DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

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EG/WK/4660 (EC)/ Part V/ 128

Dated: 19/12/2025

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

Sub: "Construction of 13th to 16th Cargo Berths at Kandla" by M/s Deendayal Port Authority (Erstwhile Deendayal Port Trust) – **Point wise Compliance to the stipulations in CRZ Recommendations reg.**

Ref.:
1) Director (Env)'s letter no.ENV-10-2006-138- P dated 14/2/2008
2) KPT letter no. EG/WK/4660 (EC)/Part III/1088 dated 9/12/2013
3) KPT letter no. EG/WK/4660 (EC)/Part III/252 dated 19/5/2014
4) KPT letter no. EG/WK/4660 (EC)/Part III/199 dated 14/11/2014
5) KPT letter no. EG/WK/4660 (EC)/Part III/255 dated 11/05/2015
6) KPT letter no. EG/WK/4660 (EC)/Part III/163 dated 15/10/2015
7) KPT letter no. EG/WK/4660 (EC)/Part III/132 dated 09/05/2016
8) KPT letter no. EG/WK/4660(EC)/Part IV/168 dated 26/12/2016
9) DPT letter no. EG/WK/4660(EC)/Part V/324 dated 26/06/2018
10) DPT letter no. EG/WK/4660(EC)/Part V/54 dated 14(16)/02/2019
11) DPT letter no. EG/WK/4660(EC)/Part V/206 dated 30(6)/11(12)/2019
12) DPT letter no. EG/WK/4660(EC)/Part V/108 dated 15/01/2021
13) DPT letter no. EG/WK/4660(EC)/Part V/91 dated 07/10/2021
14) DPA letter no. EG/WK/4660 (EC)/Part V dated 28/03/2022
15) DPA letter no. EG/WK/4660 (EC)/Part V/150 dated 19/07/2022
16) DPA letter no. EG/WK/4660 (EC)/Part V/231 dated 02/02/2023
17) DPA letter no. EG/WK/4660 (EC)/Part V/351 dated 14/08/2023
18) DPA letter no. EG/WK/4660 (EC)/Part V/38 dated 19/03/2024
19) DPA letter no. EG/WK/4660 (EC)/Part V/94 dated 24/07/2024
20) DPA letter no. EG/WK/4660 (EC)/Part V/06 dated 17/01/2025
21) DPA letter no. EG/WK/4660 (EC)/Part V/60 dated 06(07)/08/2025

Sir,

It is requested to kindly refer the above cited references for the said subject.

In this connection, it is to state, that Director (Environment), Forest & Environment Department, GoG vide above referred letter dated 14/2/2008 had granted CRZ Recommendations for the subject proposal. Accordingly, Deendayal Port Authority (Erstwhile Deendayal Port Trust) had regularly submitted point wise compliance report to the stipulated conditions in CRZ Recommendations.

In this regard, as requested under General condition no. 21 in the above referred letter dated 14/2/2008 i.e. A six-monthly report on compliance of the conditions mentioned in this letter shall have to be furnished by the DPA on a regular basis to this Department and MoEF&CC, GoI, please find enclosed herewith compliance report of Deendayal Port Authority along with necessary annexure (**Annexure 1**) for the period from April, 2025 to September, 2025 for kind information and record please.

Further, as per the MoEF&CC, Notification S.O.5845 (E) dated 26.11.2018, 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 via e-mail ID gczma.crz@gmail.com & direnv@gujarat.gov.in.

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

Thanking you.

Yours faithfully,

XEN (EMC)
Deendayal Port Authority

Copy to:
Shri Amardeep Raju,
Scientist E, Ministry of Environment Forests & Climate change,
&Member Secretary (EAC-Infra 1),
Indira Paryavaran Bhavan,
3rd Floor, Vayu Wing, Jor Bagh Road, Aliganj,
New Delhi – 110 003.
Email Id: ad.raju@nic.in

Annexure -1

<u>Annexure 1</u>

Compliance Report for the Period April, 2025 to September, 2025.

Name of Work: Construction of 13th to 16th Cargo Berth at Kandla, District Kachchh.

CRZ Recommendations: Letter No. ENV-I0-2006-138-P dated 14/02/2008 of Director (Environment), Forest & Environment Department, GoG. Further, the Ministry of Environment & Forest–New Delhi, Govt. of India accorded the Environmental/ CRZ clearance vide letter no. 11-70/2006-IA.III dated Sep 2008 & the validity of the same had been extended by MoEF, GoI vide letter No.F.NO.11–70/2006–IA.III dated 7th February, 2014 for a further period of 5 years.

STATUS OF Berths:

13th Cargo Berth: Under operation since 18/2/2013.
15th Cargo Berth: Under Operation since 16/11/2013.
14th Cargo Berth: Under Operation since 8/4/2019.
16th Cargo Berth: Under Operation since 10/3/2019.

CONSENT TO OPERATE:

Consolidated Consent & Authorization (CC&A) issued by the GPCB (Consent Order no-AWH-110594 dated of issue-8/12/2020, with a validity period upto 21/7/2025)– Detailed Order issued by the GPCB vide outward no. 581914 dated 22/1/2021 & subsequently, issued Correction in CC&A order vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/588116 dated 9/4/2021. Also, Consolidated Consent & Authorization (CC&A) issued by the GPCB (Consent Order no-AWH-143399 dated of issue-06/03/2025, with a validity period upto 21/7/2030) – Detailed Order issued by the GPCB vide letter no. PC/CCA-KUTCH-812(6)/GPCB ID 28494/331753 dated 24/04/2025.

Sr. No.	Conditions in CRZ Recommendation Letter	Compliance
Specific Conditions		
1	The provisions of the CRZ notification of 1991 and subsequent amendments issued from time to time shall be strictly adhered to by the KPT. No activity in contradiction to the Provisions of the CRZ Notification shall be carried out by the KPT.	All the 4 berths are under operation. The provisions of the CRZ notification of 1991 and subsequent amendments issued from time to time are being strictly followed by Deendayal Port Authority (Erstwhile Deendayal Port Trust).
2	The KPT shall participate financially for installing and operating the Vessel Traffic Management System in the Gulf of Kachchh and shall also take lead in preparing and operationalizing and updating regularly after getting it vetted by the Indian Coast Guard.	DPA had already contributed an amount of Rs. 41.25 Crores for installing and operating the VTMS in the Gulf of Kachchh. VTMS has been handed over to the Directorate General of Lighthouse and Lightships, Ministry of Shipping, and GoI for operating and updating regularly to statutory authorities.
3	The KPT shall strictly ensure that no creeks or rivers are blocked due to any activity at Kandla.	All the four berths are under operation
4	Mangrove plantation in an area of 1000 ha. Shall be carried out by the KPT within 5 years in time bound manner on Gujarat coastline either within or outside the Kandla port Trust area at an appropriate place in consultation with the Forest and Environment Department. A 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.	As per the directions of the GCZMA and MoEFCC, GoI, to date, DPA has undertaken a Mangrove Plantation in an area of 1600 Hectares since the year 2005. The details have already been communicated with the earlier compliance reports submitted. It is also relevant to mention here that, as per the direction of the Gujarat Coastal Zone Management Authority, DPA has already prepared and submitted a report on the mangrove conservation and management plan formulated by the Gujarat Institute of Desert Ecology during the study period of Jan-April, 2015 (Report already submitted along with earlier compliance reports submitted). For regular monitoring, DPA vide work order dated 3/5/2021 has assigned work to M/s GUIDE, Bhuj for Monitoring of mangrove plantation carried out by DPA (Period from 24/5/2021 to 23/5/2022).

5		The final report submitted by M/s GUIDE has already been communicated with the earlier compliance report submitted. Further DPA has assigned work to M/s GUIDE, Bhuj vide work order dated 10/06/2024 for "Monitoring of Mangrove Plantation 1600 Ha carried out by DPA" for the Period of 10/06/2024 to 09/06/2025. The final report submitted by GUIDE, Bhuj is attached here as **Annexure - A.**
5	No activities other than those permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.	All the four berths are under operation
6	No groundwater shall be tapped for any purpose during the proposed expansion modernization activities.	All the four berths are under operation
7	All necessary permissions from different Government Departments / agencies shall be obtained by the KPT before commencing the expansion activities.	DPA obtained Consolidated Consent & Authorization (CC&A) from the GPCB vide Consent Order no AWH-110594 date of issue-8/12/2020, with a validity period up to 21/7/2025– Detailed Order issued by the GPCB vide outward no. 581914 dated 22/1/2021 & subsequently, issued Correction in CC&A order vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/588116 dated 9/4/2021 (The copy of the Order has already been communicated with the earlier compliance report submitted). Consolidated Consent & Authorization (CC&A) issued by the GPCB (Consent Order no-AWH-110594 dated of issue-8/12/2020, with a validity period upto 21/7/2025)– Detailed Order issued by the GPCB vide outward no. 581914 dated 22/1/2021 & subsequently, issued Correction in CC&A order vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/588116 dated 9/4/2021. Also, Consolidated Consent & Authorization (CC&A) issued by the GPCB (Consent Order no-AWH-143399 dated of issue-06/03/2025, with a validity period upto 21/7/2030) – Detailed Order issued by the GPCB vide letter no. PC/CCA-KUTCH-812(6)/GPCB ID 28494/331753 dated 24/04/2025.

8	No effluent or sewage shall be discharged into the sea/creek or in the CRZ area and It shall be treated to conform to the Norms prescribed by Gujarat Pollution Control Board and would be reused/recycled within the plant premises to the extent possible.	Generated sewage is treated in DPA's existing STP (1.5 MLD capacity). In addition to that, it also has septic tanks at places where STP is inaccessible. The treated sewage is being used for gardening and plantation purposes. DPA has been appointing a NABL-accredited laboratory to monitor environmental parameters, and reports are being submitted from time to the GPCB, IRO, MoEF&CC, GoI, and Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar, to regularly monitor environmental parameters vide Work Order dated 15/02/2023. The work is in progress, and the latest environmental monitoring report submitted by GEMI, Gandhinagar, is attached herewith as **Annexure B**.
9	All the recommendations and suggestion given by the NIOT in their Comprehensive Environment Impact Assessment report for conservation / protection and betterment of environment shall be implemented strictly by the KPT.	Currently, all the four berths are under operation. As per the directions of the GCZMA and MoEFCC, GoI, to date, DPA has undertaken a Mangrove Plantation in an area of 1600 Hectares since the year 2005. The details have already been communicated with the earlier compliance reports submitted. It is also relevant to mention here that, as per the direction of the Gujarat Coastal Zone Management Authority, DPA has already prepared and submitted a report on the mangrove conservation and management plan formulated by the Gujarat Institute of Desert Ecology during the study period of Jan-April, 2015 (Report already submitted along with earlier compliance reports submitted). For regular monitoring, DPA vide work order dated 3/5/2021 has assigned work to M/s GUIDE, Bhuj for Monitoring of mangrove plantation carried out by DPA (Period from 24/5/2021 to 23/5/2022). The final report submitted by M/s GUIDE has already been communicated with the earlier compliance report submitted. Further DPA has assigned work to M/s

		GUIDE, Bhuj vide work order dated 10/06/2024 for "Monitoring of Mangrove Plantation 1600 Ha carried out by DPA" for the Period of 10/06/2024 to 09/06/2025. The final report submitted by GUIDE, Bhuj is attached here as **Annexure - A.** DPA assigned work to M/s GUIDE, Bhuj 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" since 2017. In continuation of same, DPA had issued work order to GUIDE, Bhuj for "Regular Monitoring of Marine Ecology in and around Deendayal Port Authority" for the year 2024-2027. The work is in progress. The First season report submitted by GUIDE is attached herewith as **Annexure C.** To control fugitive emissions, DPA has installed Mist Canon in the Port area. Further, regular sprinkling through tankers on roads and other staking yards is being done to control dust pollution in other areas. it is relevant to mention that Pollution under Control (PUC) Certificates have been made mandatory for vehicles in the port area. For waste generated from ships, DPA issued a Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" and for removal of "Dry Solid Waste (Non- Hazardous)" from Vessels calling at Deendayal Port through DPA contractors. Further, all ships are required to follow DG Shipping circulars regarding the reception facilities at the Swachch Sagar portal. Further, DPA vide work order dated 24/01/2023 has appointed GEMI, Gandhinagar, for "Preparation of Plan for Management of Plastic Wastes, Solid Waste including C&D waste, Hazardous wastes including Biomedical and Non-

		Hazardous Waste in the Deendayal Port Authority area". The Final report submitted by GEMI has already communicated with earlier compliance report. DPA has been appointing a NABL-accredited laboratory to monitor environmental parameters, and reports are being submitted from time to the GPCB, IRO, MoEF&CC, GoI, and Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar, to regularly monitor environmental parameters vide Work Order dated 15/02/2023. The work is in progress, and the latest environmental monitoring report submitted by GEMI, Gandhinagar, is attached herewith as **Annexure B.**
10	The construction activities and dredging shall be carried out only under the constant supervision and guidelines of the NIOT.	All the four berths are currently under operation.
11	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 Kachchh.	Point noted
12	The construction debris and/or any other of waste shall not be disposed of into the sea, creek or the CRZ areas. The debris shall be removed from the construction site immediately after the construction is over.	All the 4 berths are currently under operation.
	General Conditions	
13	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.	All the 4 berths are currently under operation.
14	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

15	The KPT shall take up massive greenbelt development activities in and around Kandla and also within the KPT limits.	Deendayal Port Authority had taken up massive greenbelt development activities in and around Kandla, Residential colony, administrative building, etc. DPA had entrusted the work to the Forest Department, Gujarat, for developing a green belt in and around the Port area at a cost of Rs. 352 lakhs in an area of about 32 hectares, and the work is already 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. The final report has already been communicated with the earlier compliance report. DPA has assigned the Greenbelt development in Deendayal Port Authority and its surrounding areas, Phase II, to M/s GUIDE vide Work order EG/WK/4751/Part (Greenbelt)/327 dated 23.06.2023. The Final Report have already been communicated along with the last compliance report. Additionally, DPA has given the work of "maintenance of Greenbelt Development in Deednayal Port Authority at Kandla (phase-II) for two years" to M/s. GUIDE vide work order Civil engineering/EMC/820/greenbeltdevelopementphaseII/2023/45 dated 17/07/2025. Further, DPA has assigned the work "Greenbelt Development in Deednayal Port Authority (DPA) and its Surrounding Areas (Phase III) along with two years maintenance period" vide work order Civilenfineering/pipeline/3564/GBDinDPA &Itssurrounding III/2024/14 dated 27/01/2025. Inception report submitted by GUIDE, is attached herewith as **Annexure D.**
16	The KPT shall have to contribute financially for talking up the socio-economic upliftment activities in this region in construction with the Forest and Environment Department and the	The details of CSR activities undertaken to be undertaken by DPA are placed at **Annexure E.**

	District Collector / District Development Officer.	
17	A separate budget shall be earmarked for environmental management and socioeconomic 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.	The allocation made under the scheme of "Environmental Services & Clearance thereof other related Expenditure" during RBE 2025-26 is Rs. 585 Lakhs. The expenditure made under the "Environmental Services & Clearance of other related Expenditure" is Rs. 136 Lakhs from April 2025 to September 2025.
18	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, the DPA has also appointed an expert agency to provide Environmental Experts from time to time. DPA appointed M/s Precitech Laboratories, Vapi, to provide Environmental Experts via a work order dated 5/2/2021 for a period of 3 years. Further, DPA appointed M.s Precitech Laboratories, Vapi, to Provide Environmental Experts via work order dated 4/10/2024. The work order is attached herewith as **Annexure F**. In addition, it is relevant to submit here that DPA has appointed a Chief Manager (Environment & Safety) and two manager (Environment & Safety) on a contractual basis for a period of 3 years, further extendable to 2 years (A copy of Office orders are attached here as **Annexure G**.
19	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, GOI.	DPA has been appointing a NABL-accredited laboratory to monitor environmental parameters, and reports are being submitted from time to the GPCB, IRO, MoEF&CC, GoI, and Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar, to regularly monitor environmental parameters vide Work Order dated 15/02/2023. The work is in progress, and the latest environmental monitoring report submitted by GEMI, Gandhinagar, is attached herewith as **Annexure B.**
20	The KPT shall have to contribute financially to support the National Green Corps Scheme	Point noted

	being implemented in Gujarat by the GEER Foundation, Gandhinagar, in construction with Forests and Environment Department	
21	Six monthly reports on compliance of the conditions mentioned in this letter shall have to be furnished by the KPT on regular basis to this department/ MoEF, GOI.	DPA has regularly submitted the compliance reports to GCZMA, Gandhinagar, MoEF&CC, and GOI. The last compliance report of the conditions stipulated in CRZ recommendations issued by GCZMA was submitted on 06(07)/08/2025.
22	Any other condition that may be stipulated by this department from time to time for environmental protection/management purpose shall also have to be complied with by the KPT.	Point noted

Annexure -A

FINAL REPORT

For the Project entitled

Monitoring of Mangrove Plantation (1600 Ha) carried out by Deendayal Port Authority, Kandla

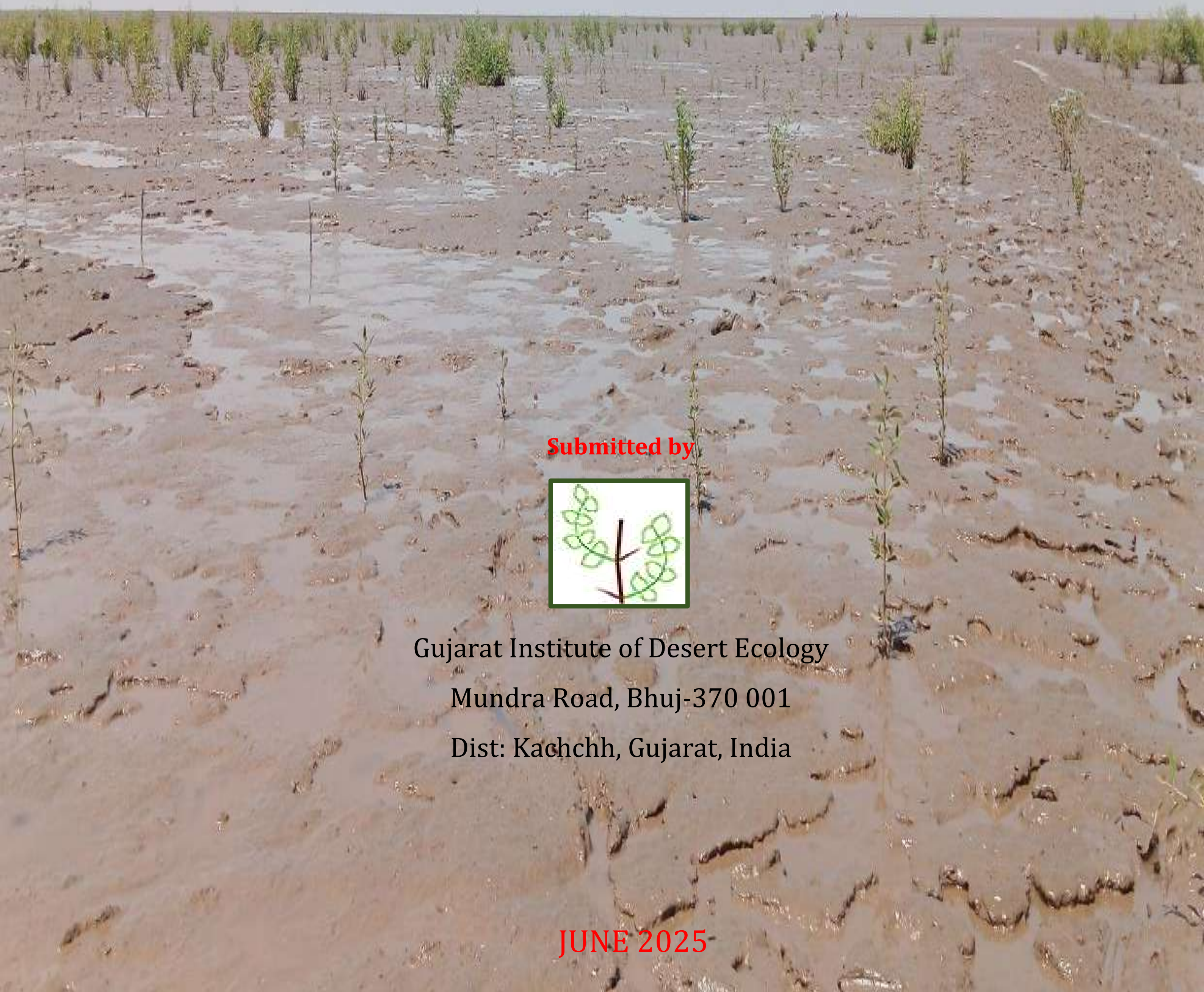
DPA Work order No. EG/WK/ 4751/Part (Marine Ecology Monitoring)/70. Dt. 10.06.2024

Submitted to

Deendayal Port Authority

Gandhidham- 370201

Dist: Kachchh, Gujarat-, India



Submitted by

Gujarat Institute of Desert Ecology

Mundra Road, Bhuj-370 001

Dist: Kachchh, Gujarat, India

JUNE 2025

FINAL REPORT

for the Project entitled

Monitoring of Mangrove Plantation (1600 ha) carried out by Deendayal Port Authority, Kandla

DPA Work order No. EG/WK/4751/Part (Marine Ecology Monitoring)/70. Dt.10.06.2024.

Submitted by

Gujarat Institute of Desert Ecology

Mundra Road, Bhuj-370 001

Dist: Kachchh, Gujarat

Submitted to

Deendayal Port Authority

Gandhidham, Dist: Kachchh, Gujarat-370201

JUNE -2025

Gujarat Institute
of Desert Ecology

Certificate

This is state that the Final Report for project entitled "**Monitoring of Mangrove Plantation (1600 ha) carried out by Deendayal Port Authority, Kandla**" has been prepared in line with the Work order issued by the Deendayal Port Authority Vide. Ref. No. EG/WK/4751/Part (Marine Ecology Monitoring)/70. Dt.10.06.2024.

The work order is for a period of one year (10.06.2024 - 09.06.2025) for the above-mentioned study.

Authorized Signatory **Institute Seal**

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Project Team

Project Coordinator: Dr. V. Vijay Kumar, Director

Project Personnel

Principal Investigator

Dr. B. Balaji Prasath, Senior Scientist

Co-Investigator

Dr. Kapilkumar Ingle, Project Scientist-II

Team Members

Dr. L. Prabhadevi, Advisor

Dr. Dhara Dixit, Project Scientist-I

Mr. Dayesh Parmar, Senior Scientific Officer

Mr. Ketan Kumar Yogi, Junior Research Fellow

Snapshot of the Project, "Regular Monitoring of Mangrove Plantation (1600 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)/70 dated 10/06/2024
2	Duration of the project	One year from 10.06.2024 to 09.06.2025
3	Period of the survey carried out for various components	September, 2024 – April, 2025
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	06 blocks in Sat Saida Bet 02 blocks in Nakti creek 05 block at Kantiyajal Site
6	Components of the report	
6a	Mangrove density	Sat Saida Bet: Density of mangrove varied from 100 to 4000 and individuals/ha and tree height ranging from 70 - 240cm Nakti creek: Density of mangrove varied from 400 – 1600 individuals/ha and tree height ranges from 100 - 170 cm. Kantiyajal: Density of mangrove varied from 500 - 1600 individuals/ha tree height ranges from 70-140 cm.
6b	Avg. Carbon stock 0-30 cm depth (%)	The Avg. Carbon stock of mangrove plantation varied from 39.87 to 62.81%. The highest Carbon stock potential was at Nakti creek.

6c	Assessment of Carbon values (Mg C ha^{-1})	The Carbon values of mangrove plantation varied from 1,920.93 to 4043.5. The highest carbon values potential was at Sat Saida Bet.
6c	Assessment of CO_2 equivalent	The CO_2 equivalent was maximum 31.65 at Sat Saida Bet while at Nakti creek it was 27.66 and at Kantiyajal it was 24.97.
7	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.

Contents

1. Introduction

Mangrove forests are important ecosystems that exhibit high productivity and biodiversity. These forests flourish in varying depths of saline waters and with specialized root structures called pneumatophores that provide vital habitat for diverse macro- and micro fauna (Mullarney et al. 2017). Additionally, mangroves can sequester carbon dioxide at rates up to four times that of terrestrial forests per unit area, further proving their importance for reducing global warming (Alongi 2022). Aquatic tourism and fisheries also rely heavily on mangroves making it economically important alongside its carbon sequestration potential. The international scientific community has gradually adopted the importance of economic ecological functions and services provided by mangroves. However, these ecosystems face unsustainable use and destruction which leads to poorly restored coverage of mangroves (Sidik et al. 2023). To address these issues, researchers have concentrated on developing restoration methods through plantation and conservation programs aimed at sustaining mangroves ecological and economic aspects.

India accounts for roughly 3.3 % of the world's total mangrove cover, equating to 0.15% of the total land area, which signifies a meagre fraction. Mangrove forests are located on the coasts of 9 Indian states and four Union Territories. The country's total area is estimated to be around 4992 Km^2, with nearly 57 % of this figure sitting on the east coast, 31 % on the west, and 12 % in the Andaman and Nicobar Islands (FSI, 2021). The three types of mangrove ecosystems in India include: insular located on the Andaman and Nicobar Islands and continental, which consist of two further classified as estuarine deltaic found on the country's east coast and backwater on the western side (Shah and Ramesh 2022). India possesses the most significant number of true mangrove species accounting for 46, which includes 42 species and 4 natural hybrids belonging to 14 groups and 22 genera. The east coast is home to 40 mangrove species which belong to 14 families and 22 genera. The west coast is populated by 27 species from 16 genera and 11 families, while the Andaman and Nicobar Islands host the richest diversity of mangroves in India – 38 species from 13 families and 19 taxa (Ragavan et al. 2016). Mangrove forests can be defined by their unparalleled primary productivity which is the rate of organic carbon conversion from carbon dioxide respiration outpacing all other forms of biomass in nearly all terrestrial habitats (Harishma et al. 2020). The living biomass and sediments are rich in nutrients sequester what's known as "blue carbon", which can be stored for centuries. The phrase "blue carbon" was coined in 2009 to highlight the importance of conserving and restoring marine and coastal ecosystems for climate change mitigation and other ecosystem services. However, "blue carbon" encompasses various definitions, and its original definition included all organic material accumulated by marine organisms, as well as the potential for managing marine ecosystems to reduce greenhouse gasses and assist mitigation and conservation efforts of climate change (Lovelock and Duarte 2019).

Although accounting for a small portion of tropical forests, it notes that the position of mangroves at the land-sea interface gives them the ability to impact the carbon cycle of the coast significantly. The contribution of coastal and marine ecosystems, including mangroves, is more effective than terrestrial systems in mitigating climate change through carbon sequestration and storage (Choudhary et al. 2024). The management of blue carbon ecosystems is disregarded concerning climate change policies and is usually missing from national carbon accounts and international carbon payment systems. There are two main accepted methods for estimating the biomass of mangroves: field measurements and remote sensing with a GIS-based approach. Petrokofsky et al. (2012) consider field measurements to be accurate and dependable while validation between remote sensing data and field data is necessary. Active protection and restoration initiatives have recently been carried out through field data collection to support the satellite data, enhancing the modelling of the global carbon cycle. Furthermore, these coastal ecosystems provide a wide range of services necessary for climate change adaptation, such as the protection of coastlines and nutrition for people globally (IUCN, 2017). Carbon sequestration by mangroves ecosystems can be included in national accounts in the international scope.

In conclusion, as woody habitats mangroves serve as crucial carbon sinks in coastal regions. In addition, Mangrove forests serve as natural barriers against storms, erosion, and rising sea levels, directly guarding coastal regions and amplifying local economies receive economies' benefits. This function is even more important in climate change due to the increasing frequency and intensity of extreme weather. In addition, healthy mangrove ecosystems aid in mitigating water pollution, which is essential for maintaining clean water, stabilizing sediments, and filtering debris. Thus, conserving and restoring mangroves is not simply an environmental obligation but one of the unique and effective measures to strategically safeguard coastal populations. Protect ecosystems and conserve them, which now builds the case for more advanced and active integrated coastal policies with greater focus on ecological systems and human welfare. The Deendayal Port Authority (DPA) has actively engaged in mangrove plantation initiatives following the directives of the Ministry of Environment, Forests, and Climate Change (MoEFCC), Government of India. The monitoring of the mangrove plantation carried out by the DPA has been undertaken by the Gujarat Institute of Desert Ecology (hereafter GUIDE) regularly as per the specification in the work order (EG/WK/4751/part Marine Ecology Monitoring)/70 dated 10.04.24. This report describes the monitoring results of the mangrove plantation managed by the DPA at Nakti creek, Kantiyajal and Sat Saida Bet from 2024 to 2025.

