Group [Rhodin, A.G.J., Iverson, J.B., Bour, R. Fritz, U., Georges, A., Shaffer, H.B., van Dijk, P.P.] (2017): Turtles of the world: annotated checklist and atlas of taxonomy, synonymy, distribution, and conservation status. *Chelonian Research Monographs* **7**: 1–292.
- Upadhyay, V.P., Mishra, P.K., Sahu, J.R. (2008): Distribution of mangrove species within Bhitarkanika National Park in Orissa, India. *Trees for Life Journal* **3**: 1–5.
- Valverde, R.A., Cornelius, S.E., Mo, C.L. (1998): Decline of the olive ridley sea turtle (*Lepidochelys olivacea*) nesting assemblage at Nancite beach, Santa Rosa National Park, Costa Rica. *Chelonian Conservation and Biology* **3**: 58–63.
- Valverde, R.A., Orrego, C.M., Tordoier, M.T., Gómez, F.M., Solís, D.S., Hernández, R.A., et al. (2012): Olive ridley mass nesting ecology and egg harvest at Ostional Beach, Costa Rica. *Chelonian Conservation and Biology* **11**: 1–11.
- Whitmore, C.P., Dutton, P.H. (1985): Infertility, embryonic mortality and nest-site selection in leatherback and green sea turtles in Suriname. *Biological Conservation* **34**: 251–272.
- Whiting, S.D., Long, J.L., Hadden, K.M., Lauder, A.D.K., Koch, A.U. (2007): Insights into size, seasonality and biology of a nesting population of the Olive Ridley turtle in northern Australia. *Wildlife Research* **34**: 200–210.
- Wildlife Institute of India (2012): Determining the Offshore Distribution and Migration Pattern of Olive Ridley Sea Turtle (*Lepidochelys olivacea*) along the East-Coast of India. Dehradun, Uttarakhand, India, Wildlife Institute of India. 197 pp.
- Whytlaw, P.A., Edwards, W., Congdon, B.C. (2013): Marine turtle nest depredation by feral pigs (*Sus scrofa*) on the Western Cape York Peninsula, Australia: implications for management. *Wildlife Research* **40**: 377–384.

Shoreline Changes and near Shore Processes along Ennore Coast, East Coast of South India

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Shoreline Changes and Near Shore Processes Along Ennore Coast, East Coast of South India

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ABSTRACT

PANDIAN, P.K.; RAMESH, S.; MURTHY, M.V.R.; RAMACHANDRAN, S., and THAYUMANAVAN, S., 2004. Shoreline changes and near shore processes along Ennore Coast, East Coast of South India. *Journal of Coastal Research*, 20(3), 828–845. West Palm Beach (Florida), ISSN 0749-0208.



The study region located north of Chennai city on the East coast of India is facing shoreline erosion/accretion related problems after the introduction of Ennore Port during 2001. For the present study 25 km of coastal stretch has been taken up, which comprises Ennore port region, natural sandy beaches of Kattupalli Island, which is a turtle breeding ground and Ennore Creek and Pulicat Lake inlets, with a total coastal settlement population of 25,000 people. After the introduction of breakwaters for the port, beach erosion and accretion are considered as critical problems, resulting in damages to the natural set up of the coastal region in the study area. Analyses of coastal dynamics and vulnerable zones of erosion and accretion along the coast were performed during the present study which are highly useful for the development of strategies for beach erosion/accretion management. Four major categories of shoreline changes were observed in the study region, viz., 1) Beach accretion south of Ennore Port, 2) Beach fill erosion north of north breakwater of Ennore Port, 3) Almost stable coastline at the central part of the study region and 4) Shifting inlet of Pulicat Lake. Quantitative analyses are made from shoreline survey using Real Time Kinematic GPS, beach profile survey in four identified transects, characteristics of environmental parameters such as tides, waves, currents and sediment nature in the near shore region. Long shore sediment transport was computed for four cells using numerical modeling package to quantify the changing littoral drift in study region. Results show reduction in sediment transport from $-0.66 \times 10^6 \text{ m}^3/\text{year}$ on the southern side of Ennore port to $-0.57 \times 10^6 \text{ m}^3/\text{year}$ on the northern side of Ennore Port.

ADDITIONAL INDEX WORDS: *Beach profile, shoreline survey, sediment characteristics, bathymetry, sediment transport, Ennore Port.*

INTRODUCTION

The position of the shoreline along coasts and around inland waters (lakes) varies over a broad spectrum of time scales in response to shoreline erosion (retreat) or accretion (advance), changes in water level, and land uplift or subsidence (CARTER, 1988). Shoreline position reflects the coastal sediment budget, and changes may indicate natural or human-induced effects alongshore or in nearby river catchments. The detailed shape and sedimentary character of a beach (e.g. beach slope, bar position and morphology, barrier crest and berm elevation, sediment size and shape) are highly sensitive to oceanographic forcing, including deep-water wave energy, near shore wave transformation, wave setup, storm surge, tides, and near shore circulation. Morphodynamic adjustments and feedbacks are also common (CARTER and WOODROFFE, 1994; COWELL and THOM, 1994).

Changes in the position of the shoreline affect transportation routes, coastal installations, communities and ecosystems. The effects of shoreline erosion on coastal communities

and structures can be drastic and costly. It is of paramount importance for coastal settlements to know without bias whether local shorelines are advancing, retreating or stable. Erosion and sediment accretion are on-going natural processes along all coasts. Human activities (e.g. dredging, beach mining, river modification, and installation of protective structures such as breakwaters, removal of backshore vegetation, reclamation of near shore areas) can profoundly alter shoreline processes, position and morphology, in particular by affecting the sediment supply (BERGER and IAMS, 1996).

KOMAR *et al.* (1976) examined the pattern of beach erosion and accretion due to the jetty construction on the Oregon coast, which has a seasonally reversing littoral drift with an insignificant net drift. He proved that even in zero or near zero net littoral sand drift, large changes in shoreline configuration occur, giving areas of pronounced shoreline erosion or stretches of beach where accretion occurs. Due to construction of a structure, the up drift side experiences accretion while the down drift side erosion; as the structure impounds sand moving in a shore parallel direction thus reducing the volume of sand reaching the down drift side (BAKKER, 1968; BAKKER *et al.*, 1970).

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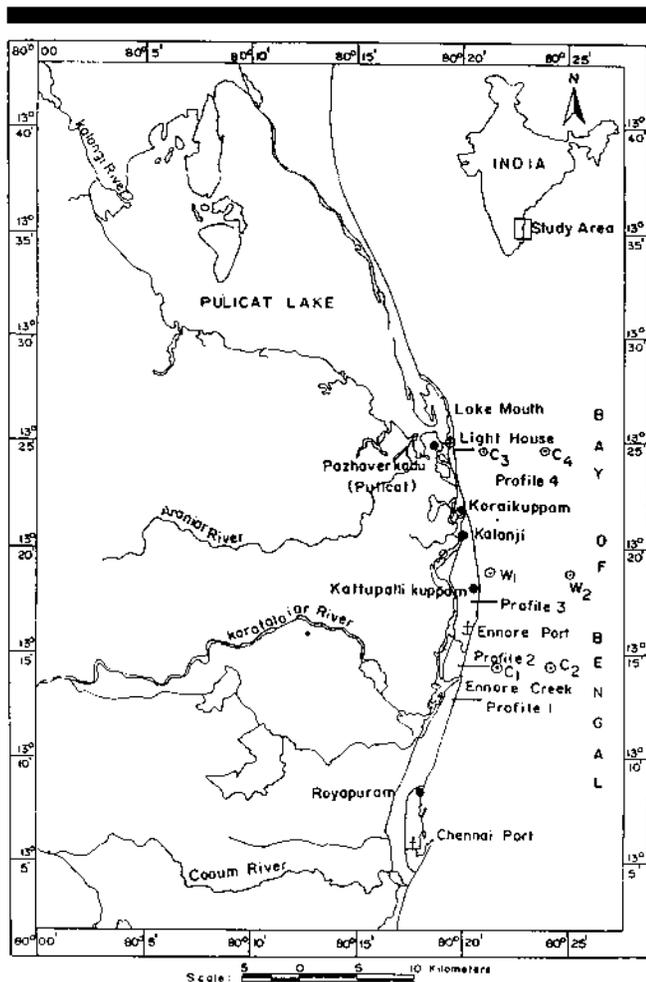


Figure 1. Map showing study area and measurement locations.

The purpose of this paper is to report on an investigation of the implications of beach factors after the introduction of Ennore Port on the east coast of India. In this case study, a detailed analysis has been made to quantify the changing littoral drift on both sides of the Ennore Port and some of the interesting observations on the shoreline changes trend with respect to the different zones identified for the detailed investigations in study region. Our analyses on beach investigation includes grain size variations trend in the near shore regions, orientation and behavior of Ennore shoals in the study region, inferences from the beach profile survey and influence of environmental parameters in the study region. This study is the first of its kind for this coastal stretch, which has to be protected by either hard or soft engineering measures from erosion/accretion factors.

STUDY SITE

The study region consists of a 25 km long stretch of coastal regions bound by two inlets—Pulicat Lake inlet on the north and Ennore Creek inlet on the south (Figure 1). Ennore port is located at a distance of 2.5 km north of the Ennore creek.

This port was commissioned during 2001 for importing coal to thermal power plants and to support proposed industrial park north of it. All the industrial development of Chennai city is taking place on the southern side of the Ennore Creek region of the study area. The south breakwater lies in an East-West direction for a length of 1.1 km and north breakwater is a length of 3 km in arcuate shape with an approach channel facing south. The western side of the Kattupalli Island has the backwater system leaving a maximum coastal land width of 2 km on the southern side and a minimum of 120 m on the northern side near Kalanji. Kattupalli Island is located north of the north breakwater and consists of medium sand rich seashore, which provides shelters and favorable condition for turtle breeding and hence is an ecologically sensitive spot (SANJEEVA RAJ, 1999). Since the Pulicat Lake is the second largest brackish water lake in India with 430 sq. km area, located on the northwestern side of the study region, the study on this coastal stretch has prime importance. The erosion and accretion dynamics of this coast has a direct impact on the Pulicat Lake ecosystem. The northern extremity of the study region is occupied with a 4 km length sand spit with an inlet for Pulicat Lake, which is highly dynamic. Coastal land forms in the study regions are occupied with low lying coastal dunes with a maximum elevation of 1 to 1.5 m. Ennore Creek mouth is located on the south and is being subjected to continuous dredging to keep the mouth open for the intake of coolant waters for the thermal power plants. This human induced dredging activity and the breakwaters constructed for the harbor are playing major roles for the sediment supply and its influence on coastal dynamics in the study region. The east coast of India has a littoral drift pattern towards the north for eight months from March to October and towards the south for four months from November to February with a net drift towards the north (CHANDRAMOHAN *et al.*, 1990). Ennore shoal, which is a shore parallel shoal, located north of the north breakwater extends in a SW-NE direction at an offshore distance of 500 m from the shore. Ennore Shoal plays a major role in dissipating the wave energy and reducing the erosion rate on the northern side of north breakwater in the study area.

METHODOLOGY

The elevation and contours of a shoreline are a response to the forcing of waves, winds and currents and depend on the supply of sediment to the beach. By measuring the dimensions of a beach repeatedly, the amounts of erosion or accretion can be determined over a period of time by the surveys as well as some indications of where the material may be going. Beach profiles vary seasonally as the wave climate changes over the long term, in response to the pressures of erosion or accretion. Taking a series of profiles along a beach and then repeating the profile measurements at later times can determine the behavior of the entire beach examined in terms of shoreline recession and volumetric sand loss. Moreover an overall sand budget (sources and sinks of sand) can also be determined. Complete beach profiles extend from the dry beach (landward expected storm damage) and extend offshore to depths beyond which the bottom does not change

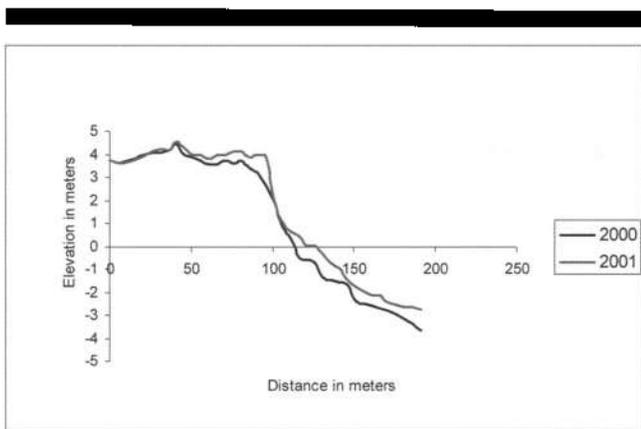


Figure 2. Profile 1 at south of Ennore Creek.

significantly with time (DEAN and DALRYMPLE, 2002). Typical procedures entail two separate surveys, an offshore survey using a boat and an inshore survey that involves level and transit survey equipment.

For the present study beach profile survey was carried out during the month of May 2000 and 2001 using graduated wave sled and beach levels with RTK. All levels were adjusted to mean sea level and related to the phase of the tide. The location of transects were fixed with RTK through an established permanent reference station at Ennore south breakwater. In total four transects were taken for comparative study and long term monitoring. Transects were fixed at EID Parry (Profile 1), South of south breakwater of Ennore Port (Profile 2), North of North breakwater of Ennore Port near Kattupalli (Profile 3) and Pulicat Lighthouse (Profile 4) (Figure 1). BMAP software was used to calculate the sediment accumulation/erosion volume calculation with respect to the datum.

For the present study the coastal region from Ennore Creek to the Pulicat mouth were surveyed for short-term shoreline changes using Kinematic Real Time GPS. Along the stable berm, survey was performed and coordinates were recorded for different seasons to know the immediate effect of the port on shoreline changes. This shoreline was plotted over the recent imagery derived from PAN data of IRS 1D (1999) and changes were clearly demarcated. The study region is divided into four different zones to discuss the results in detail. Zone 1 constitutes south of Ennore Port, Zone 2 comprises North of Ennore Port upto Kattupalli, Zone 3 extends from Kattupalli to Pulicat Lighthouse and Zone 4 is the Pulicat Lake mouth region as shown in Figure 1. In general the Pulicat inlet tends to migrate in the direction of the long shore sediment transport, which is mostly towards the north.

Bed sediments were collected from 24 locations from 7 m and 18 m water depths and 12 samples from 3 m, 5 m and 7 m water depths to know the grain size distribution in the study region. Water samples were collected to know the suspended sediments concentration and its grain size. Grain size was determined using Malvern E Particle Size Analyser (UK make), for the suspended sediments and fine bed sediments. Coarse fractions of the bed sediments were analysed using

Table 1. Berm width and foreshore slope of study region.

S. No.	Location	Berm Width (m)	Foreshore Slope
1	South of Ennore Creek	90	1:13
2	South of Ennore Port	120-180	1:17
3	North of Ennore Port	190	1:30
4	Pulicat Light House	190	1:23

the standard procedures using ASTM mesh in a mechanical sieve shaker. From the results cumulative curves were drawn to know the D_{50} , D_{90} , D_{10} values of the sediments.

Surface morphology of the ocean bottom plays a major role in the study of coastal processes and their impact on coastal erosion. Even though bathymetry chart like Naval Hydrographic Office (NHO) are available, to use the data in fine grid for prediction modeling for the near shore phenomena it is of vital importance to know the exact bathymetry of the study region. Keeping in mind the importance of the sea surface features, bathymetry survey was carried out in fine grid interval of 100×100 m from Ennore Port to Pulicat Lighthouse region using ODOM Echo sounder fixed with HYPACK software. Recorded details were brought into GIS platform for map preparations.

Environmental parameters such as waves, tides and currents were recorded from six locations during study period, using Wave and Tide gauges and Current meters. Deployment site for the instruments are given in the Figure 1. The tide and wave induced currents move sediment particles from the bed and when they settle out through the water column, the bed level changes. The changed bed level can then in turn affect the current structure and hence the sediment transport rate *etc.* Hence wave and tide gauges along with RCM 9 current meter were deployed at 6 m and 17 m depths in the study area. Apart from these two sets of current meters, wave and tide gauges were deployed on both sides of Ennore shoals to know the changing wave condition near shoal area.

Simulation of the annual littoral drift in the study region has been performed by using LITDRIFT module available within the LITPACK model of MIKE 21. LITDRIFT is able to give a deterministic description of the cross-shore distribution of long shore sediment transport for an arbitrary, non-uniform bathymetry and sediment profile as well as a detailed description of the sediment budget (DHI, 1998).

RESULTS

Profile 1: South of Ennore Creek Near EID Parry Factory

Bench mark of the Profile 1 is located at Latitude $13^{\circ}13'17.0''N$ and Longitude $80^{\circ}19'38.1''E$ on the compound wall south of Ennore Creek. The results indicate gradual accretion in the offshore and inshore profile in the study region (Figure 2). This transect is located 4 km south of Ennore Port with almost flat beach without coastal dunes and dune vegetation. Total quantity of the sediment accretion in the study region is $30 \text{ m}^3/\text{m}$ above the datum and $43 \text{ m}^3/\text{m}$ below datum with horizontal shoreline change of 13 m (Table 1).

