Paradeep-Gahirmatha-Dhamra Ecosystem Report Card

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Ecosystems worldwide are showing the stress of growing human populations, which is linked to increased development and land-use change, and is further exacerbated by climate change (Williams et al. 2009). Aquatic systems, be they freshwater (Dudgeon et al. 2006), coastal (Pantus & Dennison 2005) or ocean (Halpern et al. 2012), are of particular concern as they provide us with our drinking water, much of our food and employment, and they are where, or near where, most of us live. Therefore it is of great importance, both to humans and to "nature" more generally, that our aquatic ecosystems are healthy, which refers to the condition and functionality of an aquatic ecosystem. However, judging whether an environment is healthy is not particularly straightforward (Samhouri et al. 2012). This is why we need to monitor aquatic systems; to get an idea of the current conditions, and to ensure that we observe changes in condition over time (Olsen et al. 1999). Given that we now actively manage our interactions with these systems, information derived from monitoring will inform us what we need to do, whether what we have already done is actually working, and areas that need additional research (Schnoor 2003).

Effective monitoring is required to give a sense of the health of an ecosystem. Effective, modern methods to protect and improve ecosystems rely on an adaptive management framework (Smyth et al. 2007). This is a flexible and responsive way of ensuring that environmental management is actually achieving its goals, but it relies completely on the communication of relevant monitoring information to those doing the managing (Bunn et al. 2010). High-quality monitoring data are useful from a management perspective if they are communicated and acted upon.

The day-to-day monitoring and management of coastal ecosystems is not only the responsibility of dedicated specialists, but also obviously important and need detailed and lucid communication (Schiller et al. 2001) among the stakeholders. However costal ecosystem health is of much broader interest, and impinges upon society, the economy, and politics (Smyth et al. 2007). There are also multiple stakeholders, including the general public, special interest groups, specific industries, indigenous groups, and various levels of government (Harwell et al. 1999), need to be actively participate for its restoration.

There are a number of ways to deliver information describing the results of an environmental monitoring program. An increasingly popular way to summarize, package and communicate the results of monitoring programs and associated ecosystem health is via "Report Cards" (Bunn et al. 2010). This approach has been an effort to obtain a holistic diagnosis of ecosystem health, which would help in getting firsthand information on Coastal stretch (estuary and sea) and to aware different stake holders including decision-makers.

Significance

Odisha, located in the northeastern coast of India, is a maritime state with immense potential in natural resources. It is located between $17^0$49′ N and $22^0$34′ N latitudes and $81^0$27′ E and $87^0$29′ E longitudes. Odisha State covers an area of 156,000 km^2 covering 30 districts including six coastal districts, viz., Bhadrak, Kendrapada, Jagatsinghpur, Puri, and Ganjam, spanning a coastline of 480 km. The total population of these six coastal districts is 11.26 million and is distributed in an area of 21,887 km^2 with a population density 559 persons/ km^2 (2011 census). The assigned area enjoys international importance and is one of the tourist circuits of World heritage attracting tourists and pilgrims far and wide. It is gifted with

(1) Asia's largest brackish water lagoon, the Chilika; with largest captive Irrawadi Dolphin and one of the largest winter bird migration/ congregation sites of the world.
(2) Extensive mangrove forest and wetland, the Bhitarkanika wildlife sanctuary having about 183 sq km of mangrove vegetation (in Kendrapada district) and second largest number of mangrove species in the world and habitat for all 4 types of estuarine species of crocodiles

(3) The world's largest known mass nesting beaches of Olive Ridley sea turtles, the Gahirmatha and the Rushikulya.
(4) Paradeep and Dhamra, which are located along the eastern coast, are two fast growing industrial towns with major growing Ports and also having wide diverse natural resources in their surrounding coastal stretches.

The coastal stretch between Paradeep and Dhamra has been gaining importance after the establishment of Paradeep and Dhamra ports. Besides, many big industrial units like PPL, IFFCO, IOCL and Essar etc. have been established and at present, particularly, after commissioning of oil refinery at Paradeep, these areas are going to witness rapid infrastructure development. It will augment configuration of Special Economic Zones (SEZ) and establishment of mega projects leading to industrialization and urbanization. The development of this coastal stretch and utilization of its resources is required to be balanced mutually for developing competitive enterprises in existing and up-coming industries, ports, fisheries, tourism, offshore fishing, aquaculture, waste disposal, etc. Keeping an eye on climate change, identification of vulnerable areas and effective risk mapping and coastal health assessment is considered to be the need of the hour and to be addressed in a more scientific and systematic manner focusing its sustainability.