2. Rationale of the project

The Deendayal Port Authority (DPA) is one of India's most developed ports as it has one of the largest cargo capacities in India. DPA is located in the strategic region of Gujarat on the upper north-western coast of India and is one of the largest creek-based ports in the country. It is situated at the Gulf of Kachchh at the southern point and is regarded as one of India's twelve major ports. The most significant of this location is its semi-diurnal tidal range of around 6 to 7 meters. This enables DPA to have a powerful pull in trade since the significant tidal difference helps with navigation in the port-channel docking areas, thereby increasing maritime trade activity. For the past seven years, DPA has continuously been constructed and upgraded further enhancing its prime geographic ports and the natural resources. The Port area is complimented by a unique creek ecosystem containing diverse life forms like veracious mangrove regions of about 193.1 km^2 and extensive mudflats around 312.9 km^2. Kandla region contains a network of intricate creeks and saltwater mudflats which have sparse range of halophytic mangrove vegetation interspersed with brackish landforms.

The area within 10 kilometres of the port is predominantly developed and includes salt works, human settlements, and port infrastructure to the north and west. Eastern and southern peripheries are marked by ecological features like creek systems, mangrove formations, and mudflats, which indicate the region's ecological value. DPA has had considerable movements of materials, machines, and personnel alongside extensive construction activity as part of its infrastructural development expansion. Such activity has almost certainly changed the ecological composition of the area. To site these issues and reduce environmental degradation, DPA has undertaken considerable projects, from time to time towards the conservation of the mangroves and other plants and the protection of their coastal habitats within the borders of its property. The authority has also focused on expanding conservation efforts to improve mangrove cover because of the important ecosystem services provided by these plants such as protection of coastline, habitat for fauna and flora, and carbon dioxide storage.

From 2005 to 2024, DPA has managed a remarkable mangrove plantation project covering an area of 1,600 hectares carefully through various implementing agencies at Sat Saida Bet and Nakti creek in Kandla and Kantiyajal in Bharuch district (Figure 1). The DPA has entrusted the task of evaluating the status of 1600 ha of mangrove plantation in these locations to the GUIDE, Bhuj. The detailed report on the mangrove plantation evaluation includes periodic monitoring and reporting so that DPA obtains a comprehensive detailed evaluation of the advancement and ecological effect of the mangrove plantations, which allows for adequate management decisions concerning the preservation of these vulnerable coastal ecosystems.

3. Objectives of the Study

The evaluation and health assessment of the mangrove ecosystem are the primary scopes of this research. Focus is also given to addressing and managing ecosystem loopholes. The further findings will support the formulation of precise management propositions. To attain the above purposes the following objectives were formulated:

- To conduct an extensive survey of the 1600ha planted mangrove area in Sat Saida Bet, Nakti creek in Kachchh and in Kantiyajal, Bharuch district.
- To assess the level of the plantation and also the health of the mangroves and growth of the species.
- To estimate the carbon stock that could potentially be stored in the soil under the mangrove plantation and its carbon sink value about climate change impacts.

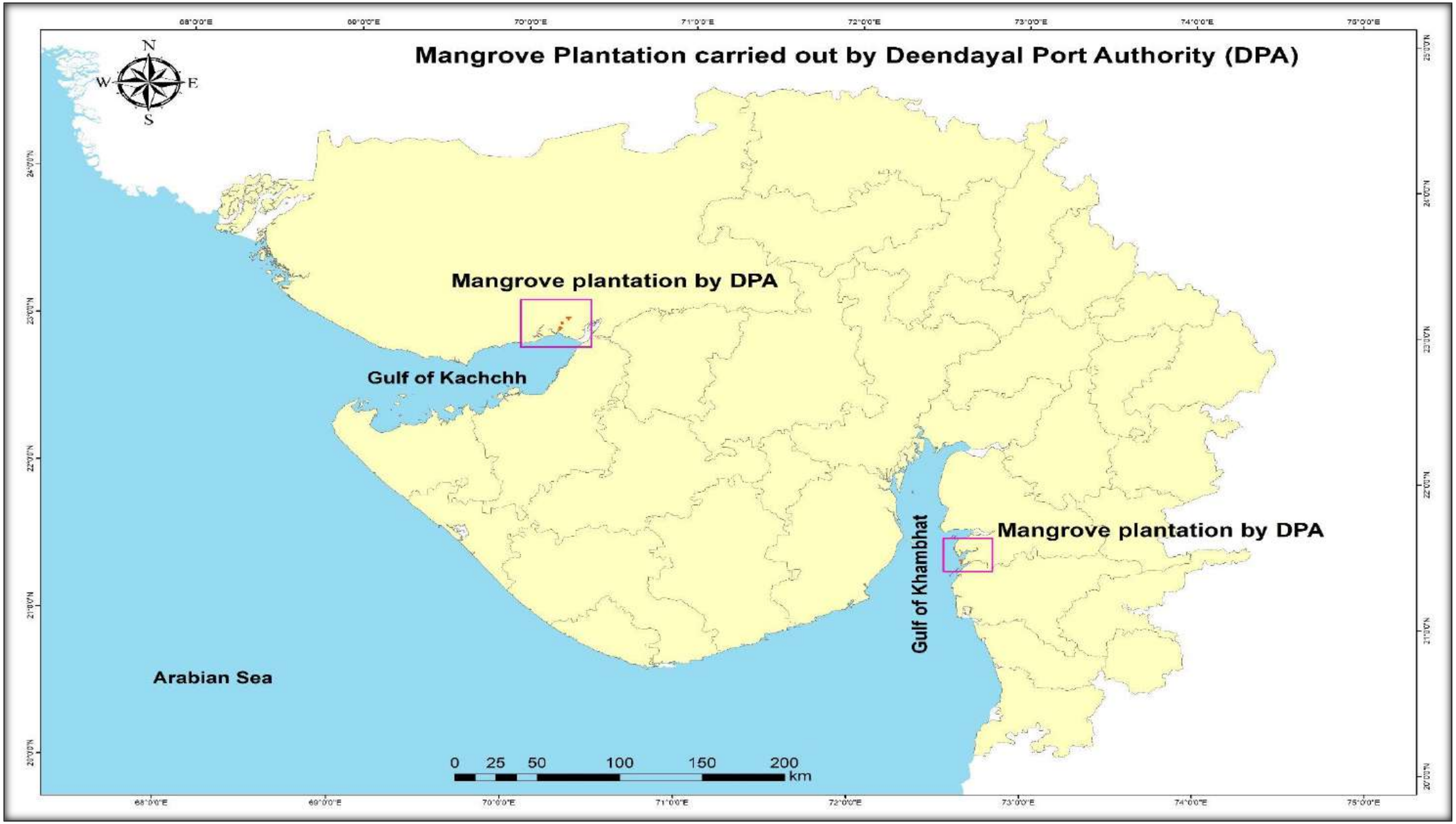


Figure 1: Mangrove plantation carried out by DPA at Sat Saida Bet and Nakti creek in Kachchh district and Kantiyajal in Bharuch district

4. Study Area

The region of Deendayal Port is examined in terms of its ecology, infrastructure, and geography which comprise the environmental setting. Additionally, the port's coordinates are located at 22°59'39.77''N, 70°13'20.14''E and its average altitude lies 20 feet above mean sea level. Moreover, the average rainfall was 466 mm (in 2021) and its climate features an annual maximum temperature of 42.8°C and an average minimum of 21.3°C.The area has high relative humidity – at 60% for the rest of the year, 80% during the southwest monsoon (June to September), and down to 50% in November-December. The average wind speed is reported at 4.65 m/s and is highest in June at 10.61 m/s. Droughts occur frequently every five years, in two out of five-year cycles (Figure 2).

The coastal area is characterized by flat marsh land featuring dense mangrove growth, mudflats, creek systems, salt marshes, halophytes, salt pans, and swamps. The only freshwater infusions accompany coastal flooding during monsoon months due to flash floods. There are no perennial or seasonal rivers and the region lacks any form of: irrigation, Cape Town water, Gandhidham taluka receives rainfall, or 15-20 erratic days a year. Besides the National Highway 8A, Gandhidham Railway Station, Bhuj airport (~60 km northwest), Tuna village (12 km North), and Gandhidham Town (12 km northwest) are the other key infrastructural features of the region. Survey of India's top sheets covering the area are 41J1, 41I4 and the port region falls under seismic zone V which has a high risk of earthquakes. There are no major rivers, streams, reserved forests, significant historical locations, or modern dams in the vicinity. These unique surroundings form the ecological balance and infrastructural development of Deendayal Port. The plantation site coordinates are (N 21°27'01.1'', to 21°26'54.24'' and E 72°40'36.04, to 72°38'58.22'') positioned to take advantage of the exuberantly developing mangrove patch which is in the Kantiyajal region of Bharuch District, Gujarat. Both summer and winter have set tropical temperature ranges of 25 °C to 42 °C and an easterly wind of 8 km/h. The area experiences low humidity of 35% as well. Strong tidal currents can be observed in the adjacent marine area, where high tidal coefficients are measured. These factors combine with the warm temperature of shallow waters to dictate the pace of marine life and fishing activities in the region year-round (Figure 3).

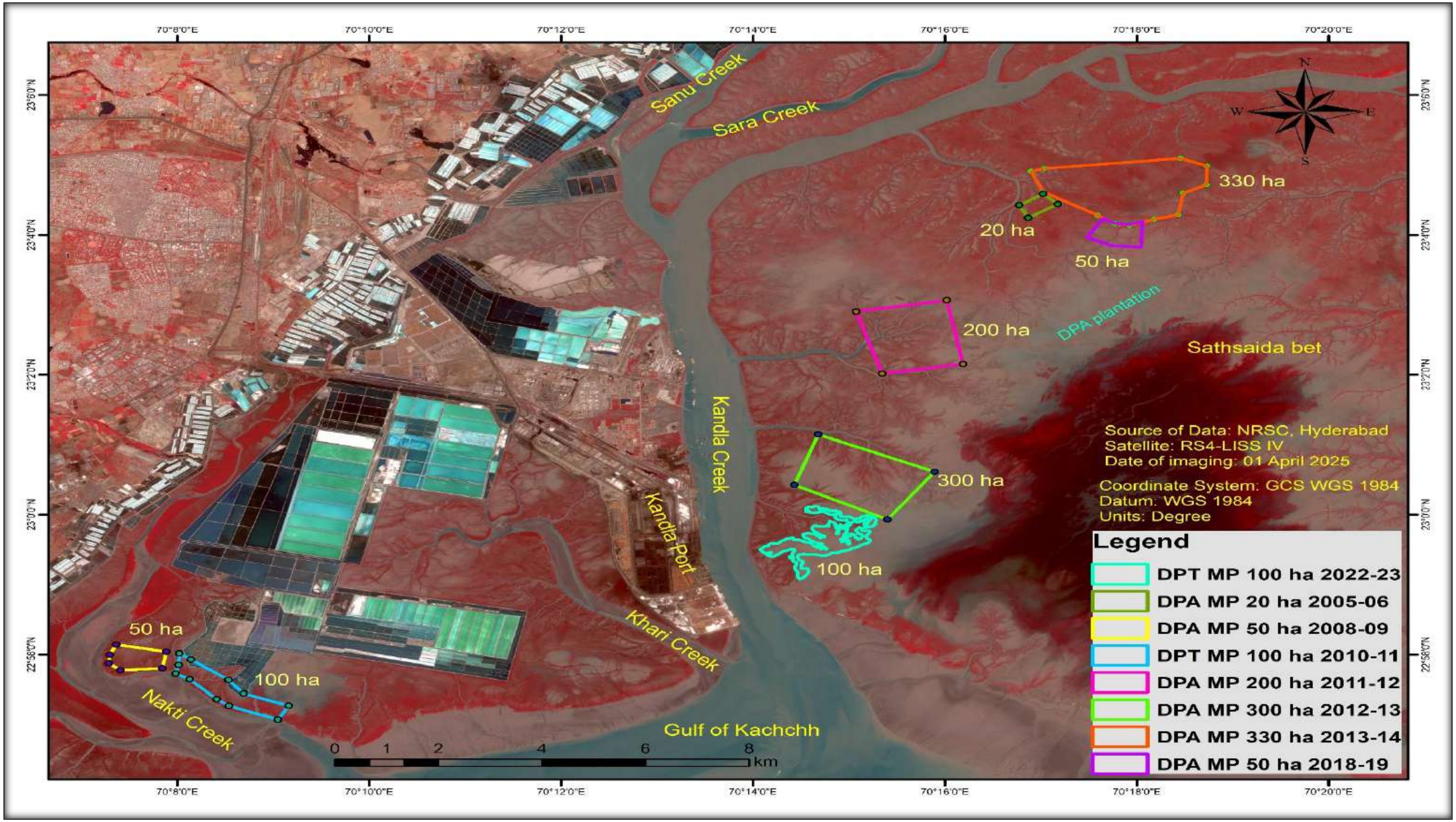


Figure 2: Location of Mangrove Plantation sites at Sat Saida Bet and Natki Creek in Kandla district

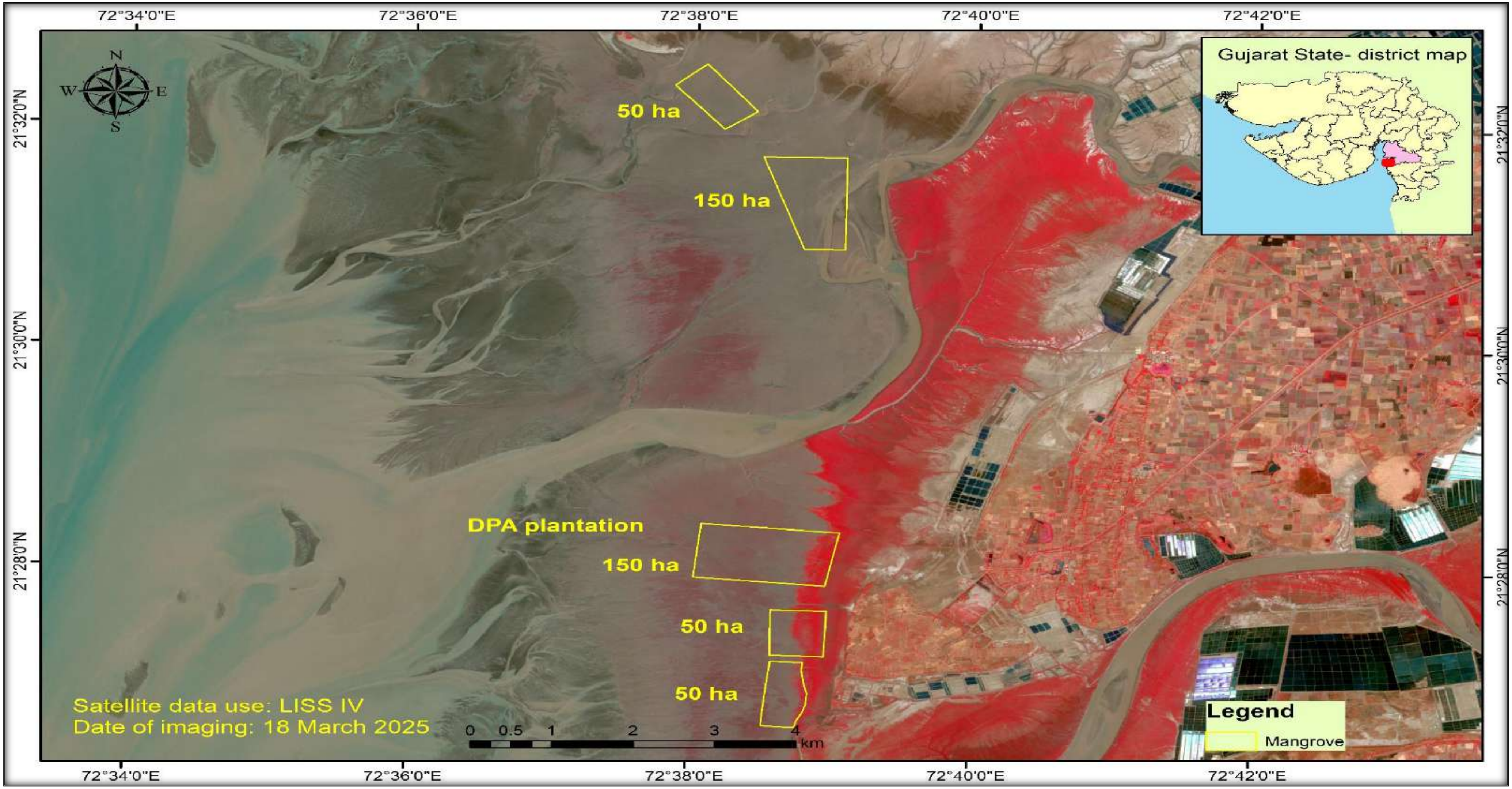


Figure 3: Location of Mangrove Plantation sites at Kantiyajal in Bharuch district

5. Details of the plantation sites

This study examined the status of mangroves at Sat Saida bet and Nakti creek in the Kandla (Kachchh) district and Kantiyajal in the Bharuch district covering more than ten blocks spanning 1400 ha, where plantation activities were conducted from 2005 to 2021. Nevertheless, this analysis (2021-2023) adds another 200 ha of plantations at Sat Saida bet (100 ha) and Kantiyajal (100 ha), which increases the area of the study to 1600ha. The focus of this study for the years 2024-2025 is to assess the actual density of the mangrove plantations developed in these areas. Together with evaluating the carbon sequestration potential of these mangrove ecosystems which are key in reducing climate change impacts through capturing and storing carbon dioxide from the atmosphere. In addition, the study attempts to recommend possible actions for the protection of these ecosystems to safeguard mangrove habitats enabling a healthy and resilient environment. The descriptions of the mangrove plantation work implemented over time by the DPA are found in Fig – 2 & 3 and Table 1. This data will help to illustrate the progress made and the ongoing need for conservation initiatives in these vital ecosystems.

Table 1. 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
	2022-2023	100	*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
	2021-2022	50	*A. marina*	Gujarat Ecology Commission
		50	*A. marina*	Gujarat Ecology Commission
Total Area (ha)		**1600**		

5.1 Plantation at Sat Saida bet (1000 ha)

The mangrove ecosystem of Sat Saida bet with six blocks has been investigated in 1000 hectares (Table 1 and Figure 4 to Figure 9) of mangrove area between 2005 - 2023 which includes studies done by Gujarat Institute of Desert Ecology (2005-2006), Forest Department of Gujarat (2011-2014), and Gujarat Ecology Commission (2018-2023). Sat Saida bet is located on the eastern shore of Kandla creek of Gulf of Kachchh. The unique Island of 253.8 km^2 area is located opposite to Deendayal port. It has sparse and 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. It is familiar that mudflats with favourable tidal amplitude are suitable for mangrove plantation. So, DPA chose Sat Saida Bet area to execute the mangrove plantation activities.

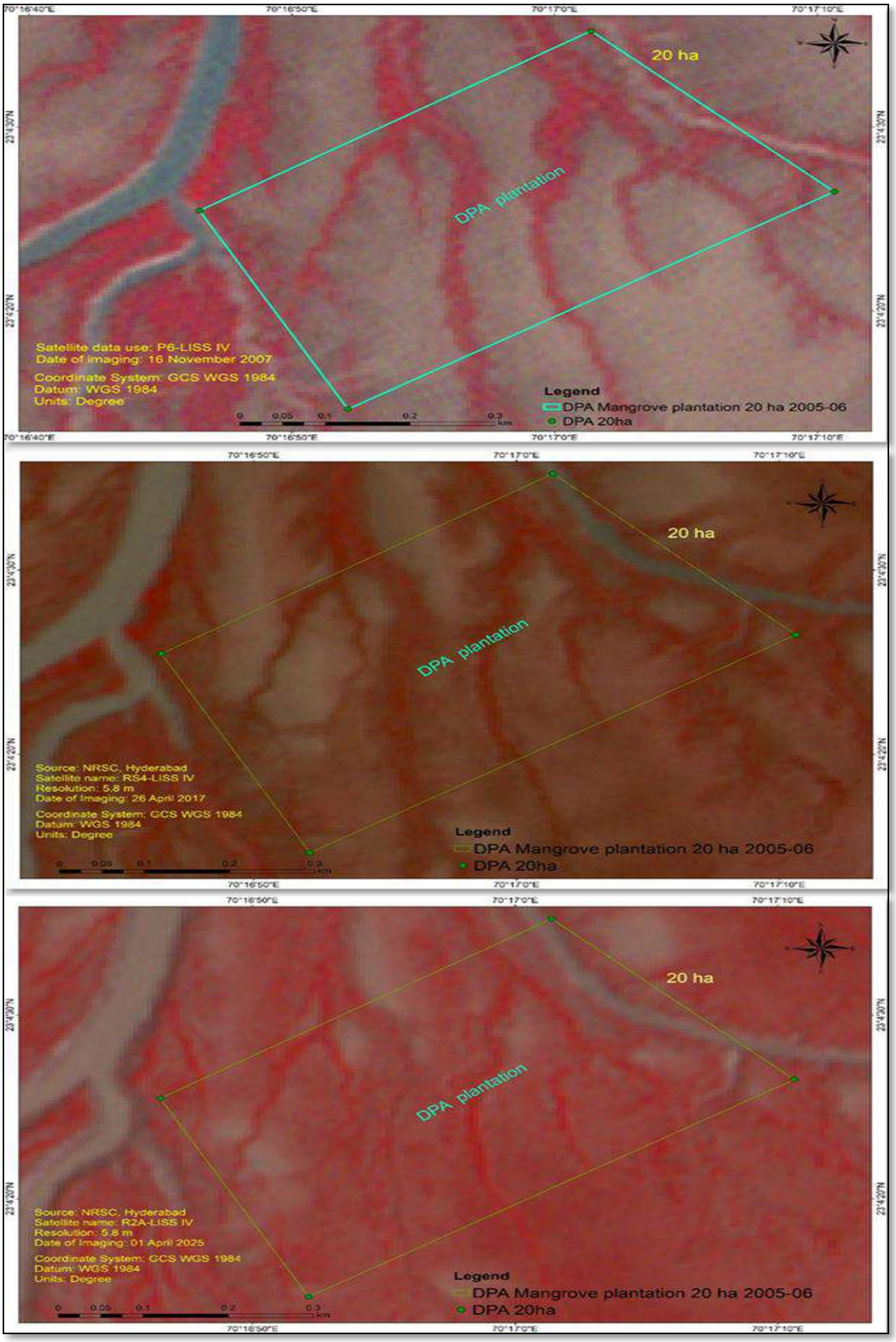


Figure 4: Satellite imageries of the 20 Ha plantation site at Sat Saida Bet (2007, 2017, and 2025)

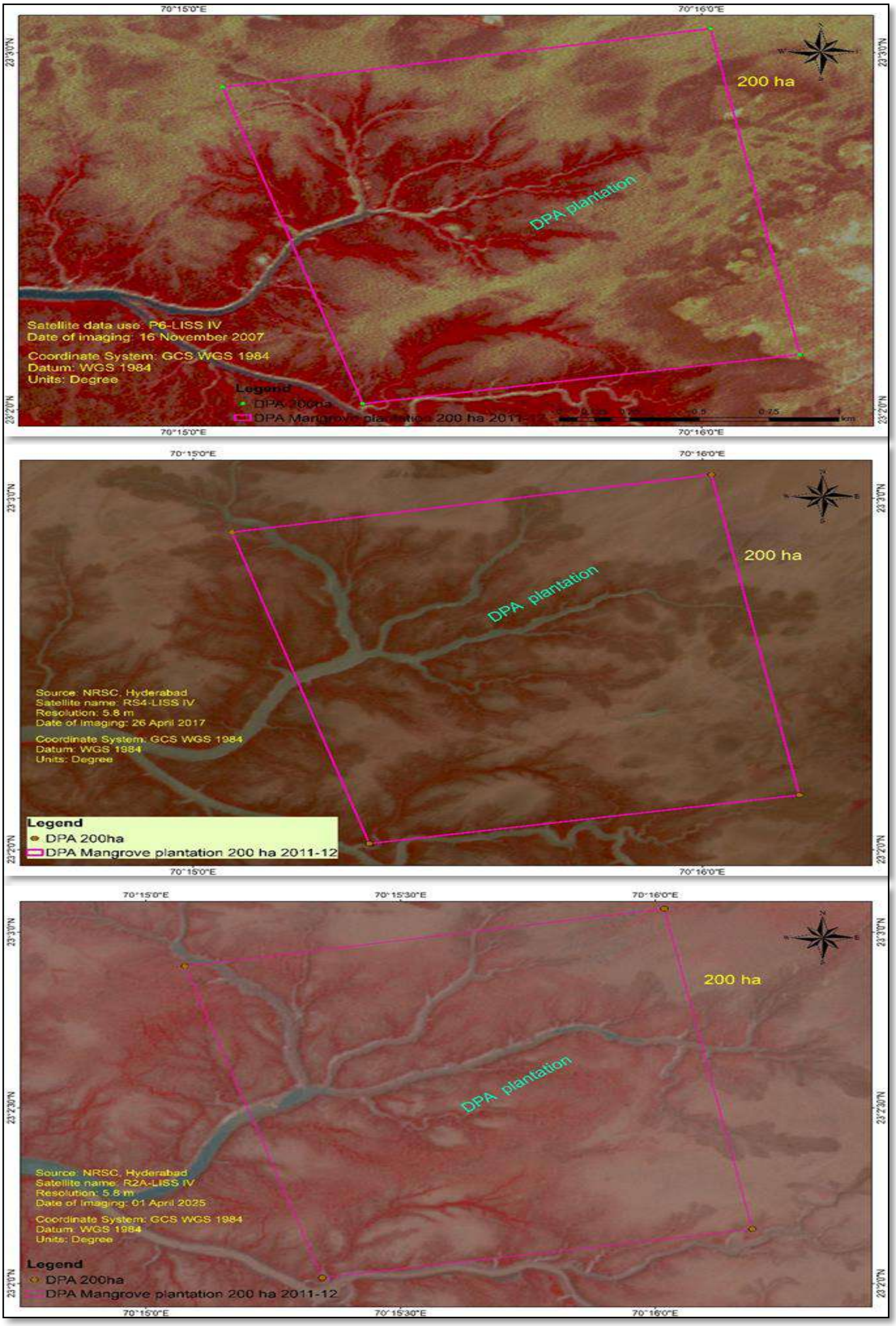


Figure 5: Satellite imageries of the 200 Ha plantation site at Sat Saida Bet (2007, 2017, and 2025)