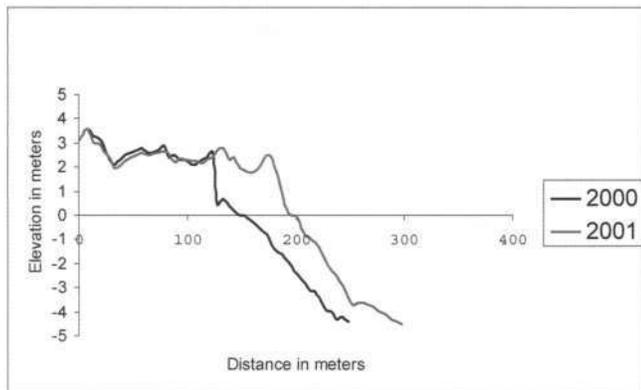


Figure 3. Profile 2 at south of Ennore Port.

Profile 2: South of Ennore Port

Profile 2 is located at Latitude $13^{\circ}15'07.5''N$ and Longitude $80^{\circ}20'06.2''E$ at a distance of 500 m south of the Southern breakwater of Ennore Port. Stable berm with coastal vegetation is seen in this region. Due to the advancing shoreline the outlet located on the eastern side of North Chennai Thermal Power Plant for coolant water discharge is being shifted to western side of the plant. Figure 3 clearly shows the accretion nature of the profile. Due to the obstruction by the southern breakwater sediments transported by long shore currents are trapped and deposited causing shoreline advancement. Total volume of accreted sediments above the datum is $114 \text{ m}^3/\text{m}$ and below the datum is $141 \text{ m}^3/\text{m}$ with a horizontal shoreline shift of 44 m towards east. Accretion due to the southern breakwater is causing closure of Ennore Creek mouth and to keep the mouth open for water intake to the coolant system of Thermal Power plant necessitates uninterrupted dredging activity at the mouth region by the Tamil Nadu Electricity Board (Figure 4).

The reason for the accretion at transects 1 and 2 is that they are located on the southern side of the south breakwater. Obstruction of long shore sediment transport by the introduction of breakwater causes the accreting nature of the studied profiles. Similar observation after the construction of Madras port was observed by the formation of Marina Beach in Chennai city. This has been confirmed earlier by various studies along the east coast since long shore sediment transport is towards north for eight months and net drift is also towards north and any barrier will definitely cause accretion on the southern side (VERNOM-HARCOART, 1881; SPRING, 1919; JOHNSON, 1957; CORNICK, 1969; SHEPARD and WANLESS, 1971; KOMAR, 1976; SAHADEVAN, 1996; CHANDRAMOHAN, 1999).

Profile 3: North of Ennore Port

This profile is located at Latitude $13^{\circ}17'31.8''N$ and Longitude $80^{\circ}20'43.4''E$ at a distance of 500 m north of the beach fill on the northern side of north break water. The beach is very flat in nature without any coastal landforms. The results on the surface level show accreting shoreline which has ad-



Figure 4. Dredging operations at Ennore Creek mouth.

vanced to a distance of 13 m towards east (Figure 5). Offshore profiles clearly show the erosion trend on the particular stretch. Almost $259 \text{ m}^3/\text{m}$ of sediments were eroded during one year period below the datum level. The profile pattern shows changes from the gentle to steeper slope in offshore profile indicating erosion phenomena. Beach fills for the 1.5 sq.km area is presently controlling the erosion process and the presence of shoals controls the wave energy in this region. Recent survey on the shoreline (April 2002) further confirmed the changing shoreline pattern of this region. The results of the shoreline survey in this region are discussed in the subsequent section on shoreline changes. Erosion behavior of this transect is of significance for the proposed TIDCO petrochemical park by the state government at the Kattupalli Island regions.

Profile 4: Pulicat Lighthouse

Profile 4 is located at Latitude $13^{\circ}25'20''N$ and Longitude $80^{\circ}19'37.2''E$ north of Pulicat Lighthouse. A wide sandy beach of 200 m width is observed with steep sloping berm at the shore face. Profile results show little change in the shape of the profile and indicates erosion with $48 \text{ m}^3/\text{m}$ of above datum sediments and $20 \text{ m}^3/\text{m}$ of below datum sediments during the one year period (Figure 6). Koraikuppam and Sattankuppam

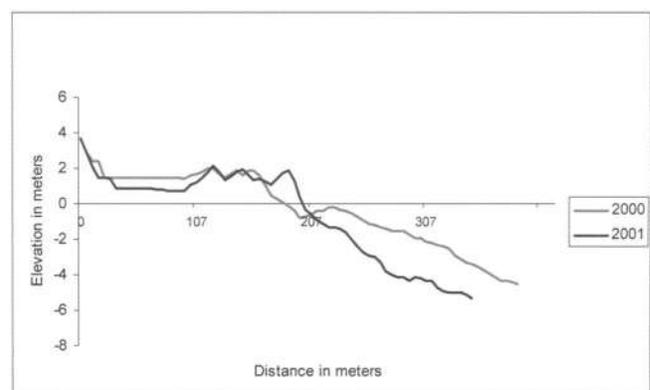


Figure 5. Profile 3 at north of Ennore Port.

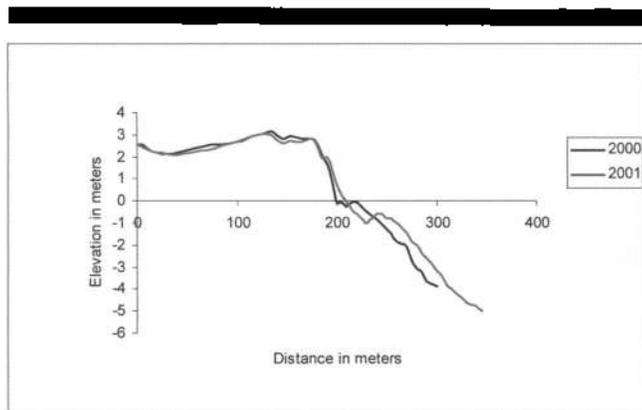


Figure 6. Profile 4 at Pulicat Lighthouse.

are the villages (south of Profile 4), which are located on the coastal sand bar and experiencing eroding shoreline for the past fifteen years (SANJEEVA RAJ, 1999).

From the beach profiles of 3 and 4, it is clearly demonstrated that due to the construction of Ennore Port erosion has started on the northern side of the port (Profile 3). It is possible that erosion will take place further north in the forthcoming years. The reason for the low rate of erosion compared to the impacts of Chennai Port on Royapuram coast, is due to presence of Ennore shoals on the offshore region north of Ennore Port, beach fills in 1.5 sq. km on the northern side of north breakwater. That is why the minimum rate of erosion on the northern coast of Ennore Port which is observed now.

Table 1 show the berm width and average foreshore slope of the study region brought out from the beach profiles survey and the calculated values of shoreline changes and volume changes from beach profiles using BMAP software is presented in the Table 2.

Shoreline Changes

Shorelines are one of the most rapidly changing landforms of the earth. The geomorphic processes of erosion and accretion, periodic storms, flooding and sea level changes continuously modify the shoreline. The accurate demarcation and monitoring of the shoreline changes (long-term and short-term) are necessary for scientific understanding of coastal processes, for assessing human impact and as a means of devising management strategies in future. The historical and

functional approaches to study the shoreline changes along with various landforms help in deciphering the coastal processes operating in an area. The cumulative impact of the aforesaid processes also forms the coast as progradational or degradational (CHORLEY *et al.*, 1984).

Detailed shoreline survey has been carried out along the entire coastline of the study area from Inlet of Pulicat Lake to the southern side of Ennore Creek during 2000 and 2001 in different seasons in order to identify the changes in the shoreline and their impacts. The entire shoreline of the study area has been divided into four zones (Figure 1) and the results of the study are presented zone wise and the positions of the shoreline during the years 1999, 2000 and 2001 are indicated (Figures 7 to 10). Changes that took place between these years have been measured for every 500 m distance of the entire 28.5 km stretch and the salient results of each zone are presented.

Zone-I occupies a total distance of almost 5 km on the southern side of the study region. From Figure 7, it is clearly seen that in Zone-I, accretion is taking place on the southern side of south breakwater of the Ennore Port. A higher rate of accretion took place at the immediate southern side of the south breakwater to the tune of 209.54 m between 1999 and 2000 and during 2000 to 2001 it is reduced to 33.27 m to get shoreline equilibrium. Accreting trend is gradually decreasing towards south up to a distance of 1.8 km. The Ennore coast was accreting, earlier to the construction of the port also. It has been reported earlier that accretion has occurred over a distance of 9 m during the past 20 years period *i.e.*, 1978 to 1998 (INSTITUTE OF HYDRAULICS AND HYDROLOGY STAFF, 2000). But it is confirmed by this study that the accretion rate has increased tremendously due to the construction of south breakwater. On the southern side of Ennore Creek significant erosion has taken place during the study period from 1999 to 2001. At the 0th point, *i.e.*, near EID Parry factory, Ennore, higher rate of erosion is observed, to the tune of 63.39 m during 1999–2001, which is due to the control measures taken up on Royapuram coast (which is located further southern side of the study region) to control erosion activity due to the Chennai Port.

Zone-II starts from north of north breakwater to south of Kattupallikuppam village and extends for a distance of 3 km. From Table 3, it could be seen that a maximum of 375.60 m of accretion has taken place at northern side of north breakwater during 1999–2001 due to artificial beach nourishment

Table 2. Shoreline changes and volume of sediment changes.

Profile No.	Shoreline Changes (m)			Datum	Volume cu.m/m		
	From	To	Difference		Erosion	Accretion	Net
1	113.06	126.63	+13.56	Above	—	30.975	74.65
				Below	—	43.675	
2	153.00	197.25	+44.25	Above	—	114.628	256.37
				Below	—	141.744	
3	184.50	197.79	+13.29	Above	-36.107	—	-295.29
				Below	-259.178	—	
4	199.70	194.00	-5.70	Above	-48.849	—	-69.36
				Below	-20.511	—	

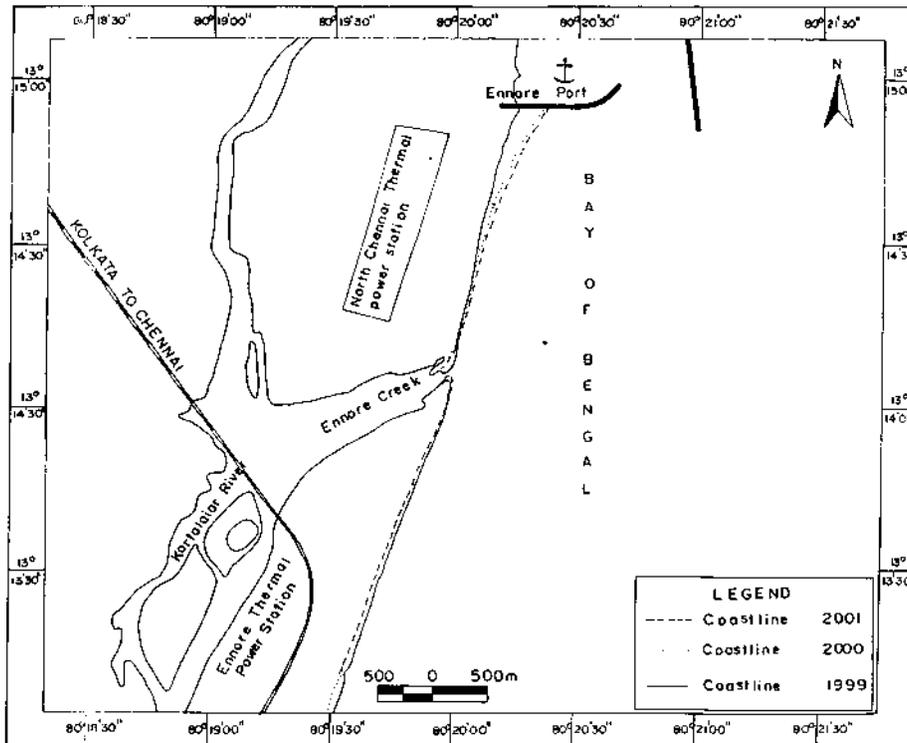


Figure 7. Shoreline changes in Zone-I.

using dredge spoils carried out by port authorities. In recent survey of 2001 and 2002 the beach fill started eroding and the eroded materials are deposited further north. Advancement of shoreline is noticed on northern side of the beach fills near Profile 3. The changing sediment nature from medium sand of natural beach to medium silt with fragmented shell materials of dredged material is clearly visible in this region. Erosion scenario adjacent to north breakwater is shown in Figure 8.

Zone III extends from Kattupalli Kuppam to Pulicat Light house covering 12 km distance. Zone-III is almost a stable coastline and started showing erosion signature on the southern side while advancing shoreline is seen on northern side. At the northern side of Kattupallikuppam village erosion has started to take place (Figure 9). From Table 3, it is clearly seen that a 3 km coastal stretch near Kattupallikuppam village is subjected to erosion. From Figure 9, it is seen that maximum erosion of 40.60 m has taken place north of Kattupallikuppam and a minimum of 11.13 m has taken place north of Kalanji village between 1999 and 2001. This is quite natural that if any coastal structure is constructed on the east coast definitely there will be erosion on the northern side (SUNDAR, 1999). Interestingly, in this case erosion has not started in the immediate north of north breakwater compared to Chennai Port, but it took place after a distance of 3.5 km. Presence of beach fills is the reason for this changing trend on the Ennore coast. In Kattupalli Island, starting from north of Kalanji village up to Pulicat Lake mouth, the width

of the sand bar is very narrow. Particularly near Kalanji and Koraikuppam villages the width of the sand bar between the lake (channel) and the sea is only about 100 m. If erosion starts in this region or even if a big storm strikes, this vulnerable zone may disappear and the possibility of these villages getting washed away by the sea cannot be ruled out. It may also lead to the merger of the Pulicat Lake into the Bay of Bengal and the disappearance of the brackish water ecosystem of the lake resulting in severe ecological and social problems (SANJEEVA RAJ, 1999).

It is observed that accretion to the tune of 14.54 m noticed during 1999 to 2000 has been reverted back to erosion of 3.65 m during 2000–2001 near Koraikuppam village with overall accretion of 10.89 m during 1999 to 2001. From Koraikuppam village upto the end of the zone the shoreline is accreting to the distance of 13.56 m, 20 m and 17.49 m during 1999 to 2001 near Sattankuppam, Vairankuppam and Nadukuppam respectively. North of Pulicat Lighthouse, accretion at a rate of 45.69 m per year has taken place. It has been reported that 18 m of beach has been lost during the past 20 year period, *i.e.*, between 1978 and 1998 at this location (INSTITUTE OF HYDRAULICS AND HYDROLOGY STAFF, 2000). But after the introduction of the port the shoreline is obtaining some equilibrium and behaving as an accreting coastline. Thus the shoreline in this coastal stretch is oscillating ± 20 m with almost a stable coastline set up.

Zone-IV represents northern end of the study area comprising bar mouth region of Pulicat Lake with a distance of

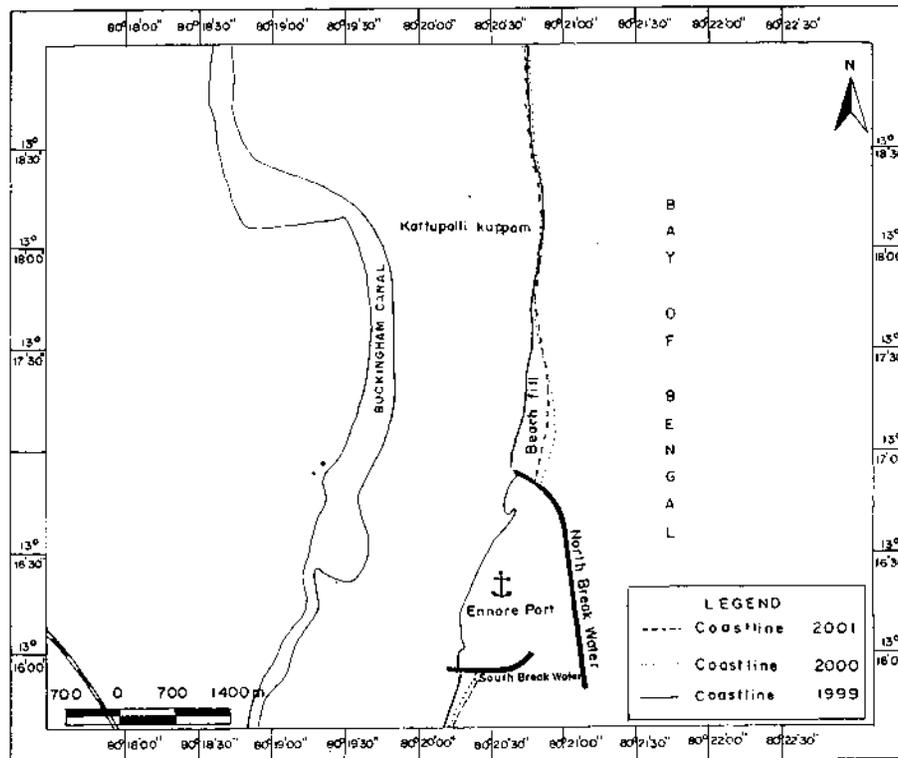


Figure 8. Shoreline changes in Zone-II.

