DEENDAYAL PORT AUTHORITY
(Erstwhile Deendayal Port Trust)

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

Administrative Office Building
Post Box NO. 50
GANDHIDHAM (Kutch).
Gujarat: 370 201.
Fax: (02836) 220050
Ph.: (02836) 220038.

www.deendayalport.gov.in

EG/WK/4751/Part (Stage II)/ 292 Date: 03 /~~04~~ 05/2023

To,
The Director (Environment) &
Member Secretary, Gujarat Coastal Zone Management Authority,
Forest & Environment Department,
Govt. of Gujarat,
Block No.14, 8th floor,
Sachivalaya,
Gandhinagar – 382 010.

Sub:- Development of Integrated facilities (Stage-II) within the existing Deendayal Port Trust (Erstwhile Kandla Port Trust) at District Kutch, Gujarat. (1. Setting up of Oil Jetty No.7. 2. Setting up of Barge jetty at Jafarwadi 3. Setting up of Barge port at Veera; 4. Administrative office building at Tuna Tekra; 5. Road connecting from Veera barge jetty to Tuna gate by M/s Deendayal Port Authority (Erstwhile Deendayal Port Trust) - **Pointwise Compliances of the conditions stipulated in CRZ Recommendations reg.**

Ref.:1)GCZMA CRZ recommendation vide Letter No- ENV-10-2015-251-E (T Cell) dated 29.06.2016
2)DPT letter EG/WK/4751/Part (Remaining 3 facilities)/53 dated 29/07/2021
3)DPT letter EG/WK/4751/Part (Remaining 3 facilities)/144 dated 08/02/2022
4) DPA letter EG/WK/4751/Part (Stage II)/141 dated 11/07/2022

Sir,

It is requested to kindly refer the above cited references.

In this connection, it is to state that, the Gujarat Coastal Zone Management Authority vide above referred letter dated 29/6/2016 had recommended the aforesaid project of Deendayal Port Authority. Subsequently, the MoEF&CC,GoI had accorded the Environmental & CRZ Clearance vide letter dated 19/2/2020.

Subsequently, DPA vide aforementioned letters had submitted the compliance reports of the conditions stipulated in the CRZ Recommendation letter 29/6/2016 to GCZMA, GoG.

.....Cont.....

Now, as directed under Specific Condition No. 28 mentioned in the CRZ Clearance letter dated 29/6/2016 i.e. ***A six-monthly report on compliance of the conditions mentioned in this letter shall have to be furnished by the DPT on a regular basis to this Department /MoEF&CC, GoI***, please find enclosed herewith compliance report (for the period up to November, 2022) **(Annexure I)** of stipulated conditions along with necessary annexure, for kind information & record please.

Further, as per the MoEF&CC, Notification S.O.5845 (E) dated 26.11.2018, which stated that "***In the said notification, in paragraph 10, in sub paragraph (ii), for the words "hard and soft copies" the words "soft copy" shall be substituted***". Accordingly, we are submitting herewith soft copy of the same in CD as well as through e-mail ID gczma.crz@gmail.com & direnv@gujarat.gov.in.

This has the approval of Chief Engineer, Deendayal Port Authority.

Thanking you.

Yours faithfully,

Manager (Env.)
Deendayal Port Authority

Copy to:

Shri Amardeep Raju,
Scientist E, Ministry of Environment, Forest and Climate Change,
& Member Secretary (EAC-Infra.1),
Indira Paryavaran Bhawan,
3rd Floor, Vayu Wing, Jor Bagh Road, Aliganj,
New Delhi- 110 003;
E-mail: ad.raju@nic.in

Annexure -I

CURRENT STATUS OF WORK (Up to November, 2022)

Subject: **Development of Integrated facilities (Stage-II) within the existing Deendayal Port Trust (Erstwhile Kandla Port Trust) at District Kutch, Gujarat. (1. Setting up of Oil Jetty No.7. 2. Setting up of Barge jetty at Jafarwadi 3. Setting up of Barge port at Veera; 4. An administrative office building at Tuna Tekra; 5. A road connecting from Veera barge jetty to Tuna gate by Deendayal Port Authority (Erstwhile Deendayal Port Trust)**

Sr.No.	Name of Project	Status
1.	**Setting up of Oil Jetty No. 7**	A total of 88% physical work is completed. The work of Jetty head, Central Platform, Berthing Dolphin, Pump House and Approach Jetty completed The work of mooring dolphin is in progress
2.	**Setting up of Barge jetty at Jafarwadi**	No construction activity has started yet
3.	**Setting up of Barge port at Veera**	No construction activity has started yet.
4.	**Administrative office building at Tuna Tekra;**	No construction activity has started yet.
5.	**Road connecting from Veera barge jetty to Tuna gate**	No construction activity has started yet.

Annexure 1

COMPLIANCE REPORT (up to November, 2022)

Subject: Point-wise Compliance of the conditions stipulated in CRZ recommendation issued by GCZMA, GoG for the project "Developing Integrated facilities (Phase-II)- within the existing Kandla Port at Kandla Dist: Kutch by M/s. Kandla Port Trust – 1. Setting up of Oil Jetty No.7; 2. Setting up of Barge jetty at Jafarwadi; 3. Setting up of Barge port at Veera; 4. Administrative office building at Tuna Tekra; 5. Road connecting from Veera barge jetty to Tuna gate by Deendayal Port Authority (Erstwhile Deendayal Port Trust)

Ref No: - GCZMA issued CRZ recommendation vide Letter No- ENV-10-2015-251-E (T Cell) dated 29.06.2016

S. No.	CRZ Conditions	Compliance Status
	SPECIFIC CONDITIONS	
1.	The provision of the CRZ notification 2011 shall be strictly adhered to by the KPT. No activity in contradiction to the provision of the CRZ notification shall be carried out by the KPT.	The work of project at Sr. No. 1 i.e. "Setting up of oil jetty no. 7" is in progress. The provisions of the CRZ Notification, 2011 is being strictly adhered to by DPA.
2.	All necessary permissions under various laws/Rules/Notifications issued thereunder from different Government Department/agencies shall be obtained by M/s. KPT before commencing any enabling activities for proposed project.	The Consent to Establish (CTE) from the GPCB had already been obtained vide CTE No. 74134 granted by the GPCB vide letter no. PC/CCA-KUTCH 1319/GPCB ID 48573 dated 27/11/2015. Subsequently, DPA obtained EC to CTE (PCB ID 48573) vide GPCB Order dated 13/10/2020 after obtaining Environmental and CRZ Clearance from MoEF&CC, GoI vide F. No. 11-13/2015-IA-III dated 19/02/2020 **(Copy Annexure A).**
3.	The KPT shall have to ensure that there shall not be any damage to the existing mangrove area.	It is hereby assured that, there will not be any damage to the existing mangrove area
4.	The KPT shall effectively implement the mangrove Development, Protection & Management plan for control of indirect impacts on mangrove habitat	DPA had already undertaken Mangrove Plantation in an area of 1500 Ha. till date since the year 2005. A statement showing details of the mangrove plantation and the cost incurred is again placed in **Annexure B**. Further, DPA is carrying out an additional mangrove plantation of 100 ha. with the consultation of the Gujarat Ecology Commission vide Work Order No. DD/WK/3050/Pt-I/GIM/PC-44 dated 02/06/2022 (**Annexure C**). In addition to the above, DPA appointed M/s GUIDE, Bhuj, for "Regular Monitoring of Mangrove Plantation carried out by DPA" (period 15/9/2017 to 14/9/2018 vide work

S. No.	CRZ Conditions	Compliance Status
		order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021). The final report submitted by M/s GUIDE, Bhuj for the year 2021 to 2022 is attached herewith as **Annexure D.**
5.	The KPT shall have to make a provision that mangrove areas get proper flushing water and free flow of water shall not be obstructed	The necessary arrangement had already been made in compliance with the condition.
6.	The KPT shall have to dispose of the dredged material only after scientific study to be carried out by the Institute of National repute and at a location suggested by them	Dredged Material will be disposed of at the designated location as identified by the CWPRS, Pune.
7.	The KPT shall have to maintain the record for generation and disposal of capital dredging and maintenance dredging.	Point noted for compliance
8.	No dredging, reclamation or any other project related activities shall be carried out in the CRZ area categorized as CRZ I (i) and it shall have to be ensured that the mangrove habitats and other ecologically important and significant areas, if any, in the region are not affected due to any of the project activities	It is hereby assured that DPA will undertake only activities recommended by the GCZMA vide letter dated 29/06/2016 and EC & CRZ clearance accorded by the MoEF&CC, GOI vide letter dated 18/02/2020. DPA has already prepared a mangrove preservation plan for the entire Kandla area. In addition to the above, DPA appointed M/s GUIDE, Bhuj, for "Regular Monitoring of Mangrove Plantation carried out by DPA" (period 15/9/2017 to 14/9/2018 vide work order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021). The final report submitted by M/s GUIDE, Bhuj, for the years 2017 to 2018 has been submitted in the earlier compliance report, and the final report for the year 2021 to 2022 is attached herewith as **Annexure D**. Further, DPA had authorised the work to M/s GUIDE, Bhuj for "Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme covering all seasons on various aspects of the Coastal Environs covering Physico-chemical parameters of marine water and marine sediment samples coupled with biological indices, as per the requirements of EC & CRZ Clearances reg. (for three years (2021-2024)). The final report for the year 2021-22 has already been communicated with the last compliance report submitted

S. No.	CRZ Conditions	Compliance Status
		vide letter 11/07/2022. The first season report for the year 2022-2023 submitted is attached herewith as **Annexure E**. It is relevant to mention here that, DPA has already undertaken Mangrove Plantation in an area of 1500 Ha. till date since the year 2005. A statement showing details of the mangrove plantation and the cost incurred is again placed in **Annexure B**. Further, DPA is carrying out an additional mangrove plantation of 100 ha. with the consultation of the Gujarat Ecology Commission vide Work Order No. DD/WK/3050/Pt-I/GIM/PC-44 dated 02/06/2022 (**Annexure C**).
9.	The KPT shall participate financially for installing and operating the vessel traffic management system in the Gulf of Kutch and shall also take lead in preparing and operational sing the Regional Oil Spill Contingency plan in the Gulf of Kutch	DPA had already contributed an amount of Rs. 98.955 crores i.e., 25% of the total project cost of 395.82crores for installing and operating VTMS in the Gulf of Kachchh
10.	The KPT shall strictly ensure that no creeks or rivers are blocked due to any activity at Kandla	Point noted for compliance
11.	Mangrove plantation in an area of 50 ha shall be carried out by the KPT within 2 years in a time bound manner on Gujarat coastline either within or outside the Kandla port Trust area and six-monthly compliance report along with the satellite images shall be submitted to the ministry of Environment and Forest as well as to this Department without fail.	DPA has signed MoU with Gujarat Ecology Commission, Gandhinagar to carry out mangrove plantation through PPP mode for the year 2020-2021. Copy of the MoU is placed at **Annexure F.** DPA (Erstwhile KPT) had already DPA had already undertaken Mangrove Plantation in an area of 1500 Ha. till date since the year 2005. A statement showing details of the mangrove plantation and the cost incurred is again placed in **Annexure B**. Further, DPA is carrying out an additional mangrove plantation of 100 ha. with the consultation of the Gujarat Ecology Commission vide Work Order No. DD/WK/3050/Pt-I/GIM/PC-44 dated 02/06/2022 (**Annexure C**). In addition to the above, DPA appointed M/s GUIDE, Bhuj, for "Regular Monitoring of Mangrove Plantation carried out by DPA" (period 15/9/2017 to 14/9/2018 vide work order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021).

S. No.	CRZ Conditions	Compliance Status
		The final report submitted by M/s GUIDE, Bhuj, for the year 2021 to 2022 is attached herewith as **Annexure D.**
12.	No activity other than those permitted by the competent authority under the CRZ Notification Shall be carried out in the CRZ area.	It is assured that no activity other than those permitted by the competent authority under the CRZ Notification will be carried out by the DPA.
13.	No ground water shall be tapped for any purpose during the proposed expansion/modernization activities.	It is assured that no groundwater will be tapped. The water will be purchased through GWSSB.
14.	All necessary permissions from different Government Departments/agencies shall be obtained by the KPT before commencing the expansion activities.	DPA had already obtained the necessary EC & CRZ clearance for the project on dated 19/02/2020. Further, Consent to establish from GPCB had already been obtained from GPCB for the same. Subsequently, DPA obtained EC to CTE (PCB ID 48573) vide GPCB Order dated 13/10/2020 after obtaining Environmental and CRZ Clearance from MoEF&CC, GoI vide F. No. 11-13/2015-IA-III dated 19/02/2020.
15.	No effluent or sewage shall be discharged into the sea/creek or in the CRZ area and it shall be treated to confirm to the norms prescribed by the Gujarat Pollution Control Board and would be reused/recycled with in the plant premises.	In this regard, it is to state that, DPA is already having a sewage treatment plant capacity of 1.5MLD for the treatment of domestic sewage. The treated sewages from STP of DPA are utilized for plantation / Gardening. In addition to the above, DPA appointed has been conducting regular Monitoring of environmental parameters including STP monitoring through NABL Accredited laboratories since the year 2016. The Environmental Monitoring Reports is enclosed herewith as **Annexure G**. Further, necessary provisions will be made for the projects at Sr. No. 2 – 5 to not discharge effluent or sewage into the sea/creek or in CRZ area.
16.	All the recommendations and suggestions given by the Mantec Consultant Pvt. Ltd. New Delhi in their Comprehensive Environment Impact Assessment report for conservation/protection and betterment of environment shall be implemented strictly by the KPT.	DPA has installed Mist Canon at the Port area to minimize the dust. Further, DPA has already installed continuous sprinkling system to prevent dust pollution. Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done. Regular sweeping of spilled cargo from roads is done by parties on regular basis. DPA appointed has been conducting regular Monitoring of environmental parameters

S. No.	CRZ Conditions	Compliance Status
		including STP monitoring through NABL Accredited laboratories since the year 2016. The Environmental Monitoring Reports is enclosed herewith as **Annexure G.** For ship waste management, DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" and "Dry Solid Waste (Non- Hazardous)" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars regarding the reception facilities at Swachch Sagar portal. DPA assigned work to M/s GUIDE, Bhuj, for regular monitoring of Marine Ecology since the year 2017 (From 2017 – 2021), and reports of the same are being submitted regularly to the Regional Office, MoEF&CC, GoI, Gandhinagar as well as to the MoEF&CC, GoI, New Delhi along with compliance reports submitted. The final report for the Holistic Marine Ecological Monitoring for the period up to May 2021 was submitted on 22.05.2021. Copy of the report was communicated vide earlier compliance report submitted vide letter dated 29/6/2021. Further, it is to submit that DPA issued a work order to M/s GUIDE vide its letter no. EG/WK/ 4751 /Part (Marine Ecology Monitoring) /11 dated 03/05/2021 for Regular monitoring of Marine Ecology in and around Deendayal Port Authority (Erstwhile Deendayal Port Trust) and continuous Monitoring Program covering all seasons on various aspects of the Coastal Environs for the period 2021-24. The copy of the final report submitted by M/s GUIDE for the year 2021-22 has already been communicated with the last six-monthly compliance report submitted vide letter dated 11/07/2022. The first season report for the year 2022-2023 submitted is attached herewith as **Annexure E**. As already informed, DPA entrusted work of green belt development in and around the

S. No.	CRZ Conditions	Compliance Status
		Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares). The work is completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022 (**Annexure H**). For dredged material management, DPA assigned work to M/s GUIDE, Bhuj for analysis of dredged material since the year 2017 and the reports are being submitted from time to time along with compliance reports submitted. The second Season Report submitted by M/s GUIDE, Bhuj for the period 2021-2022 is attached herewith as **Annexure I.** Further, Dredged Material will be disposed of at designated location as identified by the CWPRS, Pune. For energy conservation measures, DPA is already generating 20 MW of Wind energy. In addition to it, DPA has commissioned a 45 kWP Solar Plant at Gandhidham. Further, it is relevant to mention that, two out of four Nos. of Harbour Mobile Crane (HMC) made electric operated. Balance 02 Nos. shall be made electric operated by 2023-2024. Four Nos. of Deisel operated RTGs converted to e-RTGs. Retrofitting of hydrogen fuel cell in Tug Kalinga and Pilot Boat Niharika to be done as a pilot project under the guidance of MoPSW. Also, 14 Nos. of EV cars to be hired in this year and 03 Nos. EV Bus to be procured by the year 2023-24. Further, for Oil Spill Management, DPA is already having Oil Spill Contingency Plan in place and Oil Response System as per the NOS-DCP guidelines.
17.	The construction and operational activities shall be carried out in such a way that there is no negative impact on mangrove and other coastal/marine habitats. The construction activities and dredging shall be carried out only under	The work of project at Sr. No. 1 i.e. "Construction of Oil Jetty No. 7" is in progress and due care is being taken for so that, there is no negative impact on mangrove and other coastal/marine habitats.

S. No.	CRZ Conditions	Compliance Status
	the constant supervision and guidelines of the Institute of National repute like NIOT	Further, for project at Sr. No. 2 to 5 (Construction not yet started); however, the specified condition will be complied with.
18.	The KPT shall contribute financially for any common study or project that may be proposed by this Department for environmental management/conservation /improvement for the Gulf of Kutch	Point noted for compliance.
19.	The construction debris and/or any other type of waste shall not be disposed of into the sea, creek or in the CRZ areas. The debris shall be removed from the construction site immediately after the construction is over.	DPA had already issued general circular vide dated 3/9/2019 (Copy – **Annexure J**) regarding Construction and Demolition Waste Management for strict implementation in DPA.
20.	The construction camps shall be located outside the CRZ area and the construction labour shall be provided with the necessary amenities, including sanitation, water supply and fuel and it shall be ensured that the environmental conditions are not deteriorated by the construction labours.	Point noted or compliance
21.	The KPT shall regularly update their Local oil spill contingency and disaster management plan in consonance with the National oil Spill and Disaster Contingency plan and shall submit the same to this Department after having it vetted through the Indian Coast Guard.	DPA already has updated Disaster management plan and Local oil spill contingency plan. The copy of the same has already been submitted with the last compliance report communicated vide letter dated 11/07/2022. DPA has also executed MOU with Oil companies, i.e., IOCL, HPCL, BPCL etc, for setting up of Tier I facility for combating the Oil Spill at Kandla.
22.	The KPT shall bear the cost of the external agency that may be appointed by this Department for supervision/monitoring of proposed activities and the environmental impacts of the proposed activities.	Point noted for compliance.
23.	The KPT shall take up massive green belt development activities in and around Kandla and also within the KPT limits.	DPA assigned work for green belt development in an area of about 32 hectares to the Forest Department, Govt. of Gujarat, in August 2019 at the cost of Rs. 352.32 lakhs. The work is completed. Further, DPA also undertook massive green belt development in and around the Port area and at the Gandhidham area. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for

S. No.	CRZ Conditions	Compliance Status
		"Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022 (**Annexure H**).
24.	The KPT shall have to contribute financially for taking up the socio-economic upliftment activities in this region in consultation with the Forests and Environment Department and the District Collector/District development officer.	DPA has already been undertaking CSR activities. The details of CSR Activities implemented as well as proposed are enclosed herewith as **Annexure K.**
25.	A separate budget shall be earmarked for environmental management and socio-economic activities and details there of shall be furnished to this Department as well as the MoEF,GOI. The details with respect to the expenditure from this budget head shall also be furnished.	DPA has already kept Rs. 345 lakhs in B.E. 2022-23 under the scheme "Environmental Services & Clearance thereof".
26.	A separate environmental management cell with qualified personnel shall be created for environmental monitoring and management during construction and operational phases of the project.	DPA already has an Environment Management Cell. Further, DPA has also appointed an expert agency to provide Environmental Experts from time to time. Recently, DPA appointed M/s Precitech Laboratories, Vapi, vide work order dated 5/2/2021 (Copy of work order & scope of work attached as **Annexure L**). Further, DPA has appointed a Manager Environment on a contractual basis for a period of 3+2 years. A copy of the office order is attached herewith as **Annexure M.**
27.	An Environmental report indicating the changes if any, with respect to the baseline environmental quality in the coastal and marine environment shall be submitted every year by the KPT to this Department as well as to the MoEF&CC,GOI	DPA has been conducting regular Monitoring of environmental parameters since the year 2016 through NABL Accredited laboratories. The Environmental Monitoring Reports is enclosed herewith as **Annexure G**. DPA has been submitting the environmental monitoring report along with the compliance report to IRO, MoEF&CC, GoI.
28.	The KPT shall have to contribute financially to support the National Green Corps Scheme being implemented in Gujarat by the GEER foundation. Gandhinagar in consultation with Forests and Environment Department.	Point noted for compliance.
29.	A six monthly report on compliance of the conditions mentioned in this letter shall have to be furnished by the KPT on	DPA has been regularly submitting a six-monthly report in compliance with the conditions mentioned to GCZMA and

S. No.	CRZ Conditions	Compliance Status
	regular basis to this Department/MoEF&CC,GOI	MoEF&CC, GOI.
30.	Any other condition that may be stipulated by this Department and MoEF&CC,GoI from time to time for environmental protection / management purpose shall also have to be complied with by DPT.	Point noted.

Annexure -A

GPCB

GUJARAT POLLUTION CONTROL BOARD
PARYAVARAN BHAVAN
Sector-10-A, **Gandhinagar** 382010
Phone : (079) 23222425
(079) 23222152
Fax : (079) 23232156
Website : www.gpcb.gov.in

Application For CTE after EC

File No : GPCB/ **(PCB ID. - 48573)**

To,
M/s. Kandla Port Trust(Developing Integrated Facilities-Stage Ii).
within existing Kandla Port Trust Limit at Kandla, Administrative Office Building, Post Box no.50,
City :Gandhidham ,
Dist : Kutch East ,
Taluka : Gandhidham

Sub: Consent to Establish (After obtaining Environment Clearance) under Section 25 of Water Act 1974 and Section 21 of Air Act 1981.

Ref: (1) Your online application No. 181633 dated 03/09/2020

(1) Environment Clearance issued by Central Authority vide their letter no. 11-13/2015-IA-III Dated 19/02/2020

Sir,

Without prejudice to the powers of this Board under the Water (Prevention and Control of Pollution) Act-1974, the Air Act-1981 and the Environment (Protection) Act-1986 and without reducing your responsibilities under the said Acts in any way, this is to inform you that this Board grants **Consent to Establish (After obtaining Environment Clearance) under Section 25 of Water Act 1974 and Section 21 of Air Act 1981** for manufacturing of products as mentioned into the Environment Clearance (EC) granted vide letter under reference no (2) above.

Consent To Establish Is Granted Subject To The Following Conditions: -

1) The validity period of this CTE shall be Seven Years from the issue of this order.
2) Applicant shall strictly comply with all conditions stipulated by competent authority in the order of Environment Clearance issued vide letter under reference No. : 2 above.
3) The applicant shall however, not without the prior concern of the Board. Bring into use any new or altered outlet for the discharge of effluent or gaseous emission or sewage waste from the proposed industrial plant. The applicant is required to make applications to this Board for this purpose in the prescribed forms under the provisions of the water Act - 1974, the Air - 1981 and the Environment (Protection) Act - 1986.

For and on behalf of
Gujarat Pollution Control Board

K. B. Chaudhary
ROH Head - Kutch East

- This order is issued to **within existing Kandla Port Trust Limit at Kandla, Administrative Office Building, Post Box no.50, City :Gandhidham, Dist : Kutch East, Taluka : Gandhidham (48573)** for CTE amendment after obtaining EC.

Annexure -B

DEENDAYAL PORT TRUST

DETAILS OF MANGROVE PLANTATION ALREDY CARRIED OUT & Proposed To be Carried Out :

Sr. No.	Name of the Organization	Total Mangrove Plantation carried out in Hectares till date and place of plantation and agency	Cost incurred
(A) MANGROVE PLANTATION ALREDY CARRIED OUT			
1	DEENDAYAL PORT TRUST (CRZ Recommendation 13th to 16th CB issued by the GCZMA) (Total 1000 ha.)	20 Hectares – 2005-06 Satsida Bet,Kandla, by GUIDE,Bhuj 50 Hectares – 2008-09 Nakti Creek,Kandla by Patel Construction 100 Hectares – 2010-11 Nakti Creek ,Kandla by GEC. (Board 29/1/2010) 200 Hectares – 2011-12 by Forest Department, GoG at Satsaida Bet 300 Hectares – 2012-13 by Forest Department, GoG at Satsaida Bet 330 Hectares – 2013-14 by Forest Department, GoG at Satsaida Bet **TOTAL 1000 HA.**	Rs. 8.8 lakhs Rs. 27.4 lakhs Rs.24.5 lakhs Rs. 66.5 lakhs Rs. 157.5 lakhs (total 630 hectares)
2	Creation of Berthing & allied Facilities off- tekra near Tuna (Outside Kandla Creek) – EC & CRZ Clearance. (Total 500 ha. – 250Ha. by DPT & 250 ha by Adani (concessionaire) MOU signed with GEC during Vibrant Gujarat Summit 2015 for 300 Ha.	300 Hectares – 2015-17 by GEC at Kantiyajal, Bharuch District	Rs. 90.0 lakhs
3.	EC & CRZ Clearance dated 19/12/2016 for Developing 7 integrated facilities (Condition 100 Ha)	100 Ha. –2018- 20 by GEC	Rs. 45 lakhs
TOTAL MANGROVE Plantation till date by DPT 1400 Ha. – Total 419.7 lakhs			

	(B) <u>Proposed Mangrove Plantation</u>		
1.	Development of Integrated facilities (Stage-II) within the existing Deendayal Port Trust (Erstwhile Kandla Port Trust) at District Kutch, Gujarat. (1. Setting up of Oil Jetty No.7 ; 2. Setting up of Barge jetty at Jafarwadi ; 3. Setting up of Barge port at Veera; 4. Administrative office building at Tuna Tekra; 5. Road connecting from Veera barge jetty to Tuna gate by M/s Deendayal Port Trust (Erstwhile : Kandla Port Trust) - <u>Environmental & CRZ Clearance accorded by the MoEF&CC,GoI dated 19/12/2020.</u>	**<u>50 Ha. as per CRZ Recommendation issued by the GCZMA dated 29/6/2016.</u>**	Rs. 45 lakhs
2.	Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Trust (Erstwhile : Kandla Port Trust) at Gandhidham, Kutch, Gujarat - <u>Environmental & CRZ Clearance accorded by the MoEF&CC,GoI dated 18/2/2020.</u>	**<u>50 Ha. as per CRZ Recommendation issued by the GCZMA dated 29/6/2016. .</u>**	

Annexure -C

DEENDAYAL PORT AUTHORITY

(Erstwhile Deendayal Port Trust)

Ministry of Ports, Shipping & Waterways, Govt. of India

Mech. Engg. Deptt.

SAGARMALA

Tel: (02836)220636 / 270184
FAX: (02836) 270184 / 270475
Email :- cmedpt @gmail.com
cme@deendayalport.gov.in

Office of the Chief Mechanical Engineer,
Port & Customs Building,
New Kandla (Kutch), Gujarat-370210

No. DD/WK/3050/Pt-I/ GIM/PC-44 Date: 02.06.2022

Sir,

To,
Gujarat Ecology Commission
Forest & Environment Department
Block No. 18, First Floor, Udhyog Bhavan,
Gandhinagar, Gujarat

Sub: Work Order to carry out Mangrove Plantation-req.

The Competent Authority, Deendayal Port Authority has been pleased to approve:

1. To carry out mangrove plantation in 100 Ha. area with consultation of concern Gujarat Ecology Commission and at tentative estimated cost amounting to Rs. 50,00,000/- (excluding GST) for the said mangrove Plantation to be carried out in an area of 100 Ha. as per the stages mentioned by them in the MoU as follows:

Sr. No.	Terms and Condition	Rs. (in lakhs)
1	50% of the project cost of 100 Ha. Mangrove Plantation after singing the MoU.	Rs. 25.00
2	40% of the project cost of 100 Ha Mangrove Plantation after nursery preparation.	Rs. 20.00
3	10% of the project cost of 100 Ha Mangrove Plantation after plantation and submission of First year progress report.	Rs. 5.00
	Total	50.00

2. To sign MoU with the Gujarat Ecology Commission, Government of Gujarat during the ensuing Vibrant Gujarat Summit 2022, regarding proposed Mangrove Plantation to be carried out in an area of 100 Hectares through the Gujarat Ecology Commission.
3. To authorize Dy. CME & CME (I/c) to sign MoU with the Gujarat Ecology Commission, Government of Gujarat during upcoming Vibrant Gujarat Summit 2022 for proposed Mangrove Plantation in an area of 100 Hectares through GEC.

The Expenditure shall be chargeable under Code 841/587/9744 WC-13001

Authority: Approved by Board vide Resolution No. 30 in the board meeting held on 27.05.2022

Chief Mechanical Engineer(I/c)
Deendayal Port Authority

Copy to:
1) SE(M)
2) A.O. (Works Audit)

Annexure -D

Regular Monitoring of Mangrove Plantation (1400 ha) carried out by Deendayal Port Authority, Kandla

DPA Work Order No: WK/EG/4751/Part/ (Marine Ecology Monitoring)/10

Dt.03/05/2021

Submitted to

Deendayal Port Authority

Administrative office building

Post box no. 50

Gandhidham (Kachchh)

Gujarat-370201

Submitted by

Gujarat Institute of Desert Ecology

P.B. No. 83, Mundra road

Opp. Changleshwar Temple

Bhuj-Kachchh, Gujarat-370001

MAY 2022

Gujarat Institute of Desert Ecology

Certificate

This is to state that this Final report of the work entitled, **"Regular Monitoring of Mangrove Plantation (1400 Ha) carried out by Deendayal Port Authority (Statutory Requirement)"** has been prepared in the line with the work order issued by DPA vide No. EG/WK/4751/Part (Marine Ecology Monitoring))/10. Dt. 03.05.2021.

This report covers the study conducted during the period between May'2021 and May'2022.

Authorized Signatory **Institute Seal**

P. O. Box No. # 83, Opp. Changleshwar Temple, Mundra Road, Bhuj (Kachchh) - 370 001, Gujarat (India)
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PROJECT TEAM

Project Co-ordinator: Dr. V. Vijay Kumar, Director

Name of the Staff	Designation	Role
Dr. M. Jaikumar	Senior Scientist	Principal Investigator
Dr. Durga Prasad Behera	Project Scientist	Team Member
Dr. R. Ravinesh	Project Scientist	Team Member
Dr. Dhara Dixit	Project Scientist	Team Member
Dr. Kapilkumar. N. Ingle	Project Scientist	Team Member
Dr. L. Prabhadevi	Advisor	Team Member
Mr. Dayesh Parmar	Project Officer (RS&GIS)	Team Member
Mr. Sai Vineeth Perla	Senior Research Fellow	Team Member
Ms. Bhagavati Kannad	Junior Research Fellow	Team Member
Ms. Pallavi Joshi	Junior Research Fellow	Team Member

Snapshot of the Project, “Regular Monitoring of Mangrove Plantation (1400 Ha) carried out by Deendayal Port Authority (Statutory requirement)”

S. No	Components of the Study	Remarks
1	Deendayal Port's letter sanctioning the project	EG/ WK/4751/Part/ (Marine Ecology Monitoring)/10 dated 3/5/2021
2	Duration of the project	One year from 24.05.2021 to 23.05.2022
3	Period of the survey carried out for various components	July-2021 – April 2022
4	Survey area within the port limit	Sat Saida Bet, Nakti creek and Kantiyajal mangrove plantation sites
5	No of locations sampled within the port limits	05 blocks in Sat Saida Bet, 02 blocks in Nakti creek and 3 block at Kantiyajal
6	Components of the report	
6a	Mangrove density	<u>*Sat Saida Bet:*</u> Density of *A. marina* varied from 1300 to 3500 and individuals/ha and tree height ranging from 70 - 260cm <u>*Nakti creek:*</u> Density of *A. marina* varied from 900 – 3400 individuals/ha and tree height ranges from 72 - 280 cm. <u>*Kantiyajal:*</u> Density of *A. marina* varied from 1200 - 5200 individuals/ha tree height ranges from 13-220 cm. The density of *R. mucronata* at Kantiyajal was 1800 to 3500 individuals/ha and height ranges from 13 to 210 cm.
6b	Mangrove survival	The highest survival rate for *A. marina* plantation in 150 ha area at Kantiyajal was 75%, followed by 50ha area at Sat Saida bet (62.7%) and Nakti (54%).
6c	Assessment of below ground Carbon stock	The below ground Total Biomass Carbon of *A. marina* plantation varied from 42.36t/ha to 79.5t/ha. The highest below ground carbon stock potential was at Sat Saida Island.
6d	Assessment of above ground carbon	The above ground biomass was maximum 210.0 gm at Sat Saida Bet while at Nakti it was 161.0gm and at Kantiyajal 164.60gm.
7d	Management	The restoration efforts to be done to improve the sparse mangrove patches with multi-species plantation initiatives along with promotion of natural regeneration through long term efforts.
8	Status of 2017-2018 plantation	Sat Saida Bet

		Average density of *A. marina* plants 2031 - 5387 individuals/ha with average height ranging from 39 - 113 cm. Nakti creek Plant density (*A. marina)* varied from 2340 – 2370 individuals/ha with average height from 53 - 84 cm. Very few *R. mucronata* and *C. tagal* plants survived. Kantiyajal *A. marina* average density between 1460 and 2220 individuals/ha with an average height between 32 -37 cm. Average density of *R. mucronata* was 1280 individuals/ha with an average height of 30 cm and *R. mucronata* as frontline vegetation along the fringes of the block. Highest survival rate (88.8%) for *A. marina* plantation in 150 ha at Kantiyajal followed by *A. marina* plantation in 20 ha at Sat Saida bet (81.6%) during 2017-2018. The Total Biomass Carbon of A. marina plantation varied from 0.041 to 0.202 Mg/ha. The highest Carbon sequestration potential was of Nakti creek during 2017-2018.

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1 Introduction

Mangrove forests make up one of the most productive and biologically diverse ecosystems on the planet. They grow in a variety of depths of salt water with breathing roots or Pneumatophores providing habitat for different macro and micro faunal species. The ability of mangroves to absorb up to four times more carbon dioxide by area than other terrestrial forests recognize their importance in global warming (Donato *et. al.*, 2011). The mangroves are economically important by supporting fisheries, ecotourism and carbon sequestration (Baig *et. al.*, 2015). Over the years, the global scientific community has widely realized the ecological role of mangroves and the services they provide. Despite the benefits it provides, mangroves are being overexploited and deteriorated for various reasons and area under mangrove cover decreased at an alarming rate and poorly restored (UNEP, 2014). Thus, researchers eventually tried to restore mangrove through plantation/conservation to retain the ecological and economic values, and as a result the rate of loss has been decreased and stabilized during the period of 1980 to 2000 compared to the terrestrial forest loss (Duraiappah *et. al.*, 2005). India has a total of 7516.6 km coastline distributed among nine maritime states and four Union Territories (Anon, 2001), of which Gujarat possesses the longest coastline extending to 1650 km. A total of 46 true mangrove species belonging to 14 families and 22 genera are found in Indian mangrove habitats (Ragavan *et. al.,* 2016). Around 3 % of the earth's total mangrove vegetation is found in India (FSI, 2021). Gujarat has the country's second-largest mangrove cover (1175Km^2).

Mangrove being the woody habitats forms the vital carbon sinks in the coastal regions. Deendayal Port Authority (hereafter DPA) has been involved in the mangrove plantation activity as per the specifications by the Ministry of Environment Forests and Climate Change, Govt. of India, (hereafter MoEFCC) in the port premises and the adjoining creek environments in order to mitigate the environmental impacts due to the Port's regular activities in the coastal waters and the land. The coastal water itself can absorb the atmospheric carbon dioxide, and the microscopic phytoplankton tends to remove a huge amount of it through photosynthesis and diffusing oxygen into the water. The monitoring of the mangrove plantation carried out by the DPA has been undertaken by Gujarat Institute of Desert Ecology (hereafter GUIDE) regularly as per the specification in the work order (EG/WK/4751/part Marine Ecology Monitoring)/10 dated 03.05.21. This report describes the monitoring results of the mangrove plantation managed by the DPA at Nakti creek, Kantiyajal and Sat Saida Bet during the period of 2021 to 2022.

2 Objectives of the study

This study aims to assess the growth and survival rate of mangrove plantations, factors affecting the health of the mangrove and suggest appropriate remedial measures and techniques for conserving them.

The specific objectives are:

i. To evaluate 1400 Ha of mangrove plantation at Sat Saida Bet, Nakti creek in Kachchh coast, and Kantiyajal in Bharuch district carried out by the Gujarat Ecology Commission (GEC), and the Department of Forest, Govt. of Gujarat.

ii. To assess the extent of the plantation, health status, survival of the sapling, mortality rate and growth of the planted mangroves.

iii. To provide a comprehensive overview of both the composition and distribution of the planted mangroves.

iv. To assess the potential below ground carbon stock of the mangrove plantation in view of climate change.

3 Mangroves as blue-carbon stock

Mangrove ecosystems are large and dynamic carbon reservoirs, involved in the global carbon cycle and a potential sink of atmospheric carbon dioxide (Clark, 2001; Matsui *et. al.*, 2010). Currently, the world's mangroves store carbon equivalent to over 21 gigatons of CO_2. Destruction of mangrove ecosystems releases this carbon into the atmosphere, accelerating the rate of climate change. (Lovelock *et. al.*, 2022). It has been estimated that mangroves prevent more than $65 billion in property damages and reduce flood risk to some 15 million people every year (Spalding *et. al*.,.2021). In the face of accelerating climate change, mangroves are significant contributors to ecosystem-based adaptation, with a robust capacity to support lives and livelihoods, even in the expected future changes predicted by most of the general circulation models (IPCC 2013). A salient feature of mangrove forests is converting carbon dioxide to organic carbon at higher rates than almost any other existing habitat on earth (Ezcurra *et al.,* 2016). This 'blue carbon' is stored both in the living plants and their thick muddy soils, where it can remain fixed for centuries.

Although the area covered by mangrove forests represents only a tiny fraction of the tropical forests, their position at the terrestrial-ocean interface and possible exchange with coastal ocean waters make a unique contribution to the total carbon cycle in the coastal ocean (Twilley, 1992). The contribution of coastal and marine ecosystems to mitigate climate change through carbon sequestration and storage is much more compared to their terrestrial counterparts (Steven *et. al*., 2008; Yee. 2010). Blue carbon sinks include open oceans, kelp forests, salt marshes, sea grass beds, coral reefs and mangroves. Management of these blue carbon sinks is currently not being accounted for in most of the climate change policies and is excluded from national carbon inventories and international carbon payment schemes (Lasco, 2004). There are two different mangrove biomass estimation methods well established viz. field measurement and remote sensing & GIS-based approach. Amongst them, the field measurement has been considered to be precise and accurate (Petrokofsky *et al.*, 2012). Further, field-based data is also required for validation in remote sensing and GIS-based approach. Hence, in recent years, field measurements have been conducted to support and collate satellite data for meaningful estimations. Approximation of the global carbon cycle done through, scaling- up of successful protection and restoration measures (Lovelock *et. al*., 2022). And additionally, these coastal ecosystems provide numerous benefits and services that are essential for climate change adaptation, including coastal protection and food security for many communities globally (IUCN 2017). On an implementation global level, carbon stores in different level *viz*., mangroves, salt marshes and seagrasses can be included in national accounting**,** according to the Intergovernmental Panel on Climate Change (IPCC 2013). Although there was no record of sea grass in the DPA area (GUIDE 2018).

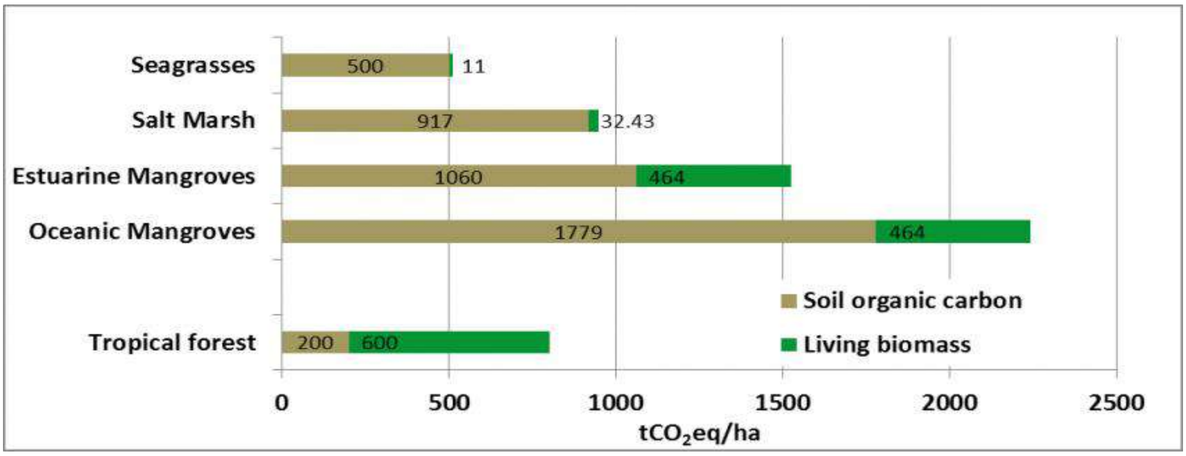

Figure 1. Different level of Carbon Storage
(*Source*-**IPCC, 2013 Supplement to the 2006 Guidelines for National Greenhouse Gas Inventories: Wetlands).**

4 Rationale

DPA is one of the largest ports in India, having one of the largest coastal habitats, with mangroves (24328.7ha) and mudflats (31089.06 ha) around its jurisdiction. The Port Authority has been very keen and dedicated in restoring the environmental quality of both the shore line and the coastal zone by implementing reliable modern technologies with the participation of the state and central government departments and the local people. Besides the legal mandates, the port authority itself has been implementing projects, time to time towards the conservation of the mangrove and other plants and protecting their coastal habitats and measures been taken to conserve and preserve mangroves within the DPA area, to retain the ecosystem services of mangroves. Accordingly, DPA has carried out mangrove plantation in 1400 ha between 2005 and 2019 through various implementing agencies at Sat Saida Bet and Nakti creek in Kandla and Kantiyajal in Bharuch district. The DPA has entrusted the task of evaluating the status of 1400 ha of mangrove plantation in these locations to the GUIDE, Bhuj. The detailed report on the mangrove plantation evaluation is submitted to the DPA time to time.

5 Study Area

5.1 Deendayal Port Environment

Deendayal Port in Kachchh District of Gujarat State (formerly Kandla Port Trust), operated by Deendayal Port Authority (DPA), is a gateway Port to the hinterland in the western and northern states of India. It is one of the 11 major Ports of India situated at 22°59'39.77’’ N latitude and; 70°13'20.14’’ E longitude on Kandla creek at Gulf of Kachchh. The inclusion of Karachi Port in Pakistan after India's partition and heavy traffic congestion at the then Bombay Port gave impetus for promoting Deendayal Port during the 1950s. In 1955, Deendayal Port acquired the status of a major Port in India. Because of its proximity to the Gulf countries. Large quantities of crude petroleum and other assorted cargo are imported through Deendayal Port.

The Port presently has 14 jetties, six oil terminals, and several allied facilities for handling dry and liquid cargo. Regular expansion/developmental activities such as the addition of jetties, allied Special Economic Zones (SEZ hereafter), industrial parks and ship bunkering facilities are underway to cope with the increasing cargo handling demands. Shri Mansukh Mandaviya, Minister of State for Ports, Shipping and Waterways (I/C) appreciated the efforts taken by Deendayal Port and added that it is indeed the major achievements in the challenging COVID times and it is significant indication that economy is bouncing back to achieve pre-COVID times. Major commodities handled by the Deendayal Port are Crude Oil, Petroleum product, Coal, Salt, Edible Oil, Fertilizer, Sugar, Timber, Soya bean, Wheat. This major achievement can be attributed to the user-friendly approach of port with the Shipping fraternity / stakeholders and constant consultations with them to improve Ease of Doing Business. An assortment of liquid and dry cargo is being handled at Deendayal Port. The dry cargo includes fertilizers, iron crap, steel, food grain, metal products, ores, cement, coal, machinery, sugar, wooden logs, salt extractions, etc. The liquid cargo includes edible oil, crude oil and other petroleum products. DPA created a new record by handling 127.10 million metric tonnes of cargo during FY 2021-22 compared to 117.566 MMT in FY 2020-21, with a growth of 8.11%. Incidentally, DPA is the only major Indian Port to handle more than 127 MMT cargo throughput, and it has also registered as the highest cargo throughput in its history. The Port has handled 3151 vessels during FY 2021-22 compared to 3095 vessels in FY 2019-20. While the Port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of Liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in September 2021.

Deendayal Port is a natural harbour located on the eastern bank of North-South trending Kandla creek at an aerial distance of 145 km from the Gulf's mouth. Being located at the inner end of the Gulf of Kachchh (GoK), Deendayal Port has a fragile marine ecosystem with a vast expanse of mangroves, mudflats, creek systems and allied biota. The Port location is marked by a network of major and minor mangrove-lined creek systems with a vast extent of mudflats. The coastal belt in and around the Port has an irregular and dissected configuration. Due to its location, the tidal amplitude varies, experiencing 6.66 m during Mean High-Water Spring (MHWS) and 0.78 m during Mean Low Water Spring (MLWS) with an MSL of 3.88 m. Commensurate with the increasing tidal amplitude, vast intertidal expanses are present in and around the Port environment. This, along with the occurrence of mudflats, enables mangrove formations at the intertidal belts. Annual rainfall during 2021 was 466 mm, which is often irregular (GWRDC, 2021). There are no perennial or seasonal rivers in Gandhidham taluka. Total rainy days during the monsoon season is limited to only 15-20 days and used to be erratic. Freshwater input into the near coastal waters is relatively meagre and appears to have less influence on the ambient coastal water quality except during monsoon months, during which freshwater through flash floods get discharged in the near coastal waters. The annual average humidity is 60%, which increases to 80% during the southwest monsoon (June to September) and decreases to 50% during November-December. The average wind speed is 4.65 m/s, with a maximum wind speed of 10.61 m/s during June. The drought phenomenon is common with two drought years in a cycle of 5 years. The annual mean maximum and minimum temperatures are 42.8°C and 21.3°C, respectively (Table 1).

The coastal belt in and around the Kandla region is characterized by a network of creek systems and mudflats covered by sparse halophytic vegetation, creek water and salt-encrusted land mass, which forms the major land forms. The surrounding environment in a radius of 10 km from the Port is mostly built-up areas consisting of salt works, human habitations and Port related structures on the west and north, creek system, mangrove formations and mudflats on the east and south. The Deendayal Port and its surroundings have mangroves, mudflats and creek systems as major ecological entities. Various ecosystem services provided by the mangrove ecosystem is depicted in Fig-2 (IUCN-2017).

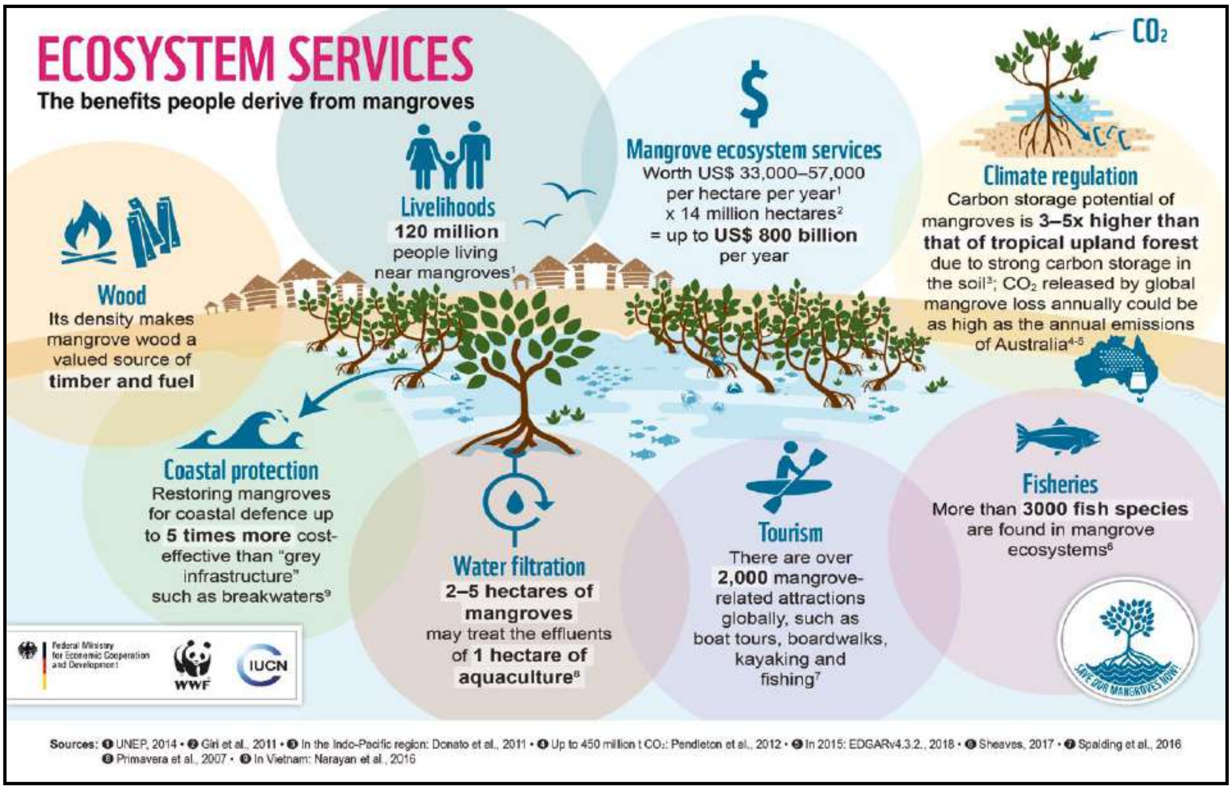

Figure 2. Schematic diagram of Ecosystem services of Mangroves (IUCN, 2017)

Table 1. Environmental setting of the Deendayal Port region

Sl. No.	Particulars	Details
1	Deendayal Port Co-ordinates	22° 59’39.77’ N, 70°13’20.14’’ E
2	Elevation above Mean Sea level	~20 ft
3	Climatic Conditions	As per Meteorological Station, Deendayal Port Annual Mean Max Temp: 42.8°C Annual Mean Min Temp: 21.3°C Rainfall: 466 mm (Annual mean 2021)
4	Land Use of nearby areas	Comparatively flat marshy land with stunted and dense mangrove formation, mudflats, creek systems, coastal halophytes, saltpans and salt swamps
5	Nearest Highway	National Highway 8A
6	Nearest Railway Station	Gandhidham RS
7	Nearest major airport	Bhuj (~60 km, NW)
8	Nearest Village habitation	Tuna (~12 km, North)
9	Nearest Major Town	Gandhidham (12 km, Northwest)
10	Reserved Forest	Nil
11	Historically Important Places	Nil
12	Rivers/streams around the project environs	Nil
13	Major Dams and barrages	Nil
14	Survey of India Topo sheet covering the proposed site and surroundings	41J1and 41I4
15	Seismic Zone	Zone –V

5.2 Details of plantation sites

The present study focused on the assessment of the present status of the mangrove at Sat Saida bet and Nakti creek in the Kandla (Kachchh) and Kantiyajal in the Bharuch district vicinity covering eight blocks occupying an area of 1300 ha, where plantation activities have been conducted during the period between 2005 and 2017. However, the present study (2021-2022) will also cover the additional 100 ha plantations carried out at Sat Saida bet (50 ha), and Kantiyajal (50 ha) during 2018 and 2019 with a total coverage area of 1400ha. The primary goal of this study is to assess the survival rate of mangrove plantations and the carbon sequestration potential of planted mangroves and suggest achievable conservation measures. The details of the mangrove plantation work carried out in a phased manner by the DPA is presented in Fig -3 & 4 and Table 2, 3 & 4.

Table 2. Details of the implemented mangrove plantation activities by DPA

Location	**Year of Plantation**	**Area (ha)**	**Species planted**	**Implementing Agency**
Sat Saida Bet, Kachchh district	2005-2006	20	*A. marina*	Gujarat Institute of Desert Ecology, Bhuj
	2011-2012	200	*A. marina*	Forest Department, GoG
	2012-2013	300	*A. marina*	Forest Department, GoG
	2013-2014	330	*A. marina*	Forest Department, GoG
	2018-2019	50	*A. marina*	Gujarat Ecology Commission
Nakti Creek, Kachchh district	2008-2009	50	*A. marina*	M/s. Patel Construction Co, Gandhidham
	2010-2011	100	*A. marina* *R. mucronata* *C. tagal*	Gujarat Ecology Commission
Kantiyajal, Bharuch District	2015-2016	150	*A. marina*	Gujarat Ecology Commission
	2016-2017	150	*A. marina* *R. mucronata*	Gujarat Ecology Commission
	2018-2019	50	*A. marina*	Gujarat Ecology Commission
Total		**1400**		

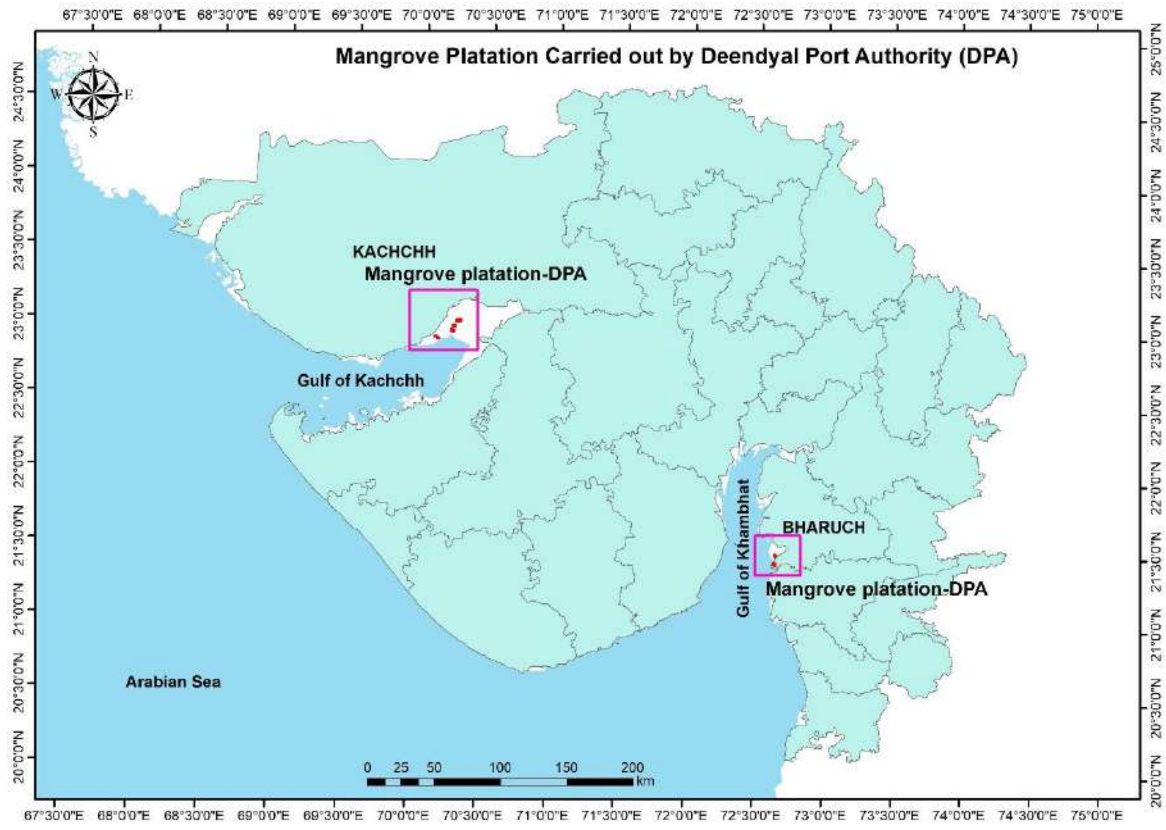

Figure 3. Mangrove plantation carried out by DPA at Kantiyajal and in the Gulf of Kachchh

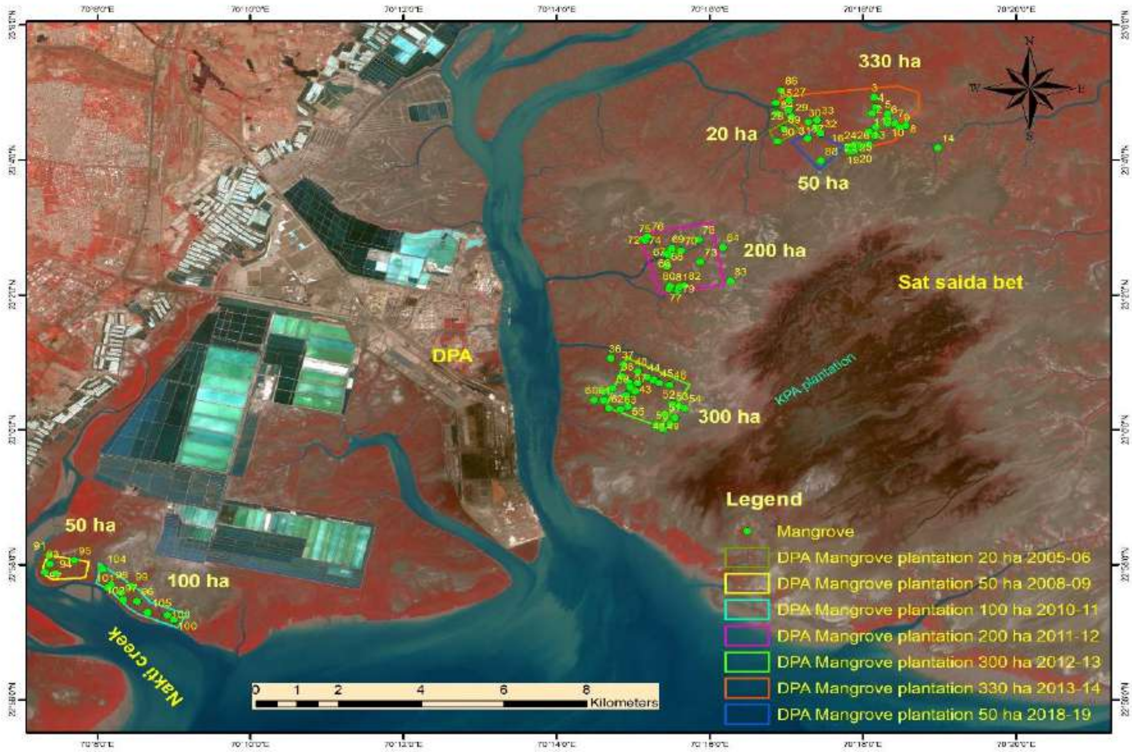

Figure 4. Location of Mangrove Plantation sites at Sat Saida Bet and Natki creek

5.3 Regular mapping through GIS & RS

Mangrove plantations in 1400 ha was regularly monitored and mapped using RS and GIS facilities as part of the conservation and management efforts. The difference in mangrove density was assessed through ArcGIS (version 9.3) and ERDAS (version 9.3) and areas having restoration priority was identified for plantation activity.

5.4 Land use/ Land cover

From April, 2017 to March, 2022 within the span of 5 years the overall mangrove area increased from 19319 ha to 24328 ha (43.7%) (Table-5). Most of the mudflat area converted to Mangrove area, and hence a decreasing trend of the mudflat is clearly observed. Good monsoon and favorable environmental conditions have positively impacted the mangroves to flourish (Saravanakumar *et. al.*, 2008, Das *et. al* 2019). The Figure -5 and 6 clearly depicts the year wise increase in mangrove area in the DPA vicinity and at present 24% of the total area is covered by mangroves.

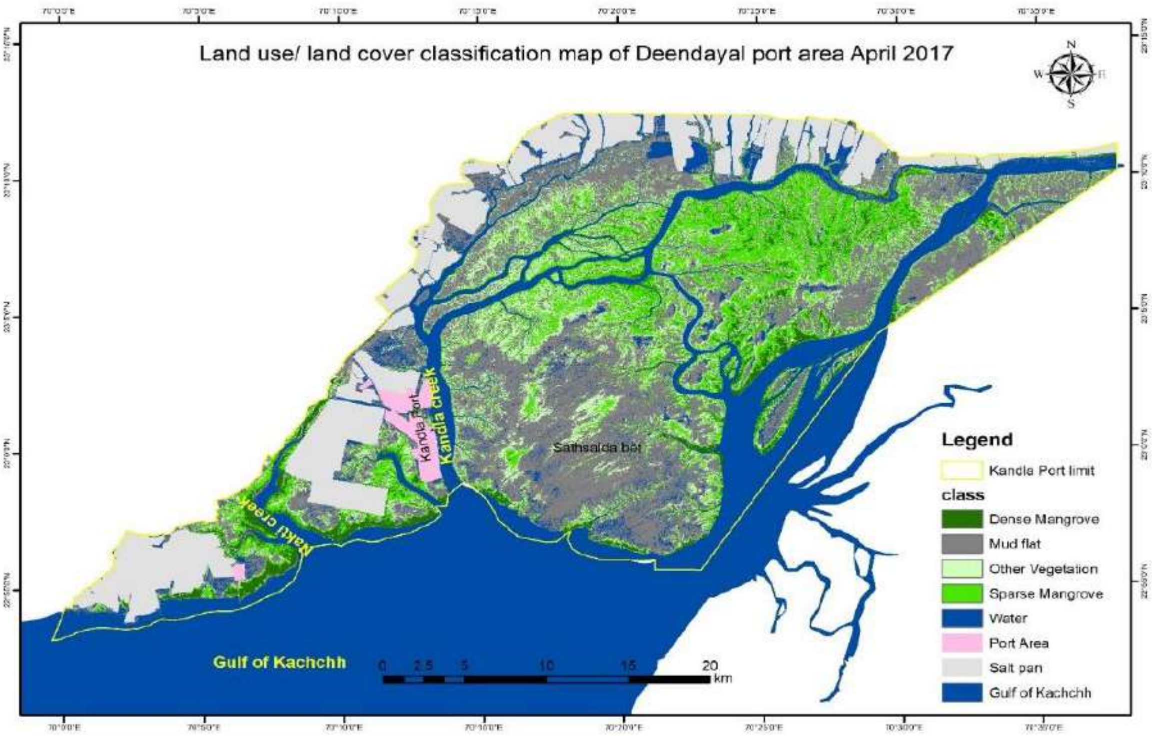

Figure 5. Land use/Land cover classification in Deendayal port area – (April 2017)

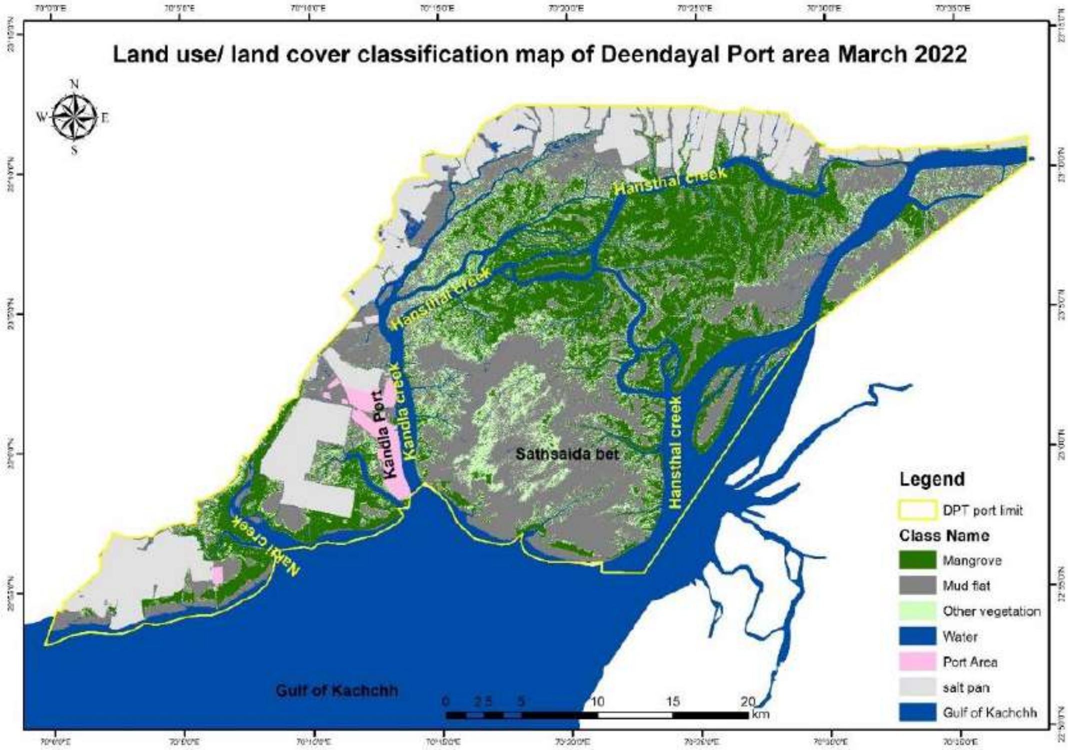

Figure 6. Land use/ land cover classification map of DPA (March-2022)

Table 3. Land use /land cover statistics in the DPA area for April-2017 and March-2022

Class name	**Area (ha) in 2017**	**Area(ha) in 2022**	**Area (ha) difference in 5 years**	**Percentage (%)**
Mangrove	19319.71	24328.7	+5009	+43.7
Mudflat	31293.43	31089.06	-204.37	-1.8
Other vegetation	12438.8	11561.2	-877.6	-7.7
Port Area	1243.67	1436.75	+193.08	+1.7
Salt pan	15016.1	15545.7	+529.6	+4.6
Water bodies	20674.3	16024.6	-4649.7	-40.6
Total	**99986.01**	**99986.01**	**11463.35**	**100**

5.5 Mangrove plantation at Nakti creek (150 ha)

A total of 150 ha of mangrove plantation was carried out in Nakti creek with two blocks with an area of 100 ha and 50 ha, by two agencies; M/s. Patel Construction Co, Gandhidham (2008-09) (Fig.6,7 & Table 4) and Gujarat Ecology Commission (2010-11), respectively. The plantation was carried out using three different techniques like transplantation of nursery raised saplings, *otla* bed, and direct seed dibbling methods. For the 50ha block in Nakti creek, *A. marina* was planted (Table 6). In the second block (other side of Nakti creek) *Ceriops tagal* was also sown. In the third block, located on the eastern side of the second block, seeds of *A. marina* were sown. The fourth block plantation was done alongside the minor creek system along the bund and road, where propagules of *Rhizophora mucronata* and *Ceriops tagal* were planted in the 100ha (Table 5). The mangrove plant density at the 100 Ha and 50 Ha plot was found increased from 2007 as deduced from the imageries as shown in Figure 8 and 11.

Table 4. Sampling location of Nakti Creek (150 ha)

Block Area covered	**Quadrate no.**	**Latitude**	**Longitude**
100ha	1	22°58’8.09”	70°7.’ 22.34”
	2	22°57’53.06”	70°7.’ 18.92”
	3	22°58’0.58”	70°7.’ 22.43”
	4	22°57’51.90”	70°7.’ 27.09”
	5	22°58’3.87”	70°7.’ 42.02”
	6	22°57’27.48”	70°8.’ 30.93”
	7	22°57’35.06”	70°8.’ 18.55”
	8	22°57’42.10”	70°8.’ 10.82”
	9	22°57’40.82”	70°8.’ 26.84”
	10	22°57’11.00”	70°8.’ 59.69”
50ha	1	22°57’39.35”	70°8.’ 8.05”
	2	22°57’28.36”	70°8.’ 20.38”
	3	22°57’15.00”	70°8.’ 54.57”
	4	22°57’56.23”	70°8.’ 4.12”
	5	22°57’17.46”	70°8.’ 39.60”

Table 5. *A marina* plantation (2010-2011) in 100 ha at Nakti creek

S. No.	Sampling Location		Density (Ha)	Height (cm)	St. Dev
Q1	22˚ 57 50.0 N	70˚ 09 40.8 E	1200	55.3	14.7
Q2	22 ˚57 47.8 N	70˚ 09 42.4 E	2000	67.1	21.04
Q3	22 ˚57 46.1N	70 ˚09 42.8E	1200	70.1	29.3
Q4	22˚ 57 42.4N	70 ˚09 44.3E	2000	80.1	41.4
Q5	22˚ 57 41.6N	70˚ 09 46.2E	3200	90.9	28.3
Q6	22˚57 31.1N	70˚ 09 49.6E	2700	90.9	23.4
Q7	22˚57 39.8 N	70˚ 09 48.8E	3400	82.8	19.9
Q8	22˚57 38.6 N	70 ˚09 51.2E	3500	88.9	20.6
Q9	22˚57 38.2N	70 09 54.5 E	2500	115.9	28.2
Q10	22˚57 37.5 N	70 09 52.9 E	2000	99.5	17.8
Average			**2370**	**84**	**--**

Figure 7. Mangrove plantation 100 ha at Nakti creek during 2017-2018

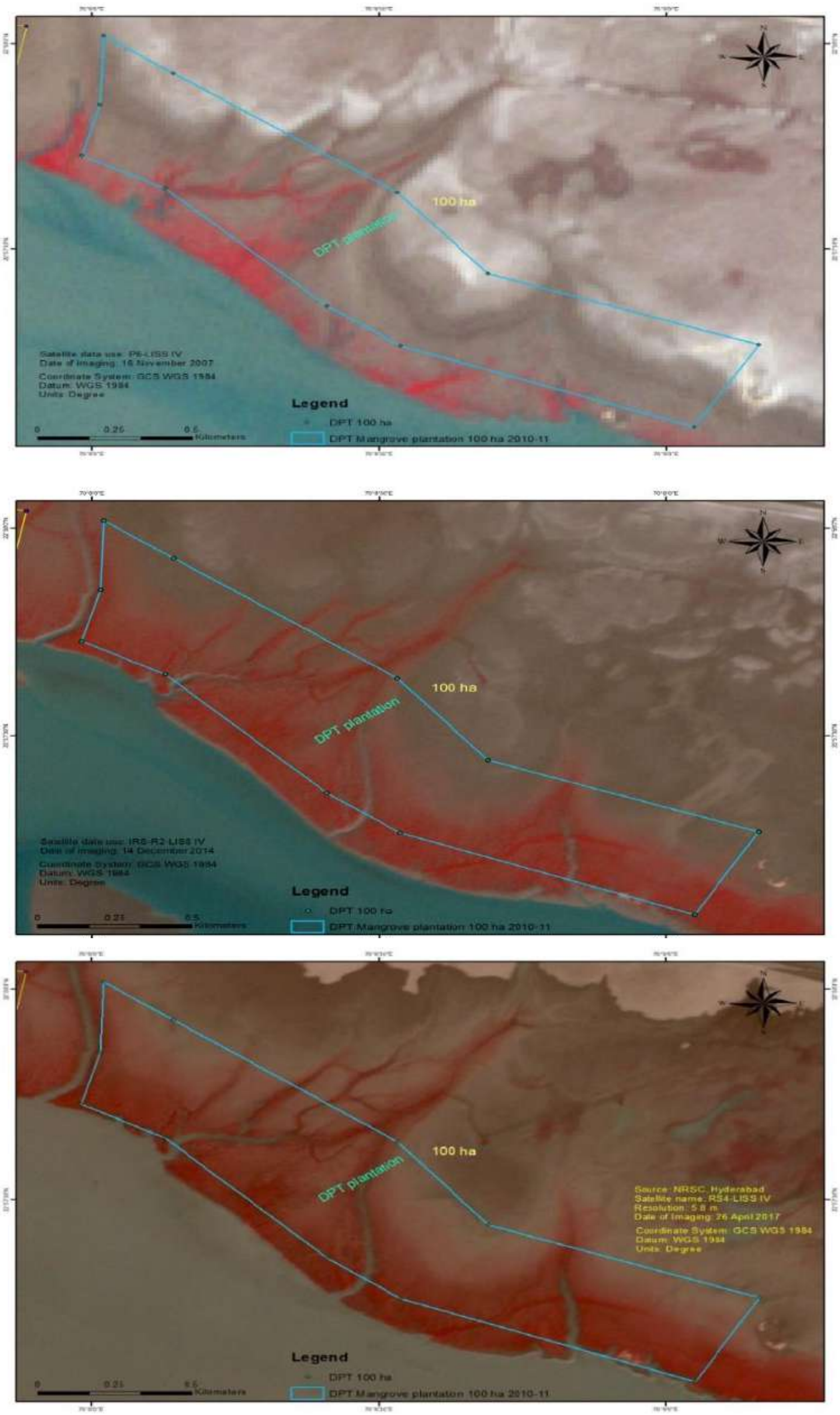

Figure 8. Satellite images of mangrove plantation at Nakti creek (2007,2014 & 2018).

Table 6. *A marina* plantation (2008-2009) in 50 ha at Nakti creek

Sl. No.	Sampling Location		Density (Ha)	Height (cm)	St. Dev
Q1	22° 57' 12. 9N	70° 09' 04.9 E	3000	53.8	19.6
Q2	22°57' 11.6 N	70° 09'04.5 E	3000	64.8	18.4
Q3	22°57'10.9 N	70°09' 04.7 E	2400	70.5	24.0
Q4	22°57'10.3 N	70°09' 05.4 E	2800	65.8	19.2
Q5	22°57'09.6 N	70°09'06.2 E	2500	63.0	15.9
Q6	22°57'09.1 N	70°09'07.2 E	2700	60.2	15.2
Q7	22°57'09.1 N	70°09'08.2 E	2500	40.9	15.6
Q8	22°57'09.2 N	70°09'08.4 E	0	0.0	0.0
Q9	22°57'08.1 N	70°09'10.0 E	2700	54.1	15.6
Q10	22°57'07.7 N	70°09'10.3 E	1800	60.9	24.6
Average			**2340**	**53**	**--**

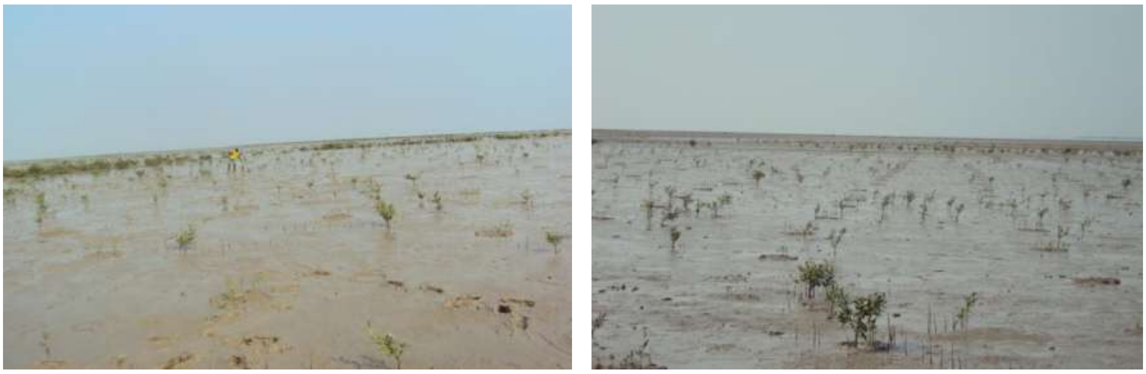

Figure 9. Mangrove plantation 50 ha at Nakti creek during 2008-2009

Figure 10. Mangrove plantation 50 ha at Nakti creek during 2017-2018

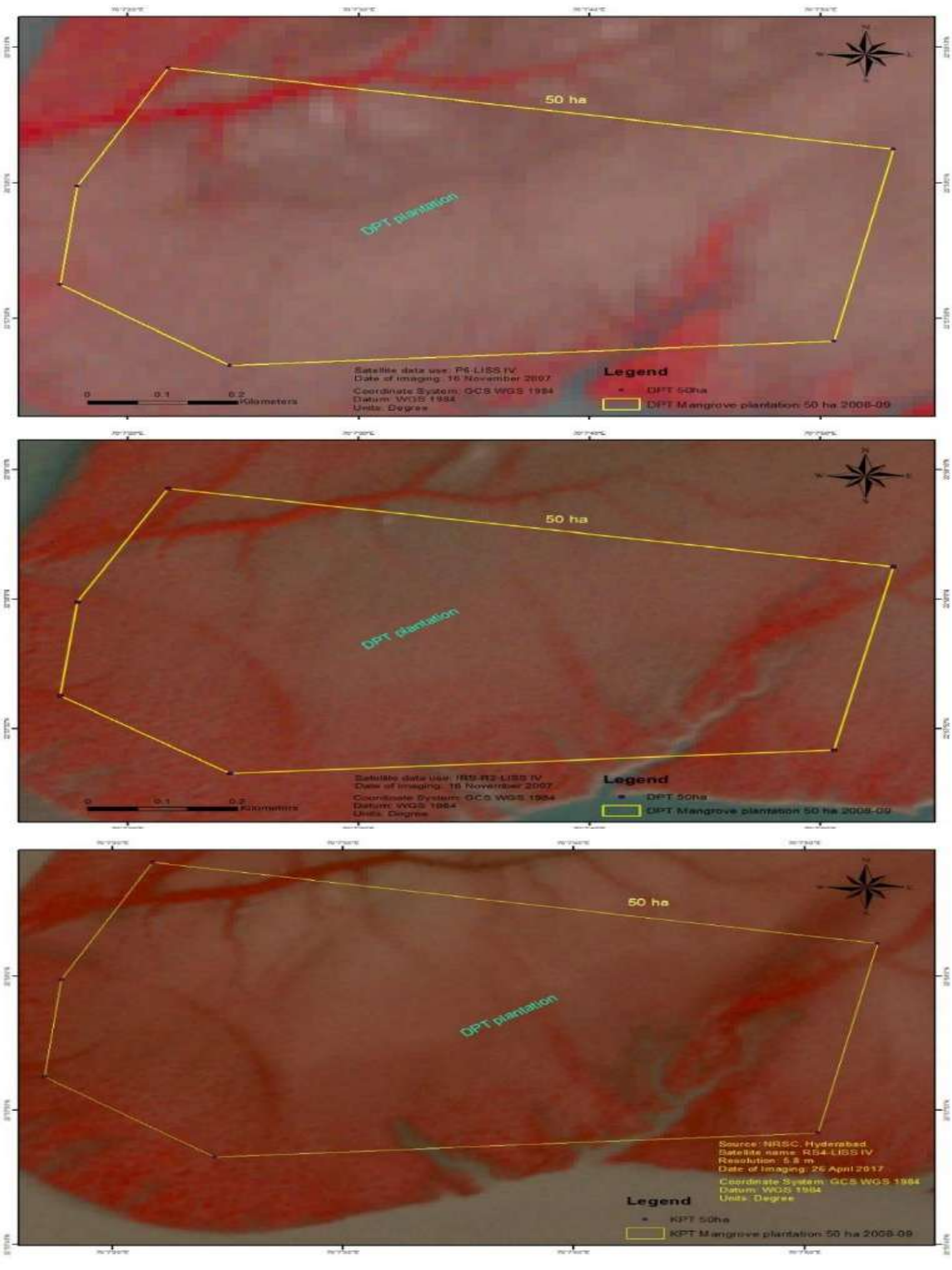

Figure 11 Satellite images of 50 ha mangrove plantation at Nakti creek during the years 2007,2014 & 2018.

5.6 Plantation at Kantiyajal (350 ha)

The plantation site at Kantiyajal has naturally growing *A. marina* extending from the lower littoral to the mid-littoral zone. The plantation site is located near (N 21°27'01.1'', to 21°26'54. 24'' and E 72°40'36.04, to 72°38'58.22'') to this luxuriantly growing mangrove patch. The site is behind the naturally growing plants away from the waterline; however, everyday tidal flushing keeps this site relatively healthy. The total 350 ha mangrove plantation was conducted in separate blocks, like 150 ha each during 2015-2016 and 2016-2017 and 50ha during 2018-2019 at Kantiyajal (Fig-12,15 & 16). Of the total 150 ha, 70 ha plantation activities were carried out following nursery raised saplings and the remaining 80 ha area by *Otla* beds of 1 x 1 x 1 m prepared to improve mangrove density. *A. marina* saplings were transplanted at a distance of 2.5 x 2 m. In total, 32,000 such beds were prepared in the 80 ha (Table 7,8 & 9). All plantation activities were taken care of by Gujarat Ecology Commission. *A. marina* was the preferred species for plantation in both blocks. The Figures 15 and 16 explains the sparse distribution of the plants as well as their stunted growth on the monitored plots.