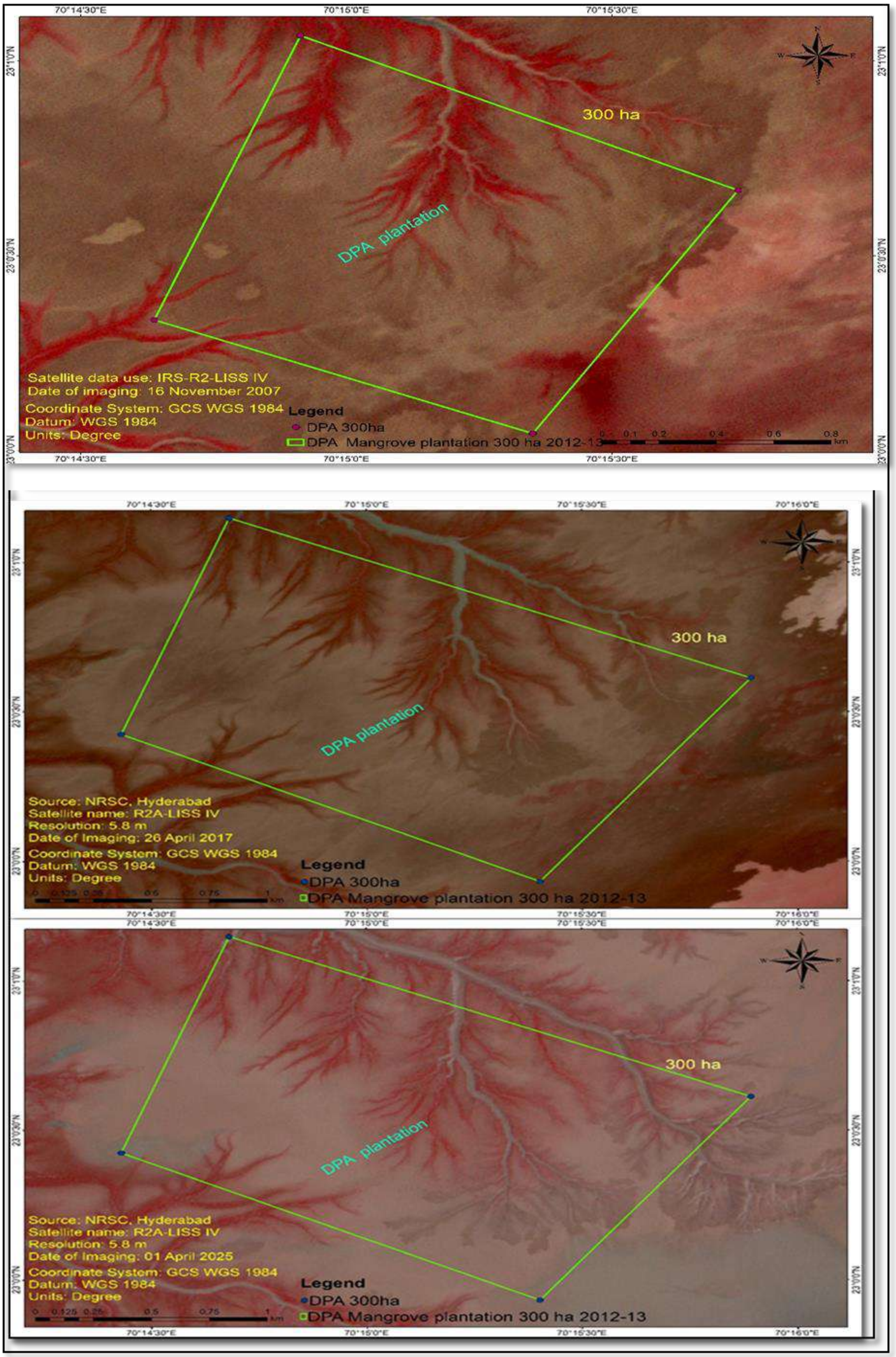


Figure 6: Satellite imageries of the 300 Ha plantation site at Sat Saida Bet (2007, 2017, and 2025)

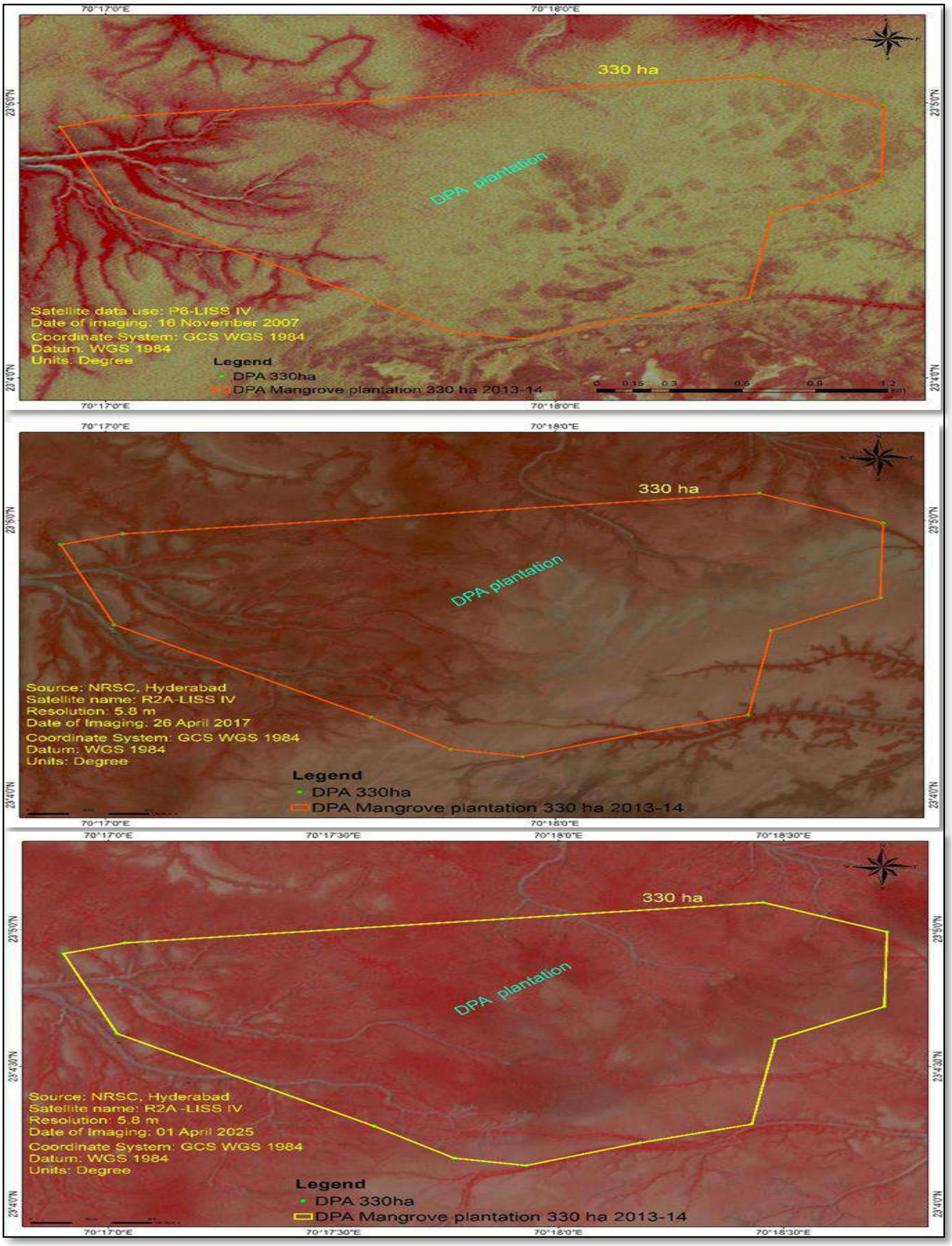


Figure 7: Satellite imageries of the 330 Ha plantation site at Sat Saida Bet (2007, 2017, and 2025)

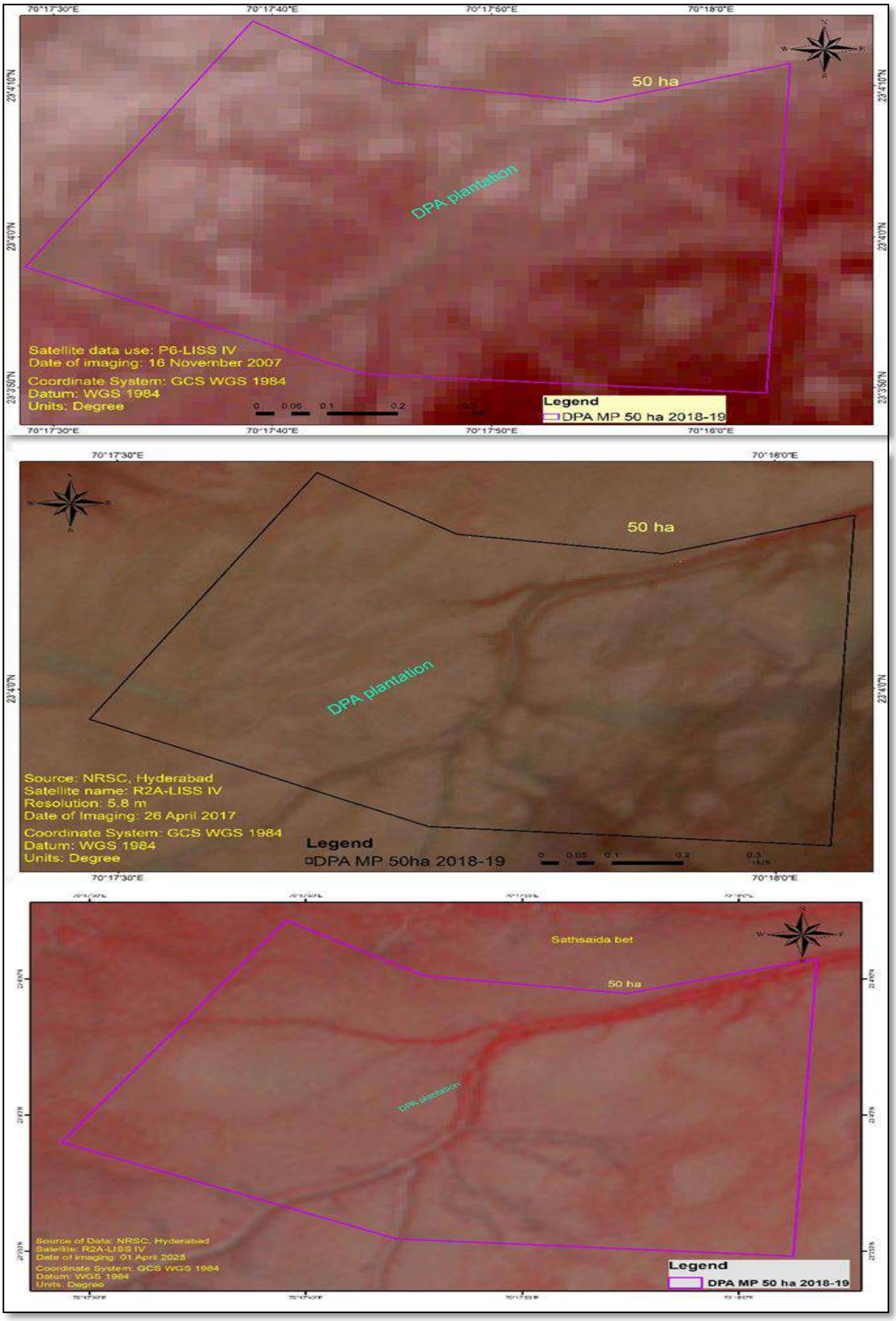


Figure 8: Satellite imageries of the 50 Ha plantation site at Sat Saida Bet (2007, 2017, and 2025)

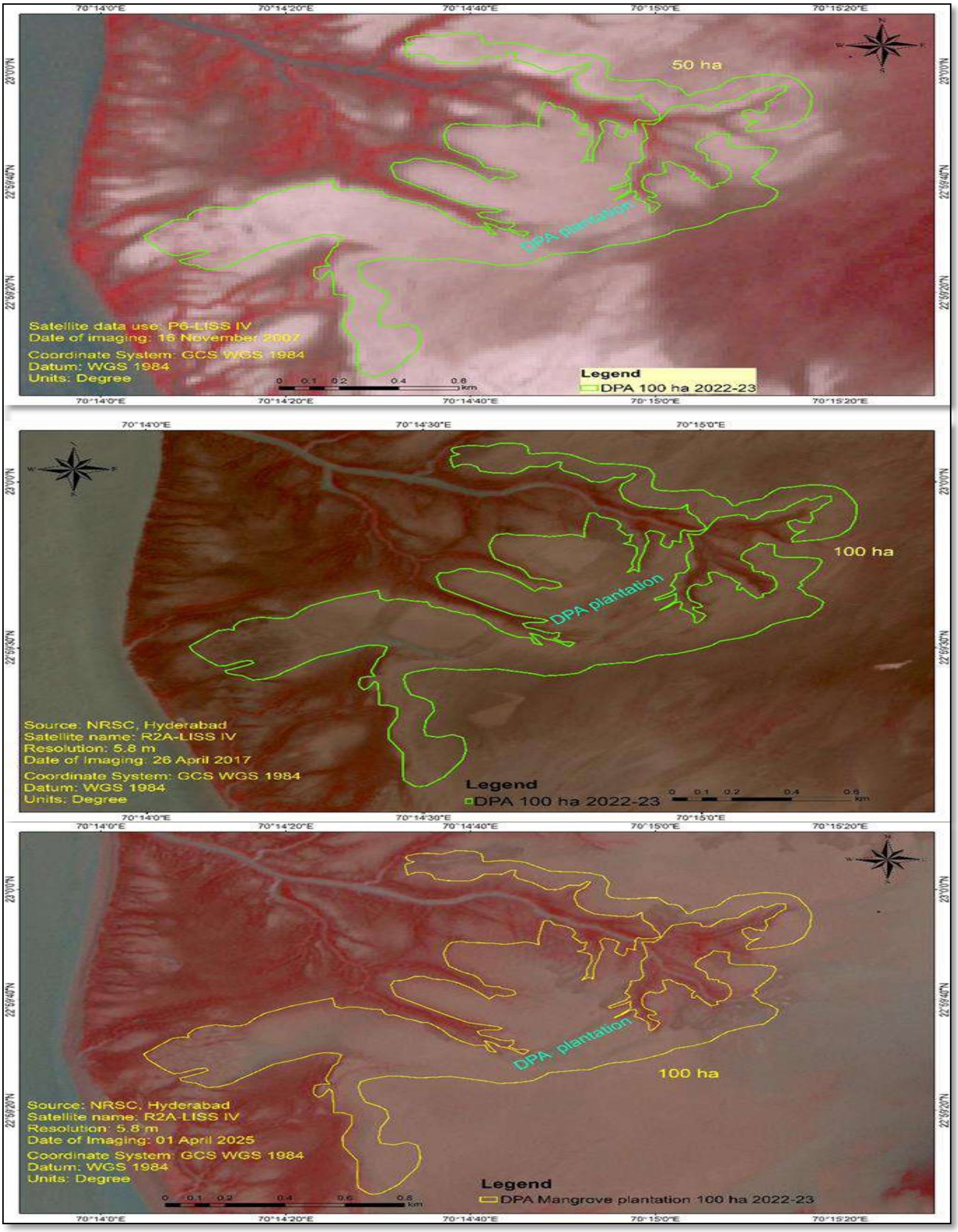


Figure 9: Satellite imageries of the 100 Ha plantation site at Sat Saida Bet (2007, 2017, and 2025)

5.2 Mangrove plantation at Nakti creek (150 ha)

A detailed area of 150 hectares of mangrove plantation, consisting of two distinct parts, was constructed in Nakti Creek; one more significant block of 100 hectares and a smaller block of 50 hectares. Additionally, this project was divided amongst multiple organizations for collaborative efforts towards maintaining the coastal habitat. The outset of the project was started by M/s Patel Construction Co. based out of Gandhidham, which started working on the project around 2008 to 2009. The second phase was executed by the Gujarat Ecology Commission from 2010 to 2011. The description of these attempts is included in Table 1, and Figures 10, 11. Both construction phases required attention to overcoming challenges related to biodiversity, so the project focused on three main techniques: replanting saplings from nurseries, creating otla beds, and using direct seed dibbling. The venture aimed to reclaim biodiversity alongside protecting the success of the mangrove plantation. Therefore, researchers decided to plant *Avicennia marina and Rhizophora mucronata*, a salt tolerant mangrove species that plays a vital role in controlling erosive forces and provides essential habitat for flora and fauna along the coast.

Unlike the former one, the more significant block which is 100 hectares on the other side of the creek had more variety in the species of mangrove to increase ecological complexity and diversity of different ecosystems. Furthermore, this section contained A. *marina, Rhizophora mucronata,* and *Ceriops tagal*. The addition of these species was intentional and improved the overall ecological balance and the overall health of the mangrove ecosystem. The project intends to restore the mangrove habitat using various plant species. However, the goal is also to strengthen, local coastal ecosystems, biodiversity, and the sustainable health of the coastal environment. This type of broad strategy regarding mangrove planting highlights the critical role that various indigenous species have in tackling the problem of coastal erosion while simultaneously sustaining both marine and terrestrial fauna and flora.

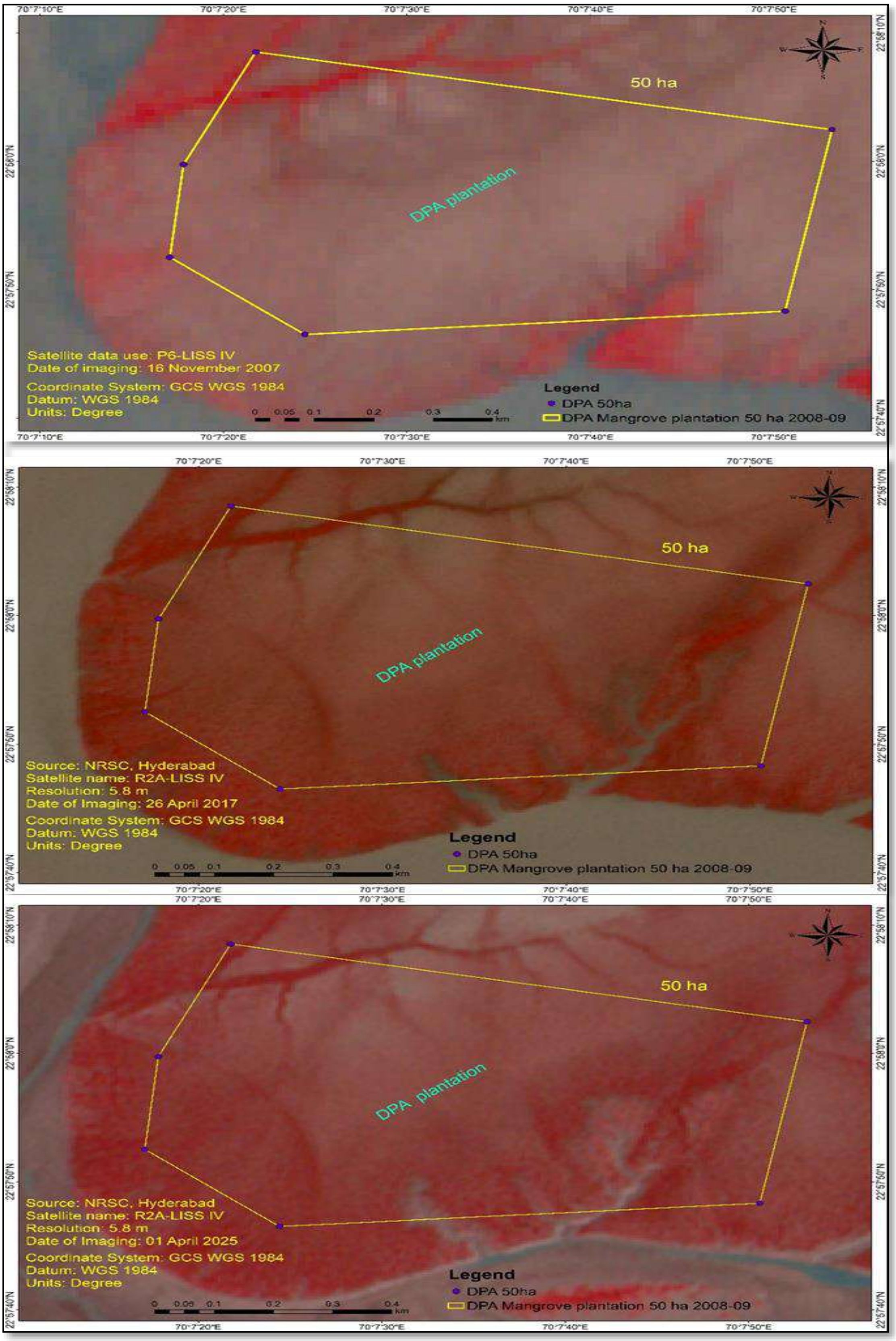


Figure 10: Satellite imageries of the 50 Ha plantation site at Nakti Creek (2007, 2017, and 2025)

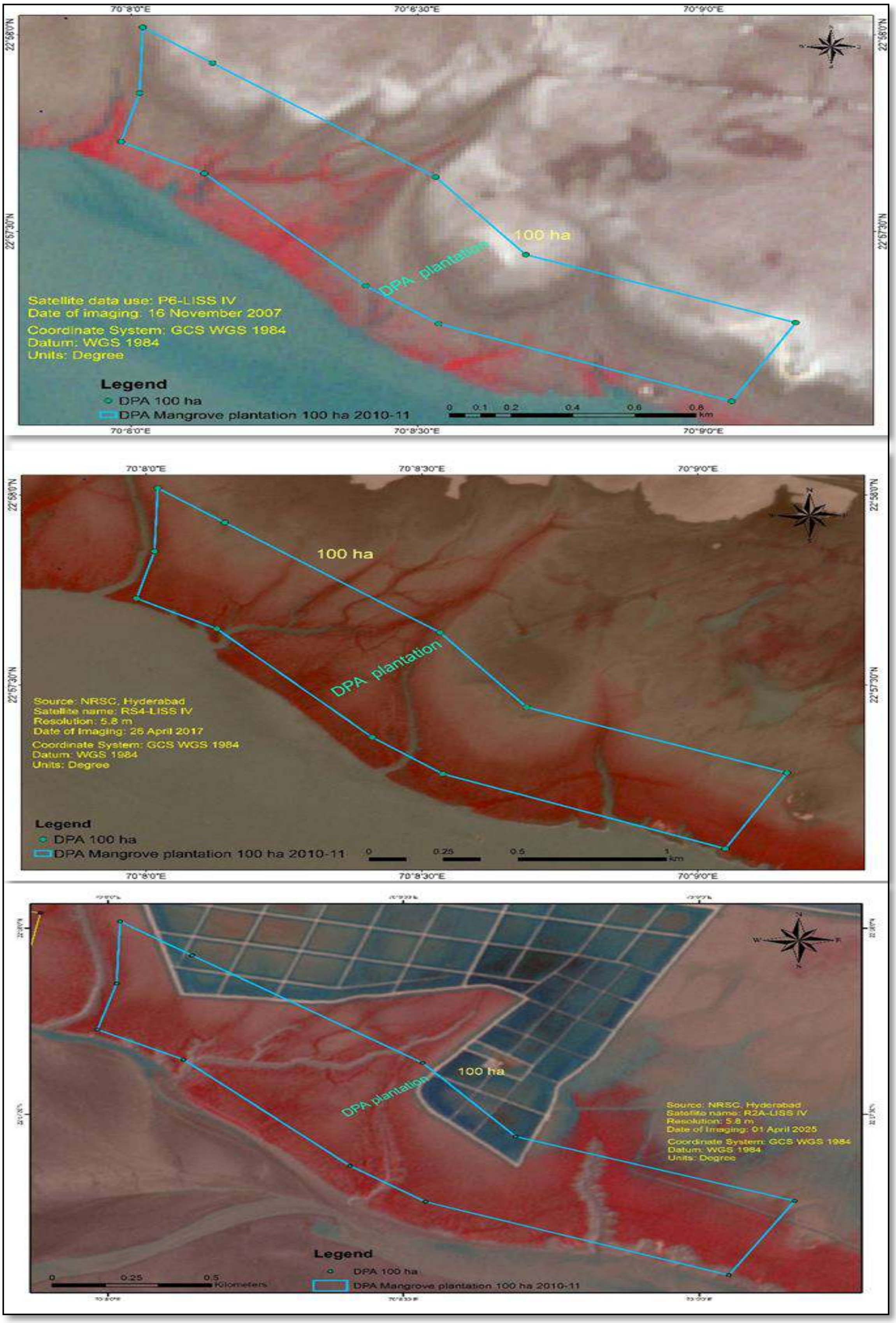


Figure 11: Satellite imageries of the 100 Ha plantation site at Nakti Creek (2007, 2017, and 2025)

5.3 Mangrove plantation at Kantiyajal (450 ha)

The mangrove ecosystem of Kantiyajal with Four blocks has been investigated in 450 hectares (Table 1 and Figure 12 to Figure 16) of mangrove area between 2015 - 2022 including studies done by Gujarat Ecology Commission (GEC). The GEC has been concentrating on the increase of local biodiversity by carrying out mangrove plantation activities in Kantiyajal area of Bharuch District. The commission undertook planting of grey mangroves *Avicennia marina* from 2015 to 2016, planting 150 hectares. A. marina is alongside coastlines and acts as a natural barrier, serving core ecological functions like habitat creation. It was a significant milestone in ecological restoration because of its importance to coastal region. During the subsequent year (2016-2017), they continued with *A. marina* planting but this time they added another key mangrove species *Rhizophora mucronata*. By replanting 150 hectares of land, the region demonstrated a commitment to a highly diverse ecological landscape and a robust environment. In the third block, 2018-2019, only 50 hectares of *A. marina* were planted. However in the fourth block, 2021-2022 mangrove plantation period, *A. marina* planting increased to 100 hectares. That indicates renewed focus towards ecological conditions, and restorations, which allows for more extensive plantation efforts. Dunes, coastal and other erosion are broader spread issues which the plantation programs would help together with losing ecosystem diversity. These steps are critical in retaining local biodiversity which showcases some of the lesser known features to be preserved in the Kantiyajal region of Bharuch District during ongoing efforts to manage balance in its unique ecological network.