What is Ecosystem Report card?

Ecosystem health is determined by the response of the environment to natural and human inputs; may be defined as the degree to which the actual state of an ecosystem diverges from an ideal state as described in management objectives. A healthy estuarine and marine ecosystem is said to have the desired characteristics: key processes operating to maintain stable and sustainable ecosystems, zones of human impacts that do not expand or deteriorate and aquatic ecosystems (critical habitats) which remain intact. These characteristics are complex and really difficult to measure the attributes comprehensibly. While compiling this report card, few key water quality as well as biological indicators, which were determined during the period monitoring and analysis were considered and compared to acceptable levels and of national and international reference conditions.

How the report card was prepared?

The protocol for the environmental monitoring, sampling and analysis of Paradeep - Dhamra coastal stretch of Odisha State Pollution Control Board, ICZMP, provides a standardized approach to evaluate estuary-sea ecosystem conditions/health by monitoring, analysis and reporting based on best practice. Environmental samples were collected, analyzed and subjected for interpretation for outcomes. Water Quality Standards were selected to evaluate the Water Quality Index (WQI) for each zone. The estuarine-sea ecosystem of Paradeep has been considered into four (04) zones viz., (1) Estuary (Atharabanki creek and River Mahanadi) (2) Mixing zone (confluence of River Mahanadi and sea) (3) Mixing zone Down Stream and (4) Mixing zone up stream. The estuarine-sea ecosystem of Gahirmatha has been considered into four (04) zones viz., (1) Bay water (Maipura creek and Gobari river impact) (2) Mixing zone 1 (confluence of River Hansua and sea) (3) Mixing zone 2 (River Hansua and Chinchiri) and (4) Sea up stream towards Dhamra. Whereas, the estuarine-sea ecosystem of Dhamra has been considered into four (04) zones viz., (1) Bay water (Maipura river impact) (2) Mixing zone 1 (confluence of maipura) (3) Mixing zone 2 (River Dhamra) and (4) Sea up stream towards Dhamra port.

Why Monitored?

The report card was developed as an integral part of the mandate of the World Bank funded ICZM Project, adopted by Odisha State Pollution Control Board, in order to enhance the understanding and

management of coastal stretch of 80 KM from Paradeep to Dhamra in Bay of Bengal. As the estuarine-sea ecosystem is quite vulnerable due to various activities; it is important to determine the quality of water in terms of health of the designated ecosystem, so that natural-resource-managers may oversee the condition of this ecosystem and to target investment to improve ecosystem health. This reporting would also provide prominence to determine appropriate management actions, monitoring the effectiveness of management and contributing to the ongoing management of sea, estuaries and their catchments. This report card of estuarine-sea ecosystem of the entire stretch, for the year 2016, is a part to the time series data collection and in continuation to health/report card published in 2015. This is prepared to understand and to improve the quality of health/conditions by addressing different issues arising out of this assessment.

Measures of Report card

pH, temperature, TSS & Turbidity: *Indicate water column characteristics and put both direct & indirect impact on nutrient cycle and indirect impact on primary productivity & influence in controlling the food chain and food web.*

Dissolved Oxygen & BOD: *Indicate the impact on biological status or health of aquatic environment (Hypoxia/anoxia)*

Nutrients (NO_2, NO_3, PO_4, silicate): *Signify the status of presence of nutrient and its enrichment in the ecosystem & suggest the extent of control on biological growth and health of the marine eco system.*

Pollutants (TOC, Fe, Mn, Cd, Pb, Hg): *Indicate potential biological response to marine matrix contamination (Toxicity)*

Chlorophyll, TC/FC: *Indicate the health status of the marine ecosystem for primary production and carbon cycle of the ecosystem*

Desired Conditions & Guide for Report card

Desired conditions (Threshold) are based on available Guidelines, current scientific knowledge, and/or data and trends, taking into account the influence of a variable climate from year to year. The table below outlines the desired conditions developed or identified for each indicator and the source of this information.