5 km. The Pulicat inlet is generally recognized as a small scale water way that connects an inland body of water with the ocean. Pulicat inlet serves as conduits for the exchange of waters during the tidal cycle between the coastal waters and large tidal water body. Sediments are brought into the lagoon during flood tides and the flows into the inlet draw sediment laden water from the surf zone as well as from the offshore. Flood tidal deltas are observed near the tidal inlets of Pulicat Lake due to the reduced velocity of ebb. The fluctuations in the tidal flows are caused by the water level difference of ocean and lagoon. Figure 10 and Table 3 clearly reveal that the entire zone is prone to accretion during the period of study. At the southern end of the zone, the length of accretion is 20 m and at the southern side of the mouth it is around 40 m during 1999 to 2001. At the southern edge of the mouth about 200 m of accretion has taken place during 1999 to 2001 and at the mouth about 170 m of accretion has taken place during 2000 to 2001 alone. Tidal inlet of Pulicat Lake was closed from April 2001 until the start of northeast monsoon period (November 2001) due to failure of monsoon during preceding years and accretion at mouth by the long shore sediment transport. The closure of bar mouth has taken place after a gap of 26 years since 1975 as reported by RAMAN *et al.* (1977). This has caused the choking of the mouth, which is the only active opening to the entire Pulicat Lake for the exchange of water with the Bay of Bengal.

Bathymetry

Bathymetry survey has been carried out in the study area between Ennore Creek and Pulicat Lake in order to understand the sea bed morphology. The entire bathymetry of the offshore region of the study area is presented in Figure 11. From the figure, it is observed that the shoal exhibits features, which are different from those depicted in the admiralty charts. Presence of ridges and runnels are distinct in the shoal region. Ennore shoals are naturally formed shoals extend up to a length of about 14 km with widths varying between 500 m and 1500 m and depths varying between 3 m and 6 m. The wave energy is attenuated as the waves travel over these shoals. As waves travel from deep water into shallow water, they generally lose energy even before breaking (VINCENT, 1981). They also change height and direction in most cases. The changes may be attributed to refraction, shoaling, bottom friction, percolation and nonlinear deformation of the wave profile (CERC, 1984). The water depths at the top of the ridges are of the order of 4.5 metres and along the runnels the water depths are of the order of 11.5 metres. The alignment and positioning of the ridges and runnels indicate that they are migratory in nature due to relatively long interaction with the southeast waves. While traversing from offshore boundary of the shoal to the Ennore coast it is observed that the water depth vary from about 24 metres along the offshore boundary, decreases to 4.5 metres

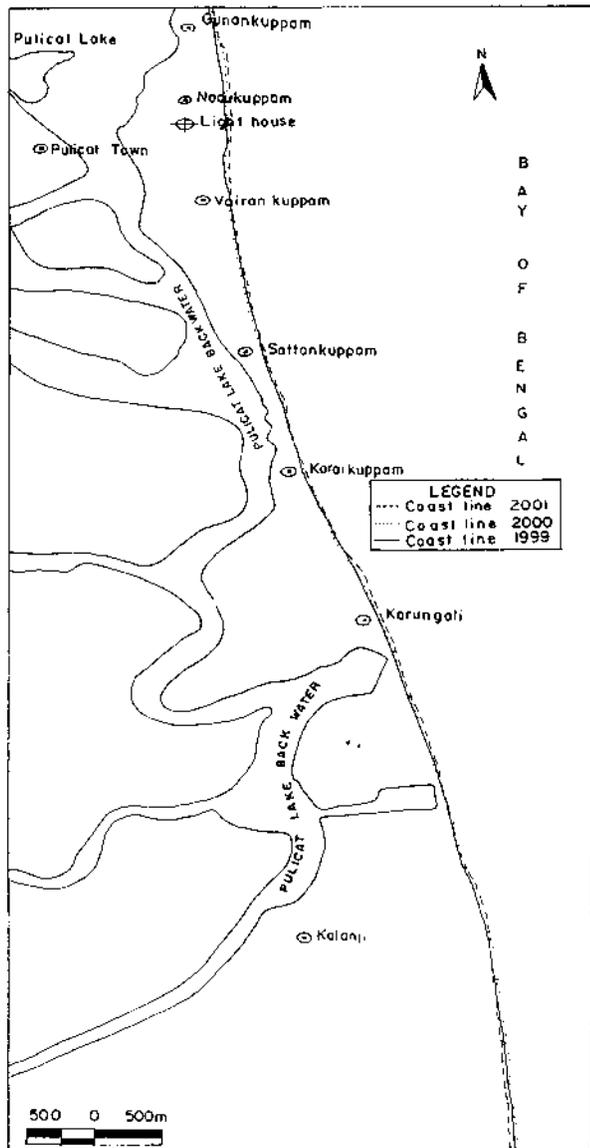


Figure 9. Shoreline changes in Zone-III.

on the ridges and then increases to a water depth of about 17 metres adjacent to the Ennore coast. This indicates that the seabed is steep adjacent to the coast. Presence of ridges and runnels act as a wave damper and protect the Ennore coast from wave attack. Presently Ennore shoals are acting as a barrier and protect the northern coast from erosion. The choice of locating the entrance to the Ennore Port on the southeast was from the point of view of maneuvering of the ships due to the presence of Ennore shoals (HASKONING, 1995).

Environmental Parameters (Tide, Wave, Currents)

Waves

Results from the observed wave parameters such as significant wave height (H_s), mean zero up-crossing period (T_p)

and peak period (T_p) are presented in Figures 12 and 13. A difference of 0.20 m is observed in the wave heights at Ennore nearshore and Pulicat nearshore.

In order to identify the magnitude of waves traveling over the Ennore shoals, situated north of north break water, wave and tide gauges were deployed at two different locations, one at the east of shoals (W_1) and the other at the west of shoals (W_2), i.e. on the shore side. This has proved clearly that as the waves travel over the shoals, they lose their energy and in turn the wave heights reduce. About 0.2 to 0.4 m difference in wave height has been observed between the eastern and western side of Ennore shoals. From the observation, it is clear that the significant wave height (H_s) has considerably reduced up to 0.4 m after the wave crossed the shoals while travelling east to west towards the shore.

The over all analysis of offshore wave data at Ennore and Pulicat also indicates a similar trend in wave height distribution whereas the comparison between offshore and nearshore region indicates changes in wave distribution due to wave transformation from deepwater to shallow water. Wave statistics obtained from the field measurements are presented in Table 4.

Tides

Similar to the wave data collection, data on tides were also collected by deploying tide gauges at the same locations. The observed tidal elevations are presented in Table 5. At the nearshore and offshore locations of Ennore Creek, the tidal elevation is more or less equal. At the nearshore and offshore regions of Pulicat mouth an elevation difference of 0.10 m is observed. The offshore tidal elevation is higher than the near shore tides. At these locations semi-diurnal type of tide is observed during the period of deployment. In order to identify the tidal difference in the shoal region tide gauges were deployed at the east and west of Ennore shoals and they reveal no significant variation in tidal elevation due to the presence of shoals as in the case of waves. It reveals identical water level variation indicating that shoals do not influence the tides with a variation range of 0.5 m to 0.7 m.

The overall tide measurements carried out at various locations suggest that the tidal variations are semidiurnal with identical water level fluctuations both at Ennore and Pulicat regions. The tidal range is in the order of 0.5 m during the period of observations. Comparison of tide measurements at foreshore regions of Ennore Creek and Pulicat mouth reveals no appreciable difference between water levels which indicate that the entire region is experiencing identical tidal conditions. However, a phase lag of 10 to 15 minutes is observed between Pulicat and Ennore Creek. Results indicate that the tide is propagating from south to north with the high water being observed first at Ennore and after 10 to 15 minutes at Pulicat.

Currents

Currents were measured at 10 minute intervals with self recording Aanderra RCM 9 current meters simultaneously at four locations C1, C2, C3 and C4 (Figure 1) between Ennore and Pulicat and at the locations on the east and western side

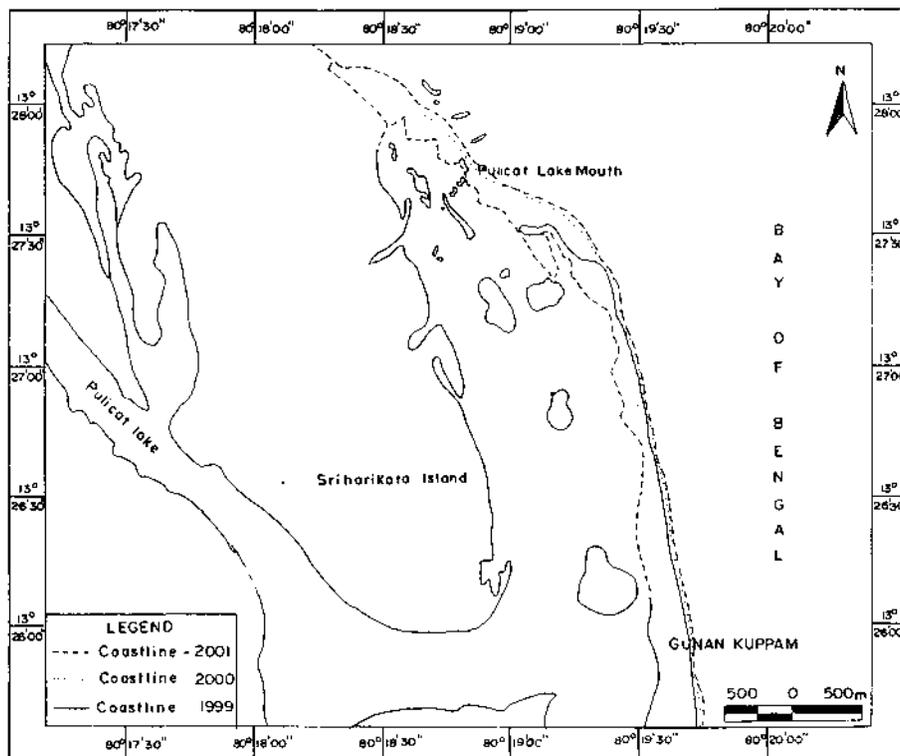


Figure 10. Shoreline changes in Zone-IV.

Table 3. Shoreline changes observed during 1999 to 2001.

S. No.	Changes in Shoreline During the Year (in m)			Remarks
	1999 to 2000	1999 to 2001	2000 to 2001	
Zone I				
1	-61.74	-63.39	-1.65	Near EID Parry Factory
2	8.67	5.30	-3.37	Ennore Creek
3	-18.29	-13.58	4.70	Ennore Creek
4	209.54	242.82	33.27	South of South Breakwater
Zone II				
5	488.35	375.60	-112.74	North of North Breakwater (Beach Fills)
6	0.93	1.07	0.14	End of Beach Fill
7	-12.34	-39.62	-27.27	Kattupalli Kuppam Village
Zone III				
8	-36.83	-40.63	-3.80	North of Kattupalli Kuppam
9	-9.08	-11.13	-2.05	North of Kalanji Village
10	14.54	10.89	-3.65	Koraikuppam Village
11	9.74	13.56	3.82	Sattankuppam Village
12	-2.91	20.02	22.93	Vairankuppam Village
13	-9.44	17.49	26.93	Nadukuppam Village
14	-22.75	22.94	45.69	North of Pulicat Lighthouse
Zone IV				
15	-21.40	20.30	41.69	Southern end of Zone IV
16	53.74	202.58	148.83	Southern edge of inlet
17	-165.97	3.43	169.40	Pulicat Lake mouth/inlet

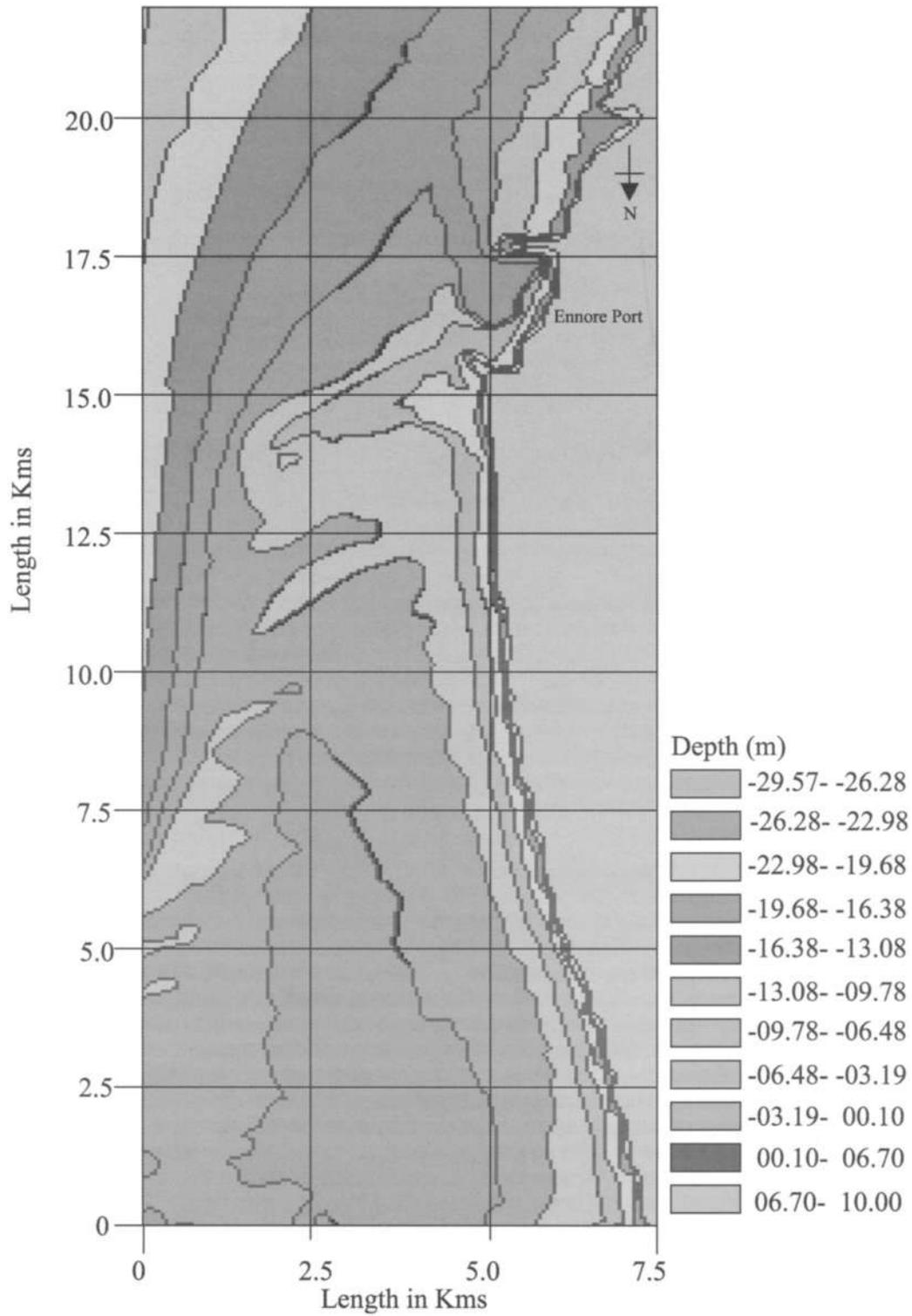


Figure 11. Bathymetry map of the study area.

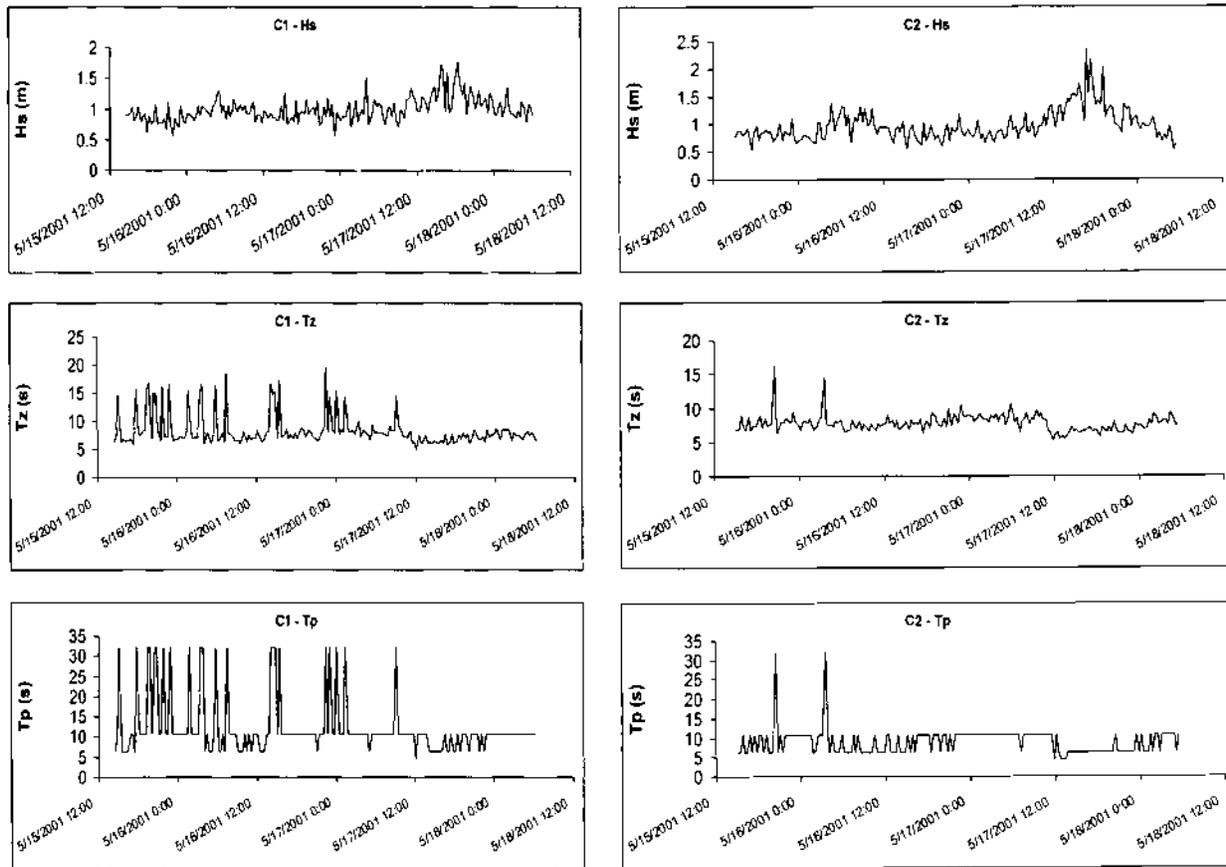


Figure 12. Wave parameters observed at Ennore nearshore (C1) and offshore (C2).

of Ennore shoals. Current meters were deployed at the same locations where wave and tide gauges were deployed and positional depth was maintained at 2 m below the water surface. The observed peak magnitude and direction of the current pattern are presented in Table 5. The comparison of nearshore current pattern of Ennore and Pulicat reveals that the current speed is more at Pulicat. Average speeds recorded at Pulicat nearshore and at Ennore were 20 cm/sec and 12 cm/sec respectively. Offshore regions of Ennore and Pulicat show an average current speed of 20 cm/sec. At Pulicat offshore, the current speed varies from 10 cm/sec to 45 cm/sec and at Ennore it is 12 cm/sec to 48 cm/sec. Comparison of current speeds at east and west of Ennore shoals show no significant change when it crosses the shoals. Maximum currents are observed at the offshore station of Ennore. Analysis of current direction shows a unidirectional trend for most of the stations except C1 (Ennore nearshore) due to the presence of Ennore Port. From the results it can be confirmed that nearshore current direction is influenced by the port structures and/or shoals.