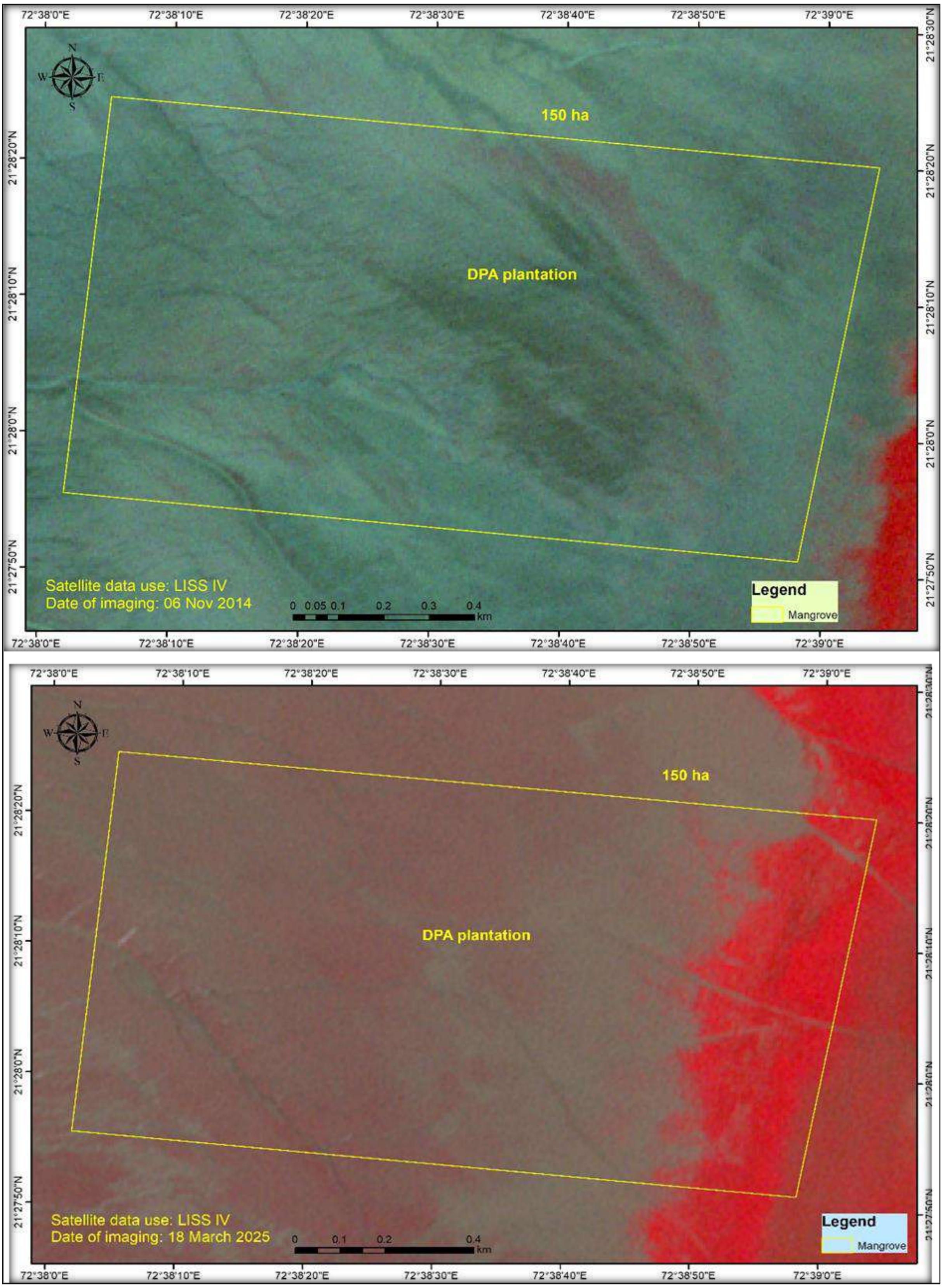


Figure 12: Satellite imageries of the 150 Ha block-1 plantation site at Kantiyajal (2014 and 2025)

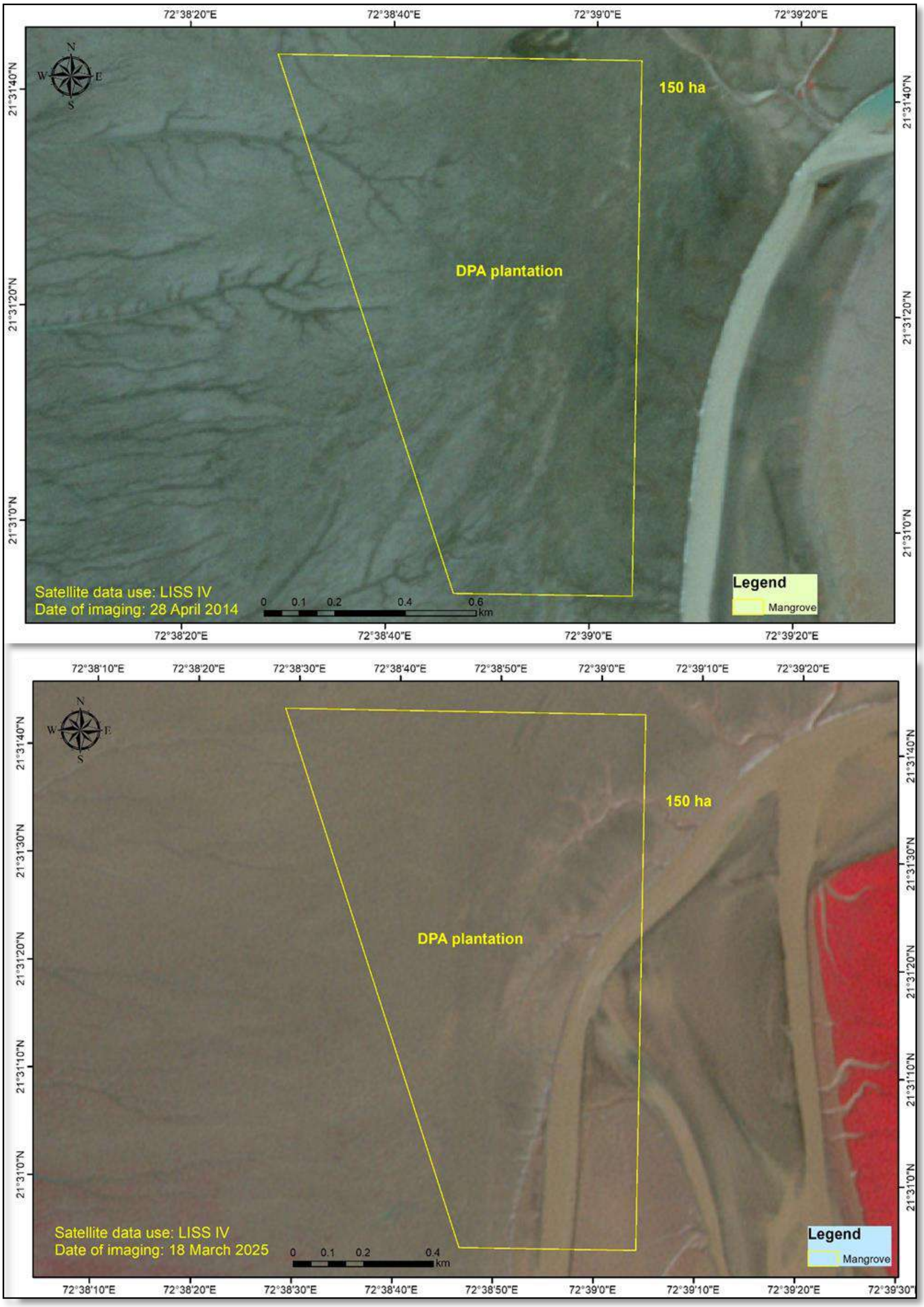
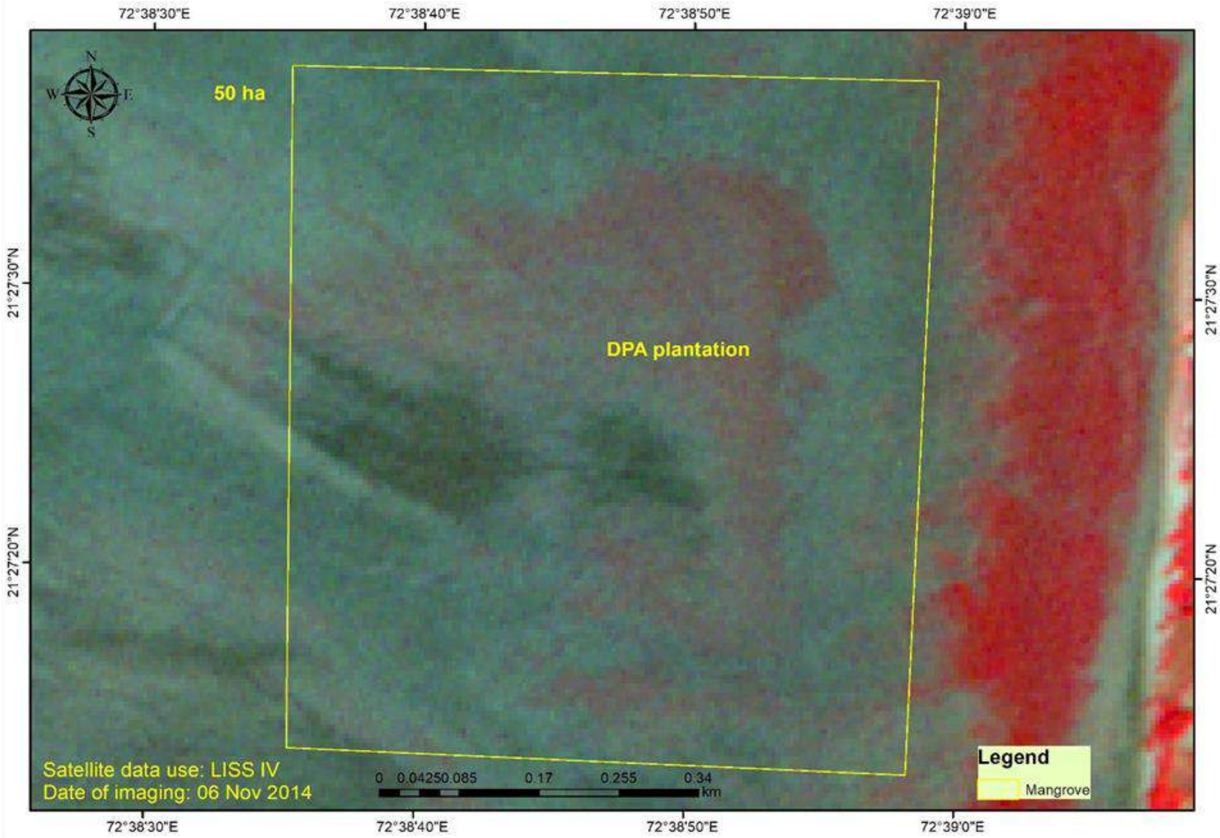


Figure 13: Satellite imageries of the 150 Ha block-2 plantation site at Kantiyajal (2014 and 2025)



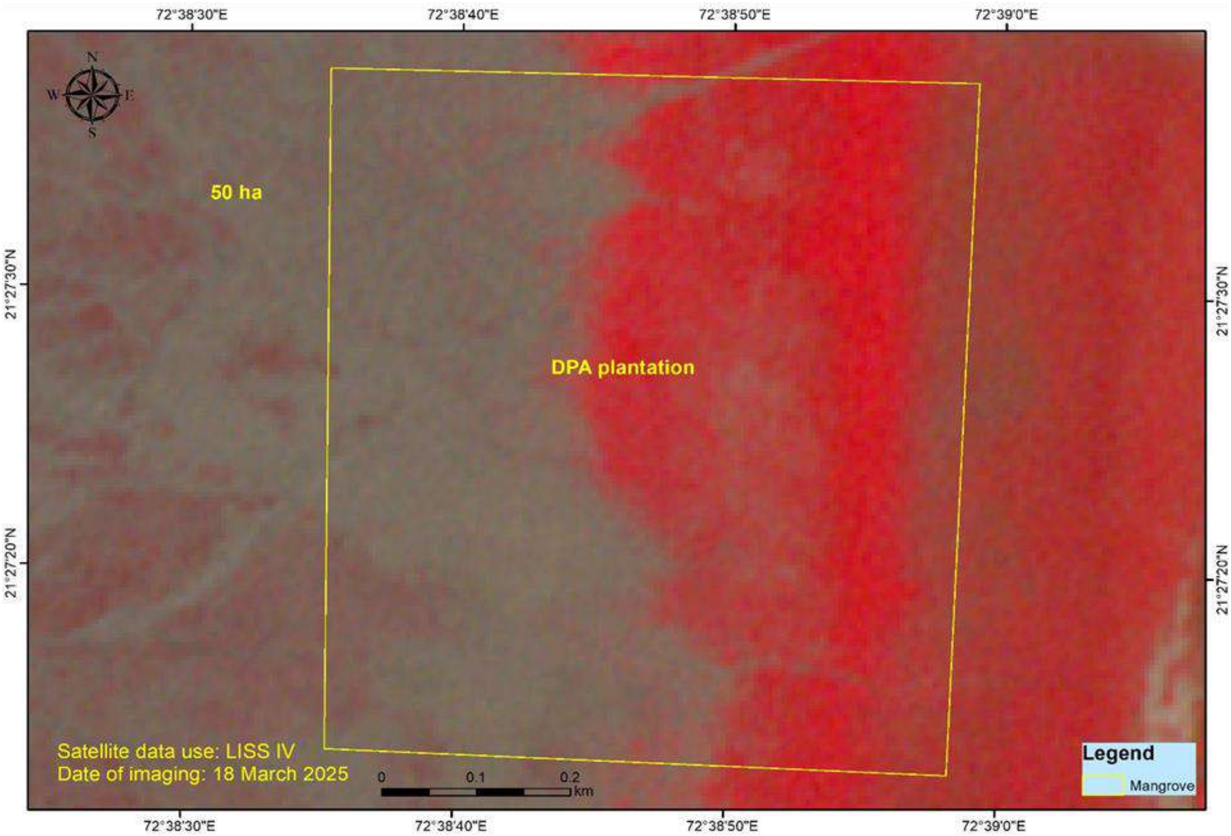


Figure 14: Satellite imageries of the 50 Ha block-3 plantation site at Kantiyajal (2014 and 2025)

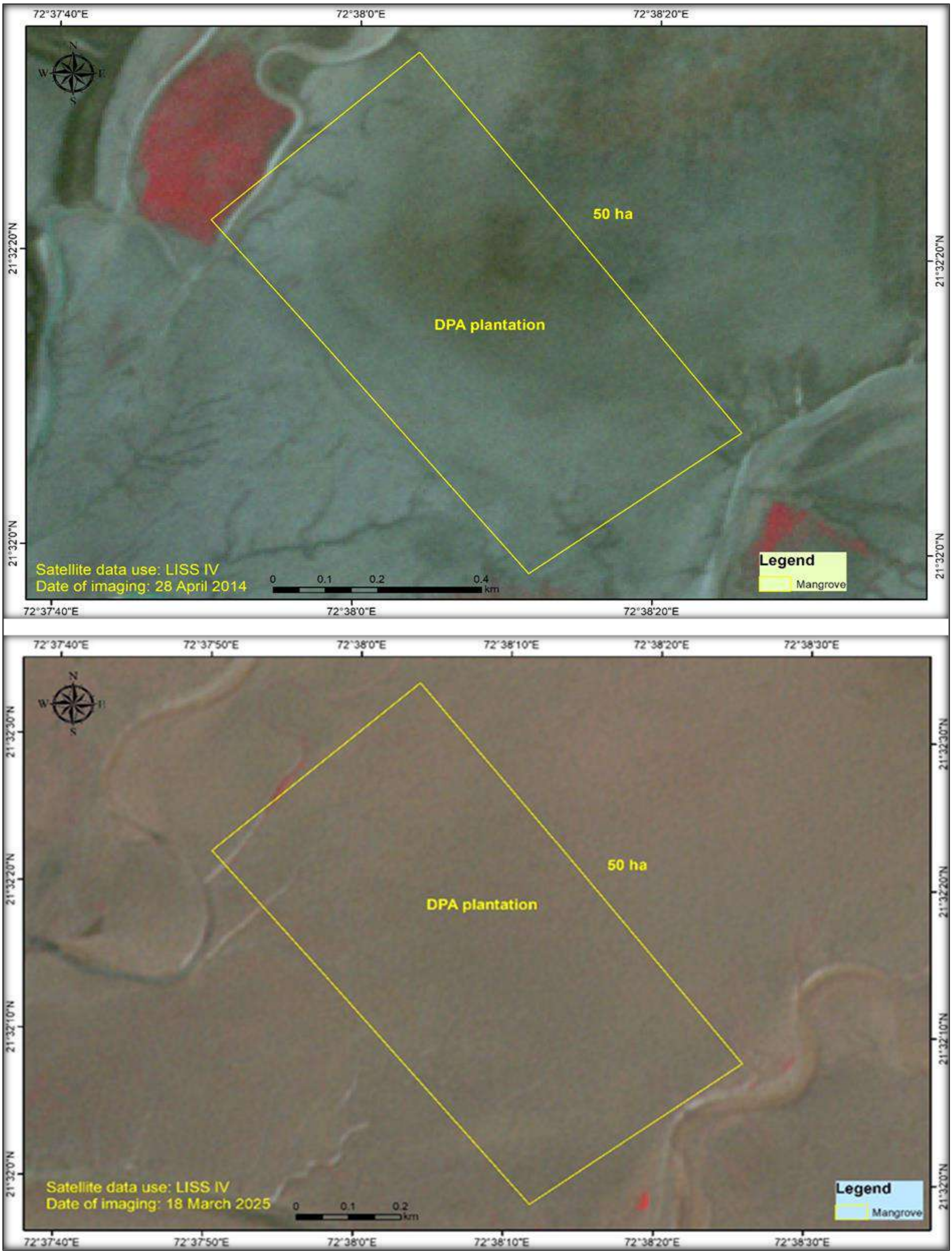
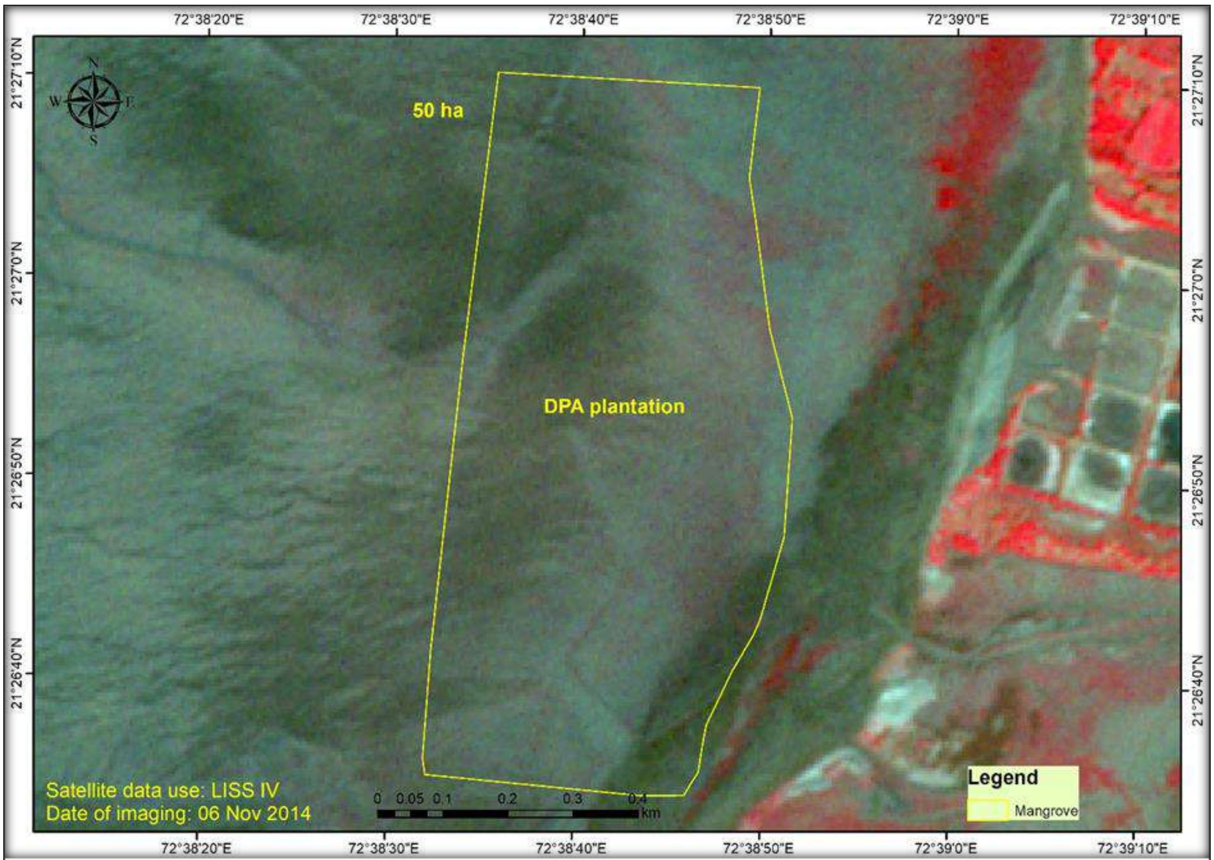


Figure 15: Satellite imageries of the 100 (50-1) Ha block-4 plantation site at Kantiyajal (2014 and 2025)



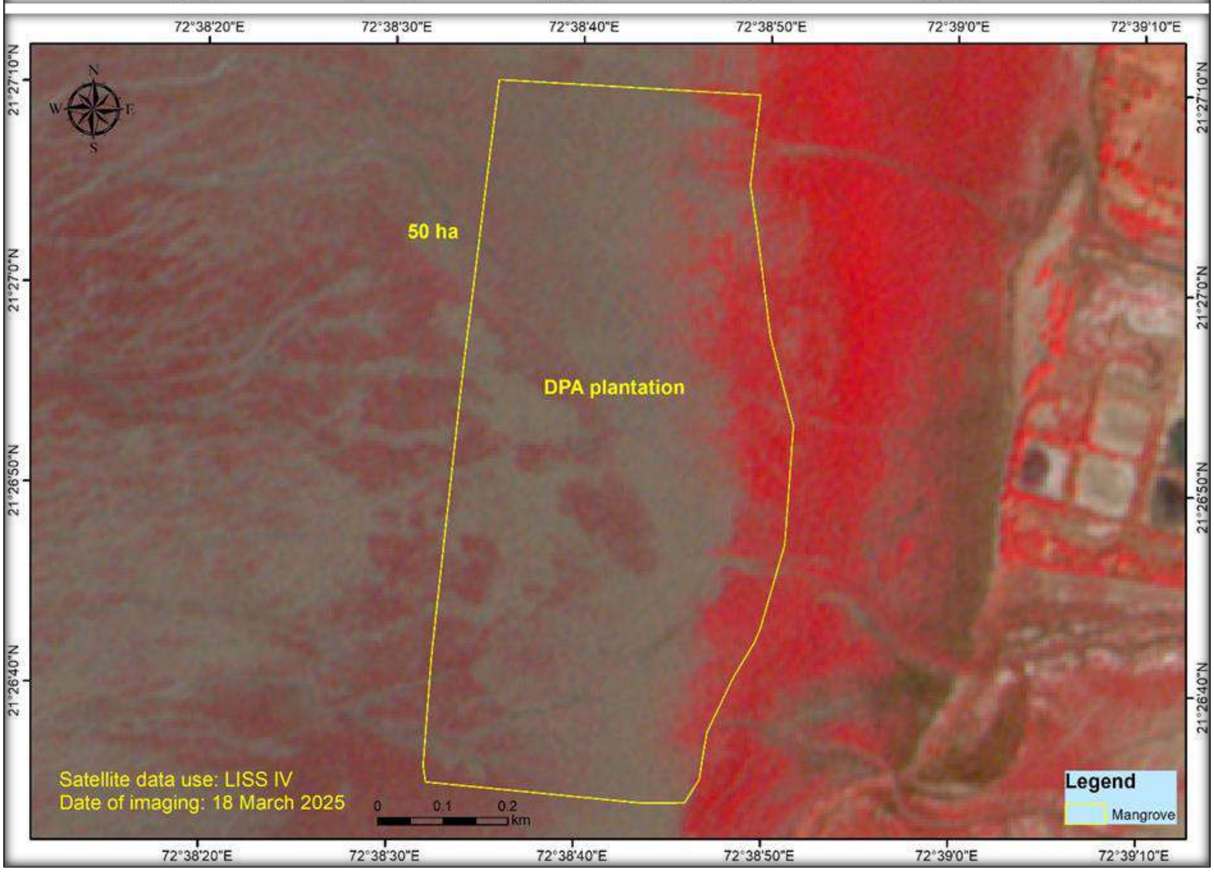


Figure 16: Satellite imageries of the 100 (50-2) Ha block-5 plantation site at Kantiyajal (2014 and 2025)

5.4 Regular mapping through GIS & RS

Mangrove plantations in 1600 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. The table 2 provides a comprehensive overview of sampling sites within a 1,600-hectare mangrove plantation in Gujarat, India, detailing specific blocks and sampling points across three locations: Sat Saida Bet and Nakti Creek in Kachchh district, and Kantiyajal in Bharuch district. Each site is divided into several blocks base on year of plantation in three different areas, with each block containing multiple sampling and GIS points identified by precise geographic coordinates. This structure enables systematic ecological monitoring by allowing researchers to track environmental changes across different spatial scales and habitats within the plantation. The detailed coordinates facilitate accurate mapping and comparison of ecological data, supporting effective management and conservation of these vital mangrove ecosystems.

Table 2. Comprehensive Details of GIS and Sampling Sites within the 1600-Hectare Mangrove Plantation in 2025

Sat Saida Bet, Kachchh district				**Nakti Creek, Kachchh district**				**Kantiyajal, Bharuch District**			
HA	**Sampling point**	**Longitude**	**Latitude**	**HA**	**Sampling point**	**Longitude**	**Latitude**	**HA**	**Sampling point**	**Longitude**	**Latitude**
Block -1				**Block -1**					**Block -1**		
20	1	70° 17' 3"	23° 4' 25"	**50**	1	70° 7' 22"	22° 57' 55"	**150**	1	72° 38′ 52.63″	21° 31′ 38.34″
	2	70° 16' 53"	23° 4' 25"		2	70° 7' 46"	22° 57' 57"		2	72° 38′ 41.87″	21° 31′ 31.73″
					3	70° 7'37.07"	22°57'50.13"		3	72° 38′ 41.31″	21° 31′ 19.26″
									4	72° 38′ 44.87″	21° 31′ 8.35″
									5	72° 38′ 52.66″	21° 31′ 8.14″
									6	72° 38′ 53.9″	21° 30′ 57.95″
									7	72° 38′ 47.47″	21° 30′ 54.83″
Block -2				**Block -2**					**Block -2**		
200	1	70° 15' 13"	23° 2' 37"	**100**	1	70° 8' 17"	22° 57' 34"	**150**	1	72° 38′ 55.72″	21° 28′ 15.14″
	2	70° 15' 11"	23° 2' 46"		2	70° 8' 18"	22° 57' 30"		2	72° 38′ 59.27″	21° 28′ 5.57″

	3	70° 15' 22"	23° 2' 44"		3	70° 8' 22"	22° 57' 35"		3	72° 38′ 46.93″	21° 28′ 4.47″
	4	70° 15' 18"	23° 2' 21"		4	70° 8' 31"	22° 57' 28"		4	72° 38′ 34.92″	21° 28′ 8.45″
	5	70° 15' 29"	23° 2' 25"		5	70° 8' 32"	22° 57' 23"		5	72° 38′ 29.21″	21° 28′ 13.88″
	6	70° 15' 40"	23° 2' 34"						6	72° 38′ 26.62″	21° 27′ 58.01″
	7	70° 15' 52"	23° 2' 40"						7	72° 38′ 50.13″	21° 27′ 56.08″
	8	70° 15' 49"	23° 2' 48"								
	9	70° 15' 40"	23° 2' 43"								
	10	70° 15' 27"	23° 2' 36"								
Block -3				**Block -3**				**Block -3**			
300	1	70° 15' 41"	23° 0' 40"					**50**	1	72° 38′ 46.3″	21° 27′ 4.29″
	2	70° 15' 43"	23° 0' 35"						2	72° 38′ 41.64″	21° 26′ 52.77″
	3	70° 15' 38"	23° 0' 29"						3	72° 38′ 44.8″	21° 26′ 41.13″
	4	70° 15' 34"	23° 0' 37"								
	5	70° 15' 31"	23° 0' 44"								
	6	70° 15' 26"	23° 0' 47"								
	7	70° 15' 22"	23° 0' 46"								
	8	70° 15' 5"	23° 0' 47"								
	9	70° 15' 7"	23° 0' 54"								
	10	70° 15' 1"	23° 0' 55"								

	11	70° 14' 55"	23° 0' 55"								
	12	70° 14' 52"	23° 0' 50"								
	13	70° 14' 49"	23° 0' 53"								
	14	70° 14' 47"	23° 0' 57"								
	15	70° 14' 42"	23° 1' 1"								
Block -4				**Block -4**				**Block -4**			
330	1	70° 17' 38"	23° 4' 30"					**50**	1	72° 38′ 51.29″	21° 27′ 32.55″
	2	70° 17' 50"	23° 4' 24"						2	72° 38′ 51.43″	21° 27′ 22.37″
	3	70° 17' 25"	23° 4' 31"						3	72° 38′ 49.22″	21° 27′ 17.0″
	4	70° 17' 10"	23° 4' 37"								
	5	70° 17' 55"	23° 4' 13"								
	6	70° 17' 42"	23° 4' 23"								
	7	70° 17' 15"	23° 4' 45"								
	8	70° 17' 27"	23° 4' 38"								
	9	70° 17' 35"	23° 4' 41"								
	10	70° 17' 42"	23° 4' 41"								
	11	70° 17' 47"	23° 4' 38"								
	12	70° 17' 54"	23° 4' 34"								
	13	70° 17' 16"	23° 4' 53"								
	14	70° 17' 24"	23° 4' 50"								
	15	70° 17' 31"	23° 4' 52"								
Block -5				**Block -5**						**Block -5**	

50	1	70°17'12.44"	23° 4'20.00"					**50**	1	72° 38′ 3.7″	21° 32′ 25.84″
	2	70°17'11.03"	23° 4'13.28"						2	72° 38′ 8.14″	21° 32′ 11.76″
	3	70°17'21.64"	23° 4'12.93"						3	72° 38′ 22.07″	21° 32′ 8.35″
Block -6				**Block -6**						**Block -6**	
100	1	70° 14' 18"	22° 59' 34"								
	2	70° 14' 31"	22° 59' 34"								
	3	70° 14' 40"	22° 59' 46"								
	4	70° 14' 56"	22° 59' 46"								

6. Results

The mangrove monitoring study results of the three sites, Nakti creek Kantiyajal and Sat Saida bet during 2025 are presented below.

6.1 Monitoring of mangrove plantation at Sat-Saida Bet

The 20 ha mangrove plantation was carried out at the Sat-Saida Bet near DPA port, Kandala. This plantation was carried out during the year 2005-06 by Gujarat institute of Desert Ecology, executed this plantation with the help of community participation. The results showing a high tree density of 2,200 trees per hectare. The average tree height is reported as 139.09 cm, while the average girth is 10.36 cm indicating relatively young or slender trees. The average canopy width is 2.3 meters, suggesting moderate foliage coverage. Overall, this area appears to be densely populated with slim, possibly young trees, and the height value should be double-checked for accuracy (Plate 1).