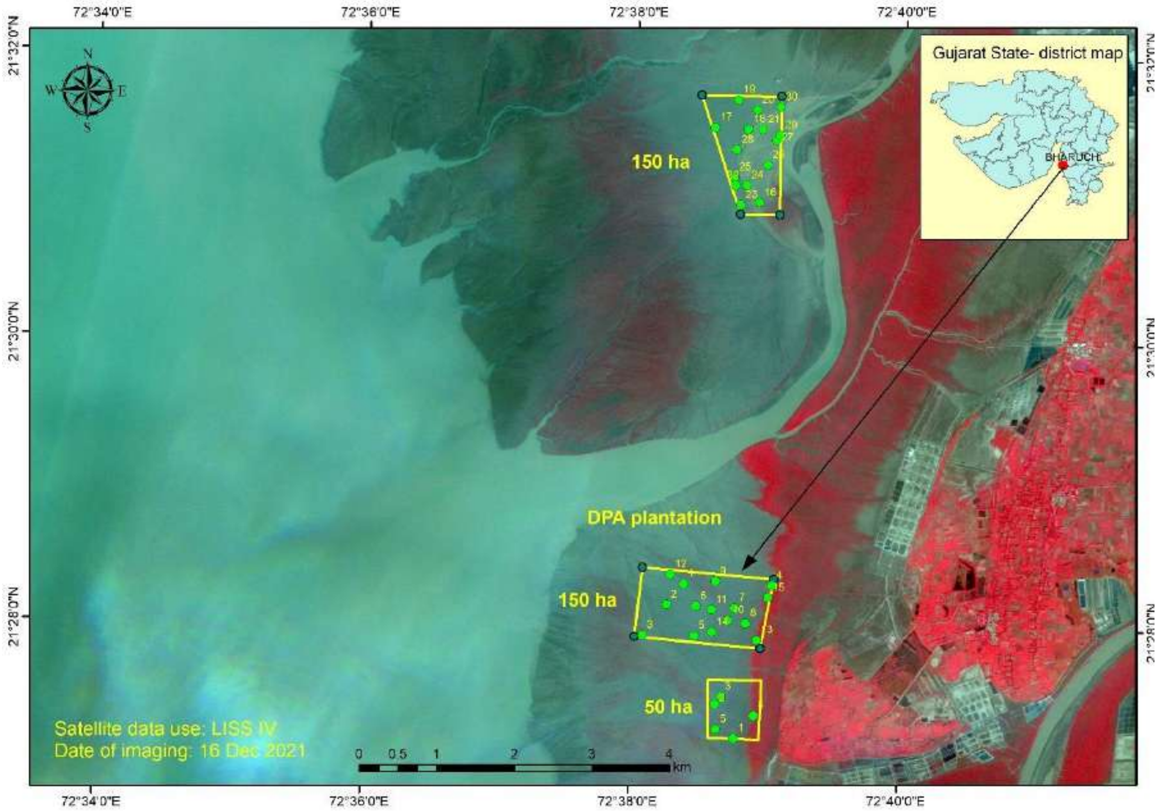

Figure 12. Mangrove plantation at Kantiyajal (350 ha)

Table 7. Sampling location of Kantiyajal (350 ha)

Block area covered	**Quadrate no.**	**Latitude**	**Longitude**
150ha	1	21°28’17.76”	72°38’24.00”
	2	21°28’9.12”	72°38’16.08”
	3	21°27’56.16”	72°38’5.64”
	4	21°28’17.76”	72°39’3.24”
	5	21°27’56.16”	72°38’28.68”
	6	21°28’8.76”	72°38’29.40”
	7	21°28’8.04”	72°38’46.68”
	8	21°28’1.56”	72°38’51.72”
	9	21°28’19.20”	72°38’38.04”
	10	21°28’3.00”	72°38’43.80”
	11	21°28’7.32”	72°38’36.24”
	12	21°28’21.72”	72°38’17.88”
	13	21°27’54.72”	72°38’56.76”
	14	27’57.96”	72°38’36.60”
	15	21°28’12.72”	72°39’1.44”
Block area covered	**Quadrate no.**	**Latitude**	**Longitude**
150 ha	1	21°30’58.68”	72°38’55.32”
	2	21°31’30.00”	72°38’35.16”
	3	21°31’29.64”	72°38’49.92”
	4	21°31’41.88”	72°38’45.24”
	5	21°31’37.56”	72°38’53.52”
	6	21°31’29.64”	72°38’56.40”
	7	21°31’5.88”	72°38’44.52”
	8	21°30’57.60”	72°38’46.68”
	9	21°31’5.88”	72°38’49.56”
	10	21°31’9.12”	72°38’43.80”
	11	21°31’14.52”	72°38’58.92”
	12	21°31’24.96”	72°39’2.52”
	13	21°31’20.64”	72°38’44.88”
	14	21°31’27.12”	72°39’4.32”
	15	21°31’39.00”	72°39’4.32”
Block area covered	**Quadrate no.**	**Latitude**	**Longitude**
50ha	1	21°27’13.32”	72°38’47.04”
	2	21°27’27.36”	72°38’38.40”
	3	21°27’30.60”	72°38’40.92”
	4	21°27’22.68”	72°38’56.04”
	5	21°27’16.92”	72°38’39.12”

Table 8 Mangrove plantation (2015-2016) in 150 ha at Kantiyajal

A. marina					
Sl. No.	**Sampling Location**		**Density (Ha)**	**Height (cm)**	**St. Dev**
Q1	21˚ 28’5.2″ N	72˚ 38’57.0" E	2000	29.8	9.0
Q2	21˚ 28’ 22.19" N	72˚38` 12. 43"	2200	42.4	10.9
Q3	21 ˚28’14.73"N	72˚38`52. 97"	1900	41.1	13.9
Q4	21˚28’05.00"N	72˚ 38`58. 66"	1000	38.1	7.1
Q5	21˚28’56.68"N	72˚ 38`50.88"	0	0.0	0.0
Q6	21˚28’59. 18" N	72˚38`28.70"	1600	40.9	11.6
Q7	21˚28’15.05"N	72˚38`32.30"	1900	36.0	11.3
Q8	21˚28’17.86"N	72˚38`39. 86"	0	0.0	0.0
Q9	21˚28’18.73"N	72˚38`50.30"	2200	44.2	12.0
Q10	21˚28’00.43"N	72˚38` 08.02"	1800	45.8	9.7
Average			**1460**	**32**	**--**
R. mucronate					
Sl. No.	**Sampling Location**		**Density (Ha)**	**Height (cm)**	**St. Dev**
Q1	21˚ 28’ 20.93″ N	72˚ 38’ 22.20″E	1700	32.5	7.4
Q2	21˚ 28’16.56″ N	72˚ 38’27.88″E	1400	41.4	4.5
Q3	21˚ 28’19.69″ N	72˚ 38’11.96″E	0	0.0	0.0
Q4	21˚ 28’9.32″ N	72˚ 38’7.73″ E	700	39.4	7.4
Q5	21˚ 28’19.73″ N	72˚ 38’57.43″E	0	0.0	0.0
Q6	21˚ 28’11.18" N	72˚ 38’5.68″E	400	36.0	2.0
Q7	21˚ 28’5.26″ N	72˚ 38’4.07″E	300	26.0	1.8
Q8	21˚ 28’8.12″ N	72˚ 38’57.79″E	0	0.0	0.0
Q9	21˚ 28’23.34″ N	72˚ 38’48.32″E	800	45.6	8.6
Q10	21˚ 28’17.6″ N	72˚ 38’40.84″E	800	48.4	13.0
Q11	21°31'7.25"N	72°38'44.82"E	2800	40.6	11.5
Q12	21°31'6.76"N	72°38'52.51"E	2300	43.4	10.4
Q13	21°31'3.83"N	72°38'49.30"E	0	0.0	0.0
Q14	21°31'0.54"N	72°38'45.11"E	2200	35.9	6.8
Q15	21°31'0.58"N	72°38'39.17"E	2600	42.4	8.7
Q16	21°31'1.28"N	72°38'33.98"E	0	0.0	0.0
Q17	21°31'5.42"N	72°38'33.96"E	2300	44.9	9.8
Q18	21°31'7.28"N	72°38'38.40"E	2800	39.4	11.5
Q19	21°31'7.10"N	72°38'42.80"E	2400	42.7	12.7
Q20	21°31'3.75"N	72°38'44.30"E	2100	44.8	12.9
Average			**1280.0**	**30**	**--**

Table 9. *A marina* (2016-2017) in 150 ha at Kantiyajal

Sl. No.	Sampling Location		Density (Ha)	Height (cm)	St. Dev
Q1	21˚ 30 58.13″ N	72˚ 38 59.38″ E	2600	44.4	13.9
Q2	21˚ 31 0.49″ N	72˚ 38 48.24″ E	2200	41.9	12.7
Q3	21˚ 31 11.8″ N	72˚ 38 41.61″ E	2300	42.9	14.7
Q4	21˚ 31 15.00″ N	72˚ 38 49.07″ E	3000	44.0	9.2
Q5	21˚ 31 26.22″ N	72˚ 38 46.59″ E	2800	37.3	11.8
Q6	21˚ 31 25.92″ N	72˚ 38 53.85″ E	0	0.0	0.0
Q7	21˚ 31 35.09″ N	72˚ 38 5.04″ E	2100	42.1	12.2
Q8	21˚ 3113.63″ N	72˚ 38 58.43″ E	2400	40.5	12.0
Q9	21˚ 31 5.94″ N	72˚38 53.41″ E	2500	41.2	10.4
Q10	21˚ 31 41.71″ N	72˚ 38 34.34″ E	2300	40.0	10.9
Average			**2220.0**	**37**	**--**

Figure 13. Mangrove plantation 150 ha at Kantiyajal-Block 1 during 2018

Figure 14. Mangrove plantation 150 ha at Kantiyajal-Block 2 during 2018

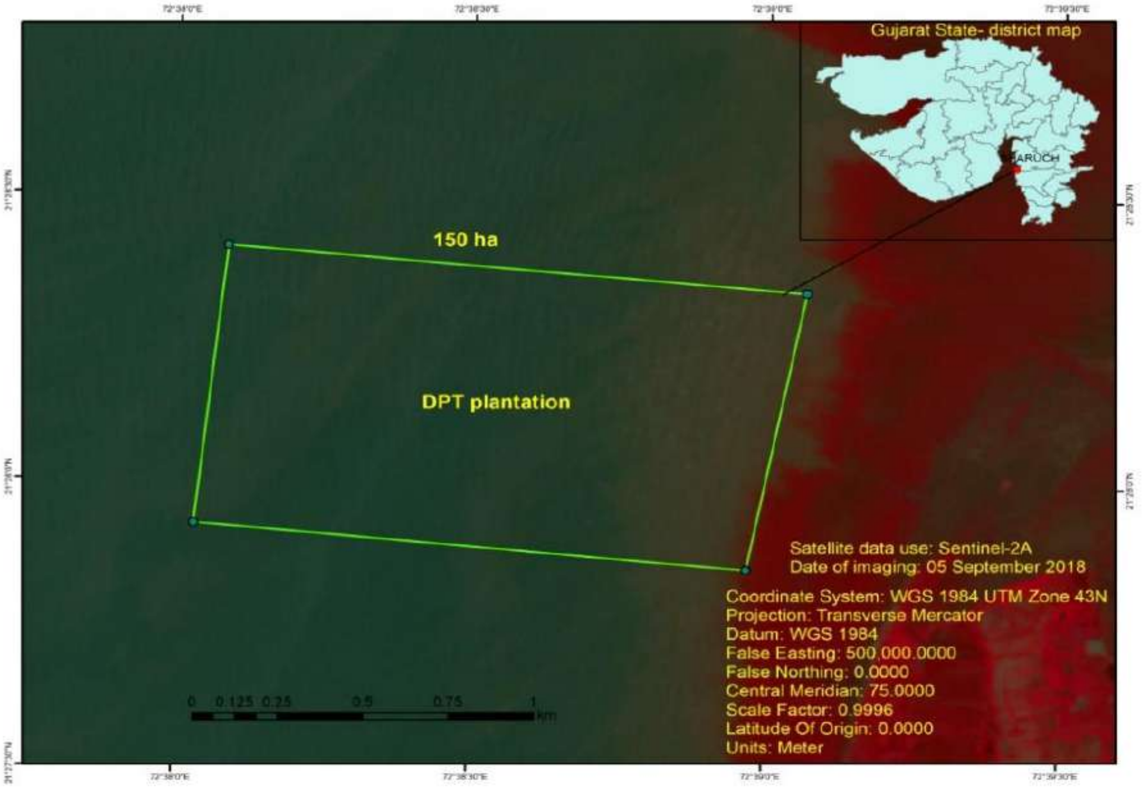

Figure 15. Satellite imageries of the plantation at Kantiyajal-block 1 (2018)

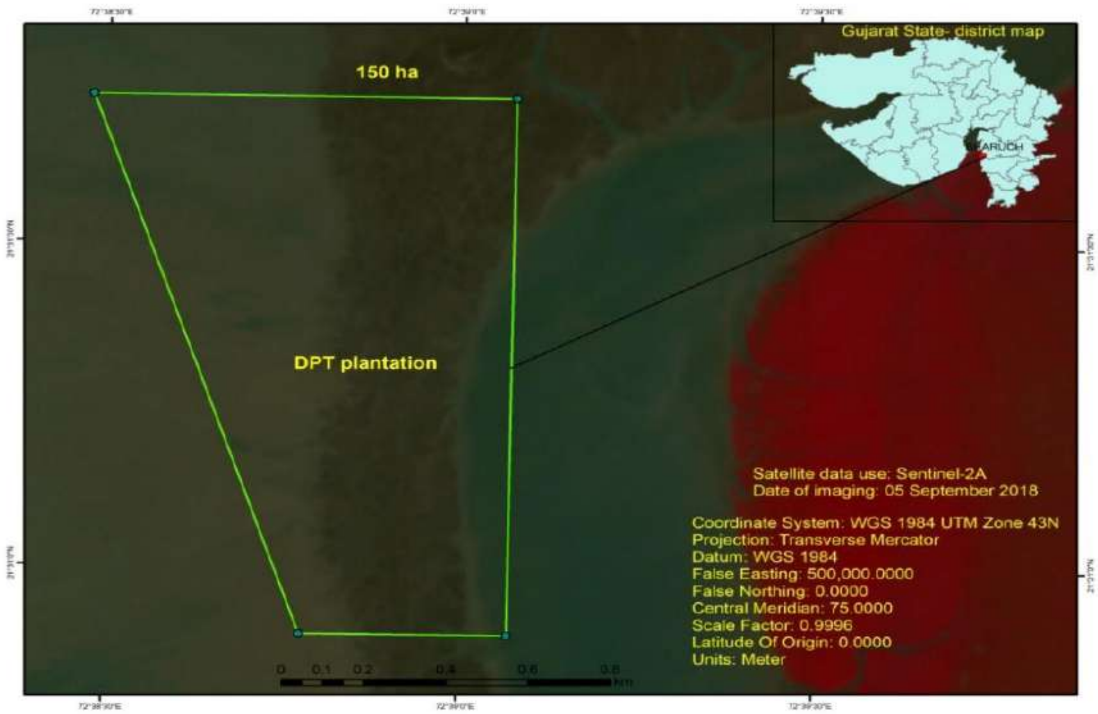

Figure 16. Satellite imageries of the plantation at Kantiyajal-block 2 (2018)

5.7 Plantation at Sat Saida bet (900 ha)

A total of 900 ha of mangrove assessment were carried out in Sat Saida bet with five blocks mentioned in Table 10 and 11 with an area of 330ha, 300 ha, 200 ha, 20 ha and 50ha by Gujarat institute of desert ecology (2005-2006), Department of Forest, Government of Gujarat (2011-2014), and Gujarat Ecology Commission during (2018-2019) the period between 2005 and 2019respectively. Sat Saida bet is situated on the eastern bank of Kandla creek of Gulf of Kachchh, the unique Island of 253.8 km^2 area is located opposite to Deendayal port, having sparse mangroves, dense mangroves, mudflats and halophytic vegetation. Surrounded by Kandla creek and its branches in the west, Navlakhi creek and its branches on the east and Sara and Phang creek on its north, Sat Saida bet is a highly potential site for mangrove plantation with its vast mudflat. Many major, medium and minor creek systems of Kandla and Navlakhi creeks ramify into this Island in varying length and dimension, supplying tidal water to the interior regions. Southern border of the Island represents the innermost end of Gulf of Kachchh with very few minor creek systems (Fig. 18,20,22 & 24). It is known that mudflats experiencing favourable tidal amplitude are suitable for mangrove plantation. Therefore, Sat Saida Bet area was chosen by DPA to carry out the mangrove plantation and restoration activities. The details showing five years (2017-2022) change in the land cover area is given in Table 12,13,14 & 15. The present study was conducted to evaluate the plantation success including the percentage of survival rate, growth, and tree density. The baseline density was fixed at the rate of 4000/ha of *A. marina* was considered for calculating survival percentage as per GEC (2015-2017). The year wise analysis of the imageries of the sites at Sat Saida Bet clearly shows the increase in the plant density at 20 Ha, 300 Ha and 330 Ha, though the survival and height of the plants are comparatively less. Whereas, at 200 Ha plantation site, the plant density has been decreased than the previous monitoring period (2018).

Table 10. Sampling locations at Sat Saida Bet (630 ha)

Block Area covered	Quadrate no.	Latitude	Longitude	Block Area covered	Quadrate no.	Latitude	Longitude
330 ha.	**1**	23°4'25"	70°18'4"	**300 ha.**	**1**	23°0'44"	70°15'16"
	2	23°4'41"	70°18'6"		**2**	23°0'42"	70°15'20"
	3	23°4'55"	70°18'8"		**3**	23° 1'3"	70°14'42"
	4	23°4'46"	70°18'10"		**4**	23° 0'57"	70°14'52"
	5	23°4'40"	70°18'19"		**5**	23° 0'47"	70°14'50"
	6	23°4'36"	70°18'18"		**6**	23° 0'42"	70°14'56"
	7	23°4'32"	70°18'24"		**7**	23° 0'51"	70°15'3"
	8	23°4'30"	70°18'33"		**8**	23° 0'38"	70°14'57"
	9	23°4'29"	70°18'28"		**9**	23° 0'41"	70°15'3"
	10	23°4'32"	70°18'19"		**10**	23° 0'34"	70°15'1"
	11	23°4'29"	70°18'10"		**11**	23° 0'46"	70°15'10"
	12	23°4'21"	70°18'9"		**12**	23° 0'41"	70°15'20"
	13	23°4'13"	70°18'4"		**13**	23° 0'39"	70°15'28"
	14	23°4'10"	70°18'58"		**14**	23° 0'10"	70°15'32"
	15	23°4'12"	70°17'49"		**15**	23° 0'5"	70°15'28"
	16	23°4'11"	70°17'48"		**16**	23° 0'0"	70°15'22"
	17	23°4'8"	70°17'49"		**17**	23° 0'4"	70°15'17"
	18	23°4'7"	70°17'51"		**18**	23° 0'13"	70°15'24"
	19	23°4'8"	70°17'52"		**19**	23° 0'22"	70°15'30"
	20	23°4'9"	70°17'54"		**20**	23° 0'21"	70°15'35"
	21	23°4'11"	70°17'57"		**21**	23° 0'19"	70°15'40"
	22	23°4'11"	70°17'59"		**22**	23° 0'20"	70°14'55"
	23	23°4'12"	70°17'59"		**23**	23° 0'30"	70°14'54"
	24	23°4'13"	70°17'57"		**24**	23° 0'37"	70°14'57"
	25	23°4'14"	70°17'54"		**25**	23° 0'36"	70°14'43"
	26	23°4'13"	70°17'52"		**26**	23° 0'33"	70°14'36"
	27	23° 4'53"	70°17'2"		**27**	23° 0'26"	70°14'29"
	28	23° 4'43"	70°17'1"		**28**	23° 0'26"	70°14'36"
	29	23° 4'38"	70°17'3"		**29**	23° 0'18"	70°14'40"
	30	23° 4'33"	70°17'16"		**30**	23° 0'18"	70°14'49"
	31	23° 4'28"	70°17'22"				
	32	23° 4'23"	70°17'26"				
	33	23° 4'35"	70°17'24"				

Table 11. Sampling location of Sat Saida Bet (270 ha)

Block Area covered	Quad rate no.	Latitude	Longitude	Block Area covered	Quadrate no.	Latitude	Longitude
200 ha.	**1**	23°2'42"	70°16'10"	**50 ha.**	**1**	23° 4'41.24"	70°16'52.19"
	2	23°2'35"	70°15'28"		**2**	23° 4'50.78"	70°16'51.53"
	3	23°2'36"	70°15'26"		**3**	23° 5'1.73"	70°16'55.65"
	4	23°2'39"	70°15'29"		**4**	23° 4'19.15"	70°17'16.46"
	5	23° 2'25.36"	70°15'26.37"		**5**	23° 3'59.06"	70°17'27.14"
	6	23°2'41"	70°15'30"				
	7	23° 2'39.21"	70°15'37.25"	**20 ha.**	**1**	23° 4'27.43"	70°16'58.03"
	8	23°2'48"	70°15'8"		**2**	23° 4'16.41"	70°16'53.03"
	9	23°2'48"	70°15'9"				
	10	23° 2'29.30"	70°15'52.53"				
	11	23°2'51"	70°15'9"				
	12	23°2'50"	70°15'8"				
	13	23°2'52"	70°15'11"				
	14	23°2'5"	70°15'28"				
	15	23° 2'48.85"	70°15'50.81"				
	16	23°2'4"	70°15'35"				
	17	23° 2'7.74"	70°15'28.60"				
	18	23°2'7"	70°15'36"				
	19	23°2'8"	70°15'40"				
	20	23°2'12"	70°16'16"				

Table 12. *Avicennia marina* plantation (2005-2006) in 20 ha at Sat Saida bet

Sl. No.	Sampling Location		Density (Ha)	Height (cm)	St. Dev
Q1	23˚ 04" 43.38N	70˚ 16"47.88E	4400	109	28.34
Q2	23˚ 04" 48.18N	70˚ 16"48.18E	4900	115	24.7
Q3	23˚ 04" 43.77N	70˚ 16"48.41E	5600	110	26.2
Q4	23˚ 04" 44.38N	70˚ 16"47.99E	5700	110	27.7
Q5	23˚ 04" 44.10N	70˚ 16"48.18E	5100	124	29.2
Q6	23˚ 04" 48.17N	70˚ 16"48.17E	4900	135	30.7
Q7	23˚ 04" 44.37N	70˚ 16"48.99E	5300	103	32.2
Q8	23˚ 04" 43.49N	70˚ 16"48.69E	5300	100	34.44
Q9	23˚ 04" 44.14N	70˚ 16"48.93E	6100	121	35.2
Q10	23˚ 04" 44.99N	70˚ 16"47.63E	5200	104	36.7
Q11	23˚ 04" 43.07N	70˚ 16"49.06E	4900	136	29.2
Q12	23˚ 04" 43.85N	70˚ 16"49.88E	5200	105	28.22
Q13	23˚ 04" 44.61N	70˚ 16"48.75E	6100	102	32.15
Q14	23˚ 04" 43.53N	70˚ 16"49.25E	6300	110	33.22
Q15	23˚ 04" 44.04N	70˚ 16"50.02E	5800	110	31.2
Average			**5387**	**113**	**--**

Figure 17. Mangrove plantation at Sat Saida bet 20 ha during 2005-2006

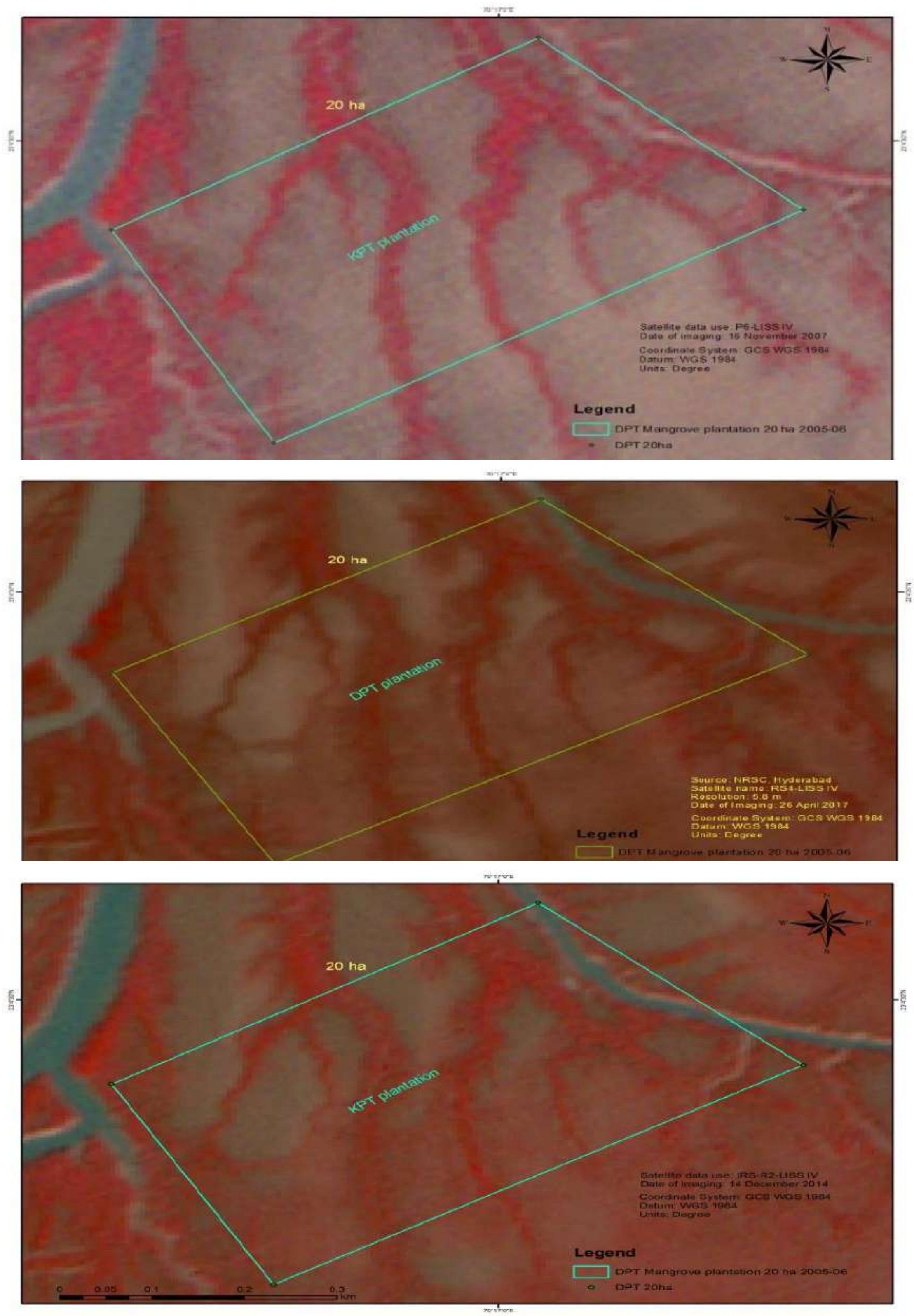

Figure 18. Satellite imageries of the plantation at Sat Saida Bet (2005-2006, 2014 & 2018)

Table 13. *Avicennia marina* plantation (2011-2012) in 200 ha at Sat Saida bet

Sl. No.	Sampling Location		Density (Ha)	Height (cm)	St. Dev
Q1	23˚ 00” 48.4N	70˚ 15”49.5E	3000	33.6	9.6
Q2	23˚ 00” 50.5˚ N	70˚ 15” 50.0 E	0	0	0
Q3	23˚ 00 ”53.1˚ N	70˚15” 49.2 E	2700	55.9	9.5
Q4	23˚ 00 ”50.9˚ N	70˚ 15” 47.2 E	3300	31.8	14.9
Q5	23˚ 00 ”50.1˚ N	70˚15” 45.4 E	3500	43.7	14
Q6	23˚ 00 ”49˚ N	70˚15” 43.5 E	3500	53.5	16.6
Q7	23˚ 00” 49.3˚ N	70˚15” 41.3 E	3500	58.8	26.5
Q8	23˚ 00” 51.4˚ N	70˚15” 42E	1700	47.9	18.7
Q9	23˚ 00” 76.9˚ N	70˚13”.50 E	4000	52.7	18.9
Q10	23˚ 00 ”52.2˚ N	70˚15” 37.9E	4600	53.6	24
Q11	23˚ 00” 51.7˚ N	70˚15” 35.6E	2100	69.9	22.1
Q12	23˚ 00 ”52.4N	70˚15” 34.4E	2600	52.7	19.6
Q13	23˚ 00 ”53.2˚ N	70˚15” 33.3E	3500	63.4	19.2
Q14	23˚ 00” 55.1˚ N	70˚15” 32.4 E	4000	57.6	18.9
Q15	23˚ 00” 57.2˚ N	70˚15” 33.4 E	2500	40.8	15.7
Q16	23˚ 00 ”57.9˚ N	70˚15 ”35.6 E	0	0	0
Q17	23˚ 00” 3.6˚ N	70˚15” 35.6 E	500	46.6	14.9
Average			**2647**	**45**	**--**

Figure 19. Mangrove plantation 200 ha at Sat Saida bet during 2017-2018

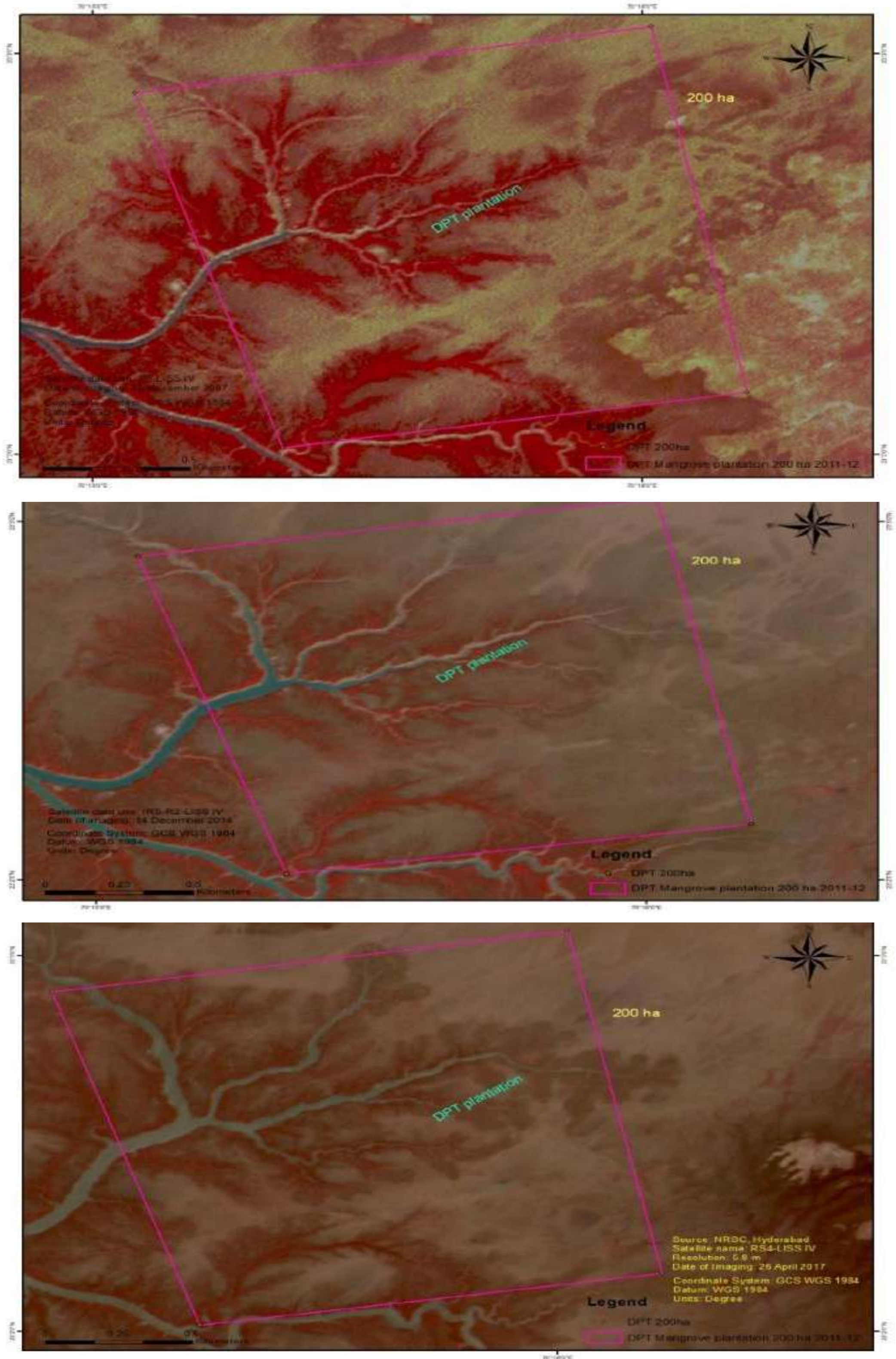

Figure 20 . Satellite imageries of the plantation at Sat Saida Bet (2007, 2014 & 2018)

Table 14. *Avicennia marina* plantation (2012-2013) in 300 ha at Sat Saida bet

Sl. No.	Sampling Location		Density (Ha)	Height (cm)	St. Dev
Q1	23˚02.06604 N	70˚ 13.25285 E	3600	68.1	25.9
Q2	23˚01.93788 N	70˚13.244884 E	3700	46.1	19.7
Q3	23˚ 1.507972 N	70˚13 23.2248E	1500	40.9	10.8
Q4	23˚ 14.5986N	70˚15.2648E	1100	35.5	15.6
Q5	23˚15.948N	70˚15.28626 E	0	0	0
Q6	23˚17.128 N	70˚15. 30816 E	0	0	0
Q7	23˚19.636 N	70˚15. 29886 E	0	0	0
Q8	23˚18.814N	70˚15. 27636 E	1000	31.4	13.4
Q9	23˚18.838N	70˚15.27648 E	4200	44.5	20.5
Q10	23˚19.768N	70˚15. 26198 E	1400	31.6	13.8
Q11	23˚11.3704N	70˚15.231 E	2800	59	20.3
Q12	23˚1 1.3644N	70˚15. 231 E	3600	56	22.1
Q13	23˚11.7004N	70˚15.2334 E	2500	70.2	23.5
Q14	23˚16.61N	70˚15.25192 E	2900	59.4	21
Q15	23˚1 1.4514 N	70˚15.27484 E	500	22.2	6.4
Q16	23˚1 1.4418 N	70˚15.27336 E	3700	57.2	22.7
Average			**2031**	**39**	**--**

Figure 21. Mangrove plantation 300 ha at Sat Saida bet during 2017-2018

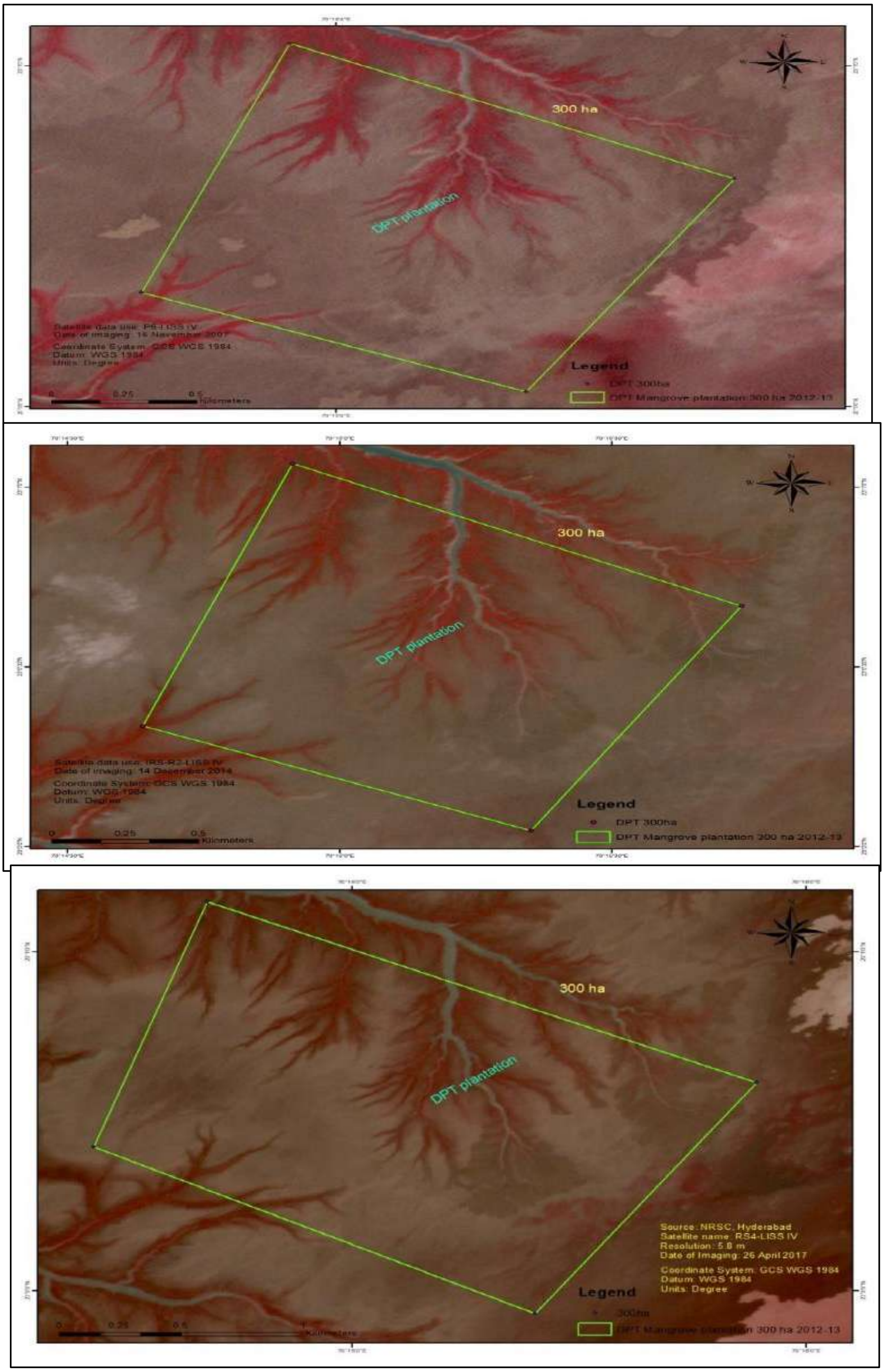

Figure 22. Satellite imageries of the plantation at Sat Saida Bet (2007, 2012-13 & 2014)

Table 15. *Avicennia marina* plantation (2013-2014) in 330 ha at Sat Saida bet

S. No.	Sampling Locations		Density (Ha)	Height (cm)	St. Dev
Q1	23°04'48.34" N	70° 17' 10.05" E	4400	109	28.34
Q2	23°04'46.55" N	70° 17' 13.94" E	4900	115	24.7
Q3	23°04'45.14" N	70° 17' 18.65" E	4100	110	26.2
Q4	23°04'41.97" N	70° 17' 16.66" E	5600	110	27.7
Q5	23°04'50.58" N	70° 17' 16.68" E	2900	124	29.2
Q6	23°04'44.43" N	70° 17' 16.54" E	4900	135	30.7
Q7	23°04'49.39" N	70° 17' 15.54" E	2800	103	32.2
Q8	23°04'45.35" N	70° 17' 06.79" E	5300	100	34.44
Q9	23°04'42.94" N	70° 17' 09.32" E	5200	121	35.2
Q10	23°04'40.49" N	70° 17' 13.53" E	2900	86	36.7
Q11	23°04'46.46" N	70° 17' 12.37" E	4900	73	29.2
Q12	23°04'44.26" N	70° 17' 15.86" E	5200	105	28.22
Q13	23°04'48.25" N	70° 17' 12.93" E	6100	102	32.15
Q14	23°04'44.174" N	70° 17' 16.32" E	6300	70	33.22
Q15	23°04'38.25" N	70° 17' 10.33" E	5800	110	31.2
Q16	23°04'40.41" N	70° 17' 12.07" E	3500	62	16.1
Q17	23°04'40.76" N	70° 17' 12.89" E	2600	51	14.7
Q18	23°04'38.16" N	70° 17' 20.60" E	3600	43	12.2
Q19	23°04'38.76" N	70° 17' 10.60" E	3300	45	11.1
Q20	23°04'40.69" N	70° 17' 06.48" E	2300	66	23.7
Q21	23°04'49.68" N	70° 17' 14.62" E	3600	72	9.3
Q22	23°04'47.10" N	70° 17' 03.65" E	3100	78	17.6
Q23	23°04'49.42" N	70° 17' 07.81" E	3300	85	19.2
Q24	23°04'49.87" N	70° 17' 10.23" E	2600	64	17.2
Average			**4133**	**89**	**--**

Figure 23. Mangrove plantation 330 ha at Sat Saida bet during 2013-2014

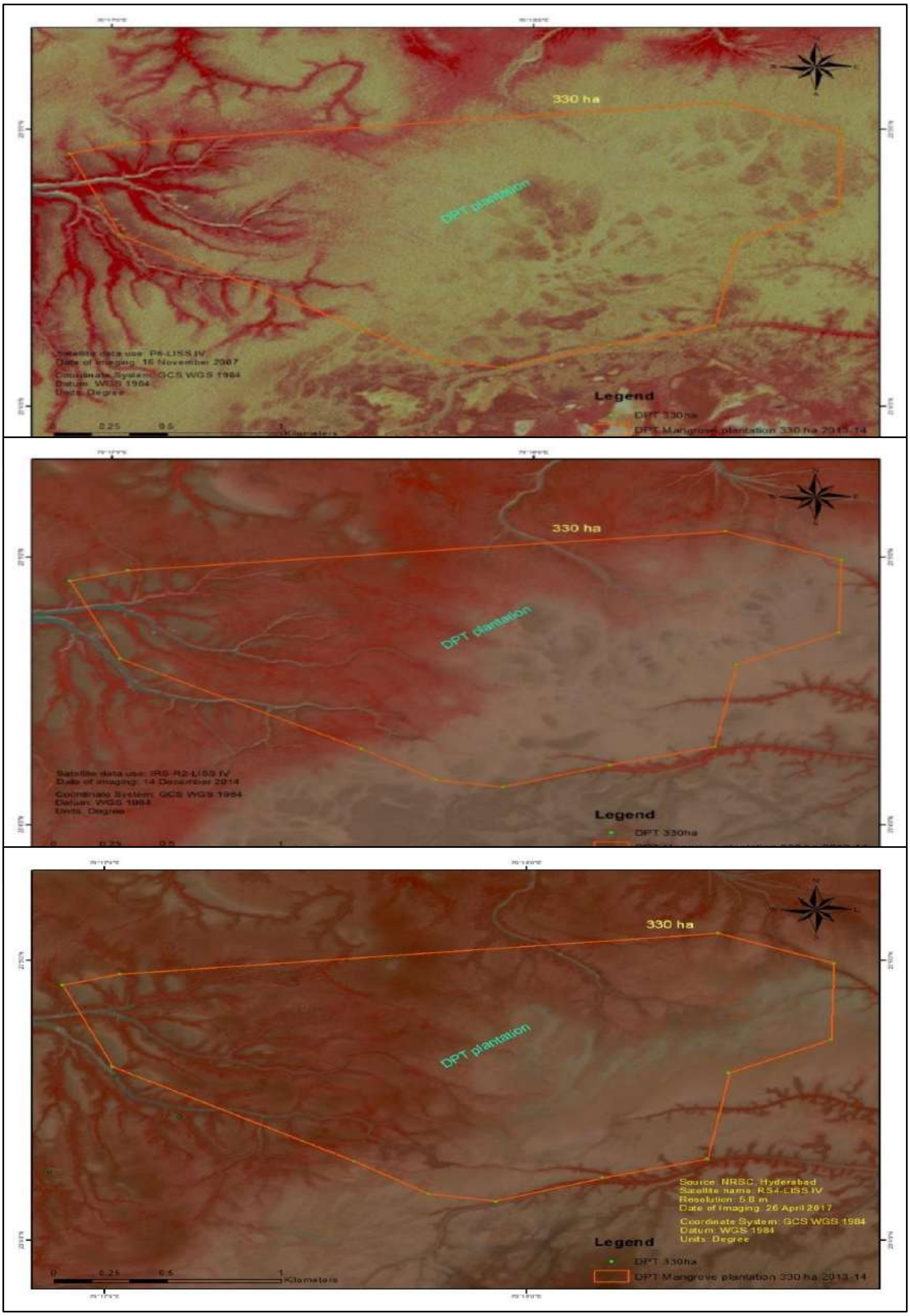

Figure 24. Satellite imageries of the plantation at Sat Saida Bet (2007, 2014 & 2018)

6 Results

The mangrove monitoring study results of the three sites, Nakti creek Kantiyajal and Sat Saida bet are presented below.

6.1 Mangrove plantation evaluation at Nakti creek

6.1.1 Evaluation of *Avicennia marina* Plantation at Nakti creek (2021-2022) 100 ha

In total, ten quadrats were laid at Nakti creek block to assess the *A. marina* survival percentage. The survival rate was recorded to be 40%, lower than the survival rate of recorded in Nakti creek within 50 ha plot. The plantation density ranged from 900 individuals/ha to 3400 individuals/ha, with an average density of 1600 individuals/ha (Table 16). In this block, the height of the plants ranged between 70- 280 cm, with an average height of 118.9 cm was recorded. The GBH in this plantation varied from 6 to 12 cm, with an average value of 6.8 cm. The minimum and maximum canopy cover in this plantation stand ranged from 0.30 to 1.5 m2 with a mean value of 0.8 m^2. Even though the plantation activities were carried out near the creek system, the poor survival of planted mangroves could be due to mixed plantation techniques. *R. mucronata* saplings were recorded outside the quadrats with heights varying from 50-60 cm. Around ten individuals were seen during the entire survey. Thus, it was apparent that the plantation of *R. mucronata* showed poor survival rate as this species needs 20-25 days of tidal flushing in a month and can tolerate only moderate salinity.

Table 16. Details of mangrove plantation at Nakti creek (100 ha)

S. No	Density (Plants/Ha)	Height (cm)			GBH (cm)			Canopy cover (m^2)		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
1	2200	70	170	120	7	9	8	0.42	1.25	0.8
2	1700	100	280	190	6	11	8.5	0.42	1.5	0.96
3	2300	100	235	167.5	7	12	9.5	1.32	1.5	1.4
4	1700	70	170	120	7	11	9	0.3	0.85	0.6
5	0	0	0	0	0	0	0	0	0	0
6	3400	70	180	125	7	8	7.5	1.32	0.75	1.03
7	2900	100	190	145	8	7	7.5	1.56	1.1	1.3
8	900	80	210	145	7	10	8.5	0.56	1.25	0.9
9	900	100	252	176	7	12	9.5	0.72	1.5	1.1
10	0	0	0	0	0	0	0	0	0	0
Overall average Density (plants/ha) 1600.0		**69.0**	**168.7**	**118.9**	**5.6**	**8.0**	**6.8**	**0.7**	**1.0**	**0.8**

6.1.2 Mangrove evaluation at Nakti creek (2021-2022) 50ha

Two mangrove plantation sites with an area of 50 ha and 100 ha were developed at the north-eastern bank of Nakti creek, one of the major creek systems of Kandla. The main creek and its branches are getting inundated by 3-4 m of tidal water during the high tide period. The two mangrove plantation sites developed is adjacent to each other with a good tidal flooding area. The findings based on-site visits and subsequent data are given in Table in 17.

To evaluate the *A. marina* plantation success at Nakti creek i.e., survival percentage and growth rate, an initial plantation density of 4000 saplings/ha as a baseline density was considered. Therefore, in the present study, six quadrates of 10×10m each were laid to evaluate the growth and survival of *A. marina*. The results revealed that the survival rate of *A. marina* in this block was 55 percent. The density ranged from 900 individuals/ha as high as 2800 individuals/ha, with an average density of 2200 individuals /ha. Similarly, the plant height ranged between 70 cm and 210 cm, with an average of 129.2 cm. The canopy cover ranged between 0.3 m^2 to 1.5 m^2 with an average of 0.8 m^2. The Girth at base (here after GB) values are ranged from 7 cm to 46 cm, with an average of 20.4 cm. The larger values of GB indicate the presence of multiple stems. It is known that direct dibbling and plantation of nursery raised trees are superior to the *Otla* bed technique. Moderate survival (55%) of the planted *A. marina* could be attributed to mixed plantation techniques as more than two species, namely *Rhizophora mucronata* and *Ceriops tagal* were also planted at this site.

Table 17. Details of mangrove plantation at Nakti creek (50 ha)

S. No	Density (Plants/ Ha)	Height (cm)			GBH (cm)			Canopy cover (m^2)		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
1	2400	100	175	137.5	7	37	22	0.42	1.2	0.8
2	2300	100	185	142.5	7	37	22	0.3	1.35	0.8
3	2800	100	210	155	7	46	26.5	0.3	1.5	0.9
4	2300	100	160	130	7	26	16.5	0.3	1.1	0.7
5	2500	80	120	100	7	34	20.5	0.56	0.75	0.7
6	900	70	150	110	8	22	15	1	0.8	0.9
Avg	**2200.0**	**91.7**	**166.7**	**129.2**	**7.2**	**33.7**	**20.4**	**0.5**	**1.1**	**0.8**

During the field surveys, it was recorded that the saplings were invaded by the alga *Enteromorpha* sp. and regular tidal flushing was lacking. Due to all these factors a variation of mortality of different tree species was recorded along the Nakti creek.

6.2 Kantiyajal mangrove plantation (350 ha)

The 350 ha mangrove plantation was carried out at the coastal stretch of Katpor village near Kantiyajal in Bharuch district. This plantation was carried out in two blocks of 150 ha each during the year 2015-16 and 2016-17 and 50 ha during the year 2019-20. The Gujarat Ecology Commission (GEC), Gandhinagar executed this plantation with the help of community participation by Samity at the Katpor village.

6.2.1 *Avicennia marina* and *Rhizophora mucronata* plantation (2015-2016) 150 ha

Sixteen quadrats were laid in this block for assessing mangrove species survival success. As per the earlier report by GEC (2015-2017), at this site, it was evident that this block had *R. mucronata* saplings in addition to *A. marina* (Table 18, 19 & 20). An overall average density of 3000 individuals/ha was recorded for *A. marina*. The tree density varied from 1200 to 5200 individuals/ha. The height of the plants ranged from 0.90 m to 2.20 m, with an average of 1.5 m. The GB of the plants ranged from 7.0 to 25 cm with an average of 14.2 cm. The canopy cover of the mangrove plants varied between 0.56 m^2 and 2.4 m^2 with an average of 1.3 m^2.

Plate 1. *Ceriops tagal* stands at Nakti creek Plantation site

Plate 2. *Rhizophora mucronata* stands at Nakti creek Plantation site

Plate 3. *Avicennia marina* (100 ha) plantation at Nakti creek

Table 18. Details of *A. marina* & *R. mucronata* plantation at Kantiyajal (150 ha)

Quadrate	**Density**	**Height (m)**			**GBH (cm)**			**Canopy cover (m^2)**		
		Min	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**
Q1	5200	1	1.9	1.45	7	20	13.5	0.56	1.82	1.19
Q2	3600	1.2	2	1.6	11	25	18	1.1	2.1	1.6
Q3	4000	0.9	1.9	1.4	8	16	12	0.9	1.56	1.23
Q4	3600	1.25	1.9	1.575	9	25	17	0.72	2.4	1.56
Q5	3600	1.1	1.75	1.425	9	22	15.5	0.72	1.1	0.91
Q6	3200	1	2.1	1.55	7	20	13.5	0.72	1.82	1.27
Q7	2800	1.2	2.1	1.65	12	23	17.5	1.2	2.4	1.8
Q8	1200	1.1	1.6	1.35	7	13	10	1.1	1.2	1.15
Q9	1600	1.2	2.2	1.7	8.5	18	13.25	0.72	2.1	1.41
Q10	1200	1	1.2	1.1	8	15	11.5	0.72	1.1	0.91
Overall average	**3000**	**1.1**	**1.9**	**1.5**	**8.7**	**19.7**	**14.2**	**0.85**	**1.76**	**1.3**

6.2.2 *Rhizophora mucronata* plantation (2016-2017) 150 ha

The assessment of the *R. mucronata* plantation at this site showed an overall density of 2520 individuals/ha (Table 19). The average height of *R. mucronate* plants was 129.5 cm, and the average canopy cover was 0.9 m^2 in this block. *R. mucronata* being a frontline mangrove, its plantation was carried out towards the lower intertidal region. Continuous tidal flushing following appropriate zonation patterns during plantation could be attributed to a higher survival percentage of *R. mucronata*. The survival and growth of the mangrove plantation at this site was (63%) comparatively good because of continuous water inundation and availability of extensive intertidal mudflats.

Table 19. Details of mangrove plantation of *Rhizophora mucronata* at Kantiyajal (150 ha)

Quadrate	**Density**	**Height (cm)**			**GBH (cm)**			**Canopy cover (m^2)**		
		Min	**Max**	**Average**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**
Q1	3500	85	175	130	5	9	22	0.52	1	0.76
Q2	2500	100	185	142.5	7	11	22	0.65	1.5	1.075
Q3	2800	110	210	160	8	12.5	26.5	1.1	1.3	1.2
Q4	2000	70	160	115	5	8	16.5	0.3	1.1	0.7
Q5	1800	80	120	100	3	5	20.5	0.6	0.75	0.675
Overall average	**2520.0**	**89.0**	**170.0**	**129.5**	**5.6**	**9.1**	**21.5**	**0.6**	**1.1**	**0.9**

6.2.3 *Avicennia marina* plantation (2018-2019) 50 ha

During the field surveys at this site saplings of both *A. marina* and *R. mucronata* saplings were also noticed (Table 20). An average density of 2480 individuals/ha was recorded for *A. marina*. The plant density varied between of 2100 individuals/ha, to 2800 individuals/ha. The height of the plants ranged from13 cm to 97 cm, with an average of 57.28 cm. The survival and growth of the mangrove plantation at this site (62%) was comparatively high because of continuous water inundation on the extended intertidal mudflats.

Table 20. Evaluation of *A. marina* plantation at Kantiyajal (50 ha) during 2018-2019

Quadrate	Density	Height (cm)		
		Min	Max	Average
Q1	2700	37	52	44.5
Q2	2100	57	93	75
Q3	2200	62	97	79.5
Q4	2600	55	73	64
Q5	2800	13	34	23.4
Average	**2480**	**44.8**	**69.8**	**57.28**

Plate 4. *Avicennia marina* plantation at Kantiyajal coast

Plate 5. *Rhizophora mucronata* plantation at Kantiyajal coast

6.3 Monitoring of mangrove plantation at Sat-Saida Bet

6.3.1 Monitoring of *Avicennia marina* at Sat-Saida Bet (2021-2022) 20 ha

During 2005-2006, the mangrove plantation at Sat Saida Bet was carried out at Dharkadia creek banks in 20 ha. The two sites on both the banks of Dharkadia creek were planted with *A. marina* by Gujarat Institute of Desert Ecology through transplanting nursery-grown seedlings and direct seed sowing for gap filling.

In total, 2 quadrats were laid at this site to assess the survival percentage of the *A. marina.* The results of the growth of these plantations are presented in Table 21. .The *A. marina* plants in the 20 ha area showed tree density varying from 2100/ha to a maximum 2500/ha, and the overall average was 2300 /ha. The overall average plant height of this site was 175cm. and the survival rate was 57.5 %. The GB ranged from 7 cm to 15 cm, with an average of 10.5 cm, while the average canopy cover was 1.89 m^2. The area was moderately dense, with *A. marina* being predominant species (Plate-16).

Additionally, the area being slightly cooler due to frequent tidal exposures and is inhabited by snakes. As the area remains moist due to the tidal influx, assessment of the area becomes difficult. This area also supports avifauna like Oriental darter (*Anhinga melanogaster*), Painted stork (*Mycteria leucocephala*), crab plovers (*Dromas ardeola*) etc.

Table 21. Evaluation of *A. marina* plantation at Sat Saida Bet (20 ha)

Quadrat	Density	Height (cm)			Girth (cm)			Canopy (m^2)		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
Q-1	2100	180	200	190	8	15	11.5	1.14	3.21	2.175
Q-2	2500	110	160	160	7	12	9.5	1.1	2.1	1.6
Average	2300	180	180	175	7.5	13.5	10.5	1.12	2.66	1.89

Plate 6. Sat Saida Bet *Avicennia marina* plantation

6.3.2 Monitoring of *Avicennia marina* plantation at Sat Saida bet (2021-2022) 200 ha.

Mangrove plantation in 200 ha was initiated by Forest Department, Kachchh circle during 2011-2012 on DPA's request. Forest Department (Anjar circle) initiated the plantation activities at Sat Saida Bet during the rainy season of June 2011. The plantation site is opposite to Deendayal port oil jetty and is around 2 km from the bank of Sat Saida bet. A buffer zone of nearly 2 km was allowed between the waterfront from the banks of Sat Saida bet and the plantation site. The seeds of *A. marina* were used for plantation activities due to the prevailing high salinity in the area. Raised bed method (*Otla*) was followed as the plantation technique, and *A. marina* seeds were collected from Kandla mangroves for plantation work.

In total, 20 quadrats were laid at this site to assess the survival percentage of the *A. marina.* The growth of these plantations was assessed, and the results were presented in Tables 22. The *A. marina* plants in the 200-ha area showed tree density varying from 1800/ha to a maximum 2800/ha, and the overall average was 2250 /ha. The overall average plant height of this site was 117.8 cm and the survival rate was 56.25 %. The GBH ranges from 7 cm to 11 cm with an average of 8.3 cm, while the average canopy cover was 1.1 m^2.

Additionally, the area supported the luxuriant growth of halophytes like *Salicornia brachiata, Sesuvium sp. and Salvadora persica*. The area becomes dry during low tides and gets converted to a hard surface, making it accessible. Interestingly, despite the dryness of the area, snakes were recorded. It was observed that they take shelter under the canopy cover and camouflage themselves by intertwining with the stem of mangroves.

6.3.3 Monitoring of *Avicennia marina* plantation (2021-2022) 300 ha.

The *A. marina* mangrove plantation carried out during 2012-2013 in 300 ha by the Range office of the Forest Department at Anjar. Initially, raised bed method was followed for mangrove plantations but was eventually replaced by direct seed sowing. In a few places, direct seed dibbling was also done.

In total, 30 quadrates were laid at this site to assess the survival percentage of the *A. marina.* The growth of these plantations was assessed, and the results are presented in Table 23. The *A. marina* plants in the 300ha area showed tree density varying from 1300/ha to a maximum 3500/ha, and the overall average was 2247/ha. The overall average plant height of this site was 125.3cm, and the survival rate was 56.17 %. The GB ranges from 0.63 cm to 19 cm with an average of 9.16 cm, while the average canopy cover was 1.44 m^2.

Table 22. Details of mangrove plantation of *A. marina* at Sat Saida Bet (200 Ha)

Quadrate	Density	Height (cm)			Girth (cm)			Canopy cover (m^2)		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
Q-1	2200	110	140	125	7	10	8.5	0.34	1.24	0.79
Q-2	1800	120	110	115	7	9	8	1	1.57	1.285
Q-3	2500	100	130	115	9	11	10	1	1.34	1.17
Q-4	1800	100	110	105	7	9	8	0.59	1.24	0.915
Q-5	2400	130	140	135	7	11	9	0.89	1.95	1.42
Q-6	2200	110	120	115	7	9	8	0.98	1.4	1.19
Q-7	2400	120	130	125	7	10	8.5	1	1.49	1.245
Q-8	1800	100	120	110	7	10	8.5	0.48	0.67	0.575
Q-9	2200	100	110	105	7	8	7.5	0.34	0.59	0.465
Q-10	1800	130	140	135	7	9	8	1	1.77	1.385
Q-11	2700	120	130	125	7	10	8.5	1	1.8	1.4
Q-12	2200	80	100	90	7	9	8	0.23	1.67	0.95
Q-13	1900	120	150	135	7	8	7.5	1.29	1.78	1.535
Q-14	2800	110	120	115	7	8	7.5	1	1.3	1.15
Q-15	2200	90	110	100	8	9	8.5	1.07	1.29	1.18
Q-16	2400	110	140	125	8	11	9.5	1.2	1.5	1.35
Q-17	2200	120	140	130	8	10	9	1	1.64	1.32
Q-18	2500	80	120	100	5	8	6.5	1.04	1.34	1.19
Q-19	2200	110	130	120	7	8	7.5	0.54	0.76	0.65
Q-20	2800	120	140	130	8	11	9.5	0.72	0.9	0.81
Average	**2250**	**109**	**126.5**	**117.8**	**7.2**	**9.4**	**8.3**	**0.8**	**1.4**	**1.1**

Table 23. Details of mangroves plantation of A. *marina* at Sat Saida Bet (300 Ha)

Quadrat No	Density	Height(cm)			Girth(cm)			Canopy cover (m^2)		
		Min	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Average**
Q-1	2200	120	160	140	9	19	14	1.32	2.7	2.01
Q-2	1500	100	120	110	11	12	11.5	1.56	1.75	1.65
Q-3	2500	90	130	110	0.99	10	5.5	0.96	1.69	1.325
Q-4	1900	120	140	130	9	12	10.5	1	1.39	1.195
Q-5	2600	90	180	135	7	18	12.5	1	1.69	1.345
Q-6	2100	90	140	115	8	9	8.5	1	2.19	1.595
Q-7	2500	100	130	115	7	11	9	1	2.56	1.78
Q-8	2500	90	120	105	0	9	4.5	0.47	1.39	0.93
Q-9	1900	100	120	110	7	12	9.5	1	1.22	1.11
Q-10	2600	110	190	150	10	16	13	1	1.38	1.19
Q-11	2100	110	190	150	12	20	16	1	2.79	1.895
Q-12	2500	120	270	195	9	24	16.5	2	4.46	3.23
Q-13	2200	130	260	195	11	21	16	3	4.39	3.695
Q-14	2200	90	120	105	5	10	7.5	0.39	2.35	1.37
Q-15	2100	130	170	150	11	13	12	0.56	1.67	1.115
Q-16	1800	90	140	115	6	10	8	0.76	1.36	1.06
Q-17	1800	120	130	125	7	9	8	1.2	1.32	1.26
Q-18	2200	80	100	90	5	7	6	0.65	1.02	0.835
Q-19	2200	90	120	105	6	7	6.5	0.89	1.29	1.09
Q-20	1300	130	140	135	7	9	8	0.9	1.34	1.12
Q-21	2200	100	120	110	6	9	7.5	0.79	1.1	0.945
Q-22	1500	80	130	105	6	10	8	0.63	1.35	0.99
Q-23	2200	110	140	125	7	9	8	1	1.45	1.225
Q-24	2800	100	110	105	5	7	6	0.56	1.06	0.81
Q-25	2900	105	130	117.5	7	11	9	1.38	2	1.69
Q-26	3500	120	150	135	9	13	11	1	2	1.5
Q-27	2200	110	130	120	0	9	4.5	1.02	1.89	1.455
Q-28	2400	100	140	120	0	9	4.5	1	1.68	1.34
Q-29	2800	110	150	130	0	10	5	0.64	1.83	1.235
Q-30	2200	70	140	105	0.63	16	8.315	1	1.45	1.225
Average	**2247**	**103.5**	**147**	**125.25**	**6.29**	**12.03**	**9.16**	**1.02**	**1.86**	**1.44**

6.3.4 Monitoring of *Avicennia marina* plantation (2021-2022) 330 ha.

During 2013-14, these sites were planted with *A. marina*, plants with nursery raised saplings and direct dibbling methods, respectively. In total, 33 quadrates were laid at this site to assess the survival percentage of the *A. marina.* The growth of these plantations was assessed, and the results are presented in Table 24. The *A. marina* plants in the 330 ha area showed the tree density varying from 1800/ha to a maximum of 3200/ha, and the overall average was 2509/ha. The overall average plant height of this site was 132.3cm, and the survival rate was 62.7 %. The girth at base ranges from 5 cm to 24 cm with an average of 9.61 cm, while the average canopy cover was 1.35 m^2.

Plate 7. Monitoring of *A. marina* on field

Table 24. Details of mangroves plantation of A. *marina* at Sat Saida Bet (300 ha)

Quadrate	Density	Height (cm)			Girth (cm)				Canopy cover(m^2)	
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1	2400	70	90	80	5	6	5.5	0.4	1.2	0.8
2	3200	110	120	115	7	8	7.5	0.28	1.62	0.95
3	2200	90	110	100	7	8	7.5	0.36	1.23	0.795
4	2600	80	100	90	5	6	5.5	1.2	2.2	1.7
5	3200	100	120	110	6	8	7	0.38	1.36	0.87
6	2200	80	90	85	5	7	6	0.7	1.9	1.3
7	3000	100	110	105	4	6	5	0.5	0.9	0.7
8	2500	110	125	117.5	6	9	7.5	0.42	1.23	0.825
9	1900	110	130	120	7	10	8.5	1.08	1.23	1.155
10	2600	110	120	115	7	9	8	0.89	1.26	1.075
11	2100	120	180	150	8	12	10	0.78	1.47	1.125
12	2500	105	150	127.5	7	14	10.5	0.42	1.68	1.05
13	2700	150	190	170	10	16	13	0.8	1.59	1.195
14	2200	110	170	140	7	18	12.5	0.89	2.38	1.635
15	2900	110	180	145	7	17	12	0.54	2.1	1.32
16	3500	110	130	120	6	10	8	0.9	1.2	1.05
17	2200	130	150	140	7	15	11	1.08	2.24	1.66
18	2400	110	140	125	7	12	9.5	0.9	2.36	1.63
19	2200	120	170	145	9	15	12	1.39	2.49	1.94
20	2400	120	140	130	7	12	9.5	1.17	2.35	1.76
21	1800	90	110	100	6	9	7.5	0.89	1.02	0.955
22	2500	100	120	110	9	10	9.5	0.64	0.98	0.81
23	3200	140	170	155	9	13	11	0.9	1.39	1.145
24	2500	80	120	100	6	8	7	0.38	0.76	0.57
25	2500	110	130	120	7	8	7.5	0.34	1.24	0.79
26	1900	110	130	120	7	9	8	0.79	1.1	0.945
27	2600	100	150	125	7	10	8.5	0.88	2.89	1.885
28	2200	100	110	105	7	10	8.5	0.54	1.96	1.25
29	2100	150	250	200	10	22	16	2.34	3.5	2.92
30	2400	160	210	185	1	18	9.5	1.78	2.7	2.24
31	2500	210	260	235	16	24	20	1.98	3.86	2.92
32	2500	150	240	195	11	19	15	2.28	2.46	2.37
33	3200	160	210	185	10	16	13	0.72	1.67	1.195
Average	**2509**	**115**	**149**	**132**	**7.3**	**12**	**9.61**	**0.90**	**1.80**	**1.35**

6.3.5 Monitoring of *Avicennia marina* plantation (2021-2022) 50ha.

During 2018-19, this site was planted with A. marina, plants with nursery raised saplings and direct dibbling methods, respectively by Gujarat Ecology Commission. In total, five quadrates were laid at this site to assess the survival percentage of the A. marina. The growth of these plantations was assessed, and the results are presented in Table 25. The A. marina plants in the 50 ha area showed tree density varying from 1600/ha to a maximum of 2500/ha, and the overall average was 2060/ha. The overall average plant height of this site was 141.6cm, and the survival rate was 51.5 %. The girth ranges from 8 cm to 19 cm with an average of 12.2 cm, while the average canopy cover was 1.45 m^2.

Table 25. Details of mangroves plantation of A. *marina* at Sat Saida Bet (50 Ha)

Quadrat No	**Density**	**Height(cm)**			**Girth(cm)**			**Canopy(m^2)**		
		Max	**Min**	**Avg**	**Max**	**Min**	**Average**	**Max**	**Min**	**Average**
Q-1	1900	180	140	160	18	11	14.5	2.98	0.9	1.94
Q-2	2200	160	136	148	15	12	13.5	2.57	0.48	1.525
Q-3	2500	150	110	130	12	9	10.5	1.82	0.59	1.205
Q-4	2100	190	110	150	19	8	13.5	2.36	1.04	1.7
Q-5	1600	130	110	120	10	8	9	1.34	0.46	0.9
Avg	**2060**	**162**	**121**	**141.6**	**14.8**	**9.6**	**12.2**	**2.214**	**0.69**	**1.45**

7 Regeneration and recruitment class

The regeneration class and recruitment class density were recorded in Sat Saida bet. The overall average density of the regeneration class (saplings with a height of <50 cm) of mangroves in the sampling site recorded was 43,658 plants/ha. The highest regeneration class (62,121 plants/ha) was recorded at 330 ha block, indicating the suitability of the site for germination and survival of young plants (Fig-25, 26). The lowest density of the regeneration class (25,667 plants/ha) was recorded at the 300 Ha block. In the case of recruitment class plants, the overall average density recorded was 5071 plants/ha. The maximum recorded at 330 Ha block (6061 plants/ha), and the minimum at 300 ha block. These results indicate that the 300 Ha block is not conducive for the growth of mangroves.

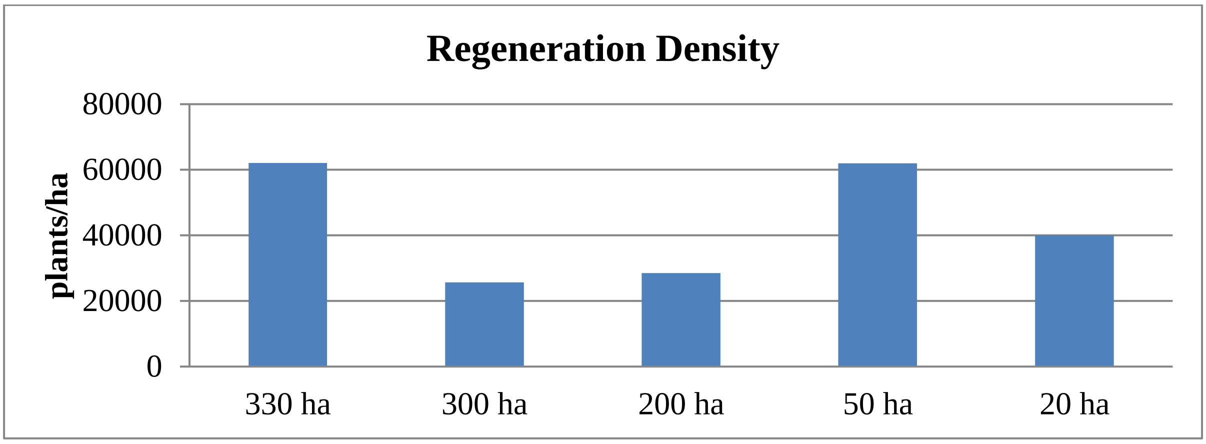

Figure 25. Regeneration class density at Sat Saida Bet

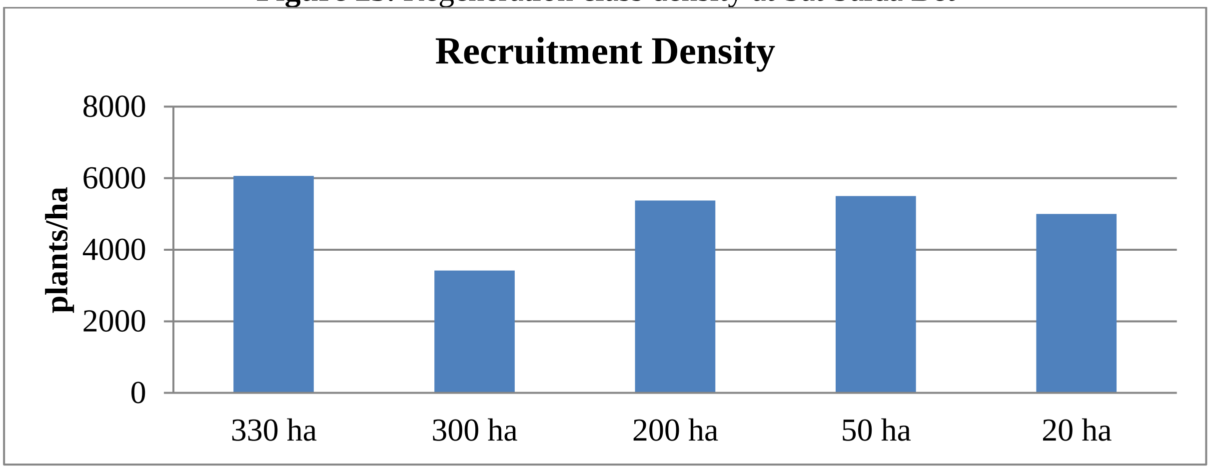

Figure 26. Recruitment class density at Sat Saida Bet

The regeneration class density was highest in 330 ha block followed by 50 ha, 20 ha, 200 ha and lowest in 300 ha. The recruitment class density was highest in 330 ha followed by 50 ha, 200 ha, 20 ha and lowest in 300 ha.

Table 26. Assessment of plant characteristics (Mean) at the plantation sites during 2017-2018

Site	Parameters	150 ha	150ha
Kantiyajal	Plant density (No/ha)	2220 (*A .marina*)	1460 (*A.marina)* 1280 *(R.mucronata)*
	Height(cm)	37	32 (*A.marina*) 30 (*R.mucronata)*
	Survival rate (%)	88.8	58.4 *(A. marina*) 64.0 (*R. mucronata)*
Nakti creek	Plant density (No/ha)	2370	-
	Height (cm)	53 – 84	-
	Survival rate	35.9	-
Sat Saida Bet	Plant density (No/ha)	4133	2031 to 5387
	Height (cm)	89	39 – 113
	Survival rate (%)	62.6%	81.6

8 Soil Biomass Carbon

8.1 Soil biomass carbon stock potential at Nakti creek mangrove site

At Nakti creek, the below ground soil carbon stock of the *A. marina* plantation was 51.76 t/ha and 62.74t/ha at 50 ha and 100ha respectively. At the 100 ha mangrove plantation area, the soil biomass carbon stock ranged from 42.36 to 84.32 t/ha with an average of 62.74 t/ha. Among the two locations, 100 ha plantation site at Nakti creek showed the higher soil Total Biomass Carbon stock (Table 27, 28).

Table 27. Soil Carbon stock in Nakti mangrove plantation site- 100 ha

Sampling Blocks	Depths	TOC (%)	Total carbon (%)	Bulk Density (g/ cm^3)	Carbon stock (%)	Carbon stock in 1 m (t/ha)
NC 1	25 cm	0.34	0.18	1.28	5.83	84.315
	50 cm	0.37	0.20	1.30	12.85	
	75 cm	0.43	0.23	1.25	21.56	
	100 cm	0.61	0.33	1.35	44.08	
NC 2	25 cm	0.43	0.23	1.33	7.66	58.63
	50 cm	0.4	0.21	1.25	13.37	
	75 cm	0.34	0.18	1.32	17.94	
	100 cm	0.28	0.15	1.31	19.65	
NC 3	25 cm	0.24	0.13	1.32	4.22	45.27
	50 cm	0.27	0.14	1.27	9.14	
	75 cm	0.21	0.11	1.28	10.80	
	100 cm	0.3	0.16	1.32	21.11	
Average Carbon stock (%)						**62.74**

Table 28. Soil Carbon stock in Nakti mangrove plantation site - 50 ha

Sampling Blocks	Different depths	TOC%	Total carbon (%)	Bulk Density (g/ m^3)	Carbon stock (%)	Carbon in 1 m stock (t/ha)
NC 1	25 cm	0.21	0.11	1.41	3.95	42.364
	50 cm	0.24	0.13	1.25	8.02	
	75 cm	0.24	0.13	1.28	12.34	
	100 cm	0.27	0.14	1.25	18.05	
NC 2	25 cm	0.33	0.18	1.37	6.04	59.12
	50 cm	0.24	0.13	1.33	8.56	
	75 cm	0.3	0.16	1.39	16.71	
	100 cm	0.39	0.21	1.33	27.81	
NC 3	25 cm	0.51	0.27	1.28	8.74	53.79
	50 cm	0.33	0.18	1.32	11.61	
	75 cm	0.27	0.14	1.33	14.44	
	100 cm	0.27	0.14	1.32	19.00	
Average of Carbon stock (%)						**51.6**

Table 29. Average Carbon Stock at Nakti Creek

Plantation (ha)	Avg. Carbon stock 1 m depth (%)
100	62.74
50	51.6
Avg	57.17

8.2 Soil biomass carbon stock potential at Kantiyajal mangrove site

At Kantiyajal creek, the average soil biomass carbon of the *A. marina* plantation was 53.13t/ha (150ha) and it ranged from 46.4 to 59.7 t/ha. Among the three locations, 150 ha *A. marina* plantation site showed the highest soil biomass carbon stock potential at Kantiyajal (Table 30,31,32 & 33). The overall average 1 meter depth soil carbon stock was 53.35t/ha**.**

Table 30. Soil Carbon stock in Kantiyajal mangrove plantation site- 150 ha (*A. marina*)

Sampling Blocks	Different depths	TOC%	Total carbon (%)	Bulk Density (g/ m^3)	Carbon stock (%)	Carbon stock in 1 m(t/ha)
KC-1	25 cm	0.30	0.15	1.27	4.8	**54.7**
	50 cm	0.42	0.21	1.20	12.6	
	75 cm	0.34	0.17	1.19	15.2	
	100 cm	0.52	0.26	1.22	22.2	
KC- 2	25 cm	0.34	0.17	1.21	5.1	**54.0**
	50 cm	0.40	0.20	1.18	11.8	
	75 cm	0.38	0.19	1.20	17.1	
	100 cm	046	0.23	1.24	20.0	
Average Carbon stock (%)						**54.4**

Table 31. Soil Carbon stock in Kantiyajal mangrove plantation site- 150 ha (*R. mucronata)*

Sampling Blocks	Different depths	TOC %	Total carbon (%)	Bulk Density (g/ m^3)	Carbon stock (%)	Carbon stock in 1 m(t/ha)
KC-1	25 cm	0.38	0.19	1.09	5.2	47.7
	50 cm	0.29	0.145	1.22	8.8	
	75 cm	0.39	0.195	1.16	17.0	
	100 cm	0.49	0.145	1.21	20.8	
KC- 2	25 cm	0.36	0.18	1.26	5.7	59.7
	50 cm	0.37	0.185	1.23	11.4	
	75 cm	0.62	0.31	1.19	27.7	
	100 cm	0.37	0.185	1.16	15.0	
Average Carbon stock (%)						**53.69**

Table 32. Soil Carbon stock in Kantiyajal mangrove plantation site- 50 ha *(A.marina*)

Sampling Blocks	Different depths	% of TOC	Total carbon (%)	Bulk Density (g/ m^3)	Carbon stock (%)	Carbon stock in 1 m(t/ha)
KC- 1	25 cm	0.29	0.145	1.24	4.5	57.5
	50 cm	0.36	0.18	1.25	11.3	
	75 cm	0.39	0.195	1.23	18.0	
	100 cm	0.54	0.27	1.26	23.8	
KC- 2	25 cm	0.32	0.16	1.24	5.0	46.4
	50 cm	0.38	0.19	1.09	10.4	
	75 cm	0.37	0.185	1.24	17.2	
	100 cm	0.32	0.16	1.24	13.9	
Average of Carbon stock (%)						**51.97**

Table 33. Average Carbon Stock at Kantiyajal Creek

Plantation (ha)	Avg. Carbon stock 1 m depth (%)
150	54.4
150	53.69
50	51.97
Avg	53.35

8.3 Soil carbon stock potential at Sat Saida bet at mangrove site

At Sat Saida bet the overall average soil biomass carbon of *A. marina* plantation site was 68.17 t/ha. Whereas, at the five blocks of mangrove plantation area, the soil biomass carbon ranged from 54.5 t/ha (50ha) to 79.5 t/ha (200ha). The soil carbon sequestration potential was highest in 200 ha plot followed by 300, 20, 330 and 50 ha plantation blocks (Table 34-39).

Table 34. Soil Carbon stock in Sat Saida bet mangrove plantation site- 300 ha

Sampling Blocks	Different depths	% of TOC	Total carbon (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 1 m (t/ha)
Sample-1	25 cm	0.37	0.185	1.30	6	69.3
	50 cm	0.40	0.2	1.29	12.9	
	75 cm	0.37	0.185	1.26	17.5	
	100 cm	0.53	0.265	1.24	32.9	
Sample- 2	25 cm	0.35	0.175	1.23	5.4	73.9
	50 cm	0.48	0.24	1.30	15.6	
	75 cm	0.39	0.195	1.22	17.8	
	100 cm	0.58	0.29	1.21	53.1	
Average of Carbon stock (%)						**71.5**

Table 35. Soil Carbon stock in Sat-Saida bet mangrove plantation site- 200 ha

Sampling Blocks	Different depths	% of TOC	Total carbon (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 1 m (t/ha)
Sample-1	25 cm	0.39	0.195	1.23	6.0	78.1
	50 cm	0.36	0.18	1.22	11.0	
	75 cm	0.67	0.335	1.13	28.4	
	100 cm	0.59	0.295	1.24	32.7	
Sample- 2	25 cm	0.42	0.21	1.21	11.6	80.9
	50 cm	0.35	0.175	1.26	11.0	
	75 cm	0.58	0.29	1.27	27.6	
	100 cm	0.52	0.26	1.18	30.7	
Average of Carbon stock (%)						**79.5**

Table 36. Soil Carbon stock in Sat Saida bet mangrove plantation site- 330 ha

Sampling Blocks	Different depths	% of TOC	Total carbon (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 1 m (t/ha)
Sample-1	25 cm	0.42	0.21	1.09	5.7	**64.8**
	50 cm	0.32	0.16	1.29	10.3	
	75 cm	0.37	0.185	1.24	17.2	
	100 cm	0.53	0.25	1.23	31.5	
Sample- 2	25 cm	0.48	0.24	1.13	6.8	**55.9**
	50 cm	0.34	0.17	1.24	10.5	
	75 cm	0.30	0.15	1.30	14.6	
	100 cm	0.42	0.21	1.14	23.9	
Average of Carbon stock (%)						**60.3**

Table 37. Soil Carbon stock in Sat Saida bet mangrove plantation site- 50 ha

Sampling Blocks	Different depths	% of TOC	Total carbon (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 1 m (t/ha)
Sample-1	25 cm	0.31	0.155	1.26	4.9	**62.8**
	50 cm	0.36	0.18	1.30	11.7	
	75 cm	0.39	0.195	1.06	15.5	
	100 cm	0.50	0.25	1.23	30.8	
Sample- 2	25 cm	0.32	0.16	1.13	5.0	**54.2**
	50 cm	0.33	0.165	1.24	10.8	
	75 cm	0.38	0.19	1.30	17.8	
	100 cm	0.34	0.17	1.14	20.6	
Average of Carbon stock (%)						**58.5**

Table 38 Soil Carbon stock in Sat Saida Bet mangrove plantation site- 20 ha

Sampling Blocks	Different depths	% of TOC	Total carbon (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 1 m (t/ha)
Sample-1	25 cm	0.35	0.175	1.32	5.8	74.5
	50 cm	0.37	0.185	1.18	10.9	
	75 cm	0.39	0.22	1.32	21.8	
	100 cm	0.55	0.275	1.31	36	
Sample- 2	25 cm	0.35	0.175	1.19	5.2	67.6
	50 cm	0.175	0.195	1.34	13.1	
	75 cm	0.29	0.27	1.32	26.7	
	100 cm	0.26	0.19	1.19	22.6	
Average of Carbon stock (%)						**71.0**

Table 39. Average Carbon Stock of all the sites at Sat Saida Bet

Plantation (ha)	Avg. Carbon stock 1 m depth (%)
300 ha	71.5
200 ha	79.5
330 ha	60.3
50 ha	58.5
20 ha	71.0
Avg	68.18

8.4 Details of carbon Sequestration at the plantation sites

The above ground biomass varied 113.30 to 210.0gm at Sat Saida Bet while at Kantiyajal it was minimum 121.74 to 164.60 gm/ha. At Nakti creek site it was minimum 133.86 and maximum 161.02 gm/ha during the present investigation (Table 40,41 & 42). The below ground biomass was comparatively less than the above ground values. At Sat Saida Bet it ranged from 22.70 to 62.80gm and that from Kantiyajal were 21.96 to 38.23gm. The below ground biomass at Nakti varied between 29.83 and 42.30gm. The Total Biomass Carbon calculated in the different plantation sites at Sat Saida varied from 112.10kg/ha to 232.74 kg/ha. The values of carbon biomass at Kantiyajal varied from 123.69 to 178.86kg/ha whereas at Nakti it varied between 142.02 and 173.46 kg/ha.

Table 40. Details of Carbon stock at Sat Saida during 2022

Carbon Sequestration - Dry weight basis (gm)										
50ha										
Sample	**Root**	**Leaves**	**Stem**	**Plant Biomass Below ground**	**Plant Biomass Above Ground**	**Total Biomass**	**Total Biomass Carbon**	**Total Biomass Carbon (mg/ha)**	**Total Biomass Carbon (kg/ha)**	**Carbon equivalent (%)**
sample-1	39.80	108.90	48.60	39.80	157.50	197.30	82.87	168325.71	168.33	617.76
sample-2	32.90	80.90	29.60	32.90	110.50	143.40	60.23	122341.14	122.34	448.99
20ha										
sample-1	29.40	80.10	37.70	29.40	117.80	147.20	61.82	125583.09	125.58	460.89
sample-2	24.60	86.40	26.90	24.60	113.30	137.90	57.92	117648.83	117.65	431.77
200ha										
sample-1	22.70	69.30	34.40	22.70	57.10	79.80	33.52	68081.05	68.08	249.86
sample-2	36.10	90.10	43.70	36.10	79.80	115.90	48.68	98879.62	98.88	362.89
300ha										
sample-1	62.80	140.30	69.70	62.80	210.00	272.80	114.58	232738.23	232.74	854.15
sample-2	39.50	93.50	32.90	39.50	126.40	165.90	69.68	141536.92	141.54	519.44
330ha										
sample-1	37.10	64.90	29.40	37.10	94.30	131.40	55.19	112103.38	112.10	411.42
sample-2	34.40	94.60	45.20	34.40	139.80	174.20	73.16	148618.03	148.62	545.43

Table 41. Details of Carbon stock at Kantiyajal during 2022

Dry weight (Gram)				Carbon Sequestration						
150ha										
Sample	**Root**	**leaves**	**stem**	**Plant Biomass Below ground**	**Plant Biomass Above Ground**	**Total Biomass**	**Total Biomass Carbon**	**Total Biomass Carbon (mg/ha)**	**Total Biomass Carbon (mg/ha)**	**Carbon equivalent (%)**
sample-1	34.29	112.30	52.30	34.29	164.60	198.89	83.53	169682.21	169.68	622.73
sample-3	38.23	124.12	47.30	38.23	171.42	209.65	88.05	178862.06	178.86	656.42
150ha										
sample-1	32.86	115.80	43.70	32.86	159.50	192.36	80.79	164111.16	164.11	602.29
sample-2	35.12	108.30	39.42	35.12	147.72	182.84	76.79	155989.21	155.99	572.48
50ha										
sample-1	21.96	84.62	38.40	21.96	123.02	144.98	60.89	123689.11	123.69	453.94
sample-2	24.30	92.14	29.60	24.30	121.74	146.04	61.34	124593.44	124.59	457.26

Table 42. Details of Carbon stock at Nakti creek during 2022

Dry weight (Gram)				Carbon Sequestration						
50 ha										
Sample	Root	leaves	Stem	Below ground	Above Ground Biomass	Total Biomass	Total Biomass Carbon	Total Biomass Carbon (mg/ha)	Total Biomass Carbon (kg/ha)	Carbon equivalent (%)
Sample-1	37.50	112.96	34.60	37.50	147.56	185.06	77.73	157883.20	157.88	579.43
Sample-2	32.90	98.63	36.94	32.90	135.57	168.47	70.76	143729.51	143.73	527.49
Sample-3	35.64	126.23	28.72	35.64	154.95	190.59	80.05	162601.10	162.60	596.75
100 ha										
Sample-1	32.61	94.35	39.51	32.61	133.86	166.47	69.92	142023.21	142.02	521.23
Sample-2	29.83	103.42	34.26	29.83	137.68	167.51	70.35	142910.49	142.91	524.48
Sample-3	42.30	129.18	31.84	42.30	161.02	203.32	85.39	173461.64	173.46	636.60

9 Phyto-sociological observation

9.1 Halophytes

Halophytes are classified based on their growth conditions as obligate halophytes, facultative halophytes, and habitat-indifferent halophytes. In the present study, four major halophytes were recorded within the selected DPA sites during the survey, *viz: Salicornia brachiata, Aeluropus lagopoides, Salvadora persica* and *Sesuvium portulacastrum*. Among the halophyte species, *Salicornia brachiata & Sesuvium portulacastrum* was found to be equally distributed in Sat Saida bet.

At the plantation site, mangroves associated plants such as *Salvadora* spp and *Ipomea* spp, were found at the high tide level; the halophytes, *Suaeda* spp, *Sesuvium* have also occurred in many sites. During the field visit, several mangroves associated fauna such as mudskippers, bivalves, crabs, gastropods and other fishes were found inside the plantation sites.

Plate 8. Mangrove associated Halophytes

10 Discussion

In the present study, the overall percentage survival of the plants on Sat Saida bet in 5 different blocks was observed between 51.5% to 62.7% at different plot size and in different geophysical condition. This indicates that *A marina* species is capable of adapting to a wide range of salinity variations and substratum types. For germination success, matured seeds should be collected and transported with proper moisture content for plantation. (Clarke and Allaway, 1993; McKee, 1995; McGuinness, 1997; Clarke *et. al*., 2001). The recruitment and growth of established mangrove seedlings and their survival to the sapling stage are mainly determined by the availability of light and nutrients (Smith, 1987; Ellison and Farnsworth, 1993) and the influence of physicochemical factors (McKee, 1995, Koch and Snedaker 1997) at Nakti creek, survival rate ranges from 40% to 54% at 100 ha and 50ha, respectively. At Kantiyajal creek, *A. marina* plantation survival rate varies from 62% to 75% within 50 ha and 150ha respectively. The survival rate of *R.mucronata* is 63% at 150 ha plantation site. This clearly indicates that *A. marina* tolerates wide ranges of temperature and salinity to withstand in extreme environmental conditions (Das *et al.*, 2019).

The results of the 1400 ha plantation study at Kantiyajal, shows higher survival rate than the Sat saida bet and Nakti creek, this is because of site to site variations in temperature, salinity and rainfall (Das *et. al*. 2019. In the plantation sites, higher survival was reported for *A. marina*, whereas the high rates of survival, for stilt-rooted *Rhizophora* species were planted as propagules as influenced by plant spacing (Kodikara *et. al*., 2017). The results of the present study are in conformity with the findings that several abiotic and biotic factors, including the local climatic conditions, determine the survival and growth of recruitment classes. It is to be highlighted that the aftercare by the local people and the management is very much important above all for achieving high survival rates of mangrove plantation efforts. The mangrove survival rates are dependent on factors like

• **Biological factors** – mangrove species and infestation of pests (e.g. algae, barnacles, insect larvae)

• **Physical factors** – tidal level and inundation, substrate, waves/typhoons, sedimentation.

• **Human factors** – harvesting of materials for fodder, grazing, fishing gear, management and enforcement.

Well-planned and executed mangrove planting efforts also results in poor survival rate because of a lack of participation by local communities, cultural barriers and adequate after-care (e.g., watering and removal of objects that are entangled with planted individuals) needed for long-term success (Blum and Herr, 2017). In most of the mangrove plantation, poor survival rate, due to restoration projects is often related to the high susceptibility of propagules, seedlings and saplings to wind and wave erosion, flooding and desiccation. The low survival of the recruitment class can be attributed by both the biotic (competition with native and planted vegetation) and abiotic factors (like erratic change in salinity, temperature wave energy and rainfall), site suitability (like high or low inundation, plantation area).

Effective coordination of multiple stakeholders in a given mangrove project was seen to have provided long-term positive impacts for both mangroves and dependent communities. Implementing agencies and community organizers could also contribute to greater success rates if well-trained and equipped by the appropriate environmental specialists (Flint *et al.*, 2018).

Mangrove rehabilitation and restoration are considered one of the most effective management options globally for dealing with lost or damaged mangrove forests (Ellison *et. al*., 2020). Although planting mangroves for restoration and afforestation has been conducted in some regions in Bangladesh (1993) and Vietnam (Hong *et. al.*, 1996) are not always successful. Many biotic and abiotic influences, including predation, seed recruitment, soil characteristics, colonization rates, salinity and temperate, can reduce the survival of the mangroves, in both early (e.g., nursery) and late stages of the planting process (Lewis, 2005). Instead, mangrove restoration projects tend to use specific success criteria; for example, mangrove restoration efforts with an 85-90% survival rate after a defined number of years of monitoring are described as successful projects (Walters *et. al*., 2008; Locatelli *et. al*., 2014).

11 Summary

Mangrove formations in the Kachchh coast are predominated by a single species, *i.e. A. marina*, with the sporadic occurrence of *R. mucronata* and *C. tagal*. The present study was carried out at Sat Saida bet and Nakti creek in Kandla and at the vicinity of Kantiyajal covering ten blocks to evaluate mangrove plantations carried out in 1400 ha during the period between 2005 to 2019. The major goal of this study was to assess the mangrove plantation survival percentage to assess the carbon sequestration potential of planted mangroves, to understand the ecological issues related to plantation success, and suggest conservation measures. The mangrove plantation was carried out in temporally from 2005 onwards. The plantation work in Sat Saida started from 2005-2006 (20 ha), followed by 200 ha in 2011-2012, 300 ha in 2012-2013, and 330 ha during the 2013-2014. The plantation work in Nakti creek was initiated in year 2008-2009 (50 ha) followed by 100 ha during 2010-2011. In Kantiyajal the plantation work initiated from 2015-2016 (150 ha) followed by 150 ha during 2016-2017 and 100 ha during 2018-2019. Due to the prevalence of high salinity in the region, *A. marina* was the preferred species for plantation. Although, *R. mucronata* and *C. tagal* were also planted in small pockets at Nakti creek, and *R. mucronata* was attempted at Kantiyajal along with *A. marina*. Among the different plantation areas, maximum density and height of plants were observed at Kantiyanjal. However, the survival rate was highest (75%) for *A. marina* plantation in 150 ha planted during 2016-2017 followed by *R. mucronata* plantation at 150 ha in Kantiyanjal (2016-2017), 330 ha of *A marina* at Sat Saida bet (62.7%) planted during 2013-2014. The lowest survival rate was observed in Nakti creek (40%) within 100 ha area carried out during 2010-2011. In this site, especially multi species plantation activity was carried out using *R. mucurata*, *Ceriops tagal and A. marina*. In rest of the blocks, the survival percentage did not reach the minimum expected (67%) despite of the mangrove species planted. Based on the field monitoring and evaluation data, it is advised to prefer nursery bed and direct seed sowing methods to the *Otla* method, since mangrove areas raised through the *Otla* method undergo high mortality rates even when initial survival rates are high.

The soil Total Biomass Carbon of *A. marina* plantation was lowest (42.36t/ha) in Nakti creek 100 ha plot and highest in 200 ha plot of Sat Saida bet (68.17t/ha). Among the three locations, i.e. Sat Saida bet, Nakti creek and Kantiyajal, the highest carbon sequestration potential was recorded at Sat Saida Bet.

12 Suggestions and recommendations

The Global Mangrove Alliance (GMA), a coalition of international nature conservation Organizations, has set the ambitious target of restoring 20% of mangroves over the current extent by 2030 (Quarto, 2013; Bayraktarov *et al.*, 2016; Wylie *et al.*, 2016; Kodikara *et al.*, 2017). Based on the data collected during the present and previous field survey, the following recommendations are suggested for current and future plantation activities.

12.1 Management approach

The present study indicates that ten blocks are the most suitable sites for further promoting mangrove plantation activities in Sat Saida Bet, as they have already shown survival success and there was space available for gap filling. The following conservation measures are suggested for the planted mangroves in order to improve their survival and make them a mature mangrove formation over the period of time:

- Appropriate site selection needs to be done.
- Both field observation and high-resolution mapping need to be used as a part of mangrove monitoring, conservation and management efforts.
- Site specific appropriate plantation techniques to be opted considering the hydro-geological features to avoid high mortality among mangrove plant species.
- Watering the nursery bed at some regular intervals with freshwater is required.
- Regular tidal flushing and inundation are to be ensured at the selected mangrove sites.
- Manual removal of algal entanglement and barnacle infestation on mangrove to be done periodically.
- Monitoring of existing mangrove plantation to control human interventions to avoid grazing by livestock.
- Mangrove plantation to be carried out using seed source from nearest area possible
- Restoration of mangroves, where it already exists, to be done instead of creating new plantation sites.
- Appropriate restoration efforts are needed such as deepening and de-silting and widening of canals.