Sediments

Totally seven transects have been selected for collecting samples for the analysis of suspended sediment concentration

and its grain size. The grain size analyses of the sediments collected from nearby regions of the Ennore Port showed medium to coarse sand sediments on the northern side of the north breakwater, south of Kattupalli village. The south side sediments are recycled from the dredged materials of Ennore Creek and they are fine sized sand particles.

The suspended sediment concentration observed in the surface waters ranged between 12 mg/l and 65 mg/l (Figure 14a) and coastal bottom waters ranged between 20 mg/l and 88 mg/l (Figure 14b). Reduction in the suspended load is noticed in transects 5 and 6, which are on the northern side of the north breakwater. Suspended sediment concentration in bottom water showed gradual reduction from the southern transects towards the Pulicat mouth region. Maximum SSC load of 87.57 mg/l observed in the bottom water in Transect 2 is due to the near shore circulation due to dredging operations in this region. Almost a constant value of around 40 mg/l was observed for the bottom water samples at different depths of Transect 5. The surface water suspended concentration did not show any specific trend from all the seven transects.

Grain size of the suspended sediments in the bottom water ranged from 11 micron to 34 micron, which falls in the coarse silt size fraction. The bivariate plot of size with respect to transects show gradual coarseness of the grains towards

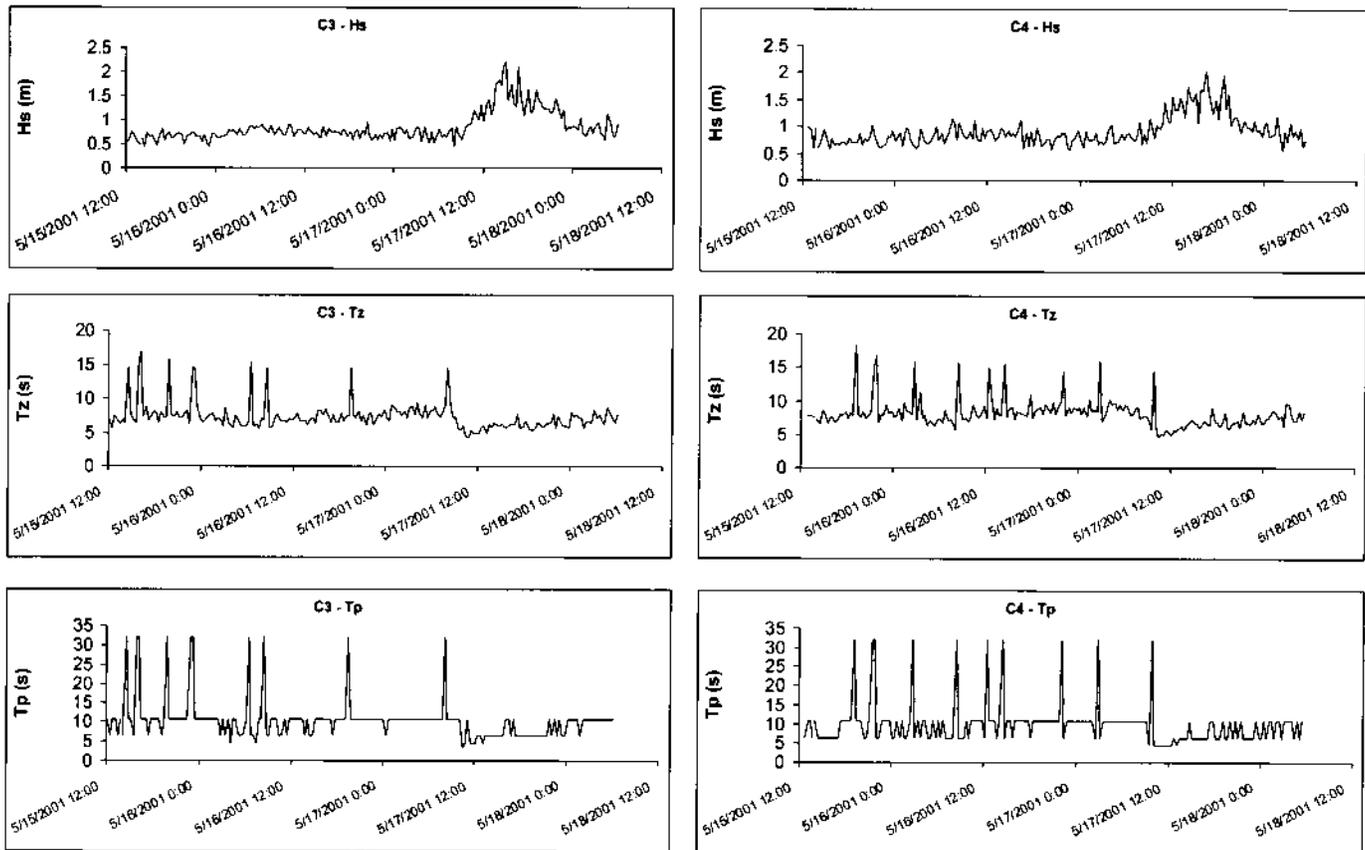


Figure 13. Wave parameters observed at Pulicat nearshore (C3) and offshore (C4).

north as shown in Figure 15. The grain size of the bed sediments ranged from 100 to 500 microns. General trend of the grain size shows (Figure 15) almost constant result with a mean grain size of 178 microns of fine sand except three samples that were collected at a depth of 3 m from transects 2, 4 and 5. Results of the grain size analyses for the bottom water sediment samples and bed sediments are given in Tables 6 and 8.

Grain size distribution of bed sediments for 24 samples observed at different locations indicate that the D_{50} is of the order of 100 microns for locations 1 to 9 and of the order of 500 microns for the locations 10 to 18. For locations 19 and 20, D_{50} is of the order of 130 microns. Analysis of bed samples

indicate the presence of coarse sediment along the offshore boundary of the shoal and the finer sediments along the coastline (Figure 16). This clearly demonstrates that the shoal while interacting with large waves around the offshore boundary reduces the energy of the incoming waves resulting in deposition of coarser sediment along the offshore boundary of the shoal. Finer fragments of the sediment are carried over the shoal by relatively low energy waves and deposited adjacent to the coastline.

Littoral Drift

There are two modes of sediment movement; suspended and bed load movement. The pattern of coastal sediment

Table 4. Wave statistics observed from field measurements.

S. No.	Location	Wave Height H_s (m)	Mean Zero Up-crossing Period, T_z (s)	Peak Period, T_p (s)
1.	C1	0.7	10	10
2.	C2	0.9	7.5	7.5
3.	C3	0.9	7	10
4.	C4	0.9	8	10
5.	W1	0.8	7	8
6.	W2	1.2	7	8

Table 5. Peak magnitude and direction of the current pattern and average tide.

S. No.	Location	Peak Current Magnitude (m/s)	Direction (deg)	Tide Elevation (m)
1.	C1	0.24	350	0.60
2.	C2	0.49	180	0.62
3.	C3	0.40	175	0.61
4.	C4	0.47	215	0.65
5.	W1	0.70	350	0.69
6.	W2	0.38	330	0.67

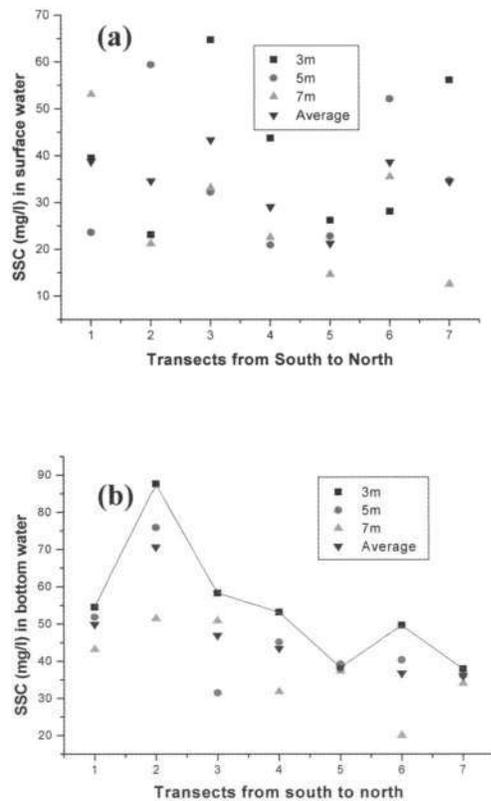


Figure 14. Suspended sediment concentration in (a) surface water and (b) bottom water.

movement is different in offshore, inshore and foreshore region (HORIKAWA, 1978). It is generally an agreed fact that the major part of the littoral transport is caused by waves that approach the shore obliquely. The suspended sediments will be entrained in to the long shore current generated by the breaking waves, thus causing transport (SAVAGE, 1962). LONGUET-HIGGINS (1953) treated theoretically the vertical distribution of mass transport due to wave action. The principle factors affecting the rate of littoral transport have been studied in detail (KRUMBEIN, 1944; SAVILLE, 1950; JOHNSON, 1953). GALVIN (1972) predicted the gross long shore sediment transport rates for eleven long term field measurements using the empirical relation, $Q = 2H_b^2$; where Q is the gross long shore transport rate in lakh of cubic yards/year and H_b is the mean breaker height in feet.

The LITDRIFT module of LITPACK numerical modeling software (Danish Hydraulic Institute) has been run for four different profiles, namely, South of Ennore Creek, South of Ennore Port, North of Ennore Port and Pulicat Lighthouse. Results obtained from the simulation as gross and net annual drift for each of the profiles have been presented in Table 9.

From the results (Table 9), it is observed that the gross transport is 1.095 million m^3 /year and net annual transport in the direction of north is at a rate of 0.628 million m^3 /year for the profile south of Ennore Creek. For the profile south of Ennore Port, it is about 1.113 million m^3 /year and 0.657

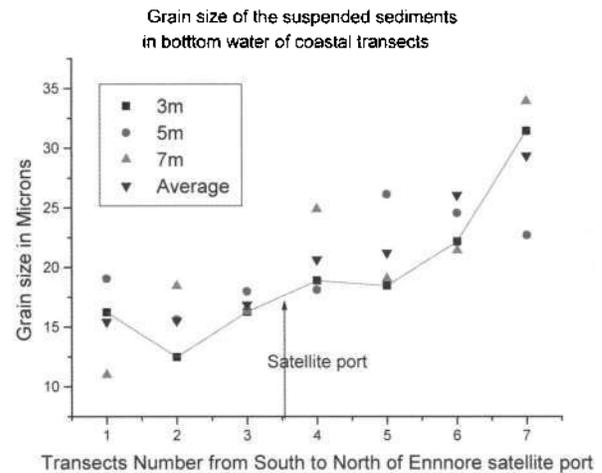


Figure 15. Grain size of the suspended sediments in bottom water.

million m^3 /year as gross and net transport respectively. North of Ennore Port, gross and net transport rate are 1.020 million m^3 /year and 0.572 million m^3 /year respectively. At the Pulicat Lighthouse, it is about 1.163 million m^3 /year and 0.663 million m^3 /year as gross and net transport respectively. It is observed from the results that for all the profiles the net transport is towards north only. The net annual transport of all the profiles except north of the port is more or less equal. At north of the port the amount of net transport is less compared to other profiles as the location is next to the north breakwater and hence the zone is starved of sediments. Considerable amount of sediments are also retained at south of the south breakwater as accretion.

DISCUSSIONS

Beach systems are highly responsive to both short and long term coastal processes. Rapid oscillations in beach width and volume can occur in response to changing wave conditions whilst long term climate induced modifications in shoreline elevation or wave climate will induce more gradual beach change (PEARMAN, 1988; COWELL *et al.*, 1992; SHORT *et al.*, 1995). In this study short-term data on shoreline changes indicate accretion of 242 m over a period of two years and variation of shoreline width near south breakwater. Results from both the beach profile survey and shoreline survey confirm that enormous accretion is taking place in the south of Ennore Port. Even though this coast has experienced accretion in the past, the present study shows that the accretion rate has increased enormously after the construction of the port.

Accretion at the tidal inlet of Ennore Creek has caused frequent closure of the mouth, which is the main source of coolant water for the Ennore Thermal Power Station and North Chennai Thermal Power Station. This has provided an additional burden on the power stations in resorting to continuous dredging to keep the inlet open. From beach profile survey it is observed that the foreshore slope on the southern side of Ennore Port is steeper than the northern side. This of course is the general pattern one finds on all coasts, with the

Table 6. Grain size (μm) distribution in bottom water suspended sediments (1999).

Transects	Depth	D ₁₀	D ₃₀	D ₅₀	D ₆₀	D ₇₀	D ₉₀
T1	3 meters	4.93	10.23	16.24	20.41	25.1	52.59
	5 meters	5.38	11.81	19.06	23.5	30.9	69.34
	7 meters	3.53	7.24	11	13.25	17.78	43.86
	Average	4.61	9.76	15.43	19.05	24.59	55.26
T2	3 meters	3.73	7.89	12.48	15.15	19.5	48.5
	5 meters	4.35	9.55	15.63	20.85	31.2	439.52
	7 meters	5.04	10.95	18.44	25.1	33.13	68.15
	Average	4.37	9.46	15.52	20.37	27.94	185.39
T3	3 meters	4.64	9.75	16.26	21.88	30.9	184.16
	5 meters	5.24	10.96	17.99	23.42	30.8	62.17
	7 meters	4.6	10.23	16.33	21.28	30.85	74.56
	Average	4.83	10.31	16.86	22.19	30.85	106.96
T4	3 meters	5.57	11.74	18.89	25.1	33.7	74.75
	5 meters	5.58	11.7	18.13	22.1	29.2	60.41
	7 meters	7.62	14.2	24.9	30.98	40.28	83.35
	Average	6.26	12.55	20.64	26.06	34.39	72.84
T5	3 meters	5.73	11.75	18.46	23.44	28.9	70.39
	5 meters	8.4	17.7	26.14	30.9	38.2	71.44
	7 meters	5.38	10.89	19.06	23.5	30.9	69.54
	Average	6.50	13.45	21.22	25.95	32.67	70.46
T6	3 meters	6.26	14.25	22.18	27.25	35.5	103.81
	5 meters	7.1	16.15	24.57	30.95	40.73	102.26
	7 meters	6.3	14.5	21.42	26.91	35.4	82.53
	Average	19.66	44.9	68.17	85.11	111.63	288.6
T7	3 meters	8.29	19.2	31.45	40.5	50.11	108.5
	5 meters	6.04	14.2	22.72	30.2	40.73	111.53
	7 meters	7.7	17.78	33.92	50.11	80	338.8
	Average	7.34	17.06	29.36	40.27	56.95	186.28
T (Average)		7.65	14.99	23.79	30.42	40.66	127.56

Table 7. Grain size (μm) distribution in bed sediments (1999).