Plate 1: Mangrove plantation 20 Ha at Sat Saida Bet site Block- 1 during a visit in 2025

The Plate 2 and figure 17 and 18 shows information from ten quadrants (Q1-Q10) within a 200-hectare area, including tree density, average height, and girth, ocular diameter of the trunk and canopy cover. Densities have quite a range of 1,200 to 3,800 trees per quadrant. Tree heights and girths do not differ tremendously, but the canopy cover is rather balanced with some quadrants such as Q5 having fairly high canopy values compared to all other quadrants density, while other quadrants like Q7 and Q10 with very high density having lower canopy values. This implies that greater tree density does not always result in increased canopy cover due to competition for resources affecting the tree growth and canopy expansion. Collectively, the data reveals the diversity in the structure of forests throughout the area sampled.

Plate 2: Mangrove plantation 200 Ha at Sat Saida Bet site Block- 2 during a visit in 2025

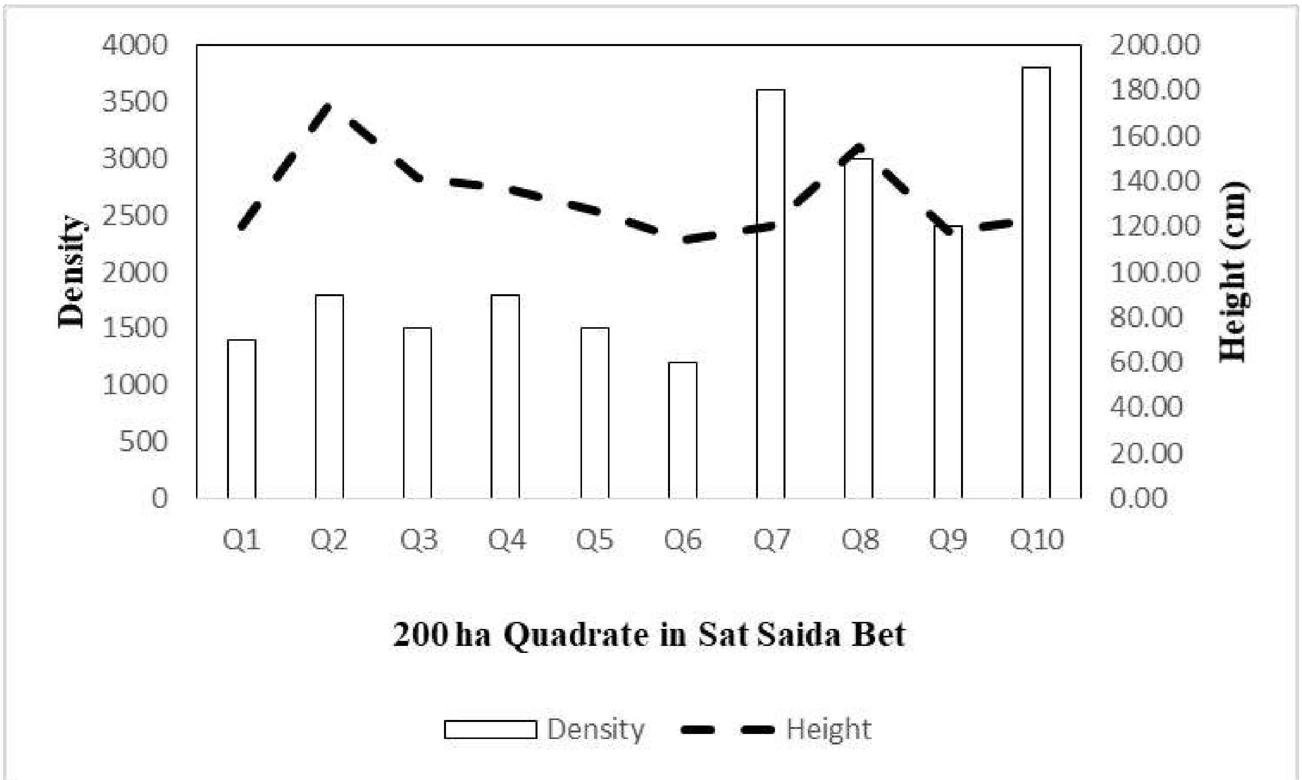


Fig.17 Details of density (No) and height of mangroves in 200 ha plantation area in 2011-2012 at Sat Saida Bet.

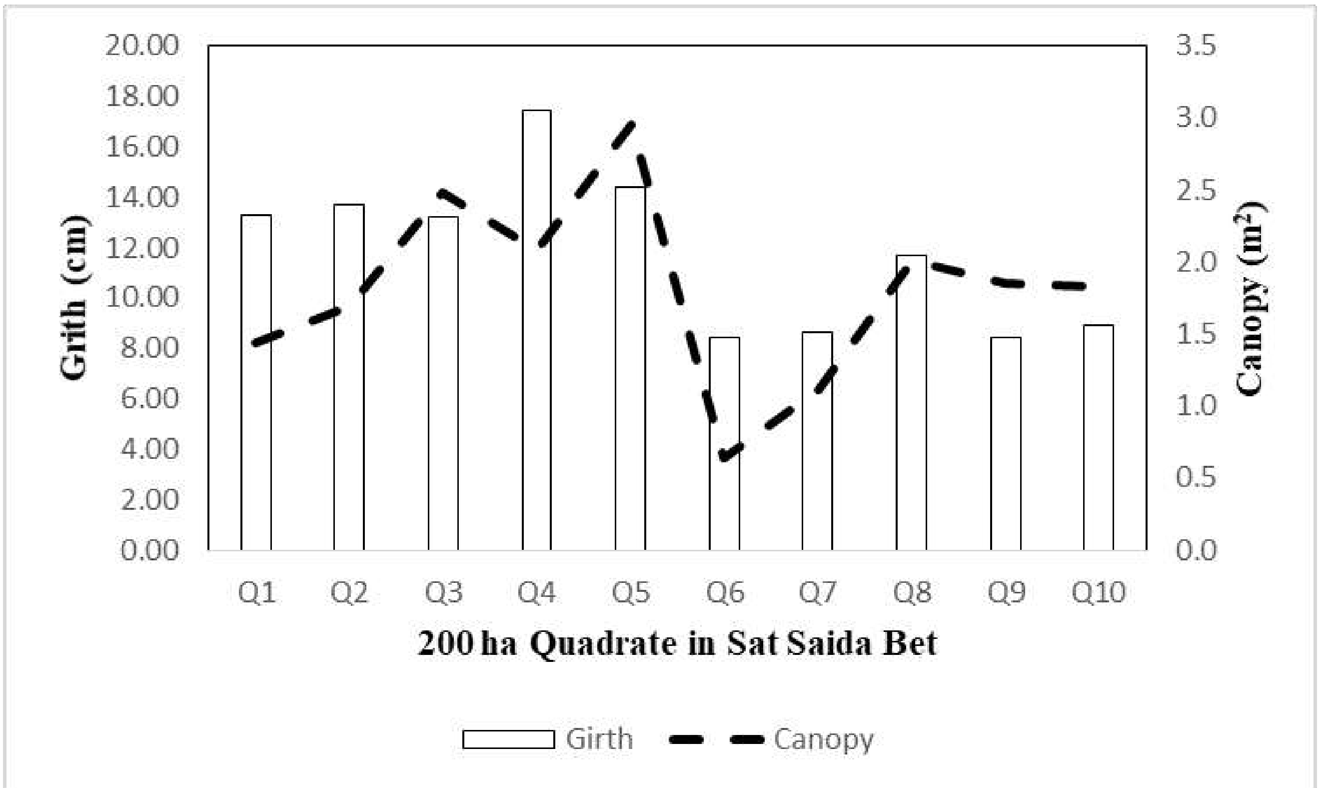


Fig. 18 Details of Canopy and Basal Girth of mangroves in 200 ha plantation area in 2011-2012 at Sat Saida Bet.

The monitoring result information related to a 300-hectare site presented in the figure 19 and 20 and plate 3 demonstrates that density of trees in this area ranges from 1300 to 2600 individuals at its peak in Q5 and lowest in Q8. Average height of the trees is from 128 to142 cm with the highest in Q6 whereas girth ranges from 11.73 to 15 cm, maxima in Q3. Canopy cover usually increases with value of height and is at its max Q6 of 2.01 and min of 1.61 m^2. The data can be interpreted that degree of density does not correlate with amount of height or girth.

Plate 3: Mangrove plantation 300 Ha at Sat Saida Bet site Block- 3 during a visit in 2025

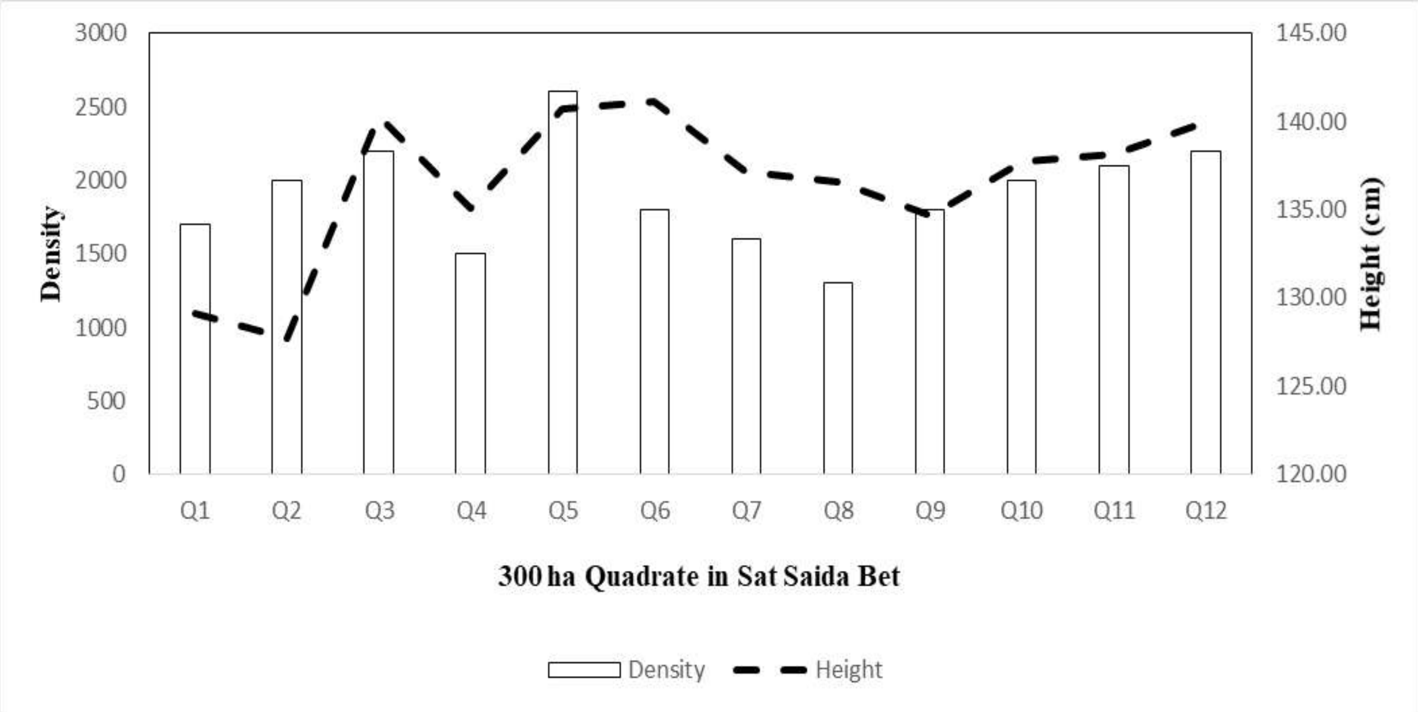


Fig.19 Details of density (No) and height of mangroves in 300 ha plantation area in 2012-2013 at Sat Saida Bet.

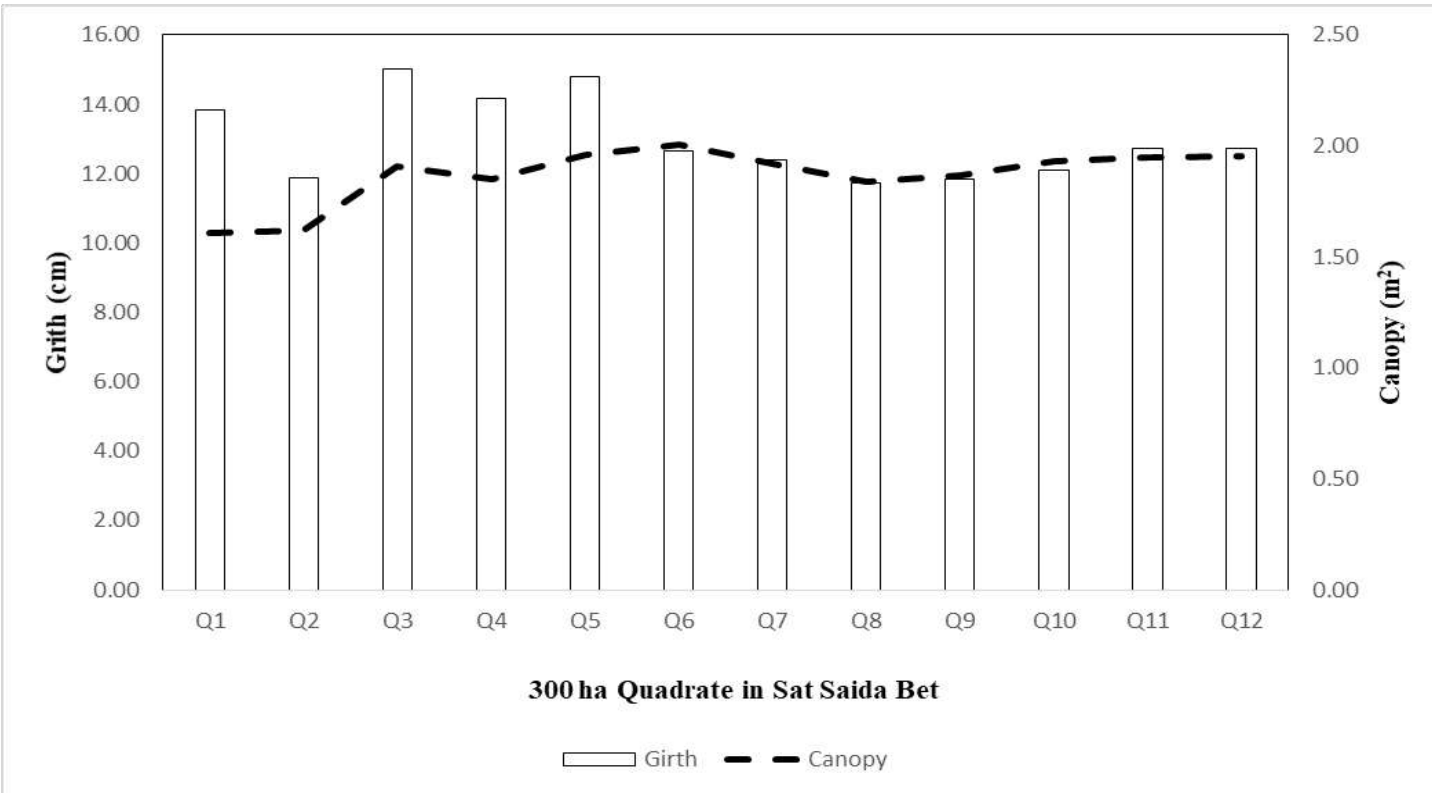


Fig.20 Details of Canopy and Basal Girth of mangroves in 300 ha plantation area in 2012-2013 at Sat Saida Bet.

The plate 4 and figure 21 and 22 shows the data on tree measurements across fourteen (Q1 to Q14) quadrants within an area of 330 ha detailing density, height, girth and canopy spread. The density seems to vary in a very wide range of 1300 to 4000 trees/ha, with a greater density often relating to lesser girth and canopy size which indicates that there is competition for resources. The height of the trees measured ranges from 127cm to 185cm, the girth ranges from 8 to 15 cm and the canopy spread from 1.08 to 3.12 m^2. It is worth mentioning that quadrants which contain lower density like Q5 and Q11 tend to have their girth and canopy size greatly expanded hence suggesting that trees which are in sparser regions are able to grow broader and larger in canopies.

Plate 4: Mangrove plantation 330 Ha at Sat Saida Bet site Block- 4 during a visit in 2025

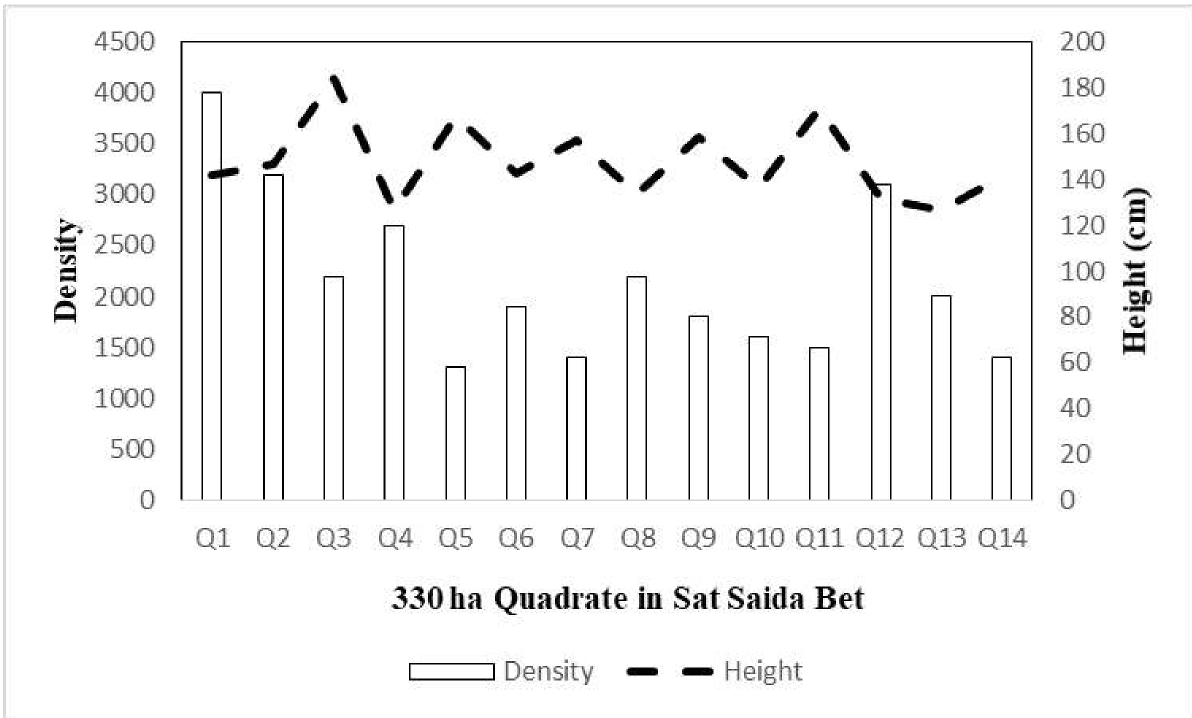


Fig. 21 Details of density (No) and height of mangroves in 330 ha plantation area in 2013-2014 at Sat Saida Bet

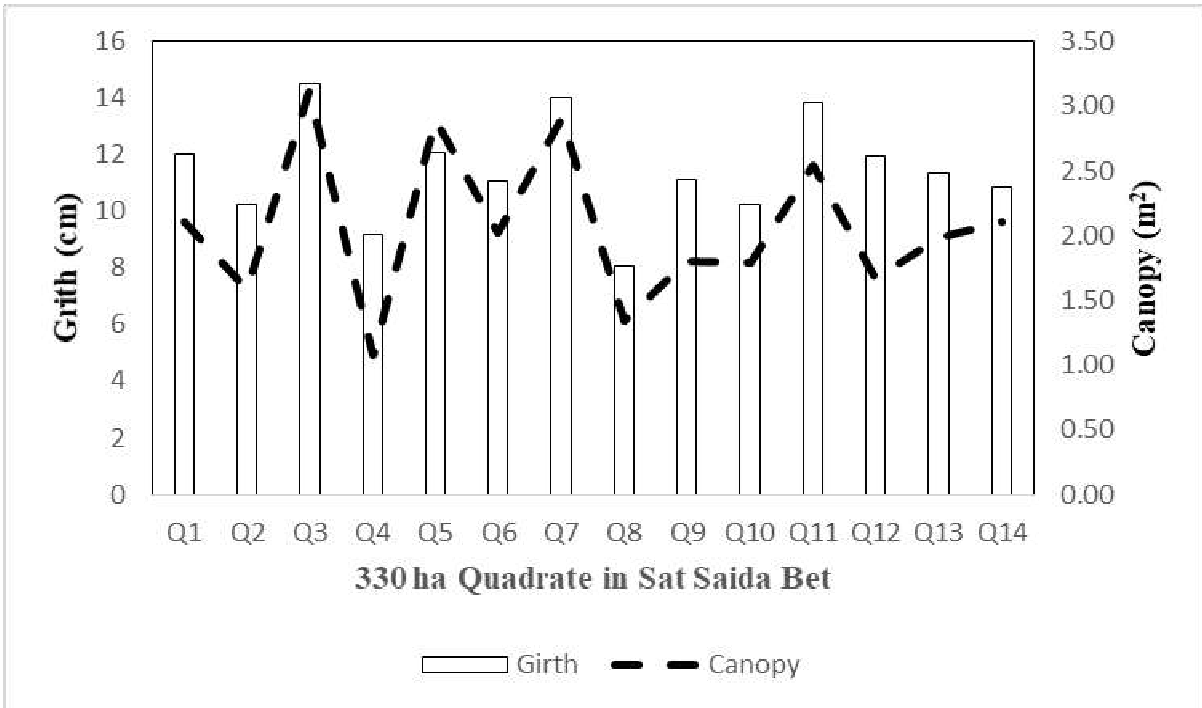


Fig. 22 Details of Canopy and Basal Girth of mangroves in 330 ha plantation area in 2013-2014 at Sat Saida Bet.

The figures 23 and 24; plate 5 illustrate that in a 50 hectare area in Sat Saida Bet, Q1 sustains the highest tree density at 2200 trees as well as the tallest average height of 133.64 and also has the largest average girth of 15.18 and broadest average canopy of 1.8 indicating a more mature. In addition, Q2 and Q3 have even lower densities of 900 and 1200 trees respectively alongside progressively smaller average height, girth, and canopy values suggesting these areas are relatively younger, less established, or more disturbed in comparison to Q1.

Plate 5: Mangrove plantation 50 Ha at Sat Saida Bet site Block- 5 during a visit in 2025

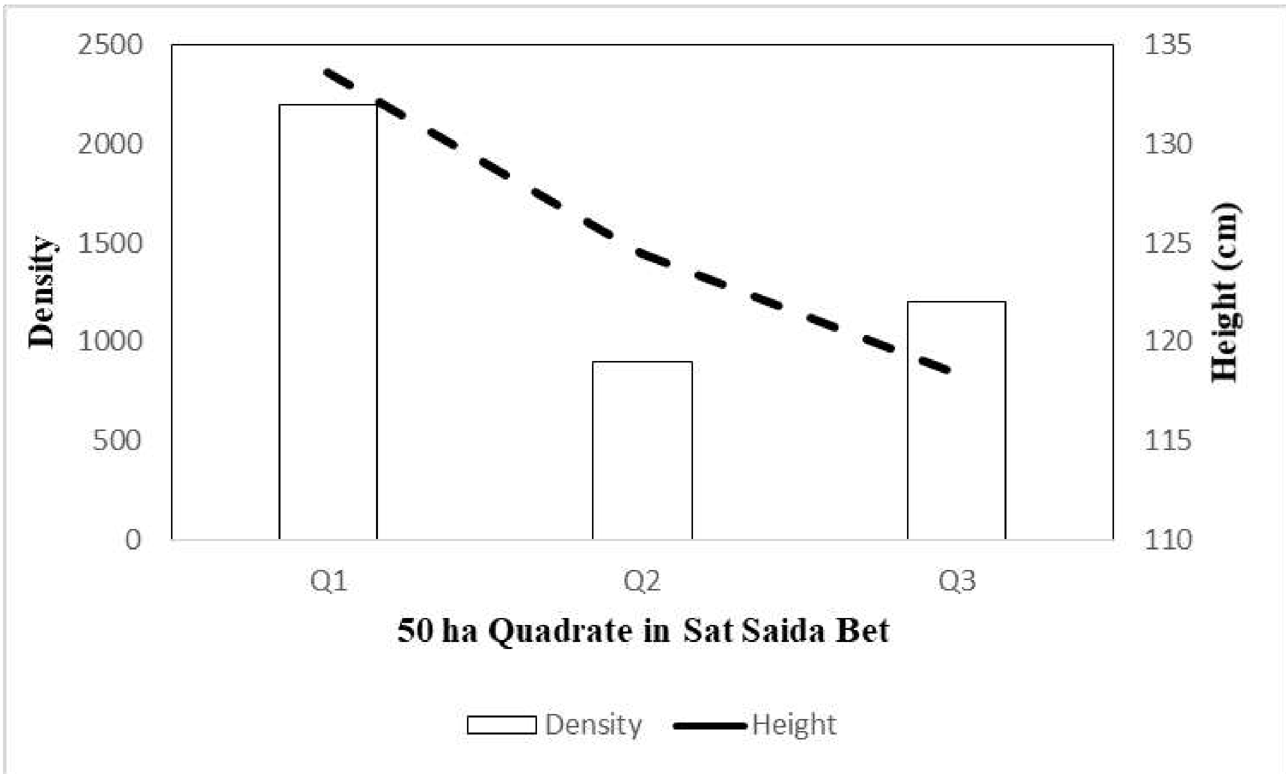


Fig.23 Details of density (No) and height of mangroves in 50 ha plantation area in 2018-2019 at Sat Saida Bet.

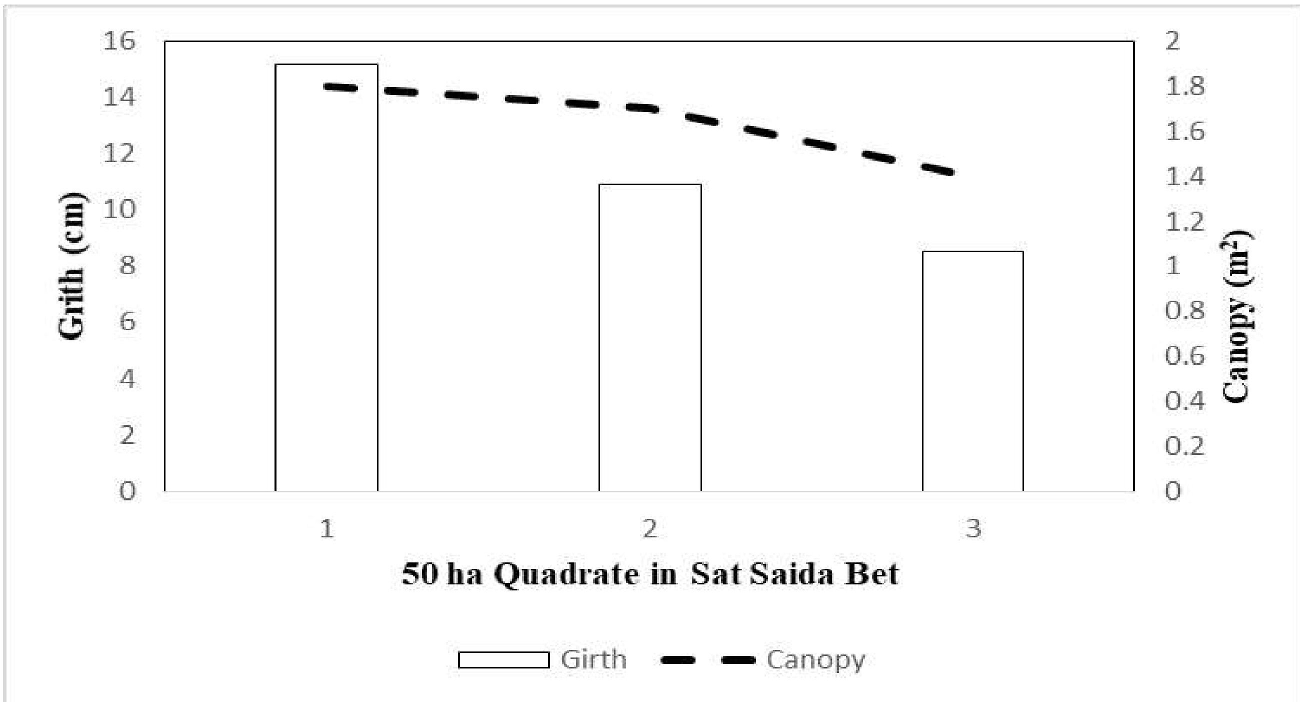


Fig. 24 Details of Canopy and Basal Girth of mangroves in 50 ha plantation area in 2018-2019 at Sat Saida Bet.