- Normal tidal hydrology should not be disrupted and the availability of water-borne dispersal of seeds should be allowed.
- Awareness and outreach programmes for DPA staff and other stakeholders would strengthen the plantation efforts.
- Multispecies plantation is to be preferred while planning
- Involvement of stakeholder communities from the nearby villages to be initiated.

The most relevant suggestive measures for successful mangrove restoration efforts are described below:

12.2 Identification of suitable sites

By far, site selection within the broader landscape for a plantation is the most important criterion that determines the plantation' success. For successful plantation, it is essential that the existing bio-physical conditions of the coastal landscape in a broader and general manner are to be thoroughly understood.

12.3Identification of stress factors

It is important that in any conservation efforts, stressors acting on the mangroves are to be identified and removed in order to maintain the ecosystem balance. Mangrove environment will continue to be stable and balanced if there are no external stressors such as change in hydrology, soil, water salinity, pH, soil texture and wave energy. In addition, anthropogenic stress factors such as collection of fodder and other resources, tree felling and other habitat modification activities will severely affect the ecosystem. It would be necessary to find the factors causing stand degradation and scientifically addressing it to remove the stressors allowing mangroves to flourish.

12.4Bio-physical management

Mostly, micro-topography controls the distribution and wellbeing of mangroves, and physical processes play a dominant role in the formation and functioning of mangrove ecosystem. A list of bio-physical parameters such as the gradient of the intertidal belt, soil nature, number of days of tidal flushing, presence/absence of natural mangroves in the vicinity and availability of adequate intertidal extent are to be considered, and grades should be assigned in a scale of 1 to 10. Duration of tidal flushing, which is influenced by the gradient of the intertidal extent is very essential.

12.5Community-based management

Involving local people and fishermen living nearby and use their traditional knowledge will render the site selection easier since they are well versed with the local conditions, especially tidal flushing rate. In addition, short term and small-scale feasibility trials could be conducted in order to ascertain the suitability of the site.

To encourage both motivation and engagement, the needs of the community need to be assessed and addressed towards their socioeconomic development for the direct benefit of community members (Flint *et al.,* 2018). Ideally, mangroves within the DPA jurisdiction should be subjected to intense management regime to protect them. It was proven in many instances that involving the stakeholder communities in the surrounding villagers will yield better results in mangrove plantation and restoration activities. Effective coordination of multiple stakeholders in a given mangrove project or programme has provided long-term positive impacts for both mangroves and dependent communities. Though the population in the port surroundings has different livelihood activities, fishermen community could be targeted to involve them in community-based mangrove restoration and management. The community-based organization *i.e.*, Samithi roles and responsibilities with reference to mangrove conservation in their vicinity should be well defined and that would play a vital role in conserving these mangrove patches.

12.6Physical protection

Physical protection of natural stand is often the best conservation measure that will fetch positive results. Employees of Deendayal port need to be made aware with the environmental and ecological significance of mangroves and other coastal resources within the port limits. Licenses for salt works and other Port allied industries are awarded by port authorities without understanding the ecological and environmental rules and regulations governing them which often lead to legal and environmental bottleneck at a later stage. Short-term awareness programs in a continuous basis to port employees could be conducted by seasoned marine/mangrove ecologists.

13 Future considerations

In all future plantation activities along with *A. marina,* other compatible species like *R. mucronata*, *C. tagal* and *A. corniculatum* which are available at Sat Saida Bet shall be chosen where ever suitable environmental parameters are available during post monsoon season. Further, such efforts would serve to create a seed bank in due course of time which would eventually convert single species stand of *A. marina* into multi-species assemblages. It is suggested that in future plantation activities, nursery raised saplings along with direct dibbling of seeds and propagules should be preferred rather than following the raised bed (*Otla*) method in order to have high survival rate of the plants. Raised bed plantation are to be conducted only on the suitable sites and not everywhere, for which surveys should be conducted before the initiation of plantation activities. Mangrove restoration is possible by enhancing the natural recruitment of propagules and seeds of the species for which the hydrologic manipulation of the mangrove plantation site is to be done so as to retain them in the bottom sediment and germinate. It is necessary to make sure that tidal water inundation is sufficient for the survival of the seedlings. Through appropriate restoration measures, the existing sparse mangroves could be converted into dense patches by regular gap filling and replantation in the already established blocks. The large plants will provide a protective shield for the newly planted or emerging young plants from water currents during the tidal water movements. Thus, it is suggested to carry out restoration activities along with direct plantation to improve mangrove vegetation cover in DPA. Based on the present monitoring results, it is inferred that Sat Saida Bet could be an ideal site for all future mangrove restoration activities with bio-physical amendments such as de-silting existing creeks, joining all the existing minor creeks with one another through modified creek systems. Increased tidal flooding and hydro-period will extend the mangrove formation in this location along with converting sparse mangrove vegetation into dense mangroves over a period of time. Earlier mangrove vegetation analysis studies at Kandla and Tuna mangroves (GUIDE, 2012 and 2015) have clearly indicated that density and addition of younger classes is good enough to become mature trees. To sum up, through sustainable long -term management practices, the mangroves can be made into a fully grown and functional ecosystem with enhanced ecosystem services.

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Annexure -E

Second Year Monsoon Report
(June 2022 to September 2022)

Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme

Submitted to

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

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Submitted by

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October 2022

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October 2022

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Snapshot

Monsoon (June 2022 to September 2022)

S. No	Components of the Study	Remarks
1	MoEF & CC sanction letter and details	(i). EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/12/16 Dev. Of 7 integrated facilities – specific condition no. xviii. (ii). EC & CRZ clearance granted by the MoEF &CC, GoI dated 18/2/2020 Dev. Remaining 3 integrated facilities – specific condition no. xxiii. (iii). EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 -specific condition no. xv. (iv). EC & CRZ clearance granted by the MoEF &CC, GoI dated 20/11/20 – Creation of waterfront facilities (OJ 8 to 11- Para VIII Marine Ecology, specific condition iv.
2	Deendayal Port letter sanctioning the project	DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/11 date 03.05.2021
3	Duration of the project	Three years-from 24.05.2021 to 23.05.2024
4	Period of the survey carried	Second Year Monsoon season (June 2022 to September 2022)
5	Survey area within the port limit	All major and minor creek systems from Tuna to Surajbari and Vira coastal area.
6	Number of sampling locations	Fifteen sampling locations in and around the DPA port jurisdiction
7	**Components of the report**	
7a	Mangroves	The overall average density was 4602 trees/ha of *A. marina* during monsoon 2022. The highest tree density was reported at the S-12 station in the Tuna creek area (7359 plants/ha). The lowest average tree density (2935 plants/ha) was reported in Phang creek. However, the lowest density in the individual site was recorded in site S-5 at Phang creek. The highest regeneration (140,000 plants/ha) at S-9 of Navlakhi creek and recruitment (31,500 plants/ha) class density were recorded at Kharo creek (S-7).
7b	Mudflats	The highest TOC value (0.83%) was recorded at station S-4 followed by S-2 site. The lowest TOC value was reported at S-12. It is observed that TOC values varied significantly among the sampling stations, which means that organic carbon depends on the living life forms and the type of life forms in the mudflats.

7c	Zooplankton	The zooplankton identified from the 15 stations falls under 10 phyla and 41 genera which are described 16 groups. The phylum Arthropoda was the predominant represented with 25 genera, including copepods, crabs, shrimps and their larvae. The highest percentage was due to the calanoid copepods (36.9%) followed by Decapoda (13.2%) and Gastropoda (8.2%).
7d	Phytoplankton	The generic number recorded during the monsoon period ranged from 24 to 33 at the sampling stations with remarkable variations concerning the composition. The maximum number (33 genera) was observed at S-11, and the minimum from S-15 represented 24 genera. The percentage composition of the various groups varied from 5 % to 47 %, of which the centrales and pennales are the dominant, constituting 47% and 27%, respectively.
7e	Intertidal Fauna	The intertidal fauna and the species diversity of the invertebrates showed the maximum for phylum Arthropoda (8 species), followed by Mollusca (6 species). The phylum Chordata was represented by two species. The overall percentage composition of the four groups of intertidal fauna at the 15 sites revealed the Arthropoda (50%), Mollusca (37%), and Chordata (13%).
7f	Sub-tidal Macrobenthos	The DPA port environment revealed that Mollusca (14 species) and Annelida (2 species) were the major constituents, followed by Arthropoda (1 species) and Cnidaria (1 species). The phylum Mollusca constituted the maximum (78%) share of the subtidal Fauna, followed by Annelida (11%), Arthropoda (5.5%) and Cnidaria (5.5%) in the total benthic samples collected.
7g	Seaweeds	No seaweed is reported in the DPA area.
7h	Seagrass	No seagrass is reported in the DPA area.
7i	Marine reptiles	One species of reptile was recorded from the DPA area.
7j	Marine mammals	One species of marine mammal was recorded from the DPA area.
7k	Halophytes	Four halophytes were recorded along the selected Deendayal Port Authority sites during the Monsoon sampling; among the halophyte species recorded, *Salicornia brachiata* alone was found in the 3 sampling locations. The percentage of *Salicornia brachiata* was found to be the highest at stations S-8 (78%) and the lowest at S-11.
7l	Avifauna	A total of 49 species belonging to 6 orders, 25 families and 38 genera were recorded from the coastal area of Deendayal Port Authority during the Monsoon season study.

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1. Introduction

Deendayal Port is located at the inner end of Gulf of Kachchh on the Kandla creek (22°59'4.93N and longitude 70°13'22.59 E) in the Kachchh district of Gujarat state, operated by Deendayal Port Authority (DPA). Being the India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private participation. Since its formation in the 1950s, the Deendayal Port provides the maritime trade requirements of states such as Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana and Gujarat. Because of its proximity to the Gulf countries, large quantities of crude petroleum are imported through this port. About 35% of the country's total export takes place through the ports of Gujarat in which the Deendayal port has a considerable contribution. Assortments of liquid and dry cargo are being handled at DPA Port. The dry cargo includes fertilizers, iron and steel, food grains, metal products, ores, cement, coal, machinery, sugar, wooden logs, etc. The liquid cargo includes edible oil, crude oil and other petroleum products. Cargo handling has increased from 117.5 MMT to127 MMT during 2021-2022. Presently, the Port has total 1-16 dry cargo berths for handling dry cargo, 6 oil jetties, and one barge jetty at Bunder basin, dry bulk terminal at Tuna Tekra, barge jetty at Tuna and two SPMs at Vadinar for handling oil. Regular expansion or developmental activities such as the addition of jetties, allied SIPC and ship bunkering facilities are underway in order to cope with the increasing demand for cargo handling during the recent times.

A developmental initiative of this magnitude is going on since past 7 decades, which will have its own environmental repercussions. Being located at the inner end of Gulf of Kachchh, Deendayal Port Authority encompasses a number of fragile marine ecosystems that includes a vast expanse of mangroves, mudflats, creek systems and associated biota. Deendayal Port is a natural harbour located on the eastern bank of North-South trending Kandla creek at an aerial distance of 90 km from the mouth of Gulf of Kachchh. The Port's location is marked by a network of major and minor mangrove lined creek systems with a vast extent of mudflats. Coastal belt in and around the port has an irregular and dissected configuration. Due to its location at the inner end of the Gulf, the tidal amplitude is elevated, experiencing 6.66 m during mean high-water spring (MHWS) and 0.78 m during mean low water spring (MLWS) with MSL of 3.88 m. Commensurate with the increasing tidal amplitude, vast intertidal expanse is present in and around the port environment. Thus, the occurrence of mudflats on the intertidal zone enables mangrove formation to an extensive area. Contrary to the southern coast of Gulf of Kachchh, the coral formations, seaweed and seagrass beds are absent in the northern coast due to high turbulence induced suspended sediment load in the water column, a factor again induced due to the conical Gulf geomorphology and surging tides towards its inner end.

1.1. Rationale of the present study

The ongoing developmental activities at Deendayal Port Authority has been intended for the following.

i. The development of 3 remaining integrated facilities (Stage 1) within the existing Port at Kandla which includes development of a container terminal at Tuna off Tekra on BOT base T shaped jetty, construction of port craft jetty and shifting of SNA section of Deendayal port and railway line from NH-8A to Tuna port.

ii. EC & CRZ clearance granted by the MoEF &CC, GoI dated 18/2/2020 Dev. Remaining 3 integrated facilities – specific condition no. xxiii.

iii. EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 -specific condition no. xv.

iv. EC & CRZ clearance granted by the MoEF &CC, GoI dated 20/11/20 – Creation of water front facilities (OJ 8 to 11- Para VIII Marine Ecology,specific condition iv).

As per the environmental clearance requirements to these developmental initiatives, by MoEF & CC, among other conditions, has specified to conduct the continuous monitoring of the coastal environment on various aspects covering the three the seasons. The regular monitoring shall include physico-chemical parameters coupled with biological indices such as mangroves, seagrasses, macrophytes and plankton on a periodic basis during the construction and operation phase of the project. Besides, the monitoring study also includes assessment of Mudflats, Fisheries, and Intertidal fauna including the macrobenthos as components of the management plan. The regular marine ecology monitoring includes Micro, Macro and Mega floral and fauna components of marine biodiversity of the major intertidal ecosystems, the water and sediment characteristics. In accord with MoEF&CC directive, DPA has consigned the project on 'Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme" to Gujarat Institute of Desert Ecology (GUIDE), Bhuj during May, 2021. Further, Deendayal Port authorities has entrusted Gujarat Institute of Desert Ecology (GUIDE) to continue the study for another three years, i.e., 2021 – 2024. The study covers all the seasons as specified by the specific condition of the Ministry of Environment, Forest and Climate Change (MoEF&CC). The present study is designed considering the scope of the work given in the EC conditions.

1.2. Scope of work

The scope of the present investigation includes physico-chemical and marine biological components as mentioned in the specific conditions of MoEF&CC, EC & CRZ clearance dated 19.12.2016,18.2.2020,19.2.2022 and 20.11.2020 with specific conditions xviii, xxiii, xv & iv respectively. A detailed holistic approach to different components of the study such as marine physico-chemical parameters of water and sediment and marine biodiversity within the Deendayal Port area will be carried out. Based on the results obtained during the project period, a detailed management plan will be drawn at the end of the project period. The biological and physico-chemical variables will be investigated during the present study on a seasonal basis i.e., monsoon, post monsoon and pre-monsoon as follows.

- ✓ Physico-chemical characteristics of water and sediment
- ✓ Detailed assessment of mangrove vegetation structure including density,
- ✓ diversity, height, canopy, and other vegetation characteristics.
- ✓ GIS and RS studies to assess different ecological sensitive land use and land cover categories within the Port area such as the extent of dense and sparse mangroves, mudflats, creek systems, and other land cover categories within the port limits.
- ✓ Quantitative and qualitative assessment of the intertidal fauna, composition, distribution, diversity, density, and other characteristics.
- ✓ Data collection on the species composition, distribution, diversity and density of sub-tidal benthic fauna.
- ✓ Estimation of primary productivity at the selected sampling sites located in around the DPA area.
- ✓ Investigation of the species composition, distribution, density, and diversity of phytoplankton and zooplankton.
- ✓ Recording the occurrence, diversity and distribution of halophytes, seagrasses, seaweeds and other coastal flora. Investigations on the Avifaunal density, diversity, composition, habitat, threatened and endangered species and characters. Fishery

Resources – Species composition, diversity, Catch Per Unit Effort (CPUE) and other socio-economic information.

1.2.1. Study Area

The coastal belt in and around Deendayal Port Authority jurisdiction is characterized by a network of creek systems and mudflats which are covered by sparse halophytic vegetation like scrubby to dense mangroves, creeks and salt-encrusted landmass which form the major land components. The surrounding environment in 10 km radius from the port includes built-up areas, salt pans, human habitations and port related structures on the west and north creek system, mangrove formations and mudflats in the east and south. The nearest major habitation is Gandhidham town located about 12 km away on the western part with population of 2,48,705 (as per 2011 census).

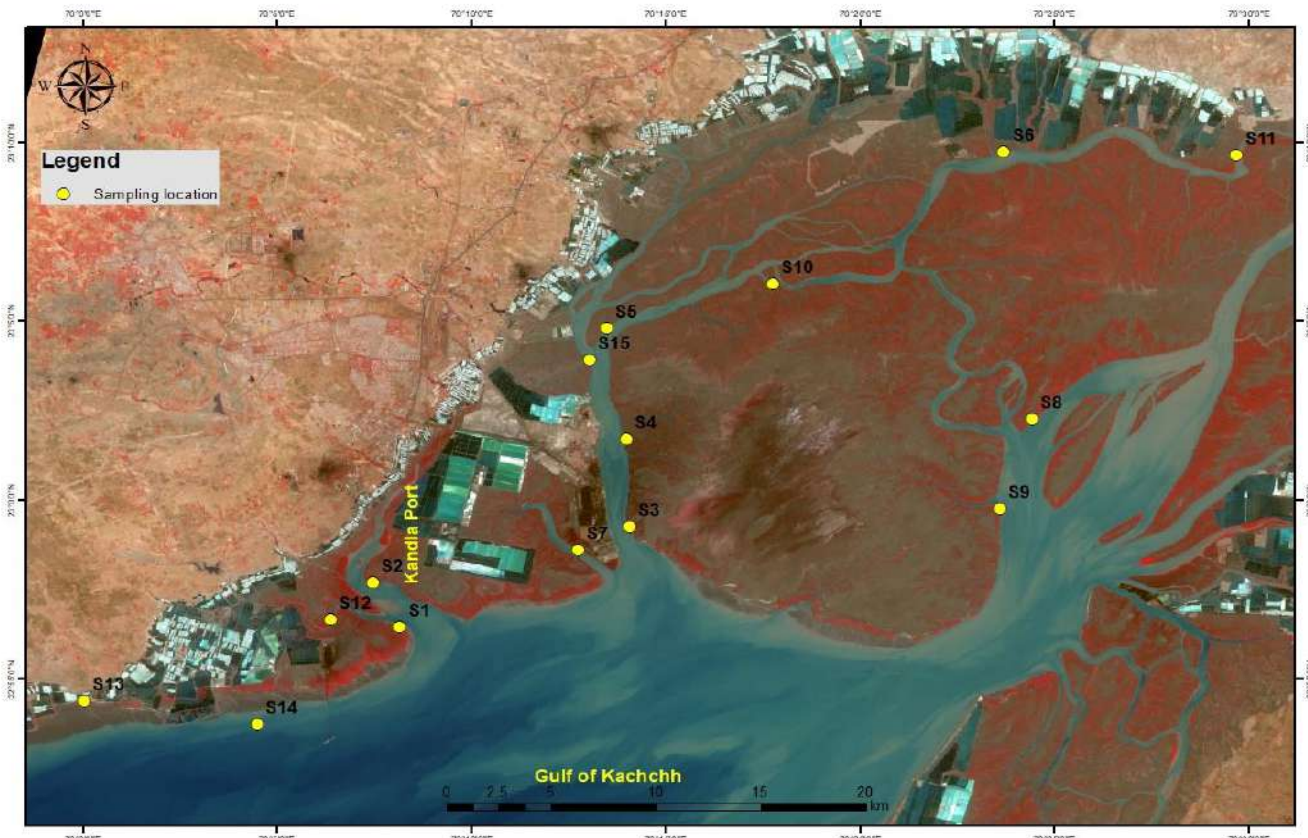

Figure 1: Map showing the sampling locations 2021-2024

2. Sampling of water and sediment samples

Sampling was carried out for the coastal water (surface) and sediment to determine physical and chemical characteristics from the prefixed sampling sites. The biological parameters (benthic and pelagic fauna, flora and productivity) were also estimated (Table.1).

Table 1: Physico-chemical and biological parameters analysed

Parameters	
Water	**Mangrove & Other Flora**
• pH	**Mangrove**
• Temperature	• Vegetation structure, density
• Salinity (ppt)	• Diversity
• Petroleum Hydrocarbons-PHC	• Height
• Dissolved oxygen	• Canopy and other vegetation characteristics
• Total Suspended Solids (TSS)	
• Total Dissolved solids (TDS)	**Halophytes:**
Nutrients	• Percentage of distribution
Nitrate (NO_3)	• Diversity
• Nitrite (NO_2)	
• Total Nitrogen	**Seagrass and Seaweed**
• **Sediment**	• Occurrence, distribution, and diversity.
• Texture	**Intertidal fauna**
• Total organic carbon (TOC)	• Composition, distribution, diversity, density and other characteristics.
• **Biological Parameters**	**Avifauna**
Phytoplankton- Genera, abundance, diversity and biomass	• Density, diversity, composition, habitat,
• Productivity-Chlorophyll a	• Threatened and endangered species and characters
• Zooplankton – Species, abundance, diversity	
• Macrobenthos - genera, abundance, diversity	
• Fishery Resources	
• Common fishes available	
• composition, diversity	
• Catch Per Unit Effort (CPUE)	

The water samples were collected from each pre-designated site in pre-cleaned polyethylene bottles. Prior to sampling, the bottles were rinsed with sample water to be collected and stored in an ice box for transportation to laboratory and refrigerated at 4°C till further analysis. The analysis of the water quality parameters was carried out by following standard methods (APHA, 2017). All extracting reagents were prepared using metal-free, AnalaR grade chemicals (Qualigens Fine Chemicals Division of Glaxo SmithKline Pharmaceuticals Limited, Mumbai) and double distilled water prepared from quartz double distillation assembly.

2.1. Methodology

Physico-chemical Parameters

pH and Temperature

A Thermo fisher pH / EC / Temperature meter was used for pH and temperature measurements. The instrument was calibrated with standard buffers just before use.

Salinity

A suitable volume of the sample was titrated against Silver nitrate (20 g/l) with Potassium chromate as an indicator. The chlorinity was estimated, and from that, salinity values were derived using a formula (Strickland and Parsons,1972).

Total Suspended Solids (TSS)

About 100 ml of the water sample was filtered through pre-weighed filter paper and placed in the Hot air oven at a specified temperature as per the protocol for 1 hour. The filter paper was allowed to cool in a desiccator to obtain a constant weight by repeating the drying and desiccation steps.

Total Dissolved Solids (TDS)

The water samples were subjected for gravimetric procedure for confirmation of the readings obtained from the hand -held meter. About 100 ml of the water sample was taken in a beaker and filtered which was then dried totally in a Hot Air Oven (105°C). The TDS values were calculated using the difference in the initial and final weight of the container.

Turbidity

The sample tube (Nephelometric cuvette) was filled with distilled water and placed in the sample holder. The lid of the sample compartment was closed. By adjusting the'SET ZERO' knob, the meter reading was adjusted to read zero. The sample tube with distilled water was removed, the 40 NTU standard solutions were filled in the tube, and the meter reading was set to read 100. Other standards were also run. The turbidity of the marine water sample was then found by filling the sample tube with the sample, and the reading was noted.

Dissolved Oxygen (DO)

DO was determined by Winkler's method (Strickland and Parsons,1972).

Phosphate

Acidified Molybdate reagent was added to the sample to yield a phosphomolybdate complex that is reduced with Ascorbic acid to a highly coloured blue compound, which is measured at the wavelength of 690 nm in a Spectrophotometer (Shimadzu UV 5040).

Total phosphorus

Phosphorus compounds in the sample were oxidized to phosphate with alkaline Potassium per sulphate at high temperature and pressure. The resulting phosphate was analyzed and described as total phosphorous.

Nitrite

Nitrite in the water sample was allowed to react with Sulphanilamide in acid solution. The resulting diazo compound was reacted with N-1-Naphthyl ethylenediamine dihydrochloride to form a highly coloured azo-dye. The light absorbance was measured at the wavelength of 543 nm in Spectrophotometer (Shimadzu UV 5040).

Nitrate

The Nitrate content was determined as nitrite (as mentioned above) after its reduction by passing the sample through a column packed with amalgamated Cadmium.

Petroleum Hydrocarbon (PHs)

The water sample (1liter) was extracted with hexane and the organic layer was separated, dried over anhydrous sulphate and reduced to 10 ml at 30°C under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with Saudi Arabian crude residue as a standard. The residue was obtained by evaporating lighter fractions of the crude oil at 120°C.

Sediment characteristics

Sediment samples were collected from the prefixed stations by using a Van Veen grab having a mouth area of $0.04m^2$ or by a non-metallic plastic spatula. Sediment analysis was carried out using standard methodologies. In each location (grid), sediment samples were collected from three different spots and pooled together to make a composite sample, representative of a particular site. The collected samples were air dried and used for further analysis.

Sediment Texture

For texture analysis, specified unit of sediment sample was sieved through sieves of different mesh size as per Unified Soil Classification System (USCS). Cumulative weight retained in each sieve was calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves (USDA,1951). The percentage of the various fractions was calculated from the weight retained and the total weight of the sample. The cumulative percentage was calculated by sequentially subtracting percent retained from the 100%.

Total Organic carbon

Percentage of organic carbon in the dry sediment was determined by oxidizing the organic matter in the sample by Chromic acid and estimating the excess Chromic acid by titrating against Ferrous ammonium sulphate with Ferroin as an indicator (Walkley and Black, 1934).

2.3. Biological Characteristics of water and Sediment

Primary productivity

Phytoplankton possess the plant pigment chlorophyll ‘a’ which is responsible for synthesizing the energy for metabolic activities of phytoplankton through the process of photosynthesis in which CO_2 is used and O_2 is released. It is an essential component to understand the consequences of pollutants on the photosynthetic efficiency of phytoplankton in the system. To estimate this, a known volume of water (500 ml) was filtered through a 0.45 μm Millipore Glass filter paper and the pigments retained on the filter paper were extracted in 90% Acetone. For the estimation of chlorophyll 'a' and pheophytin pigments the fluorescence of the Acetone extract was measured using Fluorometer before and after treatment with dilute acid (0.1N HCL) (Strickland and Parsons,1972).

Phytoplankton

Phytoplankton samples were collected from prefixed 15 sampling sites from the coastal water in and around DPA location using standard plankton net with a mesh size of 25µm and a mouth area of 0.1256 m^2 (20 cm radius). The net fitted with a flow meter (Hydrobios) was towed from a motorized boat moving at a speed of 2 nautical miles/hr. Plankton adhering to the net was concentrated in the net bucket by splashing seawater transferred to a pre-cleaned and rinsed container and preserved with 5% neutralized formaldehyde and appropriately labelled indicating the details of the collection, and stored for further analysis. The Quantitative analysis of phytoplankton (cell count) was carried out using a Sedgewick-Rafter counting chamber. The density (No/l) was calculated using the formula: $N=n \times v/V$ (Where, N is the total No/liter, n is the average number of cells in 1 ml, v is the volume of concentrate; V is the total volume of water filtered. The identification was done by following the standard literature of Desikachary, (1987), Santhanam et.al. (2019) and Kamboj et.al. (2018).

Zooplankton

Zooplankton samples were collected using a standard zooplankton net made of bolting silk having 50µm with mouth area of 0.25 m^2 fitted with a flow meter. The net was towed from a boat for 5 minutes with a constant boat speed of 2 nautical miles/hr. The initial and final reading in the flow meter was noted down and the plankton concentrate collected in the bucket was transferred to appropriately labeled container and preserved with 5% neutralized formaldehyde. One ml of the zooplankton concentrate was added to a Sedgwick counting chamber and observed under a compound microscope and identified by following standard literature. The group/taxa were identified using standard identification keys and their number was recorded. Random cells in the counting chamber were taken for consideration and the number of zooplankton was noted down along with their binomial name. This process was repeated for five times with 1 ml sample and the average value was considered for the final calculation. For greater accuracy, the final density values were counter-checked and compared with the data collected by the settlement method.

Univariate measures such as Shannon-Wiener diversity index (H'), Margalef's species richness (d), and Pielou's evenness (J'), Simpson's dominance (D) was determined using PAST software.

Intertidal Fauna

Intertidal faunal assemblages were studied for their density, abundance and frequency of occurrence during monsoon 2022 at the pre-fixed 15 sampling locations within the DPA jurisdiction. Sample collection and assessment of intertidal communities were done in the intertidal zone during the low tide period. At each site, 1 x1 m^2 quadrates were placed randomly and all visible macrofaunal organisms encountered inside the quadrate were identified, counted and recorded. At each site, along the transects which run perpendicular to the waterfront, three to six replicate quadrate samples were assessed for the variability in macro-faunal population structure and the density was averaged for the entire intertidal belt. Organisms, which could not be identified in the field, were preserved in 5% formaldehyde, brought to the laboratory and identified using standard identification keys (Abott, 1954; Vine, 1986; Oliver, 1992; Rao, 2003; 2017; Psomadakis *et al.*, 2015; Apte, 2012; 2014; Naderloo 2017; Ravinesh *et al.* 2021; Edward *et al.*, 2022). Average data at each site were used to calculate the mean density (No/m^2).

Subtidal macro benthic Fauna

The sampling methods and procedures were designed in such a way to obtain specimens in the best possible condition as to maximize the usefulness of the data obtained. For studying the benthic organisms, triplicate samples were collected at each station using Van Veen grab, which covered an area of 0.04m^2. The wet sediment was passed through a sieve of mesh size 0.5 mm for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal dye for ease of spotting at the time of sorting. The number of organisms in each grab sample was expressed as No. /m^2. All the species were sorted, enumerated and identified by following the available literature. The works of Day (1967), Hartman (1968, 1969), Rouse and Pleijel (2001), Robin et al., (2003), Amr (2021), were referred for polychaetes; Crane (1975), Holthuis (1993), Naderloo (2017). Xavier et al., (2020) for crustaceans; Subba Rao (1989, 2003. 2017), Apte (2012, 2014), Ramakrishna and Dey (2007), Ravinesh *et al*. (2021) and Edward *et al*, (2022) for molluscs. Statistical analyses such as diversity indices and quadrat richness were calculated using Paleontological Statistics Software Package for Education and Data (PAST) version 3.2.1 (Hammer et al., 2001).

Plate 1: Estimation of intertidal fauna by the quadrate method

Plate 2: Collection of Plankton and macrobenthos in subtidal habitat

2.4. Mudflats

Mudflats are ecologically and socio-economically vital ecosystems that bring benefits to human populations around the globe. These soft-sediment intertidal habitats, with >10% silt and clay (Dyer 1979), sustain global fisheries through the establishment of food and habitat (including important nursery habitats), support resident and migratory populations of birds, provide coastal defenses, and have aesthetic value. Mudflats are intimately linked by physical processes and dependent on coastal habitats, and they commonly appear in the natural sequence of habitats between subtidal channels and vegetated salt marshes. In some coastal areas, which may be several kilometress wide and commonly form the largest part of the intertidal area. Mudflats are characterized by high biological productivity and abundance of organisms but low in species diversity with few rare species. The mudflat biota reflectsthe prevailing physical conditions of the region. Intertidal mudflats can be separated into three distinct zones such as the lower tidal, middle and upper mudflats. The lower mudflats lie between mean low water neap and mean low water spring tide levels, and are often subjected to strong tidal currents. The middle mudflats are located between mean low water neaps and mean high water springs. The upper mudflats lie between the mean high-water neap and mean high water springs. The upper mudflats are the least inundated part and are only submerged at high water by spring tides (Klein, 1985). Salt marsh vegetation may colonize as far seaward as mean high water neaps. Mudflats will often continue below the level of low water spring tides and form sub-tidal mudflats (McCann, 1980). The upper parts of mudflats are generally characterized by coarse clays, the middle parts by silts, and the lower region by sandy mud (Dyer *et al*., 2000). The intertidal mudflats are prominent sub-environments that occurred on the margin of the estuaries and low relief sheltered coastal environments. The fine-grained sediments of intertidal mudflats (70%-90%) are derived from terrestrial and marine regions (Lesuere *et.al*.,2003). Estuarine mudflats are potential sites for deposition of organic matter derived from terrigenous, marine, atmospheric and anthropogenic sources and are mainly associated with fine grained particles (Wang *et.al*., 2006).

Sampling locations

The Sediment samples were collected from 15 sampling locations by using sediment corer. From each site triplicate samples were collected from up to 100 cm depth with four intervals (0-25cm, 25-50cm, 50-75cm & 75-100cm) and made into composite sample for analysis. The samples were packed in zip lock bags, stored in icebox and shifted to the laboratory for subsequent analysis.

Plate 3: Sediment sample collection at mangrove and mudflat areas

Total Organic Carbon

The organic carbon content of the mudflats was estimated to assess the biological productivity of the sediment. Soil Organic Carbon (SOC) was estimated following the method of Walkley and Black (1934). In this method, organic matter (humus) in the soil gets oxidized by Chromic acid (Potassium dichromate plus concentrated H2SO4) by utilizing the heat evolved with the addition of H_2SO4. The unreacted dichromate is determined by back titration with Ferrous ammonium sulphate (redox titration). Organic carbon was determined by following the below given formula:

$$\text{Oxidizable organic carbon (\%)} = \frac{10\ (B - T)}{B} \times 0.003 \times \frac{100}{\text{wt. of soil}}$$

Where B = volume (mL) of Ferrous ammonium sulfate required for blank titration.T = volume of Ferrous ammonium sulfate needed for soil sample. Wt. =weight of soil (g).

Estimation of Bulk Density (BD)

The soil under field condition exists as a three-phase system viz. solid (soil particles), liquid (water) and gas (mostly air). The soil organic matter contained in a unit volume of the soil sample is called its bulk density. The amount of bulk density depends on the texture, structure and organic matter status of the soil. High organic matter content lowers the bulk density, whereas compaction increases the bulk density. To determine the bulk density of the sediment samples collected during the present study, the oven-dry weight of a known sediment volume was considered, and mass per unit volume was calculated (Maiti, 2012).

2.5. Mangrove assessment

Mangroves are widely distributed on the Deendayal Port Authority jurisdiction along the Kandla coast. The 15 mangrove sites selected at the different creeks belong to Deendayal Port Authority jurisdiction and all these stations are supposed to be sufficient to represent the mangroves status in Kandla. The mangrove stations in this study were named Tuna, Jangi, Kandla, Phan and Navlakhi based on the nearest location to the respective creek system. The Point Centered Quadrate Method (PCQM) was used for the collection of data of mangrove vegetation structure. The data included measurements of density of plants, height variations, canopy and basal area of mangrove trees as per the method of Cintron and Novelli (1984). For this method, a transect of a maximum of 200 m was applied mostly perpendicular or occasionally parallel to the creek. The sampling points considered at an interval of every 10 m and the vegetation structure of the that area were recorded. As the orientation of the transect line was already fixed, it was easy for movements within the station area for data recording. The distance between trees from the center of the sampling point for nearest 4 trees of four different directions, height of trees from the ground level, canopy length and canopy width were measured to determine the canopy cover in this study. The equipments utilized in the field were handy, and easy to use such as ranging rods, pipes and for measurement of girth at root collar above the ground (GRC), a measuring tape was used. The plants with a height <50 cm was considered as regeneration class and >50 cm but <100 cm was considered as recruitment class. Along the transects, sub-plots of 1×1 m^2 for regeneration and 2×2 m^2 were laid randomly for recruitment class of the mangrove sites.

Plate 4: Assessment of mangrove density, height, canopy cover and girth

2.6. Halophytes

To quantify and document the halophytes at Deendayal Port Authority region, quadrate method was followed. At each sampling location quadrates of various sizes have been laid during every seasonal sampling. For recording the plant density at each transect, a quadrate 1 x 1m^2 has been laid within the site each tree quadrates were used randomly (Misra,1968; Bonham, 1989). Four quadrates each for shrubs and herbs were laid in side each tree quadrate to assess the halophytes and the percentage cover in the study area. To enrich the species inventory, areas falling outside the quadrates were also explored and the observed species were recorded and photographed and identified using standard keys. Specimens of the various species were collected to know more information on habitat and for the preparation of herbarium.

Plate 5: Assessment and percentage cover of halophytes

2.7. Marine Fishery

Fishery resources and the diversity were assessed from the selected sampling sites. Finfish and shellfish samples were collected using a gill net with a 10 mm mesh size. The net was operated onto the water from a canoe or by a person standing in waist deep water during the high tide using a cast net. For effective sampling, points were fixed at distances within the 15 offshore sites for deploying fishing nets to calculate the Catch per Unit effort estimated per hour. The collected specimens were segregated into groups, weighed and preserved in 10% neutralized formalin solution. Finfishes were identified following Fischer and Bianchi (1984), Masuda *et al*. (1984), de Bruin et al. (1995) and Mohsin and Ambiak (1996). Relevant secondary information pertaining to fishery resources of Deendayal Port creek systems were gathered through technical reports, the District Fisheries department, Government gazette and other research publications.

Plate 6: Collection of fisheries information from DPA environment

2.8. Avifauna

The Avifauna population was determined along DPA mangrove strands for which the area was demarcated into fifteen major stations. In each station, creeks of varying lengths from 2 to 5 km are available. These creeks were surveyed by using boat and adopting "line transect" method. A total of fifteen boat transect (one in each site) survey was conducted in the Monsoon season (June-September, 2022). Survey was done in both terrestrial habitats like Mangrove plantations adjoining the mudflats, waste land, and aquatic habitats, like creek area, rivers and wetland.

Boat Surveys

Mangrove bird diversity was calculated by using Boat Survey method. Birds were observed from an observation post on board the boat which has given the greatest angle of clear view. Birds within a 100 meter transect on one side of the boat were counted in 10-minute blocks of time (Briggs *et al.* 1985; van Franeker, 1994). Detection of birds was done with a binocular (10 x 40) and counts were made: (1) continuously of all stationary birds (swimming, sitting on mangrove, or actively feeding) within the transect limits and (2) in a snap-shot fashion for all flying birds within the transect limits. The speed of the boat determines the forward limit of the snapshot area within a range of 100 meters. Longer or shorter forward distances were avoided by adapting the frequency of the snapshot counts. Birds that following and circling the boat were omitted from both snapshot and continuous counts. If birds arrive and then follow the boat, they were included in the count only if their first sighting falls within a normal snapshot or continuous count of the transect area. For each bird observation species, number of individuals and activity at the time of sighting, were recorded. Species richness and diversity index were calculated for different mangrove patches (i.e. fifteen station) of the study station in the Deendayal port Authority.

2.9. Data analysis

Data collected in- situ and through laboratory analysis of samples were subjected to descriptive statistical analysis (PAST and Primer 7.0) for the mean, range and distribution of different variables from the selected 15 study stations.

3. Results

Water quality assessment

The data on the mean water quality parameters measured at the time of sampling of the biological components from the 15 study sites are presented in Table1.

Temperature (°C) and pH

The water temperature at the sampling sites ranged from 23°C to 31°C.The maximum temperature of seawater was reported at S-5 and the minimum at S-6 in Kandla creek. The pH of seawater ranged from 7.1 to 8.3. The highest pH was reported at sites S-15 and S-10, however, the lowest pH 7.1 was noticed at S-14 in Kandla creek. The overall observation along the port environment revealed that the temperature fluctuation might be due to high degree of warmth in summer on the land but the pH range did not show major fluctuations among the sampling locations.

Salinity (ppt)

Salinity of the water strongly influences the abundance and distribution of marine biota in coastal and marine environments. The salinity ranged from 28 ppt to 40 ppt with the average value of 37 ppt. Minimum salinity was observed S-7 and maximum at S-9, S-13 & S-15. The poor rainfall induced aridity in the Gulf of Kachchh (GoK) region renders Gulf waters hypersaline round the year. In addition, GoK is known to be a negative water body where evaporation exceeds precipitation.

Dissolved oxygen (DO)

Dissolved oxygen is the amount of oxygen dissolved in water and is a fundamental requirement of all biota and chemical processes in the aquatic environment. The concentration varies mainly due to photosynthesis and respiration by plants and animals in water. Generally, the coastal waters are having high level of dissolved oxygen due to the dissolution from the atmosphere through diffusion process on the surface layer (CCME,1999). The dissolved oxygen in the coastal waters of Deendayal port authority area ranged from 4.5 mg/L to 6.9 mg. The highest DO concentration was observed at station S-7 and lowest was observed at stati-15.

Suspended Solids (TSS)

The total suspended solids (TSS) concentration at the 15 sampling sites ranged from 127 mg/L to 403 mg/L with the average of 255 mg/L. The highest TSS values was reported at S-15 in the Phang creek followed by 354 mg/L in S-3 oil jetty. The minimum TSS value was recorded at S-7 which was 127 mg/L.

Total Dissolved solids (TDS)

The total dissolved solids (TDS) in the water consist of inorganic salts and dissolved materials which mostly comprises of anions and cations. The TDS of the samples varied from 1967 mg/L 11,288 mg/L with an average of 5,703 mg/L. The maximum value was reported at S-6.

Turbidity

The turbidity of the water samples from the study sites ranged between 44 NTU and 147 NTU with the average of 76 NTU. The lowest value was reported at S-3 and a highest value at S-6 followed by S-6 (170 NTU).

Water nutrients (Nitrate, Nitrite and Total Phosphorus)

The nutrients influence growth, metabolic activities and reproduction of biotic components in the aquatic environment. The distribution of nutrients mainly depends upon tidal conditions, season and fresh water influx from land. The nitrate concentration ranged from 0.01 mg/L to 0.02 mg/L with an average of 0.01 mg/L. The highest nitrate concentration was observed at station S-7 and the lowest at station S-11. There was no remarkable variation in concentration of nitrate among the study station. Similarly, nitrite values varied between 0.05 mg/L to 0.94 mg/L. The highest concentration was observed at station S-13 and lowest concentration was observed at station S-2.The highest concentration might be due to influx effluents from industries producing metals, dyes and celluloid in the periphery of port authority The Total phosphorus values among the study station ranged from 0.02 mg/L to 0.96 mg/L with in average of 0.47 mg/L. The highest phosphorus concentration was observed at station S-13 near veera of Kandla creek and lowest concentration was observed at station S-11 in Jhangi creek. Highest concentration might be due to leaching of phosphatic fertilizer while handling of cargo port area**.**

Petroleum Hydrocarbons (PHs)

Due to urbanization and modernization, petrochemical products are in heavy demand. Petroleum hydrocarbons (PHs) represent short-chain hydrocarbons like aromatic, paraffin, alicyclic complexes, and non-hydrocarbon mixtures such as thiol, and asphaltene, naphthenic acid, phenol, thiol, heterocyclic nitrogen, sulfuric amalgams and metalloporphyrin. Due to the hydrophobic nature of the PHs, they possess low solubility in water and a high persistence level in soil, water as well as sediments (Babu *et al.*, 2019). PHs are significant toxic compounds representing one of the major wide-scale environmental threats caused due to the coastal oil refining, production, leaks or accidental spilling, transport, shipping activities, offshore oil production and other anthropogenic activities. The release of such compounds into the environment irrespective of it being accidental or due to any anthropogenic activities leads to soil as well as water pollution. This in turn poses catastrophic health effects either directly or indirectly on all the forms of life thereby deteriorating the overall ecosystem. In the current study, the presence of PHs in water samples collected along all the 15 sampling sites were detected and estimated. The PHs ranged from 2.2 μg/L to 9.9 μg/L. The PHs detected from the individual sites have been represented in (Fig 2). The highest concentration of the PHs was detected at S-1 site (Tuna creek) while the lowest was noted for S-13 (Veera). A high level of the PHs content was noted down at site S-1 too followed by the rest of the sites.

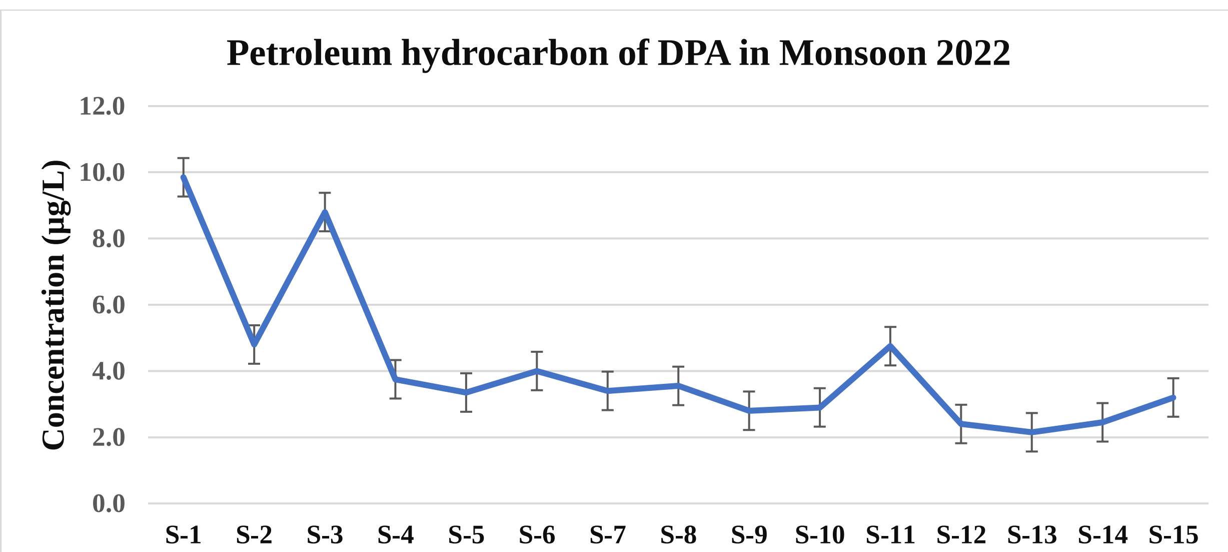

Figure 2: Petroleum hydrocarbons in water (μg/L) during Monsoon 2022

Table 2: Physico-chemical characteristics of coastal waters during Monsoon 2022

Parameters	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Temp (°C) (Air)	27	28	31	33	36	26	31	29	30	32	26	34	29	29	34
Temp (°C) (Water)	25	25	29	30	31	23	29	26	27	30	23	30	27	26	29
pH	8	8.09	7.9	7.5	7.8	7.8	7.7	7.6	8.2	7.9	7.9	8.06	8.2	7.1	8.3
Salinity (ppt)	34.7	36.7	39.2	38.7	36.5	36.2	28.3	35.8	39.9	38.8	36.4	39	40.2	38.2	40.1
Dissolved oxygen (mg/L)	4.86	4.66	6.69	5.27	5.87	4.66	6.89	6.28	5.06	5.87	4.66	6.48	5.27	5.47	4.45
Total Suspended Solids (TSS) (mg/L)	200	236	354	132	347	234	127	172	342	232	334	190	272	252	403
Total Dissolved solids (TDS) (mg/L)	3970	4676	2985	3851	7885	1967	5988	4320	7549	11288	8983	3886	5676	4792	7733
Turbidity (NTU)	48	58	147	95	93	44	45	93	119	108	57	58	58	52	63
Nitrate (NO_3) (mg/L)	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.07	0.02	0.01
Nitrite (NO_2) (mg/L)	0.39	0.05	0.36	0.39	0.41	0.74	0.38	0.53	0.58	0.27	0.73	0.39	0.94	0.63	0.55
Total Phosphorus (mg/L)	0.35	0.64	0.46	0.41	0.39	0.90	0.76	0.30	0.04	0.06	0.02	0.35	0.96	0.85	0.63
PHs (µg/L)	9.85	4.8	8.8	3.75	3.35	4	3.4	3.55	2.8	2.9	4.75	2.4	2.15	2.45	3.2
Chlorophyll a (mg/L)	0.19	0.20	0.21	0.18	0.13	0.15	0.19	0.15	0.16	0.14	0.19	0.21	0.15	0.16	0.22

3.2. Sediment

Sediment texture

The percentage composition of the soil particles in the sediment analyzed from the 15 sampling sites are presented in Fig.3.There were noticeable variations in the soil fractions, sand, silt and clay, among the stations. In the present study the highest percentage of clay was reported at S-7 followed by S-9. The highest percentage of sand was observed at S-1 followed by S-14 station. As per the observations, the percentage of silt content was less compared to clay and sand in many sampling sites except S-1 and S-14. The nature of soil texture was characterized by the proportion of clay, sand and silt fractions. The Soil texture revealed the dominance of silty-clay type in all the stations with less variations among them. This consistently high clay-loam value may be attributed to the winnowing activity of sediment transport system. The absence of perennial flow of freshwater into the coast along with lack of wave induced sand transport from open sea are the possible reasons for this uniform pattern of soil texture.

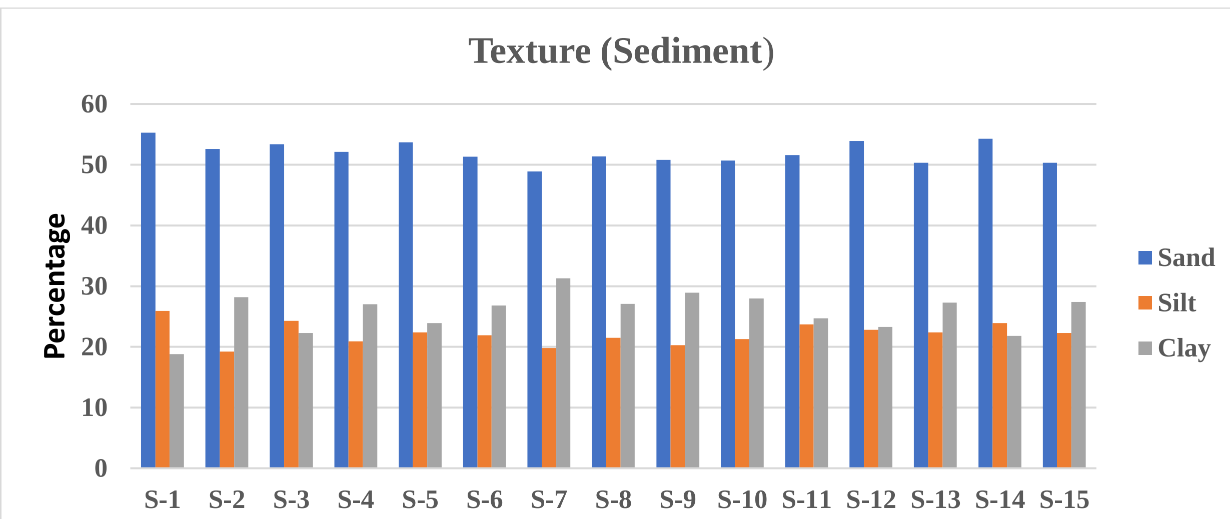

Figure 3: Characteristics of sediment at the study stations in Monsoon 2022

Total Organic Carbon (TOC)

In the present study, the total organic carbon content varied from 0.63% to 0.84% (Fig.4). The highest values of TOC were reported at S-11 followed by S-15. The lowest TOC value was recorded at the S-7. The distribution of total organic carbon closely followed the distribution of sediment type i.e., sediment low in clay content contained relatively low organic carbon.

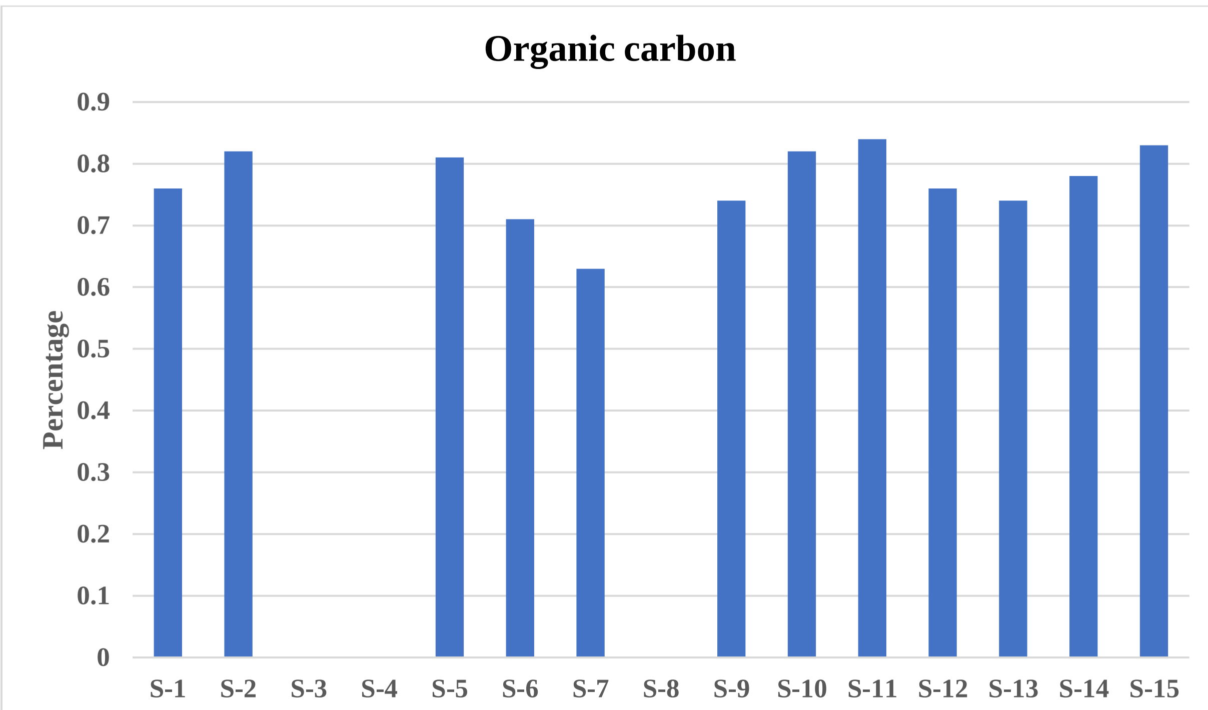

Figure 4: Total Organic Carbon content (%) in the sediment during Monsoon 2022

3.3. Biological characteristics of water and sediment

Primary productivity

Chlorophyll 'a' the photosynthetic pigment which can be used as a proxy for phytoplankton productivity and thus is an essential water quality parameter. Generally, the primary production of the water column is assessed from Chlorophyll 'a' concentration. It is well known that half of the global primary production being mediated by the activity of microscopic phytoplankton.

In the present study, Chlorophyll 'a' concentration ranged from 0.13 mg/L to 0.22 mg/L. The highest concentration 0.22 mg/L was reported at S-15 (Fig.5) followed by S-12 (0.21) and S 3 (0.20mg/L). The photosynthetic pigment chlorophyll a which is a measure of the population density of phytoplankton during the monsoon period showed narrow range of variations among the sites. The Chlorophyll 'a' content was very low at S-5.

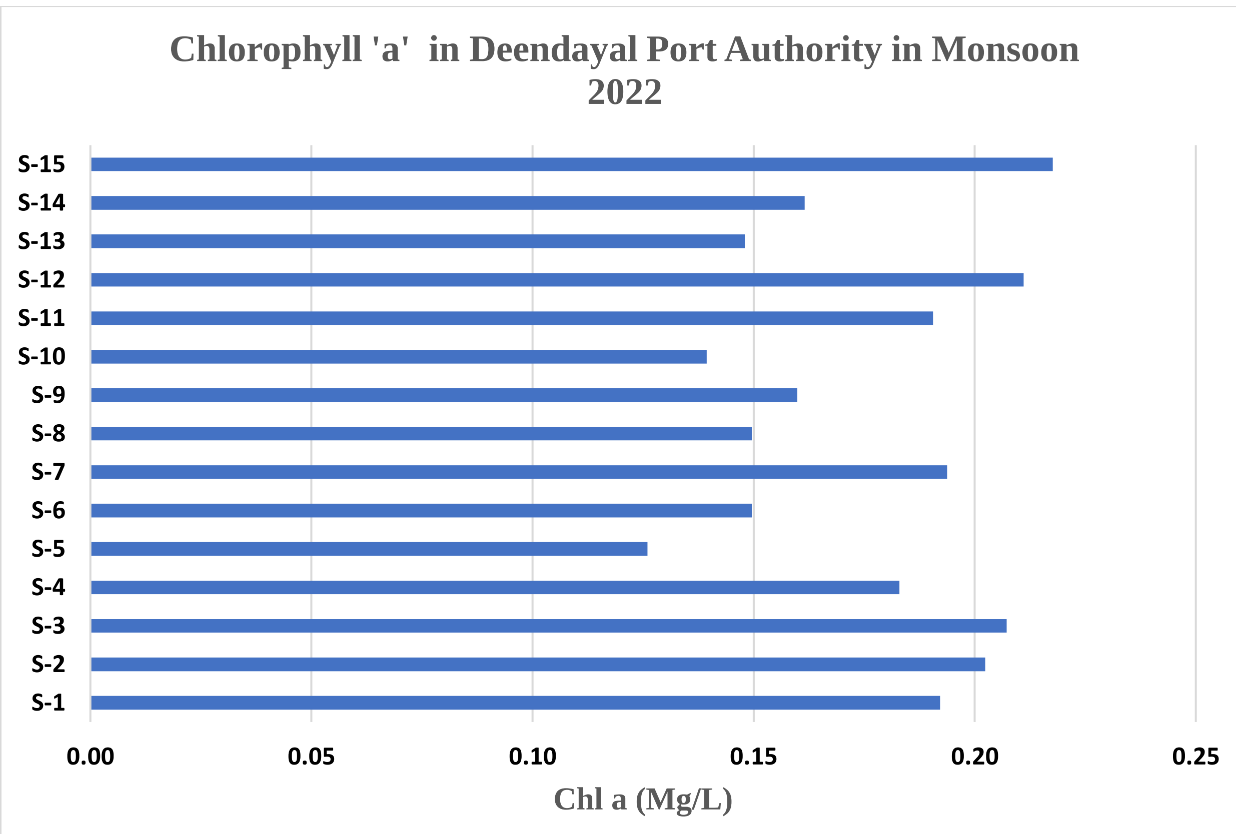

Figure 5: Chlorophyll 'a' concentration at the study stations in Monsoon 2022

3.4. Phytoplankton

Phytoplankton are free-floating, photosynthetic, aquatic microorganisms, which are distributed either actively by their locomotory organs (flagella) or passively by water currents. Most of the phytoplankton survive on the open surface waters of lakes, rivers and oceans. The phytoplankton community is mainly represented by algal representatives including both prokaryotes and eukaryotic genera. Plankton populations are mostly represented by members of Cyanobacteria, Chlorophyta, Dinophyta, Euglenophyta, Haptophyta, Chrysophyta, Cryptophyta, and Bacillariophyta. Planktonic representative taxa are absent in other algal divisions like Phaeophyta and Rhodophyta.

Generic Status

There were four groups of phytoplankton occurred during monsoon along the DPA, Kandla coast and its peripheral creek system which include Diatom (Pennales, Centrales), Dinophyceae and Cyanophyceae. The number of genera recorded during the monsoon period was 24 to 33 at the sampling stations with remarkable variations with respect to the composition. The maximum number (33) genera were observed at S-11 and the minimum from S-15 representing 24 genera. As far as generic status is concerned the centrales diatom contributed a greater number of genera (16) followed by Pennales (10) (Fig.6 & Table 3). Among the 4 groups of phytoplankton, the genera *Pseudonitzschia*, *Rhizosolenia*, *Coscinodiscus*, *Eucampia*, *Melosira* and *Planktoniella* occurred at all the sites.

Percentage composition of phytoplankton

The cumulative percentage composition of the five groups of phytoplankton from all the study sites is presented in Fig.7. The percentage composition varied from 5 % to 47 % of which the centrales and pennales are the dominant constituting 47% and 27% respectively. The diatoms pennales and centrales together formed 74% of the phytoplankton population by number of genera as well as number of individuals while the rest is constituted by Dinophyceae (10%) and Cyanophyceae (12%) and Chlorophyceae (4%) during the monsoon 2022.

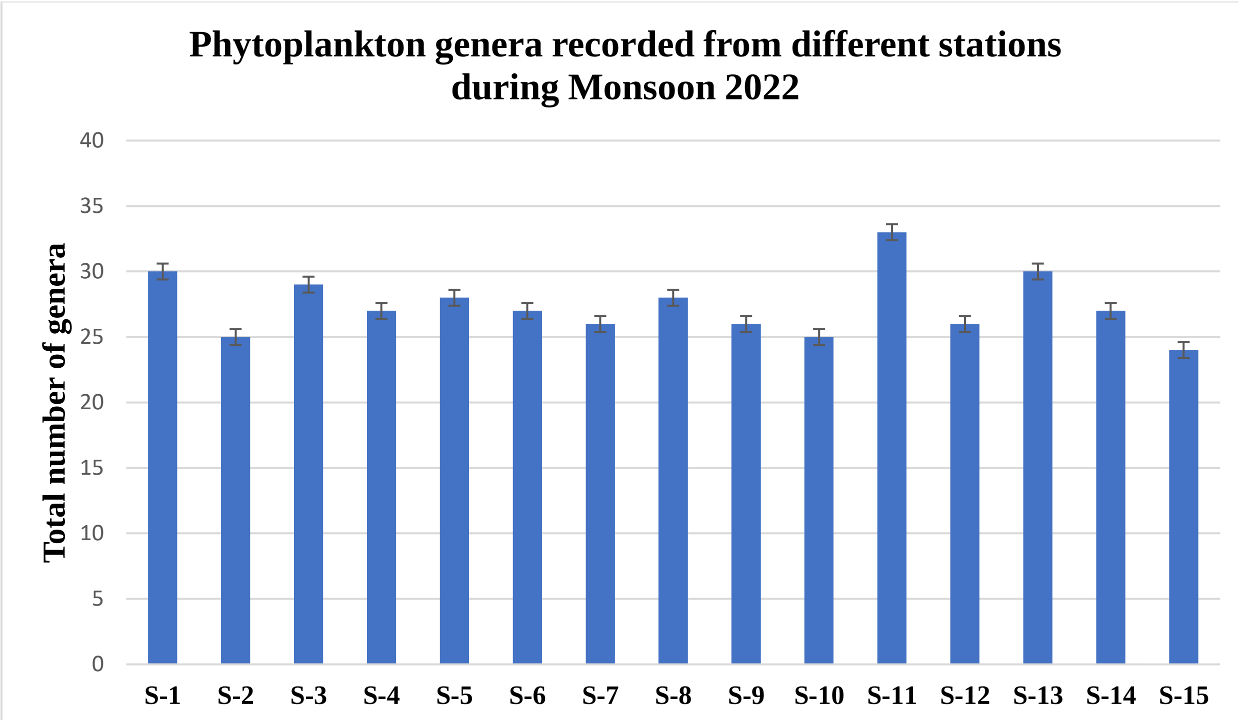

Figure 6: Number of Phytoplankton genera in Monsoon 2022

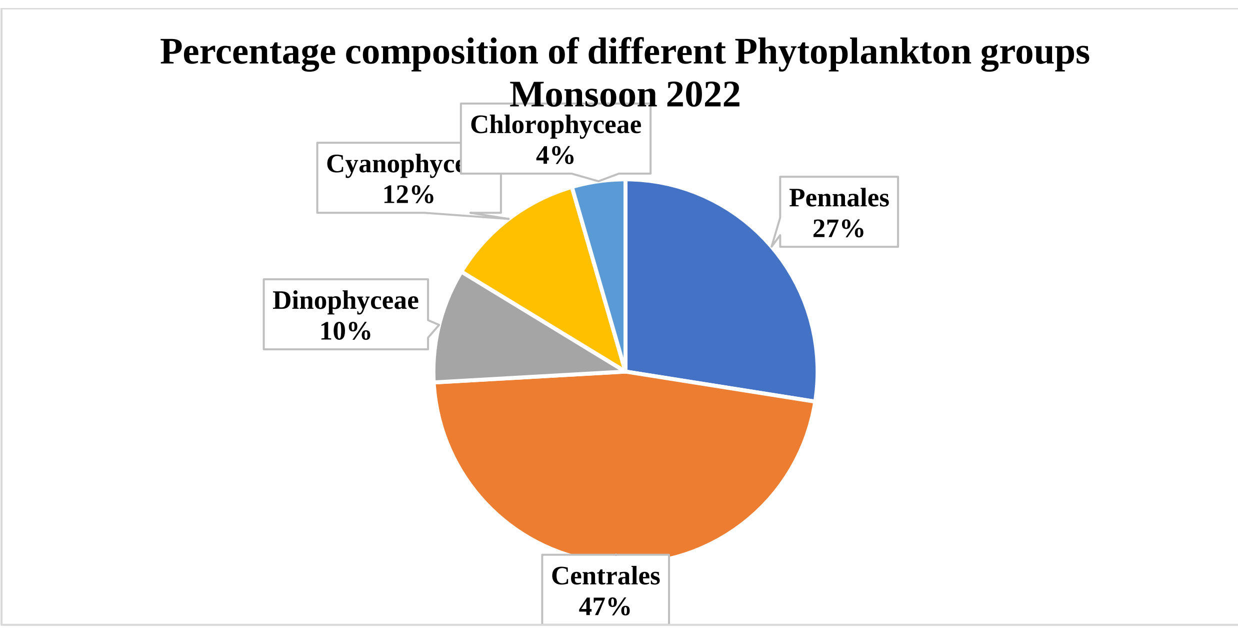

Figure 7: Percentage composition of phytoplankton groups in Monsoon 2022

Percentage of occurrence

The percentage occurrence denotes the number of representations by a genus among the sites sampled. The percentage occurrence of different phytoplankton genera varied from 27% to 100% with an average of 78%. Seven phytoplankton genera have the highest percentage of occurrence (100%) (fig 8) followed by *Pleurosigma*, *Gyrosigma*, *Thalassionema* and *Aphanizomenon* (93%) occurrence during the monsoon season

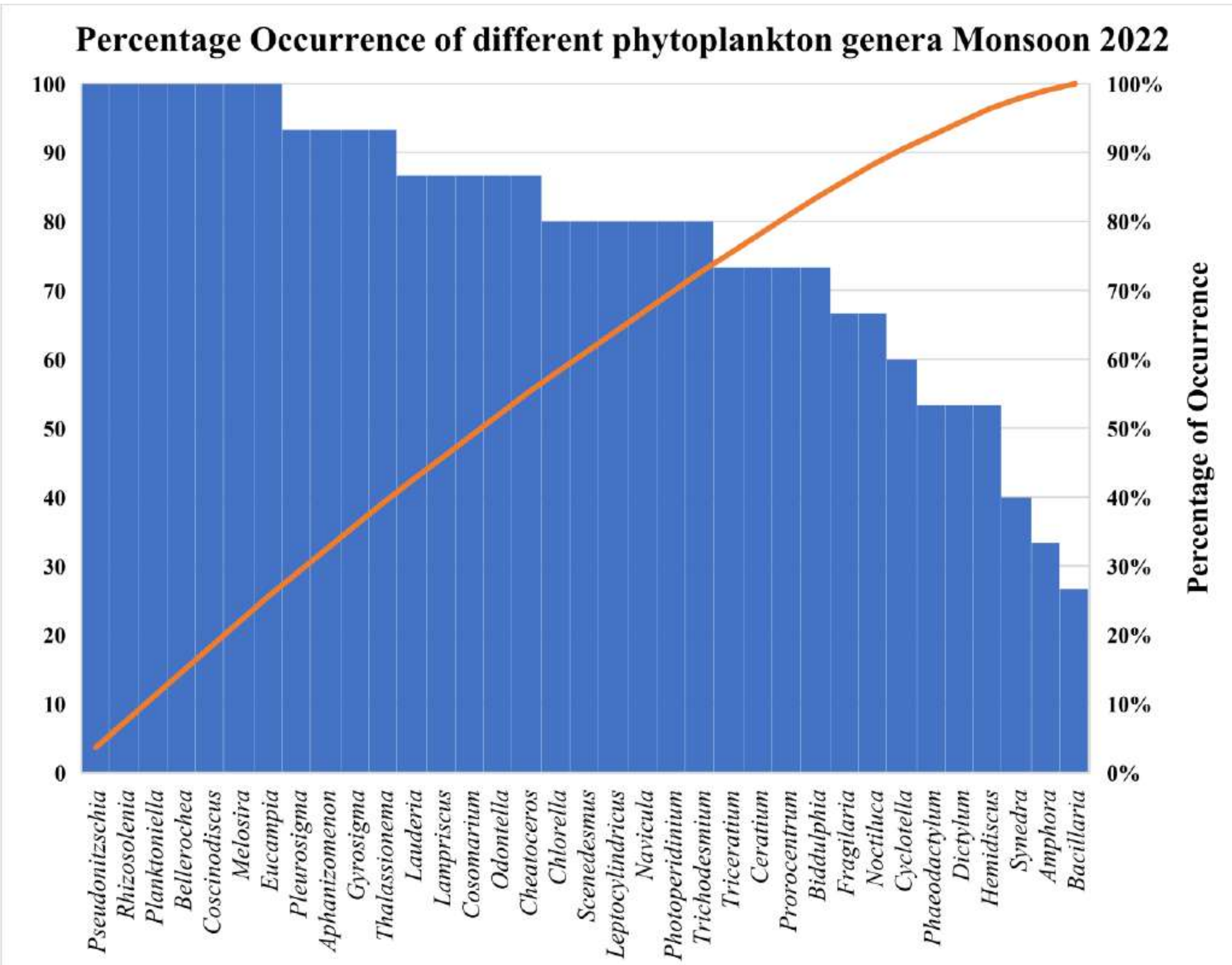

Figure 8: Percentage occurrence of phytoplankton genera in Monsoon 2022

Phytoplankton density and diversity

The density signifies the abundance of plankton which is measured as cell/ individual/L. The phytoplankton density varied from 1,760 No/L to 16,960 No/L with the average 13,483 No/L. The highest phytoplankton density was observed at station S-4 (16,960 No/L) followed by S-12 (16,480 No/L), whereas the lowest 1,760 No/L at S-1(fig.9). Diversity indices have become part of standard methodology in the ecological studies particularly, impact analysis and biodiversity monitoring of the environments (PEET,1974). Biodiversity indices reflects the biological variability which can be used for comparison with space and time. Various species diversity indices respond differently to different environmental and behavioral factors of biotic communities. Among the different stations, the phytoplankton taxa varied from 24 to 33 (Table-4). During monsoon the Margalef and Menhinik richness indices were maximum at stations S-11 (4.28& 0.79). The Shannon diversity index was maximum 3.31 (S-11) and minimum 2.93 at S-15. The Simpson index clearly reflexes the species dominance (genera) at S-11 (0.96) and the low value (0.94) was noticed at S-12.

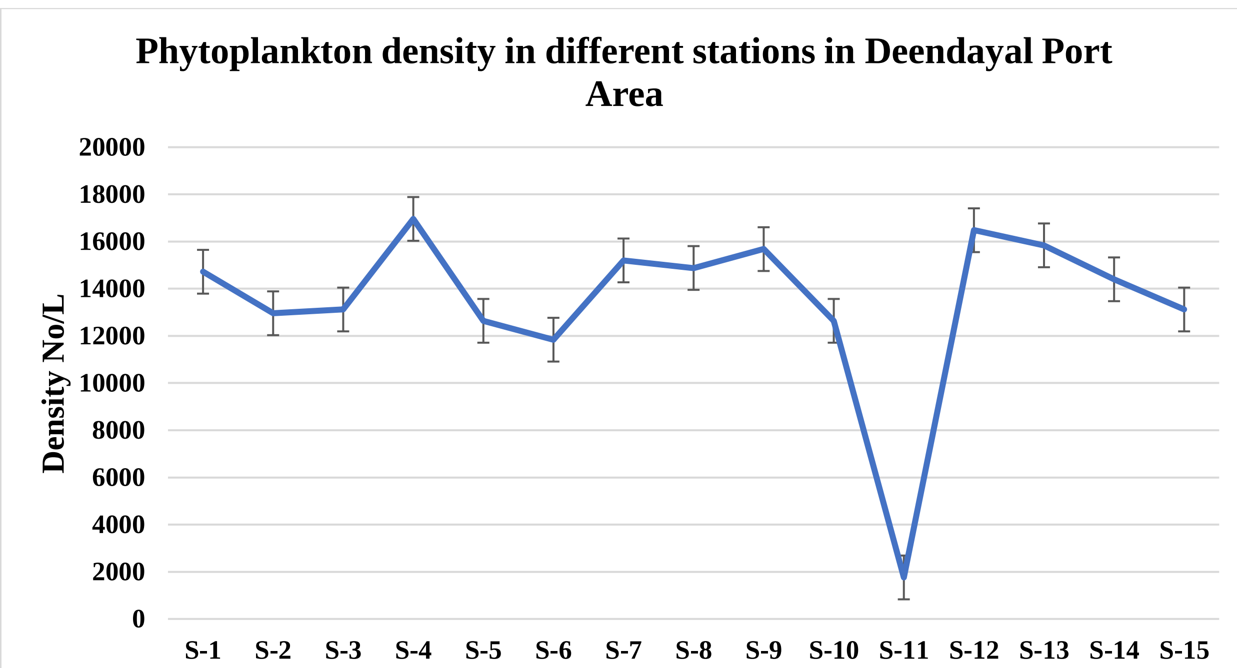

Figure 9: Phytoplankton density in Monsoon 2022

As per Shannon Wiener's rules for the aquatic environment i.e., both soil and water are classified as very good when H' value is greater than four (>4), whereas the good quality represents the H' value with a range of 4-3, similarly moderate-quality (H' value 3-2), poor quality (H' value 2-1) and very poor-quality H' value significantly less than one (<1). Presently Deendayal Port Authority and its periphery environment has been influenced by contaminants deposited from industries and the cargo movements. Accordingly, species diversity decreases at sites with poor water quality. As deduced from the Shannon diversity index values between 2.93 to 3.31 representing the moderate quality of environmental status dominated by the few genera such as *Pleurosigma, Gyrosigma, Thalassionema* and *Aphanizomenon*. A community dominated by relatively few species indicates environmental stress (Plafkin *et al.,* 1989). According to Staub *et. al* (1970) species diversity index value between 3.0 to 4.5 represents slightly polluted and the lightly polluted environment, the index value characterizes 2.0-3.0, similarly, moderately polluted environment shows index value of 1.0-2.0 and finally, the heavily polluted environment index value is 0.0-1.0. While considering the overall index values it is inferred that the study sites can be included under the category of lightly polluted.

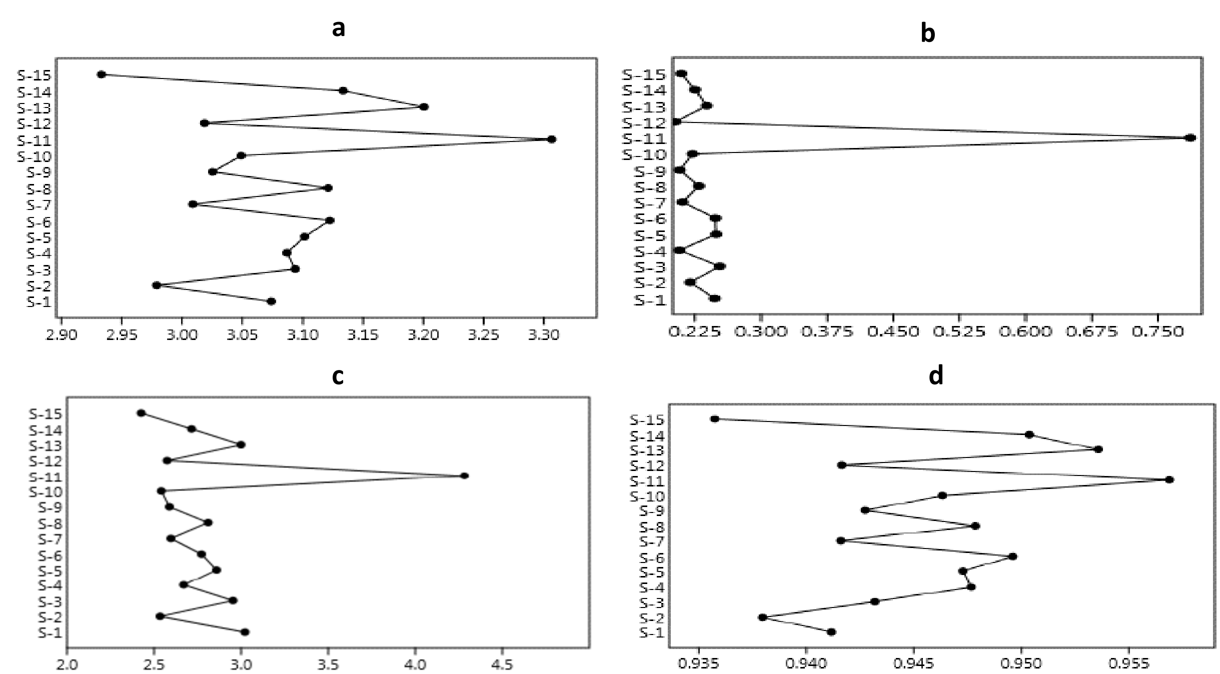

Figure 10: Different diversity indices a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index

Table 3: Phytoplankton density, percentage composition and occurrence during Monsoon 2022

Group	Genera	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	PO	PC
Pennales	*Amphora*	0	0	0	0	160	0	160	0	0	0	20	0	160	0	160	33	0.3
	Bacillaria	0	0	160	0	160	0	0	0	0	0	20	0	160	0	0	27	0.2
	Dtylum	160	0	0	960	480	0	0	640	0	320	100	640	480	0	0	53	1.9
	Pseudonitzschia	1760	320	480	640	960	640	1280	800	320	480	100	1600	960	640	1280	100	6.1
	Pleurosigma	160	320	640	1120	320	960	640	320	0	320	20	480	320	960	640	93	3.6
	Rhizosolenia	160	160	320	480	160	800	960	320	1120	160	40	640	160	800	960	100	3.6
	Synedra	320	0	320	160	0	0	0	160	0	0	20	320	0	0	0	40	0.6
	Fragilaria	480	320	480	0	0	160	0	1600	800	320	80	160	0	160	0	67	2.3
	Gyrosigma	160	320	160	640	800	320	480	1120	320	0	20	480	800	320	480	93	3.2
	Thalassionema	320	480	960	1600	1280	1120	800	480	800	640	60	0	1280	1120	800	93	5.8
Centrales	*Bellerochea*	800	480	1120	960	800	640	1760	960	1280	640	40	160	800	640	1760	100	6.3
	Biddulphia	160	0	320	160	160	480	0	160	0	640	40	320	160	480	0	73	1.5
	Cheatoceros	160	0	0	160	160	320	160	480	320	640	40	160	160	320	160	87	1.6
	Coscinodiscus	1440	640	320	480	640	800	160	320	1120	960	60	640	640	800	160	100	4.5
	Cyclotella	320	160	160	0	160	0	640	0	320	0	60	0	160	0	640	60	1.3
	Eucampia	800	960	320	1120	160	320	640	640	160	160	40	480	160	320	640	100	3.4
	Hemidiscus	0	0	160	0	0	160	320	0	320	0	40	160	0	160	320	53	0.8
	Lauderia	160	0	1600	800	320	640	160	320	480	320	60	0	320	640	160	87	3.0
	Leptocylindricus	320	480	1120	320	0	160	480	0	160	320	20	640	0	160	480	80	2.3
	Lampriscus	1120	800	480	800	640	480	0	160	320	480	120	1600	640	480	0	87	4.0
	Melosira	640	1760	960	1280	640	320	160	480	800	480	140	960	640	320	160	100	4.8
	Navicula	480	0	160	0	640	320	320	320	160	0	40	160	640	320	320	80	1.9
	Odontella	320	160	480	320	640	320	160	320	160	0	0	160	640	320	160	87	2.1
	Planktoniella	800	160	320	1120	960	480	640	800	1440	640	40	480	960	480	640	100	4.9
	Phaeodactylum	0	640	0	320	0	480	0	160	320	160	20	0	0	480	0	53	1.3
	Triceratium	160	160	160	1120	480	0	0	160	800	960	40	1120	480	0	0	73	2.8

Dinophyceae	*Ceratium*	160	0	160	160	160	160	1120	480	0	0	20	800	960	320	1120	73	2.8
	Prorocentrum	160	800	480	160	480	480	480	0	0	160	40	0	320	0	320	73	1.9
	Photoperidinium	640	1280	0	640	0	0	960	320	480	160	100	960	320	1120	160	80	3.5
	Noctiluca	160	800	160	480	160	160	160	320	160	0	0	0	160	0	0	67	1.3
Cyanophyceae	*Aphanizomenon*	160	160	160	160	160	160	320	160	640	800	40	480	1120	320	0	93	2.4
	Cosomarium	0	640	640	480	640	640	0	960	1600	1280	140	800	480	800	640	87	4.8
	Trichodesmium	160	160	0	320	0	0	1120	1120	960	800	80	1760	960	1280	640	80	4.6
Chlorophyceae	*Chlorella*	800	320	160	0	160	160	960	0	0	160	40	320	640	160	320	80	2.1
	Scenedesmus	1280	480	160	0	160	160	160	800	320	640	20	0	160	480	0	80	2.4
Total genera		**30**	**25**	**29**	**27**	**28**	**27**	**26**	**28**	**26**	**25**	**33**	**26**	**30**	**27**	**24**		
Density No/L		**14720**	**12960**	**13120**	**16960**	**12640**	**11840**	**15200**	**14880**	**15680**	**12640**	**1760**	**16480**	**15840**	**14400**	**13120**		

Table 4: Diversity indices of Phytoplankton during Monsoon 2022

Diversity Indices	**S-1**	**S-2**	**S-3**	**S-4**	**S-5**	**S-6**	**S-7**	**S-8**	**S-9**	**S-10**	**S-11**	**S-12**	**S-13**	**S-14**	**S-15**
Shannon_H	3.07	2.98	3.09	3.09	3.10	3.12	3.01	3.12	3.03	3.05	3.31	3.02	3.20	3.13	2.93
Simpson_1-D	0.94	0.94	0.94	0.95	0.95	0.95	0.94	0.95	0.94	0.95	0.96	0.94	0.95	0.95	0.94
Margalef	3.02	2.53	2.95	2.67	2.86	2.77	2.60	2.81	2.59	2.54	4.28	2.58	3.00	2.72	2.43
Menhinick	0.25	0.22	0.25	0.21	0.25	0.25	0.21	0.23	0.21	0.22	0.79	0.20	0.24	0.23	0.21
Dominance_D	0.06	0.06	0.06	0.05	0.05	0.05	0.06	0.05	0.06	0.05	0.04	0.06	0.05	0.05	0.06

3.5. Zooplankton

Zooplankton are highly sensitive to changes caused by physical and chemical factors in aquatic ecosystems and their distribution deliver information regarding the productivity and pollution of the particular area (Gajbhiye and Desai, 1981). Zooplankton are distributed in a wide range of habitats extending from the neuston to benthos and play vital roles influencing fisheries, oceanography and climate (Terdalkar and Pai, 2001). It has various significant roles in the estuarine ecosystem and connecting link between nutrient cycling and phytoplankton, primary production and many commercial fisheries in estuaries and coastal waters and form a chief food for a variety of pelagic consumers including coelenterates, ctenophores, fish larva forage fish and some benthic organisms such as sponges and molluscs (Day *et al*., 1989).

Phylum, group and generic status

The zooplankton identified from the 15 stations falls under 10 phyla and 41 genera belonging to the 16 groups (Table 5). The phylum Arthropoda was the predominant, represented with 25 genera including copepods, crabs, shrimps and their larva. The phylum Arthropoda dominated in the samples with major groups Calanoida, Harpacticoida, Cyclopoida, (Copepoda) Decapoda, and the larval forms of crustaceans. There were 14 genera of copepods in the samples. Among copepods, the Calanoida ranked first in terms of generic representation particularly *Acartia* sp, *Acrocalanus* sp, *Aetideus* sp. and *Calanus* sp. (figure-11).

Percentage composition

The overall percentage of the various groups of zooplankton varied from 0.3% to 36.9%. The highest percentage was due to the calanoid copepods (36.9%) followed by Decapoda (13.2%) and Gastropoda (8.2%). The group which contributed the least was *Chaetognatha* (0.3%) followed by Nematoda (0.4%) (Fig.12). Among the zooplankton groups calanoid group wase observed predominantly at all sites.

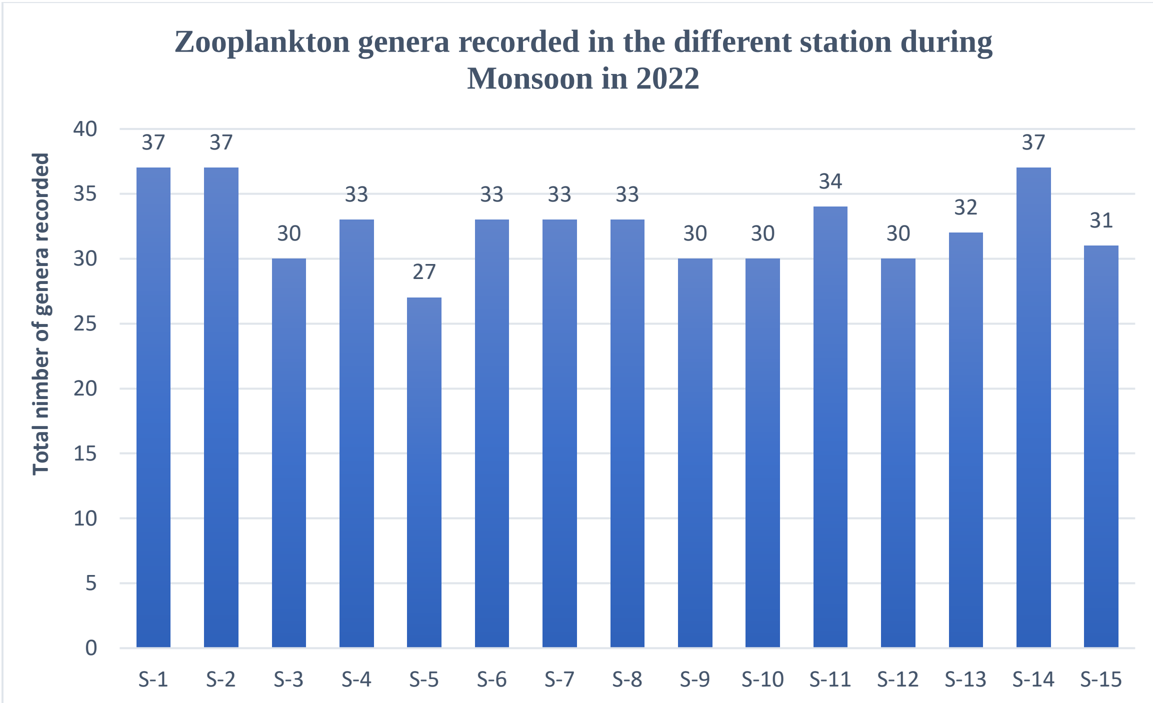

Figure 11: Phylum and generic status of zooplankton during Monsoon 2022

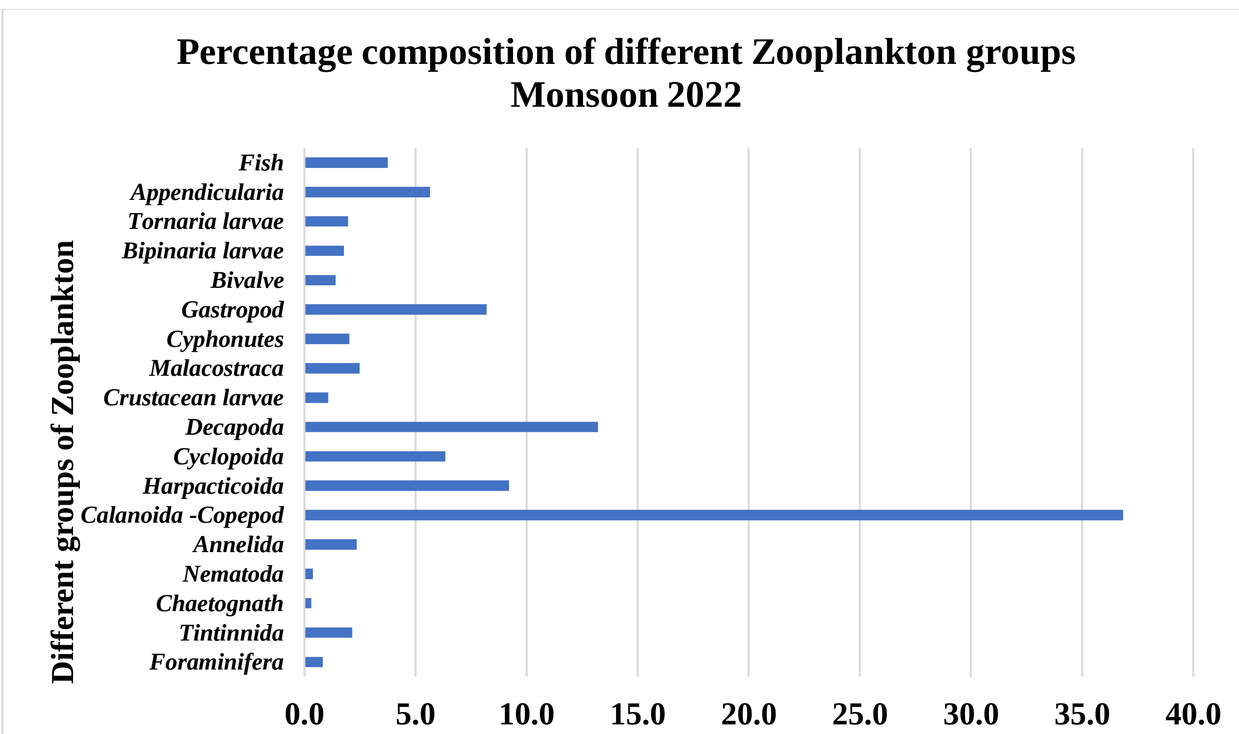

Figure 12: Percentage composition of zooplankton groups during Monsoon 2022

Percentage occurrence of zooplankton

The percentage occurrence of zooplankton communities varied from 33% to 100 %. There were 9 zooplankton genera that exhibited 100% of occurrence (Fig.12) followed by the copepods *Microsetella*, *Aerocalanus*,*Copelata*, *Eucalanus* and the Cyphonautes larva (93%) from the study sites (Table5).