Transects	Depth	D ₁₀	D ₃₀	D ₅₀	D ₆₀	D ₇₀	D ₉₀
T1	3 meters	57.15	91.25	116.32	128.2	149	217.39
	5 meters	43.01	84.32	109.49	125	145.23	262.37
	7 meters	82.32	125	164.31	190.25	248	446.17
	Average	60.83	100.19	130.04	147.82	180.74	308.64
T2	3 meters	71.6	177	509.94	520	540	584.14
	5 meters	57.58	98.26	117.02	132.3	149	239.74
	7 meters	75.92	107.8	129.02	139.26	172.5	238.39
	Average	68.37	127.69	251.99	263.85	287.17	354.09
T3	3 meters	65.59	100	133.32	152	210	511.17
	5 meters	42.64	80.25	106.32	121	142	217.94
	7 meters	75.42	108.62	144.35	195.76	262.18	562.25
	Average	61.22	96.29	128.00	156.25	204.73	430.45
T4	1 meter	188.56	270.5	320.64	354	400.25	512.73
T5	3 meters	125.41	354	504.18	510.25	520.25	582.18
	5 meters	63.7	80.25	112.57	118.02	124.5	156.39
	7 meters	53.14	78.27	102.46	118.26	131.2	198.53
	Average	80.75	170.84	239.74	248.84	258.65	312.37
T6	3 meters	101.29	140.25	173.48	198.25	215.2	307.25
	5 meters	99.08	132.5	162.25	182.5	198.5	276.13
	7 meters	100.01	138.1	169.35	185.2	216.2	305.68
	Average	100.13	136.95	168.36	188.65	209.97	296.35
T7	3 meters	57.17	120.2	145.57	155	185.5	290.55
	5 meters	90.91	125	153.76	175.24	190.5	273.79
	7 meters	86.97	121.2	150.4	168.5	187.2	263.83
	Average	78.35	122.13	149.91	166.25	187.73	276.06
T (Average)		74.94	125.68	178.01	195.28	221.50	329.66

Table 8. *Suspended sediments grain size (μm) distribution (2001).*

Location & Time	D ₁₀	D ₃₀	D ₅₀	D ₇₀	D ₉₀	Sand %	Silt %
C1/7.15am	13.94	14.01	17.39	29.02	39.67	3	97
C1/10.00am	13.79	17.1	20.27	30.25	42.36	6	94
C1/1.15pm	5.67	7.58	9.14	22.53	28.34	3	97
C1/4.30pm	14.03	18.75	21.61	43.54	51.09	10	90
			17.1025				
C4/7.15am	14.53	20.25	24.72	42.57	50.69	10	90
C4/10.00am	14.43	20	28.07	45	67.73	18	82
C4/1.15pm	14.84	16.2	17.27	19.25	23.43	0	100
C4/4.30pm	7.96	8.12	8.54	8.92	9.15	0	100
			19.65				
C3/4.30am	13.57	15.25	16.51	20.25	23.35	0	100
C3/7.15am	13.45	15.02	17.06	25.45	32	3	97
C3/10.00am	13.48	14.78	16.76	25.05	30.46	2	98
C3/1.15pm	13.97	17.25	20.84	35.45	39.68	3	97
C3/4.30pm	14.01	16.25	18.81	25.45	30.8	2	98
			17.996				
C2/1m/4.30am	13.6	16.45	18.39	25.42	29.11	0	100
C2/1m/7.15am	15.15	17.25	18.52	22.52	25.3	0	100
C2/1m/10.00am	15.6	22.42	26.22	35.45	41.7	2	98
C2/1m/1.15pm	13.65	15.26	16.59	24.25	27.55	2	98
C2/1m/4.30pm	15.57	25.42	29.85	40.26	63.33	17	83
			21.914				
C2/5m/4.30am	14.46	18.48	20.18	30.15	32.01	1	99
C2/5m/7.15am	13.83	16.58	19.69	32.45	36.3	4	96
C2/5m/10.00am	14	18.25	21.7	35.25	46.91	10	90
C2/5m/1.15pm	15.62	17.25	18.33	19.23	19.99	0	100
C2/5m/4.30pm	15.55	22.45	25.41	35.27	38.74	2	98
			21.062				

C1 = Nearshore Ennore creek (7m depth); C2 = Offshore Ennore creek (17m depth); C3 = Nearshore Pulicat Lighthouse (7m depth); C4 = Offshore Pulicat Lighthouse (17m depth).

slope of the beach face increasing with the sediment grain size and larger seasonal changes in beach elevations (BASCOM, 1951; KING, 1972; KOMAR, 1976; SUNAMURA, 1984; SHIH and KOMAR, 1994). In addition to these factors, this coast is under stress due to the port. Therefore in this part of the coastline extensive changes on the shoreline is inevitable.

But along the Ennore coast, on the northern side of north breakwater, between 2000 and 2001, the profile shows no significant change in beach but the material from nearshore was eroded resulting in steeper slope. The profile could not sustain the slope because of coarser fractions present in beach

due to beach fill. Severe erosion has started on the northern region, 3.5 km north of north breakwater at an approximate rate of 40 m per year. There is no significant erosion in the immediate north of Ennore Port as against the case of Chennai Port. The possible reason for the same could be attributed to the presence of Ennore shoals in the offshore region of Ennore in a northeast direction and beach fills adjacent to the north breakwater. If erosion of shoals takes place in future, consequences will be similar to that of Royapuram coast.

It is worth noticing that as soon as a coastal structure of an extension comparable to the width of the surf-zone has been built along such a shoreline, the downstream shoreline will suffer from erosion in future, unless artificial nourishment/bypass is introduced (MANGOR, 2001). In this case, artificial nourishment is carried out using dredged spoils from

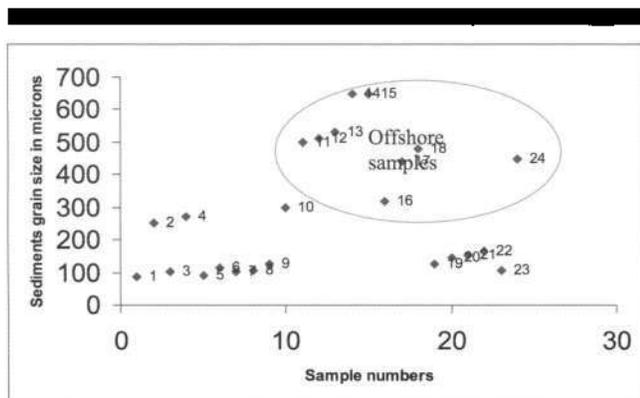


Figure 16. Grain size distribution of sediments.

Table 9. *Littoral drift pattern along Ennore coast.*

S. No.	Profile Location	Gross Littoral Drift (million m ³ /year)	Net Littoral Drift (million m ³ /year)
1	South of Ennore Creek (Profile 1)	1.095	0.628
2	South of Ennore port (Profile 2)	1.113	0.657
3	North of Ennore port (Profile 3)	1.020	0.572
4	Pulicat Lighthouse (Profile 4)	1.163	0.663

inside the port which is considerably protecting the coast. But it has not helped to restrict the accretion in the south. Until otherwise, bypassing of accreted sand to the eroding coast is done, definitely the entrance of the harbour will be closed in future.

Koraikuppam village in Zone-III was severely affected due to erosion in the past, *i.e.* pre-Ennore Port period. But after the construction of Ennore Port it is seen that the coast is accreting in this area for a distance of about 12 m during 1999–2001. In this location the width of sand bar between the sea and lake channel/Buckingham canal is only 100 m and if any severe storm takes place this vulnerable zone may vanish. It is particularly important to have a sufficiently wide beach so that temporary beach erosion will not cause erosion of the coast (MANGOR, 2001). Whereas on the Koraikuppam coast, the accreting trend which is taking place at present will be a boon to the local people. This can be confirmed only in the long run after continuous monitoring.

Coastal erosion, provoked by major harbour construction schemes, has worn away the coastline in various areas, causing the resettlement of fishermen and thwarting fishing operations (BAVINCK, 2001). In this case erosion and accretion observed are due to the Ennore Port construction only. With established sediment sources and under a certain wave climate, the coastline will tend towards a natural equilibrium where the waves are just capable of redistributing the sands supplied from the sources. When, jetties, breakwaters, groynes or other structures are constructed in the coastal zone, the natural equilibrium will be upset, sometimes with disastrous consequences. Many of the most severe cases of coastal erosion can be attributed to this disturbance of the natural equilibrium (KOMAR, 1976). Since the present problem is created due to man-made disturbances it will take many years for the coast to adjust itself to a state of equilibrium state. Until then the remedial measures should be carried out without affecting the system further.

The presence of Ennore Port has reduced the wave activity along south shore by about 60% compared to wave climate prior to construction of port. On the northern side of Ennore Port, wave energy is reduced to an extent of 20% over the shoals and increased on the eastern part by 30% during southeast waves. Northeast waves have negligible influence due to the presence of shoals. Coastal stretch at a distance of 6 km from north breakwater experiences high waves due to the addition of reflected waves and refracted waves from offshore region.

The current measurement indicates an increase in magnitude to the order of 20% at location C1 (Ennore) due to the presence of breakwater. Offshore currents are less influenced by the port. Sediment characteristics indicate the presence of coarser fractions in nearshore regions due to dumping of dredge spoils from Ennore Creek and prevailing low currents. Comparison of nearshore and offshore currents near shoal region reveals that in the offshore region the currents are unidirectional whereas at nearshore they are influenced by waves.

Grain size distribution along the coastal region revealed that coarser grains are observed in the region and it confirmed that the beaches are reflective in nature and are sub-

jected to significant seasonal variations on beach profiles as concluded by SHIH and KOMAR (1994) on the Oregon coast. Sediment characteristics in the north of port indicate the presence of coarser sediment along the offshore boundary of shoal and finer sediments on the coastline. This clearly demonstrates that the shoal while interacting with large waves around offshore boundary, reduces the energy of the incoming waves resulting in deposition of coarser sediments. Finer fragments of the sediment are carried over the shoal by relatively low energy waves and deposited adjacent to the coastline. Suspended sediment concentration in coastal waters range between 12 mg/l and 243 mg/l. However, these values are less compared to the values (25 to 321 mg/l) noted for Chennai coastal waters by GOWRI (1997) and are higher than the values (32.8 to 131.5 mg/l) obtained by SATPATHY and NAIR (1996) for Kalpakkam coastal waters. Among seven transects suspended sediment concentration, observed on surface waters at transect 2 and 4 are higher and the reason may be the dredging operations near transect 2 and beach fills near transect 4 on the Ennore Creek and north of Ennore Port respectively.

In the present scenario Pulicat Lake will not be affected by erosion due to the north break water. The configuration of the coastline, presence of shoals on the northern side and artificial beach nourishment for 2 sq. km on the northern side of the port, all will delay the erosion process on the northern side. Accreting trend obtained from the beach profile survey in the Pulicat mouth region is a serious one as it will definitely create problem of bar mouth closure permanently. During the period of mouth closure, salinity and temperature were very high and consequently the Dissolved Oxygen was very low in the Pulicat Lake (RAMAN *et al.*, 1977). IncurSION of seawater through the bar mouth is essential for maintaining the environmental features without going to extreme conditions, particularly in the tidal southern zone of the Pulicat Lake.

Beaches and shallow water coastal areas composed of unconsolidated silt and sand sized material undergo reversible (recoverable) changes beach erosion and accretion, in response to external forcing mechanisms. These forcing mechanisms include wave driven transport and current driven transport. Wave driven transport is normally divided into two constituents as long shore transport and onshore-offshore transport. Long shore transport refers to the movement of sediments along the beach in a direction that is generally perpendicular to the shoreline. Currents have the ability to transport silt and sand sized material both as bed load (near bottom movement) and in suspension. Generally speaking the stronger the current the greater will be the size of material which can be transported in suspension. Also as current speed increases, bottom material deposited during reduced current is re-suspended and transported in suspension. Littoral drift study shows that more or less equal amount of sediment transport is taking place at all the four profiles. The net annual transport rate is towards the northern direction at all the four transects. This result is in good agreement with the inferences made by the earlier researchers (KOMAR, 1976; CHANDRAMOHAN *et al.*, 1990; PRANESH, 2000; VAZE *et al.*, 2001). Capacity to transport the sediment would reduce

by 80 % along the new shoreline indicating the possibility of shallow depths near the entrance to Ennore Port, warranting an unnecessary increase in maintenance dredging. The net sediment transport rate predicted for the profile north of north breakwater is well matching with the results ($0.53 \text{ m}^3/\text{year}$) of HASKONING (1995).

CONCLUSIONS

The lessons learnt and experiences gained from the earlier cases along the Chennai coast suggests that the issues are not resolved as the measures are highly localized in nature. The behavior of coastal processes is not understood completely due to lack of proper monitoring mechanism and insufficient coordination among different agencies involved in the developmental activities. The present study reveals that the shoreline north of north breakwater is to be protected immediately with some soft/hard engineering measure to control the future erosion in this stretch. The accreting southern stretch has to be controlled with some introduced groynes, since the accreted sediments will close the approach channel of the port and it requires continuous dredging operation. LITDRIFT results clearly brought out the changing littoral drift pattern from $0.65 \times 10^6 \text{ m}^3/\text{year}$ on the southern side of port to $0.57 \times 10^6 \text{ m}^3/\text{year}$ causing deficit in the supply of sediment on the northern side, intern producing eroding shore line trend.

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LITERATURE CITED

- BAKKER, W.T., 1968. The Dynamics of Coast with a Groin System. *Proceedings of the 11th Conference on Coastal Engineering*, pp. 492-517.
- BAKKER, W.T.; KLEIN BRETELER, E.A.J., and ROOS, A., 1970. The Dynamics of a Coast with a Groin System. *Proceedings of the 12th Conference on Coastal Engineering*, pp. 1001-1020.
- BASCOM, W.N., 1951. The relationship between sand size and Beach-Face Slope. *Transactions of American Geophysical Union*, 32, 866-74.
- BAVINCK, M., 2001. *Marine Resource Management—Conflict and Regulation in the Fisheries of the Coromandal Coast*. London: Sage Publications, 395p.
- BERGER, A.R. and IAMS, W.J., 1996. *Geoindicators: Assessing rapid environmental changes in earth systems*. Rotterdam, 466p.
- CARTER, R.W.G., 1988. *Coastal Environment: An introduction to the physical, ecological and cultural systems of coastlines*. London: Academic Press, 617p.
- CARTER, R.W.G. and WOODROFFE, C.D., 1994. *Coastal evolution: Late quaternary shoreline morphodynamics*. Cambridge: Cambridge University Press, 517p.
- CERC, 1984. *Shore Protection Manual*. Virginia: Coastal Engineering Research Center, U.S. Army Corps of Engineers, Vol. I and II.
- CHANDRAMOHAN, P.; NAYAK, B.U., and RAJU, V.S., 1990. Longshore Transport Model for South Indian and Sri Lankan Coasts. *Journal of Waterway, Port, Coastal and Ocean Engineering*, 116, 408-424.
- CHORLEY, R.J.; SCHUMM, S.A., and SUGDEN, D.E., 1984. *Geomorphology*. London: Methuen, 605p.
- CORNICK, H.F., 1969. *Dock and Harbour Engineering*. London: Charles Griffin, 2, 352p.
- COWELL, P.J.; ROY, P.S., and JONES, R.A., 1992. Shore face Translation Model: Computer Simulation of coastal-sand-body response to Sea Level Rise. *Mathematics and Computers in Simulation*, 33, 603-608.
- COWELL, P.J. and THOM, B.G., 1994. Morphodynamics of coastal evolution. In: CARTER, R.W.G. and WOODROFFE, C.D., (eds), *Coastal Evolution*. Cambridge: Cambridge University Press, pp. 33-86.
- DEAN, R.G. and DALRYMPLE, R.A., 2002. *Coastal Processes with Engineering Applications*. Cambridge: Cambridge University Press, 475p.
- DHI, 1998. *User's Guide and Reference Manual (LITPACK)*. Denmark: Danish Hydraulic Institute, Release 2.7.
- GALVIN, C.J., 1972. A gross long shore transport rate formula. *Proceedings of the 13th Conference on Coastal Engineering*, 2, pp. 953-970.
- GOWRI, V.S., 1997. Impacts of Adyar and Cooum River Discharges on the Water and Sediment Qualities of Marina Beach. Chennai, Chennai, India: Anna University, Ph.D thesis, 243p.
- HASKONING, 1995. Coastal Protection Works. Haskoning Royal Dutch Consulting Engineers and Architects, *Ennore Coal Port Project—Detailed Design Report*, pp. 4-15.
- HORIKAWA, K., 1978. Coastal Sediment-Wave Induced Sediment Transport. In: *Coastal Engineering—An Introduction to Ocean Engineering*. Tokyo: University of Tokyo Press, pp. 247-278.
- INSTITUTE OF HYDRAULICS AND HYDROLOGY STAFF, 2000. Final Report on Model Studies for the proposed coastal Defence along Ennore—Manali Express Highway of North Chennai Coast. Poondi, India: Institute of Hydraulics and Hydrology, Report No. 2/2000, 67p.
- JOHNSON, J.E., 1953. Sand Transport by Littoral Currents. *Proceedings of 5th Hydraulics Conference Bulletin 34*, Iowa State University Studies in Engineering, pp. 89-109.
- JOHNSON, J.W., 1957. The Littoral Drift Problem at Shoreline Harbours. *Journal of Waterways and Harbours Division*, 83, 1-37.
- KING, C.A.M., 1972. *Beaches and Coasts*. New York: St. Martin's, 570p.
- KOMAR, P.D., 1976. *Beach Processes and Sedimentation*. New Jersey: Prentice-Hall Inc., 429p.
- KOMAR, P.D.; LIZARRAGA ARCINIEGA, J.R., and TERICH, T.A., 1976. Oregon Coast Shoreline Changes due to Jetties. *Journal of Waterways, Harbours and Coastal Engineering Division*, 102 (WW1), 13-30.
- KRUMBEIN, W.C., 1944. *Shore currents and sand movement on a model beach*. US Army Corporation of Engineers, Beach Erosion board Technical Memoir, no.7, pp. 43-47.
- LONGUET-HIGGINS, H.S., 1958. Mass transport in water waves. *Proceedings Cambridge Philosophical Society*, 245 (903), pp. 15-81.
- MANGOR, K., 2001. *Shoreline Management Guidelines*. Denmark: Delft Hydraulics Institute Water and Environment, 232p.
- PEARMAN, G.I., 1988. *Greenhouse—Planning for Climate Change*. Melbourne: CSIRO, 752p.
- PRANESH, M.R., 2000. Dredging Activities Along the Coastal Zone and its Impact on the Coastal Geomorphology. *Proceedings of Symposium on Management of Problems in Coastal Areas*, Chennai: Indian Institute of Technology, pp. 217-229.
- RAMAN, K.; KALIYAMURTHY, M., and JOSEPH, K.O., 1977. Observations on the Ecology and Fisheries of the Pulicat Lake During Drought and Normal Periods. *Journal of Marine Biological Association*. India, 19(1), 16-20.
- SAHADEVAN, P.V., 1996. Royapuram Sea Erosion: Its Varying Magnitude and the Possible Ways to Solve the Century Old Problem Permanently. *Proceedings of Workshop to Deliberate the Design to be Adopted for Controlling North Chennai Royapuram Sea Erosion*, Chennai, India: Public Works Department, pp. 34-50.