The tree population data regarding their density, height, girth, and canopy spread is presented through five quadrants (Q1–Q5) in a 100-hectare range. Q1 has the highest trees that measure 224 cm as well as having the largest girth of 17 cm and the highest canopy cover of 5.60 m²; though having moderate density of 1000. On the contrary, Q2 displays the lowest density of 100, shortest trees of 100 measuring the smallest girth of 7 cm, and the lowest canopy of 0.72 m² which points towards undeveloped sparse vegetation. Q4 has the highest density (1300) average tree height of (115), girth (8), moderate canopy of (1.15) indicating denseness but less mature trees. Q3 and Q5 display median ranges for all parameters. It can also be seen from the data that forest structure is most characteristic in Q1 which shows a stand of fewer taller trees, as opposed to Q4 which has more, but smaller trees. (Plate 6; Figure 25 and 26). There are few natural grow trees are observed.

Plate 6: Mangrove plantation 100 Ha at Sat Saida Bet site Block- 6 during a visit in 2025

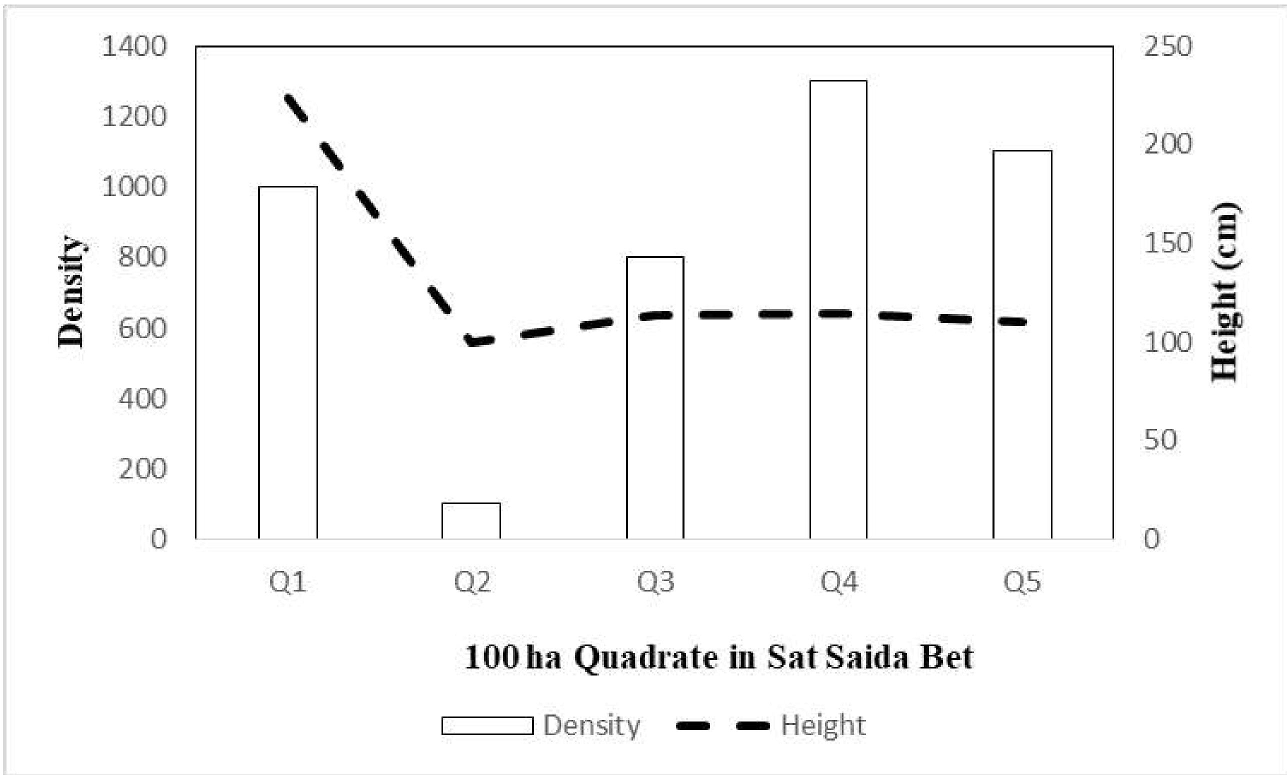


Fig. 25 Details of density (No) and height of mangroves in 100 ha plantation area in 2022-2023 at Sat Saida Bet

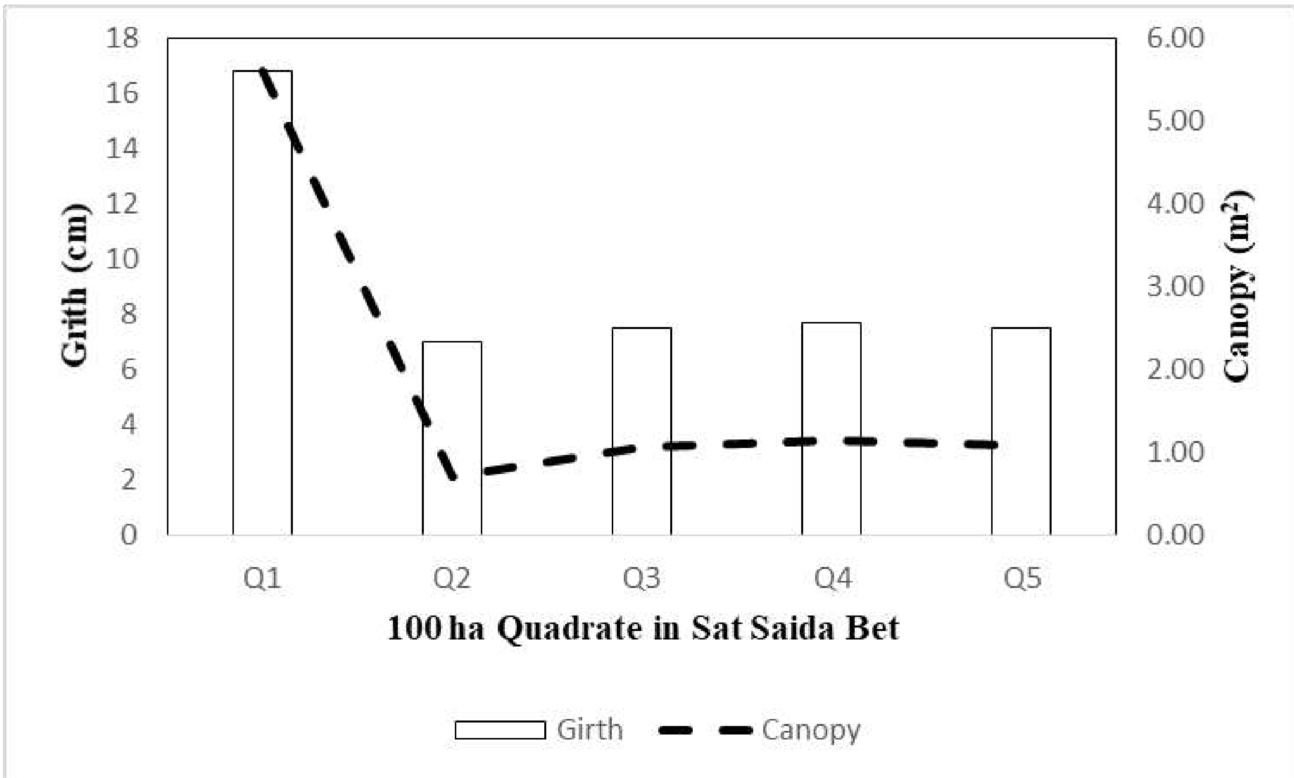


Fig. 26 Details of Canopy and Basal Girth of mangroves in 100 ha plantation area in 2022-2023 at Sat Saida Bet.

6.2 Monitoring of mangrove plantation at Nakti Creek

The figure 27 and 28; Plate 7 summarizes the structural characteristics of mangroves in a 50-hectare plantation at Nakti Creek during 2008-2009, comparing two quadrants (Q1 and Q2). Q1, with a higher density of 1500 trees per hectare, shows smaller average tree height (175 cm), basal girth (9 cm), and canopy spread (2.0 m). In contrast, Q2, with a lower density of 500 trees per hectare, has mangroves that are taller (182 cm), have thicker trunks (11 cm girth), and wider canopies (3.7 m).

Plate 7: Mangrove plantation 50 Ha at Nakti Creek site Block- 1 during a visit in 2025

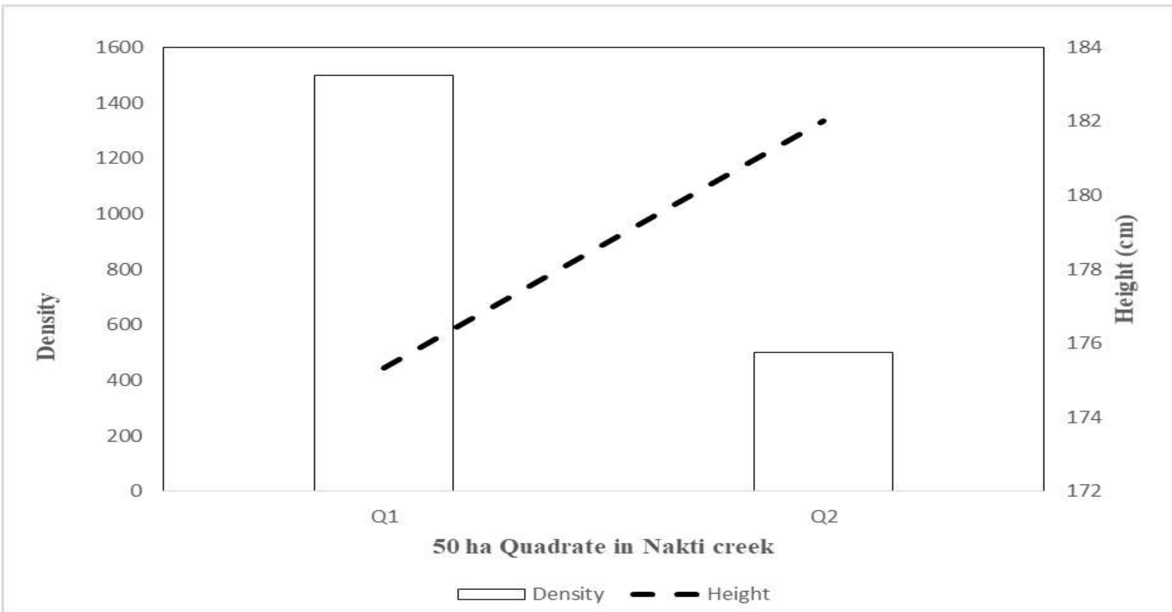


Fig. 27 Details of density (No) and height of mangroves in 50 ha plantation area in 2008-2009 at Nakti Creek.

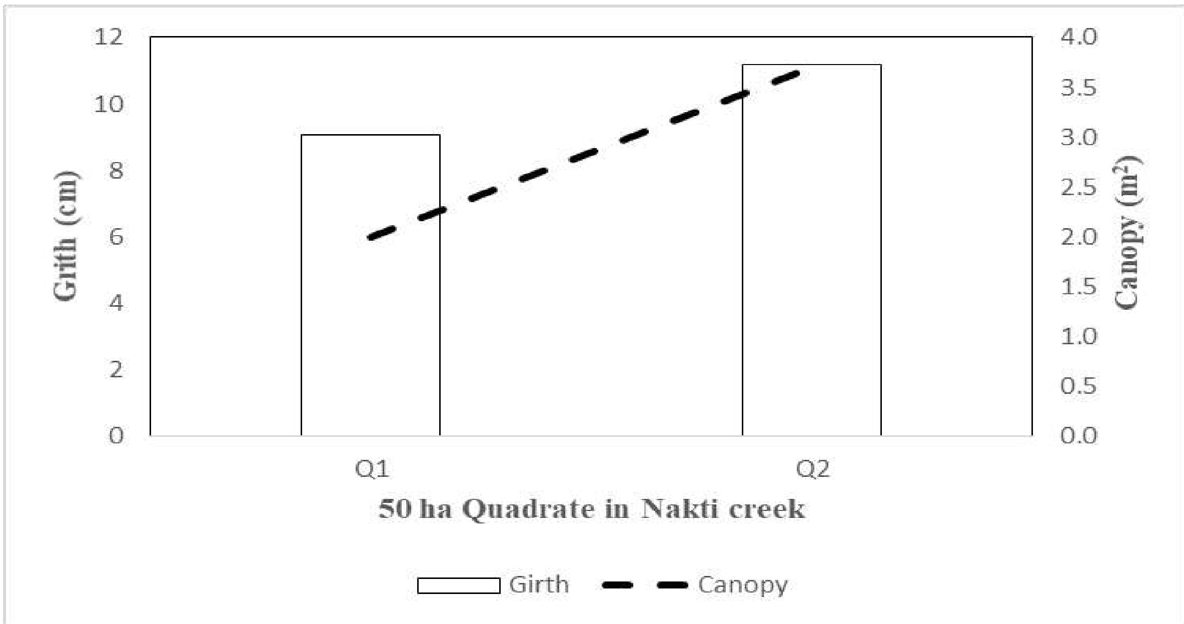


Fig. 28 Details of Canopy and Basal Girth of mangroves in 50 ha plantation area in 2008-2009 at Nakti Creek.

The Figure 29 illustrates the variations in tree density, height, girth and canopy size in five quadrants (Q1-Q5) over a 100 hectare mangrove plantation area in 2010-2011, which shows remarkable differences across that space. Q2 contains the greatest tree density (1600/Ha) along with a height that is above average (156 m) and broad canopy (3.8 m). Q5 contains the lowest density trees (1000/Ha), but reaches remarkable height (171 m) signifying that lesser competition might allow stretched growth. Moderate density in Q3 possessing the thickest trunks (15 cm girth) along with 3.5 m wide canopy could identify older or stouter trees. Q1 without exception has lower values for each of the parameters which suggests younger trees or less competitive stands, whereas Q4 shows intermediate figures 30 and plates 8.

Plate 8: Mangrove plantation 100 Ha at Nakti Creek site Block- 2 during a visit in 2025

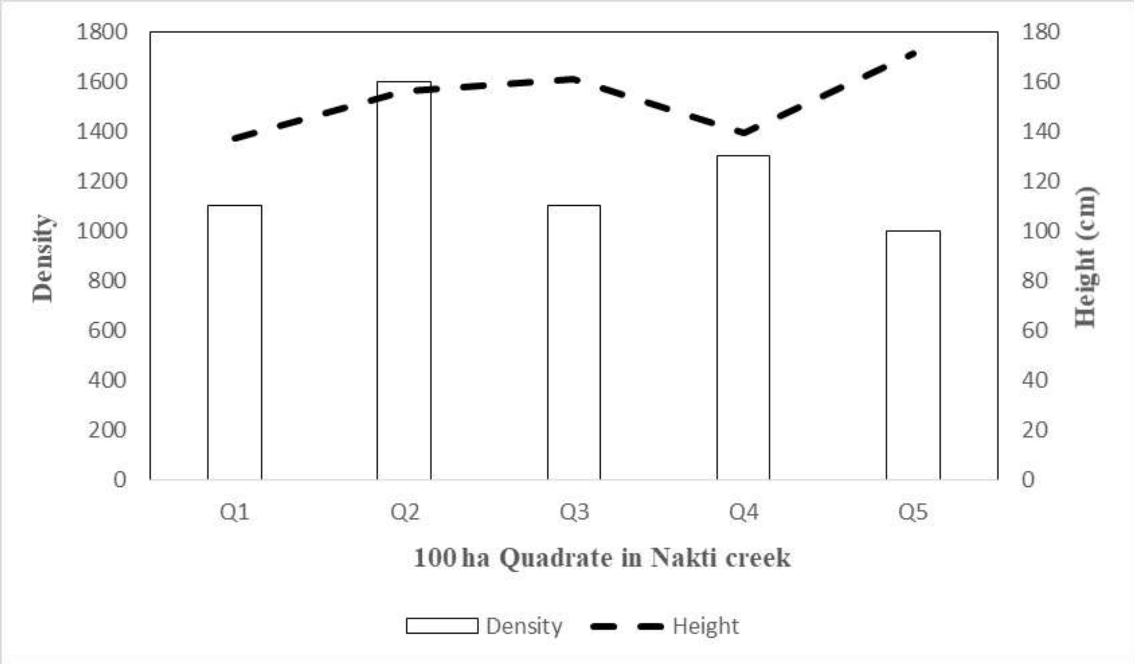


Fig.29 Details of density (No) and height of mangroves in 100 ha plantation area in 2010-2011 at Nakti Creek

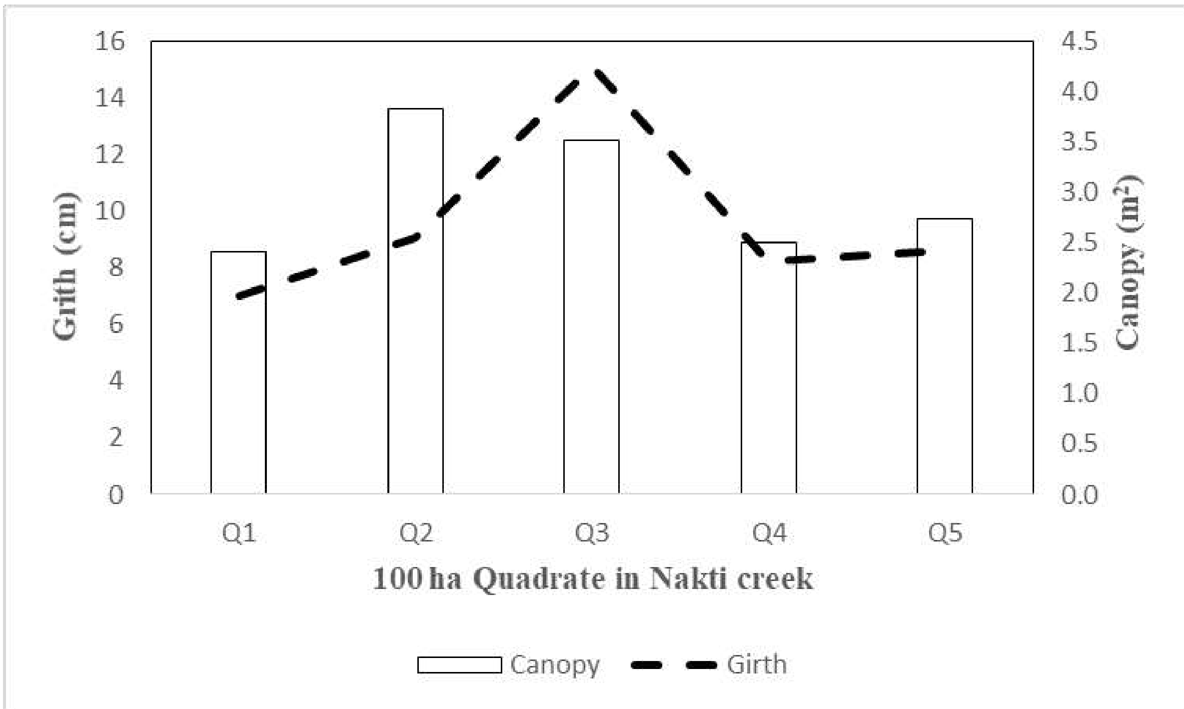


Fig.30 Details of Canopy and Basal Girth of mangroves in 100 ha plantation area in 2010-2011 at Nakti Creek.

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6.3 Monitoring of mangrove plantation at Kantiyajal

The plate 9 and figure 31 and 32 illustrates the data of tree density, mean height, girth and canopy size of individual quadrants from seven quadrants (Q1 – Q7) that lie within a 150-hectare area at kantiyajal mangrove plantation area. The values exhibit considerable: densities were found between 500 and 1200, height ranged from 108 to 152 cm, girth was between 7 and 12 cm, and canopy span varied from 0.51 to 2.29 m^2, Q2 contains the highest trees (152) but Q2 has the moderate canopy (1.24 m^2). Furthermore, Q1 and Q5 have the greater canopies (2.29 and 2.07 m^2) but have average heights. Such data can be used to study forest structure, tree growth, and the habitat diversity in the surveyed region.

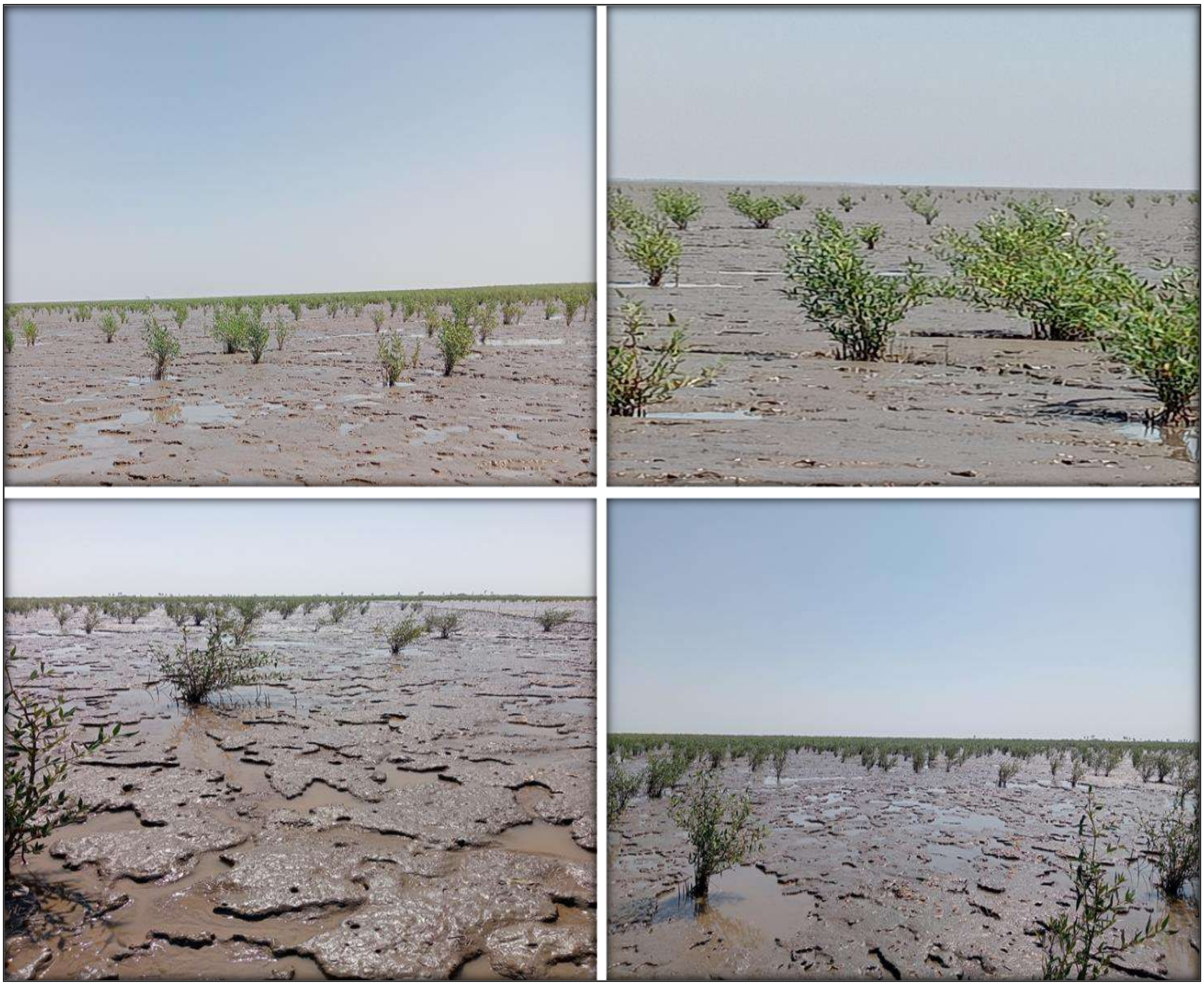

Plate 9: Mangrove plantation 150 Ha at Kantiyajal site Block- 1 during a visit in 2025

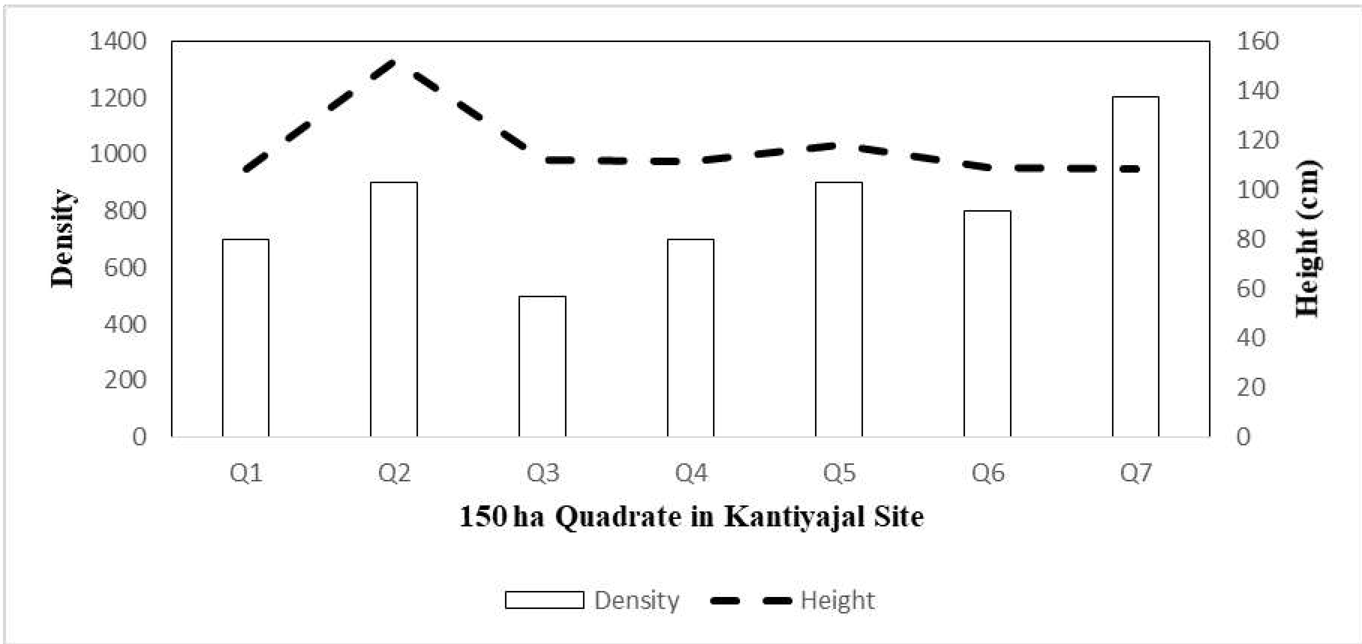

Fig.31 Details of density (No) and height of mangroves in 150 ha plantation area in 2015-2016 at Kantiyajal site

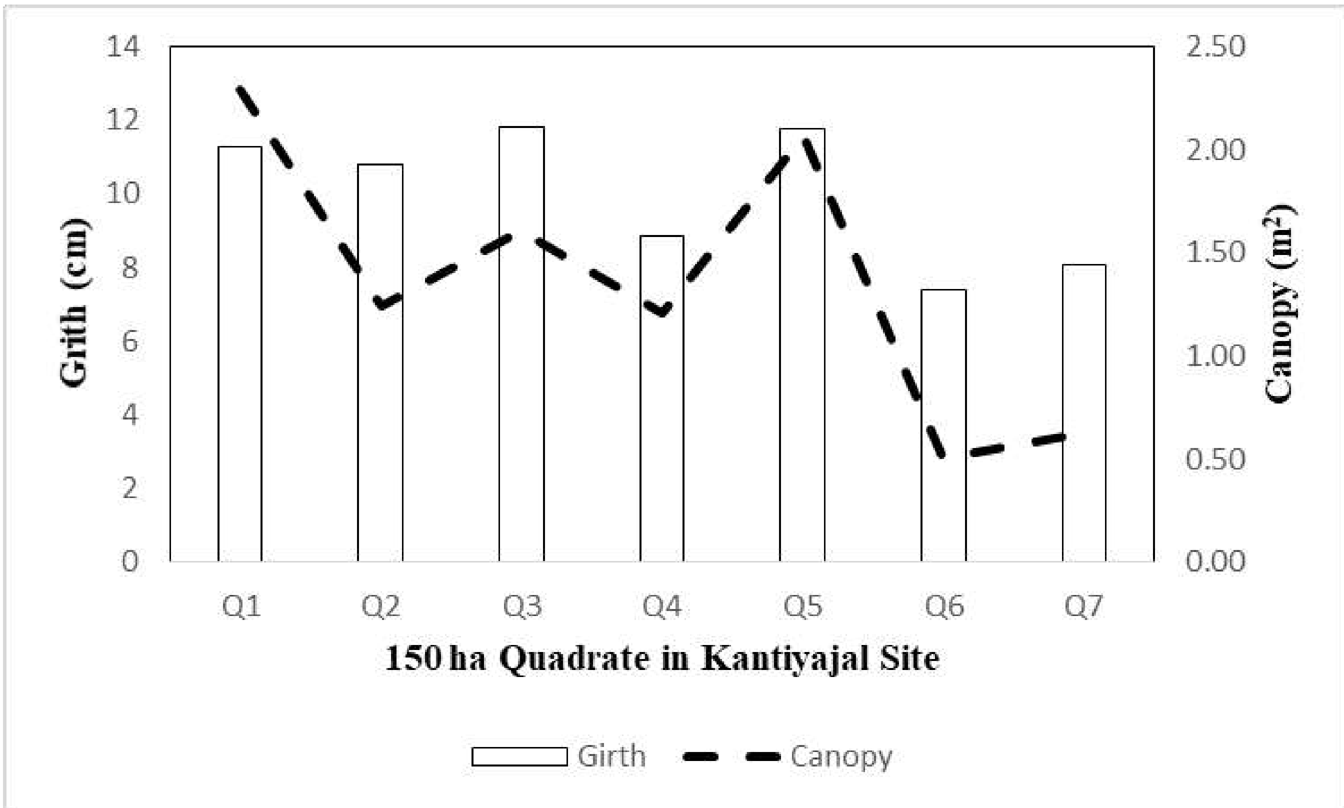

Fig.32 Details of Canopy and Basal Girth of mangroves in 150 ha plantation area in 2015-2016 at Kantiyajal site

The plate 10 shows the area where 150 ha were mangrove planted from 2016 to 2017. Since this area were many sparse mangroves with a height of less than 70 cm and a girth of less than 8 cm. The densities values also very low compare to other site were significant between 500 and 800 plants/ ha.