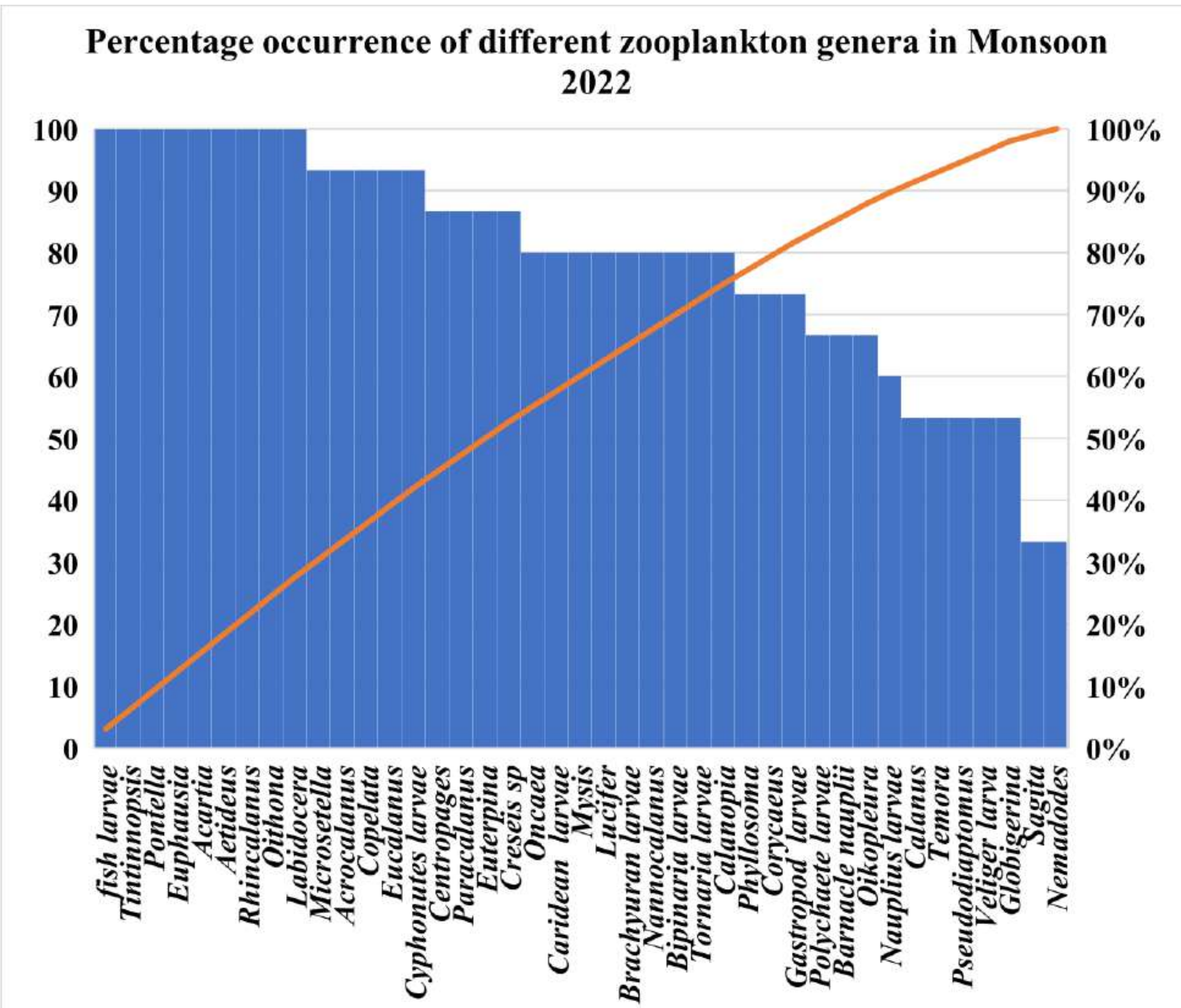

Figure 13: Percentage occurrence of Zooplankton groups during Monsoon 2022

Density of zooplankton

Zooplankton population density values during the Monsoon 2022 at the 15 sampling sites ranged from 12,640 No/L to21,120 No/L with an overall average of 16,789 No/ L (Table 5). Station-wise, the highest density of 21,120 No/ L was recorded in S-7 followed by S-2 (18,880 No/ L) and lowest density was reported at S-5 (12,640 No/ L) (Figure 14).

Diversity Index

The Shannon diversity index of the zooplankton ranged between 3.05 to 3.41. Similarly, Margalef and Menhinick species richness index also varied from 2.75 to 3.70, and 0.22 to 0.29 respectively representing the moderate quality of the environment. (Table 6).

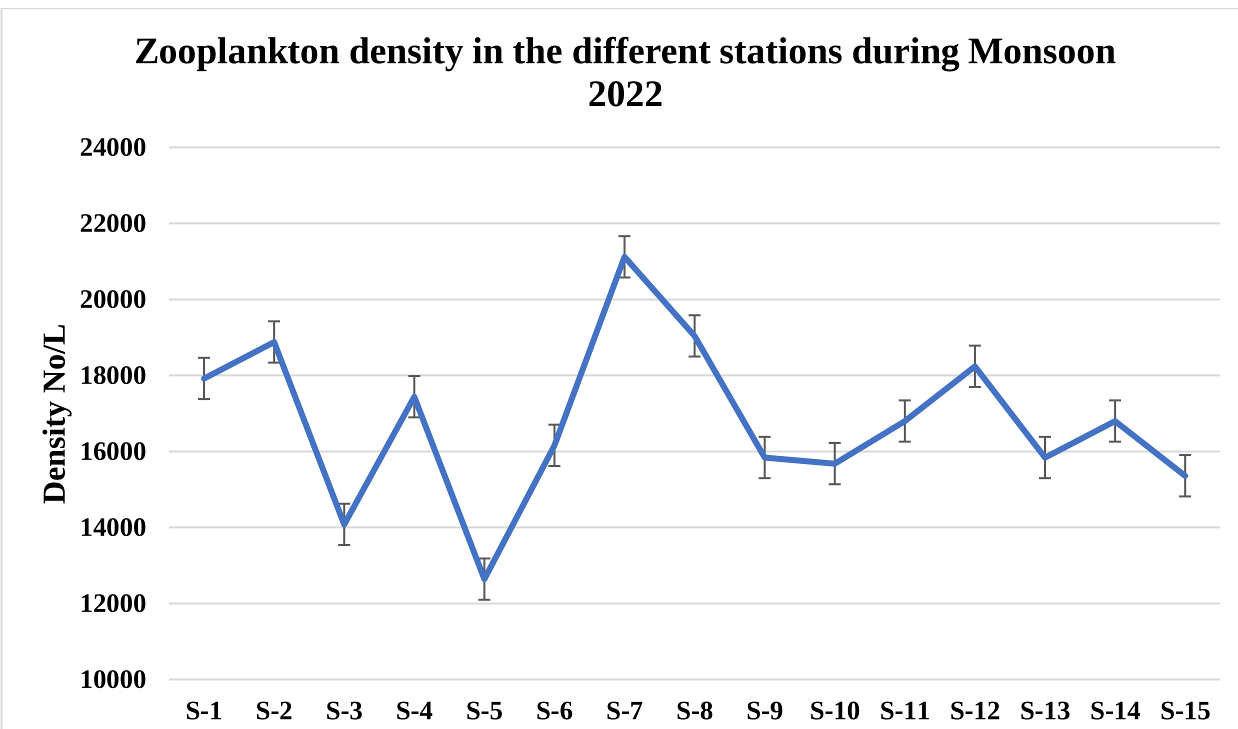

Figure 14: Zooplankton Density in the different stations during Monsoon 2022

Table 5: Zooplankton generic status during Monsoon 2022 in Deeendayal Port Authority area

Phylum	Group	Genera	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	PO	PC
Protozoa	Foraminifera	*Globigerina*	160	160	0	0	0	160	320	0	0	0	320	160	0	480	320	53	0.8
Ciliophora	Tintinnida	*Tintinnopsis*	480	320	320	160	480	160	320	640	320	480	640	320	160	320	320	100	2.2
Chaetognath		*Sagitta*	160	160	0	0	0	0	0	160	0	160	0	0	0	160	0	33	0.3
Nematoda		*Nemadodes*	320	160	0	0	0	160	0	160	0	0	0	0	0	160	0	33	0.4
Annelida		*Polychaete larva*	1120	480	320	160	0	0	960	480	0	0	640	0	320	800	640	67	2.4
Arthropoda	Calanoida	*Acartia*	480	1280	800	1760	320	480	640	960	640	1280	800	320	480	800	1600	100	5.0
		Acrocalanus	640	320	480	160	320	640	1120	320	960	640	320	0	320	160	480	93	2.7
		Aetideus	320	800	640	160	160	320	480	160	800	960	320	1120	160	320	640	100	2.9
		Calanus	480	320	0	320	0	320	160	0	0	0	160	0	0	160	320	53	0.9
		Calanopia	1120	800	320	480	320	480	0	0	160	0	1600	800	320	640	160	80	2.9
		Centropages	320	480	0	160	320	160	640	800	320	480	1120	320	0	160	480	87	2.3
		Eucalanus	640	480	160	320	480	960	1600	1280	1120	800	480	800	640	480	0	93	4.1
		Labidocera	320	160	480	800	480	1120	960	800	640	1760	960	1280	640	320	160	100	4.3
		Nannocalanus	160	320	320	160	0	320	160	160	480	0	160	0	640	320	320	80	1.4
		Paracalanus	320	160	320	160	0	0	160	160	320	160	480	320	640	320	160	87	1.5
		Pontella	1760	480	800	1440	640	320	480	640	800	160	320	1120	960	480	640	100	4.4
		Pseudodiaptomus	0	0	160	320	160	160	0	160	0	640	0	320	0	480	0	53	1.0
		Rhincalanus	320	480	160	800	960	320	1120	160	320	640	640	160	160	320	480	100	2.8
		Temora	320	160	0	0	0	160	0	0	160	320	0	320	0	320	160	53	0.8
	Harpacticoida	*Corycaeus*	480	0	0	160	0	1600	800	320	640	160	320	480	320	480	0	73	2.3
		Euterpina	160	640	800	320	480	1120	320	0	160	480	0	160	320	160	640	87	2.3

		Microsetella	960	1600	1280	1120	800	480	800	640	480	0	160	320	480	960	1600	93	4.6
	Cyclopoida	*Oithona*	1120	960	800	640	1760	960	1280	640	320	160	480	800	480	1120	960	100	5.0
		Oncaea	320	160	160	480	0	160	0	640	320	320	320	160	0	320	160	80	1.4
	Decapoda	*Caridean larva*	0	160	160	320	160	480	320	640	320	160	320	160	0	0	160	80	1.3
		Euphausia	320	480	640	800	160	320	1120	960	480	640	800	1440	640	320	480	100	3.8
		Nauplius larva	160	0	160	0	640	0	320	0	480	0	160	320	160	160	0	60	1.0
		Mysis	160	0	160	160	160	160	1120	480	0	0	160	800	960	320	1120	80	2.3
		Phyllosoma	160	800	480	160	480	480	480	0	0	160	320	0	320	0	320	73	1.7
		Lucifer	640	1280	0	640	0	0	960	320	480	160	800	960	320	1120	160	80	3.1
	Crustacean larva	*Barnacle nauplius*	160	800	160	480	160	160	160	320	160	0	0	0	160	0	0	67	1.1
	Malacostraca	*Brachyuran larva*	320	160	320	960	320	320	480	480	0	0	160	0	1600	800	320	80	2.5
Bryozoan		*Cyphonautes larva*	160	160	160	160	160	160	320	160	640	800	320	480	1120	320	0	93	2.0
Mollusca	**Gastropod**	*Creseis sp*	0	640	640	480	640	640	0	960	1600	1280	1120	800	480	800	640	87	4.3
		Gastropod larva	160	160	0	320	0	0	1120	1120	960	800	640	1760	960	1280	640	73	3.9
	Bivalve	*Veliger larva*	0	320	0	0	0	0	480	1120	160	320	640	0	160	320	0	53	1.4
Echinodermata		*Bipinnaria larva*	800	320	160	0	160	160	960	0	0	160	320	320	640	160	320	80	1.8
Hemichordata		*Tornaria larva*	1280	480	160	0	160	160	160	800	320	640	160	0	160	480	0	80	2.0
Chordata	**Appendicularia**	*Oikopleura*	800	160	0	800	0	0	480	320	0	160	480	640	480	0	160	67	1.8
		Copelata	160	960	1600	1280	1120	800	320	800	640	480	0	640	320	160	480	93	3.9
	Fish	*Fish larva*	160	1120	960	800	640	1760	0	1280	640	320	160	640	320	320	320	100	3.7
		Total genera	**37**	**37**	**30**	**33**	**27**	**33**	**33**	**33**	**30**	**30**	**34**	**30**	**32**	**37**	**31**		
		Density No/L	**17920**	**18880**	**14080**	**17440**	**12640**	**16160**	**21120**	**19040**	**15840**	**15680**	**16800**	**18240**	**15840**	**16800**	**15360**		

Table 6. Diversity indices of Zooplankton along Deendayal Port Authority area during Monsoon 2022

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Taxa_S	37	37	30	33	27	33	33	33	30	30	34	30	32	37	31
Shannon_H	3.34	3.36	3.14	3.22	3.05	3.20	3.31	3.31	3.23	3.15	3.32	3.19	3.27	3.41	3.20
Simpson_1-D	0.96	0.96	0.95	0.95	0.94	0.95	0.96	0.96	0.95	0.95	0.96	0.95	0.96	0.96	0.95
Margalef	3.68	3.66	3.04	3.28	2.75	3.30	3.21	3.25	3.00	3.00	3.39	2.96	3.21	3.70	3.11
Menhinick	0.28	0.27	0.25	0.25	0.24	0.26	0.23	0.24	0.24	0.24	0.26	0.22	0.25	0.29	0.25

3.6. Intertidal Fauna

The intertidal zone is the area above the water level at low tide and submerged at high tide. Intertidal habitats are found along the margins of the sea and include rocky shores, mudflats, salt marshes, and estuaries. The intertidal diversity was documented during monsoon at the prefixed 15 sampling locations within the DPA jurisdiction. All the macroinvertebrates and vertebrate samples were collected from the sampling stations during the low tide. At each site, 1x 1 m^2 quadrate was placed randomly, and all visible macro-faunal organisms encountered inside the quadrate were identified, counted and recorded. At each site along the transects that run perpendicular to the waterfront, three to six replicate quadrate samples were assessed for the variability in macro-faunal population structure (Davidson *et al*., 2004; Ravinesh and Biju Kumar, 2013). The density of the different faunal groups was averaged for the entire intertidal belt. Organisms, which could not be identified in the field, were preserved in 5% formaldehyde, brought to the laboratory and identified using standard identification keys (Abott, 1954; Vine, 1986; Oliver, 1992; Rao, 2003; 2017; Psomadakis *et al*., 2015; Apte, 2012; 2014; Naderloo 2017; Ravinesh *et al*., 2021; Edward *et al.*, 2022). The invertebrates' taxonomic composition, relative abundance, species richness and diversity were determined (Zar, 1984) to describe the mangrove environment's overall biodiversity at DPA premises. Statistical analyses such as diversity indices and richness were calculated using Paleontological Statistics Software Package for Education and Data (PAST) version 3.2.1 (Hammer *et al*., 2001).

Faunal composition of intertidal macrobenthos

The intertidal ecological survey has been conducted at the prefixed 15 locations within the vicinity of the Deendayal port Authority. The species diversity of the invertebrate phyla showed the maximum for phylum Arthropoda (8 species), which is followed by Mollusca (6 species). The phylum Chordata was represented by two species (Table 7 & Fig.15).

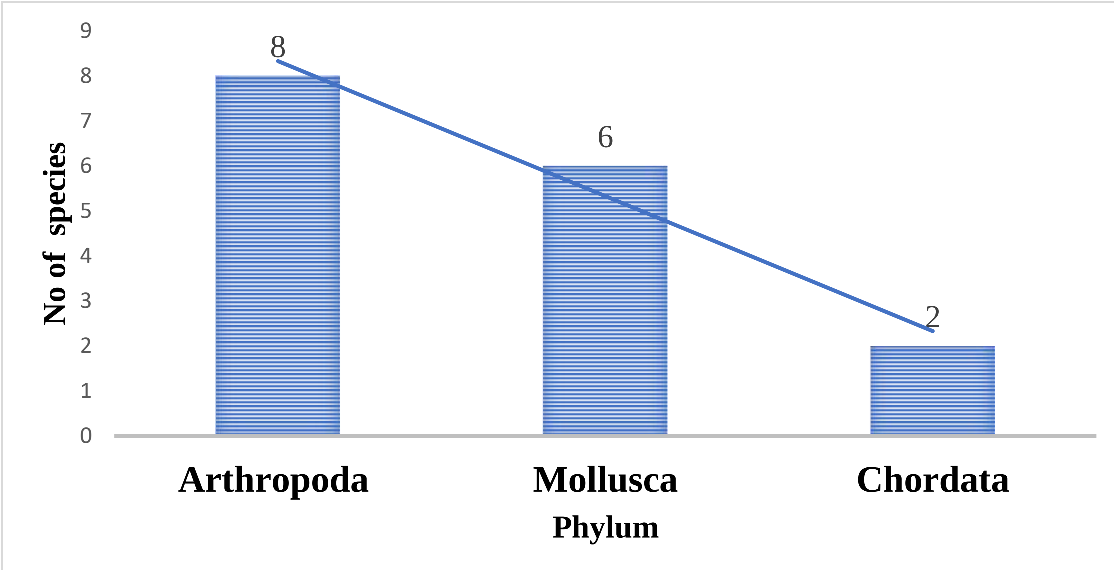

Figure 15: Number of genera of intertidal fauna (Phylum) during in Monsoon 2022

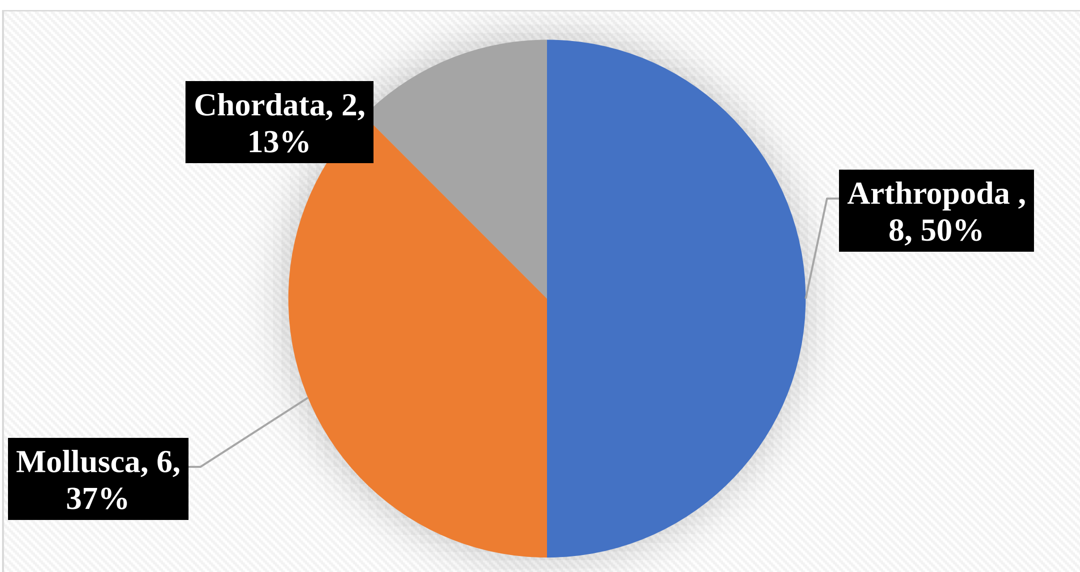

Figure 16: Percentage composition of intertidal fauna during Monsoon 2022

Cumulative percentage composition of Fauna

The overall percentage composition of the three groups of intertidal fauna at the 15 sites was followed, ie Arthropoda (50%), Mollusca (37%), and Chordata (13%), as shown in figure 16.

Intertidal Fauna density (No/m^2) variation between the stations

The number of individuals of the Fauna collected from the intertidal zone of the mangroves are presented in Fig 17. It was observed that the faunal density was the highest in stations S- 3 and S-4 while the least from S-10.

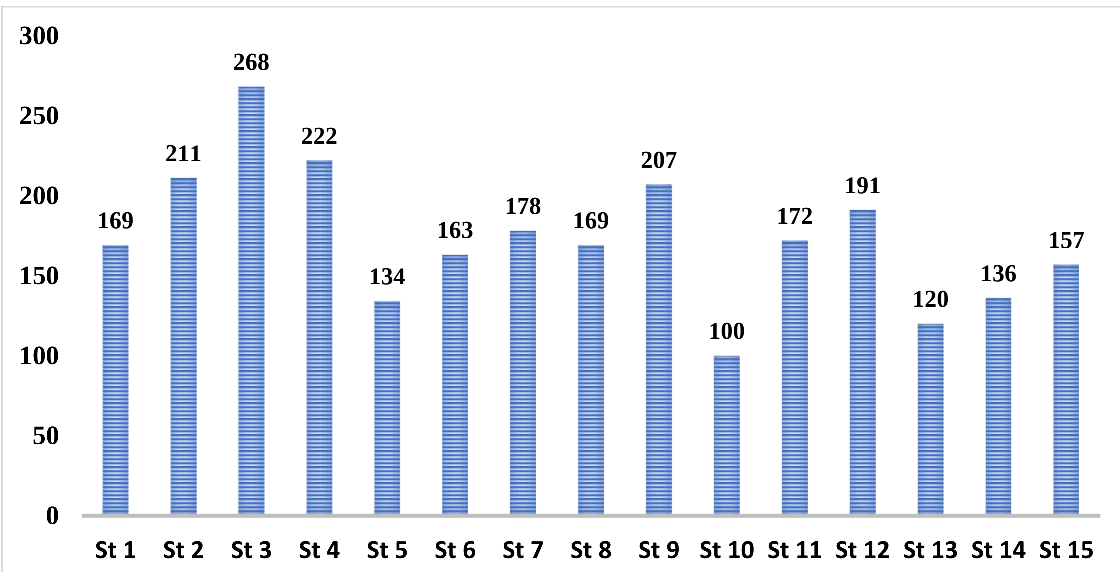

Figure 17: Density of intertidal fauna during Monsoon 2022

The Intertidal faunal diversity documented during the monsoon period of 2022 has shown that the highest number of animals were collected from S-3, and the lowest was from S-10. The most common species were the crustaceans such as *Parasesarma plicatum* and *Austruca iranica*. The lowest density noticed was that of *Littoraria pallescens* (Table.7)

Diversity indices

Table.8 presents the various diversity indices calculated for the different fauna recorded from the 15 sites adjoining the DPA port area, Kandla. Diversity indices were calculated for the subtidal fauna in which the Dominance diversity (D) values varied from 0.12 (S-5, S-15) to 0.27 (S -3). Shannon diversity (H') values varied from 1.50 (S-10) to 2.31 (S-5). The Simpson_1-D varied from 0.73 (S -3) to 0.88 (S-5, S-15). The Evenness values varied from 0.42 to 0.83, with the maximum in S-3 and the minimum at S-12. The Margalef index ranged from 1.04 to 2.15, the maximum at S-13 and the minimum at S-3.

Table 7: Intertidal faunal distribution along Deendayal Port Authority area during Monsoon 2022

Intertidal Fauna	**S-1**	**S-2**	**S-3**	**S-4**	**S-5**	**S-6**	**S-7**	**S-8**	**S-9**	**S-10**	**S-11**	**S-12**	**S-13**	**S-14**	**S-15**
Arthropoda															
Scylla serrata	0	3	0	0	5	0	6	0	0	0	5	0	0	3	4
Austruca sindensis	0	17	6	8	11	0	18	23	12	15	19	17	0	4	9
Austruca iranica	12	19	16	31	21	24	28	26	31	39	41	52	11	26	19
Parasesarma plicatum	56	72	32	52	23	42	26	53	85	19	36	42	38	52	28
Dotilla blanfordi	0	1	2	0	2	0	1	0	0	0	0	0	0	2	3
Eurycarcinus orientalis	2	0	0	1	2	5	1	0	0	0	0	0	0	0	2
Amphibalanus amphitrite	0	23	0	56	11	0	0	38	0	0	0	21	0	0	14
Tubuca dussumieri	3	2	1	6	9	1	2	1	8	2	1	6	0	0	5
Mollusca															
Pirenella cingulata	2	8	123	19	0	11	35	0	12	0	8	0	31	6	0
Telescopium telescopium	0	0	2	3	0	0	6	0	2	0	5	0	2	0	1
Bakawan rotundata	8	0	5	0	2	0	15	0	0	0	12	0	0	2	8
Littoraria pallescens	0	1	2	0	2	0	0	0	0	0	0	0	0	0	0
Platevindex martensi	0	0	1	0	2	0	0	0	0	0	5	0	0	2	1
Optediceros breviculum	35	42	52	12	7	42	0	0	34	0	15	25	0	0	19
Chordata															
Periophthalmus waltoni	25	11	15	21	12	7	8	9	11	4	2	9	11	8	26
Scartelaos histophorus	26	12	11	13	25	31	32	19	12	21	23	19	27	31	18
Total	169	211	268	222	134	163	178	169	207	100	172	191	120	136	157

Table 8: Diversity indices of Intertidal Fauna during Monsoon 2022

Indices	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Dominance_D	0.21	0.19	0.27	0.16	0.12	0.20	0.14	0.21	0.23	0.26	0.15	0.17	0.23	0.24	0.12
Shannon_H	1.77	1.95	1.70	2.02	2.31	1.75	2.12	1.69	1.77	1.50	2.11	1.89	1.56	1.70	2.30
Simpson_1-D	0.79	0.81	0.73	0.84	0.88	0.80	0.86	0.79	0.77	0.74	0.85	0.83	0.77	0.76	0.88
Evenness_e^H/S	0.65	0.58	0.42	0.69	0.72	0.72	0.69	0.77	0.65	0.75	0.69	0.83	0.79	0.55	0.71
Margalef	1.56	2.06	2.15	1.85	2.65	1.37	2.12	1.17	1.50	1.09	2.14	1.33	1.04	1.83	2.57

3.7. Subtidal Fauna (Macrobenthos)

Subtidal ecosystems are permanently submerged due to tidal influence, whereas intertidal ecosystems are found between the high tide and low tide, experiencing fluctuating influences of land and sea. Macrobenthos are an important component of estuarine and marine ecosystems. At large scales, food may be the prime limiting factor for benthic biomass. Depending on the system's characteristics, grazing by benthic suspension feeders may be the most important factor determining system dynamics. The sampling methods and procedures were designed in such a way as to obtain specimens in the best possible condition to maximize the usefulness of the data obtained. For studying the benthic organisms, triplicate samples were collected at each station using Van Veen grab, which covered an area of $0.04m^2$. The wet sediment was passed through a sieve of mesh size 0.5 mm for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal dye for the ease of spotting at the time of sorting (Ravinesh and Biju Kumar, 2022). The number of organisms in each grab sample was expressed as No $/m^2$. All the species were sorted, enumerated and identified by following available literature. The works of Day (1967), Hartman (1968, 1969), Rouse and Pleijel (2001), Robin et al., (2003), Amr (2021), were referred for polychaetes; Crane (1975), Holthuis (1993), Naderloo (2017). Xavier *et a*l., (2020) for crustaceans; Subba Rao (1989, 2003. 2017), Apte (2012,2014), Ramakrishna and Dey (2007), Ravinesh *et al.* (2021) and Edward *et al*., (2022). for molluscs. Statistical analyses such as diversity indices and quadrat richness were calculated using Paleontological Statistics Software Package for Education and Data (PAST) version 3.2.1 (Hammer *et al*., 2001).

Faunal composition of subtidal macrobenthos

The number of macrobenthic species of the various groups recorded (Fig.18) from the DPA port environment revealed that Mollusca (14 species) and Annelida (2 species) were the major constituents, while the Arthropoda (1 species) and Cnidaria (1 species) were comparatively low in the species composition.

The percentage composition of the four phyla that occurred during the monsoon is shown in (Fig 19) The phylum Mollusca is represented by maximum (78%) share of the subtidal Fauna, followed by Annelida (11%), Arthropoda (5.5%) and Cnidaria (5.5%) in the total benthic samples collected.

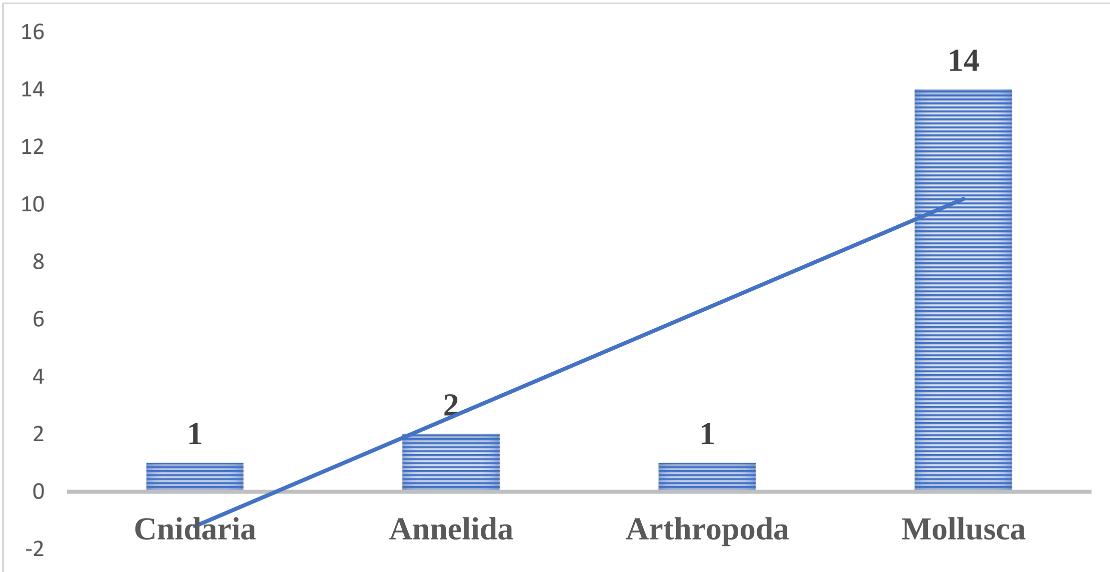

Figure 18. Number of genera of macrobenthos during Monsoon 2022

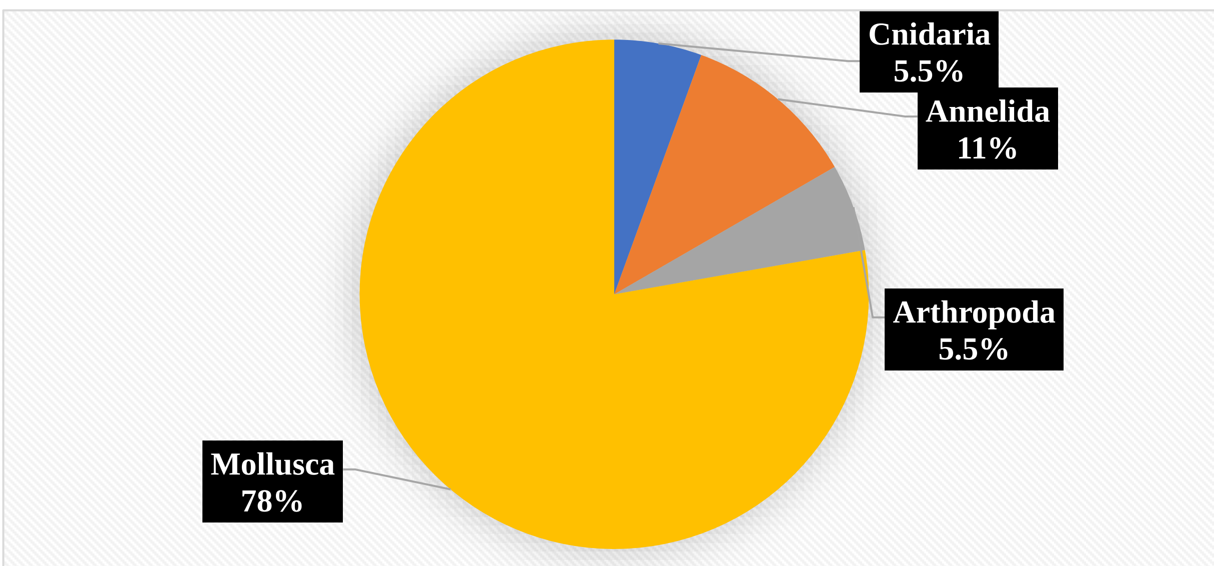

Figure 19: Percentage composition of macrobenthos during Monsoon 2022

Subtidal Faunal density (No/m^2) variation between the stations

The number of individuals of the animals collected from the different sites are shown in Fig 20. The density of the Fauna was high at S-7 (24No/m^2), and the lowest number (6/m^2) was noticed at S-13 during the monsoon season 2022.

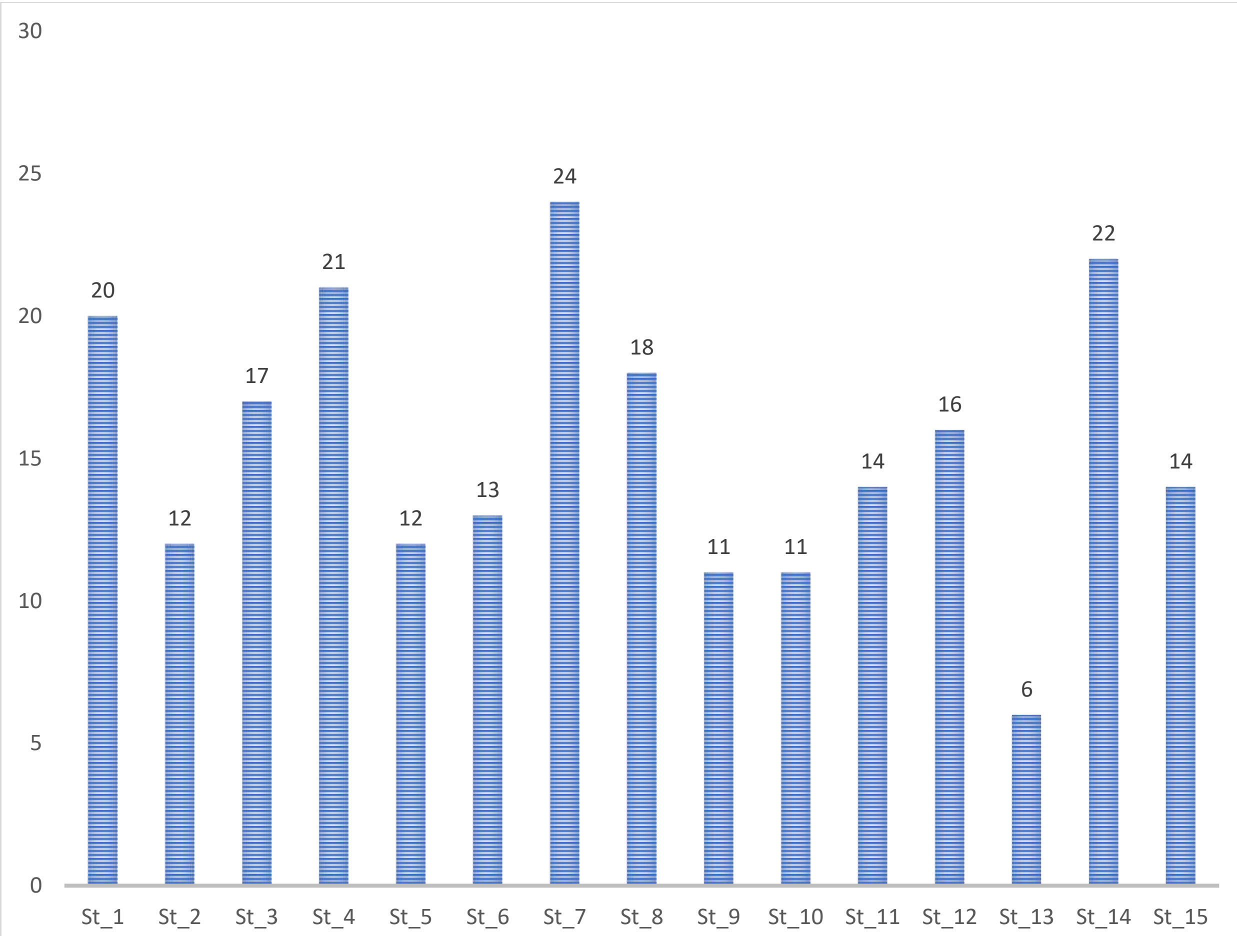

Figure 20: Subtidal fauna density during Monsoon 2022

Subtidal fauna distribution at the selected sites in the Deendayal Port area during monsoon

The table.9 depicts the subtidal microbenthic faunal diversity documented in the monsoon 2022. The highest diversity was documented from stations S-7, S-14, S-4 and S-1 and the lowest from stations S-9,10 and S- 6. The most common species are *Optediceros breviculum, Glauconome angulata and Pirenella cingulata.* The least diversity was documented for *Turritella* sp, *Stephensonactis* sp and *Natica* sp were found significantly less diversity. The Table.10 presents the various diversity indices calculated for the different Fauna recorded from the 15 sites adjoining the DPA port area, Kandla. Diversity indices were calculated for the subtidal fauna in which the Dominance diversity (D) values varied from 0.12 (S- 4) to 0.24 (S -9). Shannon diversity (H') values varied from 1.52 (S-9) to 2.27 (S-4). The Simpson_1-D varied from 0.76 (S -9) 0.87 (S-3, S-15). The Evenness values varied from 0.72 to 0.96, with the maximum in S-3 and the minimum at S-14. The Margalef index ranged from 1.67 to 3.03, the maximum at S-3 and the minimum at S-15.

Table 9: Macro-benthic faunal distribution during Monsoon 2022 in Deendayal Port Area

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	% of Occurrence
Cnidaria																
Stephensonactis sp.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0.9
Annelida																
Lumbrineries sp.	0	2	0	0	0	2	0	0	2	0	0	0	0	0	0	2.6
Nereis sp.	0	0	3	0	0	0	0	0	0	1	0	0	1	0	1	2.6
Arthropoda																
Ampithoe sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.3
Mollusca																
Umbonium vestiarium	0	0	0	3	0	1	2	1	0	0	0	0	0	1	0	3.5
Mitrella blanda	0	0	0	2	0	1	0	2	2	0	3	0	0	5	0	6.5
Clypeomorus bifasciata	1	0	2	0	1	0	0	1	0	0	0	3	0	0	2	4.3
Natica sp	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0.9
Optediceros breviculum	5	1	2	1	2	2	4	5	4	1	1	3	1	2	1	15.2
Pirenella cingulata	5	2	3	1	2	1	1	2	2	1	1	2	1	1	2	11.7
Turritella sp	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.4
Mactra sp.	0	1	0	3	0	0	2	1	0	0	0	2	0	2	3	6.1
Glauconome angulata	4	1	2	1	2	3	5	0	0	2	3	2	0	1	0	11.3
Pelecyora sp	0	0	1	2	0	1	3	0	0	2	1	1	0	0	1	5.2
Gafrarium divaricatum	2	0	0	2	1	0	0	0	0	0	0	2	1	1	0	3.9
Meretrix sp.	0	2	0	4	3	0	1	2	0	3	0	0	0	0	1	6.9
Solen sp.	1	0	2	0	0	0	4	0	1	0	2	0	0	7	1	7.8
Protapes cor	1	3	2	1	1	2	1	2	0	1	3	1	2	1	0	9.1
Total	20	12	17	21	12	13	24	18	11	11	14	16	6	22	14	100
Total No/m^2	500	300	425	525	300	325	350	450	275	275	350	400	150	550	350	

Table10: Diversity indices of the benthic fauna during Monsoon 2022

Indices	St_1	St_2	St_3	St_4	St_5	St_6	St_7	St_8	St_9	St_10	St_11	St_12	St_13	St_14	St_15
Dominance_D	0.19	0.17	0.13	0.12	0.17	0.15	0.14	0.15	0.24	0.17	0.17	0.14	0.22	0.18	0.13
Shannon_H	1.84	1.86	2.04	2.27	1.86	1.99	2.13	2.06	1.52	1.85	1.83	2.01	1.56	1.98	2.11
Simpson_1-D	0.82	0.83	0.87	0.88	0.83	0.85	0.86	0.85	0.76	0.83	0.83	0.86	0.78	0.82	0.87
Evenness_e^H/S	0.79	0.92	0.96	0.88	0.92	0.92	0.84	0.87	0.91	0.91	0.89	0.94	0.95	0.72	0.91
Margalef	2.34	2.42	2.47	3.29	2.42	2.73	2.83	2.77	1.67	2.50	2.27	2.53	2.23	2.91	3.03

3.8. Seaweeds

Along the Gujarat coast which is represented by 1600 km coastline, harbors 198 species of which 109 species from 62 genera belonging to Rhodophyta, 54 species of 23 genera to Chlorophyta, and 35 species from 16 genera to Ochrophyta (Jha *et.al*.,2009). According to Mantri *et.al*. (2020) there are 13 potential sites for the occurrence of seaweed density and diversity. The survey conducted by CSIR-CSMCRI (Jha *et.al*., 2009) confirmed the presence of industrially important taxa, namely, *Gelidiella acerosa*, *Gelidium micropterum*, *G. pusillum*, *Ahnfeltia plicata*, *Gracilaria dura*, *G. debilis*, *Gracilariopsis longissima* (formerly *G. verrucosa*), *Hypnea musciformis*, *Meristotheca papulosa*, *Porphyra sp*, *Asparagopsis taxiformis* (Rhodophyta), *Sargassum tenerrimum*, *S. plagiophyllum*, *S. swartzii*, *Turbinaria ornata* (Ochrophyta), *Ulva prolifera* (formerly *Enteromorpha prolifera*), *Ulva compressa* (formerly *Enteromorpha compressa*), and *Ulva flexuosa* (formerly *Enteromorpha tubulosa*) (Chlorophyta) from the coastal waters of Gujarat. In the present study, an attempt was made to describe the occurrence, diversity and other ecological features of seaweeds within Deendayal Port jurisdiction. It was found that except for some drifted species *Enteromorpha and Chaetomprpha* at S-13 and S-14 of Vira coast (Plate-6) no natural seaweed beds are seen in the different locations within DPA environment.

Seaweeds grow in the rocky intertidal and sub tidal habitats that offer a hard substratum for attachment. Low turbidity level in the water column with high nutrient content is a major habitat requirement that enables photosynthesis. Total dissolved solids (TDS) load in the Deendayal Port area creek waters ranged from 32088 to 42086 mg/L and suspended solids value between 88-223 mg/L restricts the photosynthetic activity of seaweeds which are highly sensitive to light. Hence, seaweed formations are absent in the creek systems of the Deendayal Port coastal environment.

3.9. Seagrass

Similar to seaweeds, sea grasses were also absent in the creek systems of Deendayal Port area and in the adjacent coastal stretches of Kachchh due to inherent habitat conditions. Sea grasses generally thrive in shallow coastal waters and are adapted to live in submerged conditions from mid intertidal to depth as much as 50 m when light penetration is sufficient; conditions contrary to the one prevailing in Deendayal Port and the nearby creek systems explain the total absence of sea grasses.

3.10. Halophytes

The holophytes are the plants that are adopted in coastal estuaries and salt marshes. It is common in arid and desert milieu which often have substantial salt accumulation. Technically it is the plant which has tolerance to moderate to high salt concentration in its growth substrate. Halophytes, that survive to reproduce in environments where the salt concentrations around 200 mM NaCl or more, constitute about 1% of the world's flora. (Timothy *et al*., 2008). Halophytes are classified based on their growth conditions as obligate halophytes, facultative halophytes, and habitat-indifferent halophytes. In the present study, four major halophytes recorded along the selected Deendayal Port Authority sites during the Monsoon sampling, were *Salicornia brachiata, Aeluropus lagopoides, Salvadora persica* and *Sesuvium portulacastrum*. Among the halophyte species recorded, *Salicornia brachiata* alone was found in the 3 sampling locations. (Table-11 and Plate-12). The percentage of *Salicornia brachiata* was found to be the highest at station S-8 (78%) and the lowest in S-11.

Table 11: Percentage of Halophytes cover in the DPA during Monsoon 2022

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Aeluropus lagopoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salicornia brachiata	0	0	0	0	0	0	0	78%	63%	0	57%	0	0	0	0
Salvadora persica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sesuvium portulacastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

a. ***Salicornia brachiata*** **b.** ***Aeluropus lagopoides*** **c.** ***Salvadora persica*** **d.** ***Sesuvium portulacastrum***

Plate 7: Halophyte species on the intertidal zone of Deendayal Port Authority area

3.11. Mangroves

In India, the second largest mangrove cover is located in the Gujarat state which accounts for 1175 km^2 (23.66%) cover of mangroves. However, it is also the fact that, this mangrove cover is predominance of *Avicennia marina*. In Gujarat, the Gulf of Kachchh shows major part of mangrove abundance, particularly of *A. marina*. The arid and hot environment of this area make it mono-species formation of *A. marina* within DPA area of Kandla.

Tree Density

In this study, totally 13 sites were surveyed for recoding the mangrove growth parameters and the density of plants. The overall average density of mangrove was 4602 plants per hector. Among all sampling stations, the mean plant density was maximum at Tuna creek (6199/ha), followed by Kandla creek (5205/ha). Considering the sampling sites individually the highest tree density was reported at S-12 station in the Tuna creek area (7359/ha). The lowest average tree density (2935 trees/ha) was reported in Phang creek, however, the lowest density (individual site) was recorded in the site S-5 at Phang creek. Form this study, it is clear that geomorphology and environmental characteristics of the Kandla coastal regions play an important role in the formation of variability in mangrove (Fig.21 & Table 12).

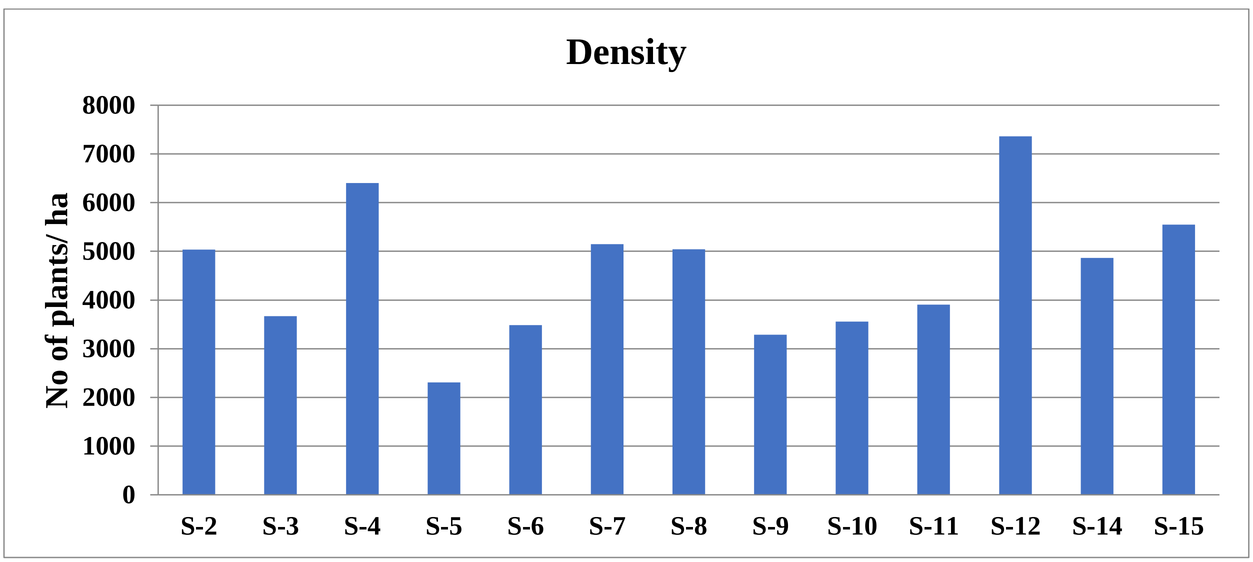

Figure 21. Mangrove Plant density during Monsoon 2022

Height

The overall mean height of the mangroves from the study sites along the DPA port environment was 105 cm. The highest average tree height was found at Phang creek area (167 cm) followed by Navlakhi creek (160 cm). The highest tree height was recorded in station S-9 of Navlakhi creek, followed by S-4 of Kandla creek (Fig. 22).

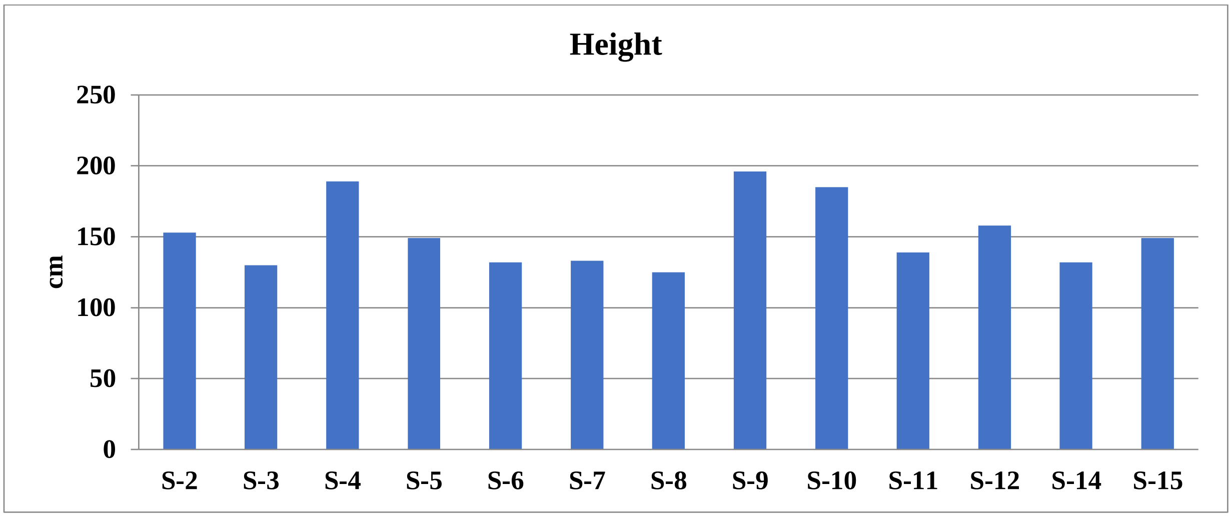

Figure 22. Plant height during Monsoon 2022

Canopy Crown Cover

The canopy cover of sampling stations exhibited wide variation and the average was 2.54 m^2. The sites S-5, S-9 and S-10 showed relatively large canopy cover. However, the lowest canopy cover was reported at S-2 and S-7 stations located at Tuna creek and Kharo creek respectively (Fig.23).

Basal area

The overall average basal area (GBH) of the mangroves of the DPA environment was 14.64 cm. Station wise the maximum mean basal area (21 cm) was at S-4 located in the Kandla creek followed by S-5 and S-11 in Phang creek and Jangi creek respectively. The minimum basal area reported to all sites was 7 cm (Fig.24). The highest value of DBH indicates the mangrove plants have multiple stems or main branches arising close to the ground from a single buttress or base. This type of growth pattern is characteristics of mangroves particularly *Avicennia marina* and *Aegiceros corniculatum*

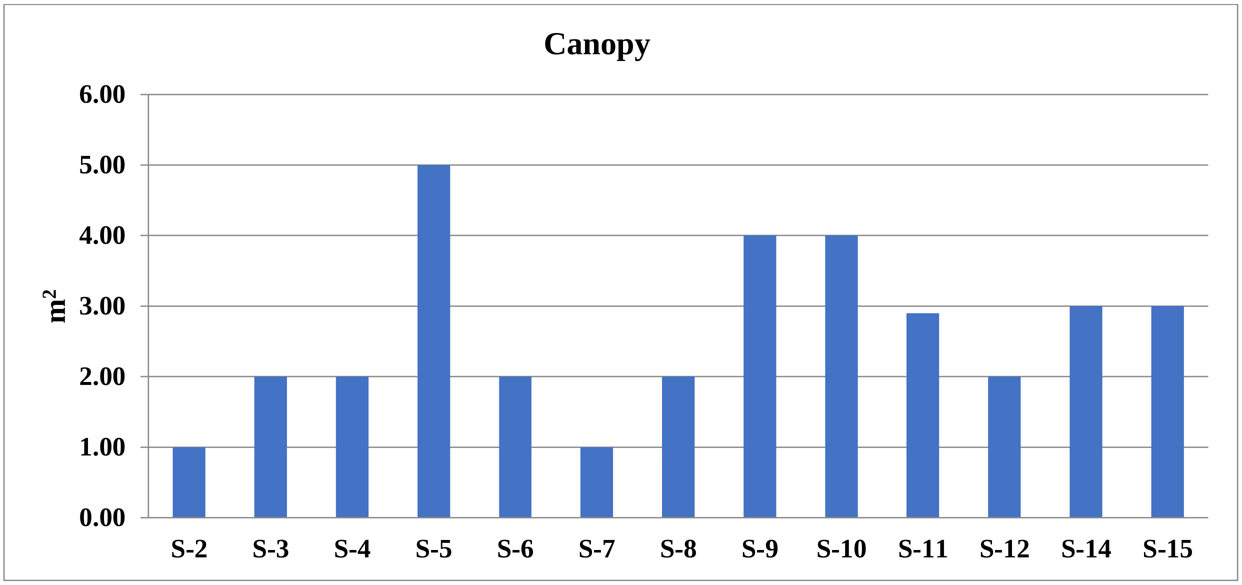

Figure 23. Mangrove canopy cover during Monsoon 2022

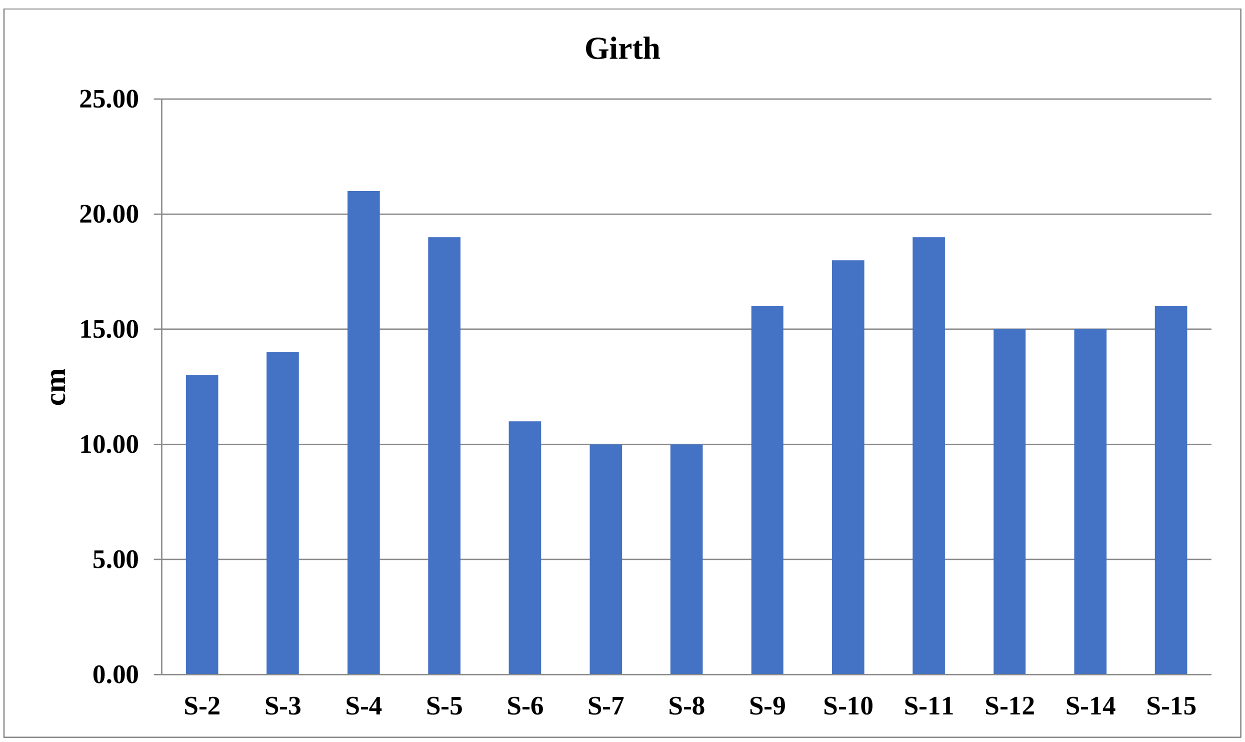

Figure 24. Mangrove basal area during Monsoon 2022

Regeneration and Recruitment class

During the monsoon, generally higher values of regeneration class of mangroves is expected, but the average density was 60167 plants/ha and that of recruitment class 15434 plants/ha. The highest regeneration (140000 plants/ha) at S-9 of Navlakhi creek and recruitment (31500 plants/ha) class density were recorded at Kharo creek (S-7). The lowest regeneration class and recruitment plant density were found at S-14 station of Vira coast site. The highest density of recruitment class after the S-7 site was observed at S-8 and S-9 sites of Navlakhi creek.

Plate 8: Mangrove species recorded along the Deendayal Port area

a. ***Avicenna marina*** **b.** ***Aegiceras corniculatum*** **c.** ***Ceriops tagal*** **d.** ***Rhizophora mucronata***

Table 12: Density of mangroves in the DPA vicinity during monsoon 2022

Sampling stations	Density (Tree/Ha)	Tree height (m)			Canopy cover (m)			Basal Area (cm)		
		Min	**Max**	**Avg.**	**Min**	**Max**	**Avg.**	**Min**	**Max**	**Avg.**
Tuna creek										
S-2	5038	110.00	230.00	153.00	0.24	6.48	1.00	7.00	36.00	13.00
S-12	7359	100.00	300.00	158.00	0.42	11.55	2.00	7.00	43.00	15.00
Mean	6198.64	105.00	265.00	155.50	0.33	9.02	1.50	7.00	39.50	14.00
Phang creek										
S-5	2311	110.00	220.00	149.00	0.88	11.20	5.00	7.00	50.00	19.00
S-10	3558	100.00	310.00	185.00	0.63	10.50	4.00	9.00	43.00	18.00
Mean	2934.70	105.00	265.00	167.00	0.76	10.85	4.50	8.00	46.50	18.50
Kandla creek										
S-3	3669	100.00	160.00	130.00	0.05	5.04	2.00	7.00	32.00	14.00
S-4	6400	110.00	310.00	189.00	0.16	6.48	2.00	8.00	50.00	21.00
S-15	5545	110.00	220.00	149.00	0.77	7.20	3.00	7.00	30.00	16.00
Mean	5204.96	106.67	230.00	156.00	0.33	6.24	2.33	7.33	37.33	17.00
Kharo creek										
S-7	5144	100.00	300.00	133.00	0.30	6.25	1.00	7.00	43.00	10.00
Jangi creek										
S-6	3483	100.00	190.00	132.00	0.17	3.99	2.00	8.00	14.00	11.00
S-11	3906	110.00	185.00	139.00	2.24	3.42	2.90	9.00	30.00	19.00
Mean	3694.59	105.00	187.50	135.50	1.21	3.71	2.45	8.50	22.00	15.00
Navlakhi creek										
S-8	5045	100.00	210.00	125.00	0.35	8.00	2.00	7.00	25.00	10.00
S-9	3290	110.00	420.00	196.00	0.30	42.25	4.00	7.00	85.00	16.00
Mean	4167.65	105.00	315.00	160.50	0.33	25.13	3.00	7.00	55.00	13.00
Vira coast										
S-14	4867.50	110.00	210.00	132.00	0.48	8.00	3.00	7.00	35.00	15.00
Overall average	4601.71	105.24	253.21	148.50	0.53	9.88	2.54	7.40	39.76	14.64

Table 13: Regeneration and Recruitment class plants during Monsoon 2022

Station	Tree density- No/ha (1)	Regeneration density- No/ha (2)	Recruitment density- No/ha (3)	Ratio of 1:3	Ratio of 2:3
Tuna creek				1 to	to 1
S-2	5038	68000	13250	2.63	5.13
S-12	7359	70000	16500	2.24	4.24
Mean	6198.64	69000	14875	2.40	4.64
Phang creek					
S-5	2311	24000	3750	1.62	6.40
S-10	3558	75000	17500	4.92	4.29
Mean	2934.70	49500	10625	3.62	4.66
Kandla creek					
S-3	3669	79000	17000	4.63	4.65
S-4	6400	56000	8250	1.29	6.79
S-15	5545	23000	3750	0.68	6.13
Mean	5204.96	52667	9667	1.86	5.45
Kharo creek					
S-7	5144	77000	31500	6.12	2.44
Jangi creek					
S-6	3483	49000	13250	3.80	3.70
S-11	3906	79000	18000	4.61	4.39
Mean	3694.59	64000	15625	4.23	4.10
Navlakhi creek					
S-8	5045	52000	26500	5.25	1.96
S-9	3290	140000	19500	5.93	7.18
Mean	4167.65	96000	23000	5.52	4.17
Vira coast					
S-14	4867.50	13000	2750	0.56	4.73
Overall average	4601.71	60166.67	15434.52	3.35	3.90

3.12. Marine Reptiles

During the field surveys, one reptilian species, the saw-scaled *viper Echis carinatus sochureki* was recorded at site S-3 located in the northern part of Sat Saida bet opposite to oil jetty during monsoon season. This species was spotted on the ground among the mangrove trees. The literature describes the species as aggressive and strikes at a lightning speed, the observed specimen was active. In monsoon, the maximum number of this snake was recorded in S-10 located on the northern part of Sat Saida bet.

Plate 9: Marine reptiles recorded along the Deendayal Port Authority area

3.13. Marine Fishery

Marine fish production of India during the financial year 2019-2020 was 37.27 lakhs tons (Fisheries statistics 2021). The production varied from 0.2 to 7.01 lakh tons and Gujarat state contributed the highest production (Fisheries statistics 2021). The Ichthyofauna diversity of the Gulf of Kachchh includes a total of 20 orders, 47 families and 96 species (Katira & Kardani 2017). Along the Sikka coast of Jamnagar where 112 ichthyofauna species belonging to 50 families, 12 orders, and 84 genera has been reported. Similarly, the locality of Jamnagar Marine National Park, Gulf of Kachchh reported 109 ichthyofauna species belonging to 58 families, 19 orders, and 93 genera (Brahmane et al. 2014). Apart from this, a recent study conducted by Sidat *et al.*, (2021) reported 96 species which include 20 order and 47 families. During the field observation, in the gill net catches *Mugil cephalus*, *Planiliza klunzinger*i, *Planiliza planiceps*, *Planiliza macrolepis* (Plate 9) were observed of which *Mugil cephalus* catch was the maximum during monsoon season of (20 kg) followed by mud crab (30 kg).

Plate 10: Fish and Crab catch along the Deendayal Port Authority in monsoon 2022

3.14. Marine Mammals

Sousa plumbea (Cuvier, 1829) is commonly referred to as the Indian Ocean humpback dolphin. During the field surveys, the Indian Ocean humpback dolphin (*Sousa plumbea*) was recorded at the site between the S-3 and S-4 opposite the oil jetty during monsoon season. The length of the humpback dolphin is approximately 1.7 to 2m. Humpback dolphins feed mostly on small fishes, sometimes shrimps; occur mostly in small groups (mostly 12 or less); have limited nearshore movements and in most parts of their range, exhibit a fission/fusion type of social organization. The evaluation of the conservation status of a species and its subsequent listing as a Threatened species is a function of its risk of extinction, which is influenced primarily by population dynamics (population size and trends, population structure) and the key biological and environmental factors influencing those dynamics (distribution, behaviour, life history, habitat use and the effects of human activities).

Plate 11. Indian Ocean humpback dolphin *Sousa plumbea*

4. Mud flat

Mudflats and mangroves establish a major ecosystem of the DPA coastal region and the significance of ecosystem services rendered by mudflat is endorsed in Coastal Regulation Zone (CRZ, 2011) as it accords special status to highly productive zone. Mudflat has an assemblage of plant-animal-geomorphological entities. DPA has been surrounded by two major ecosystems such as mangroves and mudflats which support a number of ecosystem services like nursery grounds for fish and shellfishes and breeding/feeding grounds for the birds (Spencer and Harvey, 2012). The TOC concentration is direct indicator of mudflat productivity and blue carbon sequestration.

Bulk density of the sediment samples

The data on the bulk density of the sediment samples are presented in (Fig.25). The bulk density of mangrove soil at Deendayal Port Authority coastal region ranged from 1.26 g/cm^3 to 1.34 g/cm^3. The highest bulk density was recorded at S-4 and S-12 sites followed by S-15. The lowest bulk density was recorded at site S-8 located at Tuna creek and S-1.

Total Organic Carbon (TOC)

The highest TOC value (0.83%) was recorded at station S-4 followed by S-2 site. Lowest TOC value was reported at site S-12 (Fig.26). It is observed that TOC values varied significantly among the sampling stations which means that organic carbon is dependent on the living life forms and variations in the life forms in the mudflats. The TOC concentration is a direct indicator of mudflat productivity and blue carbon sequestration. The data on monsoon samplings revealed that the different sampling sites of Deendayal Port Authority jurisdiction have considerable variations with respect to organic carbon.

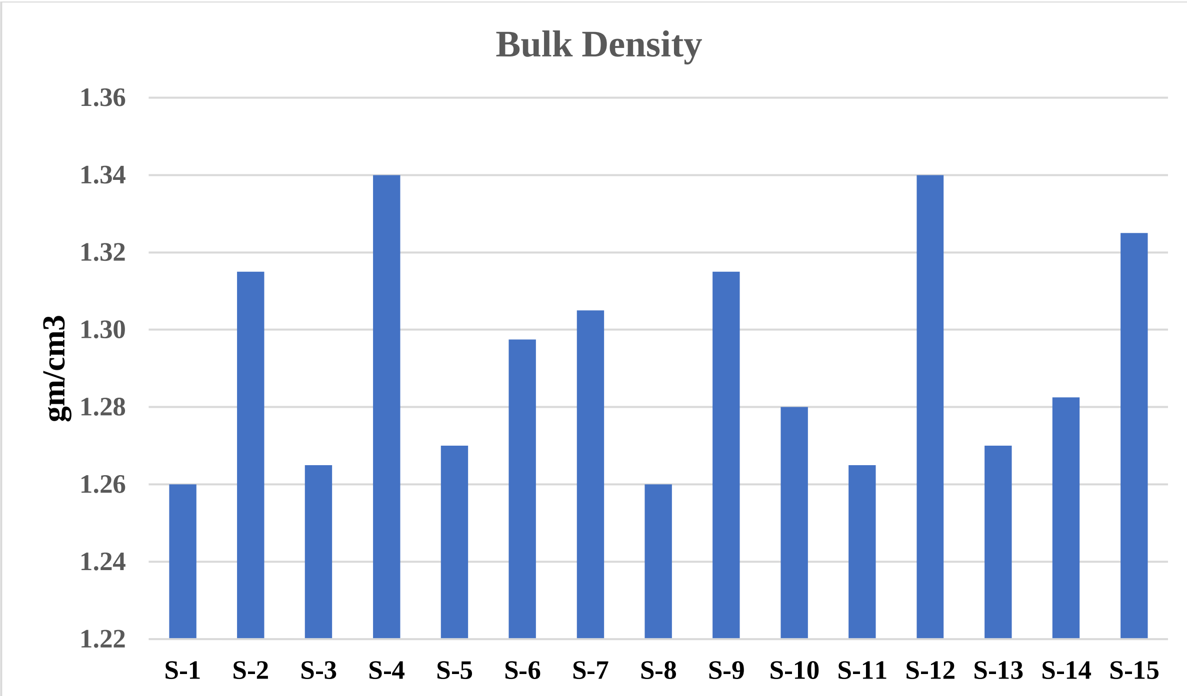

Figure 25: Bulk density of mudflat sediment during Monsoon 2022

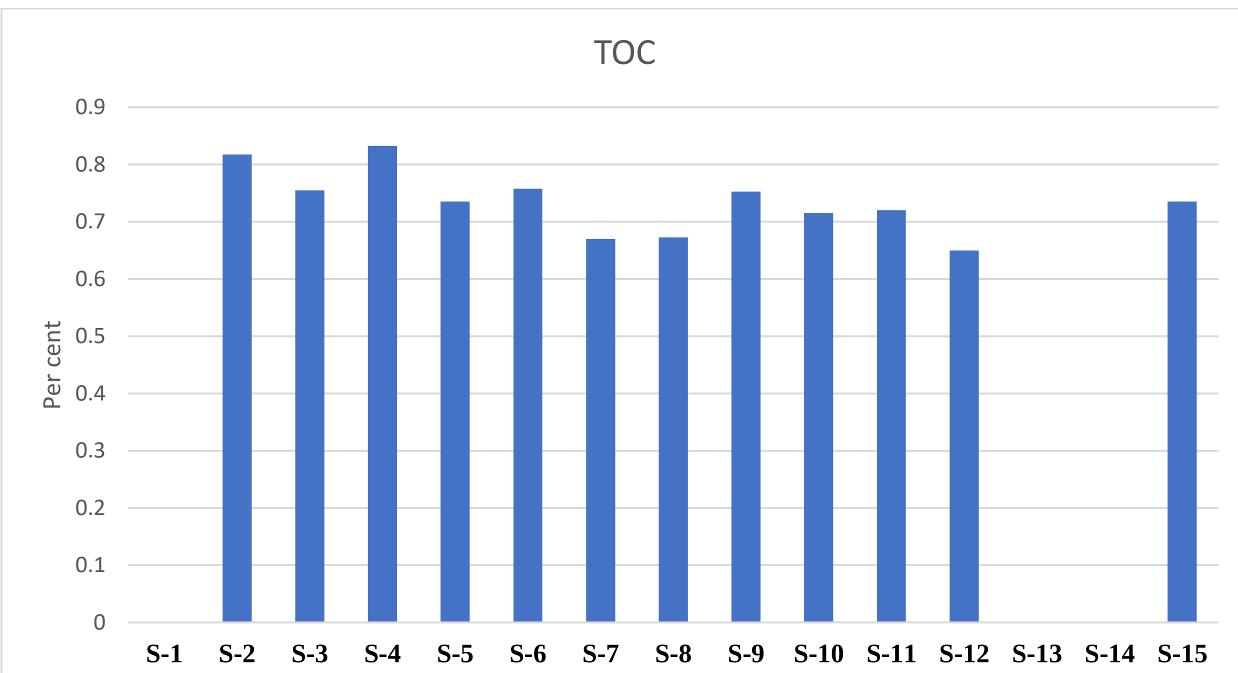

Figure 26: Percentage of Total Organic Carbon in the mudflat in Monsoon 2022

5. Avifauna

A large amount of research on bird diversity emphasizes the general negative effects of land conversion to human dominated habitats (Brooks *et al*. 1997; Castelletta *et al*. 2000). But human dominated and coastal habitats vary a lot and therefore the effect on birds can be very different. Birds depend on the habitats where they occurred, so the response of the species in particular habitat may always differ according to the habitat changes (Tworek, 2002, Winter & Faaborg, 1999; Cornelius *et al*. 2000; Zanette 2000; Zanette *et al*. 2000; Johnson & Igl, 2001; Beier *et al*. 2002; Herkert *et al*. 2003; Kurosawa & Askins, 2003). A total of 49 species belonging to six orders, 25 families and 38 genera were recorded from the coastal area of Deendayal Port during this study (Annexure 1). Among these, 26 species were aquatic and 23 species were terrestrial, which included three species listed as Near Threatened in the IUCN (2022), Red List.

Order Charadriiformes i.e. aquatic birds (including raptors and most water birds) constituted the predominant groups representing 58% of all species recorded from the study area followed by order Passeriformes (31%), i.e., perching birds (including babblers, drongos, mynas, sunbirds, doves, warblers, larks, chats, wagtails, robins). The families with a greater number of species were Ardeidae (eight spp.), Scolopacidae (seven spp.), Charadriidae (three spp.), Columbidae (three spp.), Laridae (two spp.), and Passeridae (one spp.). Among the recorded species, four were migrants, 10 were local migrants or resident migrants, 35 were breeding resident. During the present investigation, birds with diverse food habits viz., Aquatic (20 spp.), Insectivores (12 spp.), Granivores (eight spp.), Piscivores (six spp.), Omnivores (one spp.) Frugivores (one spp.), and Nectarivores (one spp.) were observed. The overall Shannon diversity (H')was 3.6 with species richness index for study area 1.2. The overall species evenness index value for study area was 0.77 and Equitability 0.93 (Table 13).

Status, distribution and diversity of avifauna in different stations:

A Total of fifteen sites were surveyed, of which the maximum number of species was found in Site 1 & 2 (33 spp.) followed by Site 9 (27 spp.) and Site 10 & 15 (26 spp.). Site 5 recorded the least richness (16 spp.) (Fig. 27).

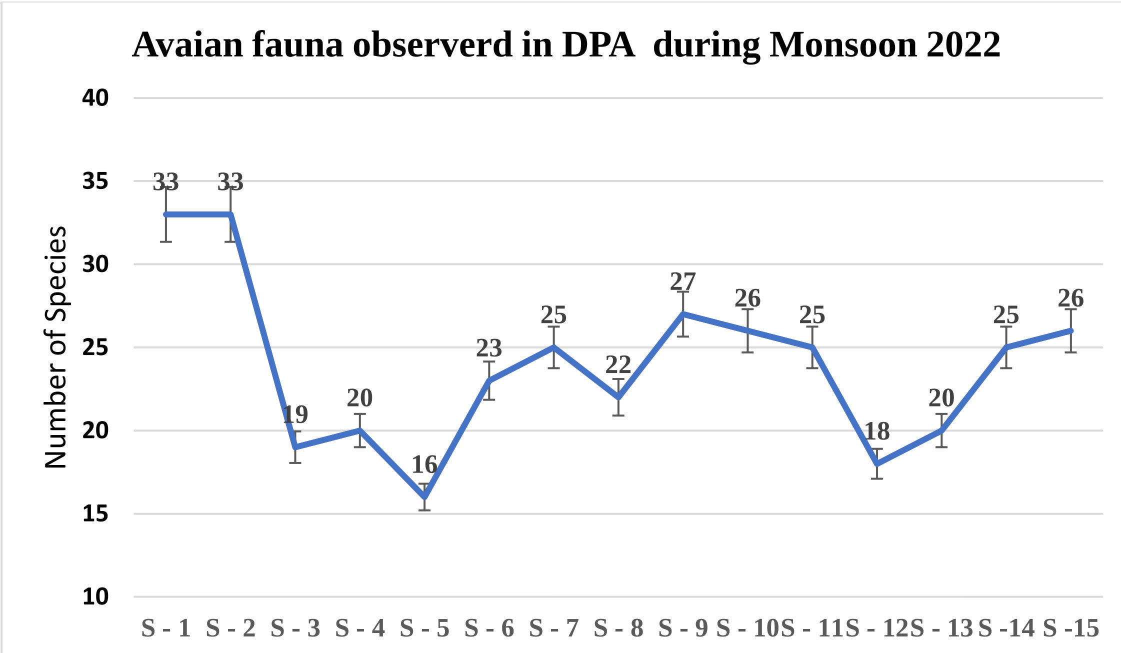

Figure 27. Number of Avian species recorded from the Deendayal Port Area

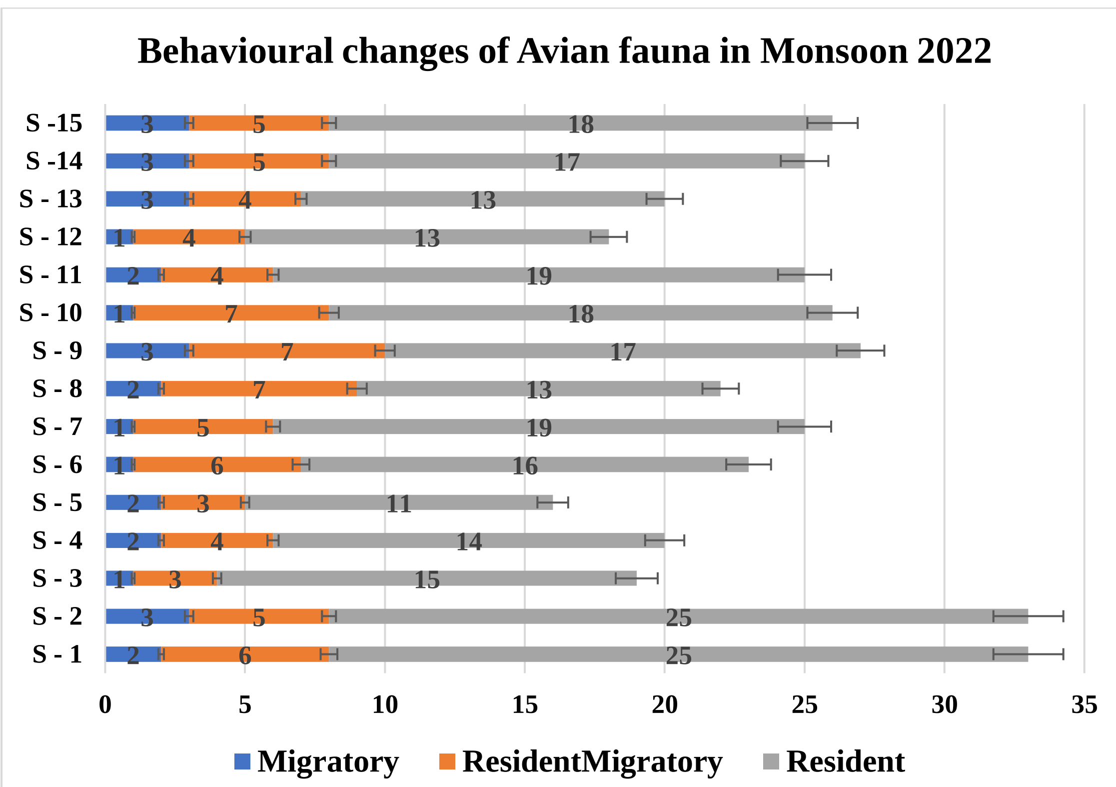

Figure 28. Behavioral status of Avian species from the DPA in Monsoon 2022

Site wise migratory status showed that maximum migratory species were found in S- 2, S-9,S-13,S-14 & S-15 (three spp.) followed by S- 1,S-4,S-5,S-8 & S-11 (two spp.) (Fig. 28). From the study area all the species were categorized into two habitats i.e. terrestrial and aquatic. Survey for terrestrial and aquatic avifauna showed that maximum terrestrial avifaunal richness was recorded from S-2 (17 spp.) followed by site S-1 (15 spp.), S-11 (13 spp.) and site S-9 (12 spp.); while aquatic avifaunal species richness was more in site S-1 (18 spp.) followed by S- 15 (17 spp.), S-2 (16 spp.) and S- 8 (15 spp.) (Fig. 29).

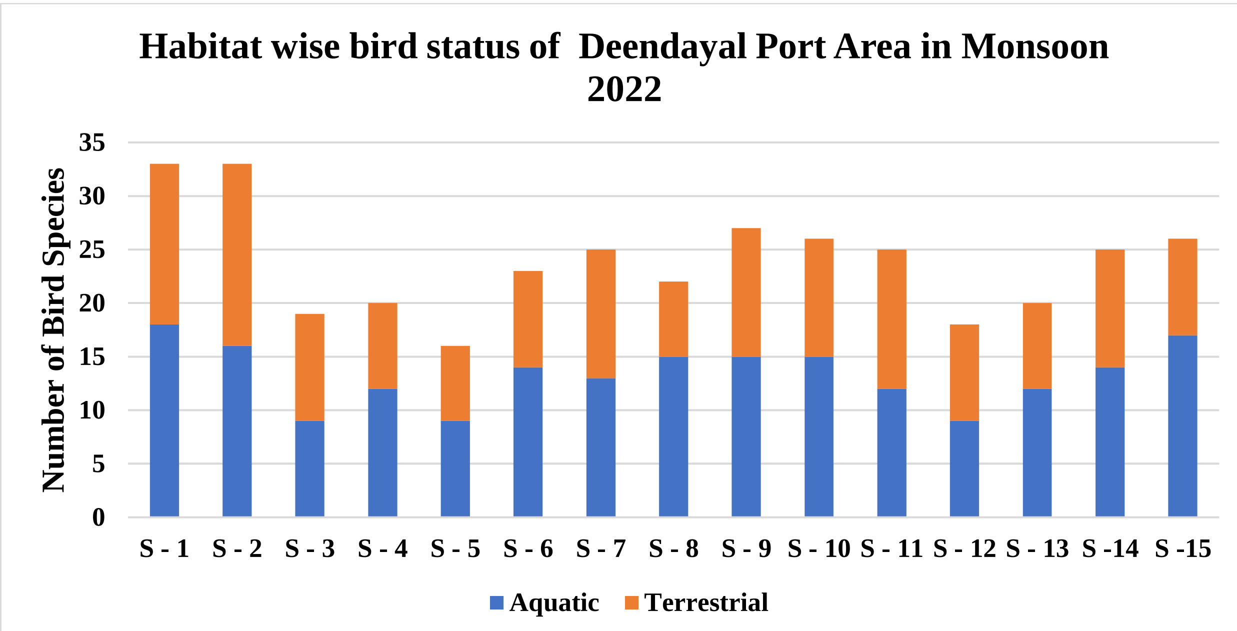

Figure 29. Habitat wise distribution of Bird species from the DPA in Monsoon 2022

During the present investigation birds with diverse food habits were observed, viz., Aquatic, Insectivores, Granivores, Piscivores, Frugivores, Omnivores and Nectarivores. All the sites have found more number of aquatic birds species (maximum 16 species recorded from S- 15) followed by Insectivores (Maximum 8 species recorded from Site 1&2), granivore (maximum 8 species recorded from S-2) and piscivores (maximum 4 species recoded from S-3,S-6,S-8&S-11) and least species found of frugivores, omnivores and nectorivores (Fig.30)

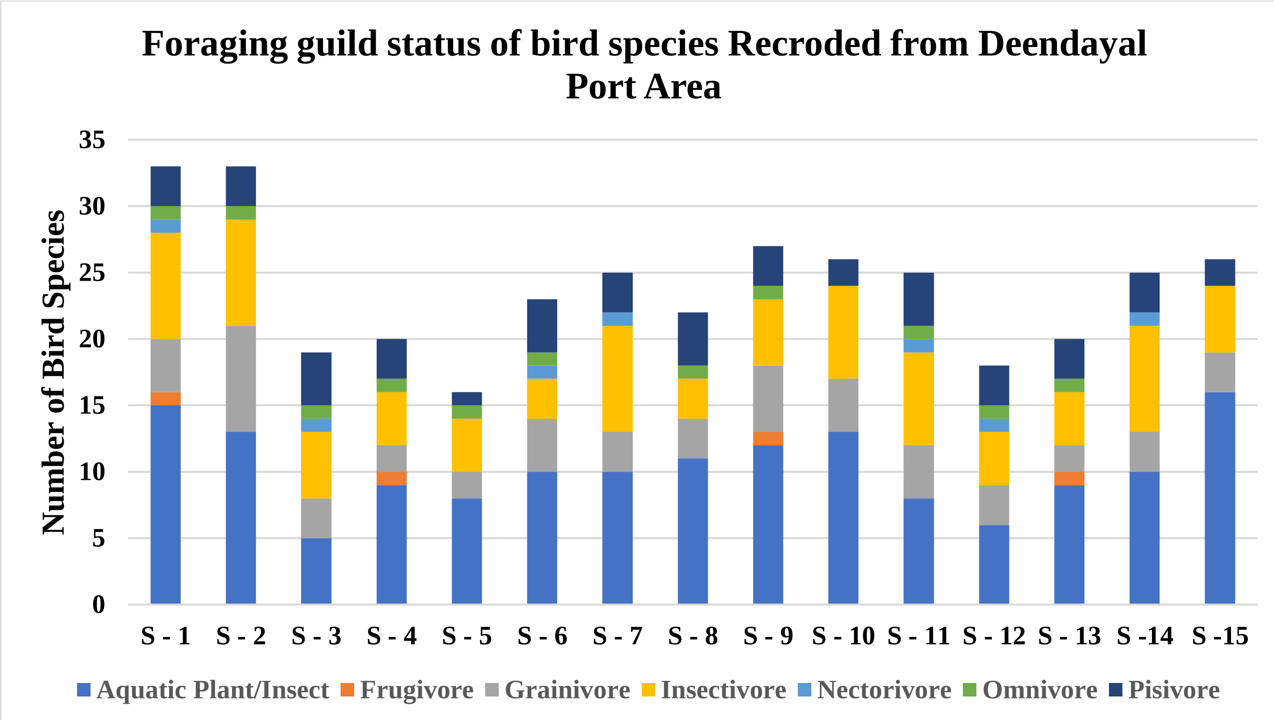

Figure 30. Station wise Foraging Guild status of species recorded during Monsoon 2022

Data collected from point counts allows us to calculate species diversity, richness and species composition. The results showed that the maximum diversity was found from the S-1 (H' 3.3) followed by S-2 (H' 3.2) and the minimum diversity recorded from site 12 (H' 2.6) and S- 5 (H' 2.5). The maximum species richness was recorded from Site 1 (2.9 spp.) and the minimum from Site 12 (2.1 spp.). These changes in individual species abundance, whether they occur independently of one another (Wiens, 1989) or are influenced by interactions with other bird species are governed by the degree of anthropogenic pressure including disturbance to habitat of species (Block & Brennan, 1993). The distribution and abundance of many bird species are mainly determined by the configuration and composition of the vegetation that comprises a major element of their habitat (Cody, 1985; Block & Brennan, 1993). As vegetation changes along complex geographical and environmental gradients, particular bird species may appear, increase in abundance, decrease, and disappear, when habitat becomes more or less suitable for its persistence. Totally 16% species were found rarely distributed in the study area while 36% species were very common. Aquatic and Insectivores species form the major groups while each of the frugivores, omnivores and nectarivores constitute about 2% of all species. Although more than 67% of the birds in the study area were Aquatic and insectivores, food competition was reduced by the utilization of different habitat types and distinct feeding behaviour. Largely insectivorous birds like babblers (Sylviidae) and drongos (Corvidae) feed on fruits and seeds of plants particularly during winter season due to the shortage of insect food. Wetland birds were dominated largely by the aquatics followed by insectivore and grainivore species (Annexure 1). The present season study shows 49 different types of birds belonging to six orders and 25 families from the coastal area of Deendayal Port. The richness of avifauna is little low, indicator of ecological health of the coastal area of Deendayal Port. Proper and in-depth study, awareness, regarding the importance of birds and their role in ecosystem, to the local peoples through different massive programs will ultimately help the protection of birds of this region

Great Egret *Ardea alba*

Grey Heron *Ardea cinerea*

Great Cormorant *Phalacrocorax carbo*

Western Reef Egret *Egretta gularis*

Plate 12: Some common Birds from the Deendayal Port Authority

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Annexure -F

Memorandum of Understanding

for

To carry out
"Mangrove Plantation through PPP Mode"

Between

DEENDAYAL PORT TRUST
KACHCHH - GUJARAT

&

Gujarat Ecology Commission
Government of Gujarat
Gandhinagar

Year: 2020 - 21

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Memorandum of Understanding

This Memorandum of Understanding signed on the date 10 / 09 /2020 between M/s. Deendayal Port Trust, Kachchh - Gujarat; (hereinafter referred to as DPT) and Gujarat Ecology Commission, Government of Gujarat, Block-18, First Floor, Udhyog Bhavan, Sector-11, Gandhinagar – 382011. (Hereinafter referred to as GEC) to implement the project "Restoration, Plantation & Conservation of Mangroves on coastline of Gujarat".