- SANJEEVA RAJ, P.J., 1999. North of Chennai, India: Developmental Impacts on Coastal Ecosystems. *The Indian Geographical Journal*, 74(1), 1-11.
- SATPATHY, K.K. and NAIR, K.V.K., 1996. Occurrence of Phytoplankton Bloom and its Effect on Coastal Water Quality. *Indian Journal of Marine Science*, 25, 145-147.
- SAVAGE, R.P., 1962. Laboratory Determination of Littoral Transport Rates. *Journal of Waterways and Harbours Division*, 88, 69-92.
- SAVILLE, T., 1950. Model study of transport along an infinitely long straight beach. *Transactions of American Geophysical Union*, 31, 555-565.
- SHEPARD, F.P. and WANLESS, H.R., 1971. *Our Changing Coastlines*. New York: McGraw-Hill, 579p.
- SHIH, S.-M. and KOMAR, P.D., 1994. Sediments, Beach Morphology and Sea Cliff Erosion within an Oregon Coast Littoral Cell. *Journal of Coastal Research*, 10(1), 144-157.
- SHORT, A.D.; COWELL, P.J.; CADEE, M.; HALL, W., and VAN DIJCK, B., 1995. Beach Rotation and Possible Relation to the Southern Oscillation. *Adelaide: Ocean and Atmosphere Pacific International Conference*, pp. 1-6.
- SPRING, F.J.E., 1919. Coastal Sand Travel near Madras Harbour. *Minutes Proceedings Institute of Civil Engineering*, 210, 27-28.
- SUNAMURA, T., 1984. Quantitative Predictions of Beach-Face Slopes. *Geological Society of American Bulletin*, 95, 242-245.
- SUNDAR, V., 1999. *Final Report on Ennore-Manali Road Improvement Project Additional Survey and Numerical Modeling*, Chennai, India: Kampsax India Ltd., 150 p.
- VAZE, V.V.; KALE, A.G., and MANJUNATHA, S.G., 2001. Effects of Drawal of Cooling Water on Tidal Inlet. *Proceedings of National Conference on Hydraulics and Water Resources (HYDRO 2001)*, Pune, India: Central Water and Power Research Station, pp. 365-372.
- VERNOM-HARCOART, L.F., 1881. Harbours and Estuaries on Sandy Coasts. *Minutes of Proceedings Institute of Civil Engineering*, 70, 1-32.
- VINCENT, C.L., 1981. A Method for Estimating Depth-Limited Wave Energy. In: *Coastal Engineering Technical Aid*. Coastal Engineering Research Center, Vicksburg: U.S. Army Corps of Engineers, 16-81.

ECOLOGICAL EFFECTS OF VARIOUS COASTAL DEFENSE SYSTEMS

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ABSTRACT

The interaction of storm waves with persistent swell from an oblique direction produces pulses of littoral drift which are of great significance in coastal engineering. The natural construction of offshore bars for beach protection should be aided by man by the provision of adequate sources of material. Groynes have been found to be ineffective in protecting a shoreline suffering from erosion. Seawalls erode the seabed in front of and downcoast of them. Beach renourishment is a transitory solution to beach denudation. The best stabilization concept is that of headland defense of coasts which copies Nature in its attempt to minimize longshore drift.

KEYWORDS

Littoral drift, beach processes, groynes, seawalls, renourishment, headland control.

BEACH PROCESSES

Sediment is moved along the coast by the oblique approach of waves, which is a necessary criterion when beach problems occur either of erosion or accretion. If waves arrive normal to the shore there is no net movement alongshore. This transport can occur both in the surf zone or beyond the breakers. The rate per unit width across the beach varies tremendously from the turbulent surf zone to that offshore, where only the coastline component of mass-transport of progressive waves is effective. In this context the possibility of two wave trains angled to each other when propagating across the shelf should not be forgotten. The suspension and carrying capacity of such a short-crested system is probably a magnitude greater than for single progressive waves of the same energy.

After swell waves have been arriving for many weeks, or a season, the bed profile will assume a parabolic shape ending with a beach face slope determined by the coarseness of the beach sand. Shoreward of this is an almost horizontal berm that extends to the toe of the foredune. The width of this berm, in which there is no vegetation, gives an idea of the volume of sand that has been demanded by storm

waves in the past year or two. If any seeds had lodged on it they would have been carried out to sea during the last storm sequence hence the lack of flora on the berm.

Accretion of the beach occurs during periods of swell since there is a reasonable time between each large wave that swashes up the beach face. It has time to percolate, with the water proceeding down to the water line which is around the mean sea-level (see Fig. 1A). The downrush is much smaller than the uprush so that any sediment carried up by the latter is left stranded on the beach face. The berm will continue to widen so long as material is available offshore to be moved shorewards by the waves. As the profile assumes its equilibrium the bed slope has its influence on the sand grains so counteracting the landward transport of the swell.

When storm waves arrive they are more frequent, a crest breaking and swashing up the slope almost every second. The beach face becomes saturated, with the water table almost coincident with it (see Fig. 1B). The downrush now almost equals the uprush and the hydraulic jump associated with it at the mean water line is enlarged. At this point also the ground water returning to the sea creates a "quick-sand" condition which causes the beach face to slump. This quickly causes the beach to erode.

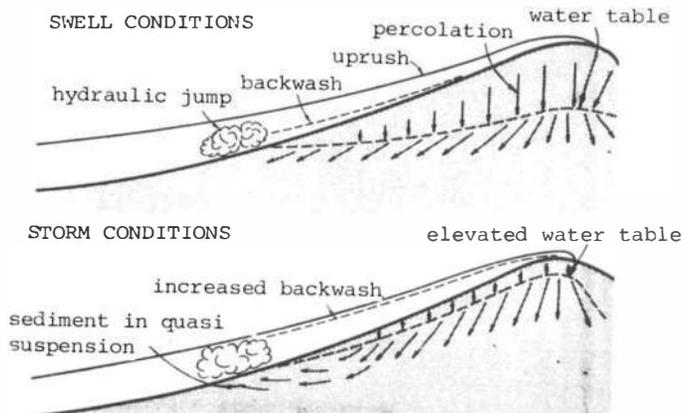


Fig. 1. Beach processes

The water returning to the sea is thus laden with sand and hence hugs the bed, aided by a strong shorewards current at the surface due to wind stress. As this virtual density current travels seawards it is reduced in velocity so that its sediment load is dropped, thus forming an offshore bar. This grows until the depth above it is sufficiently small to break the incoming storm waves (see Fig. 2). At this stage erosion of the beach stops. Minor erosion may still occur due to slight wave action between the bar and the inset waterline and the landward surface current being returned to the sea over the bar. Such a contra current to the waves also helps wave breaking. By this process the depression between the bar and beach may be filled to an almost horizontal submerged platform.

It becomes obvious that the first storm of the winter season has the most drastic effect on the beach. Any second storm is unlikely to cause greater erosion, except when it may occur with a higher water level of tidal or storm surge origin. In this case the bar must be built up further in order to break the incoming storm waves. Also a longer duration of a second storm could cause greater demand on the beach, as already noted.

Subsequent swell waves, which may arrive immediately after the storm or not until some weeks later, quickly remove the top of the bar and return it to the beach. If the swell is persistent it could take it only two or three weeks to return the complete bar as a berm. A second storm may erode a partially rebuilt beach to reform the bar to again afford protection.

This action by Nature, of constructing a protective structure to defend the coast, is beautiful to behold. It cannot be bettered by man since mammoth volumes of material are involved. Attempts to copy it by placing a rubble mound parallel to

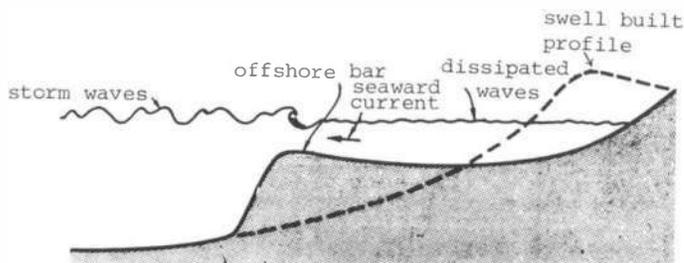


Fig. 2. Storm built profile

the shore are doomed to failure since the swell waves arriving obliquely to such a submerged structure will scour the bed seawards of it (Hom-ma and Horikawa, 1961).

If an erosion problem exists on a coast it is only because the persistent waves arrive obliquely to the general shoreline. Thus the swell arriving at an angle to the offshore bar suddenly impacts on this submerged mound. Its angle of breaking is likely to be greater than if it approached the same depth across a parabolic beach profile. Also the surf zone is very wide. Thus, at this initial transfer of material back to shore, the littoral current is excessive as well as the turbulence due to breaking. This results in a large pulse of drift travelling downcoast. The rate of transport decreases as the bar is depleted, reducing to practically zero as the swell profile is approached.

Japanese workers have concluded that 90% of the littoral drift can occur over 2 weeks and the remaining 10% over the rest of the year. Thus measurements of accretion measured upcoast of some coastal structure should not be accepted as an annual volume from which a rate of transport is assessed. Such accumulations should be monitored every day over 2 or 3 weeks after a storm to determine a realistic value. It also becomes obvious that the volume transmitted downcoast during any year will depend upon the number of storms experienced, if they are spaced sufficiently apart for the bar to be replaced each time on the beach. There are many implications of this pulsational littoral drift for engineers, and geologists making measurements, which cannot be discussed here. Suffice it to say that this mechanism is the most important among many for the observed large fluctuations in longshore transport of sediment.

PREVIOUS COASTAL DEFENSE SOLUTIONS

The basic need is to retain a beach line constant from year to year or decade to decade. If this were accomplished the coastal zone could be utilized to its full capacity, remembering always to leave sufficient sand in the beach berm to meet the demands of the infrequent severe storm waves to build a protective offshore bar. This requires that bar material returns to the beach location from whence it was removed. Whilst the shoreline will still oscillate due to the fluctuations in littoral drift some limiting degradation needs to be determined for the possibility of complete cessation of upcoast supply. Such conditions can occur today when, for example, a deep channel is dredged across the shelf to provide access to a harbour because accretion in it is generally dredged and the spoil dumped out at sea.

Prior defense measures have taken the form of groynes, seawalls and more recently beach renourishment. It is salutary to examine the success or otherwise of these so-called solutions in order to see whether research should have new directions. The costs involved in any maritime activity are generally prodigious so that even a modest percentage saving could effect reductions of many millions of dollars each year around the world.

Groynes. When man first looked at the shoreline he probably observed the great suspension of material in the surf zone where there was also a littoral current to transport it downcoast. He concluded that any impediment placed in this path of activity would retain sand in place and hence he constructed structures running normal to the beach, out to the limit of breaking waves. These were called groynes.

At this early stage the transport offshore was not recognized and even today many engineers and geologists give little credence to this mode of transport. But if erosion is occurring due to a dearth of upcoast supply it will take place offshore before its influence is felt at the shoreline. Such scouring will still take place beyond the tip of the groynes as recognized by Lehnfelt and Sevendsen (1958): "The groynes can, under favourable conditions, protect the bed of the sea from erosion as far as their extremities but not much further. Beyond the end of the groyne, erosion continues and it is evident that after a certain time this erosion will

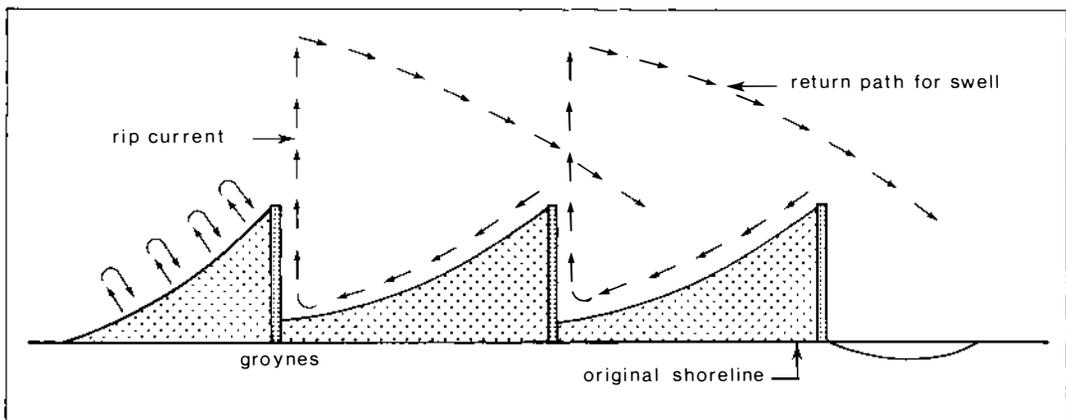


Fig. 3. Sand movement in groyne field

attack the groyne and later the land itself." This deepening and steepening offshore permits the waves to approach more obliquely and hence have a greater longshore component of mass-transport.

But even the material trapped between groynes is in jeopardy because the storm waves, which can arrive from a large fan of directions, will be more angled to the beachline than the general coast. The resulting longshore current strikes the groynes and is deflected seawards in the form of rip currents (see Fig. 3).

These carry large volumes of material offshore, much further than the offshore bar which would be the case for the original shoreline. Some of it will remain there to make up for the previous erosion but the remainder will move much further down-coast before arriving at the beach. In this way it can be concluded that a field of groynes can expedite the longshore transport it was meant to reduce.

The removal of sand between the groynes by each storm sequence requires its replacement by subsequent swell. During this filling process erosion occurs down-coast encouraging an extension of the groyne field. Balsillie and Berg (1972) concluded that groynes show a success rate of some 50% which cannot be considered good engineering.

Seawalls. In 1956 an eminent oceanographer remarked to the writer that seawalls were the answer to the coastal engineers' prayer since the reflected waves go out to sea never to be seen again. He, like many engineers unfortunately, forgets that whilst dispatched in this manner these waves are applying a second batch of energy to the seabed of equal intensity to that of the incident waves. This is not quite correct as they establish a short-crested system with very complex water particle orbits Silvester (1972).

Consider for a moment two wave trains of equal height and period propagating at right angles to each other. Where the crests intersect the wave height doubles and "island" crest form (see Fig. 4). These travel across the diagonal of the square wave pattern. Along such alignments the water particle orbits are in a vertical plane similar to that in a progressive wave. However, in this case velocities etc. must be computed for twice the height of the component trains. The wave length is the distance between successive island crests, which in this simplified case is 2 times the length of each component. The profile of the wave is also changed causing a large increase in mass-transport at this alignment. Hsu, Silvester and Tsuchiya (1980).

Island crests either side of the square pattern travel together, but have a finite distance between them, so giving the term "short-crested". This introduces the extra variable of crest length (L') which can be used to define orbital motions (see Fig. 4). Half way between the crest alignments, (occurring every half crest length) i.e. $x/L' = 1/4, 3/4, 5/4$ the orbits are rectilinear oscillations in a horizontal plane. Half way between these again i.e. $x/L' = 1/8, 3/8, 5/8$ the orbits are ellipses angled to the vertical with upward slopes towards the island crest alignments. Down through the water column these angles increase until at the bed the motions become circular in a horizontal plane. Looking down through these orbits the motion would appear of vortex form with constant rotational directions. Such vortices will extend down to a boundary and hence no matter what the water depth will influence the bed by applying a suction to it. The effect on sediment can readily be surmised. The presence of such rotational motion will generate secondary macro-turbulence which is carried throughout the whole area of the square wave pattern.

Such short-crested systems can be caused by diffraction behind island structures, differential refraction across the continental shelf and by oblique reflection at walls or even submerged objects (Silvester, 1974). The scouring capacity of such

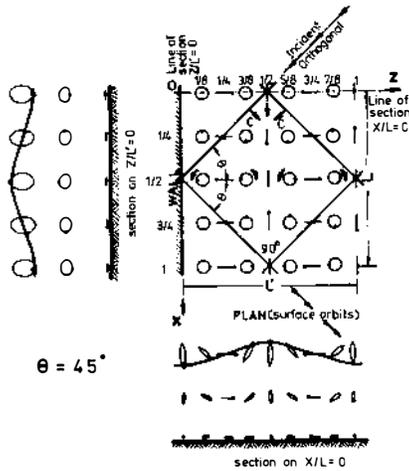


Fig. 4. Orbits within short-crested wave systems

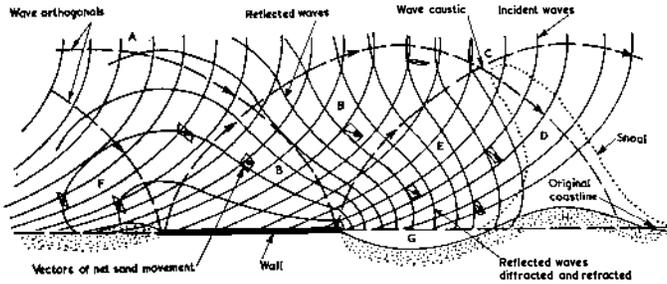


Fig. 5. Scour near seawall and downcoast

systems is apparent in storm waves where many trains are angled to each other and in the extensive scour in the vicinity of seawalls.