Plate 10: Mangrove plantation 150 Ha at Kantiyajal site Block- 2 during a visit in 2025

Plate 11: Mangrove plantation 50 Ha at Kantiyajal site Block- 3 during a visit in 2025

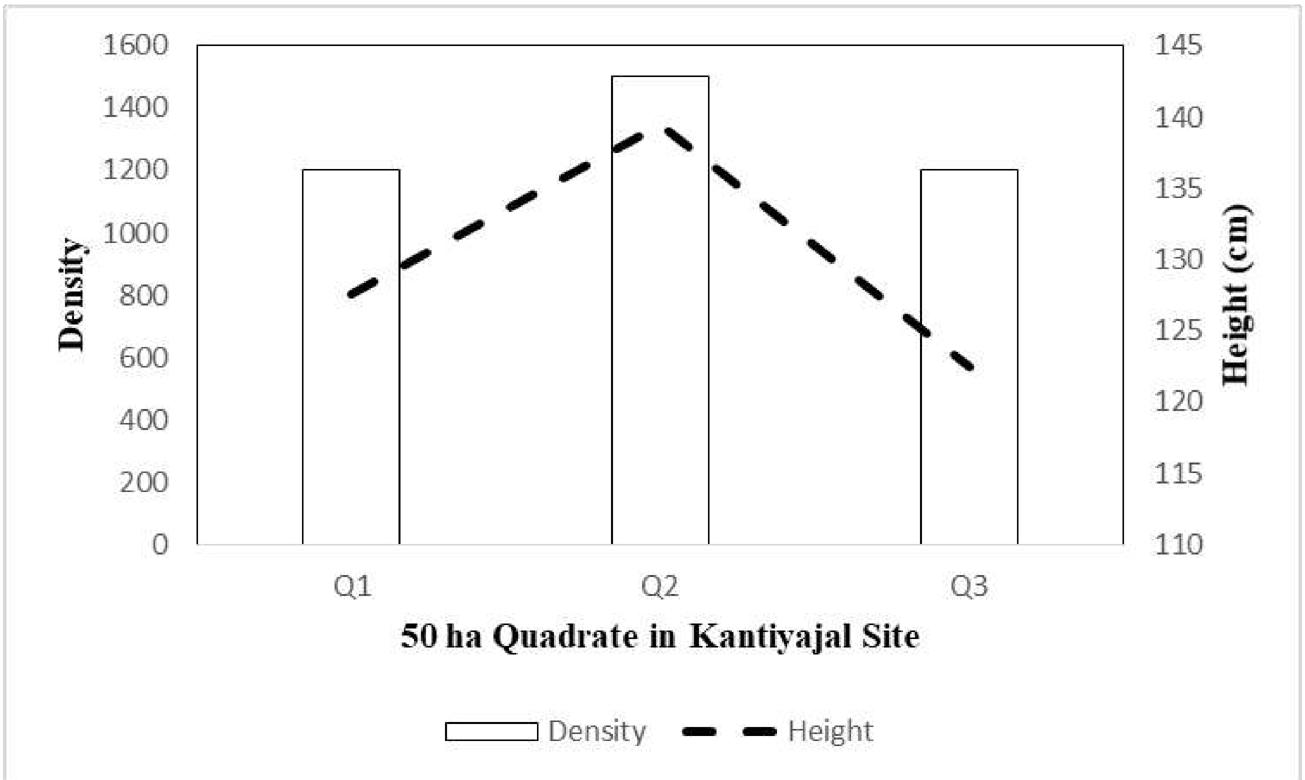

Fig.33 Details of density (No) and height of mangroves in 50 ha plantation area in 2018-2019 at Kantiyajal site

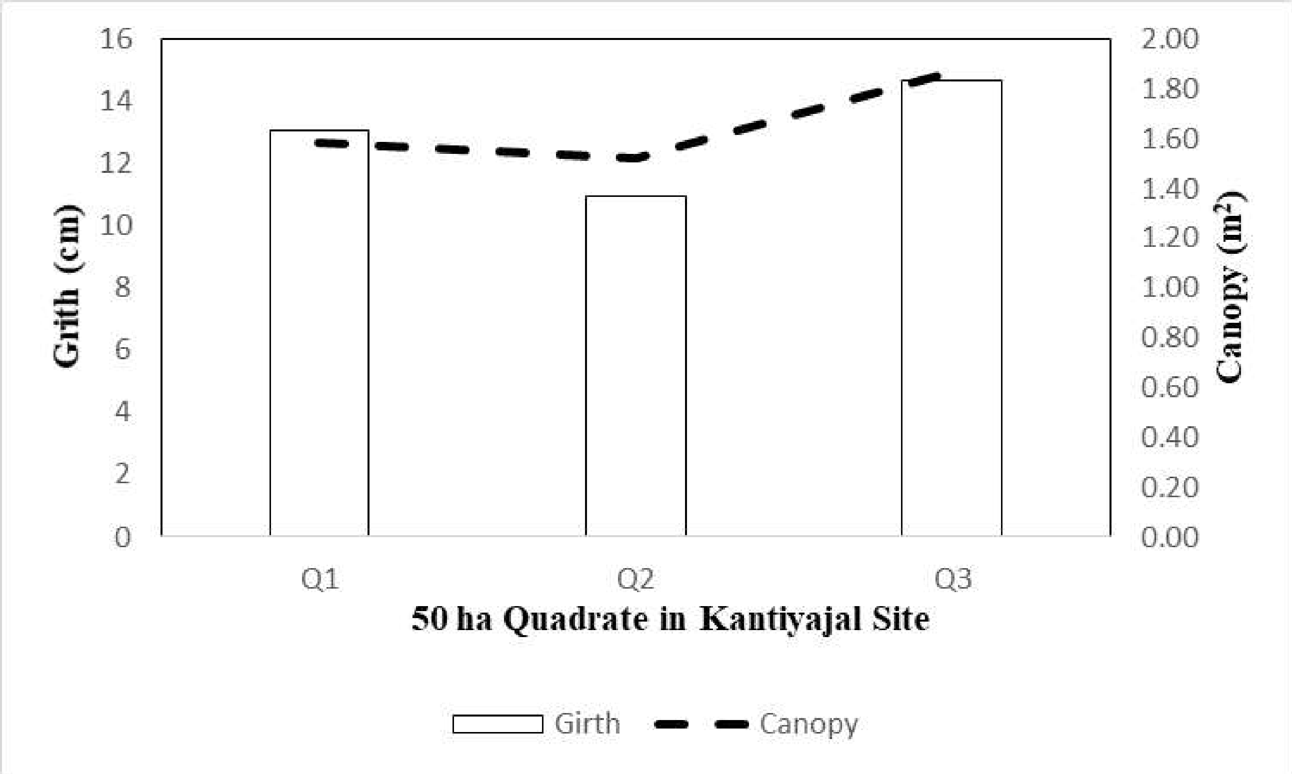

Fig.34 Details of Canopy and Basal Girth of mangroves in 50 ha plantation area in 2018-2019 at Kantiyajal site

The plate 12 shows that 50 mangrove plantation area planted area 2021 to 2022. The area was sparse so many mangrove less than 50 cm height and girth less than 6 cm. The values exhibit considerable, densities were found less than 300.

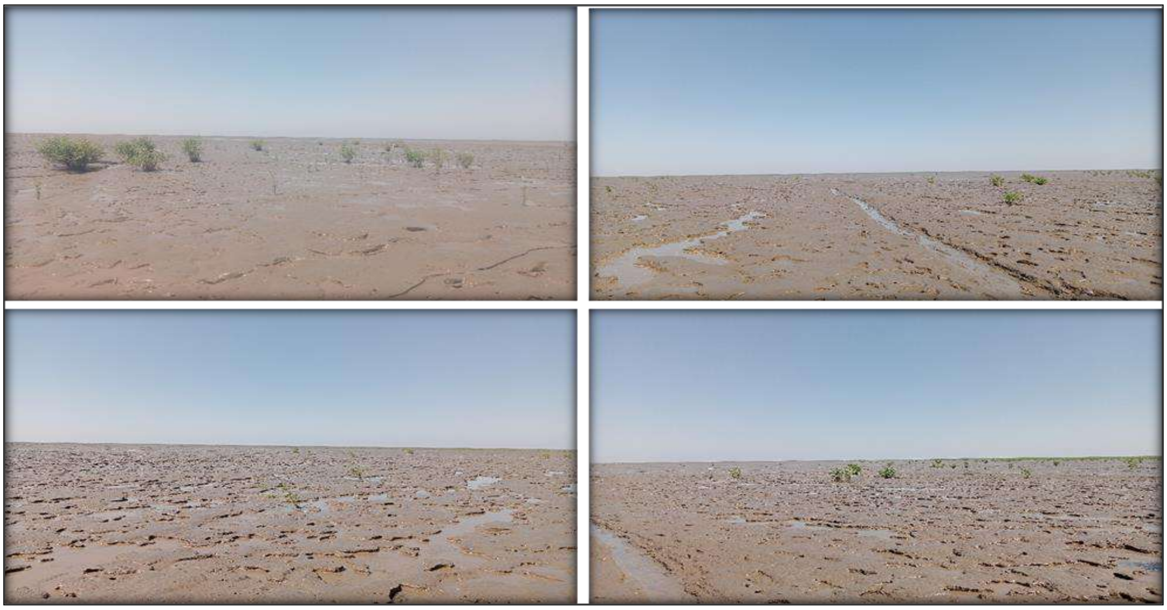

Plate 12: Mangrove plantation 100 (50-1) Ha at Kantiyajal site Block- 4 during a visit in 2025

The plate 13 and figure 35 and 36 presents data for three quarters (Q1, Q2, Q3) over a 50-hectare area in mangrove plantation 100 (50-2) Ha area in 2021-2022 at Kantiyajal site , showing tree density, average height, girth, and canopy size. In Q1, the density is 600 trees/ha, height is 116 cm, girth is 7 cm, and canopy is 3.4 m^2. In Q2, density increases to 700, height slightly decreases to 113 cm, girth remains 7 cm, but canopy drops sharply to 0.8 m^2. By Q3, density peaks at 1000, height rises to 123 cm, girth increases to 7.40 cm, and canopy recovers to 1.7 m^2. Overall, the data suggests fluctuations in tree characteristics, with density and height generally increasing, but canopy size showing significant variation across quarters.

Plate 13: Mangrove plantation 100 (50-2) Ha at Kantiyajal site Block- 5 during a visit in 2025

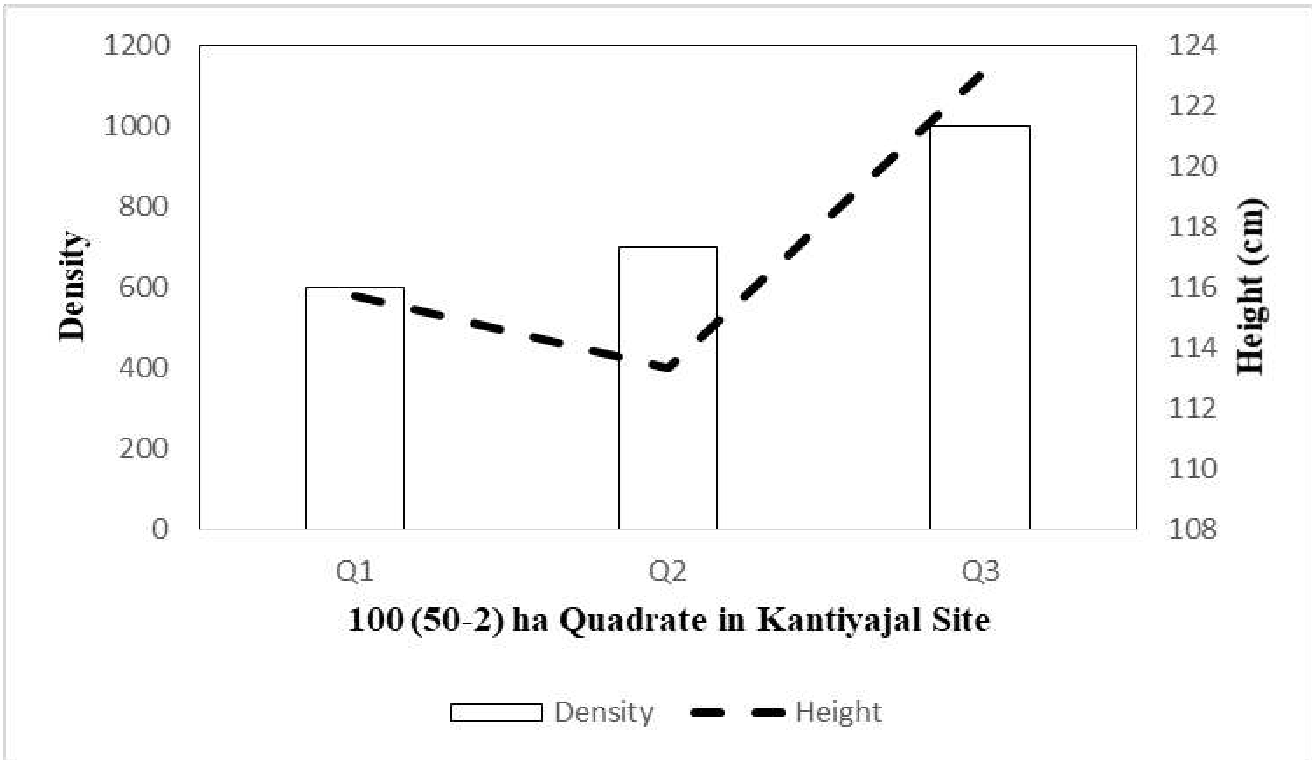

Fig.35 Details of density (No) and height of Mangrove 100 (50-2) Ha plantation area in 2021-2022 at Kantiyajal site

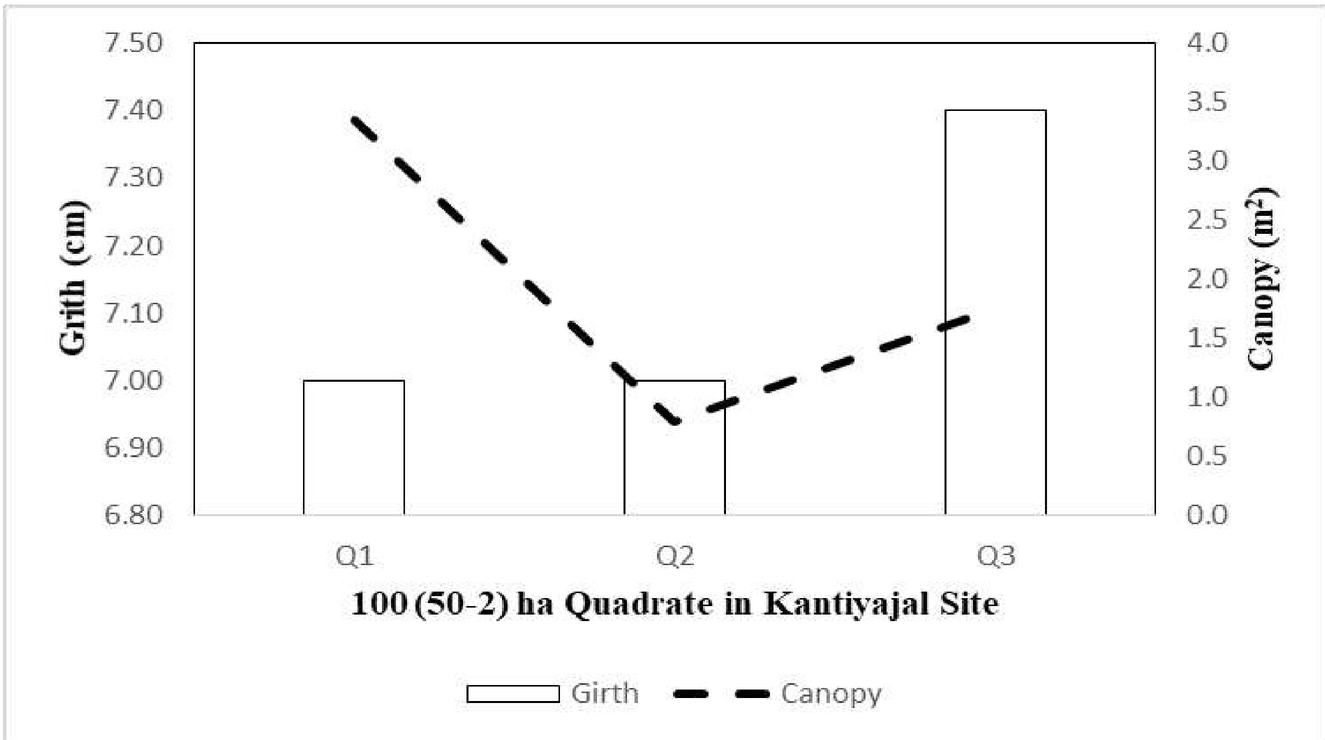

Fig.36 Details of Canopy and Basal Girth of Mangrove 100 (50-2) Ha plantation area in 2021-2022 at Kantiyajal site

7. Regeneration and recruitment class

The study conducted in various plantation blocks reveals crucial insights into the density of younger-class mangroves, particularly in their natural regeneration and recruitment phases. The findings indicate significant variations in the density of these young mangroves across different locations, highlighting both favourable and less favourable conditions for their establishment. The regeneration class, which encompasses newly established mangrove seedlings, exhibited the highest average density in the 50-hectare plantation block of Nakti Creek, with an impressive 1, 50,000 plants per hectare. This suggests highly favourable conditions for seedling establishment, potentially due to optimal salinity levels, sediment availability, and reduced anthropogenic disturbances. Conversely, the lowest density of regeneration-class mangroves was recorded in the 20-hectare plantation block of Sat-Saida Bet, where only 20,000 plants per hectare were observed. The lower density of younger-class mangroves in this particular plantation block may be influenced by multiple ecological and environmental factors. While limited seed dispersal and suboptimal hydrodynamic conditions are common constraints affecting mangrove regeneration, the structural dynamics of this block present an additional challenge to new growth. Since this plantation is relatively old, a few mature and large trees have been observed within the area. The presence of such well-established trees creates natural competition for resources such as sunlight, nutrients, and space. Larger trees tend to develop extensive root systems that dominate the nutrient supply in the soil, reducing the availability of essential elements required for the germination and survival of younger mangroves. Additionally, the shading can limit the penetration of sunlight to the forest floor which can hamper the successful establishment of younger classes' mangroves (Fig.37).

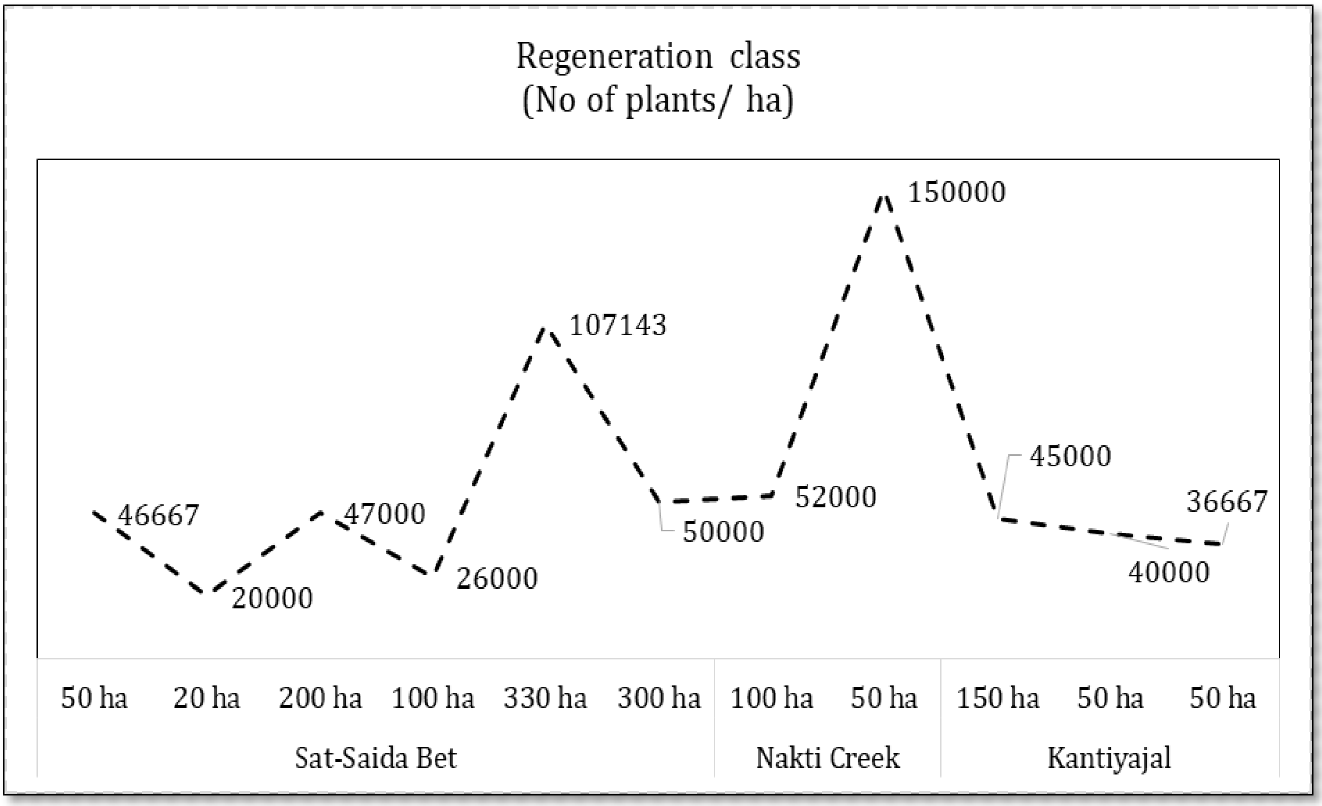

Fig. 37: Regeneration class mangroves in surveyed areas of plantations

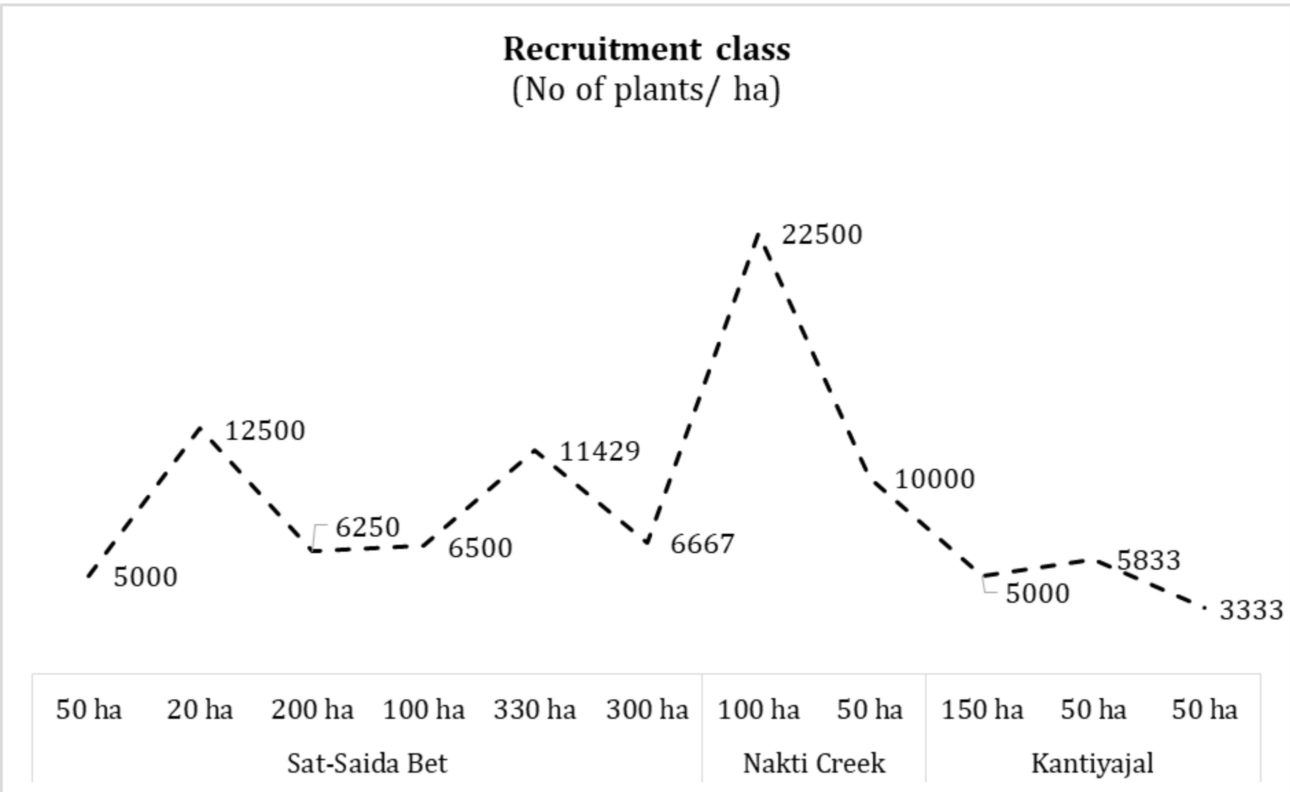

Fig. 38: Recruitment class mangroves in surveyed areas of plantations

The recruitment class, which consists of slightly older juvenile mangroves transitioning towards maturity, showed similar trends in density distribution. The highest density of 22,500 plants per hectare was recorded in the 100-hectare plantation block of Nakti Creek, reinforcing its role as a crucial site for mangrove establishment and growth. In contrast, the lowest recruitment density was observed in the 50-hectare plantation block of Kantiyajal, with only 3,333 plants per hectare. This lower density might be linked to factors such as hydrodynamic variability, nutrient availability, or mainly grazing pressures of camels in the area of plantation.