WHEREAS

A. Gujarat Ecology Commission, Forest & Environment Department, Located at Block No. 18, First Floor, Udhyog Bhavan, Gandhinagar, organizations of Government of Gujarat.

B. M/s. Deendayal Port Trust, located at Gandhidham, Kachchh, Gujarat approached Gujarat Ecology Commission, Government of Gujarat to provide technical and managerial support to partner in to carry out mangrove plantation through PPP mode, in compliance of EC & CRZ Clearance accorded by the MoEF & CC, GoI for Developing 3 Remaining Integrated facilities dated 18/2/2020 and Development of Integrated Facilities (Stage II) dated 19/2/2020.

मुख्य अभियंता
दीनदयाल पोर्ट ट्रस्ट
Chief Engineer
Deendayal Port Trust

GUJARAT ECOLOGY COMMISSION, GANDHINAGAR, GOVERNMENT OF GUJARAT

NOW THEREFORE all the two parties here to agree as follow:

1. Cost of the project

Sr. No.	Project Proposal	Name of the Company/Agency	Area (Ha.)	Amount (in lakh)
1.	Restoration, Plantation & Conservation of Mangroves on coastline of Gujarat under PPP mode	Deendayal Port Trust, Kachchh - Gujarat	**100**	**Rs. 4500000.00**

2. Project Period

The project period will be from August - 2020 to March - 2021.

Sr. No.	Plantation Year	Plantation Target	Project Area
1.	2020 - 21	100 ha (By using various techniques)	At. Kantiyajal (50 Ha.) & At. Aaliya Bet (50 Ha.), Ta. Hansot, Di. Bharuch. **[Annexure – II] (Image – I & Image – II)**

3. Budget Estimates

Budget Estimates for this project have been shown in **Annexure – I**. The cost of mangrove plantation work is **Rs. 4500000.00 @ Rs. 45000.00/Ha**. (As agreed in earlier MoU; dtd. 14th September, 2017)

4. Payment Terms & Conditions:

Sr. No.	Terms & Conditions	Rs. (in lakh)
1.	60% of total project cost amount on submission of inception report.	**Rs. 27.00**
2.	30% of total project amount at the completion of nursery preparation and submission of progress report.	**Rs. 13.50**
3.	5% of Total project amount at the completion of nursery plantation and submission of Final Activity Report.	**Rs. 02.25**
4.	5% of Total project amount at the submission of First year Progress Report.	**Rs. 02.25**
	Total	**Rs. 45.00**

मुख्य अभियंता
दीनदयाल पोर्ट ट्रस्ट
Chief Engineer
Deendayal Port Trust

GUJARAT ECOLOGY COMMISSION, GANDHINAGAR GOVERNMENT OF GUJARAT

The **Memorandum of Understanding** is hereby signed on **dt. 10 / 09 /2020**. The Memorandum of understanding has been signed to facilitate M/s. Deendayal Port Trust to establish the Mangrove plantation along the coastline of Gujarat State as a part of EC compliance and also towards sustainable environment and ecological balance through aforesaid project[s] in Gujarat State in time bound manner.

Place: Gandhinagar

Date: 10 / 09 /2020

FOR and on behalf of:

M/s. Deendayal Port Trust **Kachchh, Gujarat**	**Gujarat Ecology Commission** **Gandhinagar, Gujarat**
मुख्य अभियंता दीनदयाल पोर्ट ट्रस्ट Chief Engineer Deendayal Port Trust	Sr. Manager (Projects) Gujarat Ecology Commission Gandhinagar.

Annexure - I

GUIDELINES FOR MANGROVE PLANTATIONS UNDER PPP MODE

Gujarat Ecology Commission (GEC) has been engaged in mangrove plantation activities as part of its mandate to work for restoration of ecologically degraded areas to ensure the ecological health of Gujarat systematically. To fulfill this objective, the Commission is partnering with industries/corporates to carry out mangrove plantations through Public-Private-Partnership (PPP) mode. To make the conditions of partnership for mangrove plantations more transparent, GEC has decided the following guiding principles for taking up of mangrove plantation activities on PPP mode. Henceforth the working for mangrove plantations under PPP mode will be taken up on these principles only.

1. GEC is an extended arm of Government of Gujarat and not a Corporate party or independent Society, therefore, industries/corporates willing to associate with GEC for mangrove plantation activities need to work as a partner and should fund the project as project cost/grant. The relationship of contractor-client does not hold good.
2. Any industry/corporate/institutions willing to partner with GEC for mangrove plantation activities need to pay in advance either at the beginning of the project or signing of MoU as availability of fund at right time is essential for the success of plantations as plantation is a season-based activity.
3. The site selection for plantation is generally done jointly, however, finally site selection depends upon availability of suitable area and therefore, site necessarily may not be in the vicinity of the partnering industry/corporate.
4. As GEC is an extended arm of Government of Gujarat as well as the said work is being taken up by GEC on no profit / no loss basis for the sustainable coastal management in the State of Gujarat and

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GOVERNMENT OF GUJARAT

contractor-client relationship does not hold good, therefore, **no TDS should be deducted**.

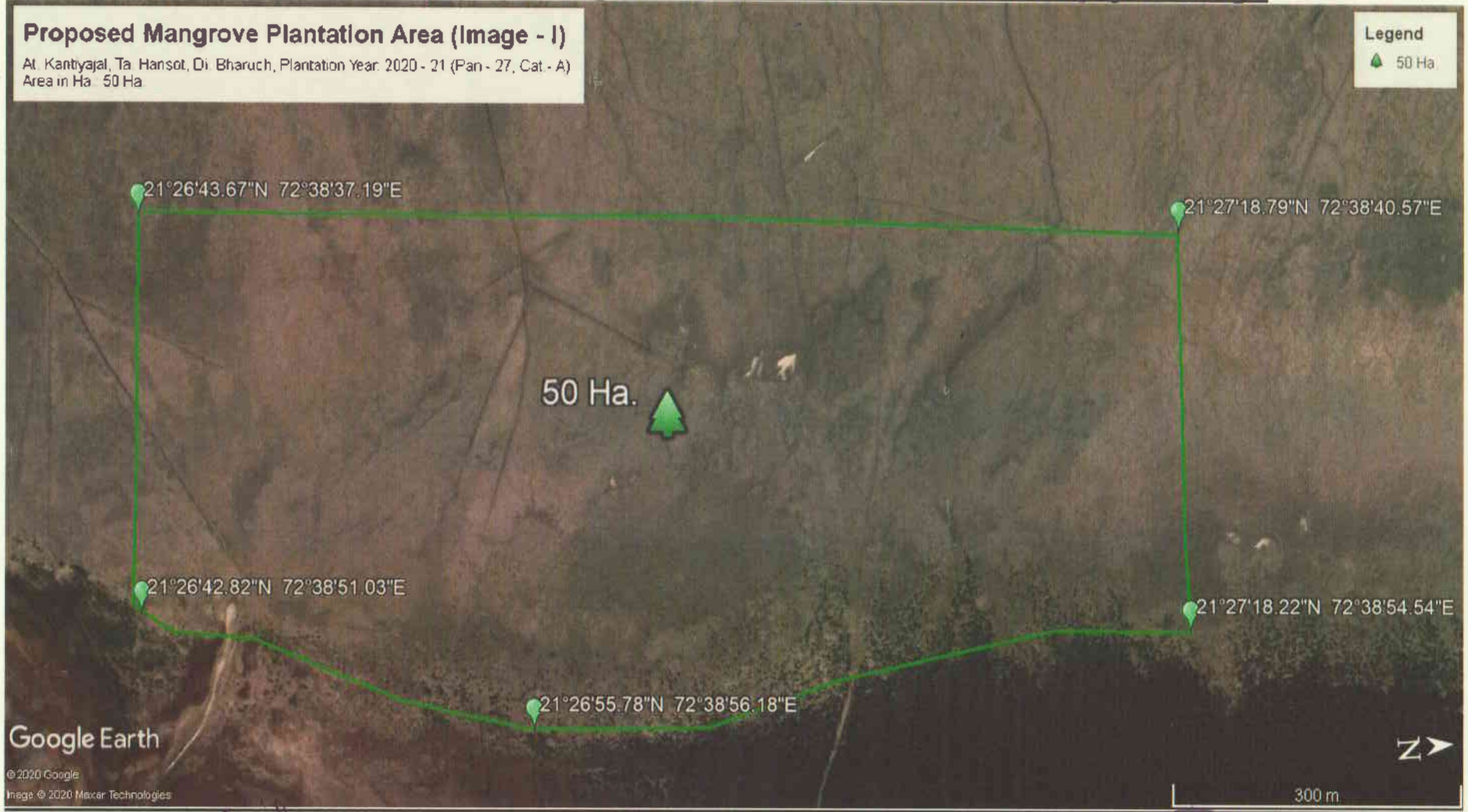
5. GEC will be responsible to submit progress report on a mutually agreed interval to the partnering industries/corporates/institutions and also facilitate to carry out monitoring/ visit of partner industries as well as certificate will be issued stating the completion of said work.
6. The cost of mangrove plantation works out to be **i. e. 45000/- per ha** and this may be subsequently revised based on the changes in daily wages rate from time to time.
7. Partnering industry/corporate can appoint any third party monitoring agency, if they wish so, at their own cost.

-SD-
[DIRECTOR]
GUJARAT ECOLOGY COMMISSION

मुख्य अभियंता
दीनदयाल पोर्ट ट्रस्ट
Chief Engineer
Deendayal Port Trust

GUJARAT ECOLOGY COMMISSION GANDHINAGAR
GOVERNMENT OF GUJARAT

Annexure – II: Proposed Mangrove Plantation Area At. Kantiyajal Village



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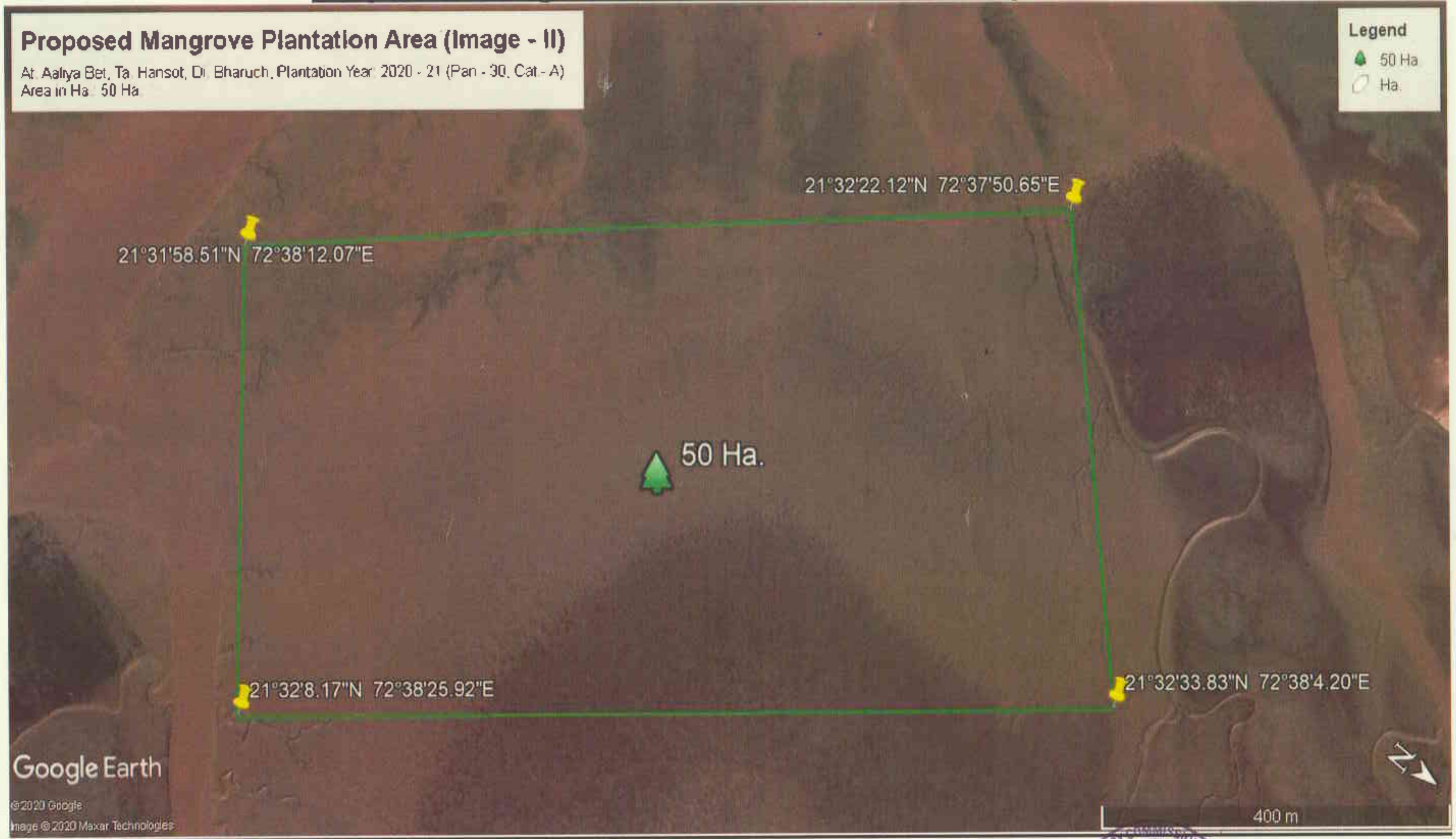
Proposed Mangrove Plantation Area At. Aaliya Bet



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Engineer
Port Trust

GUJARAT ECOLOGY COMMISSION, GANDHINAGAR • GOVERNMENT OF GUJARAT

Annexure -G

ENVIRONMENTAL MONITORING REPORT
FOR DEENDAYAL PORT AUTHORITY

REPORT	:	DCPL/DPA/21-22/31
Mont	:	November 01
Issue	:	00
Revision	:	00
Prepare	:	DETOX CORPORATION PVT. LTD.,

Index

EXECUTIVE SUMMARY

ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTALMONITORING REPORT- NOVEMBER, 2022

1. EXECUTIVE SUMMARY

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to understand status of various parameters in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

A) Ambient Air

The monitoring of Ambient Air quality at 6-locations at Deendayal Port Authority Kandla and 2- location at Vadinar Port on 24 hourly basis for TSPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2, NH_3, CO_2, CO, C_6H_6 and NMHC in twice a week 24 hourly at uniform intervals (as per NAAQS) at Gopalpuri, Tuna Port, Marine Bhavan Building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and Vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The Maximum TSPM values in month of November 2022 were found 846 µg/m^3 at Coal Storage area on 25.11.2022 and minimum 107 µg/m^3 at Gopalpuri Hospital on 01.11.2022. The Maximum PM_{10} values were 654 µg/m^3 at Coal Storage area on 25.11.2022 and minimum was 67 µg/m^3 at Gopalpuri Hospital 01.11.2022. Maximum $PM_{2.5}$ values were 187 µg/m^3 at Coal Storage area on 25.11.2022 and minimum was 34 µg/m^3 at Gopalpuri on 01.11. 2022. The PM_{10} and $PM_{2.5}$ values were found for all monitoring locations (Marine Bhavan Building, Oil Jetty, Estate Office, Gopalpuri, Coal Storage Area and Tuna Port) to exceed the Standard limit (NAAQS).

At Gopalpuri location the mean concentration of PM_{10} was 127 µg/m^3 & $PM_{2.5}$ was 66 µg/m^3 which are slightly exceed the Standard limit (NAAQS).

The AAQ monitoring for Vadinar at Admin building the mean TSPM, PM_{10} and $PM_{2.5}$ were 237µg/m^3, 138 µg/m^3 and 97 µg/m^3 respectively which was exceed the Standard limit (NAAQS) the while at Signal Building the mean TSPM, PM_{10} and $PM_{2.5}$ were 113 µg/m^3 , 74 µg/m^3 and 38 µg/m^3 respectively slightly exceed the Standard limit (NAAQS).

The overall values of November for Gaseous SO_2, NO_2, NH_3, CO_2, CO, C_6H_6 concentration were within the permissible limit at all location and NMHC were found BQL (Below Quantification Limit).

B) Weather

The mean day time temperature at Deendayal Port was 27.92 °C. The day-time maximum temperature was 32.9°C and minimum was 21.1 °C. The mean night time temperature recorded was 25.47 °C. The night-time maximum temperature was 29.7°C and minimum was 20.0 °C. The mean Solar Radiation in November month was 167.27 w/m^2. The maximum solar radiation was recorded 759 w/m^2 in 4^{th} November, 2022 and the minimum solar radiation was recorded 1.80 w/m^2 in 30^{th} November, 2022. The mean Relative humidity was 69.00 % for the month of November. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 34.0 %. The average wind velocity for the entire month of November was 1.21 m/s. Maximum wind velocity was recorded 10.19 m/s. The wind direction was mostly West-South.

C) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:

The results obtained from the study for the month of November 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

D) Drinking Water Quality

The drinking water being supplied to Deendayal Port Authority was safe for drinking purpose. At all drinking water monitoring stations around port area were in line with the standard limit as per the drinking water specifications given in IS 10500:2012 as per tested parameters only.
The average results for 20 locations were as: pH were found Min 7.24 and maximum 7.52, TDS were found min 300.0 mg/l and Max found 1060.0 mg/l, Chloride were found Min 140.31 mg/l and Max 576.28 mg/l, Total Hardness were found Min 270.0 mg/l and Max 380.0 mg/l and Calcium were found Min 34.47 mg/l and Max 43.29 mg/l, color were colorless and odor were odorless. In all water samples BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count (E-coli & Coliform) is absent in all drinking water samples.

E) Monitoring Performance of Sewage Treatment Plant

It was seen that the performance of STP at Deendayal Township Gopalpuri, DPA STP Plant Kandla and Vadinar STP plant was satisfactory by overall. The treatment plant was well maintained during [November 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. At Gopalpuri STP, the pollutant removal efficiency for TSS, BOD and COD was ranged from 49.66-81.04%, 58.97-68.42% and 45.45-73.33% respectively. At Kandla STP, removal efficiency for TSS, BOD and COD was ranged from 53.47-73.49%, 46.15-76.74% and 50.00-82.35% respectively & at Vadinar STP removal efficiency for TSS, BOD and COD was ranged from 42.09-56.69%, 50.00-78.12% and 60.00-84.61% respectively. At all STP location treated waste water the pH were ranged from 7.21-7.42,Total Suspended Solids were found 16.9-67.9 mg/l , Residual Chlorine were below Detection Limit (< 0.5) , COD were found 20-60 mg/l and 3day BOD @ 27 °C were found 7.0-16.0 mg/l.

F) Noise

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 53.2 dB(A) to 70.4 dB(A) while at Vadinar port 3 location ranged from 52.5 dB(A) to 60.6 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 45.4 dB to 61.7 dB(A) while at Vadinar port ranged from 52.5 dB (A) to 60.6 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.

CHAPTER-1

INTRODUCTION

DEENDAYAL PORT AUTHORITY

1.0 Introduction

About Deendayal Port

The Deendayal Port is situated in the Kandla Creek and is 90 Kms. From the mouth of Gulf of Kachchh. Latitude: 23° 01" N Longitude: 70° 13"E. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rise to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15 consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 127.10 million metric tons of cargo during the FY 2021-22, as against 117.566 million metric tons in FY 2020-21. Showing a growth of 8.11 %. Incidentally, DPA is the only major Indian port of handle more than 127 MMT cargo throughout and it has also registered the highest cargo throughput in its history. While the port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in Sept. 2021. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural up-gradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32 MMTPA Essar Oil Refinery in Jamnagar District. Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the prescribed standards by GPCB/CPCB/MoEF& CC. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port. The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.

CHAPTER-2

AMBIENT AIR QUALITY MONITORING

2. Introduction

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth's atmosphere. It may cause diseases, allergies or death of humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty. The consequences of industrialization and the demand for improved quality of life has been increased exposure to air pollution (Vallero, 2014). An air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Any gas could qualify as pollution if it reached a high enough concentration to do harm. Theoretically, that means there are dozens of different pollution gases. In practice, about ten different substances cause most concern. Heavy metals represent a class of omnipresent pollutants, with toxic potential, in some cases even at low exposure levels. They concentrate in each tropic level because of their weak mobility, so the concentration in plants is higher than in soil, in herbivore animals higher than in plants, in carnivores' tissues higher than in herbivore, the highest concentration being reached at the end of the tropic chain, at big predacious and human bodies.

Globally, one of the main contributors to emissions of atmospheric pollutants and a significant user of energy is the industrial sector (Conti et al. 2015).

The concentration of air pollutants depends not only on the quantities that are emitted from the polluting sources, but also on the ability of the atmosphere to either absorb or disperse such emissions (USEPA, 2008).

Nowadays, the shipping sector provides low-cost and reliable delivery services in the economic field (Arunachalam et al. 2015). Nevertheless, shipping-related activities have a considerable impact on air pollution, especially in coastal areas but also globally (Buccolieri et al. 2016). The primary air pollutants are PM, VOCs, NOx, O_3, SO_2, and CO (Bailey and Solomon 2004). As a consequence, a wide range of options toward “greener” seaports is needed (Bailey and Solomon 2004). Some of these measures are easy to adopt such as the regulation of fuel quality (by using low-sulfur alternative fuels), the speed reduction (Lack et al. 2011), and the use of alternative transportation equipment (Lai et al. 2011).

Clean air is the basic requirement of all living organisms. In recent times, due to population growth, urban sprawl, industrial development, and vehicular boom, the quality of air is deteriorating and being polluted. Pollutants of major public health concerns include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, which pose serious threats to human health and hygiene. In the present study, prime particulate pollutants (PM_{10}, $PM_{2.5}$), and gaseous pollutants (SO_2, and NO_2) were estimated at seven stations in and around Dahej Port, Gujarat, India (Soni and Jagruti Patel, 2017).

Among particulate pollutants, particulate matter (PM) is a ubiquitous entity, and is especially a grave problem due to its higher suspension rate into the atmosphere, and adverse health effects on plants, animals, humans, and materials in the form of visibility reduction, soiling of buildings, etc. (Horaginamani and Ravichandran, 2010; Chaurasia *et al*., 2013).

The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

2.1 Ambient Air Quality Monitoring

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

Table: 1. Ambient Air Sampling Location

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Marine Bhavan	AL-1	23° 0' 26.524"N	70° 13' 22.414"E	**DPA-Kandla**
2.	Oil Jetty	AL-2	23° 1' 45.613"N	70° 13' 11.052"E	
3.	Estate Office	AL-3	23° 1' 11.273"N	70° 12' 48.657"E	
4.	Gopalpuri Hospital	AL-4	23° 4' 53.551"N	70° 8' 7.047"E	
5.	Coal Storage Area	AL-5	22° 59' 31.812"N	70° 13' 9.979"E	
6.	Tuna Port	AL-6	22° 59' 15.291"N	70° 58' 57.018"E	
7.	Signal Building	AL-7	22° 26' 26.750"N	69° 40' 22.127"E	**DPA-Vadinar**
8.	Admin Building	AL-8	22° 26' 25.223"N	69° 40' 19.358"E	

- **Air Quality Monitoring Methodology**

  Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM_{10}, $PM_{2.5}$, SO_2, NO_2, NH_3 & Benzene and Grab-sampling for CO & CO_2 measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours for gaseous parameters. The absorbing reagents for $SO_{2:-}$ Absorbing Reagent TCM (Potassium Tetrachloromercurate 0.04M): Mercuric Chloride, Potassium Chloride and EDTA used. For NO_2:- Absorbing Reagent Sodium Hydroxide (NAOH): Sodium Hydroxide and Sodium Arsenite used. For NH_3 need Conc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO_2, $NO_{2,}$ NH_3. The GFA filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM_{10} & $PM_{2.5}$. The AAQ samples are collected two consecutive days a week as per CPCB guidelines, from all the eight locations as mentioned in the EMP.

2.2 Results

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of November 2022 are given in Tables 2 to 7. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 8 to 9.

The Movement of heavy transport with uncovered coal transportation, raw road around ambient location may be causes fugitive dust emission from dry conditions. Particulate Matter then enters the atmosphere through the action of wind, vehicular movement, or other activities. The dust produces tends to float in air and spread all around the vicinity. Direction and speed of wind affect the dispersion of the dust particulate matter. Humidity of air also has strong effect on the spreading of particulate matter. With increasing humidity, moisture particles eventually grow in size to a point where ‘dry deposition’ occurs, reducing PM_{10} concentrations in the atmosphere.

Location 1: Marine Bhavan (AL1)

Table 2 : Results of Air Pollutant Concentration at Marine Bhavan

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		**24hr**	**24hr**	**24hr**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**
NAAQMS Limit			**100 µg/m3**	**60 µg/m3**		**80 µg/m3**		**80 µg/m3**		**400 µg/m3**
AL1 – 1	01.11.2022	435	302	121	3.93	3.93	5.19	14.43	2.07	4.11
					6.04		23.66		6.33	
					1.81		14.43		3.91	
AL1 – 2	04.11.2022	344	228	106	3.32	2.52	17.31	12.70	2.42	3.72
					2.72		8.66		5.18	
					1.51		12.12		3.57	
AL1 – 3	08.11.2022	398	281	116	2.31	3.84	25.39	17.31	4.72	3.57
					6.34		17.89		2.42	
					2.88		8.66		3.57	
AL1 – 4	11.11.2022	445	315	124	3.63	6.35	17.89	13.08	4.03	3.61
					9.07		12.70		4.72	
					6.35		8.66		2.07	
AL1 – 5	15.11.2022	364	253	110	4.53	4.53	11.54	13.85	4.60	3.07
					6.35		19.62		2.88	
					2.72		10.39		1.73	
AL1 - 6	18.11.2022	442	315	121	8.46	4.84	23.08	16.54	3.22	4.37
					3.32		8.66		5.87	
					2.72		17.89		4.03	
AL1 - 7	22.11.2022	375	266	106	3.32	4.43	17.89	18.47	4.83	4.45
					7.55		25.97		5.87	
					2.42		11.54		2.65	
AL1 – 8	25.11.2022	483	350	129	4.53	4.63	23.66	21.55	3.22	3.68
					6.95		28.86		5.29	
					2.42		12.12		2.53	
AL1 – 9	29.11.2022	534	383	142	6.35	5.84	17.89	19.04	3.57	3.57
					8.46		25.97		4.95	
					2.72		13.27		2.19	
Monthly Average		424	299	119		4.55		16.33		3.79
Standard Deviation		61	48	12		1.12		3.03		0.44

Table 2 : Results of Air Pollutant Concentration at Marine Bhavan					
	Date	**C6H6 [µg/m3]**	**HC**	**CO [mg/m3]**	**CO2 [ppm]**
Sampling Period		**8 hr**		**Grab Sampling**	**Grab Sampling**
NAAQMS limit		**5.0 µg/m3**	**ppm**	**4.0 mg/m3**	**-**
AL1 – 1	01.11.2022	1.09	BQL	1.44	444
AL1 – 2	04.11.2022	1.2	BQL	1.54	374
AL1 – 3	08.11.2022	1.17	BQL	1.08	538
AL1 – 4	11.11.2022	1.1	BQL	1.14	470
AL1 – 5	15.11.2022	1.11	BQL	1.26	481
AL1 - 6	18.11.2022	1.1	BQL	1.64	500
AL1 - 7	22.11.2022	1.12	BQL	1.35	620
AL1 - 8	25.11.2022	1.16	BQL	1.69	511
AL1 - 9	29.11.2022	1.21	BQL	1.16	522
Monthly Average		**1.14**	**-**	**1.37**	**495.56**
Standard Deviation		**0.05**	**-**	**0.22**	**67.59**

* NMHC- Non- Methane Hydrocarbons
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2 and NH_3 is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM_{10}. The mean TSPM value at Marine Bhavan was 424 µg/m^3, the mean PM_{10} value was 299 µg/m^3, and $PM_{2.5}$ value was 119 µg/m^3 which is above the permissible limit prescribed by NAAQS. The average values of SO_2, NO_2 and NH_3 were 4.55 µg/m^3, 16.33 µg/m^3 & 3.79 µg/m^3 respectively; these values were within the standard limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.14 µg/m^3, well below the permissible limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.37 mg/m^3, well below the permissible limit of 4.0 mg/m^3 prescribed by NAAQS.

Location 3: Oil Jetty (AL2)

<table>
<tr><th colspan="12">Table 2 : Results of Air Pollutant Concentration at Oil Jetty</th></tr>
<tr><th></th><th>Date</th><th>TSPM [µg/m3]</th><th>PM10 [µg/m3]</th><th>PM2.5 [µg/m3]</th><th colspan="2">SO2 [µg/m3]</th><th colspan="2">NOx [µg/m3]</th><th colspan="2">NH3 [µg/m3]</th></tr>
<tr><th>Sampling Period</th><th></th><th>24hr</th><th>24hr</th><th>24hr</th><th>8 hr</th><th>24hr (Avg.)</th><th>8 hr</th><th>24hr (Avg.)</th><th>8 hr</th><th>24hr (Avg.)</th></tr>
<tr><th>NAAQMS Limit</th><th></th><th></th><th>100 µg/m3</th><th>60 µg/m3</th><th></th><th>80 µg/m3</th><th></th><th>80 µg/m3</th><th></th><th>400 µg/m3</th></tr>
<tr><td rowspan="3">**AL2 -1**</td><td rowspan="3">01.11.2022</td><td rowspan="3">150</td><td rowspan="3">99</td><td rowspan="3">50</td><td>2.42</td><td rowspan="3">3.22</td><td>6.35</td><td rowspan="3">13.66</td><td>2.88</td><td rowspan="3">4.53</td></tr>
<tr><td>4.53</td><td>13.27</td><td>6.79</td></tr>
<tr><td>2.72</td><td>21.35</td><td>3.91</td></tr>
<tr><td rowspan="3">**AL2 -2**</td><td rowspan="3">04.11.2022</td><td rowspan="3">253</td><td rowspan="3">180</td><td rowspan="3">70</td><td>2.72</td><td rowspan="3">3.53</td><td>5.77</td><td rowspan="3">11.73</td><td>0.81</td><td rowspan="3">3.18</td></tr>
<tr><td>3.32</td><td>17.89</td><td>4.03</td></tr>
<tr><td>4.53</td><td>11.54</td><td>4.72</td></tr>
<tr><td rowspan="3">**AL2 -3**</td><td rowspan="3">08.11.2022</td><td rowspan="3">235</td><td rowspan="3">166</td><td rowspan="3">67</td><td>2.59</td><td rowspan="3">2.50</td><td>5.19</td><td rowspan="3">14.04</td><td>2.19</td><td rowspan="3">2.80</td></tr>
<tr><td>3.46</td><td>13.27</td><td>2.65</td></tr>
<tr><td>1.44</td><td>23.66</td><td>3.57</td></tr>
<tr><td rowspan="3">**AL2 -4**</td><td rowspan="3">11.11.2022</td><td rowspan="3">275</td><td rowspan="3">194</td><td rowspan="3">76</td><td>6.35</td><td rowspan="3">4.53</td><td>10.39</td><td rowspan="3">14.24</td><td>2.42</td><td rowspan="3">2.42</td></tr>
<tr><td>4.53</td><td>20.20</td><td>3.80</td></tr>
<tr><td>2.72</td><td>12.12</td><td>1.04</td></tr>
<tr><td rowspan="3">**AL2 – 5**</td><td rowspan="3">15.11.2022</td><td rowspan="3">245</td><td rowspan="3">169</td><td rowspan="3">71</td><td>3.02</td><td rowspan="3">4.53</td><td>8.66</td><td rowspan="3">14.04</td><td>3.57</td><td rowspan="3">2.38</td></tr>
<tr><td>6.65</td><td>16.16</td><td>2.30</td></tr>
<tr><td>3.93</td><td>17.31</td><td>1.27</td></tr>
<tr><td rowspan="3">**AL2 – 6**</td><td rowspan="3">18.11.2022</td><td rowspan="3">185</td><td rowspan="3">119</td><td rowspan="3">53</td><td>5.74</td><td rowspan="3">4.94</td><td>14.43</td><td rowspan="3">13.47</td><td>4.95</td><td rowspan="3">3.84</td></tr>
<tr><td>2.72</td><td>17.31</td><td>3.57</td></tr>
<tr><td>6.35</td><td>8.66</td><td>2.99</td></tr>
<tr><td rowspan="3">**AL2 – 7**</td><td rowspan="3">22.11.2022</td><td rowspan="3">373</td><td rowspan="3">252</td><td rowspan="3">109</td><td>3.02</td><td rowspan="3">4.03</td><td>20.20</td><td rowspan="3">14.24</td><td>3.80</td><td rowspan="3">3.80</td></tr>
<tr><td>6.35</td><td>12.12</td><td>5.53</td></tr>
<tr><td>2.72</td><td>10.39</td><td>2.07</td></tr>
<tr><td rowspan="3">**AL2 -8**</td><td rowspan="3">25.11.2022</td><td rowspan="3">292</td><td rowspan="3">199</td><td rowspan="3">86</td><td>1.81</td><td rowspan="3">3.83</td><td>14.43</td><td rowspan="3">14.43</td><td>3.57</td><td rowspan="3">4.76</td></tr>
<tr><td>6.35</td><td>19.62</td><td>4.72</td></tr>
<tr><td>3.32</td><td>9.23</td><td>5.99</td></tr>
<tr><td rowspan="3">**AL1 – 9**</td><td rowspan="3">29.11.2022</td><td rowspan="3">299</td><td rowspan="3">194</td><td rowspan="3">97</td><td>3.63</td><td rowspan="3">4.63</td><td>5.19</td><td rowspan="3">13.47</td><td>2.88</td><td rowspan="3">3.49</td></tr>
<tr><td>7.55</td><td>23.66</td><td>4.95</td></tr>
<tr><td>2.72</td><td>11.54</td><td>2.65</td></tr>
<tr><td colspan="2">**Monthly Average**</td><td>256</td><td>175</td><td>75</td><td></td><td>3.97</td><td></td><td>13.70</td><td></td><td>3.47</td></tr>
<tr><td colspan="2">**Standard Deviation**</td><td>65</td><td>45</td><td>19</td><td></td><td>0.79</td><td></td><td>0.81</td><td></td><td>0.85</td></tr>
</table>

Table 3 : Results of Air Pollutant Concentration at Oil Jetty

	Date	C_6H_6 [µg/m^3]	*NMHC	CO [mg/m^3]	CO2 [ppm]
Sampling Period		**8 hr**		**Grab Sampling**	**Grab Sampling**
NAAQMS limit		**5.0 µg/m3**		**4.0 mg/m3**	**-**
AL2-1	01.11.2022	1.17	BQL	1.22	467
AL2-2	04.11.2022	1.01	BQL	1.53	451
AL2-3	08.11.2022	1.1	BQL	1.65	502
AL2-4	11.11.2022	1.19	BQL	1.04	447
AL2 –5	15.11.2022	1.24	BQL	1.27	634
AL2 –6	18.11.2022	1.16	BQL	1.22	531
AL2-7	22.11.2022	1.2	BQL	1.28	800
AL2-8	25.11.2022	1.06	BQL	1.89	1023
AL2-9	29.11.2022	1.22	BQL	1.46	576
Monthly Average		**1.15**	**-**	**1.40**	**603.44**
Standard Deviation		**0.08**	**-**	**0.26**	**193.07**

* NMHC- Non- Methane Hydrocarbons
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

Oil Jetty Area, the overall values of TSPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2 and NH_3 was mainly by motor vehicle emission produced from various types of vehicles at Oil Jetty Area. The mean TSPM value at Oil Jetty was 256 µg/m^3. The mean PM_{10} value was 175 µg/m^3 and mean $PM_{2.5}$ value was 75 µg/m^3 which was above the permissible limit. The average values of SO_2, NO_2 and NH_3 were within the permissible limit prescribed by NAAQS. The mean concentration of SO_2, NO_2 and NH_3 were 3.97 µg/m^3, 13.70 µg/m^3 and 3.47 µg/m^3 respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.15 µg/m^3 which was well below the permissible limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.40 mg/m^3, well below the permissible limit of 4.0 mg/m^3.

Location 3: Kandla Colony – Estate Office (AL-3)

Table 4 : Results of Air Pollutant Concentration at Estate Office										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL3 – 1	01.11.2022	245	172	69	1.51	2.32	10.39	9.62	3.68	5.10
					3.32		13.27		7.02	
					2.12		5.19		4.60	
AL3 – 2	04.11.2022	577	445	130	4.53	2.32	5.19	10.39	3.57	2.49
					1.51		17.31		2.88	
					0.91		8.66		1.04	
AL3 – 3	08.11.2022	440	321	109	6.05	3.94	19.04	12.31	4.72	3.64
					2.59		12.12		2.42	
					3.17		5.77		3.80	
AL3 – 4	11.11.2022	518	403	111	3.32	4.23	18.47	10.58	1.38	2.42
					2.72		8.66		3.57	
					6.65		4.62		2.30	
AL3 – 5	15.11.2022	451	340	107	1.81	3.73	23.08	15.97	3.22	2.42
					6.04		14.43		2.30	
					3.32		10.39		1.73	
AL3 – 6	18.11.2022	459	346	112	4.53	4.43	16.16	15.97	5.76	4.14
					2.72		8.66		4.72	
					6.04		23.08		1.96	
AL3 – 7	22.11.2022	453	325	116	2.42	4.33	19.62	17.31	3.91	3.84
					4.23		23.66		5.18	
					6.35		8.66		2.42	
AL3 – 8	25.11.2022	337	252	83	6.04	3.93	15.00	15.58	3.80	3.91
					3.32		23.08		5.76	
					2.42		8.66		2.19	
AL1 – 9	29.11.2022	491	359	129	4.84	4.63	17.89	16.16	3.57	3.57
					6.95		24.24		5.18	
					2.12		6.35		1.96	
Monthly Average		441	329	107		3.76		13.77		3.50
Standard Deviation		98	80	20		0.87		3.00		0.91

Table 4 : Results of Air Pollutant Concentration at Estate Office					
Sampling Period	**Date**	**C_6H_6 [µg/m^3]**	***NMHC**	**CO [mg/m^3]**	**CO_2 [ppm]**
		8 hr		**Grab Sampling**	**Grab Sampling**
NAAQMS limit		**5.0 µg/m3**		**4.0 mg/m3**	**-**
AL3 -1	01.11.2022	1.06	BQL	1.27	508
AL3 -2	04.11.2022	1.1	BQL	1.19	508
AL3 -3	08.11.2022	1.1	BQL	1.65	502
AL3 -4	11.11.2022	1.09	BQL	1.83	429
AL3 – 5	15.11.2022	1.09	BQL	1.76	813
AL3 – 6	18.11.2022	1.2	BQL	1.14	559
AL3 – 7	22.11.2022	1.19	BQL	2.18	1022
AL3 – 8	25.11.2022	1.11	BQL	2	1026
	29.11.2022	1.06	BQL	1.22	537
Monthly Average		**1.11**	**-**	**1.58**	**656.00**
Standard Deviation		**0.05**	**-**	**0.39**	**234.02**

* NMHC- Non- Methane Hydrocarbons
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2 and NH_3 at Kandla Port Colony (Estate Office) was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Estate Office were 441 µg/m^3, the mean PM_{10} value was 329 µg/m^3, and $PM_{2.5}$ value was 107 µg/m^3 which was above the permissible limit prescribed by NAAQS. The average values of SO_2, NO_2 and NH_3 were 3.76 µg/m^3, 13.77 µg/m^3 and 3.50 µg/m^3 respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.11 µg/m^3, well below the permissible limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon Monoxide was 1.58 mg/m^3, well below the permissible limit of 4.0 mg/m^3.

Location 4: Gopalpuri Hospital (AL-4)

Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
	Date	**TSPM [µg/m3]**	**PM10 [µg/m3]**	**PM2.5 [µg/m3]**	**SO2 [µg/m3]**		**NOx [µg/m3]**		**NH3 [µg/m3]**	
Sampling Period		**24hr**	**24hr**	**24hr**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**
NAAQMS Limit			**100 µg/m3**	**60 µg/m3**		**80 µg/m3**		**80 µg/m3**		**400 µg/m3**
AL4 -1	01.11.2022	107	67	34	1.21	2.22	5.77	6.93	2.42	2.53
					3.02		10.39		4.14	
					2.42		4.62		1.04	
AL4 -2	04.11.2022	177	117	54	0.91	2.22	5.19	10.00	1.61	2.49
					4.53		8.66		2.42	
					1.21		16.16		3.45	
AL4 -3	08.11.2022	148	101	44	1.15	2.21	6.93	9.81	1.73	1.69
					2.88		17.31		2.42	
					2.59		5.19		0.92	
AL4 -4	11.11.2022	184	111	68	1.51	2.62	6.93	12.89	1.04	2.30
					3.63		14.43		2.42	
					2.72		17.31		3.45	
AL4 – 5	15.11.2022	202	125	72	2.12	2.42	12.12	12.70	2.42	2.49
					3.63		8.66		3.45	
					1.51		17.31		1.61	
AL4 – 6	18.11.2022	233	153	78	1.21	2.92	8.66	12.89	2.42	2.49
					4.84		17.89		1.61	
					2.72		12.12		3.45	
AL4 – 7	22.11.2022	268	168	94	0.60	2.22	5.77	12.70	1.73	2.88
					3.32		14.43		3.68	
					2.72		17.89		3.22	
AL4 – 8	25.11.2022	202	142	56	2.12	3.42	14.43	12.50	2.07	2.99
					5.14		17.89		4.03	
					3.02		5.19		2.88	
AL1 – 9	29.11.2022	249	157	91	3.02	4.03	8.66	11.54	1.38	2.49
					6.35		20.20		3.80	
					2.72		5.77		2.30	
Monthly Average		197	127	66		2.70		11.33		2.49
Standard Deviation		50	32	20		0.65		2.05		0.37

Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital

Sampling Period	Date	C_6H_6 [µg/m^3]	*NMHC	CO [mg/m^3]	CO_2 [ppm]
		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m3		4.0 mg/m3	-
AL4 -1	01.11.2022	1.14	BQL	1.26	503
AL4 -2	04.11.2022	1.15	BQL	1.26	450
AL4 -3	08.11.2022	1.03	BQL	1.73	506
AL4 -4	11.11.2022	1.02	BQL	1.82	462
AL4 – 5	15.11.2022	1.09	BQL	1.04	1048
AL4 – 6	18.11.2022	1.14	BQL	1.32	543
AL4 – 7	22.11.2022	1.16	BQL	1.83	758
AL4 – 8	25.11.2022	1.22	BQL	1.8	816
AL4 – 9	29.11.2022	1.16	BQL	1.36	665
Monthly Average		**1.12**	**-**	**1.49**	**639.00**
Standard Deviation		**0.07**	**-**	**0.30**	**201.83**

* NMHC- Non- Methane Hydrocarbons
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2 and NH_3 at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 197 µg/m^3, the mean PM_{10} value was 127 µg/m^3 and $PM_{2.5}$ was 66 µg/m^3 which was exceed the standard limit. The average values of SO_2, NO_2 and NH_3 were 2.70 µg/m^3, 11.33 µg/m^3 and 2.49 µg/m^3 respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.12 µg/m^3, well below the permissible limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon monoxide concentration was 1.49 mg/m^3 which is well below the permissible limit of 4.0 mg/m^3.

Location 5: Coal Storage Area (AL-5)

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		**24hr**	**24hr**	**24hr**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**
NAAQMS Limit			**100 µg/m3**	**60 µg/m3**		**80 µg/m3**		**80 µg/m3**		**400 µg/m3**
AL6 – 1	01.11.2022	779	598	175	2.72	4.33	6.35	16.54	3.68	5.06
					6.65		25.97		8.17	
					3.63		17.31		3.34	
AL6 – 2	04.11.2022	635	492	137	2.12	3.53	23.08	17.70	6.79	6.60
					5.44		12.12		8.17	
					3.02		17.89		4.83	
AL6 – 3	08.11.2022	538	412	125	8.94	5.00	23.66	21.74	2.53	3.88
					3.46		12.12		2.07	
					2.59		29.43		7.02	
AL6 – 4	11.11.2022	815	635	178	4.53	4.73	18.47	17.70	5.87	4.41
					2.72		8.66		2.65	
					6.95		25.97		4.72	
AL6 – 5	15.11.2022	792	614	176	6.35	6.65	18.47	13.66	4.72	3.88
					9.07		10.39		3.68	
					4.53		12.12		3.22	
AL6 – 6	18.11.2022	771	595	171	9.37	7.15	20.20	17.12	4.83	4.37
					5.74		8.08		2.53	
					6.35		23.08		5.76	
AL6 – 7	22.11.2022	706	543	156	4.84	4.53	10.39	18.47	4.83	5.03
					6.04		23.66		5.99	
					2.72		21.35		4.26	
AL6 – 8	25.11.2022	846	654	187	3.32	5.24	17.31	19.81	3.91	4.95
					7.86		25.97		6.91	
					4.53		16.16		4.03	
AL1 – 9	29.11.2022	801	621	172	5.14	5.64	16.16	18.28	3.57	4.30
					9.07		28.86		6.22	
					2.72		9.81		3.11	
Monthly Average		743	574	164		5.20		17.89		4.72
Standard Deviation		99	78	21		1.14		2.22		0.84

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area					
Sampling Period	**Date**	**C_6H_6 [µg/m^3]**	***NMHC**	**CO [mg/m^3]**	**CO_2 [ppm]**
		8 hr		**Grab Sampling**	**Grab Sampling**
NAAQMS limit		**5.0 µg/m3**		**4.0 mg/m3**	**-**
AL5 – 1	01.11.2022	1.1	BQL	1.12	483
AL5 – 2	04.11.2022	1.06	BQL	1.48	475
AL5 – 3	08.11.2022	1.08	BQL	1.66	421
AL5 – 4	11.11.2022	1.06	BQL	1.69	492
AL5 – 5	15.11.2022	1.06	BQL	1.06	702
AL5 – 6	18.11.2022	1.22	BQL	1.18	483
AL5 – 7	22.11.2022	1.11	BQL	1.86	564
AL5 – 8	25.11.2022	1.2	BQL	1.54	777
AL5 – 9	29.11.2022	1.22	BQL	1.89	895
Monthly Average		**1.12**	**-**	**1.50**	**588.00**
Standard Deviation		**0.07**	**-**	**0.31**	**164.11**

* NMHC- Non- Methane Hydrocarbons
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2 and NH_3 at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, $PM_{10,}$ $PM_{2.5}$, SO_2, NO_2 at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 743 µg/m^3, the mean PM_{10} value was 574 µg/m^3, and the $PM_{2.5}$ value was164 µg/m^3 which was above the permissible limit prescribed by NAAQS. The average values of SO_2, NO_2 and NH_3 were 5.20 µg/m^3, 17.89 µg/m^3 and 4.72 µg/m^3 respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was1.12 µg/m^3, well below the permissible limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.50 mg/m^3, well below the permissible limit of 4.0 mg/m^3.

Location 6: Tuna Port (AL-6)

Table 7 : Results of Air Pollutant Concentration at Tuna Port

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		**24hr**	**24hr**	**24hr**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**
NAAQMS Limit			**100 µg/m3**	**60 µg/m3**		**80 µg/m3**		**80 µg/m3**		**400 µg/m3**
AL5 -1	01.11.2022	141	88	47	0.91	1.61	2.89	6.16	2.07	2.84
					2.72		12.12		4.03	
					1.21		3.46		2.42	
AL5 – 2	04.11.2022	232	166	64	1.51	2.22	6.35	7.89	1.38	2.76
					3.02		5.19		4.49	
					2.12		12.12		2.42	
AL5 – 3	08.11.2022	184	120	55	1.44	2.40	10.39	13.08	1.73	2.61
					3.46		11.54		2.65	
					2.31		17.31		3.45	
AL5 – 4	11.11.2022	233	153	78	2.12	2.32	11.54	11.54	1.27	1.57
					3.93		17.89		1.04	
					0.91		5.19		2.42	
AL5 – 5	15.11.2022	221	145	74	1.21	2.32	6.35	12.12	3.57	2.49
					3.32		12.12		2.30	
					2.42		17.89		1.61	
AL5 – 6	18.11.2022	248	162	83	1.81	2.01	17.31	17.12	2.30	10.21
					1.21		23.66		15.57	
					3.02		10.39		12.76	
AL5 – 7	22.11.2022	214	139	74	1.51	2.52	8.66	8.46	3.57	2.84
					2.72		12.70		2.88	
					3.32		4.04		2.07	
AL5 – 8	25.11.2022	255	175	77	2.72	3.02	8.66	8.08	3.45	3.30
					4.84		11.54		4.72	
					1.51		4.04		1.73	
AL1 – 9	29.11.2022	245	155	87	1.51	3.63	12.70	11.73	1.04	2.88
					6.04		17.31		5.18	
					3.32		5.19		2.42	
Monthly Average		219	145	71		2.45		10.69		3.50
Standard Deviation		36	27	13		0.58		3.37		2.56

Table 7 : Results of Air Pollutant Concentration at Tuna Port					
	Date	C_6H_6 [µg/m^3]	*NMHC	CO [mg/m^3]	CO_2 [ppm]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m3		4.0 mg/m3	-
AL6 -1	01.11.2022	1.12	BQL	1.43	543
AL6 – 2	04.11.2022	1.17	BQL	1.41	463
AL6 – 3	08.11.2022	1.13	BQL	1.39	410
AL6 – 4	11.11.2022	1.13	BQL	1.74	509
AL6 – 5	15.11.2022	1.17	BQL	1.08	911
AL6 – 6	18.11.2022	1.17	BQL	1.1	528
AL6 – 7	22.11.2022	1.06	BQL	1.88	565
AL6 – 8	25.11.2022	1.1	BQL	1.89	999
	29.11.2022	1.22	BQL	1.89	895
Monthly Average		1.14	-	1.53	647.00
Standard Deviation		0.05	-	0.33	222.45

* NMHC- Non- Methane Hydrocarbons
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port was 219 µg/m^3, the mean PM_{10} value was 145 µg/m^3 and the mean $PM_{2.5}$ value was 71 µg/m^3 which was exceed the standard limit prescribed by NAAQS. The average values of SO_2, NO_2 and NH_3 were 2.45 µg/m^3, 10.69 µg/m^3 and 3.50 µg/m^3 respectively and were all within the standard limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.14 µg/m3, well below the permissible limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.53 mg/m^3, well below the permissible limit of 4.0 mg/m^3.

Location 7: Admin Building (Vadinar) (AL-7)

Table 8 : Results of Air Pollutant Concentration at Admin Building

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		**24hr**	**24hr**	**24hr**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**
NAAQMS Limit			**100 µg/m3**	**60 µg/m3**		**80 µg/m3**		**80 µg/m3**		**400 µg/m3**
AL7 -1	01.11.2022	150	98	51	2.20	3.52	9.53	10.59	5.36	5.28
					4.84		16.51		2.81	
					3.52		5.72		7.66	
AL7 -2	04.11.2022	177	115	61	3.08	4.69	17.78	21.81	2.81	6.13
					7.03		21.60		8.93	
					3.96		26.04		6.64	
AL7 -3	08.11.2022	193	113	73	6.15	6.30	6.99	11.43	3.83	7.49
					8.79		20.96		10.47	
					3.96		6.35		8.17	
AL7 -4	11.11.2022	200	121	78	3.96	6.01	17.78	15.24	10.47	6.81
					5.28		22.23		5.87	
					8.79		5.72		4.08	
AL7 -5	15.11.2022	179	108	69	1.76	5.28	7.62	18.00	3.06	5.62
					5.71		26.04		5.87	
					8.35		20.33		7.91	
AL7 -6	18.11.2022	223	121	96	2.64	4.54	8.89	15.03	5.62	5.70
					4.40		16.51		8.17	
					6.59		19.69		3.32	
AL1 -7	22.11.2022	162	104	57	4.84	5.28	14.61	14.61	13.02	9.10
					7.03		5.72		8.68	
					3.96		23.50		5.62	
AL1-8	25.11.2022	237	138	97	6.59	4.40	9.53	15.24	7.91	8.00
					3.96		14.61		5.62	
					2.64		21.60		10.47	
AL1-9	28.11.2022	203	112	87	3.96	3.66	6.99	13.76	5.62	6.04
					2.20		14.61		7.91	
					4.84		19.69		4.60	
Monthly Average		191	114	74		4.85		15.08		6.68
Standard Deviation		28	12	17		0.96		3.34		1.28

Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar					
Sampling Period	**Date**	**C_6H_6 [µg/m^3]**	***NMHC**	**CO [mg/m^3]**	**CO_2 [ppm]**
		8 hr		**Grab Sampling**	**Grab Sampling**
NAAQMS limit		**5.0 µg/m3**		**4.0 mg/m3**	**-**
AL7 -1	01.11.2022	1.08	BQL	1.43	225
AL7 -2	04.11.2022	1.13	BQL	1.54	236
AL7 -3	08.11.2022	1.17	1.81	1.53	455
AL7 -4	11.10.2022	1.14	BQL	1.61	443
AL7 -5	15.10.2022	1.03	BQL	1.1	347
AL7 -6	18.10.2022	1.06	BQL	1.57	416
AL7 -7	22.10.2022	1.10	BQL	1.05	372
AL7 -8	25.10.2022	1.20	BQL	1.79	464
AL7 -9	28.10.2022	1.13	BQL	1.42	487
Monthly Average		**1.12**	**-**	**1.46**	**388**
Standard Deviation		**0.06**	**-**	**0.25**	**75**

*NMHC- Non- Methane Hydrocarbons
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Admin Building, Vadinar the mean TSPM value was 191 µg/m^3, the mean PM_{10} value was 114 µg/m^{3}and the mean $PM_{2.5}$ value was 74 µg/m^3 which was slightly exceed the standard limit. The average values of SO_2, NO_2 and NH_3 concentrations were 4.85 µg/m^3, 15.08 µg/m^3 and 6.68 µg/m^3 respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.12 µg/m^3, well below the permissible limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.46 mg/m^3, well below the permissible limit of 4.0 mg/m^3.

Location 8: Signal Building (Vadinar) (AL-8)

Table 9 : Results of Air Pollutant Concentration at Signal Building, Vadinar										
	Date	**TSPM [µg/m3]**	**PM10 [µg/m3]**	**PM2.5 [µg/m3]**	**SO2 [µg/m3]**		**NOx [µg/m3]**		**NH3 [µg/m3]**	
Sampling Period		**24hr**	**24hr**	**24hr**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**	**8 hr**	**24hr (Avg.)**
NAAQMS Limit			**100 µg/m3**	**60 µg/m3**		**80 µg/m3**		**80 µg/m3**		**400 µg/m3**
AL8 -1	01.11.2022	113	74	38	3.96	4.40	6.99	13.34	2.30	7.15
					6.59		19.05		8.68	
					2.64		13.97		10.47	
AL8 -2	04.11.2022	146	93	49	2.64	4.40	14.61	15.88	5.36	6.13
					4.84		22.23		8.42	
					5.71		10.80		4.60	
AL8 -3	08.11.2022	124	82	42	3.08	3.52	14.61	16.73	5.62	5.62
					5.28		26.04		7.91	
					2.20		9.53		3.32	
AL8 -4	11.11.2022	175	105	67	2.20	4.40	8.26	13.76	8.93	9.02
					7.03		19.05		12.76	
					3.96		13.97		5.36	
AL8 -5	15.11.2022	152	97	52	3.52	4.98	5.72	13.13	6.89	7.57
					4.84		13.34		10.98	
					6.59		20.33		4.85	
AL8 -6	18.11.2022	176	111	61	3.08	3.81	15.24	17.57	7.15	8.42
					3.96		26.04		7.91	
					4.40		11.43		10.21	
AL8 -7	22.11.2022	214	118	93	3.52	5.71	5.72	12.91	7.91	8.25
					5.28		13.34		6.38	
					8.35		19.69		10.47	
AL8-8	25.11.2022	219	125	92	3.08	4.54	9.53	11.01	5.36	6.04
					4.84		17.78		8.17	
					5.71		5.72		4.60	
AL8-9	28.11.2022	154	97	57	5.71	3.81	10.80	16.94	7.15	8.76
					3.96		22.23		8.93	
					1.76		17.78		10.21	
Monthly Average		164	100	61		4.40		14.59		7.44
Standard Deviation		36	16	20		0.67		2.25		1.27

Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar					
	Date	C_6H_6 [µg/m^3]	*NMHC	CO [mg/m^3]	CO_2 [ppm]
Sampling Period		**8 hr**		**Grab Sampling**	**Grab Sampling**
NAAQMS limit		**5.0 µg/m3**		**4.0 mg/m3**	**-**
AL8 -1	01.11.2022	1.06	BQL	1.5	467
AL8 -2	04.11.2022	1.05	BQL	1.46	501
AL8 -3	08.11.2022	1.14	1.81	1.31	489
AL8 -4	11.11.2022	1.16	BQL	1.38	439
AL8 -5	15.11.2022	1.17	BQL	1.29	231
AL8 -6	18.11.2022	1.10	BQL	1.31	244
AL8 -7	22.11.2022	1.00	BQL	1.34	227
AL8 -8	25.11.2022	1.05	BQL	1.37	261
AL8 -9	28.11.2022	1.02	BQL	1.29	234
Monthly Average		**1.16**	**-**	**1.46**	**442**
Standard Deviation		**0.05**	**-**	**0.27**	**63**

* NMHC- Non- Methane Hydrocarbon
BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Signal Building, Vadinar the mean TSPM value was 164 µg/m^3, the mean PM_{10} value was 100 µg/m^3 which was boundary line of the permissible limit, the mean $PM_{2.5}$ value was 61 µg/m^3 which was within the permissible limit. The average values of SO_2, NO_2 and NH_3 concentrations were 4.40 µg/m^3, 14.59 µg/m^3 and 7.44 µg/m^3 respectively and were all within the standard limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.16 µg/m^3, well below the standard limit of 5.0 µg/m^3. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.46 mg/m^3, well below the standard limit of 4.0 mg/m^3.

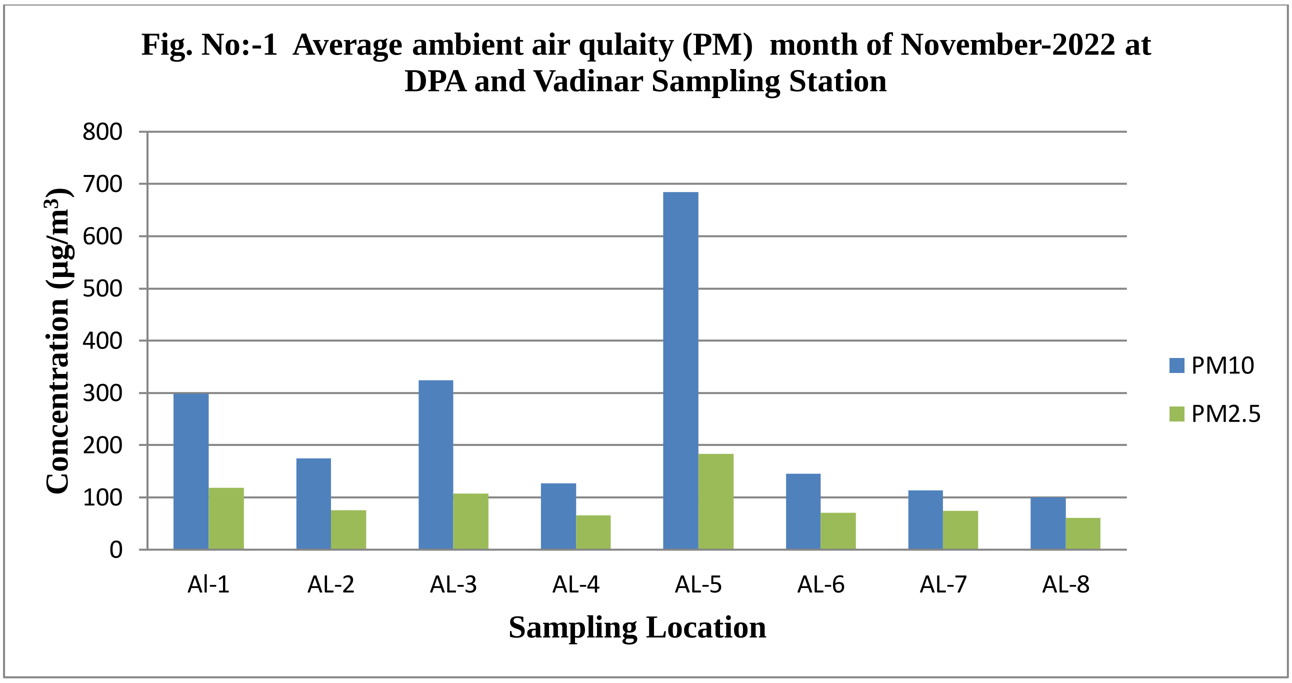


Fig. No:-1 Average ambient air qulaity (PM) month of November-2022 at DPA and Vadinar Sampling Station
Concentration (µg/m³)
800
700
600
500
400
300
200
100
0
Al-1
AL-2
AL-3
AL-4
AL-5
AL-6
AL-7
AL-8
Sampling Location
PM10
PM2.5

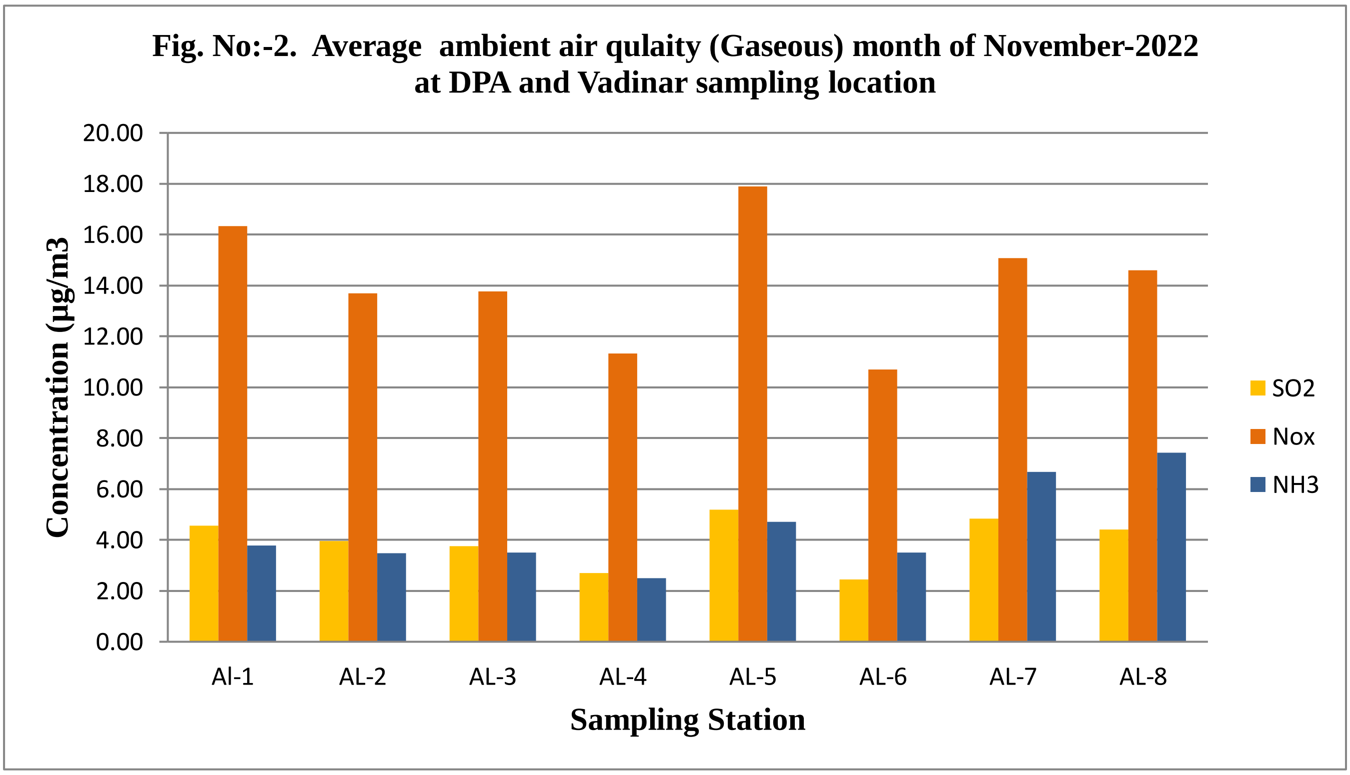


Fig. No:-2. Average ambient air qulaity (Gaseous) month of November-2022 at DPA and Vadinar sampling location
Concentration (µg/m3
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Al-1
AL-2
AL-3
AL-4
AL-5
AL-6
AL-7
AL-8
Sampling Station
SO2
Nox
NH3

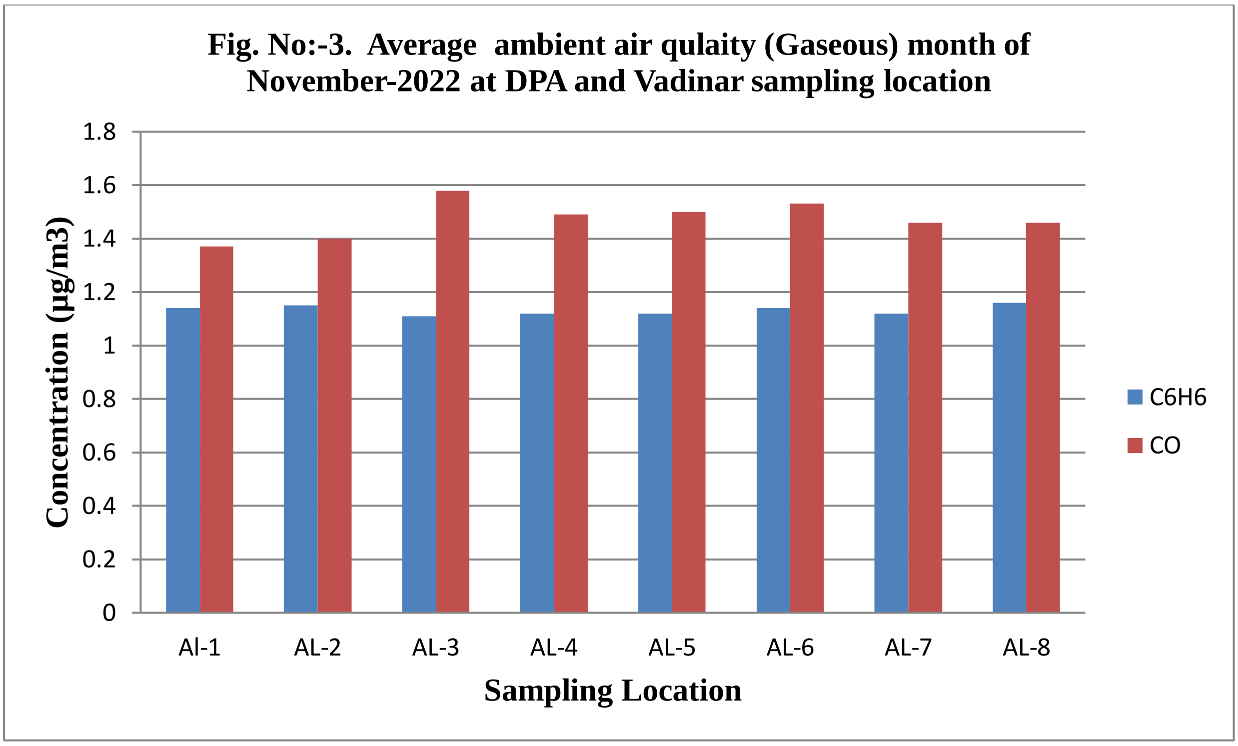


Fig. No:-3. Average ambient air qulaity (Gaseous) month of November-2022 at DPA and Vadinar sampling location
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Concentration (µg/m3)
Al-1
AL-2
AL-3
AL-4
AL-5
AL-6
AL-7
AL-8
Sampling Location
C6H6
CO

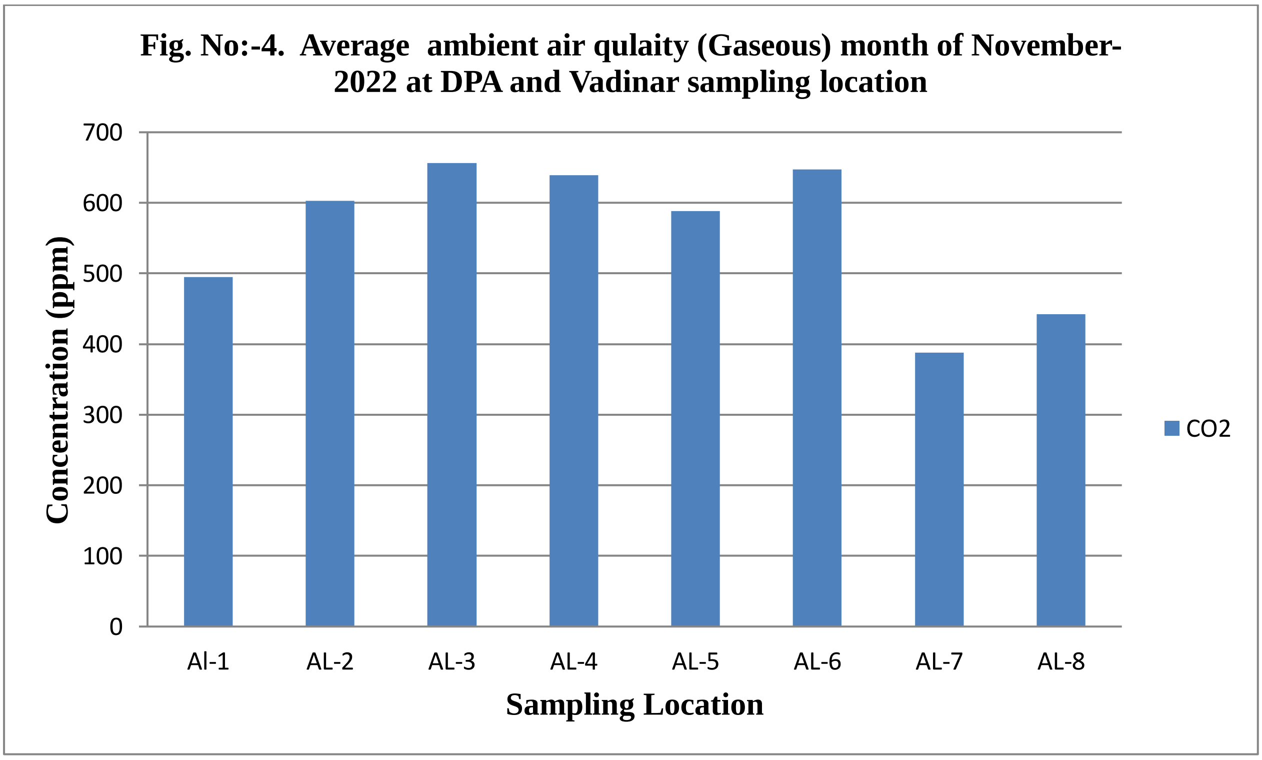


Fig. No:-4. Average ambient air qulaity (Gaseous) month of November-2022 at DPA and Vadinar sampling location
700
600
500
400
300
200
100
0
Concentration (ppm)
Al-1
AL-2
AL-3
AL-4
AL-5
AL-6
AL-7
AL-8
Sampling Location
CO2

2.3 Observations and Conclusion

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Total Suspended Particulate matter as TSPM, Particulate matter as PM_{10} and $PM_{2.5}$ was found to exceed the limits at locations at all ambient air sampling location.

The concentration of PM_{10} and $PM_{2.5}$ were slightly exceeded at Gopalpuri and Tuna Port.

The mean concentration of PM_{10} and $PM_{2.5}$ were slightly exceeded at Admin building Vadinar & at Signal building Vadinar was very close to the standard limit.

CHAPTER-3

METEOROLOGICAL OBSERVATIONS

4.1 Meteorological Data

Automatic Weather station (ID KAZPHOEN424) have been installed in Seva Sadan-3 at the Deendayal Port which records the data on Temperature (°C), Relative Humidity (%),Wind speed (m/s),Wind Direction (°), Solar radiation (w/m^2) and Rainfall mm.

Meteorological factors play an important role in environmental pollution studies particularly in pollutant transport irrespective of their entry into the environment. The wind speed and direction play a major role in dispersion of environment pollutants. Effects of pollution on receptors animate and inanimate depends on atmospheric condition.

Temperature

At Deendayal Port, the day time temperature was found range 21.1-32.9^{0}C. The average day time temperature was 27.92°C. The night time temperature was range from 20.0-29.7^{0}C. The mean night time temperature recorded was 25.47 °C.

Solar Radiation

The mean Solar Radiation in November month was 167.27 w/m^2. The maximum solar radiation was recorded 759.0 w/m^2 in 4th November, 2022 and the minimum solar radiation was recorded 1.80 w/m^2 in 30th November, 2022.

Rainfall

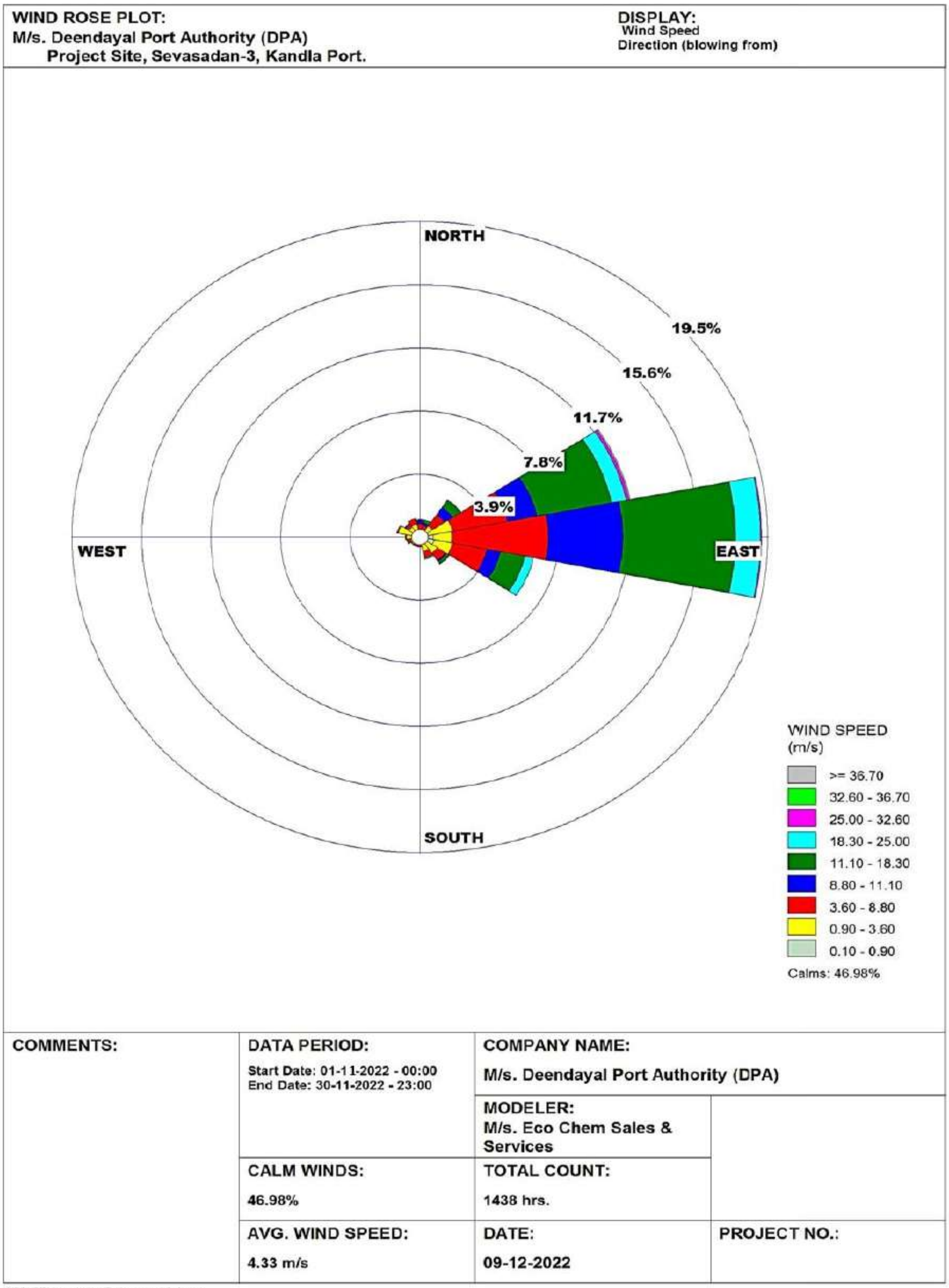
Rain fall of November month was recorded 0.00 mm.

Relative Humidity

The mean Relative humidity was 69.00 % for the month of November. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 34.0 %.

Wind Velocity and Wind Direction

Velocity and direction of wind have a significant role in the dispersion of air borne materials and therefore determines the air quality of the area. The average wind velocity for the entire month of November was 1.21 m/s. Maximum wind velocity was recorded 10.19 m/s. The wind direction was mostly North-East.



WRPLOT View - Lakes Environmental Software

CHAPTER-4

DRINKING WATER QUALITY MONITORING

4.0 Drinking Water Quality Monitoring

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

Table No:-10. Drinking Water Sampling Location

Sr. No.	Name of Location	Location Code	Latitude	Longitude
1.	Nirman Building	DL-1	23° 0' 27"N	70° 13' 21"E
2.	P & C Building	DL-2	23° 0' 33"N	70° 13' 20"E
3.	North Gate	DL-3	23° 0' 26.97"N	70° 13' 21.87"E
4.	KPT-Canteen	DL-4	23° 2' 17.2674"N	70° 13'18.2814"E
5.	West Gate	DL-5	23° 59' 40.48"N	70° 12' 50.96"E
6.	Wharf Area	DL-6	22° 59' 52.2"N	70° 13' 22.95"E
7.	Sevasadan-3	DL-7	23° 0' 22.55"N	70° 13' 15.34"E
8.	Workshop	DL-8	23° 0' 33.74"N	70° 13' 20.05"E
9.	Custom Building	DL-9	23° 1' 8.70"N	70° 12' 52.0"E
10.	Kandla Colony	DL-10	23° 11' 14.9"N	70° 12' 48.4"E
11.	KPT Hospital	DL-11	23° 1' 5.02"N	70° 12' 44.38"E
12.	A.O. Building	DL-12	23° 3' 42.89"N	70° 8' 41.5"E
13.	Gopalpuri School	DL-13	23° 5' 1.03"N	70° 7' 55.42"E
14	Gopalpuri Guest House	DL-14	23° 4' 43.14"N	70° 7' 51.92"E
15.	E-Type Quarters	DL-15	23° 4' 59.90"N	70° 7' 56.72"E
16.	F-Type Quarters	DL-16	23° 4' 38.45"N	70° 8' 8.63"E
17.	Gopalpuri Hospital	DL-17	23° 4' 54.09"N	70° 8' 7.5"E
18.	Tuna Port	DL-18	23° 58' 23.06"N	70° 5' 35.6"E
19.	Vadinar Jetty	DL-19	22° 25' 51.73"N	69° 41' 36.62"E
20.	Vadinar Colony	DL-20	22° 30' 26.25"N	69° 39' 45.03"E

4.1 Drinking Water Monitoring Methodology

Samples for physico-chemical analysis were collected in 2 Carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS: 3025 Part-1, analysis was done as per IS: 3025/APHA standard methods and, the analysis results compare with IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate, Salinity , DO, BOD, Na, K, Ca, Mg, F, NO_3, NO_2, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (CFU) .

4.2 Results

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 11 to Table No. 17

Table 11: Drinking Water Quality Monitoring Parameters for Nirman Building, P & C Building and Main Gate (North) at Kandla.

Sr. No.	Parameter	Unit	Nirman Building 1	P & C Building	Main Gate North	Acceptable Limits as per IS 10500 :2012 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.35	7.33	7.41	7.35	6.5 to 8.5
2	Total Dissolved Solids	mg/l	690	670	670	690	2000
3	Turbidity	NTU	0	1	1	0	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1229	1194	1211	NS*	NS*
7	Biochemical Oxygen	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	576.28	355.79	340.76	250	1000
9	Ca as Ca	mg/l	43.29	41.68	39.28	75	200
10	Mg as Mg	mg/l	58.8060	57.3480	56.3760	30	100
11	Total Hardness	mg/l	350	340	330	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.35	0.37	0.31	1	1.5
14	Sulphate as SO_4	mg/l	35.80	30.20	28.30	200	400
15	Nitrite as NO_2	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO_3	mg/l	12.70	16.70	15.50	45	No Relaxation
17	Salinity	‰	1.04	0.64	0.62	NS*	NS*
18	Sodium as Na	mg/l	204.00	180.00	192.00	NS*	NS*
19	Potassium as K	mg/l	3.22	3.15	3.18	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr^{+6}- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

Table 12: Drinking Water Quality Monitoring Parameters for Canteen, West Gate – I & Wharf Area at Kandla

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per IS 10500 :	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.48	7.52	7.36	7.48	6.5 to 8.5
2	Total Dissolved Solids	mg/l	640	650	680	640	2000
3	Turbidity	NTU	0	1	0	0	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1166	1152	1196	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	335.75	360.80	350.78	250	1000
9	Ca as Ca	mg/l	40.88	38.48	40.08	75	200
10	Mg as Mg	mg/l	62.6940	66.5820	53.4600	30	100
11	Total Hardness	mg/l	360	370	320	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.32	0.30	0.35	1	1.5
14	Sulphate as SO4	mg/l	31.20	28.30	26.00	200	400
15	Nitrite as NO_2	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO_3	mg/l	6.60	11.40	5.80	45	No Relaxation
17	Salinity	‰	0.61	0.65	0.63	NS*	NS*
18	Sodium as Na	mg/l	202.00	200.00	-	NS*	NS*
19	Potassium as K	mg/l	3.38	3.48	3.16	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

*NS: Not Specified,
BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

Table 13: Drinking Water Quality Monitoring Parameters for Sewa sadan–3, Workshop I and Custom Building at Kandla

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.45	7.38	7.29	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	700	670	910	500	2000
3	Turbidity	NTU	0	1	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1213	1164	1564	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	365.81	370.82	340.76	250	1000
9	Ca as Ca	mg/l	42.48	37.68	39.28	75	200
10	Mg as Mg	mg/l	59.2920	59.7780	53.9460	30	100
11	Total Hardness	mg/l	350	340	320	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.41	0.30	0.35	1	1.5
14	Sulphate as SO_4	mg/l	24.90	34.20	27.2	200	400
15	Nitrite as NO_2	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO_3	mg/l	6.90	3.90	11.00	45	No Relaxation
17	Salinity	‰	0.66	0.67	0.62	NS*	NS*
18	Sodium as Na	mg/l	-	-	-	NS*	NS*
19	Potassium as K	mg/l	3.26	4.03	3.29	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

*NS: Not Specified,
BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

Table 14: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla and A.O. Building at Gandhidham.

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 :
1	pH	-	7.39	7.31	7.24	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	760	710	1060	500	2000
3	Turbidity	NTU	1	0	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1328	1251	1821	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	335.75	345.77	365.81	250	1000
9	Ca as Ca	mg/l	41.68	42.48	40.88	75	200
10	Mg as Mg	mg/l	50.0580	54.4320	62.6940	30	100
11	Total Hardness	mg/l	310	330	360	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.35	0.32	0.46	1	1.5
14	Sulphate as SO_4	mg/l	28.10	24.50	24.50	200	400
15	Nitrite as NO_2	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO_3	mg/l	20.20	7.40	15.60	45	No Relaxation
17	Salinity	‰	0.61	0.62	0.66	NS*	NS*
18	Sodium as Na	mg/l	192.80	193.60	194.50	NS*	NS*
19	Potassium as K	mg/l	4.13	4.18	3.26	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

*NS: Not Specified,
BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

Table 15: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House) and E - Type Quarter at Gopalpuri, Gandhidham

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.3	7.24	7.26	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	830	950	1030	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1435	1638	1769	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	355.79	350.78	340.76	250	1000
9	Ca as Ca	mg/l	39.28	43.29	39.28	75	200
10	Mg as Mg	mg/l	61.2360	61.2360	51.5160	30	100
11	Total Hardness	mg/l	350	360	310	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.45	0.42	0.47	1	1.5
14	Sulphate as SO_4	mg/l	24.90	26.00	30.20	200	400
15	Nitrite as NO_2	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO_3	mg/l	7.10	8.30	12.60	45	No Relaxation
17	Salinity	‰	0.64	0.63	0.62	NS*	NS*
18	Sodium as Na	mg/l	199.00	193.80	193.00	NS*	NS*
19	Potassium as K	mg/l	3.90	3.26	3.18	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

Table 16: Drinking Water Quality Monitoring Parameters for F-Type Quarter, Hospital Gopalpuri and Tuna Port.

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.28	7.42	7.51	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1050	990	600	500	2000
3	Turbidity	NTU	1	1	-	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1796	1700	1044	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	345.77	360.80	380.85	250	1000
9	Ca as Ca	mg/l	38.48	40.88	32.87	75	200
10	Mg as Mg	mg/l	61.7220	62.6940	72.41	30	100
11	Total Hardness	mg/l	350	360	380	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.42	0.45	0.43	1	1.5
14	Sulphate as SO_4	mg/l	26.00	26.10	24.50	200	400
15	Nitrite as NO_2	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO_3	mg/l	10.30	6.80	3.00	45	No Relaxation
17	Salinity	‰	0.62	0.65	0.69	NS*	NS*
18	Sodium as Na	mg/l	201.00	201.00	193.60	NS*	NS*
19	Potassium as K	mg/l	3.15	3.16	3.21	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

Table 17: Drinking Water Quality Monitoring Parameters for Vadinar Jetty and Port Colony at Vadinar.

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.4	7.43	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	320	300	500	2000
3	Turbidity	NTU	0.00	1.00	1	5
4	Odor	-	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	5	15
6	Conductivity	µs/cm	570	300	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	160.36	140.31	250	1000
9	Ca as Ca	mg/l	36.87	34.47	75	200
10	Mg as Mg	mg/l	43.25	52.00	30	100
11	Total Hardness	mg/l	270	300	200	600
12	Iron as Fe	mg/l	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.25	0.22	1	1.5
14	Sulphate as SO_4	mg/l	0.75	0.24	200	400
15	Nitrite as NO_2	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO_3	mg/l	15.60	12.70	45	No Relaxation
17	Salinity	‰	0.29	0.25	NS*	NS*
18	Sodium as Na	mg/l	191.6	192.0	NS*	NS*
19	Potassium as K	mg/l	BQL	BQL	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

*NS: Not Specified,
BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

4.3 Results & Discussion

The colour of all drinking water samples was found Colourless and odour of the samples also agreeable. All parameters were found within the specified limit as per the Drinking water Standard.

pH

The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. At DPA Site the pH values for drinking water samples ranged from 7.24-7.52 and mean value was 7.36 while at Vadinar pH ranged from 7.40-7.43 and mean value was 7.42. All the sampling points showed pH values within the prescribed limit by Indian Standards.

Turbidity

The selected drinking water sample location turbidity range from 0-1NTU at all location of DPA and Vadinar in month of November. The Turbidity values were within the permissible limit at all sampling location prescribed limit by Indian standards.

Total Dissolved Solids (TDS)

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc.

TDS values at DPA varied between 600-1060 mg/l. The average TDS value was found 792 mg/l. The minimum value for TDS was 600 mg/l at Hospital Gopalpuri and maximum was 980 mg/l at Tuna Port while at Vadinar TDS ranged from 280-300 mg/l and mean was 290.0 mg/l. The TDS values were within the permissible limit at all sampling location prescribed limit by Indian standards.

Conductivity

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of November DPA ranged from 1044.0 µs/cm at Tuna Port to1821.0 µs/cm at A.O. Building and mean value was 1381.72 µs/cm while at Vadinar ranged from 300-570 µs/cm and mean was 435 µs/cm.

BOD

BOD value in the studied area of DPA and Vadinar was found Below Quantification Limit (<2.0 mg/l). IS 10500:2012 does not show any standard values for BOD in drinking water.