Consider now a reflecting wall installed on a straight coastline (see Fig. 5). The reflected waves refract in a similar fashion to the incident waves arriving and may pass through a caustic downcoast. There the concentration of energy causes much dissipation which involves incident waves as well. Within the ribbon of reflected waves sediment is transported parallel to the wall. But even landwards of this zone the diffraction and refraction of the reflected component maintains a short-crested system which promotes scour downcoast of the wall. In the region of the caustic the only energy available is that from the incident waves, reduced somewhat by the caustic previously alluded to. The excess supply from the denuded section cannot be carried without shoaling taking place and even resulting in a protuberance of the coast. The engineer sees erosion from the extremity of his

wall to such a protrusion and his immediate reaction is to extend the wall, which obviously exacerbates the problem.

This phenomenon is excluded when seawalls, revetments, or breakwaters are tested for stability in flumes since this implies that all waves are arriving normal to the structure. It requires 3 dimensional models to investigate sand movement in the vicinity of coastal structures. It is concluded that some structures have small coefficients of reflection because waves at the surface are broken by armour units of various designs. However these may only extend to half the depth, the lower portion consisting of relatively small rubble material. Waves applied to such slopes, especially those of longer period, treat these as smooth faces and are reflected readily. Coastal engineers have concentrated on the stability of armour units at the expense of stability of the bed in close proximity to the structure.

Renourishment. This is the latest panacea for coastal protection, promoted vigorously by organisations selling dredging services. It should be remembered at the outset that the same wave climate exists as before, which is oblique persistent waves in an erosive situation.

When sand is dumped on a beach, or offshore from it, it will rest at its angle of repose for this saturated state, which is much steeper than the natural profile (see Fig. 6). Nature will not countenance such a condition and quickly smooths this material out to greater depths in order to approach the original bed shape. It is acknowledged (Everts, DeWall and Czerniak, 1974) that 30 to 50% of the initial renourishment is lost in this process. This of course is accompanied by downcoast movement as the waves will be as oblique as before.

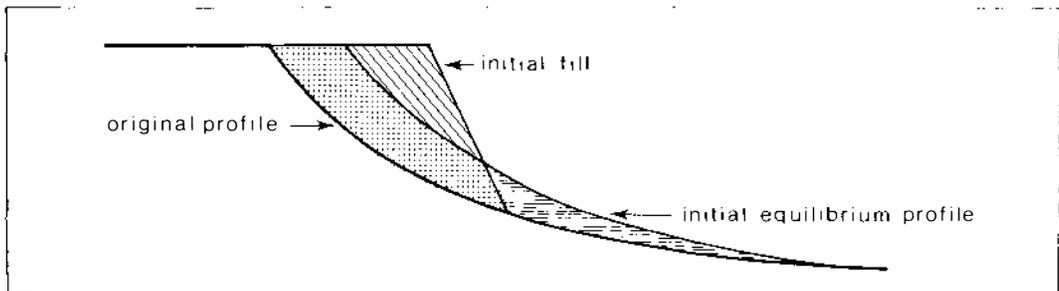


Fig. 6. Fill profile of renourished beach

Renourishment to the writer is symbolic of the pill used by the medical profession, to ease the pain without getting to the root of the problem. It is a palliative which gives less incentive to deal with the real issues. These engineering doctors recognize the transitory nature of the remedy and recommend an annual consumption of painkiller to the tune of 20% of the initial dose. The actual need, of course, will depend upon the wave climate, or more specifically the number of storms experienced each year. As time goes by these pills become more expensive because sediment in the locality gets scarce, necessitating longer hauls. The alternative of dredging from offshore is also promoted even though it may show some side effects.

HEADLAND DEFENSE OF COASTS

When working at the National Institute of Oceanography in England in 1956 the author observed that many coastlines exhibited smooth bay formations between headlands. Silvester (1960) then carried out some tests on a straight sedimentary coastline with 3 headlands spaced apart. He applied persistent waves from a 45° direction and let the shoreline erode whilst removing excess material downcoast. Bays formed between the headlands which increased their indentation to some limit when no further degradation took place. They had a specific shape with a downcoast straight segment and an upcoast curved zone, constituting what he termed a "half-heart" shape.

At about this time Yasso (1965) reported measurements of such bays and had concluded that the curved section was of logarithmic spiral form. Subsequent tests by Silvester (1970) derived the constant (β), for these spirals as the bay progressively eroded and hence the value at static equilibrium, it being the case when no upcoast sediment was available. The only input variable is the angle (β) of wave crests to the headland alignment which is the same as the downcoast straight beach to the same alignment when the bay is in static equilibrium (see Fig. 7).

Another variable found by Silvester and Ho (1972) that can be related to β is the indentation ratio (a/b) of greatest distance from the headland alignment (a) to the clear distance between headland (b). This is more readily measured than the logarithmic spiral constant. Both parameters are shown in Fig. 8, which are applicable to static equilibrium or when no sediment is being fed to the bay from either upcoast or from a river debouching into it. In the case of continued supply such crenulate or zeta shapes, as they are now termed, exist but the values of a/b

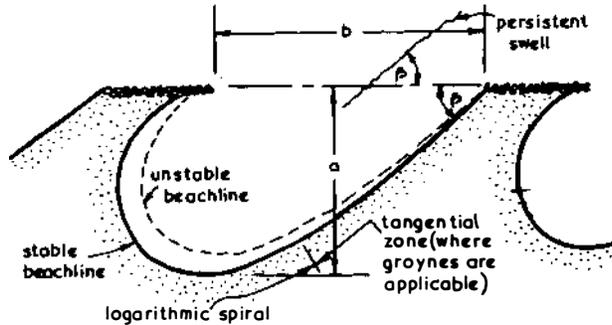


Fig. 7. Definition sketch

and fall either below or above the curves in Fig. 8 respectively. In the event of cessation of supply the coast will erode back to the shape where these points fall on the curves provided. Thus two tools are available for the determination of the static equilibrium shape. These are useful where littoral drift fluctuates incessantly, as it does, since the final limit of erosion is predictable.

Such bays in maps or hydrographic charts indicate the direction of nett sediment movement along the coast, which Silvester (1962) examined for the coastlines of

the world, together with other indicators and knowledge of swell roses in any region. This indicated similar movements over extensive margins of continents, which implies transport over geologic time with all its ramifications.

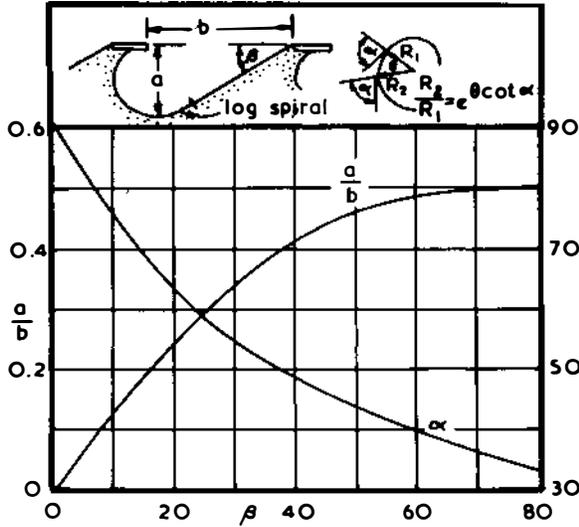


Fig. 8. Zeta shaped bay characteristics

Silvester, Tsuchiya and Shibano (1980) have shown that the same bay forms from headlands running virtually parallel to the coast as groynes running normal to it, but in the case of groynes the straight downcoast is the only segment available (see Fig. 9). In the event of storms material eroded around a bay is kept within its confines and is not discharged out to sea for transmission further downcoast. This infers that headlands are placed further seawards and further apart than groynes for optimum benefit.

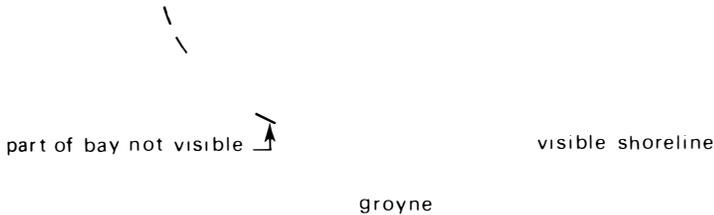


Fig. 9. Comparison of groynes versus headlands

It was found that a static equilibrium the waves oblique to the headland alignment were breaking simultaneously around the periphery of the bay, or were arriving normal to it at all locations. This means that no littoral drift could occur. Any offshore bar is thus returned straight back to its original position. The model study also proved that no littoral current was present and no sediment was being fed to the downcoast trap.

The method of installing headlands, their best orientation and shape and many other interesting points of design are available elsewhere (Silvester, 1982). Suffice it to say that the expense involved could be recouped from the accumulation of new land which can be sold or leased. Reclamation being carried out in Singapore will pay for the Rapid Transit System, giving a precedent for other countries. There is no question that land accreted on the coast is of great value, especially where erosion has been causing losses due to prior development on this margin.

CONCLUSIONS

1. For erosion to be a problem persistent waves must be arriving obliquely to a coast.
2. The action of Nature in constructing an offshore bar to protect the beach can not be bettered by man who should help in this process by providing beach berms for the purpose.
3. During the return of bar material to the beach by swell waves over two or three weeks a large pulse of littoral drift occurs which has many implications for coastal engineers.
4. Groynes are ineffective in an erosive situation as material within the surf zone and beyond it can still bypass the field and, in fact, be expedited down-coast.
5. Seawalls do not solve the problem of diminished supply of sediment from upcoast but cause erosion offshore from them and also in the near downcoast area.
6. Beach renourishment should be accompanied by complimentary structures, preferably headlands, to keep it in place.
7. The static equilibrium shape of the bays as noted in (6) above can be predicted which can determine the stable condition for zero supply of sediment to the area.

REFERENCES

- Balsillie, J.H. and D.W. Berg (1972). State of groin design and effectiveness. Proc. 13th Conf. Coastal Eng. 2, 1367-1383.
- Everts, C.H., A.E. DeWall and M.T. Czerniak (1974). Behaviour of beach fill at Atlantic City, New Jersey. Proc. 14th Conf. Coastal Eng. 2, 1370-1388.
- Hom-ma, M. and K. Horikawa (1961). A study on submerged breakwaters. Coastal Eng. in Japan 4, 85-102.
- Hsu, J.R.C., R. Silvester and Y. Tsuchiya (1980). Boundary layer velocities and mass transport in short-crested waves. Jr. Fluid Mechs. 99(2), 321-342.
- Lehnfelt, A. and S.V. Svendsen (1958). Thyboroen channel - difficult coast protection problem in Denmark. Ingenioeren. 2, 66-74.
- Silvester, R. (1960). Stabilization of sedimentary coastlines. Nature (London) 188 (4749), 467-469.
- Silvester, R. (1962). Sediment movement around the coastlines of the world. Proc. Conf. Instn. Civil Engrs. (London), 289-315.
- Silvester, R. (1970). Development of crenulate shaped bays to equilibrium. Proc. ASCE, J. Waterways and Harbors Divn. 96(WW2), 275-287.

- Silvester, R. (1972). Wave reflection at seawalls and breakwaters. Proc. Instn. Civil Engrs. 51, 123-131.
- Silvester, R. and S.K. Ho (1972). Use of crenulate shaped bays to stabilize coasts. Proc. 13th Conf. Coastal Eng. 2, 1347-1365.
- Silvester, R. (1974). Coastal Engineering, Vol. I. Elsevier Publ. Co., Amsterdam.
- Silvester, R., Y. Tsuchiya and Y. Shibano (1980). Zeta bays, pocket beaches and headland control. Proc. 17th Conf. Coastal Eng. (IN PRESS).
- Silvester, R. (1982). Planning for artificial islands. Symp. Eng. in Marine Environment (Brugge), 2, 115-122.
- Yasso, W.E. (1965). Plan geometry of headland-bay beaches. J. Geology. 73, 702-714.



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Ministry of Earth Sciences

National Centre for Coastal Research

National Shoreline Assessment System (N-SAS)

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National Assessment of Shoreline Changes
along Indian Coast

Volume 1 - East Coast

March 2022

3.4 Mapping of Shoreline Change

The results obtained from the analysis of shoreline changes are in the form of numbers i.e., \pm m/yr, where +ve is for accretion, and -ve is for erosion.

Table 3: Shoreline classification schemes used in the analysis

Classification	Rate (m/year)	Colour Schemes
High Erosion	>-5.0	
Moderate Erosion	-5.0 to -3	
Low Erosion	-3.0 to -0.5	
Stable Coast	-0.5 to 0.5	
Low Accretion	0.5 to 3.0	
Moderate Accretion	3.0 to 5.0	
High Accretion	> 5.0	

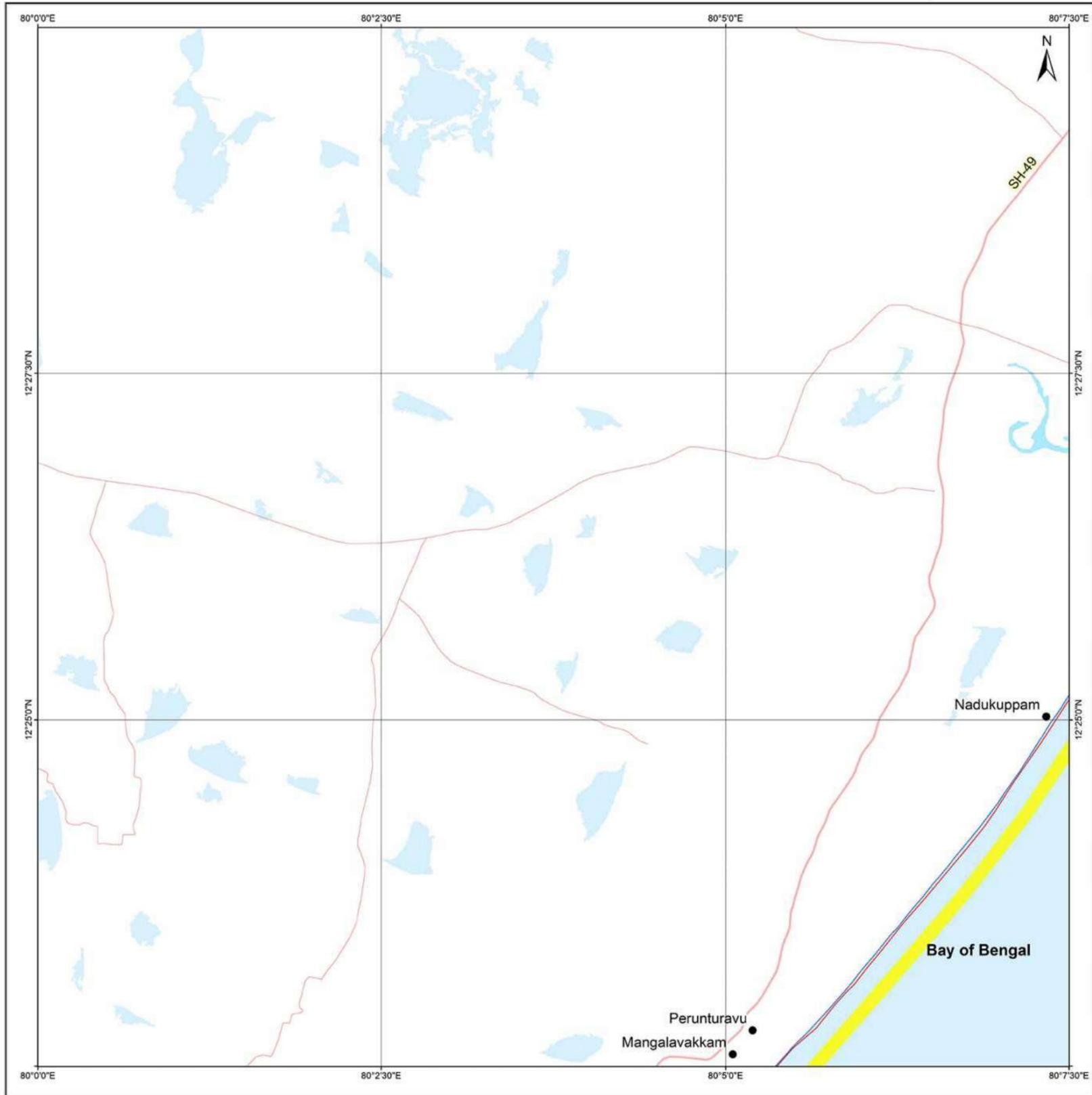
These quantitative results are plotted in GIS environment using standard mapping format in 1:25000 scale. However, mapping requires classifications of accretion/erosion rates in sub-classes considering the magnitude of changes. The classification of shoreline changes is further a subjective aspect. We have classified the shoreline change rates into seven classes (Table 3) (Kankara et al., 2014; Kankara et al., 2015 and Selvan et al., 2020). The marginal change of ± 0.5 m/yr is considered as no change or stable coast, in view of uncertainties in the data.