Category	Indicator	Desired Condition	Source of Data
Water Quality	Temperature	20^0C-30^0C	SPCB, ICZMP
	pH	6.5-8.5	CPCB
	Dissolved Oxygen	≥3 mg/l	CPCB
	BOD	≤ 3 mg/l	CPCB
	TSS	≤ 20 mg/l	ANZECC(2000)
	Turbidity	8 NTU	ANZECC(2000)
	TOC	≥ 0.3 mg/l	ANZECC(1992)
	Nitrate	≤ 1 mg/l	ANZECC(2000)
	Phosphate	≤ 0.1 mg/l	ANZECC(2000)
	Silicate	0.3-1.0 mg/l	ANZECC(2000)
	Fecal Coliform	≤ 100 nos./100 ml	CPCB
	Chlorophyll-a	≤ 3.4 µg/l	ANZECC(2000)
	Mercury	≤ 1 µg/l	CPCB
	Manganese	≤ 500 µg/l	CPCB
	Iron	≤ 500 µg/l	CPCB
	Lead	≤ 1 µg/l	CPCB
	Cadmium	≤ 10 µg/l	CPCB

Calculating Report card grade for Estuarine-Sea Conditions of entire stretch of Paradeep to Dhamra

The report card for estuarine-sea ecosystem is developed by comparing with standards for different indicators (Temperature, pH, dissolved oxygen, BOD, TSS, Turbidity, TOC, Nitrate, Phosphate, Silicate, Chlorophyll-a, Fecal coliform, Fe, Mn, Hg, Pb and Cd) and derived thresholds scientifically. These indicators are combined into an Overall Health Index, which is presented as percent score.

How is it measured?

The overall water quality index is calculated by comparing the threshold of water quality standards to the average of the water quality indicators for the period (Temperature, pH, dissolved oxygen, BOD, TSS, Turbidity, TOC, Nitrate, Phosphate, Silica, Chlorophyll-a, Fecal coliform, Fe, Mn, Hg, Pb and Cd) specified for. Alternately the index is the computed average of the water quality indicators.

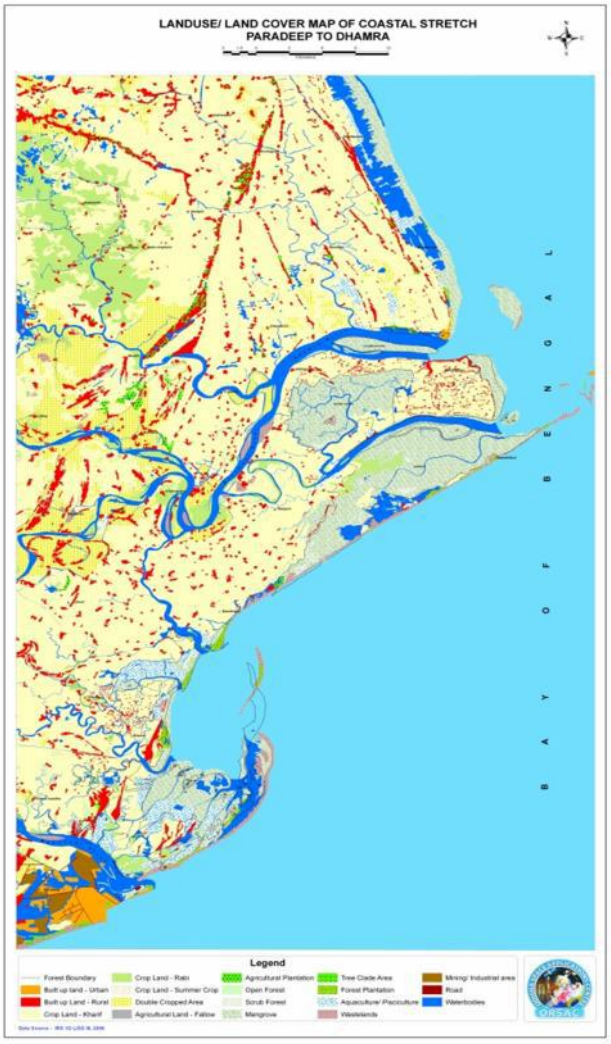
A 80-100% All water quality indicators meet the desired levels of Standard. The water quality in those locations tends to be very good, most often leading to very good habitat condition for Marine lives

B 60-80% Most water quality indicators meet the desired levels of Standard. The water quality in those locations tends to be good, most often leading to good habitat condition for Marine lives