Chlorides

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. The Chloride value in the studied area of DPA ranged from 335.75-576.28 mg/l. The mean value was 365.53 mg/l. The minimum chloride was 335.75 mg/l at Port colony and maximum was 576.28 mg/l at Nirmal Building while at Vadinar location chloride ranged from 140.31-160.36 mg/l and mean was 150.33 mg/l. The Chloride was found within the Permissible limit of the Drinking Water Standard.

Calcium

Calcium is most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases.

The Calcium value in the studied area of DPA ranged from 32.87-43.29 mg/l. The mean value was 40.12 mg/l. The minimum calcium was 32.87 mg/l at Tuna Port and maximum was 43.29 mg/l at Gopalpuri Hospital while at Vadinar location Calcium ranged from 34.47-36.87 and mean was 35.67 mg/l. All the locations had calcium within the prescribed limits of 75-200 mg/L.

Magnesium

The magnesium value in the studied area of DPA ranged from 50.06-72.41 mg/l. The mean value was 59.24 mg/l. The minimum magnesium was 50.06 mg/l at Port Colony and maximum was 74.41 mg/l at Tuna Port while at Vadinar location magnesium ranged from 43.25-52.00 and mean was 47.61 mg/l. All the locations had magnesium within the prescribed limits of 30-100 mg/L.

Total Hardness

Total Hardness value in the studied area of DPA ranged from 310.0 mg/l at Port Colony to 380.0 mg/l at Tuna Port and mean value was 343.89 mg/l while at Vadinar location total hardness ranged from 270.0-300.00 mg/l and mean was 285.0 mg/l. The values of total hardness were found within the Permissible limit of the Drinking Water Standard (200-600 mg/L). These results clear, that hardness of water is according to the IS standards and it is not harmful for local inhabitants.

Iron

Iron values in the studied area of DPA & Vadinar were Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards are 0.3 mg/L.

Fluoride

Fluoride value in the studied area of DPA varied between 0.3-0.47 mg/l and mean was 0.38 mg/l. The minimum value was 0.3 mg/ at West gate workshop and maximum was 0.47 mg/l at E-Type and mean was 0.38 mg/l while at Vadinar location fluoride ranged from 0.22-0.25 mg/l and mean was 0.24 mg/l. The Fluoride values were well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

Sulphate

Sulphate value in the studied area of DPA varied between 24.5–35.8 mg/l and mean was 27.83 mg/l. The minimum value was 24.5 mg/ at A.O. Building, Hospital Kandla and Tuna Port and maximum was 35.8 mg/l at Nirmal Building while at Vadinar location Sulphate ranged from 0.24-0.75 mg/l and mean was 0.50 mg/l. All the sampling points showed Sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

Nitrites (NO_2) and Nitrates (NO_3)

The all values of Nitrite were found BQL (<0.05 mg/l) and Nitrate were well within the permissible limit of the Drinking water Standard.

Salinity

Salinity in drinking water in the present samples collected at DPA ranged from 0.61 ‰ at Canteen to 1.04 ‰ at Nirmal Building and average salinity was 0.66 ‰ while at Vadinar sampling location salinity ranged from 0.25-0.29 ‰. There are no prescribed Indian standards for salinity in Drinking water.

Sodium and Potassium Salts

Sodium values in the samples collected at DPA ranged from 180 - 204 mg/l and average was 195.74 mg/l while at Vadinar sodium ranged from 191.6- 192.0 mg/l and average was191.8 mg/l . Potassium salts ranged at DPA ranged from 3.15 to 4.18 mg/l while average was 3.42 mg/l while at Vadinar sampling locations potassium were BQL (<2.0 mg/l). There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

Heavy Metals in Drinking Water

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

Bacteriological Study

Analysis of the bacteriological parameter (E-coli and total coliform) at all location shows that Bacteria were not detectable. This shows that drinking water samples were safe for human consumption as per tested parameters.

4.4 Conclusions

These results were compared with permissible limits as prescribed in IS 10500:2012 – Drinking Water Specification. It was seen from the analysis data that during the study period at selected sampling location the water was safe for human consumption as per analyzed parameters at all drinking water monitoring stations.

CHAPTER-5

NOISE MONITORING

5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

5.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

5.2 Results

Table 18: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	**6:00 am to 10:00 PM**	**10:00PM to 6:00 AM**
1	Marine Bhavan	60.8	51.9
2	Nirman Building 1	69.9	52.0
3	Tuna Port	53.2	45.4
4	Main Gate North	63.3	51.9
5	West Gate I	67.7	58.1
6	Canteen Area	68.2	51.2
7	Main Road	66.3	52.2
8	ATM Building	69.1	51.1
9	Wharf Area /Jetty Area	70.4	61.7
10	Port & Custom Office	54.7	50.2
Vadinar Port			
11	Entrance Gate of Vadinar Port	55.0	53.5
12	Nr. Port Colony, Vadinar	60.6	57.6
13	Nr. Vadinar Jetty	52.5	51.0

5.3 Conclusions

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships.

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 53.2 dB(A) to 70.4 dB(A) while at Vadinar port 3 location ranged from 52.5 dB(A) to 60.6 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 45.4 dB to 61.7 dB(A) while at Vadinar port ranged from 52.5 dB (A) to 60.6 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.

CHAPTER-6

SOIL MONITORING

6.0 Soil Monitoring

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

Table No.:-19. Soil Sampling Location

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Tuna Port	SL-1	22° 58' 10.18''N	70° 6' 3.7''E	Near main gate of Port
2.	IFFCO Plant	SL-2	23° 26' 8.37''N	70° 13' 4.4''E	10 m away from main gate
3.	Khori creek	SL-3	22° 58' 10.18''N	70° 6' 3.7''E	Sand from creek after tide
4.	Nakti Creek	SL-4	23° 2' 1.10''N	70° 9' 33.6''E	
5.	DPA admin site	SL-5	22° 26' 30.9''N	69° 40' 37.03''E	Vadinar
6.	DPA colony	SL-6	22° 23' 57.09''N	69° 42' 49.42''E	

6.1 Methodology

The soil samples were collected in the month of November 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

6.2 Results

Table-20: Chemical Characteristics of Soil in the Study Area for Tuna port, IFFCO, Khori Creek, Nakti Creek, DPA admin site, DPA colony.

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main	Sand from creek after tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	7.79	7.80	7.54	7.58	8.14	7.54
3	Electrical Conductivity	µs/cm	35000.0	36100.0	26,820.00	12,700.0	155.0	594.0
4	Phosphorus	mg/kg	10.3	10.5	9.19	8.49	6.00	4.80
5	Moisture	%	15.9	20.3	20.90	3.50	7.20	10.10
6	Total Organic	%	4.04	1.7	3.64	7.80	2.30	2.00
7	Alkalinity	mg/kg	900.0	1000.0	800.0	500.0	800.0	600.0
8	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
9	Sulphate	mg/kg	820.00	982.00	1,080.00	810.00	30.0	70.0
10	Chloride	mg/kg	15598.0	14275.0	12,600.00	2,950.00	140.00	525.00
11	Calcium	mg/kg	2,605.00	2,505.00	31,600.00	3,086.00	1,729.00	1,849.00
12	Sodium	mg/kg	5657	7136.0	7,649.00	4,675.00	33.02	116.90
13	Potassium	mg/kg	552	694	708.00	437.00	44.60	44.52
14	Copper as Cu	mg/kg	27.4	15.5	30.50	14.50	54.10	31.60
15	Lead as Pb	mg/kg	7.4	7.4	9.50	6.30	74.10	75.30
16	Nickel as Ni	mg/kg	39.40	32.70	44.40	27.20	30.30	32.00
17	Zinc as Zn	mg/kg	62.4	77.40	79.20	56.50	50.60	86.00
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (TN: 0.001%, Cd: 1.0mg/kg)

6.3 Discussion

- DPA Kandla soil sampling data shows that value of pH ranges from 7.54 at Khori Creek to 7.80 at IFFCO Plant while the average value was 7.68. At Vadinar sampling location pH were 7.54 at DPA colony and 8.14 at DPA Admin Site.
- The Electrical Conductivity of DPA Kandla soil sample ranged from 12700.0 µs/cm at Nakti Creek (Sand from creek after tide) to 36100 µs/cm at IIFCO Plant and mean was 27655 µs/cm while Vadinar soil sampling location conductivity were 155 µs/cm at DPA Admin Site and 594 µs/cm at DPA Colony site.
- Total organic Carbon of DPA Kandla soil sample ranged from 1.7 % at IFFCO Plant to 7.80 % at Nakti Creek (Sand from creek after tide) and mean was 4.30 % while Vadinar soil sample were 2.0 % at DPA Colony and 2.30 % at DPA admin Site.
- The concentration of Phosphorus in the soil samples of DPA Kandla varies from 8.49 mg/kg at Nakti Creek (Sand from creek after tide) and 10.5 mg/kg at IIFCO Plant and mean was 9.62 mg/kg while the Vadinar soil sample for Phosphorus were 4.80 mg/kg at DPA Colony and 6.00 mg/kg at DPA Admin Site.
- Chloride in soil sample of DPA ranged from 2950.00 mg/kg at Nakti Creek (Sand from creek after tide) to 15598 mg/kg at Tuna Port and mean was11356 mg/kg while Vadinar soil sample were 140 mg/kg at DPA admin and 525 mg/kg at DPA Colony.
- The Concentration of Potassium in the soil samples of DPA Kandla ranged from 437 mg/kg at Nakti creek and 708 mg/kg at Khori Creek and mean was 597.75 mg/kg while the Vadinar soil sample for Potassium were 44.52 mg/kg at DPA Colony Site and 44.60 mg/kg at DPA Admin Site.
- The concentration of Sodium in the soil samples of DPA Kandla ranged from 4675.0 mg/kg at Nakti creek and 7649.0 mg/kg at Khori Creek and mean was 6279 mg/kg while the Vadinar soil sample for Sodium were 33.00 mg/kg at DPA Admin Site and 117 mg/kg at DPA Colony.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) were coastal soil; where as other locations are inland locations and have different chemical properties.

Heavy Metals in the Soil

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port Authority Kandla and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

6.4 Conclusion

The soils of Deendayal Port Authority Kandla and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

CHAPTER-7

SEWAGE TREATMENT PLANT MONITORING

7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guidelines of State Pollution Control Board and other statutory bodies.

7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

A new STP with an improved capacity of 1 MLD is being constructed at Gopalpuri Colony.

Table No. 21. Sewage Treatment Plant

Sr. No.	Location of STP	Types of Treatment	STP Capacity	Treated water Utilization
1.	Gopalpuri Township	MBBR	450 KLD	Plantation and Gardening
2.	Deendayal Port, Kandla	MBBR	600 KLD	Discharge to marine through pipeline, Plantation, Gardening
3.	Vadinar Port Colony	MBBR	1.5 MLD	Plantation and Gardening

7.2 Results

Table 22: Sewage Water Monitoring at Kandla STP (1st Week)

Date of Sampling	03.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.55	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	100.6	46.8	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	80.8	30.3	100
5	BOD @ 27 °C	mg/l	22	11	30
Aeration Tank					
6	MLSS	mg/l	14.0		
7	MLVSS	%	99.73		

Table 23: Sewage Water Monitoring at Kandla STP (2nd Week)

Date of Sampling	10.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.41	7.36	6.5 - 8.5
2	Total Suspended Solids	mg/l	127	52.6	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	90.9	40.4	100
5	BOD @ 27 °C	mg/l	23	11	30
Aeration Tank					
6	MLSS	mg/l	18.0		
7	MLVSS	%	85.00		

Table 24: Sewage Water Monitoring at Kandla STP (3rd Week)

Date of Sampling	17.11.2022

Sr. No.	Parameters	Unit	Results		CPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.48	7.29	6.5 - 8.5
2	Total Suspended Solids	mg/l	86.4	22.9	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	101	50.5	100
5	BOD @ 27 °C	mg/l	26	14	30
Aeration Tank					
6	MLSS	mg/l	20.0		
7	MLVSS	%	98.0		

Table 25: Sewage Water Monitoring at Kandla STP (4th Week)

Date of Sampling	24.10.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.41	7.29	6.5 - 8.5
2	Total Suspended Solids	mg/l	164.2	58.7	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	171.7	30.3	100
5	BOD @ 27 °C	mg/l	43	10	30
Aeration Tank					
6	MLSS	mg/l	20.0		
7	MLVSS	%	89.0		

Table 26: Sewage Water Monitoring at Gopalpuri STP (1st Week)

Date of Sampling	03.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.47	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	121.2	61	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	111.1	60.6	100
5	BOD @ 27 °C	mg/l	32	13	30
Aeration Tank					
6	MLSS	mg/l	22.0		
7	MLVSS	%	97.16		

Table 27: Sewage Water Monitoring at Gopalpuri STP (2nd Week)

Date of Sampling	10.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.35	7.27	6.5 - 8.5
2	Total Suspended Solids	mg/l	189	67.9	100
3	Residual Chlorine	mg/l			-
4	COD	mg/l	141.4	60.6	100
5	BOD @ 27 °C	mg/l	37	15	30
Aeration Tank					
6	MLSS	mg/l	16.0		
7	MLVSS	%	89.6		

Table 28: Sewage Water Monitoring at Gopalpuri STP (3rd Week)

Date of Sampling	17.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.41	7.36	6.5 - 8.5
2	Total Suspended Solids	mg/l	127	52.6	100
3	Residual Chlorine	mg/l			-
4	COD	mg/l	90.9	40.4	100
5	BOD @ 27 °C	mg/l	23	11	30
Aeration Tank					
6	MLSS	mg/l	08.0		
7	MLVSS	%	98.0		

Table 29: Sewage Water Monitoring at Gopalpuri STP (4th Week)

Date of Sampling	24.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.48	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	110.2	42.1	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	78	40	100
5	BOD @ 27 °C	mg/l	24.0	12.0	30
Aeration Tank					
6	MLSS	mg/l	18.0		
7	MLVSS	%	90.0		

Table 30: Sewage Water Monitoring at Vadinar STP (1st Week)

Date of Sampling	03.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.35	7.25	6.5 - 8.5
2	Total Suspended Solids	mg/l	74.9	39.5	100
3	Residual Chlorine	mg/	-	<0.5	-
4	COD	mg/l	101	40.4	100
5	BOD @ 27 °C	mg/l	26.0	10.0	30

Table 31: Sewage Water Monitoring at Vadinar STP (2nd Week)

Date of Sampling	10.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.38	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	69.6	40.3	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	131.3	50.5	100
5	BOD @ 27 °C	mg/l	32.0	7.0	30

Table 32: Sewage Water Monitoring at Vadinar STP (3rd Week)

Date of Sampling	17.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.51	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	38.6	16.9	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	80.8	20.2	100
5	BOD @ 27 °C	mg/l	24.0	12.0	30

Table 33: Sewage Water Monitoring at Vadinar STP (4th Week)

Date of Sampling	24.11.2022

Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.61	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	76.9	33.3	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	131.3	20.2	100
5	BOD @ 27 °C	mg/l	20.0	8.0	30

Table No. 34. General Standards for discharge of Environmental Pollutant Part-A

Sr. No.	Parameter	Inland Surface Water	Land Irrigation	Marine Coastal Areas
1.	pH	5.5-9.0	5.5-9.0	5.5-9.0
2.	Total Suspended Solids (mg/l)	100	200	100
3.	Residual Chlorine (mg/l)	1.0	-	1.0
4.	BOD (mg/l)	30	100	100
5.	COD (mg/l)	250	-	250

Sources:-CPCB

7.3 Results & Discussion

The STP Sample carried out to evaluate the efficiency and performance of the wastewater treatment plant at Gopalpuri, Kandla and Vadinar STP. The performance of these plants is an essential parameter to monitor because the treated sewage water is discharged for irrigation purposes and discharge into marine. Wastewater samples were collected from different unit operations of the plant i.e, the inlet, aeration tank and the final treated outlet. These samples were analyzed for various physico-chemical characteristics such as pH, TSS, Residual Chlorine, COD, BOD, MLSS and MLVS.

The final treated outlet observed pH values were within the allowed range at STP Gopalpuri, STP Kandla & STP Vadinar ranged from 7.22 -7.35, 7.29-7.42 & 7.21-7.42 respectively. The wastewater treatment makes it suitable for irrigation. These values are below the allowed limit of the GPCB.

- The final treated outlet observed Total suspended solid values at Gopalpuri, DPA Kandla & Vadinar ranged from 27.10-67.90 mg/l, 22.90-58.70 mg/l & 16.60-40.30 mg/l respectively. These values are below the allowed limit of the GPCB.
- The final treated outlet observed Residual Chlorine values were <0.5 at Gopalpuri, DPA Kandla & Vadinar. These values are below the allowed limit of the CPCB.
- The final treated outlet observed COD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 40.40-60.60 mg/l, 30.30-50.50 mg/l & 20.20-50.50 mg/l respectively. These values are below the allowed limit of the CPCB.

- The main focus of wastewater treatment plants is supposed to reduce the BOD in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The final treated outlet observed BOD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 12.0-16.0 mg/l, 10.0-14.0 mg/l & 7.0-12.0 mg/l respectively. These values are below the allowed limit of the GPCB.

7.4 Conclusions:

All parameters for STP outlet are within limit prescribed by CPCB. After the final treatment, it is found that the treated water is satisfactory.

CHAPTER-8

MARINE WATER MONITORING

8.0 Marine Water Monitoring

Marine Water Quality

The Forty Second Amendment to the Constitution in 1976 underscored the importance of 'green thinking'. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the "fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures".

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at "integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources." The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

Sampling Stations

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 01st & 02nd November-2022 in harbor regions of DPA & Vadinar during Neap tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 8th & 9th November-2022 in harbor regions of DPA & Vadinar during Spring tide period first quarter of Lunar Cycle.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbor area and two stations in Nakti creek and one station in Khori creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

Sampling Locations

Offshore monitoring requirement	Number of locations
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khori creek 1 near Vadinar Jetty 1 near 1st SBM
Total Number of locations	**8**

8.1 Marine Water Quality and Results

Marine water quality of marine waters of Deendayal Port Harbor waters, Khori & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 35 to 42. *During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.*

Table 35: Marine Water Quality Monitoring Parameters for Location Near DPA Colony

Sr. No.	Parameters	Unit	Kandla Creek Near DPA Colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.61	7.58	7.55	7.46
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	19.0	19.9	20.4	19.0
5	Turbidity	NTU	38	35	42	35
6	Total Dissolved Solids	mg/l	34152.0	30868.0	30941.0	31974.0
7	Total Suspended Solids	mg/l	639.6	600.6	646.4	595.6
8	Total Solids	mg/l	34791.6	31468.6	31587.4	32569.6
9	DO	mg/l	5.8	5.6	5.7	5.5
10	COD	mg/l	88.0	79.0	82.0	86.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.06	0.82	0.99	0.91
13	Phosphate	mg/l	0.48	0.31	0.09	0.04
14	Sulphate	mg/l	3580	3407	3708.0	3658
15	Nitrate	mg/l	4.70	0.50	0.75	0.42
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	521.04	440.88	561.12	480.96
18	Magnesium	mg/l	1773.9	1749.6	1701	1773.9
19	Sodium	mg/l	8011.0	8399.0	8396.0	8699.0
20	Potassium	mg/l	299.0	385.0	391.0	395.0
21	Iron	mg/l	BQL	BQL	0.88	0.57
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

Table 36: Marine Water Quality Monitoring Parameters for Location Near Passenger Jetty One at Kandla

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.43	7.28	7.33	7.41
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	20.8	20.4	19.9	18.6
5	Turbidity	NTU	43	48	36	41
6	Total Dissolved Solids	mg/l	35468.0	37102.0	34662.0	33398.0
7	Total Suspended Solids	mg/l	679.7	665.5	703.7	663.8
8	Total Solids	mg/l	36147.7	37767.5	35365.7	34061.8
9	DO	mg/l	5.9	6.2	5.6	5.2
10	COD	mg/l	86.0	94.0	90.0	92.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.26	0.86	1.33	0.85
13	Phosphate	mg/l	0.29	0.13	0.33	0.19
14	Sulphate	mg/l	3571	3470	4072	3407
15	Nitrate	mg/l	3.40	2.70	1.17	4.36
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	561.12	601.20	601.2	521.04
18	Magnesium	mg/l	1701	1603.8	1749.6	1701
19	Sodium	mg/l	9142.0	9345.0	9247.0	9219.0
20	Potassium	mg/l	370.0	385.0	370.0	380.0
21	Iron	mg/l	0.47	BQL	1.76	0.30
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Nitrite: 0.05mg/lCu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

Table 37: Marine Water Quality Monitoring Parameters for location Near Coal Berth

Sr. No.	Parameters	Unit	Near Coal Berth 22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.37	7.51	7.53	7.25
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	18.6	18.1	19.5	20.8
5	Turbidity	NTU	33	42	38	45
6	Total Dissolved Solids	mg/l	39222.0	37586.0	37123.0	36668.0
7	Total Suspended Solids	mg/l	540.2	638.4	620.6	580.2
8	Total Solids	mg/l	39762.2	38224.4	37743.6	37248.2
9	DO	mg/l	7.3	6.4	7.1	6.5
10	COD	mg/l	81.0	874.0	88.0	84.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.56	0.98	0.69	1.76
13	Phosphate	mg/l	0.06	0.56	0.12	0.61
14	Sulphate	mg/l	4222	3458	2981	3758
15	Nitrate	mg/l	2.20	4.60	2.68	4.70
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	480.96	641.28	641.28	721.44
18	Magnesium	mg/l	1628.1	1628.1	1676.7	1603.8
19	Sodium	mg/l	8346.0	9380.0	9245.0	9814.0
20	Potassium	mg/l	391.0	300.0	392.0	384.0
21	Iron	mg/l	BQL	BQL	BQL	1.34
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

Table 38: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla

Sr. No.	Parameters	Unit	Khori creek			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.48	7.27	7.34	7.21
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	20.4	19.5	18.6	17.7
5	Turbidity	NTU	35	31	43	39
6	Total Dissolved Solids	mg/l	32557.0	34294.0	30473.0	33329.0
7	Total Suspended Solids	mg/l	641.2	616.3	594.7	731.2
8	Total Solids	mg/l	33198.2	34910.3	31067.7	34060.2
9	DO	mg/l	7.6	6.3	7.3	6.8
10	COD	mg/l	85.0	96.0	92.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.78	1.04	1.39	1.18
13	Phosphate	mg/l	0.44	0.67	0.35	0.42
14	Sulphate	mg/l	4047	3646	3157	3170
15	Nitrate	mg/l	3.70	1.10	1.34	5.20
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	561.12	480.96	480.96	561.12
18	Magnesium	mg/l	1725.3	1676.7	1701	1628.1
19	Sodium	mg/l	9112.0	8436.0	7966.0	8696.0
20	Potassium	mg/l	299.0	385.0	382.0	377.0
21	Iron	mg/l	0.44	BQL	0.17	0.31
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	0.02
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

Table 39: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port 22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.41	7.36	7.48	7.23
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	19.0	18.6	19.0	19.5
5	Turbidity	NTU	45	36	40	42
6	Total Dissolved Solids	mg/l	30214.0	28996.0	31047.0	31957.0
7	Total Suspended Solids	mg/l	642.7	526.2	682.5	606.8
8	Total Solids	mg/l	30856.7	29522.2	31729.5	32563.8
9	DO	mg/l	8.1	7.5	6.4	7.2
10	COD	mg/l	94.0	112.0	98.0	100.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.12	1.20	1.42	1.22
13	Phosphate	mg/l	0.71	0.37	0.46	0.12
14	Sulphate	mg/l	4172	3846	3445	3433
15	Nitrate	mg/l	1.50	1.70	5.12	1.69
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	440.88	641.28	601.2	521.04
18	Magnesium	mg/l	1725.3	1555.2	1701	1773.9
19	Sodium	mg/l	8639.0	9143.0	8655.0	7939.0
20	Potassium	mg/l	395.0	386.0	384.0	386.0
21	Iron	mg/l	BQL	0.33	0.34	0.18
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

Table 40: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A 23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.45	Sampling not possible during Low Tide	7.45	Sampling not possible during Low Tide
2	Color	-	Agreeable		Agreeable	
3	Odor	-	Agreeable		Agreeable	
4	Salinity	‰	19.9		20.8	
5	Turbidity	NTU	45		44	
6	Total Dissolved Solids	mg/l	30288.0		32796.0	
7	Total Suspended Solids	mg/l	529.6		595.7	
8	Total Solids	mg/l	30817.6		33391.7	
9	DO	mg/l	7.4		6.9	
10	COD	mg/l	118.0		110.0	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	1.02		0.16	
13	Phosphate	mg/l	0.75		0.46	
14	Sulphate	mg/l	4109		4961	
15	Nitrate	mg/l	2.70		3.52	
16	Nitrite	mg/l	<0.05		BQL	
17	Calcium	mg/l	681.36		641.28	
18	Magnesium	mg/l	1506.6		1628.1	
19	Sodium	mg/l	9280.0		8528.0	
20	Potassium	mg/l	427.0		427.0	
21	Iron	mg/l	BQL		0.54	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		0.01	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

Table 41: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty 22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.43	7.26	7.36	7.29
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	20.4	20.8	19.0	19.9
5	Turbidity	NTU	39	42	38	42
6	Total Dissolved Solids	mg/l	35265.0	37685.0	36325.0	36681.0
7	Total Suspended Solids	mg/l	585.3	590.8	681.4	657.6
8	Total Solids	mg/l	35850.3	38275.8	37006.4	37338.6
9	DO	mg/l	5.7	5.4	6.3	5.8
10	COD	mg/l	87.0	89.0	96.0	92.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.55	0.45	0.36	0.28
13	Phosphate	mg/l	0.18	0.42	0.33	0.19
14	Sulphate	mg/l	3608	3558	3683	3645
15	Nitrate	mg/l	2.35	1.09	1.00	2.43
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	480.96	601.20	521.04	480.96
18	Magnesium	mg/l	1603.8	1652.4	1676.7	1749.6
19	Sodium	mg/l	9448.0	7368.0	7810.0	8912.0
20	Potassium	mg/l	371.0	354.0	452.0	456.0
21	Iron	mg/l	BQL	BQL	0.31	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.29	BQL	0.77	0.35

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

Table 42: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM

Sr. No.	Parameters	Unit	Nr. Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.37	7.22	7.41	7.35
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	19.0	17.7	19.5	18.6
5	Turbidity	NTU	37	40	37	39
6	Total Dissolved Solids	mg/l	39961.0	39198.0	42642.0	40730.0
7	Total Suspended Solids	mg/l	545.5	493.6	714.3	657.9
8	Total Solids	mg/l	40506.5	39691.6	43356.3	41387.9
9	DO	mg/l	6.1	5.5	5.6	6.1
10	COD	mg/l	95.0	98.0	96.0	94.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.47	0.37	0.34	0.30
13	Phosphate	mg/l	1.08	0.19	0.46	0.28
14	Sulphate	mg/l	3495	3796	3745	4008
15	Nitrate	mg/l	3.86	2.18	4.95	2.10
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	561.12	400.80	681.36	641.28
18	Magnesium	mg/l	1628.1	1676.7	1555.2	1628.1
19	Sodium	mg/l	8473.0	10386.0	9131.0	8526.0
20	Potassium	mg/l	452.0	406.0	413.0	441.0
21	Iron	mg/l	BQL	BQL	0.24	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.28	BQL	0.40	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l)

8.2 Results & Discussion for Marine water samples

Marine water quality of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and mostly found below quantification limit.

pH

During spring tide the pH values was ranged from 7.27-7.61 at DPA Kandla and 7.22-7.43 at Vadinar while during Neap Tide pH values was ranged from 7.21-7.55 at DPA Kandla and 7.29-7.41 at Vadinar.

Color and Odor

All marine samples for Odor and Color were found agreeable at all sampling locations.

Turbidity

During spring tide the Turbidity values was ranged from 31-48 NTU at DPA Kandla and 37-42 NTU at Vadinar while during Neap Tide Turbidity values was ranged from 35-45 NTU at DPA Kandla and 37-42 NTU at Vadinar. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity (Yap et al, 2011). Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler, 2004). The turbidity affects the amount of light penetrating to the plants for photosynthesis.

Total Dissolved Solids (TDS)

TDS values in the studied area during Spring Tide varied between 28966- 39222 mg/l at DPA Kandla and 35265-39961 mg/l at Vadinar while during Neap Tide TDS values was varied 30473-37123 mg/l at DPA Kandla and 36325-42642 mg/l at Near Vadinar.

Calcium

Calcium value in the studied area during Spring Tide varied between 440.9-681.4 mg/l at DPA Kandla and 400.8-601.2 mg/l at Vadinar while during Neap Tide calcium values between 481.0-721.4 mg/l at DPA Kandla and 481.0-681.4 mg/l at Vadinar.

Magnesium

Magnesium value in the studied area during Spring Tide varied between 1506.6-1773.9 mg/l at DPA Kandla and 1603.8-1676.7 mg/l at Vadinar while during Neap Tide magnesium values between 1603.80-173.9 mg/l at DPA Kandla and 1555.2 -1749.60 at Vadinar. Calcium and magnesium both play an important role in antagonizing the toxic effects of various ions and neutralizing the excess acid produced (Narayan R. et. al., 2007)

Nitrate

Nitrate value in the studied area during Spring Tide varied between 0.5-4.7 mg/l at DPA Kandla and 1.09-3.86 mg/l at Vadinar while during Neap Tide Nitrate values between 0.42-5.2 mg/l at DPA Kandla and 1.0-4.95 at Vadinar.

The variations were observed due to variation in phytoplankton excretion, oxidation of ammonia, reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007).

Iron

Iron values in the studied area during Spring Tide ranged from 0.33-0.47 mg/l at DPA Kandla and at Vadinar were BQL (<0.10) while during Neap Tide Iron values ranged from 0.17-1.76 mg/l at DPA Kandla and 0.24-0.31 mg/l at Vadinar.

Sulphates

Sulphate values in the studied area during Spring Tide ranged from 3407-4222 mg/l at DPA Kandla and 3495-3796 mg/l at Vadinar while during Neap Tide the Sulphate values was varied 2981-4961 mg/l at DPA Kandla and 3645-4008mg/l at Vadinar.

Salinity

Salinity values in the studied area during Spring Tide varied ranged 18.11 to 20.82 ‰ at DPA Kandla and 17.65 to 20.82 ‰ at Vadinar while during Neap Tide the Salinity values was varied 17.65 to 20.82 ‰ at DPA Kandla and 18.55 to 19.92 ‰ at Vadinar.

Sodium and Potassium Salts

During Spring Tide the Sodium values ranged from 8011-9380 mg/l at DPA Kandla & 7368-10386 mg/l at Vadinar and Potassium salts ranged from 299-427 mg/l at DPA Kandla & 354-452 mg/l at Vadinar while during Neap Tide the Sodium values was ranges from 7939-

9814 mg/l at DPA Kandla & 7810-9131 mg/l at Vadinar and Potassium salts ranged from 370-427 mg/l at DPA Kandla & 413-456 mg/l at Vadinar.

DO

The DO refers to the amount of oxygen dissolved in the water and it is particularly important in limnology {(aquatic ecology) (Weiss 1970)}. The fate and behavior of DO is of critical importance to marine organisms in determining the severity of adverse impacts (Best et al. 2007). The major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best et al. 2007). From the studied samples, DO in marine water during Spring Tide was found in ranges from 5.6-8.1 mg/l at DPA Kandla and 5.4-6.1 mg/l at Vadinar while during Neap Tide 5.2-7.3 mg/l at DPA Kandla and 5.6-6.3 mg/l at Vadinar.

BOD

BOD in marine water at all sampling location in the studied samples were found BQL (<2.0 mg/l).

Heavy Metals in Marine Water

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. Maximum heavy metals parameters were well Below the Quantification limits.

9.3 Conclusion

In the present study period marine water samples were analyzed and found inline as per Primary Water Quality criteria for class-IV WATERS (For Harbour Waters).

CHAPTER-9

MARINE SEDIMENT MONITORING

9.0 Marine Sediments

The deep-sea ocean floor is made up of sediment. This sediment is composed of tiny particles such as fine sand, silt, clay, or animal skeletons that have settled on the ocean bottom. Over long periods of time, some of these particles become compressed and form stratified layers. Scientists that study these layers look at particle size, particle composition, and origin to help them create historical records of the deep ocean floor. This process is called weathering. Weathering can be either mechanical or chemical. Mechanical weathering can occur as ice, wind, or water wears away the rock’s surface. Chemical weathering can occur as rocks are dissolved by a chemical such as acid rain. The particles created as a result of weathering are called terrigenous sediments. These particles are transported to the ocean by wind and by rivers and streams. Once the particles enter the ocean, they are dispersed by waves, currents, and tides. The heaviest and largest particles that reach the oceans, such as sand, settle very quickly to the bottom as a result of gravity. Sand is deposited near the coast whereas the smaller silt and clay particles are transported farther distances offshore before they settle to the bottom. Sediments are an important component of aquatic ecosystems because they provide nutrients and habitat for aquatic organisms (Benhamed et al. 2016). However, human activities result in accumulation of toxic substances such as heavy metals in marine sediments. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulation. Metals affect the ecosystem because they are not removed from water by self-purification, but accumulate in sediments and enter the food chain (Astakhov et al. 2015).

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Benthic surface grab samplers look like giant metal jaws. They dig into the bottom and take a bite of the sediment. These samplers are good for collecting softer, sandy or silty sediments that do not contain rocks. A box corer is a cross between a surface sampler and a sediment corer. It is a special device that is used to collect an undisturbed sample of the very top surface layers and the sediment underneath. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

10.1 Results

The Sediment Quality results are given in below from table no. 43 & 44.

Table 43: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	1.32	0.6	0.1	0.1	0.16	1.14	1.59
3	Organic Carbon	mg/kg	0.76	0.35	0.07	0.06	0.09	0.66	0.91
4	Inorganic Phosphate	mg/kg	89.00	90.00	101.00	92.00	100.00	90.00	100.00
5	Moisture	%	3.90	2.37	4.12	3.00	4.10	3.40	4.00
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	7.30	7.68	8.90	9.30	9.10	8.90	9.60
8	Phosphate	mg/kg	5.20	4.99	4.09	5.25	9.00	3.28	10.40
9	Sulphate	mg/kg	759.00	849.00	555.00	496.00	768.00	732.00	496.00
10	Nitrite	mg/kg	0.11	0.11	0.10	0.10	0.12	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	2765.00	1523.00	861.00	961.00	981.00	1162.00	2485.00
13	Magnesium	mg/kg	1372.00	1300.00	1020.00	1263.00	1032.00	1089.00	2065.00
14	Sodium	mg/kg	2410.0	2760.0	2644.0	2940.0	2722.0	1394.00	1082.00
15	Potassium	mg/kg	404.00	459.00	390.00	510.00	447.00	811.0	560.0
16	Chromium	mg/kg	61.30	71.90	66.00	53.30	56.40	42.80	49.70
17	Nickel	mg/kg	26.80	31.70	29.00	23.00	24.10	13.80	29.20
18	Copper	mg/kg	17.40	19.40	17.80	15.50	15.80	13.80	47.10
19	Zinc	mg/kg	43.40	55.80	49.80	41.80	46.00	32.00	64.30
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	5.20	6.20	5.70	9.80	8.40	12.00	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

Table 44 : Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.91	0.50	1.52	0.37	0.27	1.45	1.68
3	Organic Carbon	mg/kg	0.52	0.29	0.87	0.21	0.15	0.83	0.97
4	Inorganic Phosphate	mg/kg	98.00	90.00	80.00	78.00	100.00	88.00	90.00
5	Moisture	%	17.00	8.70	15.00	6.60	4.80	14.24	13.14
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	7.20	8.26	9.02	5.50	7.80	9.20	10.02
8	Phosphate	mg/kg	7.87	9.29	6.16	5.75	9.49	11.61	10.80
9	Sulphate	mg/kg	745.00	862.00	585.00	490.00	510.00	590.00	396.00
10	Nitrite	mg/kg	0.11	0.12	0.12	0.11	0.10	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	12.00	16.6	26.2	BQL	BQL
12	Calcium	mg/kg	1723.00	1057.00	1320.00	1220.00	1390.00	1907.00	1643.00
13	Magnesium	mg/kg	1044.00	716.00	1090.00	690.00	896.00	1563.00	2320.00
14	Sodium	mg/kg	2733.00	2720.00	2578.00	2107.00	1558.00	1042.00	952.00
15	Potassium	mg/kg	302.00	332.00	378.0	357.0	87.8	384.00	325.00
16	Chromium	mg/kg	38.00	24.40	51.70	16.10	60.00	48.90	69.20
17	Nickel	mg/kg	15.60	9.50	21.70	6.00	24.70	19.70	28.30
18	Copper	mg/kg	7.80	BQL	11.30	31.40	16.40	12.10	19.90
19	Zinc	mg/kg	30.10	21.90	35.70	13.70	44.90	31.50	51.90
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0 mg/kg,Cd: 1.0 mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg)

9.2 Discussion of Marine Sediment samples

Marine Sediments of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

9.3 Conclusion

The sediment types are majority Sandy loamy. Also maximum heavy metals parameters found below Quantification limit wise, Pb, Cd, Hg , As, Al was not Detected and Nitrate for some locations.

CHAPTER-11

MARINE ECOLOGICAL MONITORING

10.0 INTRODUCTION:

10.1 Sampling Stations:

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 01st November 2022 in harbour region of DPA at Kandla Creek, and on 02nd November 2022 in creeks near by the port during Neap tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 08th November, 2022 in harbour region of DPA at Kandla Creek and on 09th November, 2022 in creeks near by the port during spring tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar Jetty at Path Finder Creek during Neap tide on 01/11/2022 and Spring tide period on 08/11/2022.Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative and quantitative evaluation of phytoplankton, qualitative and quantitative evaluation of zoo plankton density and their population.

TABLE 43. SAMPLING LOCATIONS

monitoring requirement	Number of locations
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near I stSPM
Total Number of locations	**8**

Sampling methodology adopted:

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample was taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with Nylobolt cloth of 20µm mesh size. . During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.

Samples Processing for chlorophyll estimation:

Samples for chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 2017).

PLANKTON:

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is a general term for organisms which have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplanktons are free floating organisms that are capable of photosynthesis and zooplankton is the various free-floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, ***plankton*** and ***nekton*** (Lalli and Parsons, 1997). ***Plankton*** consists of all organisms drifting in the water and is unable to swim against water currents, whereas ***Nekton*** includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term ‘Plankton’ first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos*meaning “passively drifting or wandering”) is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

Phytoplankton in the marine environment:

Phytoplanktons are free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio-purifier and bio-indicators of the aquatic ecosystems of which diverse array of the life depends .They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (Bacillariophyceae) and Dinoflagellates (Dinophyceae).The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; Diatoms and Dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (Blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

Zooplankton in the marine environment:

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of ‘biological pump’ in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean’s interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

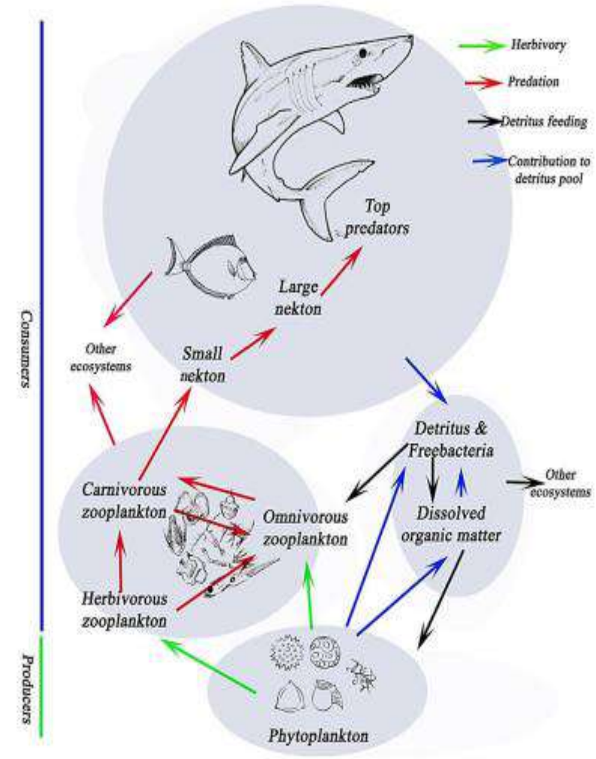
Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991 ;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplanktons are efficient grazers of the phytoplankton and are referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajbhiye, 2002).



Simplified marine food web

Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilo metres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton in the month of Novemberalso exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

Methodology adopted for Plankton sampling:

Preservation and storage:

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

Sample concentration:

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

Taxonomic evaluation:

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerin to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of phytoplankton and zooplankton that were encountered

Cell counts by drop count method:

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22 mm x 60 mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total amount of phytoplankton in the original volume of sample filtered was calculated as units/L and Zooplankton as N/m^3.

BENTHIC ORGANISMS:

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment–water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42µ in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes

SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:

Van veen sampler ($0.09m^2$) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

Sample sieving:

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

Sample staining:

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

DIVERSITY INDICES:

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A. E. (1988)

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H. R. *etal*. 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate specie richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness (*S)* and evenness (*J)*

Simpson's diversity index

Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran , 2004).

The formula for calculating D is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

Where n_i = the total number of organisms of each individual species

N = the total number of organisms of all species

The value of D ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When D increases diversity decreases. Simpson's index is therefore usually expressed as 1-D or 1/D. (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment

- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

Species richness indices

The species richness***(S)*** is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness in may be concomitant with severe or chronic human-induced perturbation (Fair Fair weather 1990) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke &Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness***(S)*** is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by Mc Intosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximised when all types are equally abundant [Rosenzweig, M. L. (1995)]

Shannon-Wiener's index:

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index **(H),** which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index (**H**) reproduces community parameters to a single numberby using an equation.

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxan. It varies from 0 for communities with only single taxa to high values for community with many taxan each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than

3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

10.2:- RESULTS:

$$H' = -\sum_{j=1}^{s} \frac{n_j}{N} \ln\left(\frac{n_j}{N}\right)$$

CHLOROPHYLL-a:

In the sub surface water chlorophyll-a was varying from 0.472-0.969 mg/m^3 with an average value 0.645 mg/m^3 in harbour region of DPA in Kandla Creek during sampling done in spring tide period of November 2022. In the nearby creeks chlorophyll-a was varying from 0.359-0.717 mg/m^3 with an average value 0.552 mg/m^3 Pheophytin –a level was below detectable limit- the all the sampling stations during springtide. Even though the plankton diversity and abundance were more during the spring tide sampling,the chlorophyll-content was detected lesser than expected because, the phytoplankton communities were mainly represented by diatoms *Skeletonema* sp. *Coscinodiscus sp.* and *Chaetoceros* sp.

In the sub surface water chlorophyll-a was varying from 0.338-0.547 mg/m^3 with an average value 0.437 mg/m^3 in harbour region of DPA in Kandla Creek during sampling done in Neap tide period of November2022. In the nearby creeks chlorophyll-a was varying from 0.205- 0.440mg/m^3 with an average value 0.370 mg/m^3. Pheophytin–a level was below detectable limit- the all the sampling stations. During neap tide sampling phytoplankton communities were mainly represented by *Coscinodiscus sp. and Ditylum sp.*

In the sub surface water chlorophyll-a was varying from 0.598-0.968 mg/m^3 in harbour region of DPA OOT in path finder Creek during sampling done in spring tide period of November 2022. In the sub surface water chlorophyll-a was varying from 0.709 - 0.987mg/m^3 in harbour region of DPA OOT in path finder Creek during sampling done in Neap Tide period of November 2022

TABLE:-45 VARIATIONS IN CHLOROPHYLL–a PHEOPHYTIN-a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINARDURING SPRING TIDE IN NOVEMBER 2022

Sr. No.	Station	Tide	Chlorophyll-a (mg/m^3)	Pheophytin- a (mg/m^3)	Algal Biomass (Chlorophyll method) mg/m^3
DPA HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.969	BDL	64.92
		Low tide	0.647	BDL	43.35
2	KPT 2	High tide	0.511	BDL	34.24
		Low tide	0.521	BDL	34.91
3	KPT 3	High tide	0.749	BDL	50.18
		Low tide	0.472	BDL	31.62
CREEKS					
4	KPT-4 Khori-I	High tide	0.638	BDL	42.75
		Low tide	0.359	BDL	24.05
5	KPT-5 Nakti-I	High tide	0.717	BDL	48.04
		Low tide	0.493	BDL	33.03
6	KPT-6 Nakti-II	High tide	ND	ND	ND
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.968	BDL	64.86
8		Low tide	0.732	BDL	49.04
9	SPM	High tide	0.953	BDL	63.85
10		Low tide	0.598	BDL	

BDL: Below Detectable Limit., ND: Not detected

TABLE:-46. VARIATIONS IN CHLOROPHYLL–a PHEOPHYTIN-a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA, NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINARDURING NEAP TIDE IN NOVEMBER 2022

Sr.No.	Station	Tide	Chlorophyll-a (mg/m^3)	Pheophytin- a (mg/m^3)	Algal Biomass (Chlorophyll method) mg/m^3
DPA HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.547	BDL	
		Low tide	0.450	BDL	
2	KPT 2	High tide	0.338	BDL	
		Low tide	0.409	BDL	
3	KPT 3	High tide	0.354	BDL	
		Low tide	0.523	BDL	
CREEKS					
4	KPT-4 Khori-I	High tide	0.440	BDL	
		Low tide	0.408	BDL	
5	KPT-5 Nakti-I	High tide	0.205	BDL	
		Low tide	0.426	BDL	
6	KPT-6 Nakti-II	High tide	ND	ND	ND
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.799	BDL	
8		Low tide	0.709	BDL	
9	SPM	High tide	0.857	BDL	
10		Low tide	0.987	BDL	

BDL: Below Detectable Limit.ND: Not detected

PHYTOPLANKTON POPULATION:

For the evaluation of the Phytoplankton population in DPA harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms, blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 26 genera, Blue green algae were represented by 2 genera and Dinoflagellates were represented by 6 genera during the sampling conducted in spring tide in November, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 39-243units/ L during high tide period and115-199 units/L during low tide of Spring Tide. During spring tide sampling phytoplankton communities were dominated by *Skeletonema* sp almost forming a bloom in the Kandla creek and other nearby creek area and abundant population of *Coscinodiscus sp.* and *Chaetoceros* sp.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and DinoflagellatesduringNeap tide period. Diatoms were represented by 24 genera, Blue green algae were represented 2 genera and Dinoflagellates with 5 genera during the sampling conducted in Neap tide in November, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 43-299 units/ L during high tide period and 143-193 units/L during low tide of Neap Tide. During Neap tide sampling phytoplankton communities were dominated by, *Ditylum sp and Coscinodiscus sp.*

For the evaluation of the Phytoplankton population in DPA OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; Jetty area and SPM area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 25 genera, Blue Green algae by 5 genera and Dinoflagellates by 6 genera during the sampling conducted in spring tide in November, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty area was 209 units/L during high tide period and 177 units/L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the SPM area was varying from 206 units/ L during high tide period and 131 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 32 genera and Blue green algae by 4 genera and Dinoflagellates by 6 genera during the sampling conducted in Neap tide in November, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 244units/ L during high tide period and 200 units/L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 259 units/L during high tide period and 294 units/L during low tide of Neap Tide.

Species Richness Indices and Diversity Indices:

Margalef's diversity index (Species Richness)

Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 2.184- 4.688 with an average of 3.346 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from1.963- 3.589 with an average of 2.835during the consecutive low tide period.

Margalef's diversity index (Species Richness) of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 2.393-4.279 with an average of 3.586during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.821-3.86 with an average of 3.357during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 4.867 at OOT jetty area and 4.129 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 4.443 and 3.692 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) of phytoplankton communities in the stations was 4.73 at OOT jetty area and 4.139 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the path finder creek near OOT jetty was 4.152 and SPM area was 5.454 during the consecutive low tide period.

Shannon-Wiener's index:

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.786- 1.034 between selected sampling stations with an average value of 0.925 during high tide period of spring tideat Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.790-0.915 between selected sampling stations with an average value of 0.855 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.867–1.022 between selected sampling stations with an average value of 0.932 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.926- 1.001 between selected sampling stations with an average value of 0.951during consecutive low tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the stations was1.037 at OOT jetty area and 0.946 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.043 and 0.982 at SPM during the consecutive low tide period of spring tide.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.998 at OOT jetty area and1.035 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.942 and at SPM area was1.036 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

Simpson's diversity index:

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.778-0.851 between selected sampling stations with an average of 0.823 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.787-0.842 between selected sampling stations with an average of 0.814 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during Neap tide also, which was varying from 0.813-0.874 with an average value of 0.847 between selected sampling stations during high tide period and 0.840-0.871 varying from with an average value of 0.858 between selected sampling stations during consecutive low tide period Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was0.863 at OOT jetty area and 0.820 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.876 and 0.867 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.838 at OOT jetty area and 0.881 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.832 and at SPM area was 0.867 during the consecutive low tide period.

Table:-47 4PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND , NEAR BY CREEKS DURING SPRING TIDE IN NOVEMBER 2022

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% Of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index H (log_{10})	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	207	26/34	76.47	4.688	1.034	0.8511
	2	183	22/34	64.71	4.031	1.005	0.8437
	3	193	13/34	38.24	2.28	0.811	0.7778
	4	243	18/34	52.94	3.095	0.9391	0.8192
	5	193	21/34	61.76	3.8	0.9777	0.8281
	6	39	9/34	26.47	2.184	0.786	0.8178
LOW TIDE	1	178	14/34	41.18	2.509	0.8042	0.787
	2	199	20/34	58.82	3.589	0.8982	0.8075
	3	115	14/34	41.18	2.74	0.8696	0.8365
	4	154	18/34	52.94	3.375	0.915	0.8416
	5	163	11/34	32.35	1.963	0.7895	0.7957

Table:-48 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN NOVEMBER 2022

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index H (log_{10})	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	216	24/31	77.42	4.279	0.98	0.8568
	2	229	22/31	70.97	3.865	0.958	0.853
	3	228	22/31	70.97	3.868	1.022	0.8743
	4	299	23/31	74.19	3.859	0.8667	0.8127
	5	254	19/31	61.29	3.251	0.8929	0.8307
	6	43	10/31	32.26	2.393	0.8712	0.8571
LOW TIDE	1	183	18/31	58.06	3.263	0.9504	0.8636
	2	143	15/31	48.39	2.821	0.946	0.8666
	3	178	21/31	67.74	3.86	1.001	0.8708
	4	193	19/31	61.29	3.42	0.931	0.84
	5	193	19/31	61.29	3.42	0.9259	0.8469

Table:-49 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN NOVEMBER2022

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Species Composition % (Group level)
HIGH TIDE	Sub surface	6	BLUE GREEN ALGAE	0-8	2/34	5.88
			DIATOMS	38-238	26/34	76.47
			DINOFLAGELLATES	0-11	6/34	17.65
			TOTAL PHYTO PLANKTON	**39-243**	**34**	
LOW TIDE	Sub surface	5	BLUE GREEN ALGAE	1-6	2/34	5.88
			DIATOMS	110-190	26/34	76.47
			DINOFLAGELLATES	1-7	6/34	17.65
			TOTAL PHYTO PLANKTON	**115-199**	**34**	

TABLE:-50 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN NOVEMBER 2022

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Species Composition % (Group level)
HIGH TIDE	Sub surface	6	BLUE GREEN ALGAE	0-6	2/31	6.45
			DIATOMS	43-293	24/31	77.42
			DINOFLAGELLATES	0-9	5/31	16.13
			TOTAL PHYTO PLANKTON	**43-299**	**31**	
LOW TIDE	Sub surface	5	BLUE GREEN ALGAE	2-6	2/31	6.45
			DIATOMS	133-186	24/31	77.42
			DINOFLAGELLATES	3-8	5/31	16.13
			TOTAL PHYTO PLANKTON	**143-193**	**31**	

TABLE:-51 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR &NEAR BY SPM, DURING SPRING TIDE IN NOVEMBER 2022

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log_{10})	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	209	27/36	75.00	4.867	1.037	0.863
	SPM	206	23/36	63.89	4.129	0.946	0.820
LOW TIDE	Jetty	177	24/36	66.67	4.443	1.043	0.876
	SPM	131	19/36	52.78	3.692	0.982	0.867

TABLE:-52 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN NOVEMBER 2022

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index H (log_{10})	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	244	27/42	64.29	4.73	0.998	0.838
	SPM	259	24/42	57.14	4.139	1.035	0.881
LOW TIDE	Jetty	200	23/42	54.76	4.152	0.942	0.832
	SPM	294	32/42	76.19	5.454	1.036	0.867

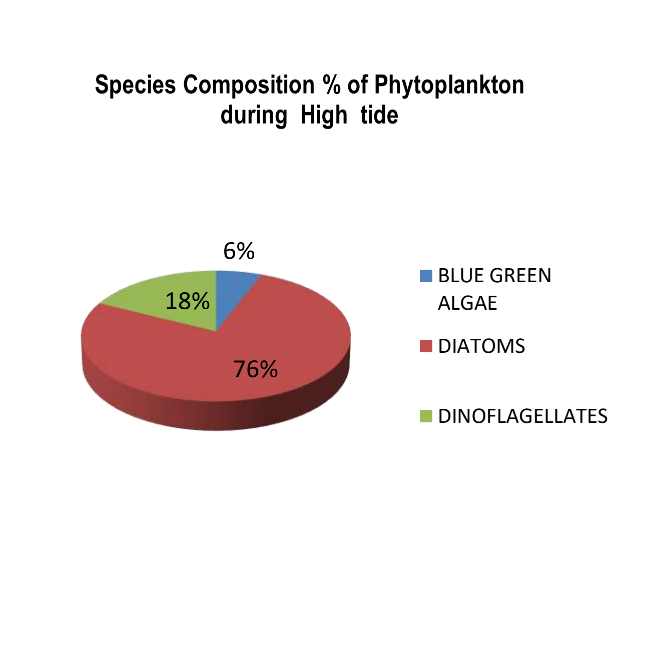
TABLE:-53 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPAOOT AT PATH FINDER CREEK, VADINAR & NEAR BY SPM, DURING SPRING TIDE IN NOVEMBER 2022

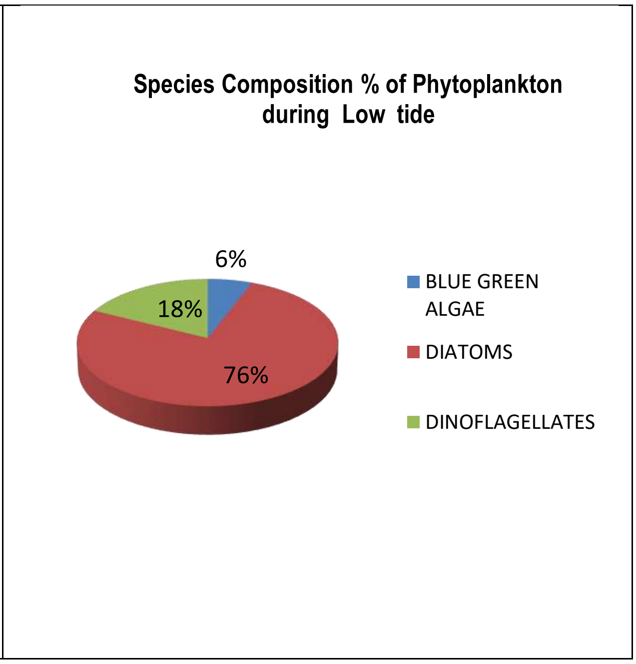
Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAE	14-20	5/36	13.89
			DIATOMS	180-192	25/36	69.44
			DINOFLAGELLATES	3-6	6/36	16.67
			TOTAL PHYTO PLANKTON	**206-209**	**36**	
LOW TIDE	Sub surface	2	BLUE GREEN ALGAE	12-19	5/36	13.89
			DIATOMS	118-156	25/36	69.44
			DINOFLAGELLATES	1-2	6/36	16.67
			TOTAL PHYTO PLANKTON	**131-177**	**36**	

Table:- 54 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN NOVEMBER 2022

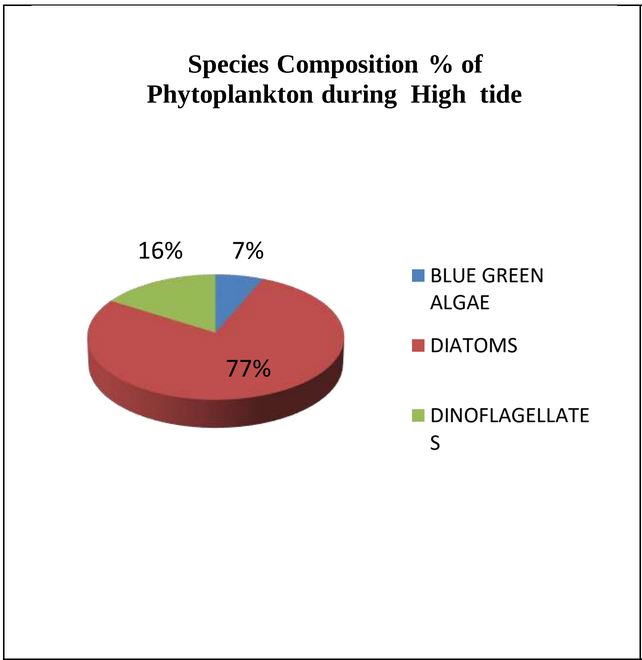
Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Species Composition % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAE	5-7	4/42	9.52
			DIATOMS	238-248	32/42	76.19
			DINOFLAGELLATES	1-4	6/42	14.29
			TOTAL PHYTO PLANKTON	**244-259**		
LOW TIDE	Sub surface	2	BLUE GREEN ALGAE	4-8	4/42	9.52
			DIATOMS	194-282	32/42	76.19
			DINOFLAGELLATES	2-4	6/42	14.29
			TOTAL PHYTO PLANKTON	**200-294**		

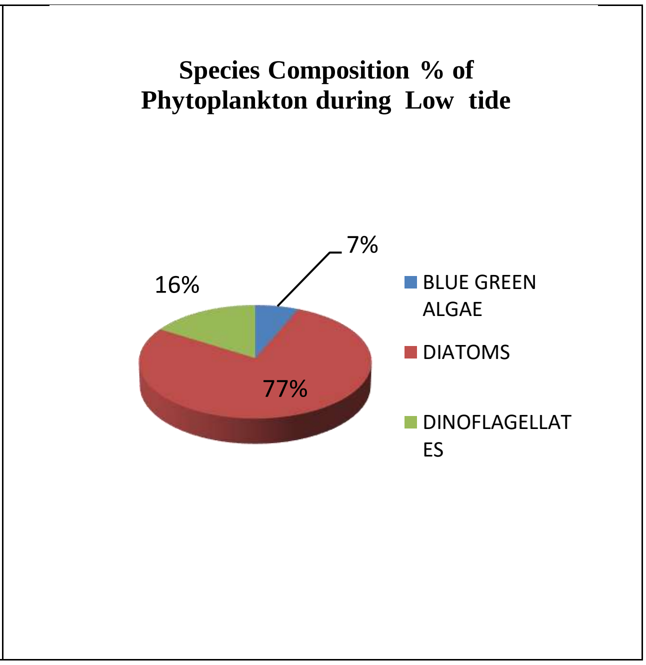
Species Composition % of Phytoplankton during High tide and Low tide period during spring tide in Kandla creek and nearby creeks



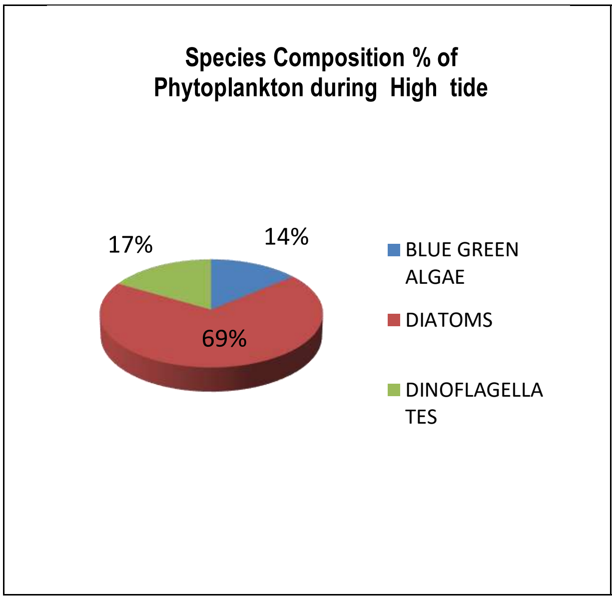


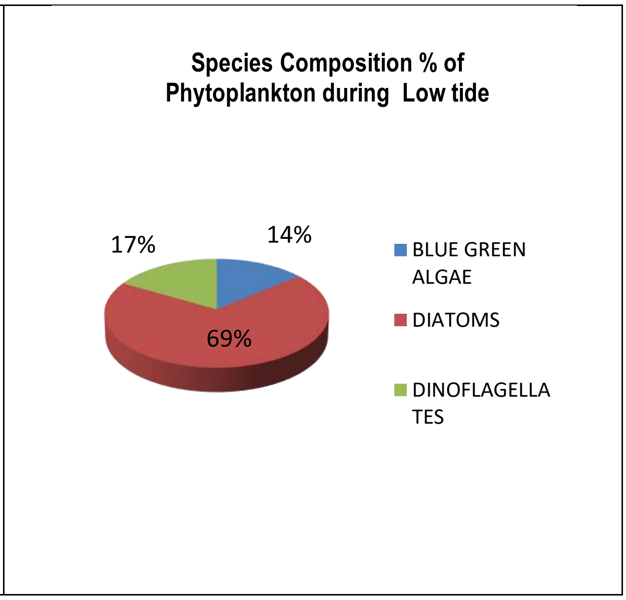
Species Composition % of Phytoplankton during High tide and Low tide period during Neap tide in Kandla creek and nearby creeks



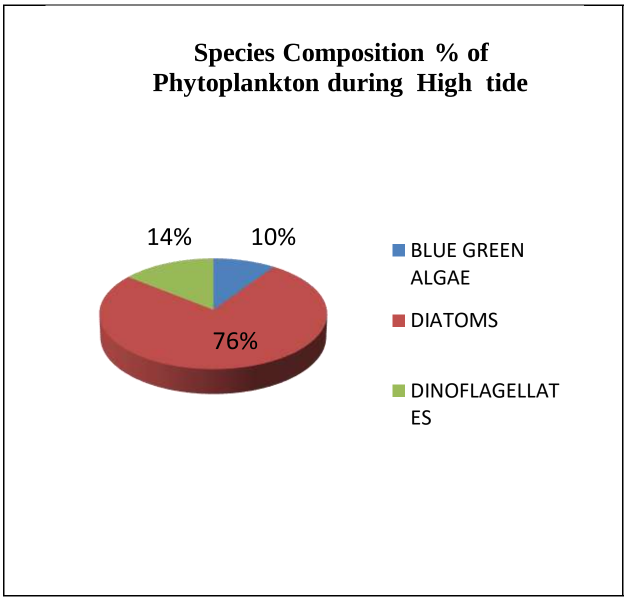


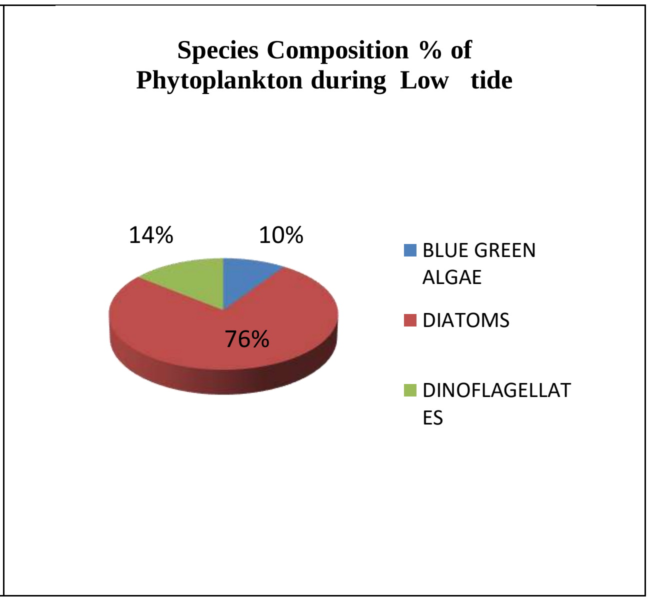
Species Composition % of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar





Species Composition % of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar





ZOOPLANKTON POPULATION:

For the evaluation of the Zooplankton population in DPA harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khoricreek) during high tide period and low tide period of spring tide and Neap tide in November, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was representedby mainly six groups;Tintinnids, Copepods,Arrow worms,Mysids, Urochordata,Ciliates and 8 larval forms.The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly six groups;Tintinnids, Copepods,Arrow worms, Mysids, Urochordata, Ciliatesand 6 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from 25-128 $x10^3$ N/m^3 during high tide and 103-144$x10^3$ N/m^3 during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from 19-114$x10^3$ N/m^3 during high tide and 76-106$x10^3$ N/ m^3 during low tide of Neap Tide period.

For the evaluation of the Zooplankton population in DPA OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM).

During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly four groups Tintinnids, Copepods, Urochordata, Ciliatesand 4 larval forms. While the Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by four groups, Tintinnids, Copepods, Arrow worms, Urochordataand 5 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT Jetty area of path finder creek was 91$x10^3$ N/m^3 during high tide and 86$x10^3$ N/m^3 during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA SPM area of path finder creek was 101$x10^3$ N/m^3 during high tide and 70$x10^3$ N/ m^3 during low tide of spring Tide period.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT jetty area in path finder creek was recorded 87$x10^3$ N/m^3 during high tide and 65$x10^3$ N/ m^3 during consecutive low tide period of Neap tide. Zooplankton of the sampling stations at sub surface layer in the DPASPM area in path finder creek was recorded 64$x10^3$ N/m^3during high tide and 87$x10^3$ N/ m^3 during consecutive low tide period of Neap Tide.

Species Richness Indices and Diversity Indices:

Margalef's diversity index (Species Richness)

Margalef's diversity index (Species Richness) of Zooplankton communities in the stations Kandla creek region and nearby creeks was varying from 2.175- 5.186 with an average of 3.450 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) of Zooplankton communities varying from 2.373-3.823 with an average of 3.261 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations were varying from1.358-3.858 with an average of 2.930 during the sampling conducted in high tide and varying from 2.289- 4.618 with an average of 3.513 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling stationnear jettyat Path Finder Creek, Vadinar during the sampling conducted inconsecutive high tide period and low tide of spring tide was recorded as 1.995 and 1.796 respectively. Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive high tide period and low tide of spring tide was recorded as 2.600 and 2.118 respectively.

Margalef's diversity index (Species Richness) of Zooplankton communities near Jetty at Path finder creek were varying from 3.807 and 2.396 respectivelyduring the sampling conducted in consecutive high tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) of Zooplankton communities near SPM at Path finder creek were varying from 2.645-3.135 respectively during the consecutive high tide and low tide period.

Shannon-Wiener's index:

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.778-1.164 between selected sampling stations with an average value of0.939 during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.795-1.015 between selected sampling stations with an average value of0.938 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.490-0.914 between selected sampling stations with an average value of 0.805 during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 0.797-1.041 of between selected sampling stations with an average value of 0.928 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.816-0.793 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.834-0.808 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.956-0.755 respectively during the sampling conducted consecutive high tide period and low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 0.775-0.751during the consecutive high tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

Simpson's diversity index:

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.780-0.909 between selected sampling stations with an average of 0.837 during high tide period and was varying from 0.785- 0.864 with an average value of 0.837 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of Neap tide except few, which was varying from 0.591-0.827 between selected sampling stations with an average of 0.753 during high tide period and was varying from 0.793-0.852 with an average value of 0.820 between selected sampling stations during consecutive low tide. This species diversity suggests a relatively few successful species in this habitat during November, 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.821 and 0.815 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.812 and 0.828 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.836- 0.766 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.768 and 0.719 respectively.

TABLE:-55 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDEIN NOVEMBER 2022

Tide	Sampling Station	Abundance In Nx10^3/ m^3	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log_{10})	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	124	26/33	78.79	5.186	1.164	0.9089
	2	114	18/33	54.55	3.589	0.8655	0.7802
	3	102	16/33	48.48	3.243	0.9207	0.8189
	4	128	17/33	51.52	3.298	0.9062	0.8124
	5	107	16/33	48.48	3.21	0.997	0.8686
	6	25	8/33	24.24	2.175	0.7777	0.83
LOW TIDE	1	117	16/33	48.48	3.15	0.9709	0.8609
	2	144	20/33	60.61	3.823	0.9468	0.8238
	3	121	19/33	57.58	3.753	1.015	0.8639
	4	108	16/33	48.48	3.204	0.9609	0.8505
	5	103	12/33	36.36	2.373	0.7949	0.7853

TABLE:-56 ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREAAT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE INNOVEMBER 2022

Tide	Sampling Station	Abundance In No x10^3/ m^3	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log_{10})	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	82	18/32	56.25	3.858	0.9017	0.7814
	2	99	16/32	50.00	3.264	0.9138	0.8273
	3	89	13/32	40.63	2.673	0.8264	0.7763
	4	114	18/32	56.25	3.589	0.8478	0.7645
	5	98	14/32	43.75	2.835	0.8503	0.7766
	6	19	5/32	15.63	1.358	0.4901	0.5906
LOW TIDE	1	79	11/32	34.38	2.289	0.797	0.7932
	2	76	21/32	65.63	4.618	1.041	0.8516
	3	106	21/32	65.63	4.289	1.026	0.8446
	4	90	15/32	46.88	3.111	0.9087	0.8177
	5	100	16/32	50.00	3.257	0.865	0.7939

Table:-57 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREAATKANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN NOVEMBER 2022

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $x10^3/m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	tintinnids	9-26	11/33	33.33
			Copepods	11-51	9/33	27.27
			Arrow worms	0-1	1/33	3.03
			Mysids	0-2	1/33	3.03
			Urochordata	1-6	2/33	6.06
			Ciliates	0-2	1/33	3.03
			Larval forms	4-50	8/33	24.25
			TOTAL ZOOPLANKTON N/ M^3	**25-128**	**33**	
LOW TIDE	Sub surface	5	Tintinnids	18-33	11/33	33.33
			Copepods	37-49	9/33	27.27
			Arrow worms	0-4	1/33	3.03
			Mysids	0-2	1/33	3.03
			Urochordata	0-2	2/33	6.06
			Ciliates	0-2	1/33	3.03
			Larval forms	41-65	8/33	24.25
			TOTAL ZOOPLANKTON N/M^3	**103-144**	**33**	

TABLE:-58 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN NOVEMBER 2022

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $x10^{3}/m^{3}$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinnids	0-14	10/32	31.25
			Copepods	6-49	10/32	31.25
			Arrow worms	0	1/32	3.13
			Mysids	0-6	2/32	6.25
			Urochordata	0-4	2/32	6.25
			Ciliates	0-2	1/32	3.13
			Larval forms	13-50	6/32	18.74
			TOTAL ZOOPLANKTON N/M^{3}	**19-114**	**32**	
LOW TIDE	Sub surface	5	tintinnids	4-17	10/32	31.25
			Copepods	25-45	10/32	31.25
			Arrow worms	0-2	1/32	3.13
			Mysids	0-6	2/32	6.25
			Urochordata	0-5	2/32	6.25
			Ciliates	0-1	1/32	3.13
			Larval forms	27-47	6/32	18.74
			TOTAL ZOOPLANKTON N/M^{3}	**76-106**	**32**	

Table:-59 ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN NOVEMBER 2022

Tide	Sampling Station	Abundance In $x10^{3}N/m^{3}$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ($\log_{10}$)	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	91	10/20	50.00	1.995	0.816	0.821
	SPM	101	13/20	65.00	2.6	0.834	0.812
LOW TIDE	Jetty	86	9/20	45.00	1.796	0.793	0.815
	SPM	70	10/20	50.00	2.118	0.808	0.828

TABLE:-60 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURINGNEAP TIDE IN NOVEMBER 2022

Tide	Sampling Station	Abundance In $Nx10^3/m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log_{10})	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	87	18/21	85.71	3.807	0.956	0.836
	SPM	64	12/21	57.14	2.645	0.775	0.768
LOW TIDE	Jetty	65	11/21	52.38	2.396	0.755	0.766
	SPM	87	15/21	71.43	3.135	0.751	0.719

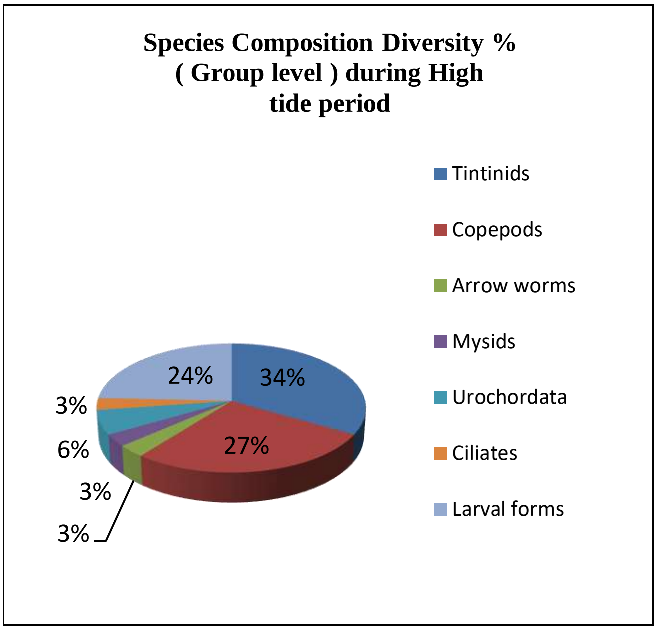
Table:-61 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREAAND PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN NOVEMBER 2022

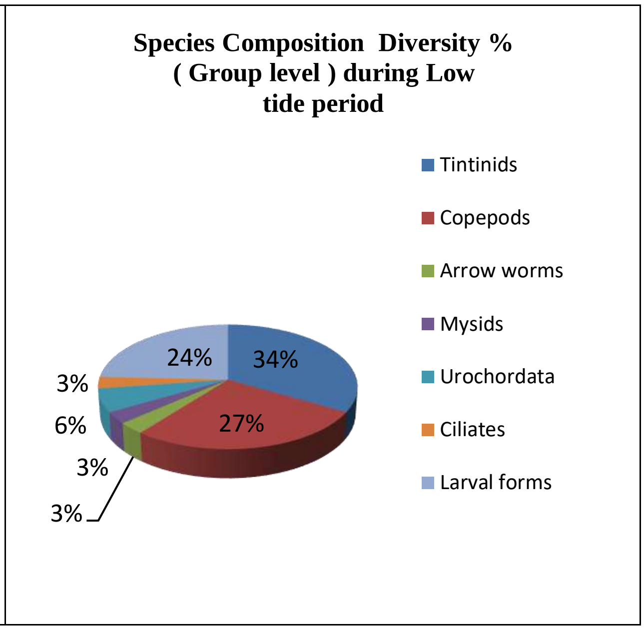
Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $x10^3/m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinnids	24-32	5/20	25.00
			Copepods	28-38	8/20	40.00
			Urochordata	1-2	2/20	10.00
			Ciliates	0-1	1/20	5.00
			Larval forms	30-36	4/20	20.00
			TOTAL ZOOPLANKTON	**91-101**	**20**	
LOW TIDE	Sub surface	2	Tintinnids	17-21	5/20	25.00
			Copepods	30-37	8/20	40.00
			Urochordata	0	2/20	10.00
			Ciliates	0	1/20	5.00
			Larval forms	19-32	4/20	20.00
			TOTAL ZOOPLANKTON	**70-86**	**20**	

TABLE:-62 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN NOVEMBER 2022

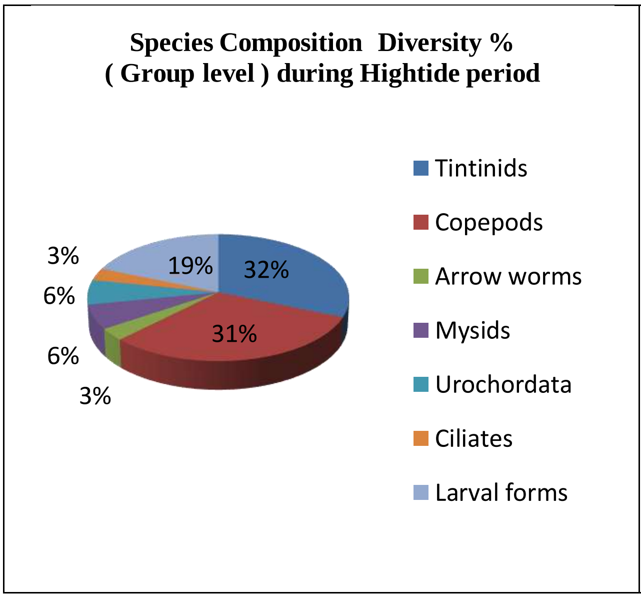
Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $x10^3/m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	tintinnids	9-16	7/21	33.33
			Copepods	23-34	6/21	28.57
			Arrow worms	0	1/21	4.76
			Urochordata	0-2	2/21	9.52
			Larval forms	32-35	5/21	23.82
			TOTAL ZOOPLANKTON	**64-87**	**21**	
LOW TIDE	Sub surface	2	tintinnids	6-9	7/21	33.33
			Copepods	29	6/21	28.57
			Arrow worms	0-1	1/21	4.76
			Urochordata	0-3	2/21	9.52
			Larval forms	27-48	5/21	23.82
			TOTAL ZOOPLANKTON	**65-87**	**21**	

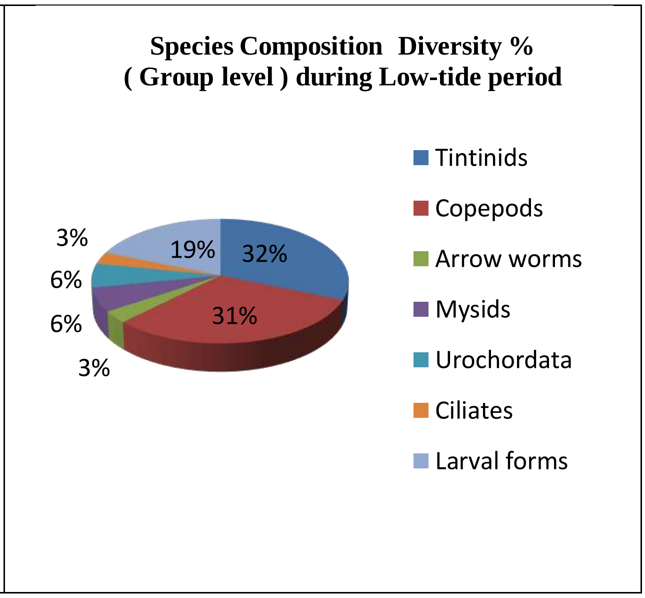
Species Composition % of Zooplankton during High tide and Low tide period of spring tide In Kandla Creek and nearby Creeks



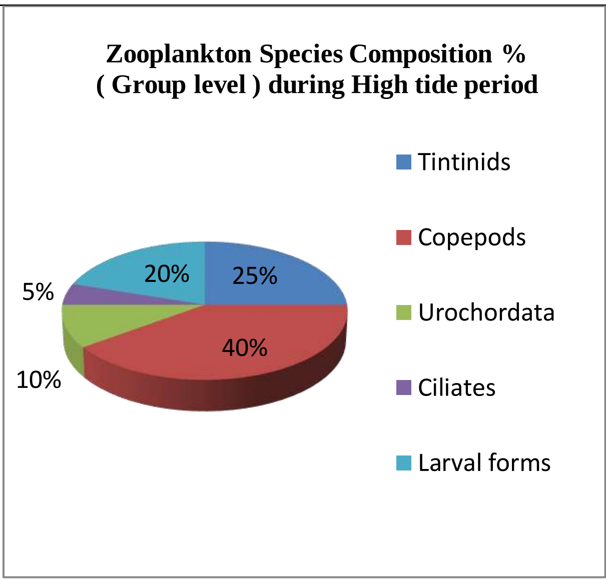


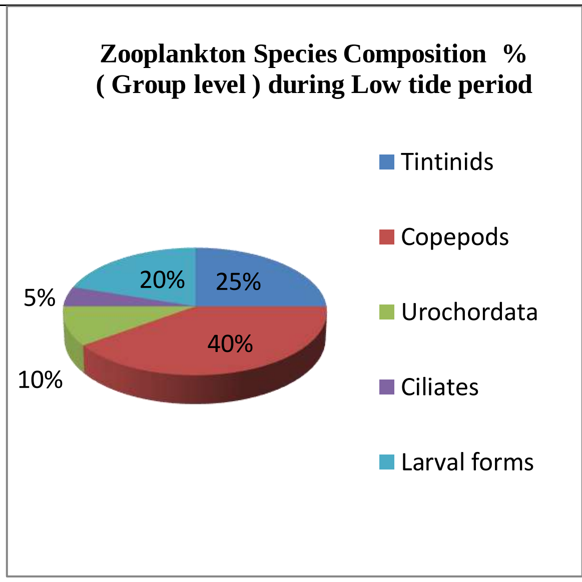
Species Composition % of Zooplankton during High tide and Low tide period of Neap tide In Kandla Creek and nearby Creeks



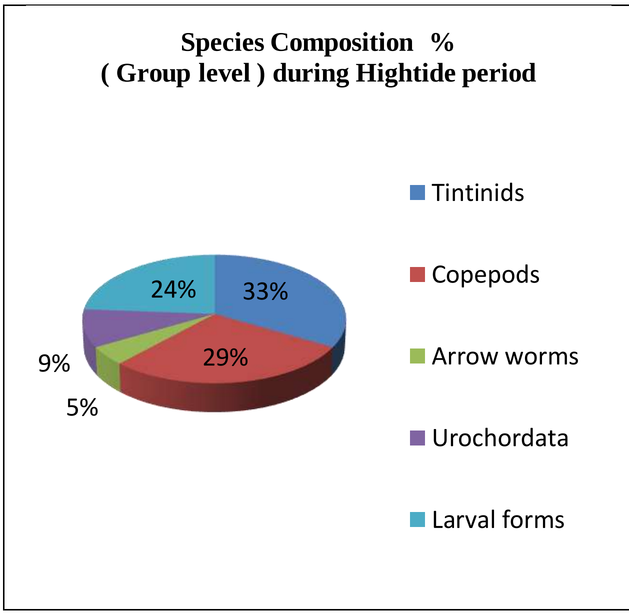


Species Composition % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty





Species Composition % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM



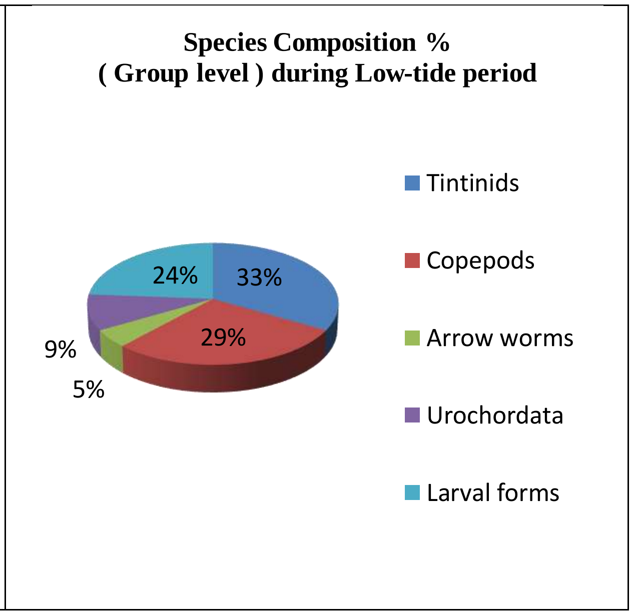


TABLE:-63 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF NOVEMBER 2022

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	*Oscillatoria sp.*	B1	Very sparse
	Oscillatoriales	Phormidiaceae	*Planktothrix sp.*	B2	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	*Biddulphia*sp	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	*Bacteriastrum sp*	D2	Very sparse
			Chaetoceros sp.	D3	Scattered
	Corethrales	Corethraceae	*Corethron* sp	D4	Very sparse
	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus sp.*	D5	Dominant
	Hemiaulales	Bellerocheaceae	*Bellerochea* sp	D6	Very sparse
		Streptothecaceae	*Helicotheca sp*	D7	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia sp.*	D8	Sparse
	Lithodesmiales	Lithodesmiaceae	*Ditylum sp*	D9	Dominant
	Thalassiosirales	Thalassiosiraceae	*Planktoniella*sp	D10	Very sparse
		Skeletonemataceae	*Skeletonema*sp	D11	Abundant
	Triceratiales	Triceratiaceae	*Odontella* sp.	D12	Very sparse
			Triceratium sp.	D13	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	*Bacillaria* sp.	D14	Very sparse
			Nitzschia sp	D15	Sparse
			Pseudo-nitzschia sp.	D16	Very sparse
	Naviculales	Pleurosigmataceae	*Pleurosigma* sp.	D17	Very sparse
	Surirellales	Entomoneidaceae	*Entomoneis sp.*	D18	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	*Asterionellopsis sp*	D19	Scattered
			*Fragilaria*sp	D20	Very sparse
			*Synedra*sp	D21	Very sparse

	Striatellales	Striatellaceae	*Grammatophora sp*	D22	Very sparse
	Thalassionematales	Thalassionemataceae	*Thalassionema sp.*	D23	Sparse
			Thalassiothrix sp.	D24	Very sparse
Noctilucea / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	*Noctiluca* sp.	DF1	Sparse
Dinophyceae	Peridiniales	Protoperidiniaceae	*Protoperidinium sp.*	DF2	Very sparse
	Gonyaulacales	Pyrophacaceae	*Pyrophacus sp.*	DF3	Very sparse
		Ceratiaceae	*Ceratium furca*	DF4	Very sparse
			Ceratium tripos	DF5	Very sparse

TABLE:-64 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF NOVEMBER 2022:

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	*Oscillatoria sp.*	B1	Very sparse
	Oscillatoriales	Phormidiaceae	*Planktothrix sp.*	B2	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	*Biddulphia*sp	D1	Sparse
	Chaetocerotales	Chaetocerotaceae	*Chaetoceros* sp.	D2	Abundant
	Corethrales	Corethraceae	*Corethron* sp	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus sp.*	D4	Abundant
	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia sp.*	D5	Sparse
	Leptocylindrales	Leptocylindraceae	*Leptocylindrus sp*	D6	Very sparse
	Lithodesmiales	Lithodesmiaceae	*Ditylum sp*	D7	Scattered
	Thalassiosirales	Thalassiosiraceae	*Planktoniella*sp	D8	Very sparse
		Lauderiaceae	*Lauderia* sp	D9	Very sparse
		Skeletonemataceae	*Skeletonema*sp	D10	Dominant
	Triceratiales	Triceratiaceae	*Odontella* sp.	D11	Very sparse
			Triceratium sp.	D12	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	*Bacillaria* sp.	D13	Very sparse
			Nitzschia sp	D14	Very sparse
			Pseudo-nitzschia sp.	D15	Very sparse
	Naviculales	Naviculaceae	*Navicula* sp.	D16	Very sparse
		Plagiotropidaceae	*Plagiotropis sp*	D17	Very sparse
		Pleurosigmataceae	*Pleurosigma* sp.	D18	Sparse
	Surirellales	Entomoneidaceae	*Entomoneis sp.*	D19	Very sparse
		Surirellaceae	*Surirella sp.*	D20	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	*Asterionellopsis sp*	D21	Sparse

			*Fragilaria*sp	D22	Very sparse
			*Synedra*sp	D23	Sparse
	Striatellales	Striatellaceae	*Grammatophora sp*	D24	Very sparse
	Thalassionematales	Thalassionemataceae	*Thalassionema sp.*	D25	Scattered
			Thalassiothrix sp.	D26	Sparse
Noctilucea / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	*Noctiluca* sp.	DF1	Sparse
Dinophyceae	Peridiniales	Protoperidiniaceae	*Protoperidinium sp.*	DF2	Very sparse
	Gonyaulacales	Ceratiaceae	*Ceratium breve*	DF3	Very sparse
			Ceratium furca	DF4	Very sparse
			Ceratium fusus	DF5	Very sparse
			Ceratium tripos	DF6	Very sparse

TABLE:-65 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING NEAP TIDE OF NOVEMBER 2022:

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	*Lyngbya sp.*	B1	Very sparse
			Oscillatoria sp.	B2	Very sparse
			Spirulina sp.	B3	Very sparse
	Oscillatoriales	Phormidiaceae	*Planktothrix sp.*	B4	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	*Biddulphia*sp	D1	Scattered
	Chaetocerotales	Chaetocerotaceae	*Chaetoceros*sp	D2	Scattered
	Corethrales	Corethraceae	*Corethron* sp	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus sp.*	D4	Dominant
	Hemiaulales	Bellerocheaceae	*Bellerochea*sp	D5	Very sparse
		Hemiaulaceae	*Cerataulina sp.*	D6	Very sparse
			Eucampia sp	D7	Very sparse
		Streptothecaceae	*Helicotheca sp*	D8	Very sparse
	Leptocylindrales	Leptocylindraceae	*Leptocylindrus sp*	D9	Very sparse
	Lithodesmiales	Lithodesmiaceae	*Ditylumsp*	D10	Abundant
	Rhizosoleniales	Rhizosoleniaceae	*Dactyliosolen sp.*	D11	Very sparse
			Rhizosolenia sp.	D12	Sparse
	Thalassiosirales	Skeletonemataceae	*Skeletonema sp.*	D13	Abundant
		Lauderiaceae	*Lauderia sp*	D14	Very sparse
		Thalassiosiraceae	*Planktoniella*sp	D15	Very sparse
	Triceratiales	Triceratiaceae	*Odontellasp*	D16	Very sparse
			*Triceratium*sp	D17	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	*Bacillaria*sp.	D18	Abundant
			Nitzschia sp	D19	Very sparse

			*Pseudo-nitzschia*sp	D20	Scattered
	Naviculales	Naviculaceae	*Meuniera sp.*	D21	Very sparse
			Navicula sp	D22	Very sparse
		Pinnulariaceae	*Pinnulariasp*	D23	Very sparse
		Pleurosigmataceae	*Pleurosigma* sp	D24	Very sparse
	Surirellales	Entomoneidaceae	*Entomoneis sp.*	D25	Very sparse
		Surirellaceae	*Surirella*sp	D26	Very sparse
Fragilariophyceae	Climacospheniales	Climacospheniaceae	*Climacosphenia sp.*	D27	Very sparse
	Fragilariales	Fragilariaceae	*Asterionellopsis sp.*	D28	Very sparse
			Synedra sp.	D29	Very sparse
	Striatellales	Striatellaceae	*Striatella*sp	D30	Very sparse
	Thalassionematales	Thalassionemataceae	*Thalassionema sp.*	D31	Sparse
			Thalassiothrix sp.	D32	Sparse
Dinophyceae	Peridiniales	Protoperidiniaceae	*Protoperidinium sp.*	DF1	Very sparse
	Dinophysales	Dinophysaceae	*Dinophysis sp.*	DF2	Very sparse
	Gonyaulacales	Pyrophacaceae	*Pyrophacus sp.*	DF3	Very sparse
		Ceratiaceae	*Ceratium furca*	DF4	Very sparse
			Ceratium fusus	DF5	Very sparse
			Ceratium tripos	DF6	Very sparse

TABLE:-66 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPAOOT AREA AT PATH FINDER CREEKAND NEARBY SPM AT VADINAR DURING AND SPRING TIDE OF NOVEMBER 2022:

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Chroococcales	Chroococcaceae	*Merismopedia sp.*	B1	Very sparse
	Nostocales	Oscillatoriaceae	*Lyngbya sp.*	B2	Very sparse
			Oscillatoria sp.	B3	Sparse
	Oscillatoriales	Phormidiaceae	*Planktothrix sp.*	B4	Very sparse
	Stigonematales	Stigonemataceae	*Stigonema sp.*	B5	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	*Biddulphia*sp	D1	Sparse
	Chaetocerotales	Chaetocerotaceae	*Chaetoceros* sp.	D2	Dominant
	Corethrales	Corethraceae	*Corethron* sp	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	*Coscinodiscus sp.*	D4	Abundant
	Hemiaulales	Bellerocheaceae	*Bellerochea* sp	D5	Very sparse
		Hemiaulaceae	*Cerataulina sp.*	D6	Very sparse
		Streptothecaceae	*Helicotheca sp*	D7	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia sp.*	D8	Scattered
	Leptocylindrales	Leptocylindraceae	*Leptocylindrus sp*	D9	Very sparse
	Lithodesmiales	Lithodesmiaceae	*Ditylum sp*	D10	Abundant
	Thalassiosirales	Thalassiosiraceae	*Planktoniella*sp	D11	Very sparse
		Lauderiaceae	*Lauderia* sp	D12	Very sparse
	Triceratiales	Triceratiaceae	*Odontella* sp.	D13	Sparse
			Triceratium sp.	D14	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	*Bacillaria* sp.	D15	Scattered
			Nitzschia sp	D16	Very sparse
			Pseudo-nitzschia sp.	D17	Sparse
	Naviculales	Pinnulariaceae	*Pinnulariasp*	D18	Very sparse

		Pleurosigmataceae	*Pleurosigma* sp.	D19	Very sparse
	Surirellales	Entomoneidaceae	*Entomoneis sp.*	D20	Very sparse
		Surirellaceae	*Surirella sp.*	D21	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	*Asterionellopsis sp*	D22	Sparse
			*Synedra*sp	D23	Very sparse
	Thalassionematales	Thalassionemataceae	*Thalassionema sp.*	D24	Sparse
			Thalassiothrix sp.	D25	Very sparse
Dinophyceae	Peridiniales	Protoperidiniaceae	*Protoperidinium sp.*	DF1	Very sparse
	Dinophysales	Dinophysaceae	*Dinophysis sp.*	DF2	Very sparse
	Gonyaulacales	Pyrophacaceae	*Pyrophacus sp.*	DF3	Very sparse
		Ceratiaceae	*Ceratium furca*	DF4	Very sparse
			Ceratium fusus	DF5	Very sparse
			Ceratium tripos	DF6	Very sparse

TABLE:-67 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKSDURING NEAP TIDE OF NOVEMBER 2022:

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	*Leprotintinnussp.*	T1	Very sparse
		Codonellidae	*Tintinnopsis dadayi*	T2	Very sparse
			Tintinnopsisfailakkaensis	T3	Very sparse
			Tintinnopsis gracilis	T4	Very sparse
			Tintinnopsis mortensenii	T5	Very sparse
			Tintinnopsis radix	T6	Very sparse
			Tintinnopsis tocantinensis	T7	Very sparse
		Tintinnidae	*Amphorellopsis sp.*	T8	Very sparse
			Eutintinnus sp.	T9	Very sparse
		Xystonellidae	*Favella sp.*	T10	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	*Acrocalanus* sp.	C1	Sparse
			Parvocalanus sp.	C2	Very sparse
		Acartiidae	*Acartia sp.*	C3	Very sparse
		Clausocalanidae	*Clausocalanus sp.*	C4	Very sparse
		Centropagidae	*Centropages sp.*	C5	Very sparse
		Temoridae	*Temora sp.*	C6	Very sparse
	Cyclopoida	Oithonidae	*Oithona sp.*	C7	Abundant
	Harpacticoida	Ectinosomatidae	*Microsetella*sp.	C8	Scattered
		Euterpinidae	*Euterpina sp.*	C9	Sparse
	Poicilostomatatoida	Oncaeidae	*Oncaea sp.*	C10	Very sparse
Sagittoidea	Aphragmophora	Sagittidae	*Sagitta sp.*	A1	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	*Metapenaeussp.*	M1	Very sparse
		Solenoceridae	*Solenocera sp.*	M2	Very sparse

Appendicularia		Fritillariidae	*Fritillaria sp.*	U1	Very sparse
		Oikopleuridae	*Oikopleura sp.*	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	*Zoothamnium sp.*	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea	L2	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Polychaeta			Trochophore larvae	L6	Very sparse

TABLE:-68 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKSDURING SPRING TIDE OF NOVEMBER 2022:

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	*Leprotintinnussp.*	T1	Scattered
		Codonellidae	*Tintinnopsis dadayi*	T2	Very sparse
			Tintinnopsisfailakkaensis	T3	Very sparse
			Tintinnopsis gracilis	T4	Very sparse
			Tintinnopsis mortensenii	T5	Very sparse
			Tintinnopsis radix	T6	Sparse
			Tintinnopsis tocantinensis	T7	Very sparse
		Metacylididae	*Metacylis*sp.	T8	Very sparse
		Tintinnidae	*Amphorellopsis sp.*	T9	Very sparse
			Eutintinnus sp.	T10	Very sparse
		Xystonellidae	*Favella sp.*	T11	Sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	*Acrocalanus* sp.	C1	Scattered
			Parvocalanus sp.	C2	Very sparse
		Acartiidae	*Acartia sp.*	C3	Very sparse
		Clausocalanidae	*Clausocalanus sp.*	C4	Very sparse
		Centropagidae	*Centropages sp.*	C5	Very sparse
		Eucalanidae	*Subeucalanus sp.*	C6	Very sparse
	Cyclopoida	Oithonidae	*Oithona sp.*	C7	Abundant
	Harpacticoida	Ectinosomatidae	*Microsetella*sp.	C8	Sparse
		Euterpinidae	*Euterpina sp.*	C9	Sparse
Sagittoidea	Aphragmophora	Sagittidae	*Sagitta sp.*	A1	Very sparse
Malacostraca	Mysida, Decapoda	Solenoceridae	*Solenocera sp.*	M1	Very sparse

Appendicularia		Fritillariidae	*Fritillaria sp.*	U1	Very sparse
		Oikopleuridae	*Oikopleura sp.*	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	*Zoothamnium sp.*	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea	L2	Sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L6	Very sparse
Polychaeta			Trochophore larvae	L7	Sparse
Pelecypoda			Veliger larvae of bivalves	L8	Very sparse

TABLE:-69 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING NEAP TIDE OF NOVEMBER 2022:

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	*Leprotintinnussp.*	T1	Sparse
		Codonellidae	*Tintinnopsisfailakkaensis*	T2	Very sparse
			Tintinnopsis gracilis	T3	Very sparse
			Tintinnopsis radix	T4	Very sparse
			Tintinnopsis tocantinensis	T5	Very sparse
		Tintinnidae	*Amphorellopsis sp.*	T6	Very sparse
		Xystonellidae	*Favella sp.*	T7	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	*Acrocalanus* sp.	C1	Scattered
			Parvocalanus sp.	C2	Very sparse
	Cyclopoida	Oithonidae	*Oithona sp.*	C3	Abundant
	Harpacticoida	Euterpinidae	*Euterpina sp.*	C4	Very sparse
		Ectinosomatidae	*Microsetella*sp.	C5	Very sparse
	Poicilostomatatoida	Oncaeidae	*Oncaea sp.*	C6	Very sparse
Sagittoidea	Aphragmophora	Sagittidae	*Sagitta sp.*	A1	Very sparse
Appendicularia		Fritillariidae	*Fritillaria sp.*	U1	Very sparse
		Oikopleuridae	*Oikopleura sp.*	U2	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Maxillopoda Thecostraca			Cirripede larvae	L2	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L3	Very sparse
Polychaeta			Trochophore larvae	L4	Very sparse
Pelecypoda			Veliger larvae of bivalves	L5	Very sparse

TABLE:-70 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF NOVEMBER 2022:

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	*Leprotintinnussp.*	T1	Abundant
		Codonellidae	*Tintinnopsisgracilis*	T2	Very sparse
			Tintinnopsis mortensenii	T3	Very sparse
			Tintinnopsis radix	T4	Very sparse
		Xystonellidae	*Favella sp.*	T5	Scattered
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	*Acrocalanus* sp.	C1	Sparse
			Parvocalanus sp.	C2	Very sparse
		Centropagidae	*Centropages sp.*	C3	Very sparse
		Tortanidae	*Tortanus sp.*	C4	Very sparse
	Cyclopoida	Oithonidae	*Oithona sp.*	C5	Abundant
		Euterpinidae	*Euterpina sp.*	C6	Very sparse
	Harpacticoida	Ectinosomatidae	*Microsetella*sp.	C7	Scattered
	Poicilostomatatoida	Corycaeidae	*Corycaeus sp.*	C8	Very sparse
Appendicularia		Fritillariidae	*Fritillaria sp.*	U1	Very sparse
		Oikopleuridae	*Oikopleura sp.*	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	*Zoothamnium sp.*	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea	L2	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L3	Very sparse
Pelecypoda			Veliger larvae of bivalves	L4	Very sparse

BENTHIC ORGANISMS:

Few Benthic organisms were observed in the collected sediments by using the Van-Veen grabs during the sampling conducted during spring tide period and Neap tide period from DPA harbour region and nearby creek. The Meio-benthic organisms during spring tide were represented by Polychaetes *Tharyx sp*and *Nereis sp.*, during Neap tide *by Neries sp*. and few Amphipods. Population of benthic fauna was varying from 10-60- N/m^2 during spring tide and 0-80 N/m^2 during Neap tide. The benthic communities at path finder Creek were represented by Polychaetes *Glycera* sp. *Cirratulus* sp. *Nereis sp*. and few Amphipods. Their population was varying as 60 N/m^2 at OOT jetty premises and 80 N/m^{2} near the SPM area during spring tide and 50 N/m^2 at OOT jetty premises and 50 N/m^2 near the SPM area during Neap tide period.