The shoreline towards seaward are referred as “accretion” and shoreline towards landward are referred as “erosion”. These classification is categorised based on the rate of change results considering the shift in shoreline position. This phenomenal changes defines the shoreline classification from high to low based on rate (m/yr). The rate of change whichever less than 1 m is considered as stable coast, other than rocky coast, cliff are define the same stable condition, The intermitted distance between 1 to 3m difference are considered as low accretion / erosion which means which means the coast is mere effect on coastal erosion. Subsequently, the area between 3 to 5m is considered as moderate accretion / erosion which means the coastal areas need more attention to take precautions measures. All along the rate of change in results greater than 5m is considered as coastal hotspot regions required immediate action plan for coastal protection. This regions needs a periodical monitoring to ascertain the coastal landforms. The above classification schemes are formalised based on previous studies (Kankara et al., 2014). The seasonal field observations were carried out for ground truth verifications and validations. Overall, the significant changes all along the entire Indian coast is mapped with 1:25,000 scale which are depicted in the following sections.

1990 - 2018
KANCHEEPURAM

SHORELINE CHANGE MAP TAMIL NADU

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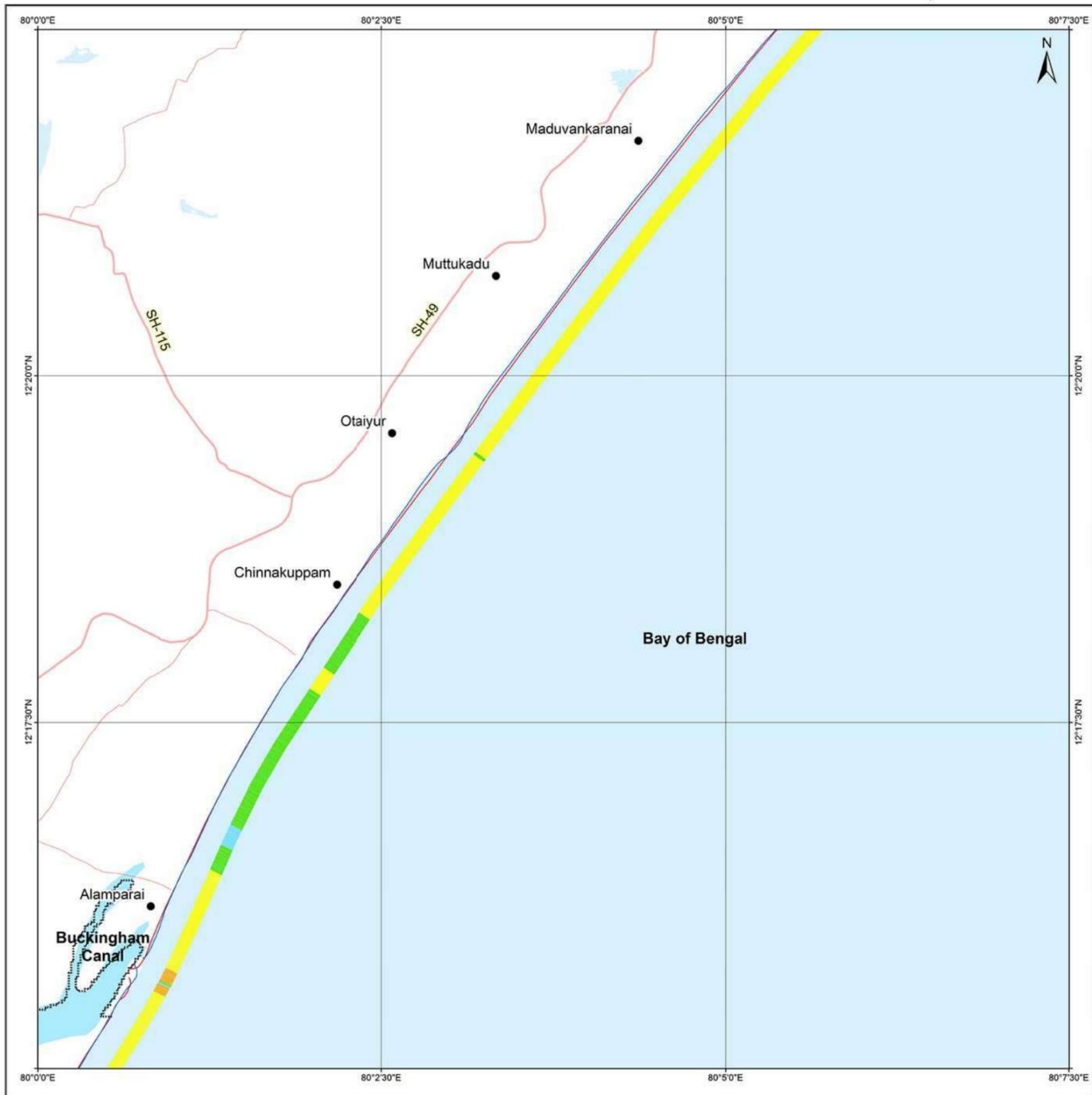
<p>Shoreline Change Trend for Period 1990 - 2018</p> <ul style="list-style-type: none"> High Erosion Moderate Erosion Low Erosion Stable Coast Low Accretion Moderate Accretion High Accretion <p>Shoreline date</p> <ul style="list-style-type: none"> 07/25/1990 04/04/2018 	<p>Index to sheets</p> <table border="1"> <tr> <td>SP P/14/SE</td> <td>66 D/2/SW</td> <td>66 D/2/SE</td> </tr> <tr> <td>SP P/15/NE</td> <td>66 D/3/NW</td> <td>66 D/3/NE</td> </tr> <tr> <td>SP P/15/SE</td> <td>66 D/3/SW</td> <td>66 D/3/SE</td> </tr> </table> <p>Incidence on 1:50,000 Sheets</p> <table border="1"> <tr> <td>SP P/14</td> <td>66 D/2</td> <td>66 D/3</td> </tr> <tr> <td>SP P/15</td> <td>66 D/3</td> <td>66 D/7</td> </tr> <tr> <td>SP P/16</td> <td>66 D/4</td> <td>66 D/8</td> </tr> </table>	SP P/14/SE	66 D/2/SW	66 D/2/SE	SP P/15/NE	66 D/3/NW	66 D/3/NE	SP P/15/SE	66 D/3/SW	66 D/3/SE	SP P/14	66 D/2	66 D/3	SP P/15	66 D/3	66 D/7	SP P/16	66 D/4	66 D/8	<p>Scale</p> <p>1000 m 500 0 1 2 km</p> <p>1:25,000</p> <p>UTM Coordinates Zone 44 Datum : The World Geodetic System 1984 (WGS84) Spheroid : The World Geodetic System 1984 (WGS84)</p> <p>Data Sources: Satellite Data</p> <table border="1"> <thead> <tr> <th>Sensors</th> <th>Date of acquisition</th> </tr> </thead> <tbody> <tr> <td>LISS-IV</td> <td>04/04/2018</td> </tr> <tr> <td>LISS-IV</td> <td>02/06/2017</td> </tr> <tr> <td>LISS-IV</td> <td>04/14/2016</td> </tr> <tr> <td>LISS-IV</td> <td>07/01/2015</td> </tr> <tr> <td>LISS-IV</td> <td>06/12/2014</td> </tr> <tr> <td>LISS-IV</td> <td>05/24/2013</td> </tr> <tr> <td>LISS-IV</td> <td>03/18/2012</td> </tr> <tr> <td>LISS-III</td> <td>05/14/2008 & 10/29/2008</td> </tr> <tr> <td>PAN (Cartosat-1)</td> <td>07/01/2006</td> </tr> <tr> <td>ETM+</td> <td>10/28/2000</td> </tr> <tr> <td>TM</td> <td>07/25/1990</td> </tr> </tbody> </table>	Sensors	Date of acquisition	LISS-IV	04/04/2018	LISS-IV	02/06/2017	LISS-IV	04/14/2016	LISS-IV	07/01/2015	LISS-IV	06/12/2014	LISS-IV	05/24/2013	LISS-IV	03/18/2012	LISS-III	05/14/2008 & 10/29/2008	PAN (Cartosat-1)	07/01/2006	ETM+	10/28/2000	TM	07/25/1990		<ul style="list-style-type: none"> Settlements Port Harbour Groynes Jetty Breakwater Seawall/Ripraps Rocky Coast Administrative Boundary National Highways State Highways Other Roads Railways Lakes Rivers
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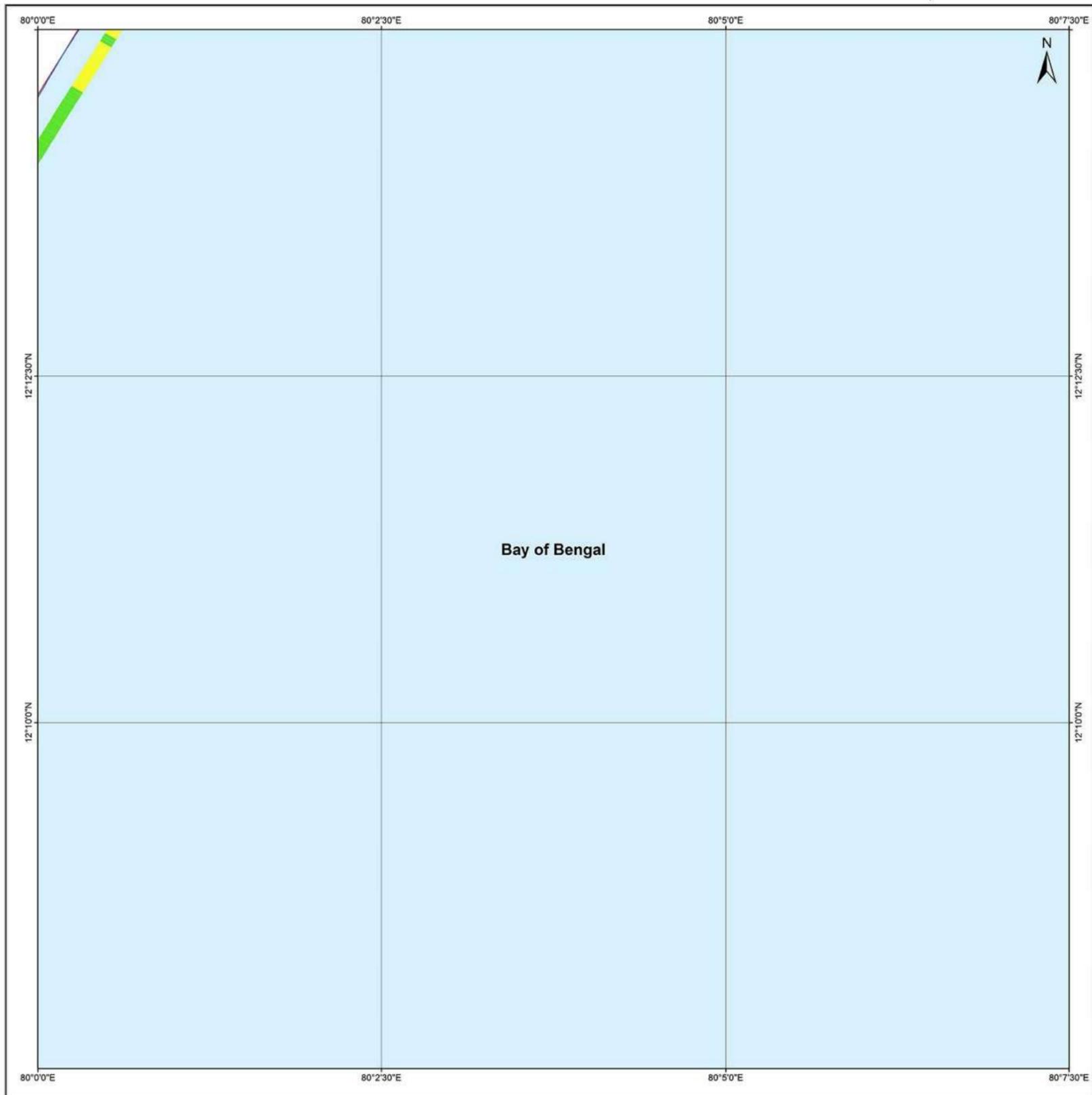
<p>Shoreline Change Trend for Period 1990 - 2018</p> <ul style="list-style-type: none"> High Erosion Moderate Erosion Low Erosion Stable Coast Low Accretion Moderate Accretion High Accretion <p>Shoreline date</p> <ul style="list-style-type: none"> 07/25/1990 04/04/2018 	<p>Index to sheets</p> <table border="1"> <tr> <td>57 P / 15 / NE</td> <td>66 D / 3 / NW</td> <td>66 D / 3 / NE</td> </tr> <tr> <td>57 P / 15 / SE</td> <td>66 D / 3 / SW</td> <td>66 D / 3 / SE</td> </tr> <tr> <td>57 P / 16 / NE</td> <td>66 D / 4 / NW</td> <td>66 D / 4 / NE</td> </tr> </table> <p>Incidence on 1:50,000 Sheets</p> <table border="1"> <tr> <td>57 P / 14</td> <td>66 D / 2</td> <td>66 D / 5</td> </tr> <tr> <td>57 P / 15</td> <td>66 D / 3</td> <td>66 D / 7</td> </tr> <tr> <td>57 P / 16</td> <td>66 D / 4</td> <td>66 D / 8</td> </tr> </table>	57 P / 15 / NE	66 D / 3 / NW	66 D / 3 / NE	57 P / 15 / SE	66 D / 3 / SW	66 D / 3 / SE	57 P / 16 / NE	66 D / 4 / NW	66 D / 4 / NE	57 P / 14	66 D / 2	66 D / 5	57 P / 15	66 D / 3	66 D / 7	57 P / 16	66 D / 4	66 D / 8	<p>Scale</p> <p>1000 m 500 0 1 2 km</p> <p>1:25,000</p> <p>UTM Coordinates Zone 44 Datum : The World Geodetic System 1984 (WGS84) Spheroid : The World Geodetic System 1984 (WGS84)</p> <p>Data Sources: Satellite Data</p> <table border="1"> <thead> <tr> <th>Sensors</th> <th>Date of acquisition</th> </tr> </thead> <tbody> <tr> <td>LISS-IV</td> <td>04/04/2018</td> </tr> <tr> <td>LISS-IV</td> <td>02/06/2017</td> </tr> <tr> <td>LISS-IV</td> <td>04/14/2016</td> </tr> <tr> <td>LISS-IV</td> <td>07/01/2015</td> </tr> <tr> <td>LISS-IV</td> <td>06/12/2014</td> </tr> <tr> <td>LISS-IV</td> <td>05/24/2013</td> </tr> <tr> <td>LISS-IV</td> <td>03/18/2012</td> </tr> <tr> <td>LISS-III</td> <td>10/29/2008</td> </tr> <tr> <td>PAN (Cartosat-1)</td> <td>07/01/2006</td> </tr> <tr> <td>ETM+</td> <td>10/28/2000</td> </tr> <tr> <td>TM</td> <td>07/25/1990</td> </tr> </tbody> </table>	Sensors	Date of acquisition	LISS-IV	04/04/2018	LISS-IV	02/06/2017	LISS-IV	04/14/2016	LISS-IV	07/01/2015	LISS-IV	06/12/2014	LISS-IV	05/24/2013	LISS-IV	03/18/2012	LISS-III	10/29/2008	PAN (Cartosat-1)	07/01/2006	ETM+	10/28/2000	TM	07/25/1990		<ul style="list-style-type: none"> Settlements Port Harbour Groynes Jetty Breakwater Seawall/Ripraps Rocky Coast Administrative Boundary National Highways State Highways Other Roads Railways Lakes Rivers
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1990 - 2018
KANCHEEPURAM

SHORELINE CHANGE MAP TAMIL NADU

Restricted Use
66 D / 4 / NW
Map No. : NCCR/SCM/350



Shoreline Change Trend for Period 1990 - 2018

- █ High Erosion
- █ Moderate Erosion
- █ Low Erosion
- █ Stable Coast
- █ Low Accretion
- █ Moderate Accretion
- █ High Accretion

Shoreline date

- █ 07/25/1990
- █ 04/04/2018

Index to sheets

57 P / 15 / SE	66 D / 3 / SW	66 D / 3 / SE
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Incidence on 1:50,000 Sheets

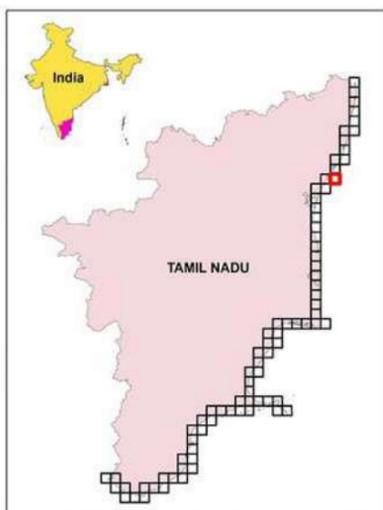
57 P / 15	66 D / 3	66 D / 7
57 P / 16	66 D / 4	66 D / 8
58 M / 13	67 A / 1	67 A / 5

Scale
1000 m 500 0 1 2 km
1:25,000

UTM Coordinates Zone 44
Datum : The World Geodetic System 1984 (WGS84)
Spheroid : The World Geodetic System 1984 (WGS84)

Data Sources: Satellite Data

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Prepared by
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National Centre for Coastal Research (NCCR)
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