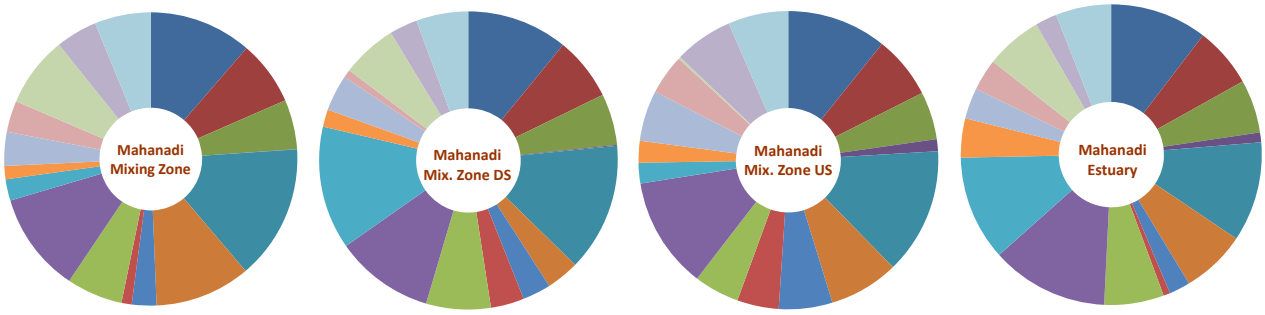
C 40-60% Blend of good and poor levels of water quality indicators. Quality of water in these locations tends to be fair, leading to fair habitat conditions for Marine lives

D 0-20% Very few or no water quality indicators meet desired levels. Quality of water in these locations tends to be very poor, most often leading to very poor habitat conditions for Marine lives

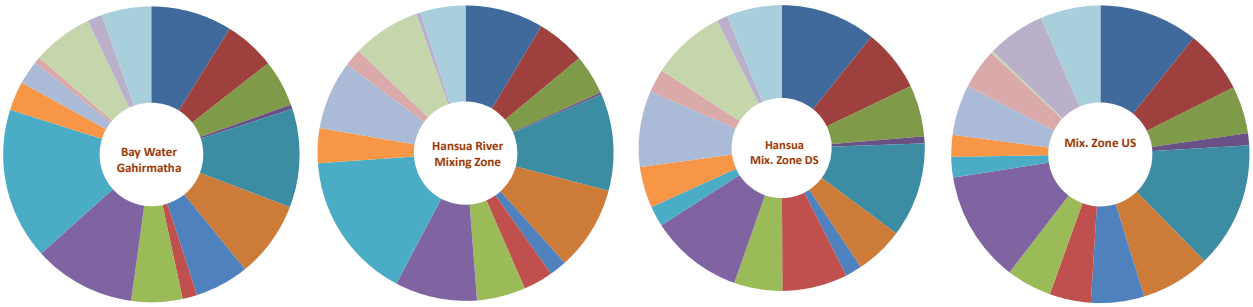
F 20-40% Few water quality indicators meet desired levels. Quality of water in these locations tends to be poor often leading to poor habitat conditions for Marine lives



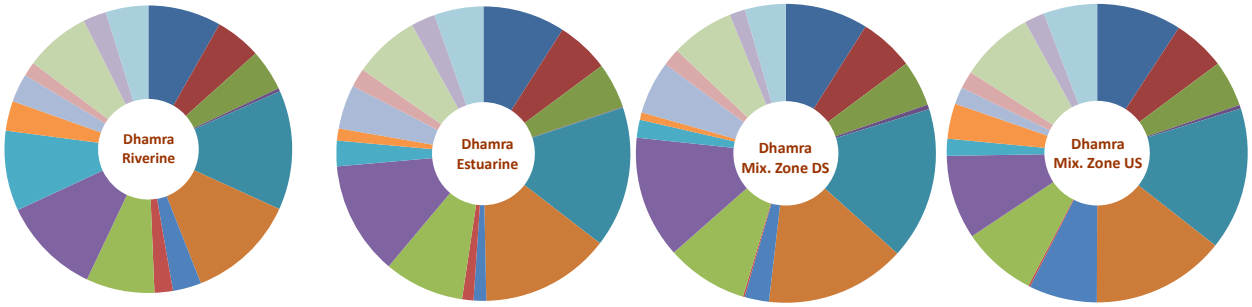
Contribution of different parameters in the Estuarine-Sea Conditions at Paradeep



Contribution of different parameters in the Estuarine-Sea Conditions at Gahirmatha