Table:-71 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING SPRING TIDE IN NOVEMBER 2022

ABUNDANCE IN NO/M ^{2} DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
Benthic fauna						
POLYCHAETES	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family : CIRRATULIDAE *Tharyxsp.*	20	10	10	0	0	NS
Family :NEREIDAE *Nereis sp.*	0	0	0	20	40	NS
AMPHIPODA	0	0	0		20	NS
TOTAL Benthic Fauna NUMBER/ M^2	20	10	10	20	60	NS

NS: No sample

Table:-72 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING NEAP TIDE IN NOVEMBER 2022

ABUNDANCE IN NO/M^2 DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
Benthic fauna						
POLYCHAETES	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family :NEREIDAE *Nereis sp.*	0	0	0	40	60	NS
Amphipoda	0	20	10	10	20	NS
TOTAL Benthic Fauna NUMBER/M^2	0	20	10	50	80	NS

Table:-73 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA, VADINAR DURING SPRING TIDE IN NOVEMBER 2022

ABUNDANCE IN NO/M ^{2} DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
POLYCHAETES		
Family : Glyceride *Glycera*sp.	20	40
Family : CIRRATULIDAE *Cirratulus*sp.	0	20
Family: *NEREIDAE* *Nereis sp.*	30	10
Amphipoda	10	20
TOTAL Benthic Fauna NUMBER/ M^2	60	80

Table:-74 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA, VADINAR DURING NEAP TIDE IN NOVEMBER 2022

ABUNDANCE IN NO/M ^{2} DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
POLYCHAETES		
Family : Glyceridase *Glycera* sp.	20	40
Family: *NEREIDAE* *Nereis sp.*	30	10
TOTAL Benthic Fauna NUMBER/ M^2	50	50

CHAPTER-11

CONCLUSIVE SUMMARY & REMEDIAL MEASURES

11.0 Conclusive Summary and Remedial measures Suggested

- The AAQ monitoring of six locations at Deendayal Port Authority indicates that the mean PM_{10} and $PM_{2.5}$ values for four locations viz. Marine Bhavan, Oil Jetty, Estate Office and Coal storage area were found higher than the permissible limit (standards100 µg/m^3, 60 µg/m^3). The higher concentration of Particulate matter at Marine Bhavan may be due to vehicles emissions during loading-unloading of food grains and timbers; at Estate office due to construction work, vehicles emission produced from trucks, heavy duty vehicles that pass through the road outside Kandla port and Oil jetty area; while at Coal Storage area lifting of coal from grab yard and other coal handling processes. Moreover, the transportation of coal produces pollution from heavy vehicles. At Tuna Port location, concentration of PM_{10} varied from 88-175 µg/m^3 and mean value was observed 145 µg/m^3 which was exceed the prescribed standard limit (100 µg/m^3), concentration of $PM_{2.5}$ was ranged from 47-87 µg/m^3 and mean was found 71 µg/m^3 which was exceed the standard limit (60 µg/m^3). At Gopalpuri PM_{10} concentration ranged from 67-168 µg/m3 and mean was 127 µg/m3 while $PM_{2.5}$ concentration ranged from 34-94 µg/m3 and mean was 66 µg/m3 were found exceed standard limit prescribed by NAAQS.
- At Vadinar, the average concentration of PM_{10} was 114 µg/m^3 and $PM_{2.5}$ was 74 µg/m^3 at Admin Colony which was slightly exceed the standard limit while at Signal building the mean concentration PM_{10} was 100 µg/m3 and $PM_{2.5}$ was 61 µg/m^3 which were very close to standard limit.
- During winter, the concentration of PM_{10} and $PM_{2.5}$ has been slowly augmented and reached a peak in the evening due to surface inversion of temperature after sunset. Thus, the pollutants are subsequently trapped in the lower layer of the atmosphere due to high atmospheric air pressure.
- Further, precautionary measures and management strategies to minimize the effect of particulate as well as gaseous pollutants have also been suggested for achieving its ambient levels in and around Kandla Port and Vadinar Port, Gujarat, India.

- Drinking water at all the twenty locations was found potable and it was found within in line of BIS standards (IS: 10500-2012).
- Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading

containers and ships. All sampling location were within the permissible limit day time 75 dB (A) and night time 70 dB (A) for the industrial area.

- The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) STP and Vadinar were in line with the standards set by the Central Pollution Control Board.
- It was suggested to monitor the STP performance on regular basis to avoid flow of contamination / Polluted water into the sea.
- Good species diversity suggests a relatively successful species in this habitat. A greater number of successful species and a more stable ecosystem. More ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole.
- The results obtained from the study for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.
- The mean day time temperature at Deendayal Port was 27.92 °C. The day-time maximum temperature was 32.9°C and minimum was 21.1 °C. The mean night time temperature recorded was 25.47 °C. The night-time maximum temperature was 29.7°C and minimum was 20.0 °C. The mean Solar Radiation in November month was 167.27 w/m^2. The maximum solar radiation was recorded 759 w/m^2 in 4^{th} November, 2022 and the minimum solar radiation was recorded 1.80 w/m^2 in 30^{th} November, 2022. The mean Relative humidity was 69.00 % for the month of November. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 34.0 %. The average wind velocity for the entire month of November was 1.21 m/s. Maximum wind velocity was recorded 10.19 m/s. The wind direction was mostly North-East.
- The results obtained from the study for the month of November 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

Reasons for higher Values of PM_{10}

- The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.

- Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

Remedial Measures

The values of PM_{10} & $PM_{2.5}$ during the month of November, 2022 were beyond the standard limit at all locations (Coal Storage, Marine Bhavan, Oil Jetty and Estate office, Tuna Port) except Gopalpuri the concentration of particulate matter was slightly exceed. Given below are the remedial measures suggest to minimize the Air pollution.

- During November, 2022 overall ambient air quality of the DPA was within CPCB permissible limits except TSPM, PM_{10}, $PM_{2.5}$ at Coal storage area, Marine Bhavan, Oil Jetty and Estate Office. To improve air quality the port was using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

Solution towards the Green port:

Today, it is increasingly recognized that air pollution hurts human health. Consequently, efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits.

The guidelines can be considered a basis for governments for the implementation of a strategic plan focused on the reduction of multi pollutant emission, as well as of the overall air pollution related risk.

- The plantation should be all along the periphery of the port and inside and outside the port along with the road. Trees having high dust trapping efficiency (*Azadirachta indica, Cassia fistula, Delonix regia, Ficus religiosa, Pterocarpus marsupium*) are to be grown alongside the roads.
- The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.

- The vehicles should be covered during transportation and the vehicle carrying the coal should not be overloaded by raising the height of carriage.
- The water sprinklers should be use during transportation of loaded heavy vehicles on raw road.
- It should be ensure that regular sweeping of coal internal, main road and space a free circulation.
- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle- Mask advised in sensitive areas.
- Department for use maintenance should have a routine checkup noise level by replacing bearings, tights of all loose parts that can vibrate.
- Speed control is also an effective way to mitigate noise pollution, the lowest sound emission arise from vehicles moving smoothly.
- Use of renewable energy like solar energy should be optimal and ensure to work continuously.
- Keep neat and clean public transport and all basic items at public interaction places as much as possible.
- Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.
- Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.
- Initiate Natural Gas (CNG) as fuel by all buses and trucks.

Green Ports Initiative

- Deendayal Port is committed to sustainable development and adequate measures are being taken to maintain the Environmental well-being of the Port and its surrounding environs. Weighing in the environmental perspective for sustained growth, the Ministry of Shipping had started “Project Green Ports” which will help in making the Major Ports across India cleaner and greener. “Project Green Ports” will have two verticals - one is “Green Ports Initiatives” related to environmental issues and second is “Swachh Bharat Abhiyaan”.

- The Green Port Initiatives include twelve initiatives such as preparation and monitoring plan, acquiring equipments required for monitoring environmental pollution, acquiring dust suppression system, setting up of waste water treatment plants/ garbage disposal plant, setting up Green Cover area, projects for energy generation from renewable energy sources, completion of shortfalls of Oil Spill Response (OSR) facilities (Tier-I), prohibition of disposal of almost all kind of garbage at sea, improving the quality of harbour wastes etc.

- Deendayal port has also appointed GEMI as an Advisor for “Making Deendayal Port a Green Port - Intended Sustainable Development under the Green Port Initiatives.
- Deendayal Port has also signed MOU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Trust. The plantation is being carried out by the Social Forestry division of Kachchh.

CHAPTER-12

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Annexure -H

DEENDAYAL PORT AUTHORITY

Administrative Office Building
Post Box NO. 50
GANDHIDHAM (Kutch).
Gujarat: 370 201.
Fax: (02836) 220050
Ph.: (02836) 220038

www.deendayalport.gov.in

NO.EG/WK/4751/Part (Greenbelt-GUIDE) 196 Dated : 31/5/2022

M/S Gujarat Institute of Desert Ecology,
P.O.Box No. 83,
Opp. Changleshwar Temple, Mundra Road,
Bhuj (Kachchh)- 370 001,Gujarat (India).
Tel.: 02832-329408, 235025.
Tele/Fax: 02832-235027
Email: desert_ecology@yahoo.com

Kind Attn.: Dr.V.Vijay Kumar, Director, M/s GUIDE, Bhuj.

Sub: Greenbelt Development in Deendayal Port Authority and its Surrounding Areas Charcoal site (Phase-I).

Ref.: M/s GUIDE, Bhuj offer vide letter no. M/s GUIDE, Bhuj vide communication no. GUIDE/DPA/GRN/080/2022-23 dated 24/5/2022.

Sir,

Your offer for the subject work submitted vide above referred letter dated 24/5/2022 amounting to Rs. 38,22,900.00 + applicable GST (Rupees Thirty-Eight Lakhs Twenty-Two Thousand and Nine Hundred Only Plus Eighteen Percent GST), with all terms & conditions mentioned in the offer letter, has been accepted **(Copy of offer letter M/s GUIDE attached)**.

2. Scope of work:

Development of Greenbelt in Charcoal site – Kandla, DPA and its surrounding areas. The activities under the Greenbelt Development include; inventory of suitable sites for greenbelt development in DPA, soil & Moisture conservation and management at Plantation sites, selection of suitable species of Plants for plantation, Procurement and plantation of plant saplings and seeds (5000 plants), along with management and monitoring of plantation, including drip/tanker water supply for a period 1 year.

.......Cont.........

3. Obligation of Deendayal Port Authority :

- Assistance regarding the statutory clearance from authorities concerned to be rendered by DPA for field visits/plantation activities.

4. The Terms of Payment:

1. 50% of the project budget to be paid to GUIDE within 15 days from the date of acceptance of Work order by GUIDE.
2. 20% of the project budget to be paid to GUIDE within 15 days from the date of completion of plantation works.
3. 20% of the project budget to be paid to GUIDE within 15 days from the date of submission Progress Report (December 2022).
4. 10% of the project budget to be paid to GUIDE within 15 days from the date of submission of Final Completion Report (May 2023).

5. Time Period : One year (from 5/6/2022 to 4/6/2023).

6. Kindly send the acceptance of this work order & start the work w.e.f. 5/6/2022 .

Thanking you.

Yours faithfully,

Superintending Engineer (PL) & EMC (I/c)
Deendayal Port Authority

Copy To :1) A.O.(W/A) - The proposal has been approved by the Board in its meeting held on 27/5/2022.

The expenditure shall be charged to the scheme Environmental Services & Clearance thereof (Allocation: 841/587/9744 WC - 5-13001).

2) TPA to CE for kind information of the Chief Engineer, please.

3) DA (PL) for further necessary action.

4) M/s Precitech Laboratorie ,Vapi, Environmental Management Cell to coordinate with M/s GUIDE,Bhuj.

5) RAO, DPA

Annexure -I

Brief Report (Second Season)

Studies on Dredged Materials for the presence of Contaminants and suggesting suitable disposal options

(As per EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific Condition No. vii)

DPA Work order No. EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021.

Submitted by

Gujarat Institute of Desert Ecology
P.B. No. 83, Mundra Road
Opp. Changleshwar temple
Bhuj - Kachchh, Gujarat – 370001, India

Submitted to

Deendayal Port Authority
Administrative Office Building
Post Box NO. 50
Gandhidham (Kachchh)
Gujarat - 370201

October 2022

Project Team

Project Co-Ordinator **:** Dr. V. Vijay Kumar, Director

S. No	Name & Designation	Role	Background
1.	Dr. K. Karthikeyan Principal Scientist & Head	Principal Investigator	M.Sc., Ph.D. in Environmental Sciences; 15 years of experience in water and sediment studies.
2.	Dr. G. Jayanthi Scientist	Co- Investigator	MSc., MPhil., PhD in Botany; 13 years of Research and teaching experience inclusive of Post-Doctoral experience for 5 years.
3.	Dr. Krushnakant D Baxi Scientific Officer	Co- Investigator	Ph.D in Zoology (Marine Biology) with 5 years of experience
4.	Mr. T. Dhananjayan Sr. Scientific Assistant	Team Member	M.Sc. in Environmental Sciences; 8 years of experience in sediment, water analysis and instrumentation.
5.	Ms. Dipti Parmar Jr. Scientific Assistant	Team member	M.Sc. in Environmental Sciences; 4 years of experience in sediment and water analysis.

Dr. V. Vijay Kumar
Director

Gujarat Institute of Desert Ecology

Certificate

This is to state that the **Second Season report** of the work entitled, **"Studies on dredged material for the presence of contaminants"** has been prepared in line with the Work order issued by DPA vide No.EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021 as per the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016, Specific Condition No. vii. The work order is for a period of Three years from November 2021 – October 2024 for the above-mentioned study.

This Second Season report is for the project period from November 2021 – October 2022.

Gujarat Institute of Desert Ecology Bhuj

Authorized Signatory **Institute Seal**

P. O. Box No. # 83, Opp. Changleshwar Temple, Mundra Road, Bhuj (Kachchh) - 370 001, Gujarat (India)
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CONTENTS

One among the twelve major ports of the country, Deendayal Port is located at the tail end of Gulf of Kachchh, which is a largest Creek based Ports in the county which is located in the north-western coast of India in the state of Gujarat. DPA caters the maritime trade requirement of many hinterland states and is well connected by the network of rail and road and serves as a gate way port for export and import of northern and western Indian states of Jammu & Kashmir, Delhi, Punjab, Himachal Pradesh, Haryana, Rajasthan, Gujarat and parts of Madhya Pradesh, Uttaranchal and Uttar Pradesh. About 35% of the country's total export takes place through the ports of Gujarat in which the contribution by Deendayal port is considerable. The port handled a total cargo of 105 MMTPA during 2016-17, 110 MMTPA during 2017-18, 115 MMTPA during 2018-19, 122.5 MMTPA during 2019-2020 and 117.5 MMTPA during 2020-21. DPA is the only major Indian port to handle more than 127 MMT cargo throughput, and it has also registered the highest cargo throughput in its history. The port has handled a total of 3151 vessels during FY 2021-22.

Further, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. With such capacity, the Port ranks No. 1 among all the major ports in India for 12th Consecutive year. Further, a regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. The port has high commercial importance in the Indian maritime trade as it handled 36.1 million tons (17%) of Cargo out of total Cargo of 213.1 million tons of the maritime Cargo of India during 2015. In addition, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements.

In recent times, Deendayal Port Authority (DPA) has taken up Development of 7 Integrated facilities, and the Ministry of Environment, Forest and Climate Change (MoEF & CC), has put up some conditions while according Environmental and CRZ clearance. One of the conditions is to carry out the *"Study on Dredged Material for presence of contaminants"* as accorded by the MoEF&CC,GoI dated 19/12/2016 - Specific condition no. vii)" which states that ***"Dredged materials should be analyzed for presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted and the findings should be shared with the Gujarat SPCB and Regional Office of the Ministry"***.

1.1 Need of the study

Based on the above condition, DPA has assigned the task of carrying out the study to Gujarat Institute of Desert Ecology (GUIDE), Bhuj. This study will be attempted three times in a year at two specified locations. Further, the study will envisage the evaluation of physico-chemical constituents in the dredged materials in the dumped locations in the study area. GUIDE has received the Work order for this project with project time period being Three years (01.11.2021 – 31.10.2024). In this connection, the study was taken up for evaluation of dredged materials for the presence of contamination was conducted with the methodical investigation of evaluating physical, chemical and biological characteristics of the dredged materials with special reference to pollutants including heavy metal, Petroleum hydrocarbon etc.

1.2. Scope of the study

a. To monitor the locations where dredged materials are dumped will be conducted.
b. Dredged materials in the area will be analyzed for the presence of contaminants in two different locations.
c. Detailed assessment of the dredged materials for physical, chemical and biological characteristics will be studied.
d. Suggesting suitable disposal options for the dredged material will be made.

1.3. Sampling locations for 2021-22

The study on the presence of contaminants in the dredged materials for the year 2021-22 was designed by considering the location details (Table 1 and Plate 1) as provided to DPA by Hydraulic & Dredging Division regarding location of dumping ground and the details has been shared to GUIDE by DPA in the e-mail dated 24 October 2018. Three seasonal study covering Location 1, Location 2 and Location 3 with the Second season of the study was conducted during 20.04.2022 – 22.04.2022.

Table 1: GPS Co-ordinates of sampling locations

Station	Latitude (N)	Longitude (E)
Location 1 (Offshore)	22° 51' 00" N	70° 10’ 00" E
Location 2 (Cargo jetty)	22°56' 31" N	70 13' 00" E
Location 3 (Phang Creek)	23° 04' 28" N	70°13’ 28" E

1.4. Details of work done during 3rd Quarter (May – July 2022)

In this quarter, as part of Second season sampling, during April 2022, bottom water and sediment samples were collected from the Offshore and Creek system in three designated locations as earmarked was done. All the samples were subjected for various Physical, Chemical and Biological characteristics both in water (36 Nos.) and sediment samples (18 Nos) following standard methods as prescribed by ICMAM 2012. All the samples were done in triplicates and the data was compared with the limits as prescribed by CPCB for marine waters or with other relevant standards.

Plate 1: Map showing locations of proposed sampling (2021-22)

For the purpose of sediment characterization, the samples from the study area were collected employing standard methodology and the analysis of the samples were also performed as per standard protocol and the data of sediment analysis is presented in this Chapter 1. The sediment samples were collected in pre-fixed stations using a Van-veen type of grab sampler. After collection, the sediment samples were preserved with Rose Bengal and formalin to avoid decomposition of samples and processed for analysis and the samples after collection were brought to the laboratory on the same day of collection and air dried and used for further analysis for the test parameters (Table 2).

Table 2: Physico-chemical and biological characteristics of sediment samples

S. No.	Physico-chemical and Biological parameters
1	pH (1: 10 suspension)
2	Salinity (ppt)
3	Sand (%)
4	Silt (%)
5	Clay (%)
6	Total organic carbon (%)
7	Phosphorus (mg/kg)
8	Sulphur (mg/kg)
9	Petroleum Hydrocarbon (µg/kg)
10	Cadmium (mg/kg)
11	Lead (mg/kg)
12	Chromium (mg/kg)
13	Copper (mg/kg)
14	Cobalt (mg/kg)
15	Nickel (mg/kg)
16	Zinc (mg/kg)
17	Magnesium (mg/kg)
18	Macrobenthos

2.1. pH and Salinity (1: 10 suspension)

pH of the sediment is the measure of H^+ ion activity of the sediment water system. It indicates whether the sediment is acidic, neutral or alkaline in nature. Since ions are the carrier of electricity, the electrical conductivity (EC) of the sediment water system rises according to the content of soluble salts. The measurement of EC can be directly related to soluble salts concentration of the sediment at any particular temperature. Ten gram of the finely sieved sediment will be dissolved in 100ml of distilled water to prepare a leachate. This will be subjected to vigorous shaking using a rotator shaker for 1 hour to facilitate proper homogenization of the suspension. The suspension will be allowed to settle for two 2 hours and the supernatant after filtration will be used for the analysis of pH and salinity using the pH and EC meter (Make: Systronics 361) and Refractometer (Make: Atago). Each sample will be analysed in triplicates and the mean values will be taken into consideration.

2.2. Textural analysis (Sand/Silt/Clay)

Sediments will be collected using Van Veen grab whereas intertidal sediments will be collected using a handheld shovel. After collection, the scooped samples will be transferred to polythene bags, labeled and stored under refrigerated conditions. The sediment samples will be thawed, oven dried at 40ºC and ground to a fine powder before analyses.

For texture analysis, specified unit of sediment samples will be sieved using sieves of different mesh size as per Unified Sediment Classification System (USCS). Cumulative weight retained in each sieve will be calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves. The percent retained will be calculated from the weight retained and the total weight of the sample. The cumulative percent will be calculated by sequentially subtracting percent retained from 100%.

2.3.Total organic carbon

Total organic carbon is the carbon stored in sediment organic matter which enters the sediment through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, sediment biota etc. Total Organic carbon in the sediment is oxidized with potassium dichromate in the presence of concentrated sulphuric acid. Potassium dichromate produces nascent oxygen, which combines with the carbon of organic matter to produce CO_2. The excess volume of $K_2Cr_2O_7$ is titrated against the standard solution of ferrous ammonium Sulphate in presence of H_3PO_4 using Ferroin indicator to detect the first appearance of unoxidised ferrous iron and thus volume of $K_2Cr_2O_7$ can be found out which is actually required to oxidize organic carbon.

Procedure

Percentage of Total organic carbon in the sediment/sediment will be determined by oxidizing organic matter in the sediment samples by chromic acid and estimating excess chromic acid by titrating it against ferrous ammonium sulphate with ferroin as an indicator. The detailed step-by-step procedure is as follows:

One gm of 0.5 mm sieved sediment will be weighed and put into 500 ml conical flask and to which 10 ml of 1N $K_2Cr_2O_7$ will be added with pipette and swirled. Immediately using a burette, 20 ml Conc. H_2SO_4 will be added and mixed gently until sediment and reagents are mixed. The reaction will be allowed to proceed for 30 min in a marble stone to avoid the damage caused due to release of intense heat due to reaction of sulphuric acid. Further, 200 ml of distilled water will be added slowly and 10 ml of concentrated Orthophosphoric acid and about 0.2 gm NaF will be added and allowed the sample and reagent mixture to stand for 1.5 hrs because the titration end point is better visible in a cooled solution. One ml of ferroin indicator will be added into the conical flask just before the titration and then titrated the excess K_2Cr_2O with 0.5 N Ferrous Ammonium Sulphate till the color flashes from yellowish green to greenish and finally brownish red at the end point. Simultaneously a blank test will be also run without sediment sample.

2.4.Total Phosphorus

Phosphorus in sediment is commonly performed by Bray's extraction method and in this method, specific colored compounds are formed with the addition of appropriate reagents in the solution, the intensity of which is proportionate to the concentration of the element being estimated. The color intensity is measured spectrophotometrically. In spectrophotometrically analysis, light of definite wavelength (not exceeding say 0.1 to 1.0 nm in band width) extending to the ultraviolet region of the spectrum constitutes the light source. The photoelectric cells in spectrophotometer measure the light transmitted by the solution.

Fifty ml of the Bray's extractant will be added to 100 ml conical flask containing 5 gm of sediment sample and shaken for 5 minutes and filtered. Exactly 5 ml of the filtered sediment extract will be taken with a bulb pipette in a 25 ml measuring flask and 5 ml of the molybdate reagent with an automatic pipette will be added and diluted to 20 ml with distilled water and shaken well. Further, to this, 1 ml of the dilute Stannous Chloride solution will be added and volume made upto 25 ml mark and shaken thoroughly. The mixture will be kept for color development and after 10 minutes the readings will be taken in the spectrophotometer at 660 nm wave length after setting the instrument to zero with the blank prepared similarly but without the sediment.

2.5. Total Sulphur

Sulphur in the sediment extract was estimated turbidimetrically using a spectrophotometer. The standards of sulphur were prepared in series such as 2, 4, 6, 8 and 10 ppm working solution from stock solution. In this, 25ml of solution was added in the volumetric flask separately to each flask and 2.5 ml of conditioning reagent solution was also added followed by 5 ml of extraction solution was added. To this mixture, 0.2-0.3 gm of barium chloride was also added and shaken well and made-up to 25 ml with distilled water and the readings were taken at 340nm spectrophotometer.

The sample was analysed by taking 5g of marine sediment into a 100ml conical flask, to which, 25 ml of 0.15 % $CaCl_2$ solution was added and shaken for 30 minutes. Then this was filtered through Whatman no. 42 filter paper and then 5 ml of sample aliquot was taken in a 25 volumetric flask, to which 2.5 ml of conditioning reagent and 0.2 to 0.3 g of barium chloride powder was added and made up to 25 ml distilled water and shaken well for 2 minutes and the absorbance was read in the same manner as standard solutions.

2.6. Petroleum Hydrocarbons

Sediment after refluxing with KOH-methanol mixture will be extracted with hexane. After removal of excess hexane, the residue will be subjected to clean-up procedure by silica gel column chromatography. The hydrocarbon content will be then estimated by measuring the fluorescence as per standard method.

2.7. Heavy metals

Heavy metals are of concern especially as it relates to the environment are Cadmium (Cd), Lead (Pb), Chromium (Cr), Nickel (Ni), Cobalt (Co),Copper (Cu), Zinc (Zn), Manganese (Mn) etc. For the release of mineral elements from sediment and sediments, wet oxidation of samples are generally performed. Wet oxidation employs oxidizing acids (Tri / Di-acid mixtures).

Sediment sample will be weighed to 1.0 gm and taken in 100ml beaker covered with a watch glass and 12 ml of Aqua regia in (1: 3 HNO_3 : HCl) will be added and the beaker will be kept in digestion for 3 hours at 100^0c on a hot plate using sand bath and the samples will be evaporated to near dryness and the samples will be kept cool for 5 mins and then 20 ml of 2% nitric acid will be added and kept for 15 minutes in hot plate for digestion and remove from hot plate and cooled and filtered using Whatman No. 42 mm filter paper and then the final make up to 50 ml with 2 % nitric acid will be made. The extracted sample will be then aspirated to an AAS.

2.8. Results

2.8.1. pH (Hydrogen Ion)

pH values in marine sediments, subatomic concentrations in seawater and deposited in the sediment core. However, these processes are generally depending with cycles of carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron and manganese and are associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and dissolution of calcium carbonate marine water and sediments. In the present investigation pH average values were recorded to be 7.95±0.11 in the offshore, 8.04±0.08 in the cargo jetty and 7.71±0.34 in the Phang creek. Among all the stations, the maximum concentration of pH was recorded to be 8.17 in the cargo jetty station and the minimum concentration of pH was recorded to be 7.02 in the Phang creek station Fig.1

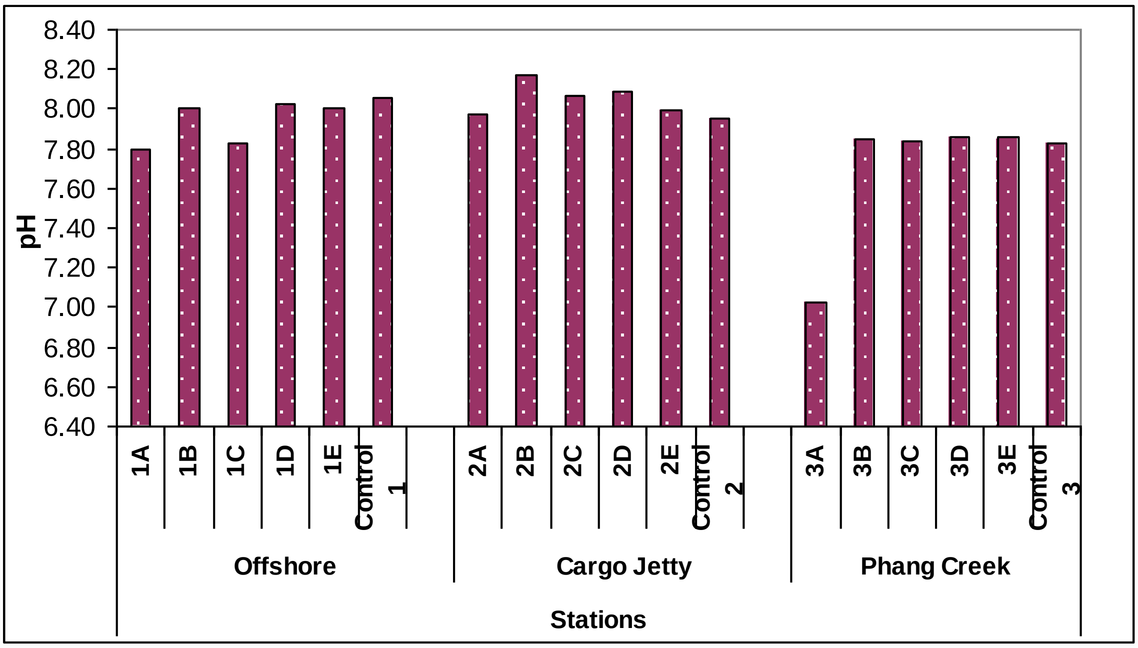

Fig .1 pH (Hydrogen ion) values in the various stations at Deendayal Port

2.8.2. Salinity

In the marine water and sediment, salinity typically varies from 0 to 36 ppt in most estuaries with hyper salinity occurring in many semi-enclosed bays. As well as, salinity concentration is associated with water temperature typically oscillates in diurnal and seasonal cycles in response to atmospheric temperature. In this study, during season two, salinity was observed to the highest concentration of 24.73 ppt in the phang creek station and the lowest concentration of salinity was found to be 7.78 ppt in the offshore station and mean ±SD salinity of 9.63±2.89ppt in the offshore station, 21.73±1.30ppt in the cargo jetty station and 22.36±2.01ppt in phang creek station. Among all the stations values shown in Fig.2.

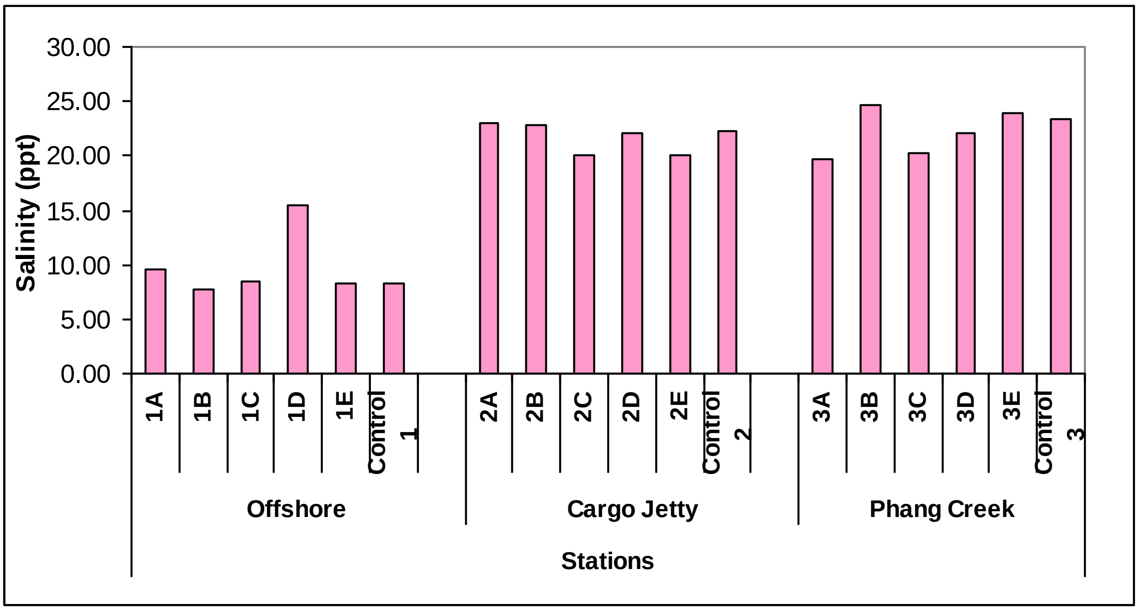

Fig.2 Salinity concentration in the various stations at Deendayal Port

2.8.3. Sediment Texture

One of the most important physical characteristics is sediment texture which (Sand, Silt and Clay) to marine benthic groups, in the study was investigated in different stations sediment texture, in which highest sediment texture percentage was observed of sand 54.80 % in the cargo jetty, silt 68.80% in the offshore station and clay 55.30% in the cargo jetty and lowest sediment texture percentage was observed of sand 10.10% in the phang Creek, silt 14.20% in the cargo jetty and Clay 10.60% in the offshore stations and among all the stations and the data shown in the Fig.3

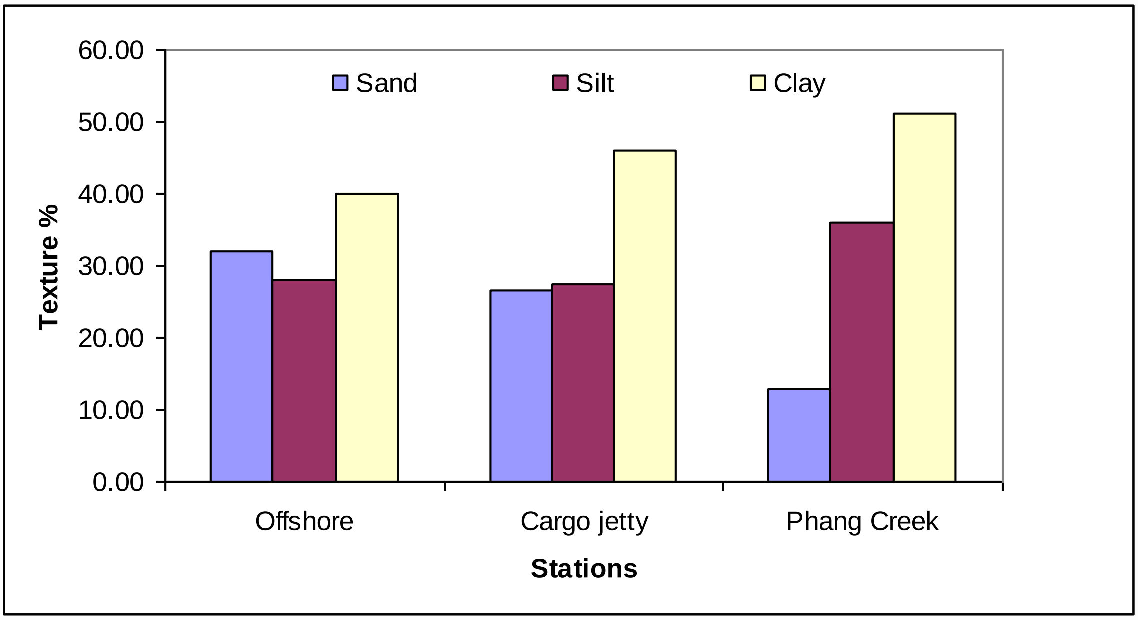

Fig.3. Sediment texture average values in various stations at Deendayal port

2.8.4. Total organic Carbon

The organic carbon in the marine sediment are mainly coming from decomposition from animals, plants and anthropogenic sources such as chemical waste, fertilizers and organic – rich wastes which enrich the marine environment and that organic load settling to the bottom sediments from water column, in the path way that TOC values increasing and it affects the faunal communities. During season two, that TOC mean ±SD % of 0.41±0.17% in the offshore station, 0.69±0.21% in the cargo jetty station and 0.67±0.09 % in phang creek station, among all the station TOC concentration shown in the Fig .4.

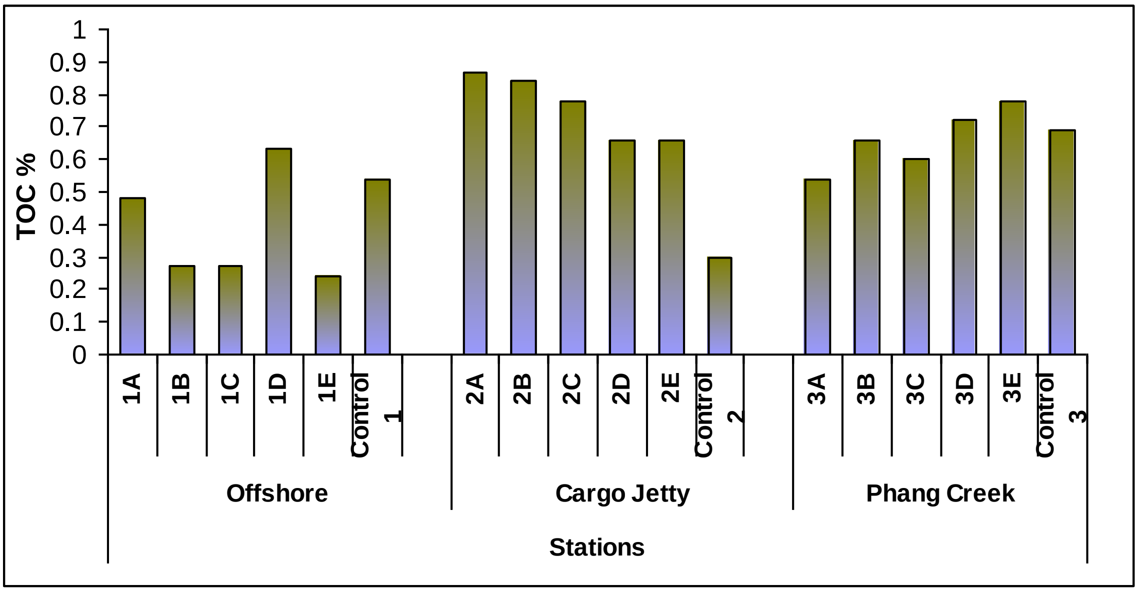

Fig.4. Total organic carbon concentration in various stations at Deendayal port

2.8.5. Organic matter

In the marine sediment organic matter is the major reservoir of organic carbon, which is a chemical, physical and biological effect of degradation to produce the organic matter in marine environment. Moreover, composed of material derived from the various planktons and benthic species that comprise the ecology of primary producers and consumers in overlying surface sediment. In the study, during season two, determined the organic matter ranged between 0.41 to1.50 % among all the stations data shown in the Fig.5.

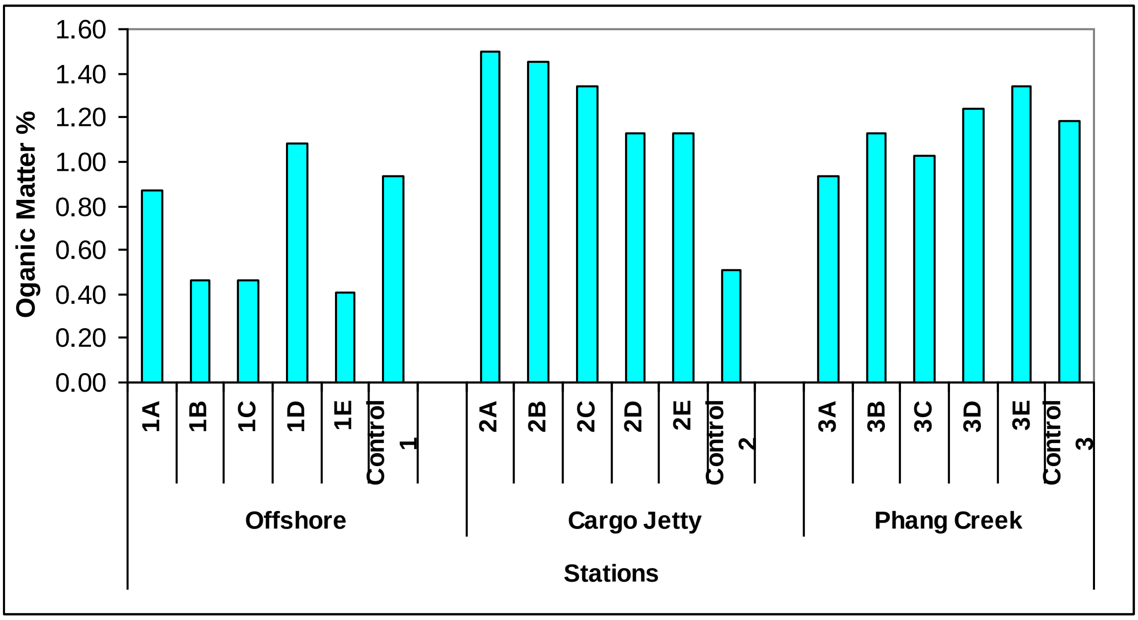

Fig.5. Organic matter concentration in various stations at Deendayal port

2.8.6. Phosphorus

Phosphorus (P) is an essential nutrient for life that plays a key role in regulating primary productivity in the marine systems. During season two, the maximum concentration of phosphorus was found to be 93.17 mg/kg in the Cargo jetty station and the minimum concentration of phosphorus was found to be 2.70 mg/kg in the offshore station and the average ±SD being 10.09±4.17 mg/kg in offshore, 30.28±31.16 mg/kg in cargo jetty and13.82 ±4.10mg/kg in phang creek.

2.8.7. Sulphur

Sulphur is a most significant primary source in sediments, the oxidation of sulphur and subsequent processing of oxidation intermediates. However the sulfur cycle of marine sediments is primarily driven by the dissimilatory sulfate reduction to sulfide by anaerobic microorganisms. In the present study, we aimed to examine the sulphur concentration which varies in different seasons, during season two, the maximum concentration of sulphur was recorded to be 28.08mg/kg in the phang creek and the minimum concentration of sulphur was recorded to be 13.0mg/kg in the offshore station, among all stations data shown in Fig.6.

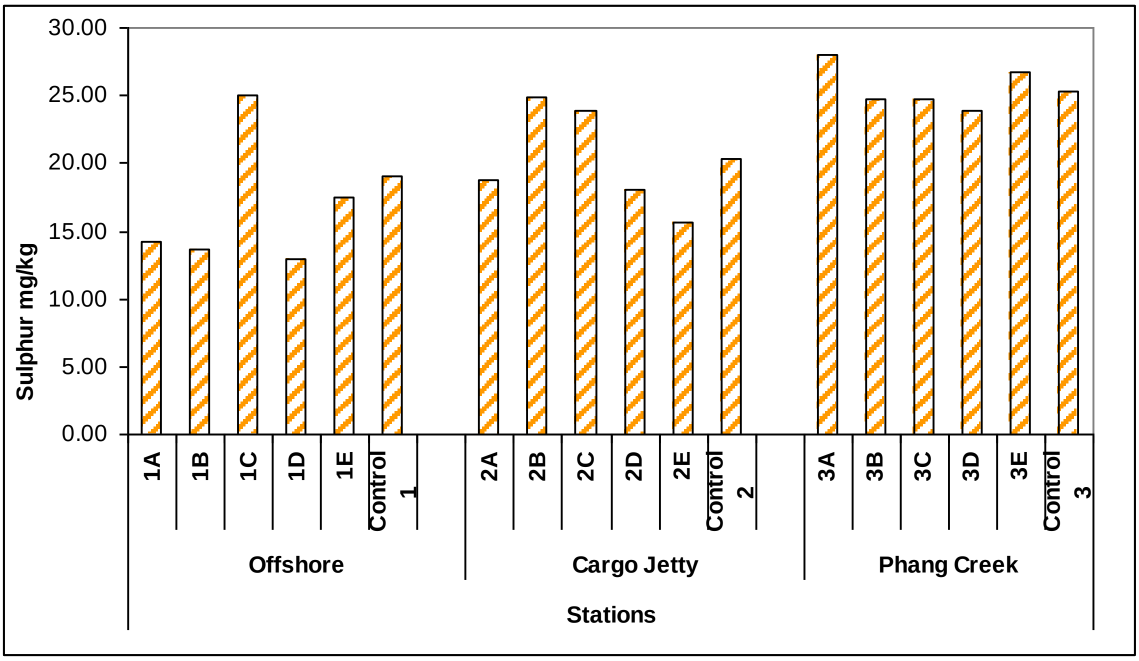

Fig.6. Sulphur concentration in various stations at Deendayal port

2.8.8. Petroleum hydrocarbon

Petroleum hydrocarbon (PHc) contaminating the marine environment which comprises mainly of three classes of groups such as alkanes, olefins, and aromatics. Moreover, the petroleum hydrocarbons has less solubility in marine water and adsorbing by particulate matter showing a long-term persistence on the bottom of sediments and it cause a significant negative impact on benthic aquatic communities in the marine ecosystem. During season two, various stations the PHC ranged between 1.25 to 2.26µg/kg and the maximum was observed to be 2.26µg/kg in the offshore stations and minimum was observed to be 1.25µg/kg in the cargo jetty station Fig.7

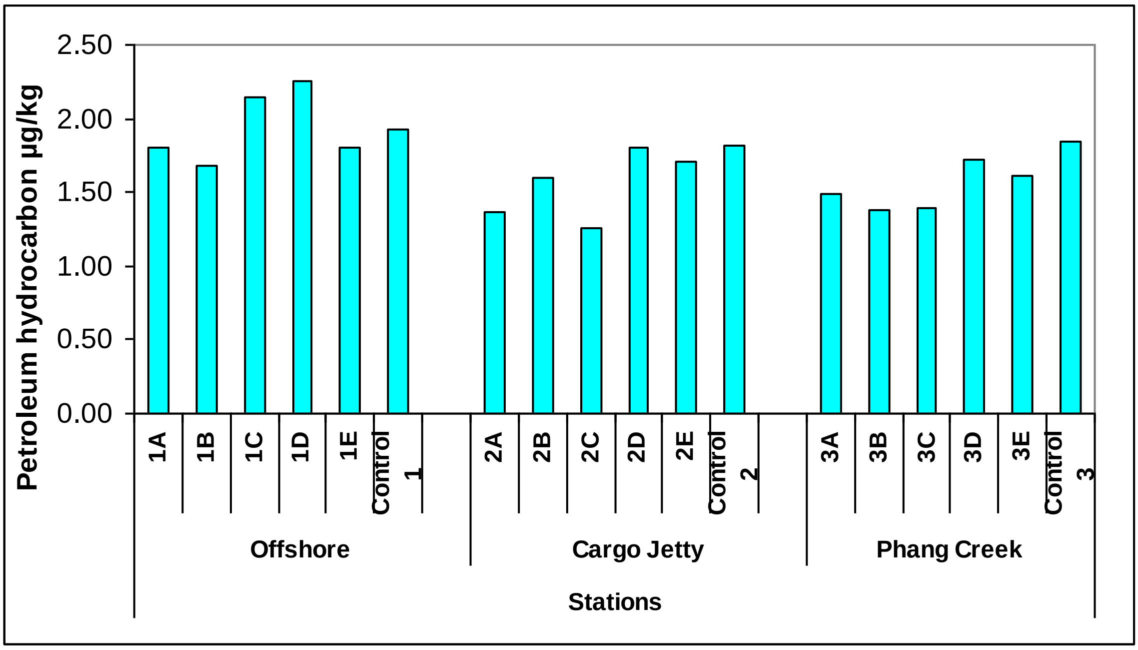

Fig. 7. Petroleum hydrocarbon concentration in the various stations at Deendayal port

2.8.9. Heavy metals

The maximum concentration of heavy metals in the sediment samples for the metals such as Nickel, Lead, Cadmium, Chromium, Zinc, Copper, Manganese and Cobalt are in the levels 29.34 mg/kg, 1.44 mg/kg, 0.70 mg/kg, BDL, 21.43 mg/kg, 0.38 mg/kg, 1.50 mg/kg and 8.55 mg/kg respectively. Whereas, the mean concentration of the metals were in the Cargo Jetty location where in the range of 60.46 mg/kg, 9.64 mg/kg, 0.47 mg/kg, BDL, 42.06 mg/kg, 1.02 mg/kg, 3.27 and 33.73 for the metal species Nickel, Lead, Cadmium, Chromium, Zinc, Copper, Manganese and Cobalt respectively. In case of the creek system, the metal concentrations were observed in the range as 24.58 - 32.24 mg/kg for Nickel, 8.56- 13.57 mg/kg for Lead, 0.57-2.15 mg/kg for Cadmium, 0.11 -0.21 mg/kg for Chromium, 28.56-42.80 mg/kg for Zinc, 0.87 - 2.24 mg/kg for Copper, 3.56 - 10.28 mg/kg for Manganese and 9.85 - 18.75 in case of cobalt metal. During the second season, determination of magnesium in the different station in the study area was in the Average ± SD of 449.53±155.33 mg/kg (Offshore site), 397.62±75.65 mg/kg (Cargo Jetty) and 467.60±29.75 mg/kg (Phang Creek) and the maximum and minimum was 612.48 mg/kg at Control site and 218.56 mg/kg at 1B (Offshore site) respectively.

3.1. Introduction

Earth is unique within the solar system to behold a large amount of water mostly contained in oceans. Life on earth originated in the oceans 3.1 to 3.4 billion years ago, and continuous mixing and dynamic characteristics of the ocean support very high biodiversity mostly unexplored. Indian peninsula surrounded by the Arabian Sea in the West, the Bay of Bengal in the East and the Indian Ocean in the South. The state of Gujarat is the western most in India and having the largest coastline of around 1600 km, along the Arabian sea with both Gulf of Kachchh and Khambhat. Gujarat coasts having different coastal ecosystems like the mangroves, sandy shores, muddy shores, rocky shores, mixed shores, wet sand shores, coral reefs and intertidal mudflats (Brink, 1993; Parasharya and Patel, 2014). Along with the high coastal diversity, there are developmental paradigm also and coastal development was also astonishing with the development of port for easy transportation. Deendayal Port Authority (DPA) is one among the 12 major ports of the country located near Gandhidham of Kachchh district. The port is the largest creek-based port in the country.

The word benthos originated from the Greek word *benthos* meant the depth of the seas. The benthic zone is the substratum zone of any water body mostly begins from the shore and reaches to the bottom of the waterbody and consists of organism living on and attached to or burrowing in the sediments commonly termed as benthos. Benthic community includes diverse group of animals including Gastropod and Bivalve molluscs, corals, sponges, polychaetes and nematode worms, crabs, different crustaceans, echinoderms, etc. Benthos are important predators and scavengers within the food chain and cleans the sea floor or freshwater bodies. Benthic organisms, play an important role as a food source for fish and other higher level of organisms.

The sediments of benthic zone play an important role in providing nutrients for the organisms that live in the benthic zone. The up-down movement of the bottom sediments mainly occurred by these benthic organisms results in a rise of the oxygen concentration of water and hence the overall productivity of the water bodies rich in high level of productivity. Major factors affect which benthic community are depth of water, salinity, temperature, types of substrate, pre-predation ratio and sudden changes in environmental condition. Nowadays, different anthropogenic activities affect aquatic systems including substratum habitat. Most of these animals lack a backbone and are called invertebrate animals.

Based on size, Benthos mainly divided into 3 types namely, Macrobenthos (> 1 mm), Meiobenthos (< 1 mm or > 0.1 mm) and Microbenthos (< 0.1 mm). These animals are further divided into two types Phytobenthos and Zoobenthos and based, on location it is furthermore classified as, Endobenthos, Epibenthos, Hyperbenthos.

The study was conducted summer season at 3 sites of Deendayal Port Authority with the locations namely, Offshore, Cargo Jetty and Phang Creek.

3.2. Methodology

To study the benthic organisms, triplicate samples were collected at each station using Van-veen grab which covered an area of $0.1m^2$. The wet sediment was sieved with varying mesh sizes (0.5 mm-macrofauna) for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution for easy spotting at the time of sorting. The number of organisms in each grab sample was expressed as number/ meter square (No/m^2). All the species were sorted, enumerated and identified to the advanced taxonomic level possible with the consultation of available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; Subba Rao *et al.* (1991) and Ramakrishna (2003) for molluscs.

Further, the data were treated with univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clarke and Warwick, 1994)

a) Shannon – Wiener index

In the present study, the data were analyzed for diversity index (H') by following Shannon – Wiener's formula (1949):

$H' = -\sum^{S} Pi \log 2\ Pi\ldots\ldots \quad i = 1$

which can be rewritten as

$$H' = \frac{3.3219\ (N \log N - \sum ni - \log ni}{N}$$

where, H'= species diversity in bits of information per individual

ni = proportion of the samples belonging to the ith species

(number of individuals of the ith species)

N = total number of individuals in the collection and

$\sum$ = sum

b) Species richness(S) was calculated using the following formula given by Margalef (1958)

c) Margalef index (d)

$d = (S-1) / \log N$

d) Pielou's evenness index

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\ln S}$$

Where, J' = evenness; H' = species diversity in bits of information per individual and S = total number of species.

3.3. Results on Species Composition, Population density and Biomass of Macrofauna of selected sites

3.3.1. Location 1 - Offshore site

Data collection was done at six sites (1A, 1B, 1C, 1D, 1E and 1- control). A Total of 4 groups of Benthic community were recorded in all stations at Offshore sites and they are Bivalves, Crustaceans, Gastropods (Mollusca) and Scaphopoda (Mollusca). Data on Density and Biomass expressed in (Nos/m^2), (gm/m^2) respectively.

Highest population density of benthic organisms was recorded in station 1E-Offshore (2350 nos/m^2), whereas lowest in station 1D-Offshore (1425nos/m^2). The density range of all stations varied from 1425 nos/m^2 to 2350 nos/m^2. Bivalves and Gastropoda were more abundant among all the benthic organisms (Table 3). The highest biomass value (expressed wet weight) of benthic fauna was observed in station 1B-Offshore (8.41 gm/m^2) and lowest value was 1E-Offshore (4.14 gm/m^2) (Table 3).

3.3.2. Cargo Jetty

In Cargo Jetty, frequently observed Benthic groups were Bivalves-Gastropods than Scaphopoda (Mollusca), and Razor clam (Bivalves). The population density range of 1100 to 4000 nos/m^2 was recorded between all the stations (Cargo Jetty2A, 2B, 2C, 2D, 2E & 2-Control) during the study period. Highest and Lowest density were recorded in station 2E-Cargo Jetty (4000 nos/m^2) and 2B-Cargo Jetty (1100 nos/m^2) respectively. The Biomass value indicated a highest value in station 2A- Cargo Jetty (13.86 gm/m^2) and lowest in 2B-Cargo Jetty (5.08 gm/m^2) (Table 3 and Fig. 8).

3. Phang creek

Six Stations of Phang creek were selected for the study namely 3A, 3B, 3C, 3D, 3E and 3-control-Phang creek. In this Phang creek benthic organisms were represented by Bivalves, Gastropods & *Razor clam* (Mollusca). The population density was highest in station 3Control-Phang creek (3400 nos/m^2) and on the other side, lowest density was recorded in

3A-Phang creek (1200 nos/m^2). Station 3D-Phang creek comprises highest wet wt (11.81 gm/m^2), whereas low at was recorded in 3A-Phang creek (0.87 gm/m^2).

Overall result of macrofaunal community showed highest population density in 2E-Cargo Jetty (400 nos/m^2) and biomass observed in 2A-Cargo Jetty (13.86 gm/m^2). Table 3 showed highest population values of Bivalves in 2E- Cargo Jetty (2800 nos/m^2) and lowest value comprised by Scaphopoda 50 nos/m^2 at 2D and 2-Control (Cargo Jetty). Optediceros breviculum (Common name Mangrove snail-Small Gastropoda shell) was only recorded at 3B and 3-Control site of Phang Creek. The Muddy habitat of Phang creek is preferred for many benthic organisms**.** This might be due to relatively stable and less polluted environment provided by muddy creek area of Phang creek further added that very low level of predation pressurs on benthic community and also might be due to lesser anthropogenic activities in that area. Table 3 showed that average population density and biomass higher in Cargo Jetty area where mostly rocky or covered with coral base providing a unique habitat for gastropod, bivalves and other benthic organisms.

Frequently found species at all sites were *Pirenella cingulata, Umbonium vestiarium, Optediceros breviculum, Tellina sp., Clypeomorus bifasciata, Cly Pholas orientalis, Dentalium sp Dosinia sp, Donax sp, Anadara sp, Turris sp etc. The percentage of occurrence (Table 3) revealed highest group present was Gastropoda (100%), Bivalves (94.44%) then followed by Razor clam (55.55%), Scaphopoda (38.88%) and others. Lowest percentage of occurrence by Pirenella cingulata (5.55%).* Compared to three sites, lowest density and biomass was observed at Offshore area (Table 3 and Figure 9) which indicated pollution level or stressful environment, monsoon effect and also might be some chemical and biological changes in water. Detail status of Population density, Group composition and biomass of the benthic community of all selected sites were depicted in (Table 3) and (Figure 9). In all the stations, highest percentage composition recorded by Bivalves (53%) followed by Gastropoda (23%), Razor clam (7%), *Optediceros breviculum* (5%), Scaphopoda (3%) and 1% comprises by Polychaete, Pirenella cingulata(gastropods) and Crustacean (Figure 9.). Phytoplankton abundance and their size, zooplankton Body composition, pathcy distribution of zooplankton, water currents, ebb and flow tides, and water churning process, changing in structure of muddy, rocky and sandy habitats are the main reasons for biomass and density fluctuation in Benthic cummunities. In Crustacean most commonly observed species are Crabs and attached Barnacles. Main Gastropods families recorded Trochidae, Cerithidea, Turritellidae, Mitridae and Bucciniae etc. *Nereis sp*, *Capitella sp*, *Nephtys sp*. like polychaete were observed in samples. More number of the broken bivalves, debris, plat items and broken gastropods are frequently observed in the Microscope.

3.4. Diversity indices of Benthic Community

Table 4 shows various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.444-1.547) indicated very low to near moderate diversity. Highest diversity indices was recorded in Station 3B-Phang creek (1.547) where moderate value of density and biomass of benthos and other side in 1A-Offshore diversity indices value was 0.444 where only two groups were present. The evenness values ranged between (0.634 to 0.960). The highest evenness value is 0.960 observed in station 1C-Offshore and the lowest evenness index value 0.634 was at station 2E-Cargo Jetty and where the population density was recorded highest. Simpson's Index value ranged between 0.273 to 0.776 indicated to lower to moderate diversity.

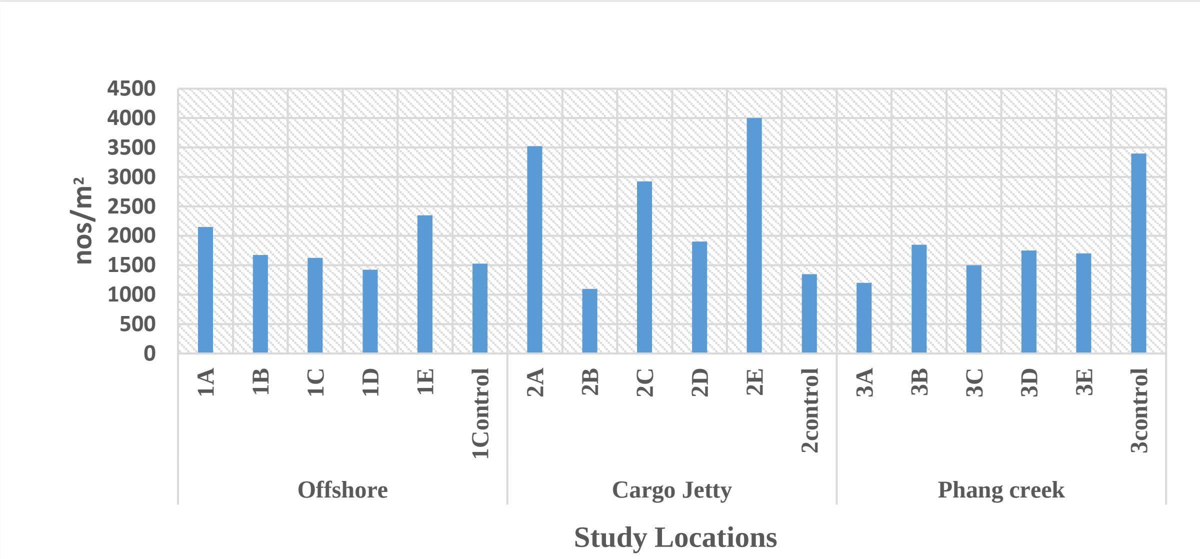

Figure 8. Population densities of Macro Benthos in various sites

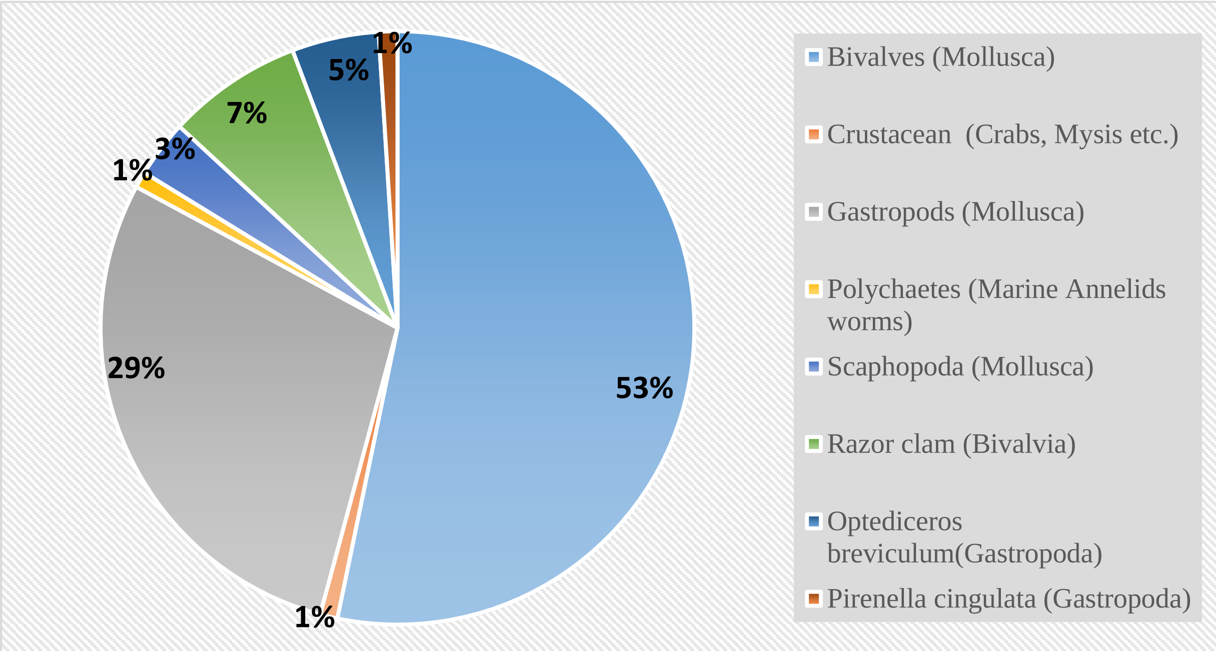

Figure 9. Percentage composition of Macrobenthos in various sites

Table 3. Macrobenthos distribution in different sites of Deendayal Port

Name of Station	Offshore						Cargo Jetty						Phang creek						% of Occurrence
	1A	**1B**	**1C**	**1D**	**1E**	**1-Control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Control**	
Name of Benthic Group																			
Bivalves (Mollusca)	1800	1100	725	1000	1550	1150	1925	625	1900	1100	2800	575	0	525	650	650	600	1000	94.44
Crustacean animals (Crabs, Mysis etc.)	0	0	350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.55
Gastropoda (Mollusca)	350	425	550	425	800	375	1050	350	550	525	550	450	900	225	550	975	800	750	100
Polychaeta worms (Marine Annelids worms)	0	0	0	0	0	0	0	25	0	0	0	0	300	0	0	0	0	0	11.11
Scaphopoda (Mollusca)	0	150	0	0	0	0	225	100	225	50	350	50	0	0	0	0	0	0	38.88
Razor clam (Bivalvia)	0	0	0	0	0	0	325	0	250	225	300	275	0	225	300	125	300	400	55.55
Optediceros breviculum (Gastropoda)	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	1250	11.11
Pirenella cingulata (Gastropoda)	0	0	0	0	0	0	0	0	0	0	0	0	0	375	0	0	0	0	5.55
Total Population Density Nos/m^2	2150	1675	1625	1425	2350	1525	3525	1100	2925	1900	4000	1350	1200	1850	1500	1750	1700	3400	-
Biomass wet wt gm/m^2	**6.61**	**8.41**	**8.26**	**5.38**	**4.14**	**6.64**	**13.86**	**5.08**	**8.3**	**7.22**	**10.45**	**6.49**	**0.87**	**7.68**	**10.66**	**11.81**	**9.51**	**8.94**	**-**

Table 4: Diversity indices of benthic faunal groups at various station of Deendayal Port (Benthos)

Variables	Offshore						Cargo Jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-Control	2A	2B	2C	2D	2E	2-Control	3A	3B	3C	3D	3E	3 - Control
Taxa_S	2	3	3	2	2	2	4	4	4	4	4	4	2	5	3	3	3	4
Individuals (Nos/m^2)	2150	1675	1625	1425	2350	1525	3525	1100	2925	1900	4000	1350	1200	1850	1500	1750	1700	3400
Dominance_D	0.727	0.504	0.360	0.581	0.551	0.629	0.400	0.433	0.471	0.426	0.522	0.335	0.625	0.224	0.362	0.454	0.377	0.284
Shannon Diversity	0.444	0.840	1.057	0.609	0.641	0.558	1.087	0.990	1.002	1.020	0.930	1.176	0.562	1.547	1.052	0.882	1.028	1.313
Simpson_1-D	0.273	0.496	0.640	0.419	0.449	0.371	0.601	0.567	0.530	0.574	0.478	0.665	0.375	0.776	0.638	0.547	0.623	0.716
Evenness	0.780	0.772	0.960	0.920	0.950	0.873	0.741	0.673	0.681	0.693	0.634	0.810	0.877	0.940	0.955	0.805	0.932	0.929
Menhinick	0.043	0.073	0.074	0.053	0.041	0.051	0.067	0.121	0.074	0.092	0.063	0.109	0.058	0.116	0.077	0.072	0.073	0.069
Margalef	0.130	0.269	0.271	0.138	0.129	0.136	0.367	0.428	0.376	0.397	0.362	0.416	0.141	0.532	0.274	0.268	0.269	0.369

4.1. Introduction

Rapid urbanization and industrial growth showed a significant impact on coastal ecosystems, such as estuaries and the surrounding coastal areas. The presence of a dense human population in their watersheds contaminates the environment (Jha et al., 2015). Coastal environment reference characteristics are necessary to provide a better management solution for the coastal ecosystem (Barbier Edward et al., 2011). Another major activity carried out in industrial port environment in the coastal environment is Dredging which is often carried out to create accesses to oil exploitation, marine/coastal transportation and other waterborne commerce. Dredging in sensitive environments is often accompanied by ecological impacts including damage to flora and fauna, alteration of coastal topography and hydrology, impairment of water quality etc (Adesobande and Associate, 1998). Hence assessing the water for various characteristics will indicate the intensity of pollutants present in such environments.

4.2. Materials and Methods

In the present study, the marine water and marine sediment samples were collected using standard protocol and analysis of the same was done following standard methods for marine water and sediment analysis as prescribed by APHA (2012), NIO manual (1982) and ICMAM Manual (2012). Surface water samples for general analysis were collected using a clean polyethylene bucket while an adequately weighted Niskin sampler was used to collect water samples from the bottom. A glass bottle sampler (1 L) was used for collecting water samples at 1 m below the surface. Parameters such as pH, Temperature, Salinity were recorded on spot using hand held meters and the same was also verified in the Laboratory. The water samples collected were stored in refrigerated conditions until further analysis of other parameters. As per the standard protocol, the fixatives and preservatives were added to the samples in case of parameters such as Dissolved Oxygen using Winkler A&B solution immediately, Chemical Oxygen Demand using concentrated H_2SO_4 to bring the <2 pH and preservation using nitric acid for heavy metals. In case of biological characteristics, the marine water samples for planktonic analysis were added with formalin. In general, all the collected water and sediment samples were stored in a sterile, polythene bottles and ziplock bags in an icebox to maintain suitable conditions till it is brought to the Laboratory. The list of parameters (Table 5) and the method adopted for the analysis of samples are detailed below.

Table 5: Physico-chemical and biological characteristics of marine water samples

S. No	Physico-chemical and Biological parameters
1	pH
2	Salinity (ppt)
3	Total Dissolved Solids (mg/L)
4	Total Suspended Solids (mg/L)
5	Turbidity (NTU)
6	Dissolved Oxygen (mg/L)
7	Bio-Chemical Oxygen Demand (mg/L)
8	Chemical Oxygen Demand (mg/L)
9	Phenolic compound (µg/L)
10	Petroleum Hydrocarbons (µg/L)
11	Oil and grease (mg/L)
12	Cadmium (mg/L)
13	Lead (mg/L)
14	Chromium (mg/L)
15	Copper (mg/L)
16	Cobalt (mg/L)
17	Nickel (mg/L)
18	Zinc (mg/L)
19	Magnesium (mg/L)
20	Chlorophyll (mg/m^3)
21	Phaeophytin (mg/m^3)
22	Phytoplankton Phytoplankton cell counts (no/L) Total Genera (no.) Major Genera
23	Zooplankton Biomass ($ml/100m^3$) Population ($no/100m^3$) Total Group (no.) Major Groups

4.2.1. pH, Temperature and Salinity

A Thermo fisher pH / EC / Temperature meter was used for pH and Temperature measurements. The instrument was calibrated with standard buffers just before use. A suitable volume of the sample was titrated against silver nitrate (20 g/l) with potassium chromate as an indicator. The chlorinity is estimated and from that salinity values were derived using formula.

4.2.2. Total Dissolved Solids (TDS)

The samples were subjected for gravimetric procedure for confirmation of the readings obtained from the hand held meter. About 100 ml of the water sample was taken in a beaker and filtered which was then dried totally in a Hot Air Oven (105°C). TDS values were calculated using the difference in the initial and final weight.

4.2.3. Total Suspended Solids (TSS)

Hundred ml of the sample was filtered through each pre-weighed filter and placed in the Hot air oven at specified temperature as per the protocol for 1 hour. The filter paper was allowed to cool in a desiccator and obtain a constant weight by repeating the drying and desiccation steps.

4.2.4. Turbidity

The sample tube (Nephelometric cuvette) was filled with distilled water and placed in the sample holder. The lid of the sample compartment was closed. By adjusting the '*SET ZERO*' knob, the meter reading was adjusted to read zero. The sample tube with distilled water was removed and the 40 NTU standard solution was filled in the tube and the meter reading was set to read 100. Other standards were also run. The turbidity of the marine water sample was then found out by filling the sample tube with the sample, and the reading was noted.

4.2.5. Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

DO was determined by Winkler's method. For the determination of BOD, direct unseeded method was employed. The sample was filled in a BOD bottle in the field and incubated in the laboratory for 3 days after which DO was again determined and the difference was calculated.

4.2.6. Chemical Oxygen Demand (COD)

A known quantity of sea water was placed in a 50 ml Erlenmeyer flask and to which 3.0 g of silver sulphate was added and kept in a magnetic stirrer for proper mixing at room temperature to remove the chloride interference in the form of Silver chloride precipitate. The sample with white precipitate turned to a fade lilac mixed coloured precipitate is the indication. At this point, mixing of samples was stopped and the flasks were kept at 40˚ inclined position. Sedimentation of the coloured precipitate was very quick and 20 ml of the cleared sea water was taken carefully from the upper end of the flask bottom after a rest period of 5-10 min. To the 20ml of sea water sample diluted with 150 ml of distilled water, to which 10 ml of standard $K_2Cr_2O_7$ was added, to which 30 ml of Sulphuric acid was added. The tubes were connected to condensers and refluxed for 2 hours at 150±2^{0}C. After refluxion, the flasks were allowed to cool and titrated against Standard Ferrous Ammonium Sulphate with Ferroin as Indicator. Green blue to wine red is the indication of the end point of the experiment and a blank was run under simultaneous conditions.

4.2.7. Phenolic compounds

Phenols in water (500 ml) were converted to an orange coloured antipyrine complex by adding 4-aminoantipyrine. The complex was extracted in chloroform (25 ml) and the absorbance was measured at 460 nm using phenol as a standard.

4.2.8. Petroleum Hydrocarbons (PHc)

Water sample (1 l) was extracted with hexane and the organic layer was separated, dried over anhydrous sulphate and reduced to 10 ml at 30^{o}C under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with Saudi Arabian crude residue as a standard. The residue was obtained by evaporating lighter fractions of the crude oil at 120^{o}C.

4.2.9. Oil and Grease

About 500 ml of sample was transferred to the separating funnel and sample bottle was carefully rinsed with 30ml of trichlorotrifluoroethane and add the solvent washings was added to the separating funnel. To this, 5ml of 1:1 HCL was added and shaken vigorously for about 2 minutes If soluble emulsion was formed, then the sample container was shaken for 5 to 10 minutes. Then the layers were allowed to separate and the lower layer (organic layer) was discarded from separating funnel. Then the solvent layer was drained through a funnel containing solvent moistened filter paper into a clean pre weight distillation flask. Then solvent was distilled from distillation flask over a water bath at 70 ^{0}C. Then the residue was transferred using minimum quantity of solvent into a clean pre weighed dried beaker and the beaker was placed on water bath for 15 minutes at 70 ^{0}C and evaporate off all the solvent and it was cooled in desiccators for 30 minutes and weight was taken.

4.2.10. Heavy metals

Metals are of great concern especially when it relates to the coastal environment as it has chances of biomagnification from lower organisms to higher organisms through water and sediment. Among common metals are Cadmium (Cd), Lead (Pb), Chromium (Cr), Copper (Cu), Cobalt (Co), Nickel (Ni), Zinc (Zn), Magnesium (Mg) etc. For the release of mineral elements from sediment and sediments, wet oxidation of samples is generally performed. Wet oxidation employs oxidizing acids (Tri / Di-acid mixtures).

Sediment sample will be weighed to 0.5 gm and taken in 100ml beaker covered with a watch glass and 12 ml of Aqua regia in (1: 3 HNO_3 : HCl) will be added and the beaker will be kept in digestion for 3 hours at 100^0c on a hot plate using sand bath and the samples will be evaporated to near dryness and the samples will be kept cool for 5 mins and then 20 ml of 2% nitric acid will be added and kept for 15 minutes in hot plate for digestion and remove from hot plate and cooled and filtered using Whatmann No. 42 mm filter paper and then the final make up to 50 ml with 2 % nitric acid will be made. The extracted sample will be then aspirated to an AAS.

4.3 Results

During the current year of study, three locations namely Offshore (Site 1), Cargo Jetty (Site 2) and Phang Creek (Site 3) were monitoring for various Physico-chemical characteristics in the marine water samples and the data is presented in Table 6-8. The description of the values recorded in each station is detailed as below.

4.3.1. Location 1 - Offshore location

The marine water samples in the Offshore locations revealed the pH values ranged between 7.83-8.06 with the average pH being 8.01 which was well within the prescribed limits for Coastal waters. In case of significant parameters like Phenolic compounds, Petroleum hydrocarbon and Oil & Grease, the maximum concentrations observed for the parameters are 19.55 µg/L, 21.61 µg/L and 4.0 mg/L. The data on different heavy metal concentrations observed in the sampling sites are given in Table 6.

4.3.2. Location 2 - Cargo Jetty

The mean pH value among the twelve samples collected in the Cargo Jetty samples are 8.037. Typical Kachchh water salinity concentrations were in the range of 39.33 - 42.79 ppt with the mean salinity of Kandla water was 40.917 ppt which is slightly higher than the salinity of any of the Indian coastal waters. Due to its tail end location, both the Turbidity and Total Suspended Solids concentrations are comparatively high in the waters with the maximum concentrations recorded as 73.59 NTU and 187.91 mg/L. The mean concentrations of Phenolic compounds, Petroleum hydrocarbon and Oil and Grease were recorded to be 13.564 µg/L, 29.290 µg/L and 1.033 mg/L. In addition to this, various toxic heavy metals were recorded which is presented in Table 7.

4.3.3. Location 3 - Phang Creek

In case of the creek system in DPA vicinity, Phang creek was monitored to understand the impact of disposed dredged materials as this is one the pre-designated sites. In this scenario, the pH value of the waters ranged between 8.01 - 8.1 and the mean pH value of this location is 8.055. Further, the possibility of higher load prevailing in the creek systems when compared to Offshore, the maximum concentration of Total Dissolved Solids, Total Suspended Solids and Turbidity concentrations were 43533 mg/L, 302 mg/L and 110.5 mg/L and these characteristics are indicator of a high turbidity nature of this area. Similarly, in case of major polluting parameters are concerned, the concentrations were 15.57 µg/L (Phenolic compounds), 42.38 µg/L (Petroleum hydrocarbon) and 7.2 mg/L in case of Oil and Grease. The highest concentration of Oil and Grease was found from this location. Similar to previous location metal data, the concentrations of metals recorded in the Phang creek is given in Table 8.

Table 6: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore)

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	28.50	28.00	29.00	28.50	28.80	28.50	28.50	28.00	28.30	28.00	28.00	27.80
2	pH	8.01	8.00	8.01	8.01	7.96	7.83	8.05	8.03	8.03	8.03	8.06	8.04
3	Salinity (ppt)	40.20	36.74	34.15	38.04	36.31	37.17	34.58	36.31	37.60	35.87	38.04	35.44
4	Total Dissolved Solids (mg/L)	42368	42292	41527	42281	41219	41493	40084	40231	40759	41714	42215	42900
5	Total Suspended Solids (mg/L)	226.00	218.00	242.00	228.00	323.00	202.00	256.00	247.00	244.00	221.00	204.00	187.00
6	Turbidity (NTU)	120.10	60.10	153.90	132.90	141.30	139.20	108.20	100.80	146.70	133.60	158.10	104.50
7	Dissolved Oxygen(mg/L)	5.80	5.50	5.70	5.70	5.50	4.90	6.00	5.70	6.40	6.10	5.90	5.90
8	Bio-Chemical Oxygen Demand (mg/L)	1.30	1.20	1.60	1.00	2.30	1.80	1.10	1.10	1.70	1.40	0.90	0.90
9	Chemical Oxygen Demand (mg/L)	52	48	44	42	50	46	48	38	42	40	36	34
10	Phenolic Compounds (µg/L)	14.55	11.91	16.98	12.86	12.05	19.55	12.55	10.80	11.10	15.90	14.48	7.86
11	Petroleum Hydrocarbons (µg/L)	20.515	20.11	18.63	18.64	21.61	21.605	18.93	18.965	17.865	17.91	19.59	19.68
12	Oil and grease (mg/L)	3.20	4.00	2.80	2.80	2.00	2.00	0.80	1.20	2.80	1.60	4.00	2.80
13	Magnesium (mg/L)	1286.52	1187.56	1347.58	1287.98	1187.59	1045.89	1247.89	1148.98	1335.24	1258.47	1542.57	1422.24
14	Nickel (mg/L)	1.84	1.85	2.45	2.22	4.24	3.21	1.80	1.47	2.89	2.41	3.54	2.36
15	Lead (mg/L)	1.21	0.98	1.20	0.98	0.86	0.34	0.28	0.87	1.01	0.58	0.48	1.24
16	Cadmium (mg/L)	0.43	0.22	0.56	0.87	1.45	1.01	1.22	0.89	1.21	1.01	0.48	0.35
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	1.25	0.89	1.47	0.48	2.12	2.01	1.85	1.22	0.58	0.42	0.22	0.18
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	1.85	1.48	2.22	2.15	1.48	1.54	0.89	1.22	1.78	1.45	1.62	1.50
21	Cobalt (mg/L)	3.25	2.54	1.28	0.89	2.54	2.48	2.47	1.45	1.58	0.98	1.48	1.22

Note: BDL denotes Below Detection Limit.

Table 7: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty)

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	29	28.5	29	28.5	28.9	28	28.7	28.5	29	28.8	29.5	29.2
2	pH	8.09	8.09	7.94	7.92	8.05	7.96	8.08	8.06	8.08	8.05	8.06	8.06
3	Salinity (ppt)	42.79	39.33	41.49	40.63	41.49	40.63	40.63	39.77	41.06	41.06	41.06	41.06
4	Total Dissolved Solids (mg/L)	41146	42035	42887	42285	41929	41658	43796	42232	41308	42098	42762	41774
5	Total Suspended Solids (mg/L)	189	172	190	174	201	189	187	174	212	192	195	180
6	Turbidity (NTU)	67	65.7	74.1	73.9	99.8	96.7	54.2	53.6	98.5	64.1	55.6	79.9
7	Dissolved Oxygen(mg/L)	6.42	5.61	5.81	5.94	5.72	5.14	5.52	5.34	5.35	5.51	5.81	5.34
8	Bio-Chemical Oxygen Demand (mg/L)	1.2	0.5	1.2	0.8	0.9	0.7	0.5	0.42	1.02	0.72	1	0.3
9	Chemical Oxygen Demand (mg/L)	42	38	44	40	52	38	34	32	44	42	38	32
10	Phenolic Compounds (µg/L)	12.77	9.7	6.74	7.82	11.98	24.19	20.6	6.24	20.74	12.99	8.11	20.89
11	Petroleum Hydrocarbons (µg/L)	30.865	30.975	29.425	29.335	27.875	27.49	32.925	33.235	26.18	26.08	29.205	27.895
12	Oil and grease (mg/L)	0.8	1.2	0.4	0.8	0.8	1.2	0.4	1.6	1.2	0.4	2.8	0.8
13	Magnesium (mg/L)	1548.25	1347.23	1258.59	11875.69	1358.47	1258.47	1547.38	1482.36	1542.82	1462	1358.68	1284.49
14	Nickel (mg/L)	0.32	0.28	0.58	0.45	1.25	0.89	1.14	0.98	1.25	0.87	0.98	0.87
15	Lead (mg/L)	0.35	BDL	BDL	0.25	0.18	BDL	0.21	0.15	BDL	0.98	BDL	BDL
16	Cadmium (mg/L)	0.02	0.03	0.07	0.05	0.18	0.09	0.54	0.24	0.05	BDL	BDL	BDL
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	0.89	0.75	1.25	1.01	1.54	1.21	0.98	0.75	1.1	0.58	1.48	1.3
19	Copper (mg/L)	0.25	BDL	0.18	0.16	BDL	0.25	0.2	BDL	0.21	BDL	0.08	BDL
20	Manganese (mg/L)	3.21	2.58	3.11	3.18	2.45	2.78	1.58	1.48	2.01	BDL	BDL	0.28
21	Cobalt (mg/L)	1.22	BDL	1.22	0.89	0.45	1.32	0.89	BDL	0.21	BDL	0.22	0.67

Note: BDL denotes Below Detection Limit

Table 8: Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek)

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	29.2	29	28.8	28.7	28.5	28.3	29	28.8	30	29.5	28.9	28.7
2	pH	8.01	8.01	8.08	8.06	8.03	8.02	8.1	8.07	8.03	8.07	8.09	8.09
3	Salinity (ppt)	42..36	38.04	37.17	38.47	43.22	40.36	39.33	39.33	43.22	44.09	40.63	40.63
4	Total Dissolved Solids (mg/L)	40235	42246	43315	40769	42393	40806	41903	42599	41307	42128	43533	41175
5	Total Suspended Solids (mg/L)	245	221	287	262	302	274	287	268	301	289	301	278
6	Turbidity (NTU)	90	104.1	89.4	93.3	71.1	68.7	110.5	108.1	102.5	73.2	94.7	95.3
7	Dissolved Oxygen(mg/L)	5.54	5.31	5.72	5.51	5.32	5.1	5.37	5.24	5.38	5.11	5.47	5.26
8	Bio-Chemical Oxygen Demand (mg/L)	1.4	1.2	0.9	0.7	0.8	0.7	0.82	0.46	0.92	0.52	0.74	0.42
9	Chemical Oxygen Demand (mg/L)	38	32	40	34	42	36	48	40	34	32	40	36
10	Phenolic Compounds (µg/L)	12.27	13.35	15.57	14.71	11.98	15.14	13.35	15.49	5.38	10.26	12.77	10.19
11	Petroleum Hydrocarbons (µg/L)	24.93	25.07	35.14	35.325	42.285	42.38	25.38	25.44	21.875	21.85	26.005	27.325
12	Oil and grease (mg/L)	4	4.4	3.2	1.6	6.4	6	3.6	4	7.2	4.4	6.8	7.2
13	Magnesium (mg/L)	1536.65	1487.59	1325.25	1258.45	1456.25	1352.56	1478.59	1254.69	1458.87	1602.25	1458.56	1324.87
14	Nickel (mg/L)	BDL	BDL	0.85	0.48	1.22	0.25	1.02	0.89	1.21	0.22	0.45	1.12
15	Lead (mg/L)	0.03	BDL	0.52	0.42	BDL	BDL	BDL	BDL	0.24	0.32	BDL	BDL
16	Cadmium (mg/L)	0.18	0.11	0.25	0.45	0.36	0.34	0.48	0.35	0.48	0.35	BDL	0.25
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	0.35	0.28	0.48	0.32	1.28	0.65	1.04	0.75	0.46	0.57	0.32	0.25
19	Copper (mg/L)	0.32	0.18	BDL	0.24	0.62	0.21	BDL	0.58	0.4	0.08	0.2	0.34
20	Manganese (mg/L)	3.24	1.18	2.25	1.14	3.78	1.25	1.54	2.54	2.35	3.58	2.78	1.58
21	Cobalt (mg/L)	1.32	1.21	1.65	2.58	2.58	1.36	1.36	1.54	2.14	2.87	1.56	0.89

Note: BDL denotes Below Detection Limit

5.1. Introduction for Plankton

Planktons denotes a group of organisms either animal (zooplankton) or plants (phytoplanktons) origin. Major phytoplankton in sea water are Diatoms (Tiwari and Nair, 1998; Thakur et al, 2015), Cocolithophores, Sillicoflagellates, Blue green algae (Cyanobacteria) and Dinoflagellates. Diatoms constitute the major part of the phytoplankton in sea water. Zooplankton comprises the second level in the food chain and includes Tintinnids, Foramoniferan, Radiolarians, Amphipoda, Copepoda, Calanoida, Chaetognaths, larvae of benthic invertebrates and fish larvae etc. (Gajbhiye and Abidi, 1993; Thirunavukkarosu, 2013; Chakrabarty et al. 2017). Many species spend their entire lifecycle as zooplankton, whereas, barnacles, Copepoda and other Crustacean includes different Nauplius stages (larval stages) of zooplankton within their lifecycle also known as meroplankton. The planktonic stages of invertebrates are economically important as a food for pelagic fishes. Zooplankton require a constant supply of oxygen (Dodson, 1992).

The zooplankton may be classified according to their habitat and depth, distribution, size and duration of planktonic life period (Omori and lkeda, 1984). There are the two main classification on the bases of habitat which are Marine plankton or Haliplankton and Freshwater plankton or Limnoplankton. Marine plankton is further divided in to 3 types; Oceanic plankton, Neritic plankton and Brackish water plankton. Oceanic plankton or Off-shore plankton generally found in surface water and continental shelf region water whereas neritic zooplankton means occurring to continental zone to neritic or deep sea (Besiktepe et al, 2015). Brackish water plankton generally inhabiting brackish water like mangrove, estuaries and sea vegetation area.

Size is very important to understanding about the classification of both zooplankton and phytoplankton. Based on size, various categories of plankton are smallest one Picoplankton (0.2-2 µm), Nanoplankton (2-20 µm), Microplankton (20-200 µm), Mesoplankton (200 µm-2 mm), Macroplankton (2-20 mm) and Megaplakton(> 20 mm) .

Phytoplankton are primary producers of sea whereas as a primary consumer are zooplankton which play precious role to control the primary producers in sea. Benthic organisms and higher vertebrate animals uses plankton as a food material in Ocean life. Zooplankton and Phytoplankton are main prey food sources for different Fishes. The main food items of mesopelagic fishes are zooplankton larvae, juvenile fish and many small invertebrate animals.

Population of plankton and other marine living organisms on which the whole aquatic life depends directly or indirectly is largely governed by the interaction of a number of biological, chemical and physical processes and tolerance to one or more of these conditions (Reid and Wood 1976). Understanding of diversity and distribution of marine organisms would not be complete without consideration of abiotic and biotic factors of marine environment. Amongst the various abiotic factors affecting the survival of marine invertebrates in coastal and estuarine regions, salinity and temperature are of primary importance (Rao and Balasubramanian, 1996; Sreenivasulu et al, 2017). Planktons are affected by changes in biotic and abiotic factors of environment and can rapidly respond to climatic changes. The population of plankton diversity is largely related to Seasonal and Monthly variability in Physical, Chemical and Biological parameters; Interspecific competition among the Zooplankton; Inter-relationship for prey and predator between zooplankton and their mostly predator animals; Grazing ratio of Zooplankton; Suspension of sediment; Fluctuation in Phytoplankton abundance; Waves, Curents and Tidal turbulence effect; Fluctuation in Chlorophyll a and Nutrients; Input of Organic and other Pollution creating sources; Fish potential ratio; Monsoon effect; Suddenly changes in atmosphere; Peak time of every seasons and it's effect; Vertical migration of Zoopalnkton; Food selection pattern of predator; Collection time and number of collected samples, mixing of water column, high surface action, Seasonal upwelling and down welling process in water column.

5.2. Methodology

5.2.1 Estimation of Chlorophyll and Phaeophytin

Estimating Chlorophyll and Phaeophytin was done using known volume of water (500 ml) was filtered through a 0.45µm Millipore membrane filter paper and the pigments retained on the filter paper were extracted in 90% acetone overnight at 50°C. The extinction of the acetone extract was measured using fluorimeter before and after treatment with dilute acid (0.1N HCI).

5.2.2. Phytoplankton sampling and analysis

Phytoplankton samples were collected in the ten prefixed sampling sites using a standard plankton net with a mesh size of 51 µm. Plankton nets are with a square mouth covering an area of 0.900 cm^2 (30cm square mouth) fitted with a flow meter (Hydrobios). Nets were towed from a moving boat for 10 minutes and the plankton adhering to the net was concentrated in the net bucket. Plankton soup from the net bucket was transferred to a pre-cleaned and rinsed container and preserved with 5% neutralized formaldehyde. The containers were appropriately labelled. The initial and final flow meter reading was noted down for calculating the amount of water filtered to estimate plankton density. As per flow meter reading, a total amount of $165m^3$ of water was filtered by the net. One liter of water was separately collected for density estimation to counter check density estimation obtained by the flow meter reading. Quantitative analysis of phytoplankton (cell count) was carried out using a sedge wick-Rafter counting chamber. One ml of soup added to a Sedgwick counting chamber was observed under an inverted compound microscope. The number of cells present in individual cells of the counting chambers (1/1000) was noted and identified up to a generic level. Several observations were fixed to represent the entire quantity of the soup (generally more than30 times) and the recorded data were used to calculate the density (No/l) using the formula, $N = n \times v/V$ (where N is the total no/l; n is an average number of cells in 1 ml; v is the volume of concentrate; V is the total volume of water filtered). The phytoplankton diversity richness and evenness were past software.

5.3. Phytopigments

The concentration of phytopigments are directly proportional to the turbidity of the waters and in general, Kandla waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.31-1.31 mg/m^3 with a mean ± SD being 0.60±0.28 mg/m^3 in the Offshore (Table 9), 0.17 to 0.52 mg/m^3 with mean ± SD of 0.356±0.098 mg/m^3 in the Cargo Jetty (Table 10) and 0.21 to 0.75 mg/m^3 with mean ± SD being 0.391±0.149 mg/m^3 in the Phang creek location (Table 11).

The another phytopigment estimated was Phaeophytin, which is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.19 – 0.73 mg/m3 with a Mean±SD of 0.35±0.16 mg/m^3 in the Offshore location. In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.11 – 0.41 mg/m^3 with a Mean±SD of 0.256±0.082 mg/m^3 and in case of the creek location, the concentration of phaeophytin was almost similar when compared to the other two locations and was ranging between 0.18 – 0.51 mg/m^3 with a Mean±SD of 0.306±0.111 mg/m^3 (Table 11). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 9: Chlorophyll and Phaeophytin concentration observed in the Offshore site

Parameters	1A		1B		1C		1D		1E		1 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	1.31	0.67	0.81	0.61	0.66	0.36	0.66	0.4	0.31	0.35	0.35	0.67
Phaeophytin	0.41	0.28	0.73	0.56	0.21	0.31	0.19	0.21	0.28	0.27	0.29	0.47

Table 10: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site

Parameters	2A		2B		2C		2D		2E		2 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.45	0.17	0.33	0.35	0.35	0.27	0.52	0.35	0.32	0.51	0.35	0.3
Phaeophytin	0.34	0.11	0.27	0.27	0.27	0.18	0.41	0.22	0.19	0.32	0.3	0.19

Table 11: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site

Parameters	3A		3B		3C		3D		3E		3 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.36	0.22	0.37	0.42	0.58	0.36	0.3	0.21	0.31	0.39	0.75	0.42
Phaeophytin	0.21	0.2	0.21	0.34	0.5	0.32	0.27	0.18	0.28	0.27	0.51	0.38

5.4. Phytoplankton

The study was conducted at 3 sites (or regions) at Deendayal Port and near area where dredging activities is going on Creek and the stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

In this site, frequently observed species were *Coscinodiscus oculus-iridis*, *Coscinodiscus radiatus*, *Coscinodiscus granii*, *Gyrosigma sp*, *Synedra ulna*, & *Thalassiosira fraunfeldii colony, Thalassiosira nitzschioides colony, Triceratium broeckii*. whereas less observed species were *Ceratium furca, Ceratium tripos, Entomoneis sp, Pinnularia sp, Protoperidinium sp, Pyrophacus sp, Triceratium favus.* Highest population density was recorded at site 1C-Offshore (896000 NoS/l) and low density recorded at site 1control-Offshore (33120 no/l). The maximum number of species observed in site 1a-Offshore (21 nos.) followed by 1B-Offshore (19 nos.), 1C-Offshore (11 nos), 1E-Offshore (10 nos) and 1D-1Control-Offshore (8 nos). The population density greatly varied (33120 nos/l to 89600nos/l). Among all recorded Phytoplankton Centric diatoms were 18, Pennate diatom- 9, Dinoflagellated -4 and Unidentified -1. Dinoflagellats like Ceratium furca, Ceratium tripos, Protoperidinium sp and Pyrophacus sp were recorded which are sometimes responsible for Algal Blooms in water.

Cargo jetty

The population density greatly varied between 34240 Nos/l to 62080 Nos/l. Highest density value recorded at 2B-Cargo Jetty (62080 No/l) and lowest value was at 2D-Cargo Jetty (34240). The highest number of species noticed in the site 2B- Cargojetty (17 nos.) where as density was also higher and lowest number of species noticed at 2C and 2E-Cargo Jetty (12 nos.). In this Cargo Jetty station commonly or frequently observed species were *Coscinodiscus granii*, *Coscinodiscus oculus-iridis*, *Coscinodiscus radiatus*, *Navicula sp, Pleurosigma sp*, *Thalassionema frauenfeldii colony*, *Thalassionema nitzschioides colony*, *Thalassiosira sp*. The rarely found species were *Biddulphia*, *Cyclotella sp*, *Odontella sp,, Surirella sp, Tripos azoricus, Coccolithoohores etc.* Among all Phytoplankton 18 Centric Diatoms, 2 Dinoflagellated cysts, 1 Coccolithophore, 1 Green algae, 9 Pennate Diatoms and 1 unidentified phytoplankton recorded.

Phang Creek

The population density of phytoplankton ranged from 26240 No/l to 71040 No/l same way species availability ranged from 12 to 25 nos. Maximum and minimum value of population density were recorded in site 3A-Phang Creek (71040 No/l) to 3E-Phang Creek (26240 No/l). Highest number of species recorded in site 3D-Phang Creek (25 nos) and lowest in site 3A-Phang Creek (12 nos).

Coscinodiscus centralis, *Coscinodiscus oculus-iridis*, *Coscinodiscus radiatus*, *Coscinodiscus granii Coscinodiscus wailesii*, *Euglena sp*, *Planktoniella blanda*, *Synedra sp*, *Synedra ulna Thalassiosira leptopus* were frequently noticed in samples whereas less observed species were *Planktoniella sol*, *Thalassiosira ecenntrica*, *Triceratium favus*, *Oscillatoria sp*, *Ditylum brightwelii* in this site.

Overall view of Phytoplankton showed that a total 54 species of Marine phytoplankton were identified during winter season of the year 2022. Among them, 25 were Centric diatoms, 14 were Pennate diatoms, 6 were Dinoflagellates, 1 was a Blue Green Algae, 1 was a Coccolithophores, 1 belong to Silicoflagellata, 2 were Green algae, 1 species was Unidentified. Plankton identification, both zooplankton and phytoplankton, was done by using relevant identification and taxonomic keys and with standard literatures, monographs and research articles. Some species like *Biddulphia sp*, *Thalassiosira leptopus*, *Climacosphaenica sp*, *Tripos azoricus*, *Pediastrum sp*, *Ditylum brightwelli*, *Protoperidinium sp*, *Scendesmus sp.* were rarely recorded during sample analysis. Input of the fresh water indicated by the presence of some common fresh water species like *Euglena sp*, *Green algae*, *Oscillatoria sp*, *Pediastrum sp*, *Scenedesmus sp*. Highest phytoplankton density was observed at the site 1C-Offshore (89600 No/l) and lowest was observed at site 3E-Phang creek (26240 No/l) (Table 12). Total number of highest species observed at site 1A-Offshore (21 nos) and lowest in site 1D-Offshore and also 1-control-Offshore (8 nos). **During** laboratory analysis some Dinoflagellate species were also recorded like *Ceratium tripos*, *Protoperidinium sp*, *Pyrophacus sp*, *Tripos azoricus*. **Some** Blue green algae represented by *Oscillatoria sp and Scenedesmus sp*. The high population density composed by species like *Coscinodiscus granii*, *Coscinodiscus radiatus*, *Coscinodiscus granii*, *Planktoniella blanda*, *Thalassiosira sp*, *Thalassionema frauenfeldii colony*, *Thalassionema nitzschioides colony and Synedra ulna.* (Table 12). This result indicated that genus *Coscinodiscus sp*. was very common with good numbers in all sites. In some sites, least number of species and low density of phytoplankton might be responsible due to by the high Pre-Predation ratio, Pollution, High turbidity, Total suspended solids, Water current of water and suddenly changes in favourable environment conditions. The individual density of species of sites viz. has been depicted in Table 12. All values of zooplankton density, list of zooplankton and others shown in Table 12.

5.4.4. Diversity Indices of Phytoplankton

The Table 13 shows diversity indices calculation for phytoplankton showed that the Shannon Index ranged from (1.784 to 3.004) indicated moderate to slightly higher level of diversity status. High Shannon Index was recorded at 3D-Phang Creek (3.004) and low at 1control-Offshore (1.784). Lowest evenness recorded at site 1A-Offshore (0.486) where highest phytoplankton numbers (21 Nos) were noticed, whereas highest was in at 3E-Phang Creek (0.925) where density was low recorded (26240 nos/l). Simpson dominance index 1-D-Offshore was showed the range from 0.782 to 0.940 whereas higher value in 3D-Phang Creek (0.940) and lowest was at in 1-Control-Offshore (0.782) (Table 13)

Table 12. Density of Phytoplankton at different sites of Deendayal Port

Name of Sites	**Offshore**						**Cargo Jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1 control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2 control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3 control**
Genus of Phytoplankton																		
Actinocyclus sp	0	960	8320	0	3040	3520	2720	0	0	1920	0	0	0	2240	0	4480	0	0
Biddulphia sp.	1760	0	0	0	0	0	0	0	0	640	0	0	0	0	0	0	0	0
Campylodiscus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratium furca	640	1440	0	0	0	0	0	0	0	0	0	0	0	0	0	1280	0	0
Ceratium sp.	0	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	0
Ceratium tripos	0	960	0	0	0	0	0	0	0	0	0	0	0	0	0	2080	0	0
Climacosphaenia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	960	0	0	0	0
Coccolithophores	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	1760	0	0
Coscindiscus centralis	0	0	0	0	0	0	0	0	0	1440	0	2560	0	960	1600	1280	1440	2080
Coscindiscus oculus-iridis	3040	4320	10560	9920	4640	3360	4160	4160	2560	1440	960	0	11840	2400	3200	0	800	0
Coscindiscus radiatus	1600	4480	4160	0	2560	3040	2560	4480	1920	0	3200	3360	800	960	1920	5760	2080	4160
Coscinodiscus granii	16480	5440	29920	10080	11360	13120	12000	13280	13760	0	13920	9920	11680	9600	3360	2720	2080	3200
Coscinodiscus sp	0	2720	0	0	0	0	3200	0	0	0	0	4320	0	0	0	1760	0	0
Coscinodiscus wailesii	0	0	0	0	0	0	0	0	0	0	0	0	0	8480	1600	3200	2560	1920
Cyclotella sp.	0	0	0	0	0	0	0	0	0	1440	0	2560	0	0	1760	4320	0	1600
Dictyocha sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	0	0
Ditylum brightwelli	0	0	0	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0
Entomoneis sp	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euglena sp.	0	0	0	0	0	0	0	0	0	0	0	0	2560	3040	0	1760	2400	0
Green algae	0	0	0	0	0	0	0	0	0	0	0	800	0	800	0	1120	0	0
Guinardia sp	0	480	0	0	0	0	0	0	0	0	0	640	0	0	640	0	0	0
Gyrosigma sp.	1120	0	0	2080	0	0	1440	2880	0	0	0	0	0	0	0	0	0	0
Navicula lyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	800	960	0	0
Navicula sp.	640	1440	0	0	0	0	800	1440	1280	1440	0	0	0	0	2240	0	0	0
Nitzschia sp.	320	0	0	0	0	0	0	0	0	0	0	800	0	0	960	0	0	0
Odontella sinensis	0	0	0	0	0	0	0	0	0	0	0	1440	0	0	0	0	320	0
Odontella mobiliensis	0	0	0	0	0	0	1920	0	0	0	2560	0	0	0	0	0	1120	1600
Odontella sp.	0	0	0	0	0	0	0	0	0	0	960	0	0	0	0	0	0	0
Oscillatoria sp.	0	0	0	0	0	0	0	0	0	960	1280	0	0	1120	0	0	0	0
Pediastrum sp.	0	0	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0
Pinnularia sp.	800	0	0	0	0	640	640	0	0	0	0	0	0	0	0	0	0	0
Planktoniella blanda	1440	0	8160	2560	4320	3840	0	3360	0	4480	0	0	6400	3840	3360	4320	1760	5920
Planktoniella schutt	1920	0	3360	0	0	0	0	0	0	0	0	2080	3520	0	0	0	0	0

Planktoniella sol	0	0	0	0	1920	0	0	1920	0	1760	0	0	0	800	0	0	0	0
Pleurosigma sp.	0	3040	0	0	320	0	1600	2080	1440	2240	0	0	3040	0	0	1920	1280	0
Protoperidinium sp.	0	960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrophacus sp.	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus sp.	0	0	0	0	0	0	0	3840	0	0	0	0	0	0	0	0	0	0
Stellate trichome microplant parts	0	0	0	0	0	0	1280	0	0	0	0	0	0	0	0	0	0	0
Surirella sp.	0	1920	0	0	1120	0	0	1280	0	1440	0	0	0	0	0	0	1920	0
Synedra sp.	1440	0	0	1120	0	0	0	0	960	0	2720	0	0	3040	800	1280	1600	1120
Synedra ulna	0	2880	1120	0	2880	1600	3840	0	1600	0	2720	2240	0	0	480	1440	0	960
Thalassionema frauenfeldii colony	0	8480	4960	4160	0	0	1120	6720	1760	3360	7520	0	5920	5920	3040	4320	2240	3200
Thalassionema nitzschioides colony	5120	12000	6560	5920	0	0	960	2560	4160	2720	3360	5120	0	5280	0	7520	2560	4160
Thalassiosira ecentrica	1760	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1760	0	0
Thalassiosira ferelineata	0	4960	0	0	0	0	0	0	0	0	0	0	8960	0	0	0	0	0
Thalassiosira leptopus	1440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalassiosira sp	160	14400	11040	6560	6720	4000	3840	8800	4160	6560	3840	1920	13120	8480	5120	2240	2080	5440
Triceratium broeckii	800	2080	1440	0	0	0	0	960	1600	1600	0	0	2720	1600	0	1600	0	1280
Triceratium favus	480	0	0	0	0	0	0	1600	480	0	0	0	0	320	0	480	0	0
Triceratium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tripos azoricus	0	0	0	0	0	0	0	1920	0	0	0	0	0	0	0	0	0	0
Unidentified sp.	320	8000	0	0	0	0	0	0	0	0	3200	0	0	640	640	640	0	4480
Density of Phytoplankton (diff. sites wise.) (no/lit)	**42560**	**80960**	**89600**	**42400**	**38880**	**33120**	**42080**	**62080**	**35680**	**34240**	**46240**	**38560**	**71040**	**60480**	**31520**	**61120**	**26240**	**41120**
Total=877920 No/l																		
Total No Of Genus/Species= **53**																		

Table 13. Diversity Indices of Phytoplankton at different selected sites of Deendayal Port

	Offshore						Cargo jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	21	19	11	8	10	8	15	17	12	16	12	14	12	19	16	25	15	14
Individuals (Nos/m^2)	42560	80960	89600	42400	38880	33120	42080	62080	35680	34240	46240	38560	71040	60480	31520	61120	26240	41120
Dominance_D	0.182	0.095	0.170	0.171	0.161	0.218	0.129	0.103	0.194	0.093	0.150	0.125	0.127	0.096	0.089	0.060	0.075	0.093
Shannon Diversity	2.324	2.594	2.054	1.886	2.022	1.784	2.375	2.533	2.046	2.576	2.177	2.34	2.205	2.567	2.567	3.004	2.63	2.49
Simpson_1-D	0.818	0.905	0.830	0.829	0.839	0.782	0.871	0.897	0.806	0.908	0.850	0.876	0.873	0.904	0.911	0.940	0.925	0.907
Evenness	0.486	0.705	0.709	0.824	0.756	0.744	0.717	0.741	0.645	0.822	0.735	0.741	0.756	0.686	0.814	0.807	0.925	0.861
Menhinick	0.102	0.067	0.037	0.039	0.051	0.044	0.073	0.068	0.064	0.086	0.056	0.071	0.045	0.077	0.090	0.101	0.093	0.069
Margalef	1.88	1.59	0.88	0.66	0.85	0.67	1.32	1.45	1.05	1.44	1.02	1.23	0.98	1.64	1.45	2.18	1.38	1.22

5.5. Zooplankton

The study was conducted at 3 sites in Deendayal Port area and nearby areas where dredging activities are going on. The three selected study stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

The *Ostracoda, Sponge spicules, Eggs capsules of Littorinids, Euterpina sp (Harpacticoida), Globigerina sp (Foraminifera), Nauplius larva of Copepoda, Nauplius larva of Barnacles, Tintinnopsis radix (Tintinnida), Copepoda egg sacs(pouch)* were the mostly common zooplankton throughout observed in all sites of Offshore points. Highest population density was recorded at site 1D-Offshore (128800 No/100m^3) and lowest in 1-control-Offshore (44000 No/100m^3). **Site** 1B-Offshore has maximum number of species (28 nos) whereas minimum was found in the site 1-control-Offshore (15 nos). High biomass was observed in the site 1Control-Offshore (55.97 ml/100m^3) and low biomass was in site 1E-Offshore (10.17 ml/100m^3). The range of the population density, biomass and number of species were (44000 to 128800 no/100m^3), (10.17 to 55.97 ml/100m^3) and (12 to 33 nos) respectively in all sites. Less observed species are *Ammonia sp* (Foraminifera), *Arcella sp* (Protozoa) *Sagitta sp, Dentilium, Calcarina sp* (Foraminifera), *Spirilina sp* (Foraminifera), Centropages sp (Calanoida) etc. rarely recorded in this station. Total 52 zooplankton was recorded in Offshore station adding that more composition of zooplankton by phylum Crustacea and Foraminifera as shown in Table 14.

Cargo Jetty

The population density of zooplankton varied from 47320 No/100m^3 to 96140 No/100m^3. Maximum density was noticed in site 2C-Cargo Jetty (96140 no/100m^3) and minimum was at site 2Control-Cargo Jetty (47320 no/100m^3) as given in Table 15. The site 2C-Cargo Jetty comprises highest number of species (33 nos) and minimum number of species was observed in site 2B-Cargo Jetty (15 nos). Biomass ranged between 15 to 57.14 ml/100m^3 where highest biomass noted in site 2B-Cargo Jetty and lowest in 2A-Cargo Jetty. Frequently observed species were *Centropages sp* (Calanoida), *Clausocalanus sp* (Calanoida) Zoea larva of Crustacean, *Oithona sp* (Cyclopoida), *Subeucalanus sp* (Calanoida), *Tintinnopsis beroidea* (Tintinnida), Tintinnopsis radix (Tintinnida), and *Egg capsules of Littorinids* whereas less observed species were *Nodosaria sp* (Foraminifera), Copepoda egg sacs(pouch), *Euchaeta sp*

(Calanoida), *Diacyclops sp* (Cyclopoida), *Leprotintinnus nordqvistii* (Tintinnida), *Leprotintinnus simplex* (Tintinnida). Total recorded zooplankton was 60 nos. in Cargo Jetty.

Phang Creek

This Creek area was represented by the zooplankton fauna majority of Egg capsule of Littorinids, Nauplius larva of Copepoda, Sponge spicules, *Clausocalanus sp* (Calanoida), *Oithona sp* (Cyclopoida), *Tintinnopsis beroidea* (Tintinnida). **Very** less time or rarely recorded species were *Amphipoda*, *Cibicides sp* (Foraminifera), Coccolithophores, *Eponidis sp* (Foraminifera) The range of zooplankton Biomass was between 0.50 to 30.49 ml/100m^3 . Highest Biomass was recorded in site 3D-Phang creek (30.49 ml/100m^3) and lowest in site 3B-Phang creek (0.50 ml/100m^3). Maximun and Minumum species count was at in site 3A,3C and 3D-Phang creek (25 nos) and 3E-Phang creek (12 nos) respectively. Population density was maximum recorded in site 3C-Phang creek (101600 No/100m^3) and minimum in site 3E-Phang creek (36360 No/100m^3).

Overall assessment of zooplankton showed that the total number of 38 Zooplankton recorded during monsoon season. Out of these (86 nos) zooplankton, 52 zooplankton recorded in Offshore region, 60 zooplankton at Cargo Jetty and 55 zooplankton in Phang Crek region. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea) as presented in Table 16. Protozoa (mainly foraminifera and tintinnids), Porifera (Sponge spicules) Generally zooplankton population dynamics and studies emphasize is given up to group level rather than to species level because of microscopic size of zooplankton so owing to the difficulty in identifying the zooplankton as some species are considered as a group or genus level. The most dominant or frequently observed species were *Clausocalanus sp* (Calanoida), *Egg capsules of Littorinids, Ostracoda, Tintinnopsis radix, Oithona sp* (Cyclopoida), *Zoea larva of Crustacea*, *Sponge spicules*, *Globigerina sp (Foraminifera)* and other Foraminifera. The range of Population density, Biomass and Number of Species were (36360 to 128800 no/100 m^3), (0.50 to 57.14 ml/100m^3) and (12 to 33 nos) respectively. **Averag**e high biomass noted at Cargo Jetty followed by Offshore and Phang creek (Table 14,15,16). Highest population density was recorded in site 1D-Offshore (128800 no/100m^3) and lowest was recorded in site 3E-Phang Creek (36360 No/100m3). Among all recorded zooplankton, majority dominance occurrence was by the Copepoda, Crustacean larvae, Spong Spicules, Foraminifera (Protozoa), Tintinnids (Protozoa), Egg capsules of Littorinids (Mollusca). Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda, Mollusca, Protozoa and Poriffera. The Chaetognatha and tunicata groups were only represented by the one species namely Sponge spicules, *Sagitta sp* and *Oikopleura sp* respectively. In Offshore**,** maximum Occurrence (%) was by the Egg Capsules of Littorinids (18.33%) and minimum by the Radiolarian (0.10%). In Cargo Jetty, maximum Percentage of Occurrence (%) by the Eggs of Littorinids (14.31%) and minimum by the Nodosaria sp (0.07%) (Foraminifera).. In Phang Creek maximum Occurrence (%) was by the Egg capsules of Littorinids (12.42%) and minimum (0.08%) by the *Cibicides sp* (Foraminifera).

During analysis, some Species of Foraminifera and Spicules of sponge were frequently observed. These both are very important for paleontological study aspects and also for evolutionary, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Some deep sea species also recorded that is indication of water circulation pattern. Data on zooplankton density, list of zooplankton is shown in Table (14, 15 & 16).

Diversity Indices of Zooplankton

Table 17 shows *diversity zooplankton*. The Shannon-wiener diversity index (H') fluctuated between 2.42 to 3.22 indicated moderate to quite high range of diversity with a maximum value in site 2C-Cargo Jetty (3.22) and minimum value in site 3E-Phang creek (2.42). Range of the evenness was 0.514 to 0.938 where highest and lowest recorded in site 3E-Phang Creek (0.938) where lowest density was recorded and 1D-Offshore (0.514) respectively. Highest Simpson index 0.95 noted at site 2C-Cargo Jetty whereas lowest in site 1A (0.88).

Table 14. Density of Zooplankton at Offshore site of Deendayal Port

Name of Genera/Group	1A	1B	1C	1D	1E	1 Control	Individual total density (no/100m^3)	% of Occurrence
Acartia sp (Calanoida)	0	0	5120	0	0	0	5120	1.06
Ammonia sp. (Foraminifera)	0	0	0	0	3360	0	3360	0.70
Arcella sp (Amoebozoa)	0	0	1280	0	0	0	1280	0.27
Bolivina sp.(Foraminifera)	0	0	7040	3360	1440	0	11840	2.46
Calcarina sp. (Foraminifera)	0	0	0	0	800	0	800	0.17
Centropages sp. (Calanoida)	0	1440	0	0	0	0	1440	0.30
Clausocalanus sp (Calanoida)	2560	5120	0	3520	0	0	11200	2.32
Copepoda egg sacs (egg pouch)	0	4320	3840	0	0	6880	15040	3.12
Cyclops sp (Cyclopoida)	0	0	0	6560	0	0	6560	1.36
Cyphonautes larva of bryozoans	640	0	0	0	1920	0	2560	0.53
Dentalium	0	0	0	0	0	640	640	0.13
Diacyclops sp. (Cyclopoida)	5440	1920	0	0	0	0	7360	1.53
Egg Capsules of Littorinids	12480	13120	13920	43040	0	5760	88320	18.33
Eucalanus sp. (Calanoida)	0	0	0	3200	0	0	3200	0.66
Euchaeta sp (Calanoida)	0	0	0	1600	0	0	1600	0.33
Euterpina sp (Harpacticoida)	960	3520	0	0	480	2560	7520	1.56
Eutintinnus apertus (Tintinnida)	0	0	0	2240	1920	0	4160	0.86

Globigerina sp. (Foraminifera)	2720	3520	12320	4640	4160	0	27360	5.68
Labidocera sp. (Calanoida)	0	1120	0	0	0	0	1120	0.23
Larva of Hydrozoa (Phylum: Cnidaria)	0	2880	0	0	3040	1440	7360	1.53
Leprotintinnus nordqvistii (Tintinnida)	0	2080	0	0	2720	0	4800	1.00
Leprotintinnus simplex (Tintinnida)	0	0	0	0	1760	0	1760	0.37
Nauplius larva of Copepoda	1920	3360	1600	0	7360	2720	16960	3.52
Nauplius larva of Harpacticoida	0	0	0	0	0	1600	1600	0.33
Nauplius larvae of Barnacles	2720	2720	0	0	1920	1120	8480	1.76
Nauplius larvae of Crustacea	0	0	0	0	0	4960	4960	1.03
Nonion sp. (Foraminifera)	0	0	0	2240	960	0	3200	0.66
Oithona sp. (Cyclopoida)	0	5120	9120	3520	0	0	17760	3.69
Ophiopluteus larva of (Echinodermata)	1440	0	0	0	1440	0	2880	0.60
Ostracoda	1120	320	2720	0	4640	4640	13440	2.79
Other Calanoida	0	0	0	16960	0	1280	18240	3.78
Other Cyclopoida	0	1440	0	7040	0	0	8480	1.76
Parvocalanus sp (Calanoida)	1760	1920	0	0	0	0	3680	0.76
Quinqueloculina sp.(Foraminifera)	0	10240	0	2720	0	0	12960	2.69
Radiolaria skeleton	320	800	0	320	160	0	1600	0.33
Radiolaria sp (Protozoa)	0	320	0	160	0	0	480	0.10

Rosalina sp. (Foraminifera)	800	1440	3200	4640	4960	0	15040	3.12
Sagitta sp (arrow worm)	1120	0	0	0	0	0	1120	0.23
Small Gastropoda	0	0	0	1280	0	0	1280	0.27
Spirillina sp. (Foraminifera)	0	0	0	0	3360	0	3360	0.70
Spiroloculina sp (Foraminifera)	1440	1920	1760	0	0	0	5120	1.06
Sponge spicules	10880	8480	10240	9920	5760	5920	51200	10.62
Temora sp (Calanoida)	0	0	3040	0	5280	2720	11040	2.29
Thermocyclops sp. (Cyclopoida)	0	0	0	0	3360	0	3360	0.70
Tintinnopsis beroidea (Tintinnida)	3680	0	0	960	0	0	4640	0.96
Tintinnopsis cylindrica (Tintinnida)	1280	4480	4000	2720	0	0	12480	2.59
Tintinnopsis lobiancoi (Tintinnida)	0	2240	0	3680	0	0	5920	1.23
Tintinnopsis orientalis (Tintinnida)	0	2720	5760	0	1280	0	9760	2.03
Tintinnopsis radix (Tintinnida)	1920	1120	5600	2720	1920	0	13280	2.76
Veliger larvae of Bivalve	0	640	3520	1760	0	1760	7680	1.59
Zoea larva of Crustaceans	0	4000	0	0	2880	0	6880	1.43
Unidentified sp.	0	0	640	0	0	0	640	0.13
Total No. Of Genera/Groups =52								
Site-wise Total Density (no/100m^3)	55200	92320	94720	128800	66880	44000	**Total Density =481920**	**100%**
Biomass (ml/100m^3)	**11.24**	**13.38**	**15.67**	**16.91**	**10.17**	**55.97**		

Table 15. Density of Zooplankton at Cargo Jetty site of Deendayal Port

Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Individual total density (no/100m^3))	% of Occurrence
Acartia sp (Calanoida)	0	1600	960	800	2080	0	5440	1.27
Acrocalanus sp. (Calanoida)	1920	0	0	1280	0	0	3200	0.75
Bolivina sp.(Foraminifera)	0	0	1920	2240	0	0	4160	0.97
Calcarina sp. (Foraminifera)	0	0	960	960	0	0	1920	0.45
Centropages sp. (Calanoida)	640	2240	1760	960	1760	0	7360	1.72
Clausocalanus sp (Calanoida)	1920	1760	2560	1920	2880	0	11040	2.58
Copepoda egg sacs (egg pouch)	1280	0	0	0	0	0	1280	0.30
Corycaeus sp (Calanoida)	0	0	0	1440	0	0	1440	0.34
Cyphonautes larva of bryozoans	2720	0	0	0	1440	1600	5760	1.35
Diacyclops sp. (Cyclopoida)	0	0	0	1760	0	0	1760	0.41
Egg Capsules of Littorinids	11680	8640	9920	14880	5600	10400	61120	14.31
Euchaeta sp (Calanoida)	0	0	0	0	1440	0	1440	0.34
Euterpina sp (Harpacticoida)	7040	3520	0	2080	2880	0	15520	3.63
Eutintinnus sp. (Tintinnida)	0	0	0	0	1920	0	1920	0.45
Fish larva	0	0	0	0	1120	0	1120	0.26
Globigerina sp. (Foraminifera)	0	0	6400	12480	3360	2400	24640	5.77

Heterolaophonte (Harpacticoida)	0	0	0	0	1760	0	1760	0.41
Larva of Crustacea	0	0	0	0	640	0	640	0.15
Larva of Hydrozoa (Phylum: Cnidaria)	1920	0	300	1440	0	0	3660	0.86
Leprotintinnus nordqvistii (Tintinnida)	0	0	0	1760	0	0	1760	0.41
Leprotintinnus pellucidus (Tintinnida)	0	0	0	1920	1120	0	3040	0.71
Leprotintinnus simplex (Tintinnida)	0	0	0	0	3360	0	3360	0.79
Microsetella sp (Harpacticoida)	0	2520	0	0	0	1760	4280	1.0
Nauplius larva of Calanoida	0	0	3040	0	0	0	3040	0.71
Nauplius larva of Copepoda	0	0	4320	2720	0	0	7040	1.65
Nauplius larvae of Barnacles	4160	0	1760	2240	1760	0	9920	2.32
Nauplius larvae of Cyclopoida	0	0	4000	0	0	0	4000	0.94
Nodosaria sp (Foraminifera)	0	0	320	0	0	0	320	0.07
Oithona brevicornis	0	0	1440	0	0	0	1440	0.34
Oithona sp. (Cyclopoida)	3360	3520	4320	2400	2240	2400	18240	4.27
Ophiopluteus larva of (Echinodermata)	0	0	1440	960	0	0	2400	0.56
Ostracoda	3840	3840	1440	0	0	1720	10840	2.54
Other Calanoida	3040	2720	0	0	0	0	5760	1.35
Other Cyclopoida	1760	0	1280	0	0	0	3040	0.71
Paracalanus sp. (Calanoida)	2240	0	3200	0	0	0	5440	1.27
Parvocalanus sp (Calanoida)	1920	1280	0	1760	0	1920	6880	1.61
Polychaeta larvae (Annelida)	0	2560	0	0	0	0	2560	0.60

Pseudodiaptomus sp (Calanoida)	0	0	0	0	2080	0	2080	0.49
Quinqueloculina sp.(Foraminifera)	0	0	1760	3680	3840	0	9280	2.17
Radiolaria skeleton	0	0	0	0	320	480	800	0.19
Radiolaria sp (Protozoa)	0	0	320	0	160	0	480	0.11
Rosalina sp. (Foraminifera)	0	0	1920	3520	0	800	6240	1.46
Sagitta sp (arrow worm)	0	1600	0	0	0	0	1600	0.37
Small Gastropoda	0	0	1600	0	0	0	1600	0.37
Spirillina sp. (Foraminifera)	0	0	0	320	0	640	960	0.22
Spiroloculina sp (Foraminifera)	0	0	1920	640	2720	1920	7200	1.69
Sponge spicules	16320	8320	7040	0	0	8320	40000	9.36
Subeucalanus (Calanoida)	3360	0	0	1920	1280	1920	8480	1.98
Temora sp (Calanoida)	4640	0	0	0	0	1760	6400	1.75
Tintinnopsis beroidea (Tintinnida)	1920	2560	5280	6240	2720	1600	20320	4.76
Tintinnopsis cylindrica (Tintinnida)	0	0	0	0	0	1440	1440	0.34
Tintinnopsis lobiancoi (Tintinnida)	0	0	0	0	1440	0	1440	0.34
Tintinnopsis mortenseni (Tintinnida)	0	0	800	0	0	0	800	0.19
Tintinnopsis radix (Tintinnida)	2560	0	6400	1760	1920	2240	14880	3.48
Tintinnopsis sp (Tintinnida)	0	0	4960	0	0	1600	6560	1.54
Tintinnopsis tubulosa (Tintinnida)	0	0	2400	3200	0	1920	7520	1.56

Triloculina sp (Foraminifera)	0	0	1280	0	0	0	1280	0.30
Veliger larvae of Bivalve	0	0	2560	1760	3040	0	7360	1.72
Zoea larva of Crustaceans	2080	8480	6560	5120	8960	0	31200	7.30
Unidentified sp.	0	0	0	320	0	480	800	0.19
Total No. Of Genera/Groups =60								
Site-wise Total Density (no/100m^3)	**80320**	**55160**	**96140**	**84480**	**63840**	**47320**	**Total Density =427260**	**100%**
Biomass (ml/100m^3)	**15**	**57.14**	**20**	**27.27**	**20.55**	**41.03**		

Table 16. Density of Zooplankton at Phang Creek site of Deendayal Port

Name of Genera/Group	3A	3B	3C	3D	3E	3 Control	Total density (no/100m3)	% of Occurrence
Acartia sp (Calanoida)	0	0	1440	1440	0	0	2880	0.74
Acrocalanus sp. (Calanoida)	1280	0	2880	0	0	2080	6240	1.60
Amphipoda	0	0	0	800	0	0	800	0.21
Arcella sp (Amoebozoa)	1120	0	0	0	0	0	1120	0.29
Centropages sp. (Calanoida)	2560	0	0	0	0	0	2560	0.66
Cibicides sp (Foraminifera)	0	320	0	0	0	0	320	0.08
Clausocalanus sp (Calanoida)	7360	7200	9920	0	0	4960	29440	7.57
Clytemnestra sp (Harpacticoida)	0	0	0	1120	0	1280	2400	0.62
Cyclops sp (Cyclopoida)	0	960	2240	0	0	0	3200	0.82
Cyphonautes larva of bryozoans	800	0	0	1600	0	0	2400	0.62
Diacyclops sp. (Cyclopoida)	0	0	1440	0	0	1280	2720	0.70
Egg Capsules of Littorinids	9920	7520	12160	3040	4960	10720	48320	12.42
Eponides sp (Foramonifera)	0	800	0	0	0	0	800	0.21
Eucalanus sp. (Calanoida)	1280	2560	0	2080	0	0	5920	1.52
Euterpina sp (Harpacticoida)	0	0	2560	0	3520	3360	9440	2.43
Eutintinnus apertus (Tintinnida)	2400	0	0	800	0	0	3200	0.82
Eutintinnus lususundae (Tintinnida)	0	0	0	0	0	2080	2080	0.53
Eutintinnus sp. (Tintinnida)	1600	0	0	0	0	0	1600	0.41
Gastrula embryo of Seastar	0	0	0	800	0	0	800	0.21

Globigerina sp. (Foraminifera)	0	2560	0	7040	2080	0	11680	3.00
Labidocera sp. (Calanoida)	0	0	800	960	0	800	2560	0.66
Larva of Hydrozoa (Phylum: Cnidaria)	0	800	0	0	0	0	800	0.21
Leprotintinnus nordqvistii (Tintinnida)	1280	1440	0	0	0	0	2720	0.70
Microsetella sp (Harpacticoida)	2080	5440	0	2880	0	0	10400	2.67
Mysis larva	0	1120	0	960	0	0	2080	0.53
Nauplius larva of Copepoda	4800	5120	2080	10080	3360	5760	31200	8.02
Nauplius larvae of Barnacles	2400	3360	5120	3520	0	1760	16160	4.15
Nauplius larvae of Cyclopoida	0	0	0	1760	0	0	1760	0.45
Nonion sp. (Foraminifera)	0	0	0	640	0	0	640	0.16
Oithona sp. (Cyclopoida)	1920	3040	9440	1600	0	4000	20000	5.74
Ophiopluteus larva of (Echinodermata)	0	0	2080	2720	0	1920	6720	1.73
Ostracoda	1440	1280	2880	0	3840	0	9440	2.43
Other Calanoida	0	0	0	1280	0	3200	4480	1.15
Other Cyclopoida	1280	0	2240	0	0	4160	7680	1.97
Paracalanus sp. (Calanoida)	0	0	3680	0	0	0	3680	0.95
Parvocalanus sp (Calanoida)	0	2400	0	0	0	1440	3840	0.99
Planispirinella sp (Foraminifera)	0	0	480	0	0	0	480	0.12
Polychaeta larvae (Annelida)	0	0	2240	0	0	0	2240	0.58

Pontellopsis sp. (Calanoida)	480	0	0	0	0	0	480	0.12
Quinqueloculina sp.(Foraminifera)	5920	1280	0	0	0	2080	9280	2.39
Sagitta sp (arrow worm)	0	0	0	0	1600	0	1600	0.41
Sponge spicules	10880	5280	0	3040	3200	2080	24480	6.29
Subeucalanus (Calanoida)	0	0	0	0	0	2720	2720	0.70
Temora sp (Calanoida)	2720	1280	7520	1120	3520	0	16160	4.15
Textularia sp. (Foraminifera)	0	0	0	1760	0	0	1760	0.45
Tintinnopsis beroidea (Tintinnida)	1440	1440	0	1760	3200	0	7840	2.02
Tintinnopsis cylindrica (Tintinnida)	0	0	6880	0	0	1440	8320	2.14
Tintinnopsis karajacensis (Tintinnida)	0	0	0	0	0	800	800	0.21
Tintinnopsis lobiancoi (Tintinnida)	0	0	2720	0	0	0	2720	0.70
Tintinnopsis orientalis (Tintinnida)	3840	0	8480	0	0	0	12320	3.17
Tintinnopsis radix (Tintinnida)	0	0	0	0	2560	0	2560	0.66
Tintinnopsis tubulosa (Tintinnida)	1920	2400	2080	3360	960	0	10720	2.76
Veliger larvae of Bivalve	0	0	7520	0	0	0	7520	1.93
Zoea larva of Crustaceans	1760	2560	2560	2400	3560	0	12840	3.30
Unidentified sp.	320	0	160	0	0	0	480	0.12
Total No of Genera/ Groups =55								
Site-wise Total Density (no/100m^3)	72800	60160	101600	58560	36360	57920	Total density =387400	100%
Biomass (ml/100m^3)	2.50	0.50	13.57	30.49	19.09	11.59		

Table 17. Diversity indices of Zooplankton at different sites of Deendayal Port

Variables	Offshore						Cargo jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	19	28	18	23	24	15	21	15	33	30	27	20	25	22	25	25	12	20
Individuals (Nos/m^2)	55200	92320	94720	128800	66880	44640	80320	55160	96140	84480	63840	47320	72800	60160	101600	58560	36360	59520
Dominance_D	0.12	0.06	0.08	0.15	0.06	0.10	0.09	0.10	0.05	0.08	0.06	0.10	0.08	0.07	0.07	0.07	0.09	0.08
Shannon Diversity	2.50	3.01	2.65	2.47	2.97	2.48	2.72	2.51	3.22	2.98	3.08	2.64	2.87	2.83	2.92	2.94	2.42	2.81
Simpson_1-D	0.88	0.94	0.92	0.85	0.94	0.90	0.91	0.90	0.95	0.92	0.94	0.90	0.92	0.93	0.93	0.93	0.91	0.92
Evenness	0.639	0.722	0.786	0.514	0.813	0.795	0.726	0.818	0.755	0.655	0.802	0.701	0.705	0.773	0.740	0.754	0.938	0.792
Menhinick	0.081	0.092	0.058	0.064	0.093	0.071	0.074	0.064	0.106	0.103	0.107	0.092	0.093	0.090	0.078	0.103	0.063	0.086
Margalef	1.649	2.362	1.484	1.87	2.07	1.308	1.771	1.282	2.789	2.556	2.35	1.765	2.144	1.908	2.082	2.186	1.047	1.819

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Annexure -J

DEENDAYAL PORT TRUST

Office of the Chief Engineer
A.O. Building,
Gandhidham (Kutch)

No.EG/WK/4751/Part 243(B)

Dated : 03/09/2019

CIRCULAR

The Ministry of Environment, Forest & Climate Change, GoI vide G.S.R. 317 (E) dated 29/3/2016 had issued Notification to address in detail the management of Construction & Demolition Waste. In order to implement the said rules issued by the MoEF&CC,GoI in the Deendayal Port Trust, following instructions may kindly be followed:

- Proper management of Construction & demolition waste in accordance with the provisions of Construction and Demolition of Waste Management Rules, 2016.
- Records of generation and disposal of the waste is required to be maintained by the contractor/Lessees at source.
- All trucks before leaving the storage yards shall be covered with tarpaulin and not over loaded as well as there shall not be spillage during transportation.
- Appropriate containers shall be placed for collection of waste, removal at regular intervals, transportation to appropriate sites for processing and disposal.

This is issued with the approval of Competent Authority in DPT.

3/9

Chief Engineer
Deendayal Port Trust

1. All HoD's – For information and necessary action
2. Sr. PS to Chairman – For kind information of Chairman
3. PS to Dy. Chairman – For kind information of Dy. Chairman

Annexure -K

Annexure C

CSR Activities at Deendayal Port Trust

Details of CSR

Sr. No	Year	Board Resolution For Budget Provision	Board Approved Budget Provision	Board Resolution for approval of the CSR activities	Board Approved Amount For CSR Activities	Actual Exp. Upto Nov'20 (Rs. In Lakhs)	Net balance (Rs. In Lakhs)	Remarks
1	2	3	4	5	6	7	6-7	
1	2011-2012	369 of 28.03.2012	3.00 Cr					
2	2012-2013	17 of 31.05.2012	4.00 Cr					
				61 of 30.08.2012	564.00 Lakh	564.00	Nil	Works completed
3	2013 -2014	99 of 30.09.2013	6.43 Cr					
4	2014-2015	322 of 21.11.2014	1.07 Cr	20 of 16.04.2015	236.22 Lakh	188.18	8.04	Works in progress
5	2015-2016	151 of 12.02.2016	1.50 Cr	48 of 12.08.2016	28.00 Lakh	5.00	23.00	Works in progress
6	2016-2017	138 of 06.01.2017	2.60 Cr	32 of 2.8.2017	140.30 Lakh	146.00	-5.70	Works completed
7	2017-2018	41 of 2.08.2017	7.02 Cr	15 of 04.05.2018	155.10 Lakh	115.37	39.73	Works in progress
8	2018-19	51 of 07.08.2019	6.70 Cr	111 of 4.12.2018	154.90 Lakh	50.50	104.40	Works in progress
					1278.52 Lakh	**1069.05**	**209.47**	
9	2019-20	58 of 10.10.2019	5.49 Cr	92 of 06.12.2019	1838.57 Lakh	Nil		MoS approval is awaited
		Total	**37.81 Cr**		**3117.09 Lakh**			
						Spent in PM Fund for COVID-19--800 Lakhs		

Year-wise details of CSR works undertaken by DPT during 2012 – 13 to 2019 – 20 are given in **Tables 7.3a, 7.3b, 7.3c, 7.3d, 7.3e, 7.3f** and **7.3g**.

Table 7.3a: CSR Works Undertaken by DPT during 2011-12 and 2012 – 13

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	Repair of road from Dr. Baba Saheb Ambedkar Circle to NH 8A (via Ganesh Nagar)	518
2	Repair of road from S.T. Bus Stand to Sunderpuri Cross Road via Collector Road	
3	Repair of road from NH 8A Railway Crossing to Maninagar (along railway track)	
4	Repair of road from Khanna Market Road (Collector Road) to Green Palace Hotel	
5	Construction of internal roads at "Shri Ram" Harijan Co-operative Housing Society (near Kidana)	
6	Construction of cremation ground and graveyard with other facilities at Vadinar	19.44
7	Providing cement concrete internal roads in Village Vadinar Stage - I	16.16
8	Approach road provided for developing tourism at Village Veera near Harsidhi Mata Temple	4.65
9	Water tank along with R.O. provided near developing tourism area	0.30
10	Creating facilities of flooring and steps surrounding lake to stop soil erosion and attract tourists at Village Veera.	4.80
	TOTAL	563.35

Table 7.3b: CSR Works Undertaken by DPT during 2014-15

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	Construction of community hall – cum – school at Maheshwari Nagar, Gandhidham	51.90
2	Renovation of "Muktidham" (cremation ground) at Kandla	10.65
3	Sunderpuri – 1 Valmiki Community Hall	5.00
4	Sunderpuri – 2 Valmiki Community Hall	5.00
5	Ganeshnagar Community Hall	10.00
6	Jagjivan Maheshwari Community Hall	10.00
7	Various works of road at Sapnanagar	99.19
8	Construction of compound wall in the dam of Jogninar Village	14.48
	TOTAL	206.22

Table 7.3c: CSR Works Undertaken by DPT during 2015-16

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	Construction of Bus Stand at Vadinar Village	10.00
2	Providing drainage system at Vadinar Village	6.00
3	Providing and laying of water supply lines in Vadinar Village	6.00
4	Road from Gandhidham Post Office to Merchantile Marine Department Office along with toilet facilities	60.00
5	Construction of toilets for girls / women at Khari Rohar, Village	3.00
6	Construction of toilets for girls at Mathak Primary School, Mathak, Village	3.00
	TOTAL	**88.00**

Table 7.3d: CSR Works Approved by DPT Board for 2016-17

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	RCC community hall at Harsidhi Mata Temple, Village Veera, Anjar Taluka	19.00
2	Fabricated Community Hall at Sanghad Village, Anjar Taluka	21.00
3	CSR Works for Shri Maheshwari Meghvad Samaj, Gandhidham at graveyard behind Redison Hotel	8.00
4	CSR Works for Shri Dhanraj Matiyadev Mukti Dham, Sector 14, Rotary Nagar, Gandhidham	30.50
5	CSR Works for Nirvasit Harijan Co-operative Housing Society, Gandhidham Health Cum Education Centre	41.00
6	CSR Works for Shri Rotary Nagar Primary School, Gandhidham	2.80
7	CSR Works at NU-4, NU-10(B) Sapnanagar & Saktinagar, Golden Jubilee Park at Gandhidham	18.00
	TOTAL	**140.30**

Table 7.3e: CSR Works Approved for 2017-18

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
1	CSR Works at Shri Ganesh Nagar High School, Gandhidham	Principal, Shri Ganesh Nagar Govt High School, Gandhidham	38.30 Lakhs
2	CSR Works for MOLANA AZAD Primary School, Kandla	Shri M L Bellani, Trustee, DPT, Shri Kandla Port Education Society, New Kandla	7.00 Lakhs
3	Grant financial contribution for facility of Army Cantonment for 50 nos. air coolers at Kutch Border Area	Shri Vinod L Chavda, MP	15 Lakhs
4	40% of the estimated cost of providing drainage lines at Tuna and Vandi villages under Swachh Bharat Abhiyan.	Shri Sarpanch, Tuna Village & Vandi village & Shri M L Bellani, Trustee, DPT	**Rs. 39.80 Lakhs** *Approx. estimated Cost Rs.99.50 Lakhs, of which 40% to be contributed by DPT.*
5	CSR works for S.H.N. Academy English School (managed by Indian Inst. Of Sindhology – Bharati Sindhu Vidyapeeth), Adipur	Director, S.H.N Academy English School	**40 Lakhs**
6	Construction of internal roads at Bhaktinagar Society, Kidana	Smt Maltiben Maheshwari, MLA	**15 Lakh**
		TOTAL	**155.10**

Table 7.3f: CSR Works Approved for 2018-19

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
1	CSR work to Donate 100 Nos of Computers to Daughters of Martyred Soldiers in the country under the "BETI BACHAO BETI PADHAO" program by Atharva Foundation, Mumbai	Chairman, Atharva Foundation, Mumbai	**24.00**
2	CSR work to Donate ONE (40 Seater) School Bus for Deaf Children Students for the Institute of Mata Lachmi Rotary Society, Adipur	Mata Lachmi Rotary Society, Adipur	**18.00**
3	CSR work to Providing One R.O Plant with Cooler at PanchyatPrathmikSala, Gadpadar Village for the ANARDE Foundation, Kandla&Gandhidham Center.	Dist. Rural Development Officer, Annarde Foundation-Kandla & Gandhidham	**1.50**
4	CSR work for Providing Drainage Line at MeghparBorichi village, AnjarTaluka	Shri Vasanbhai Ahir, MLA, Gujarat Govt	**25.00**
5	CSR work for Construction of Health Centre at Kidana Village	Shri Vinod L Chavda, MP	**13.00**
6	CSR work to provide 4 Nos. of Big Dust Bin for MithiRoharJuth Gram Panchayat.	Shri Sarapanch, Mithi RoharJuth Gram Panchayat	**3.40**

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
7	CSR work for Renovation & construction of shed at CharanSamaj, Gandhidham –Adipur.	Shri Vinod L Chavda, MP	**10.00**
8	CSR Work for Renovation/Repairing of Ceiling of School Building at A. P Vidhyalay, Kandla.	Smt Maltiben K. Maheshwary, MP, Gandhidham.	**10.00**
9	CSR work for Construction of Over Head Tank & Providing 10 Nos of Computers (for students) of NavjivanViklangSevashray, Bhachau, Kutch	Shri Jitendra Joshi, Founder Secretary, Shri Navjivan Viklang Sevashray, Bhachau, Kutch	**9.50**
10	CSR work to Provide Books & Tuition fees for Educational facilities to weaker section children of ValmikiSamaj, Kutch.	Shri Manohar Jala, Chairman of “National Commission of Safai Karamcharis”	**2.00**
11	CSR work to provide Water Purifier & Cooler for the ST. Joseph’s Hospital, Gandhidham	Smt. Maltiben K Mahewari, MLA ,Gandhidham	**1.50**
12	CSR work for Construction of Second Floor (Phase – I) for Training Centre of “GarbhSanskran Kendra” “Samarth Bharat Abhiyan” of Kutch Kalyan Sangh, Gandhidham	Shri Vinod L Chavda, MP, Kutch	**37.00**
		TOTAL	**154.90**

Table 7.3g: CSR works approved for the year 2019-20 (approval from Ministry of Shipping still awaited)

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
1	CSR activities for Providing Drainage line at Nani Nagalpar village.	Sarpanch of Village:-Nani Nagalpar, Taluk: Anjar.	**3.00**
2	CSR activities for Development of ANGANWADI Building at School no- 12 at Ward no 3 & 6 at Anjar.	Shri Vasanbhai Ahir, MLA	**7.00**
3	CSR activities for Improving the facilities of Garden at Sapna Nagar(NU-4)& (NU-10 B),Gandhidham.	Shri K P Maheshwari, Resident Sapnanagar, Gandhidham	**18.00**
4	CSR activities for Providing of Plastic Shredding Machine to Mirror Charitable Trust, Gandhidham.	Mirror Charitable Trust ,Gandhidham	**4.75**
5	CSR activities for development of School premises of Shri Guru Nanak Edu. Society, Gim.	Shri Guru Nanak Education Society, Gandhidham.	**30.00**
6	CSR activities for the improvement of the facilities at St. Joseph Hospital & Shantisadan at Gandhidham	St. Joseph Hospital Trust, Gandhidham	**20.00**
7	CSR activities for the improvement of the facilities at SVP (SardarValabhbhai Patel) Multipurpose Hall at Gandhidham	Request from MarwadiYuva Munch & UNION Gandhidham	**500.00**
8	Consideration of Expenditure for running of St Ann’s High School at Vadinar of last 5 years 2014 to 2019 under CSR.	Proposal from COM, OOT Vadinar, DPT	**825.00**
9	CSR activities for development of school premises of Shri Adipur Group Kanya Sala no-1 at Adipur	Principal, Shri Adipur Group KanyaSala, Adipur	**6.50**
10	CSR activities for development of school premises of Shri Jagjivan Nagar Panchyat Prathmiksala, Gandhidham.	Principal, Shri Jagjivan Nagar Panchyat Prathmiksala, Gandhidham.	**16.50**
11	CSR activities for development of school premises of Ganeshnagar Government high school, Gandhidham.	Shri Vinod L Chavda, MP, Kutch	**9.00**
12	CSR activities for improving greenery, increase carbon sequestration and beat Pollution at Kandla, DPT reg.	Work awarded to Forest Department , Bhuj	**352.32**
13	CSR activities for providing infrastructures facilities at “Bhiratna Sarmas Kanya Chhatralaya” under the Trust of Samaj Nav- Nirman at Mirjapur highway, Ta Bhuj.	SamajNav- Nirman at Mirjapur highway, Ta Bhuj.	**46.50**
		TOTAL	**1838.57**

List of CSR applications received from various NGOs , Organizations , Village Sharpanchs etc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
1	CSR activities for the development of gardening at Sector -5 , Gim	Shri Sarvodaya Co-Operative Housing Society Ltd	**Appx Cost – Rs 25.00 Lakhs** **Cost for** – Comp wall, Benches, Plantation, walkway, other facilities (Land is reserved for Garden development only since from 50 years)
2	CSR activities for providing various facilities in SHRI GANESHNAGAR GOVT HIGHSCHOOL, GANDHIDHAM	Principal of School	**Appx cost –Rs 20.00 Lakhs** (Two times CSR works carried out at school by DPT)
3	CSR activities for the VadhiyarVankarSamajvaadi, NaviSunderpuriGim	SmtMaltiben K Maheswari, MLA	**Appx Cost Rs 6.00 Lakhs** Cost for Const. of Comp Wall
4	CSR activities for Construction work of Cabin at Oslo Area- Gim	SmtMaltiben& Shri VinadChavda	Cost not mentioned.
5	CSR activities & Land requirement forAkhil Kutch SamastaMeghvanshiGurjarmeghwal Charitable Trust ,Gim.	Shri Akhil Kutch SamastaMeghvanshiGurjarmeghwal Charitable Trust. Shri Dharmendra R Gohil	Cost Not mentioned. (demand of Land for development of SAMAJ VADI in Gandhidham)
6	CSR Activities for providing Water supply pipe line, Play ground and sports equipment, electric facilities, drinking water facilities for poor people & Fishermen at VANDI Village.	Shri R RKhambhra, PRO , Collector Office, Bhuj.	**Appx Cost Rs 51.00 Lakhs** (Last year also applied by village Sarpanch) & Recommended by Shri VASANBHAI AHIR, MLA, Shri V L Chavda, MP)
7	CSR activities for the Tuna village,	Sarpanch, Tuna village	**Appx Cost Rs. 25 Lakhs** **Cost for :-**

List of CSR applications received from various NGOs , Organizations , Village Sharpanchs etc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
	Ta -Gim		2 No Fab shed 20'x20'x1250= 10 Lakh 2 Nos of Agnawadi =10 Lakh Fab shed for school=5 Lakh
8	CSR activities for the Global Vision India Foundation, Gim	Global vision India Foundation, G'dham	Requirement of Land –OR- Old building at Gandhidham for foundation of welfare activities.
9	CSR activities for the UNITED ORPHANAGE FOR THE DISABLED, TAMIL NADU	UNITED ORPHANAGE FOR THE DISABLED, TAMIL NADU	**Cost Rs 25,000.00** (Winter sweaters for children)
10	CSR activities for the Garden Development on already bounded area with Compound wall near Plot no 448 Sector-1/A, Gandhidham.	Residents, near Plot no 448, Sector-1/A, Gim.	**AppxCost Rs 20.00 Lakhs** (Requirement to provide benches, drinking water facility, plantation, lightings & walkways in side bounded area)
11	CSR activities for donation of Land for the Shri SUNDARPUI Govt Primary School, Gim	SmtMalti ben Maheshwari, MLA	(request for Land Requirement)
12	CSR activities for Extension of Adarsh Primary School building, Adipur	GandhidhamMatri Mandal, English Medium School, Adipur	**Appx Cost Rs. 40.00 Lakhs** (Construction for 4 Rooms extension) (Trust registered under Societies Registration Act XXI -1860, Reg No F-42 dtd 23.9.1965. Land belong to Trust)
13	CSR Activities for providing HD projector for KANYA MAHA VIDYALAYA, Adipur	Principal, KANYA MAHA VIDYALAYA, Adipur	**Cost Rs 1.50 Lakhs** (School Managed by G'dhamMaitry Mandal, Adipur)

List of CSR applications received from various NGOs , Organizations , Village Sharpanchs etc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
14	CSR activities for DONATION various Medical Equipment for the Hospital of Gandhidham Jain SevaSamiti, Adipur	Gandhidham Jain SevaSamiti, Adipur	**Cost for** :- 1) Fresenius Haemodialysis Machine Rs 38.00 Lakh 2) Maltislice Helical CT Scanner- Rs 52.00 Lakhs 3) Others Rs 54.00 Lakhs (**Total Appx Cost Rs 144 Lakhs**)
15	CSR activities for SHRI VIDI JUTH GRAM PANCHAYAT, Vidi, Anjar	Sarpanch, Vidi Gram	**Appx Cost Rs 30.00 Lakhs** Cost for- Drainage , Garbage vehicle, and Cattle shed (Already applied earlier at Sr-5/12)
16	CSR activities for SOS CHILDRESN'S VILLAGES INDIA, Madhapar, Bhuj	Director, SOS Children's Village of India-Bhuj	**Appx Cost Rs 31.00 Lakhs** (request for Financial support towards parentless and abandoned Children Education support located at Bhuj) & support to women working in SOS.
17	Gujarat Biodiversity Board, Gandhinagar invites to involved National & Global endeavour of conservation of biodiversity by creating financial partnership with GBB under CSR programme of expenditure to be incurred 187 Lakh.	GUJARAT BIODIVERSITY BOAD, GANDHINAGAR	**Requirement-** Financial Support from DPT for **AppxRs 1.88 Cr.** (Cost for various meetings, collection of primary data from villagers , processing of documentation, printing , TA DA of Technical support &Miscexp for 150 Peoples Biodiversity Register (PBR).

List of CSR applications received from various NGOs , Organizations , Village Sharpanchs etc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
18	CSR activities for providing furniture & Home appliances for ROJAVANAM TRUST at Madurai.	Shri Arul Kannan, Director	**Appx Cost Rs 30 Lakhs** (seeking help to provide facilities to Aged & Homeless people living in Trust and Purchasing of New Ambulance)
19	CSR activities for providing Dialysis Machine for treatment of Kidney patients at "ST JOSEPH'S HOSPITAL TRUST" at Gandhidham.	Sr. Franciline, Administrator of Hospital.	**Appx Cost Rs 31.36 Lakhs** (Cost of 5 Nos of Dialysis Machines for treatment of kidney patients)
20	CSR activities for providing facilities in Girls Hostel of Gasturba Gandhi BalikaVidhyalay, Gandhidham.	Shri Vinod L Chavda, MP	**Appx cost Rs 30 Lakhs.** (Cost of Comp Wall, Entrance gate, Girls toilets etc)
21	CSR works for providing Oxygen Generator Plant and 45 KV Silent Generator for COVID HOSPITAL at Swami LilashahKutia, Adipur.	Secretary, BHARAT VIKAS PARISHAD, Gandhidham	**Appx Cost Rs 80.00 Lakhs** (Facilities for 100 Beds of COVID patient which it to be extend upto 240 Beds)
22	CSR works for providing Two Numbers of Oxygen Concentrator and others medical equipment for the Trust ,Antarjal, Gim.	President SHRI SARV JEEV KALYAN TRUST, ANTARJAL, Gandhidham	**Appx Cost Rs21.50 Lakhs** (Facilities to be provided for the treatment of CORONA PATIENTS at their trust.)
23	CSR works for providing Fabricated Shed , Construction of Compound Wall and Land levelling for the Cattle of **GauSevaSamiti-Tappar** at Gram-Tappar, Ta Anjar.	Shri Vinod Chavda, MP &Presedent , GauSevaSamiti, village Tappar, Ta-Anjar	**Appx Cost Rs84 Lakhs** (Facilities to be provided for Cattle shelters at Village.) (Land belongs to Gram-panchayat)
24	CSR works for Construction of Auditorium Hall at RSETI (Rural Self Employment Training Institute) at	Shri Vinod Chavda, MP & Director of RSETI, Bhuj	**Cost not mentioned.** (Facilities to be provided

List of CSR applications received from various NGOs , Organizations , Village Sharpanchs etc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
	Bhujodi-Bhuj.		for the people needs Self-employment activities.)
25	CSR works for Providing of Furniture for the School "SHRI GALPADAR PANCHAYAT PRATHMIC KUMAR GROUP SALA " atGalpadar Village Ta Gim.	Principal, SHRI GALPADAR PANCHAYAT PRATHMIC KUMAR GROUP SALA " atGalpadar Village Ta Gim.	**Cost not mentioned.** (Facilities to be provided for the Students of Workers & poor village people who study in the school.)
26	Construction of Shed, hall and Gate for the DADA Bhagwandas Charitable Trust, Adipur. (Sr no -4)	Shri Vinod Chavda, MP & DADA BHAGWANDAS CharitableTrust, Gandhidham	As per CSR Guideline- ➢ Promoting gender equality and empowering women ➢ Eradicating extreme hunger and poverty (Considered shed and hall) Fab Shelter Shed - 30'x100' x 1250=37.00 Lakh & RCC Hall – 20'x100'x1500=30.00 Lakh (**Appx Cost Rs67.00 Lakhs**) Land authority belongs to Trust given by GDA and NOC given by SRC.Doc submitted.
27	CSR work for reconstruction of the Internal Roads of the Sector-9B-C and Sector-10 area in Gandhidham.	President, Shri TejaKangad, The Gandhidham Chamber of Commerce and Industry, Gandhidham.	Cost not mentioned.

List of CSR applications received from various NGOs , Organizations , Village Sharpanchsetc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
	CSR Applications kept pending in last year Agenda:-		
27	CSR Activities for providing Water supply pipe line, Play ground and sports equipment, electric facilities, drinking water facilities for poor people & Fishermen at VANDI Village. (Sr no-3)	Sarpanch ,Village-VANDI , Ta- Anjar (Recommd. By Shri VASANBHAI AHIR, MLA, Shri V L Chavda, MP)	As per CSR Guideline- ➢ Env Sustainability ➢ Eradicating extreme hunger and poverty (to be Consider for health Center ,Drainage line, Water sump etc activities) **(Appx Cost - 51.00 Lakhs)** (Land authorization of Gram Panchayat)
28	Construction of Shed, hall and Gate for the DADA Bhagwandas Charitable Trust, Adipur. (Sr no -4)	DADA BHAGWANDAS CharitableTrust, Gandhidham (Recommd. By Shri V L Chavda, MP)	As per CSR Guideline- ➢ Promoting gender equality and empowering women ➢ Eradicating extreme hunger and poverty (Considered shed and hall) Fab Shed - 30’x100’ x 1250=37.00 Lakh & RCC Hall – 20’x100’x1500=30.00 Lakh (**Appx Cost Rs 67.00 Lakhs**) Land authority belongs to Trust given by GDA and NOC given by SRC. Doc submitted.
29	10 Nos of Computers required for ShirMaheswarinagar Panchayat Girls Primary School, Gandhidham& Boys Group School, Gandhidham. (Sr no-8)	Maheswarinagar Panchayat Primary Kanya Sala, Gandhidham (Contact no 9913903686)	**AppxRs 5.00 Lakhs** As per CSR Guideline- ➢ Promotion of Education (to be consider for 20 Computers)

List of CSR applications received from various NGOs , Organizations , Village Sharpanchsetc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
			Visited the site. Land belongs to MahewariMeghwadSamaj given by SRC for school purpose, doc are awaited.
30	Construction of Shed and Roof at JeparMatiyadev, shamsanbhumi at Kidana village &Maheswari Community Hall at JuniSundarpuri ,Gandhidham. (Sr no-10)	Shri VINOD CHAVDA, MP	**AppxRs 15.00 Lakhs** (Land authorization not mentioned)
31	Drainage, road, Dust bins, & shed for Cattle shelters at VIDI Village, Ta –Anjar. (Sr no- 12)	Village- VIDI, Ta: Anjar	**AppxRs 30.00 Lakhs** As per CSR Guideline- ➢ Env Sustainability ➢ Eradicating extreme hunger and poverty (Consider for Garbage vehicle & Drainage Cost)
32	Education, Women empowerment and Primary health care services at Kutch area. (Sr no-13)	Light of Life Trust, **Mumbai.**	Cost not mentioned.
33	Request for Help Divyang persons to employment by providing machineries. (Sr no-14)	Kutch DivyangSangthan, Gandhidham.	Cost not mentioned
34	Construction of 2nd Floor of Shri MaheswariMeghwadSamaj, Gandhidham. (Sr no-20)	Shri MaheswariMeghwadSamaj, Gandhidham	**AppxRs. 15.00 Lakhs** (Visited the site and Land ownership documents awaited) (Name plate of DPT fixed at the Asset)

List of CSR applications received from various NGOs , Organizations , Village Sharpanchsetc for the FY 2021-22 .

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
35	Installation of Mini Science Center at Anjar and Gandhidham. (Sr no-21)	STEM Learning Pvt Ltd, Mumbai.	Cost not mentioned.
36	CSR work for Shri Rampar Gram Panchayat. ➢ Wall Plastering for Cattles -7 Lakhs ➢ Shed for Cattel's-15 Lakhs (Sr no-25)	Shri Sarpanch, Rampar Village.	**AppxRs 22.00 Lakhs** (Land authorization of Gram Panchayat and under taking submitted by applicant)
37	CSR activities for the 45,000 Patients over the period of 3 years by "SMILE FOUNDATION", Mumbai. 1. Concept for Nutrition covering 3 years 2. Concept for Mobile Health Unit reaching beneficiaries for 3 years 3. Concept for Vocational Training with NGO (Sr no-29)	Proposal from "SMILE FOUNDATION " Mumbai.	Appx Cost- **Rs 539 Lakhs** for 3 years
38	Development of Park in Public utility plot in between Block "C" & "D" of Sapna Nagar (NU-4) , Gandhidham (Sr no -31)	Shri RAVI MAHESHWARI, DPT	Land belongs to DPT earmarked for recreational purpose. (Total Cost –Rs**88.75 Lakhs**)
39	CSR works for NariJanshsktiVikas Foundation at Gandhidham near Shakti Nagar. (Sr no-33)	NariJanshsktiVikas Foundation, Ahmedabad	➢ Promoting gender equality and empowering women ➢ Env Sustainability ➢ Under promotion of education (Consider for Computers with printers, Sewing machine & RO plant**Cost Rs 48 Lakhs**)

Annexure -L

DEENDAYAL PORT TRUST

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Administrative Office Building
Post Box NO. 50
GANDHIDHAM (Kutch).
Gujarat: 370 201.
Fax: (02836) 220050
Ph.: (02836) 220038

www.deendayalport.gov.in

NO.EG/WK/4783/V/ 131 Dated : 05/02/2021

To,
M/s Precitech Laboratories Pvt Ltd,
1st Floor, Bhanujyot Complex,
Plot No C5/27, B/h Panchratna Complex,
Nr. GIDC Char Rasta,
VAPI-396195.

Sub: **Work order** for "STRENGTHENING OF EXISTING ENVIRONMENTAL MANAGEMENT CELL AT DEENDAYAL PORT TRUST: Appointment of environment experts for two years further extendable for one year"-**reg**.

Ref: 1) Tender dated 21.06.2019 submitted by M/s Precitech Laboratories Pvt.Ltd, Vapi.
2) Letter of Acceptance vide no-EG/WK/4783/V/100 dtd 01(04).01.2021
3) Letter from DPT no E/WK/4783/V/103 dtd 06.01.2021
4) Performance Guarantee submitted by M/s Precitech Laboratories Pvt Ltd in the form of Bank Guarantee of Rs. 3,60,000.00 vide Bank Guarantee no. 1102921BG0000016 dated 19.01.2021 issued by State Bank of India, Vapi.

Sir,

Kindly refer above cited Letter of Acceptance dtd 01(04).01.2021.

2) You shall have to provide Key Experts as per tender requirement during the entire contract period. Accordingly, you shall have to submit the qualification and experience certificates of the Key experts to be appointed at DPT, as per tender conditions for verification & approval.

3) Please submit the Agreement of contract as per tender conditions no 1.29.

4) Kindly commence the work on or before 15.02.2021.

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Please note that the time period for providing Consultancy services for the subject work will be initially for two years and further extendable for one year on mutual consent as per tender conditions.

Thanking you.

Yours faithfully,

Superintending Engineer (Design & EMC (i/c))
Deendayal Port Trust

Annexure -M

DEENDAYAL PORT TRUST

ISO 9001 : 2008 : ISO 14001 : 2004

Ph. : 02836-220167
Fax: 02836-233172
website: deendayalport.gov.in
e-mail : secretary@deendayalportgov.in

General Administration Deptt.
Administrative Office Building,
Post Box No. 50,
Gandhidham (Kutch) 370 201

By Speed Post / E-mail

No. GA/PS/4292/HE(PF)/2017/ 304 Dated, 17 January, 2022

OFFER OF CONTRACTUAL ENGAGEMENT AS MANAGER(ENVIRONMENT), IN DEENDAYAL PORT TRUST.

With Reference to your application for contractual engagement as Manager – Environment, in response to the advertisement, inviting applications for the subject position, on assessment and interview before the Services Selection Committee on 06.01.2022, the Competent authority has been pleased to offer the contractual engagement as Manager (Environment) in Deendayal Port Trust, purely on contractual basis, subject to the following terms and conditions :

a) Roles & Responsibilities

- Develop, implement and manage long term port environmental programmes such as the Green Marine Programme, sustainability plan, air strategies, tenant environment plan and tenant lease management.
- Represent the Port in local, state and federal agency meetings.
- Assist in the development and updating of the Port's comprehensive scheme of Harbour improvements and strategic plan.
- Monitor and conduct regular mock drills to train the employees at different levels.

b) Remuneration :-

Your consolidated remuneration per month will be Rs.1,00,000/- (Rupees One Lakh Only). Suitable increase depending upon the performance and variation in the AICP index may be given after successful completion of yearly service. Applicable taxes will be deducted at the time of payment.

c) Period of Contract :

The contract will be for a period of 3 years, extendable by another two years, subject to satisfactory performance.

d) Duty Hours :

You may be posted at/under any department/authority of Deendayal Port Trust, as per requirement, Duty Hours are from 10.00 AM to 06.00 PM or as may be decided by the Administration from time to time. In case of requirement, you may have to work beyond the normal duty hours, for which no other compensation, monetary or otherwise will be considered.

....

(Mukkannawar Utkarsh Suresh)

Contd....

You will normally be entitled to a weekly off on Sunday. If situation warrants, the weekly day of rest may be changed with prior intimation. For work on any weekly day off / declared national holiday in exigencies of work, a compensatory day of rest as per the convenience of the Administration, in lieu thereof, will be granted and for which no other compensation, monetary or otherwise will be considered.

Failure to report for duty will entail deduction of wages on pro-rata basis.

e) Medical facility : Only Outdoor Medical treatment facility for self and your spouse will be provided in the Port Trust Hospital. No other medical facilities will be provided to you/ your family.

f) Leave entitlement : 10 days leave in a year and National Holidays will be given. No other leave will be admissible and for any absence beyond the said leave, pro-rata deduction will be made from the consolidated remuneration.

g) Accommodation : Suitable accommodation, if available, may be provided, subject to recovery of charges under FR-45A, and the element of HRA excluded from the lumpsum remuneration.

h) Your engagement on contractual basis is subject to strict adherence to the norms and conduct.

i) The engagement can be terminated by giving one month's notice in writing from either side. However, in case of unsatisfactory performance or for any act considered derogatory/ detrimental to the interest of Deendayal Port Trust, this contractual engagement will be terminated forthwith.

j) If you leave without notice or without acceptance of notice of termination, the amount due i.e., consolidated remuneration payable will be forfeited.

k) You shall not claim any right/title/interest on par with the regular employees of the Port or otherwise.

l) You shall not have any claim/right whatsoever for regular appointment / absorption in Deendayal Port Trust under any circumstances.

m) Your contractual engagement is subject to verification of antecedents by the police. If any adverse report is received from the Police, your contractual services are liable to be terminated forthwith.

n) You will not be permitted to take any other assignment during the period of contract with Deendayal Port Trust.

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(Mukkannawar Utkarsh Suresh)

Contd....

l) On official tour outside Head Quarters, you will be entitled to TA/DA as admissible under the rules.

m) The terms and conditions shall be amended / modified depending upon the requirement of the Port. Any dispute(s)/difference(s) shall be decided solely by the Chairman, Deendayal Port Trust, which shall be final and binding.

n) You are required to submit discharge letter / relieving letter from your present employer at the time of joining Deendayal Port Trust, without you may not be allowed to join.

o) The contractual engagement is subject to your being found medically fit as per the requirements of Deendayal Port Trust.

2. You have to report for medical examination before the Medical Board of DPT at Gopalpuri Hospital on any working day between 10.00 hrs to 12.00 hrs.

3. If you agree to the above terms and conditions, you may convey acceptance by signing the duplicate of the letter in token of your acceptance and submit the same to this office and call at this office with all certificates and two copies of passport size photographs latest by 27th January, 2022 failing which the offer of contractual engagement stands automatically cancelled.

C. Hariharan

Secretary
Deendayal Port Trust

To
Shri. Mukkanawar Utkarsh Suresh,
21/1, Madhukunj Housing Society,
Near Canara Bank, Panchavati,
Pashan, Pune, Maharashtra - 411008.
Email : utkaish@gmail.com

I accept the above terms and conditions and will report for duty on __________.

Name :

Date :

Copy to: CMO – for conducting Medical Examination.