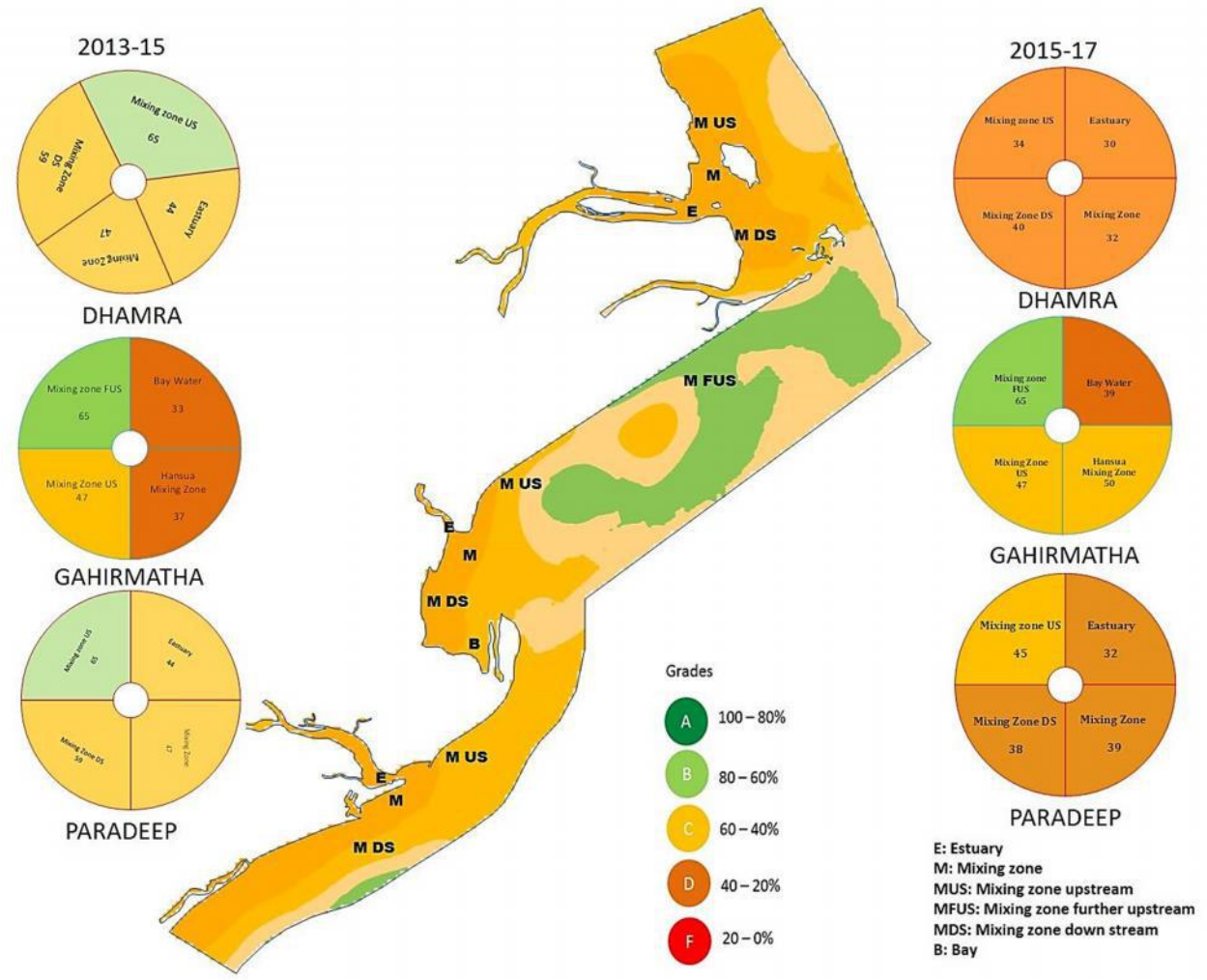


Contribution of different parameters in the Estuarine-Sea Conditions at Dhamra



Temp pH DO BOD TSS Turbidity
TOC Nitrite-N PO4-2 Silicate Fc Chl-a
Hg Mn Fe Pb Cd

OVERALL WATER QUALITY OF THE ESTUARINE-SEA CONDITIONS OF PARADEEP-DHAMRA COASTAL STRETCH: COMPARISON OF 2013-15 & 2015-2017



Estuarine-Sea Ecosystem conditions:

Paradeep

During the monitoring of Paradeep - Dhamra (80 kms) coastal stretch since 2013; it has been observed deviations/divergence with regard to water quality in certain areas adversely as well as favorably. The influential changes those being undergone during course of time adversely has been considered here as ***hot spots*** or ***important areas*** for concern.

The coastal stretch of Paradeep in 2013-15 was broadly found in 'C' grade as per water quality index (WQI); whereas it was found 'D' grade in 2015-17, indicating a deteriorating trend. The influence of riverine impact is more in this stretch. The result also corroborated the same as the riverine and estuarine stretch found more or less in same scale of D-grade; which might be due to their influences respectively

or vice versa. The lower value in the upstream (U/S) of mixing zone (45%) in 2015-17 in comparison to the WQI value in 2013-15 (65%), is strongly indicating additional impacts; which might be due to port activities situated in close vicinity. Storm water contributes a high load of sediment, nutrients and heavy metals to the Paradeep coastal stretch. The dredging of the Mahanadi river mouth, discharges from agricultural runoff & other discharges from catchment area entering with riverine systems, might have been those factors for deteriorating the qualities (Grade-D) in the estuary as well as in the mixing zone heavily; which further put impacts on the upstream deteriorating the water quality.

The changes observed in the locations at MS1, M6, M7, M8, M9 and M10 (Refer sampling points in Map) particularly near Muhana (confluence) and U/S of Muhana (confluence) towards Gahirmatha. The water qualities found deteriorated in those sampling locations are being considered as hotspot/important points in Mahanadi Transects (Refer Map), which is required further study for ratification of the problems.

Gahirmatha

The overall score of Gahirmatha coastal stretch broadly falls into three distinct visible groups (B, C & D) due to pressure from mainly riverine influx. The improvement of water quality scored over 2015, in 2016 has been observed. The score of 39 % for Bay, 50% for Hansua river estuarine zone and 47% in the in mixing zone U/s in the grading scale indicated the impacts of load in the estuary which in turn might have been diluted at confluence. The impact of load in downstream of mixing zone further reduced in spite of the influence of Chinchiri though it still falls in grade-C quality. However, upstream towards Dhamra beyond the mixing zone observed having better water quality with score of 65%, which falls under grade-B. Storm water contributes a high load of sediment, nutrients and heavy metals to the Gahirmatha coastal stretch. However it has been observed that quality of mixing zone of Hansua river improved from 'D' (37%) grade in 2015 to 'C' (50%) grade in 2016, indicating less impact of riverine discharges, from boats in fishing jetty, agricultural runoff & other discharges from catchment, thus showing an improving trend. This result may also be due to stringent action taken by the concern authority towards effort taken during 2016, to making this stretch incorporating into the world heritage list.

As the Gahirmatha Coastal Stretch is encircled the sensitive Bhitarkanika sanctuary; the entire stretch is considered to be a sensitive zone. As such the water quality is comparatively good in comparison to the water quality at Paradeep & Dhamra stretch under study. The water quality in this stretch mostly found in the 'B' & 'C'-grade in the entire monitoring period from 2013-17.

Dhamra

Similarly the water quality of Dhamra coastal stretch broadly found in 'D' grade during 2015-17. The quality deteriorated from 2013-15 status (grade 'C'). The influence of riverine impact is also more in this stretch. It is ascertained that the impact of Dhamra Port has influenced more rather than riverine impact. The result also corroborated the same. The impacts of port activities, contribution of storm water with high load of sediment, nutrients and heavy metals to the coastal stretch have been the major factors in the change observed. *The sampling points D2, D3 and D4 in Dhamra transect (Refer sampling points in Map), located near the Dhamara Port and U/S of port towards north, found deteriorated in 2015-17 from its status of 2013-15. These locations are considered important (hotspot) areas in Dhamra Transects (Refer Map); which are needed for further study.*

Key management response strategies to be adopted including as follows:

1. **Establishing hierarchical and multi scalar inventory** of hydrological, ecological, socioeconomic and institutional features and ecosystem services to support management planning and decision making including different Stakeholders (*Water Resource, Wildlife, Fisheries, IMD, Coast Guard, etc*.) to understand the complexities of the ecosystem.
2. **Detailed studies** with collaboration of different institute to calculate other aspects like silt movement and nutrient dynamicity of the estuary-sea ecosystem to promote sustainable management practices.
3. **Help to promote sustainable livelihood** by maintaining nutritional security to ensuring health of the coastal ecosystem and promoting institutional integration with other institutes such as Universities, IITs and other working groups/stakeholders in this field for sharing of knowledge and formulating innovative strategies to restore.

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Few photographs of field monitoring of Paradeep – Bhitarkanika - Dhamra coastal stretch & Laboratory Analysis:

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