The presence of younger mangroves in these plantation blocks plays a fundamental role in ecological stabilization. These juvenile trees contribute significantly to sediment trapping and soil stabilization, reducing coastal erosion and enhancing overall shoreline resilience. Moreover, their ability to capture and retain sediments ensures the maintenance of water quality in adjacent coastal ecosystems by filtering out pollutants and excess nutrients. The ongoing regeneration and recruitment processes in these areas indicate a promising trajectory for mangrove forest development, emphasizing the importance of conservation efforts and sustainable management practices (Fig.38).

8. Soil biomass carbon

Mangrove soils are regarded as some of the most important carbon sinks, with carbon storage surpassing the biomass present above ground. These ecosystems are among the most sophisticated systems for the capture and retention of carbon because of the vast deposits of organic-rich sediments that form and the slow decomposition of matter in their waterlogged, saline and anoxic soil. The capability of mangroves to accumulate and sequester carbon in their biomass and sediments categorizes them into significant 'blue carbon' ecosystems that help slow down climate change. The carbon stock in mangrove soils is subject to change due to the presence of some, or all, species of mangrove, the age of the forest, and many soil characteristics. Through the long term capture of atmospheric carbon, mangroves play an important role in global climate regulation.

8.1 Soil biomass carbon stock potential at Sat saida Bet mangrove site

This table 3 shows data regarding soil carbon stock from two sampling blocks at three different depths in a 20-hectare *Avicennia marina* mangrove plantation at Sat Saida Bet. The soil parameters which include total organic carbon (TOC), and bulk density were measured to assess the amount of carbon stocked in the soil. Results indicate that the carbon stock at a depth of 0-30 cm from the surface is about **29.63** (%) for the total area, which implies that the studied mangrove soils could be considered as an important carbon sink. The almost same values from different blocks and depths imply that soil conditions are relatively the same and carbon capture is efficient throughout the plantation which highlights the importance of the mangroves under climate change impact mitigation through blue carbon storage.

Table: 3 Soil Carbon stock in Sat Saida Bet mangrove plantation site- 20 ha (*A. marina*)

Sampling Blocks	**Depth (cm)**	**TOC (%)**	**Bulk Density (g/cm^3)**	**Carbon stock (%)**	**Carbon stock in 0-30 cm (%)**
SC-1	10	0.42	1.27	5.33	30.77
	20	0.39	1.18	9.20	
	30	0.41	1.32	16.24	
SC-2	10	0.33	1.33	4.39	28.48
	20	0.33	1.32	8.71	
	30	0.41	1.25	15.38	
Average Carbon Stock (%)					**29.63**

The table 4 provides specified measurements of soil carbon from four sampling blocks (SC-3, SC-4, SC-5, and SC-6) within a 200-hectare region, with samples taken from 10, 20, and 30 cm depth intervals. For each block and depth, values are given for Total Organic Carbon, Bulk Density, Carbon Stock (%), and the estimated Carbon Stock in the top 30 cm of soil (%). Results indicate that carbon stock accumulations show increases with depth and there are distinct differences among blocks: SC-3 and SC-6 have the highest carbon stocks per hectare while SC-5 has the lowest. Average carbon stock for all the blocks is 43.78 % which suggests that relatively moderate levels of soil carbon is stored on in this 200-hectare region. The fact that these are average values points to the explanation of the local soil and environmental conditions, as well as changes and management interventions sought via spatial planning within the area facilitated CO_2 soil sequestration.

Table: 4 Soil Carbon stock in Sat Saida Bet mangrove plantation site- 200 ha (*A. marina*)

Sampling Blocks	Depth (cm)	TOC (%)	Bulk Density (g/cm³)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
SC - 3	10	0.69	1.30	8.97	48.27
	20	0.74	1.27	18.80	
	30	0.56	1.22	20.50	
SC-4	10	0.56	1.25	7.00	44.37
	20	0.65	1.27	16.51	
	30	0.57	1.22	20.86	
SC-5	10	0.57	1.39	7.92	36.23
	20	0.50	1.35	13.50	
	30	0.35	1.41	14.81	
SC-6	10	0.65	1.33	8.65	46.15
	20	0.62	1.30	16.12	
	30	0.54	1.32	21.38	
Average Carbon Stock (%)					**43.78**

The values of soil carbon stock for 300 ha five sampling blocks (SC-7 to SC-11) at three different depths (10 cm, 20 cm, and 30 cm). Most blocks to the seem to have an increase in TOC percentage with an increase in depth, including with the carbon stock that is calculated. The values of bulk density remain fairly uniform with the exception of being between 1.18 and 1.35 g/cm³. Carbon stock over 30 cm differs between blocks with SC-11 having the highest value measured at 48.27 % and SC-7 having the lowest value at 28.31 %, measuring an average of 36.14 % across all blocks. This shows uneven distribution of carbon in soil which is important in determining the condition of the soil as well as its ability to retain carbon in the selected location (Table 5).

Table: 5 Soil Carbon stock in Sat Saida Bet mangrove plantation site- 300 ha (*A. marina*)

Sampling Blocks	Depth (cm)	TOC (%)	Bulk Density (g/cm³)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
SC-7	10	0.24	1.32	3.17	28.31
	20	0.39	1.28	9.98	
	30	0.38	1.33	15.16	

SC-8	10	0.41	1.27	5.21	31.48
	20	0.45	1.32	11.88	
	30	0.39	1.23	14.39	
SC-9	10	0.51	1.18	6.02	37.39
	20	0.47	1.30	12.22	
	30	0.48	1.33	19.15	
SC-10	10	0.38	1.35	5.13	35.28
	20	0.44	1.25	11.00	
	30	0.48	1.33	19.15	
SC-11	10	0.50	1.28	6.40	48.27
	20	0.60	1.33	15.96	
	30	0.68	1.27	25.91	
Average Carbon Stock (%)					**36.14**

The table 6 showed soil carbon stock data 330ha for four sampling blocks (SC-12 to SC-15) with three depth increments (10 cm, 20 cm, and 30 cm). The mean carbon stock for all blocks stands at 57.54 %. These significant levels of stored carbon illustrate how important these soils are for carbon sequestration, especially in mitigating climate change through the storage of atmospheric carbon in soil. The differences among blocks and depths also suggest different inputs of organic matter, soil practices, or other environmental parameters which highlight the need for more targeted soil carbon management plans for specific locations.

Table: 6 Soil Carbon stock in Sat Saida Bet mangrove plantation site- 330 ha (*A. marina*)

Sampling Blocks	**Depth (cm)**	**TOC (%)**	**Bulk Density (g/cm³)**	**Carbon stock (%)**	**Carbon stock in 0-30 cm (%)**
SC-12	10	0.44	1.28	5.63	48.87
	20	0.68	1.30	17.68	
	30	0.71	1.20	25.56	
SC-13	10	0.79	1.25	9.88	56.55
	20	0.75	1.20	18.00	
	30	0.81	1.18	28.67	
SC-14	10	0.84	1.39	11.68	82.59
	20	1.11	1.37	30.41	
	30	1.08	1.25	40.50	
SC-15	10	0.50	1.25	6.25	42.16
	20	0.50	1.28	12.80	

	30	0.60	1.27	22.86	
Average Carbon Stock (%)					**57.54**

The data displays soil carbon stock quantifications for 50 Ha from two sampling blocks (SC-16 and SC-17) at three distinct depths: 10 cm, 20 cm, and 30 cm. It describes total organic carbon (TOC) percentage, bulk density, and the carbon stock values calculated for each depth. From all samples taken, average carbon stock is calculated to be 50.02 % for the top 30 cm of soil. This indicates a moderate to high amount of soil carbon storage which improves soil fertility, structure, and helps mitigate climate change. These results capture the need of careful soil management to bolster soil carbon stocks considered vital for agricultural and environmental sustainability (Table. 7).

Table: 7 Soil Carbon stock in Sat Saida Bet mangrove plantation site- 50 ha (*A. marina*)

Sampling Blocks	Depth (cm)	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
SC-16	10	0.72	1.32	9.50	40.2
	20	0.56	1.28	14.34	
	30	0.41	1.33	16.36	
SC-17	10	0.60	1.27	7.62	59.85
	20	0.75	1.22	18.30	
	30	0.87	1.30	33.93	
Average Carbon Stock (%)					**50.02**

An assessment of the carbon stocks on soil in the Sat Saida Bet mangrove plantation (100 ha, dominated by *Avicennia marina*) shows considerable carbon sequestration potential over three sampled blocks (SC-18, SC-19, SC-20) at 10, 20, and 30 cm depths. Soil up to30 cm in depth has an average carbon stock of 40.31 % and individual block values range from 29.88 to 46.04 %. Especially, TOC (%) in the bulk of samples increase with depth which indicates that major carbon accumulation happens across the entire soil profile. In any case, the high bulk density values also spatially imply carbon storage capacity, thus superposing the observation. In any case, the findings of the study demonstrate the importance of mangroves in enhancing soil carbon stocks and combating climate change through blue carbon sequestration. (Table. 8).

Table: 8 Soil Carbon stock in Sat Saida Bet mangrove plantation site- 100 ha (*A. marina*)

Sampling Blocks	Depth (cm)	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
SC-18	10	0.35	1.35	4.73	29.88
	20	0.44	1.33	11.70	
	30	0.38	1.18	13.45	
SC-19	10	0.50	1.18	5.90	45.01
	20	0.56	1.30	14.56	
	30	0.62	1.32	24.55	
SC-20	10	0.53	1.32	7.00	46.04
	20	0.63	1.23	15.50	
	30	0.59	1.33	23.54	
Average Carbon Stock (%)					**40.31**

The mean carbon stock value from different sized plantations at the Sat Saida Bet mangrove site was 42.90 % at 30 cm depth with a range of 29.63 % - 57.54 % proportional to plantation area which is shown in Table 9. This difference is most likely attributed to the age of the plantations, species composition, site conditions and the management practices which are all known to influence the rate of carbon accumulation in mangrove ecosystems. Mangroves have an international reputation for their capability to store carbon in the soil and above it, and therefore play an important role in fighting climate change because they sequester huge amount of carbon and store it over long periods of time. This average figure can be used as a starting point to track carbon shifts at the site, and adds to the reasoning for conserving and managing mangrove ecosystems in the region for natural carbon emission mitigation.

Table 9 Average Carbon Stock at Sat saida Bet mangrove site

Plantation (ha)	Avg. Carbon stock 0-30 cm depth (%)
20	29.63
200	43.78
300	36.14
330	57.54
50	50.02
100	40.31
Avg.	**42.90**

8.2 Soil biomass carbon stock potential at Nakti creek mangrove site

The soil carbon stock at the Nakti creek mangrove plantation site (50 ha), dominated by *Avicennia marina* was analyzed through two sampling blocks (TC-1 and TC-2) at depths of 10 cm, 20 cm, and 30 cm. For TC-1, the carbon stock increased with depth: 12.01 % (10 cm), 18.80 % (20 cm), and 32.87 % (30 cm), totalling 63.68 (%). Similarly, TC-2 showed stocks of 9.44 % (10 cm), 17.27 % (20 cm), and 45.24 % (30 cm), totalling 71.95 (%). The average carbon stock across both blocks was 67.82 (%), for the entire 50-hectare site (Table 10).

Table: 10 Soil Carbon stock in Nakti creek mangrove plantation site- 50 ha (*A. marina*)

Sampling Blocks	Depth (cm)	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
TC-1	10	0.78	1.54	12.01	63.68
	20	0.74	1.27	18.80	
	30	0.83	1.32	32.87	
TC-2	10	0.71	1.33	9.44	71.95
	20	0.68	1.27	17.27	
	30	1.16	1.30	45.24	
Average Carbon Stock (%)					**67.82**

The present's data on soil carbon stock from different sampling blocks in a 100-hectare mangrove plantation with *Avicennia marina, Rhizophora mucronata*, and *Ceriops tagal* species. It includes total organic carbon (TOC) percentage, bulk density. TOC at three depths (10, 20, 30 cm) for each block alongside their respective carbon stock, leading up to carbon stock per hectare within 30 cm of soil, which was estimated. The results indicate variability among blocks, with TC-4 yielding the highest carbon stock at 77.64 % and TC-6 yielding the lowest at 45.1 %. Overall, the mean carbon stock across blocks stood at 57.8 %. This demonstrates the capacity of mangrove soils in relation to carbon sequestration and emphasizes the importance of the contribution of these ecosystems in climate change mitigation (Table 11).

Table: 11 Soil Carbon stock in Nakti creek mangrove plantation site- 100 ha (*A. marina, R. mucronata, C. tagal*)

Sampling Blocks	Depth (cm)	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
TC-3	10	0.3	1.18	3.54	56.14
	20	0.93	1.23	22.88	
	30	0.78	1.27	29.72	
TC-4	10	1.01	1.25	12.63	77.64
	20	0.98	1.30	25.48	
	30	1.08	1.22	39.53	
TC-5	10	0.75	1.18	8.85	61.3
	20	0.72	1.25	18.00	
	30	0.87	1.32	34.45	
TC-6	10	0.38	1.32	5.02	45.1
	20	0.69	1.30	17.94	
	30	0.60	1.23	22.14	
TC-7	10	0.62	1.37	8.49	49.59
	20	0.59	1.32	15.58	
	30	0.63	1.35	25.52	
Average Carbon Stock (%)					**57.8**

The mean carbon stock at Nakti creek site is calculated by taking the percentage of 30 cm depth on the soil and comparing it to the two sizes of plantations (50 ha and 100 ha) and mangrove carbon reserve. It indicates that the 50-hectares carbon reserve plantation has a higher average Carbon stock (67.82 %) compared to 100-hectare plantation's (57.8 %), with an overall average of 62.81 % .This implies that the smaller plantations at this site store more carbon per unit area than the larger ones which can be attributed to differences in age or management practices. The study demonstrates the need for such data to optimize understanding of mangrove carbon capture (Table 12).

Table 12 Average Carbon Stock at Nakti creek mangrove site

Plantation (ha)	Avg. Carbon stock 0-30 cm depth (%)
50	67.82
100	57.8
Avg.	**62.81**

8.3 Soil biomass carbon stock potential at Kantiyajal mangrove site

The Kantiyajal mangrove plantation site (150 ha of *Avicennia marina*) exhibited considerable variation of soil carbon stock within its two sampling blocks. Block KC-1 tended to have average carbon stocks of 39.91 (%) and was gradually increasing in contribution with depth to: 5.62% (10cm), 12.51% (20cm), and 21.78% (30cm) whereas KC-2 demonstrated greater sequestration at 63.78 (%) due to deeper-layer storage (7.58% at 10cm, 18.35% at 20cm, and 37.85% at 30cm). This variability demonstrates greater carbon density of KC-2 (bulk density 1.43-1.45 g/cm^3; KC-1 1.37-1.39 g/cm^3) which is likely due to accumulation of organic matter in mangrove sediments (Table 13). The average carbon stock of the *A. marina* plantation was 51.85 (%) (150ha).

Table: 13 Soil Carbon stock in Kantiyajal mangrove plantation site- 150 ha (*A.marina*)

Sampling Blocks	Depth cm	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
KC-1	10	0.41	1.37	5.62	39.91
	20	0.45	1.39	12.51	
	30	0.53	1.37	21.78	
KC-2	10	0.53	1.43	7.58	63.78
	20	0.66	1.39	18.35	

	30	0.87	1.45	37.85	
Average Carbon Stock (%)					**51.85**

The soil carbon stock at the Kantiyajal mangrove plantation site (150 ha), dominated by *Avicennia marina* and *Rhizophora mucronata*, was analyzed through two sampling blocks (KC-3 and KC-4) at depths of 10 cm, 20 cm, and 30 cm. For KC-3, the carbon stock increased with depth: 3.99% (10 cm), 10.01% (20 cm), and 18.23% (30 cm), totalling 32.23 (%). Similarly, KC-4 showed stocks of 6.03% (10 cm), 13.44% (20 cm), and 16.07% (30 cm), totalling 35.54 (%). The average carbon stock across both blocks was 33.88 (%), for the entire 150-hectare site (Table 14).

Table: 14 Soil Carbon stock in Kantiyajal mangrove plantation site- 150 ha (*A. marina* and *R. mucronata*)

Sampling Blocks	Depth cm	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
KC-3	10	0.30	1.33	3.99	32.23
	20	0.35	1.43	10.01	
	30	0.45	1.35	18.23	
KC-4	10	0.44	1.37	6.03	35.54
	20	0.47	1.43	13.44	
	30	0.38	1.41	16.07	
Average Carbon Stock (%)					**33.88**

The soil carbon stock assessment in the 50-hectare Kantiyajal mangrove plantation site dominated by *Avicennia marina* reveals notable variation across sampling blocks and soil depths. In block KC-5, soil carbon stock values increased with depth, from 3.53 % at 10 cm; 9.57% at 20 cm and 23.37 % at 30 cm, indicating substantial carbon accumulation in deeper layers. Similarly, KC-6 showed a rise from 1.89% at 10 cm; 7.23 at 20 cm and 13.97% at 30 cm. The average soil carbon stock across the site was 29.78 (%) (Table 15).

Table: 15 Soil Carbon stock in Kantiyajal mangrove plantation site- 50 ha (*A. marina*)

Sampling Blocks	Depth cm	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
KC-5	10	0.24	1.47	3.53	36.47
	20	0.33	1.45	9.57	
	30	0.53	1.47	23.37	
KC-6	10	0.14	1.35	1.89	23.09
	20	0.26	1.39	7.23	
	30	0.35	1.33	13.97	
Average Carbon Stock (%)					**29.78**

The soil carbon stock at the Kantiyajal mangrove plantation site (100 ha), dominated by *Avicennia marina*, was analyzed through two sampling blocks (KC-7 and KC-8) at depths of 10 cm, 20 cm, and 30 cm. For KC-7, the carbon stock increased with depth: 7.15% (10 cm), 15.85% (20 cm), and 25.89% (30 cm), totalling 48.89 (%). Similarly, KC-8 showed stocks of 3.72% (10 cm), 11.02% (20 cm), and 24.36% (30 cm), totalling 39.1(%). The average carbon stock across both blocks was 43.99(%), for the entire 150-hectare site (Table 16).

Table: 16 Soil Carbon stock in Kantiyajal mangrove plantation site- 100 ha (50 ha and 50 ha) (*A. marina*)

Sampling Blocks	Depth cm	TOC (%)	Bulk Density (g/cm^3)	Carbon stock (%)	Carbon stock in 0-30 cm (%)
KC-7	10	0.50	1.43	7.15	48.89
	20	0.57	1.39	15.85	
	30	0.63	1.37	25.89	
KC-8	10	0.26	1.43	3.72	39.1
	20	0.38	1.45	11.02	
	30	0.56	1.45	24.36	
Average Carbon Stock (%)					**43.99**

The soil carbon stock at the Kantiyajal mangrove plantation site reflects the critical role of mangroves in carbon sequestration, with the average carbon stock at 30 cm depth (%) across different plantation areas (totalling 450 hectares) calculated to be 39.87%, based on observed values of 51.85%, 33.88%, 29.78%, and 43.99% for individual plots. This substantial soil organic carbon pool highlights the effectiveness of mangrove plantations in trapping and storing carbon, as mangrove soils are known to accumulate and retain carbon due to their ability to trap sediments and maintain anaerobic conditions that slow decomposition processes (Table 17).

Table.17 Average Carbon Stock at Kantiyajal mangrove site

Plantation (ha)	Avg. Carbon stock 0-30 cm depth (%)
150	51.85
150	33.88
50	29.78
100 (50 +50)	43.99
Avg.	**39.87**

9. Details of carbon Sequestration at the plantation sites

Each block randomly selected 10 trees that were >7 cm dbh and in good health plants. The allometric equations pertaining to *A. marina* (Vikarant et al., 2013) were used in estimating above ground biomass (AGB), below ground biomass (BGB), and tree biomass. The total tree biomass carbon was then converted into CO2 equivalent by multiplying it with a factor of 3.67 (Kauffman and Donato, 2012; Kathiresan et al., 2021). The data from 2025 from across Sat Saida Bet, Nakti Creek and Kantiyajal shows that there is a notable difference in biomass and carbon values across different hectare (HA). Sat Saida Bet tends to show greater tree biomass and carbon values as well as in larger plots like 330 HA, with CO_2 equivalents peaking at 6042.32 Mg C ha^{-1}, indicating greater carbon sequestration potential than the rest of the regions, while Nakti Creek has moderate biomass and carbon storage. Despite Nakti Creek showing the 100 HA plot having a quite high tree biomass and carbon value of 1887.81 Mg C ha^{-1}. Kantiyajal does has some blocks with high tree biomass like to 50 HA at 2849.60 Mg C ha^{-1}, but they still have lower carbon values because it makes the area appear to contain less dense or younger vegetation (Table 17).

This finding confirms once more the spatial differences in carbon sequestration capacity across these sites and emphasizes area size and specific local ecological conditions as prime determinants of carbon storage potential in mangrove and coastal ecosystems.

Table. 17 Details of Carbon Sequestration at 1600ha mangrove plantation site

Sat Saida Bet during 2025					
Hectare (HA)	**Above Ground Biomass**	**Below Ground Biomass**	**Tree Biomass**	**Carbon values (Mg C ha^{-1})**	**CO_2 equivalent**
20 HA	3.83	2.63	6.61	3875.96	24.25
200 HA	4.99	3.30	8.50	5053.82	31.21
300 Ha	6.07	3.89	10.23	5301.18	37.54
330 Ha	4.32	2.92	7.41	6042.32	37.54
50 Ha	5.16	3.39	8.77	2849.60	27.21
100 Ha	2.88	2.06	5.04	1138.56	32.17
Average	**4.54**	**3.03**	**7.76**	**4043.57**	**31.65**
Nakti creek during 2025					
50	3.16	2.23	5.50	2904.33	20.18
100	5.66	3.67	9.57	1887.81	35.13
Average	**4.41**	**2.95**	**7.535**	**2396.07**	**27.66**
Kantiyajal during 2025					
150	3.56	2.47	6.17	1335.92	22.64
50	6.07	3.89	10.23	3627.13	37.54
100(50-2)	2.27	1.68	4.01	799.75	14.73
Average	**3.97**	**2.68**	**6.80**	**1,920.93**	**24.97**

10. Phyto-sociological observation

Halophytes are an example of a specialized plant that can live in areas with high salinity. They can be divided into three categories based on their growth conditions: obligate halophytes, which depend entirely on a saline environment; facultative halophytes which can exist in both saline non-saline environments; and habitat indifferent halophytes which have some degree of preference for their environment. In the course of the comprehensive survey, we identified four prominent species of halophytes within the designated DPA mangrove plantation sites. These were: *Salicornia brachiata, Aeluropus lagopoides, Salvadora persica,* and *Sesuvium portulacastrum*. At the plantation site, we recorded an interesting form of relationship between halophyte species and mangrove associated plants. Numerous halophyte associated species recorded for the first time during the field trips began the quest to understanding these intricate ecosystems. Also observed were mudskippers, bivalves, crabs, gastropods and many fish that contribute to the ever changing ecological relationships at the plantation sites. This abundance of both plant life and animal life is why we believe that halophytes are important for the condition of the entire ecosystem along the coast. The working commingling of halophytes and mangrove associated ecosystems forms a zone of high productivity and biodiversity.

The roots of mangrove trees house many microorganisms that aid plants in osmoregulation and dealing with both heat and salt stress. The vegetation and fauna flora of such ecosystems enables nutrient cycling to occur and supports higher trophic levels in the biological community. It also helps in the conservation of natural diversity and the stability of the environment. Furthermore, halophytes boost soil structure by capturing salts and favourable rhizobacteria, which contribute to the salt tolerance of supplementary flora. Taking care of and acclimatizing coastal areas that are abundant in these halophytes is important for the ecological sustainability of fish resources, protection of coastal zone against natural calamities, and climate mitigation through efficient carbon sequestration (Plate 14).

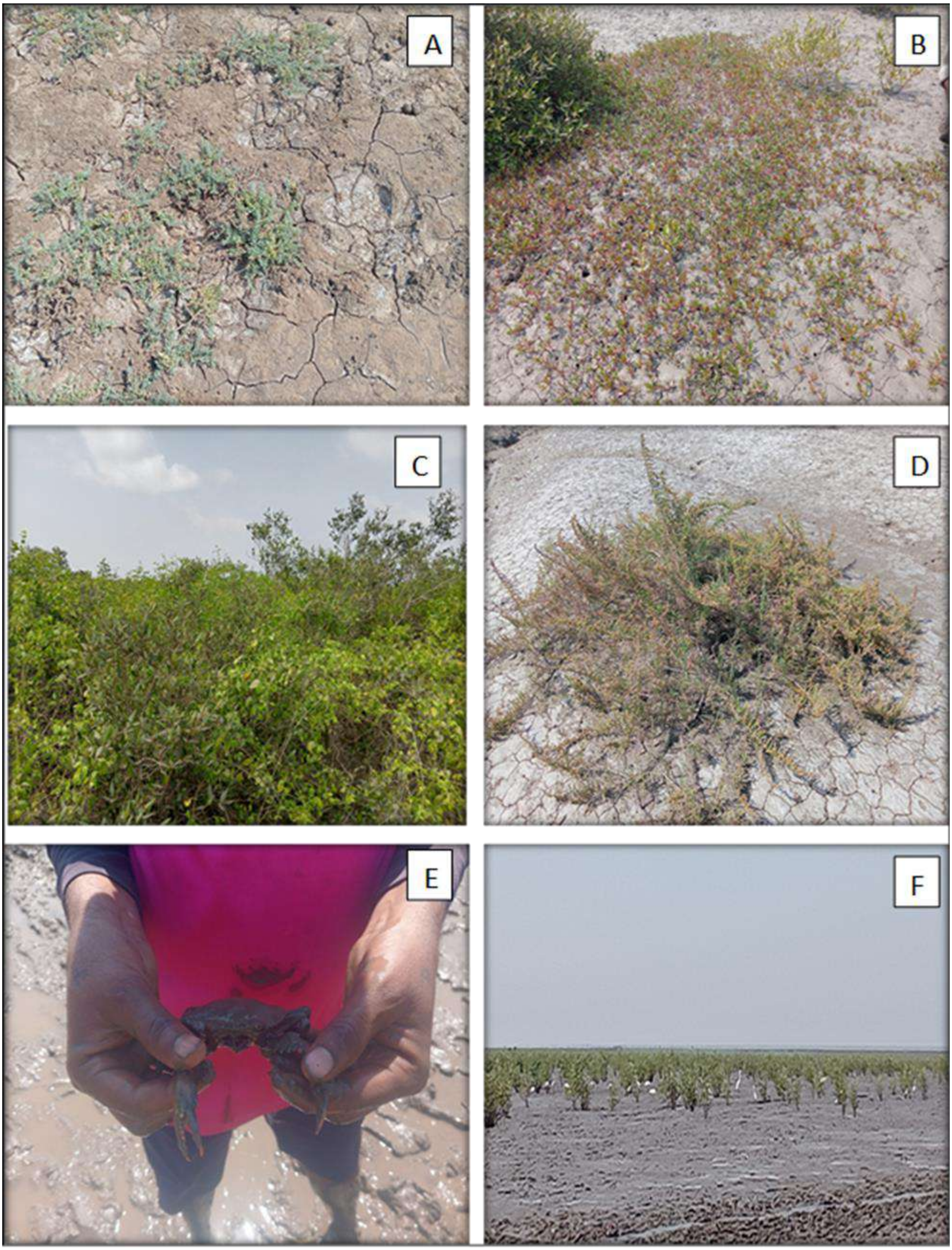

Plate 14. Mangrove associated Halophytes and fauna diversity in plantation site during a visit in 2025

[A-*Sueda* sp.; B- *Sesuvium* sp; C- *Salvadora* sp; D- *Salicornia* sp; E- Crab; F-Birds]

11. Field observation of threats for Mangroves

Plate 15 captures a coastal mudflat environment where the existing threats stress on the mangrove is most clear during the filed trip in 2025. The aforementioned plant's aerial roots suggests that this more or less eroded and unstable mangrove was subjected to tidal forces or soil erosion. The second and third image depicts dry mangrove vegetation which is indicative of an either experiencing salinity stress coupled with water logging or some unpleasant conditions that inhibit the development of a mangrove. The fourth image shows a grazing camel in what can be described as an all around difficult area of observing and holding sustained environmental control, capturing the extra attention on the stress mangroves experience in this region. Cumulatively, these evidences unveils the relative intense environmental load on mangroves like erosion, alternating human and animal interaction, salinity levels above normal and scarcity of water which deepens their fragility and lowered resilience in this habitat.

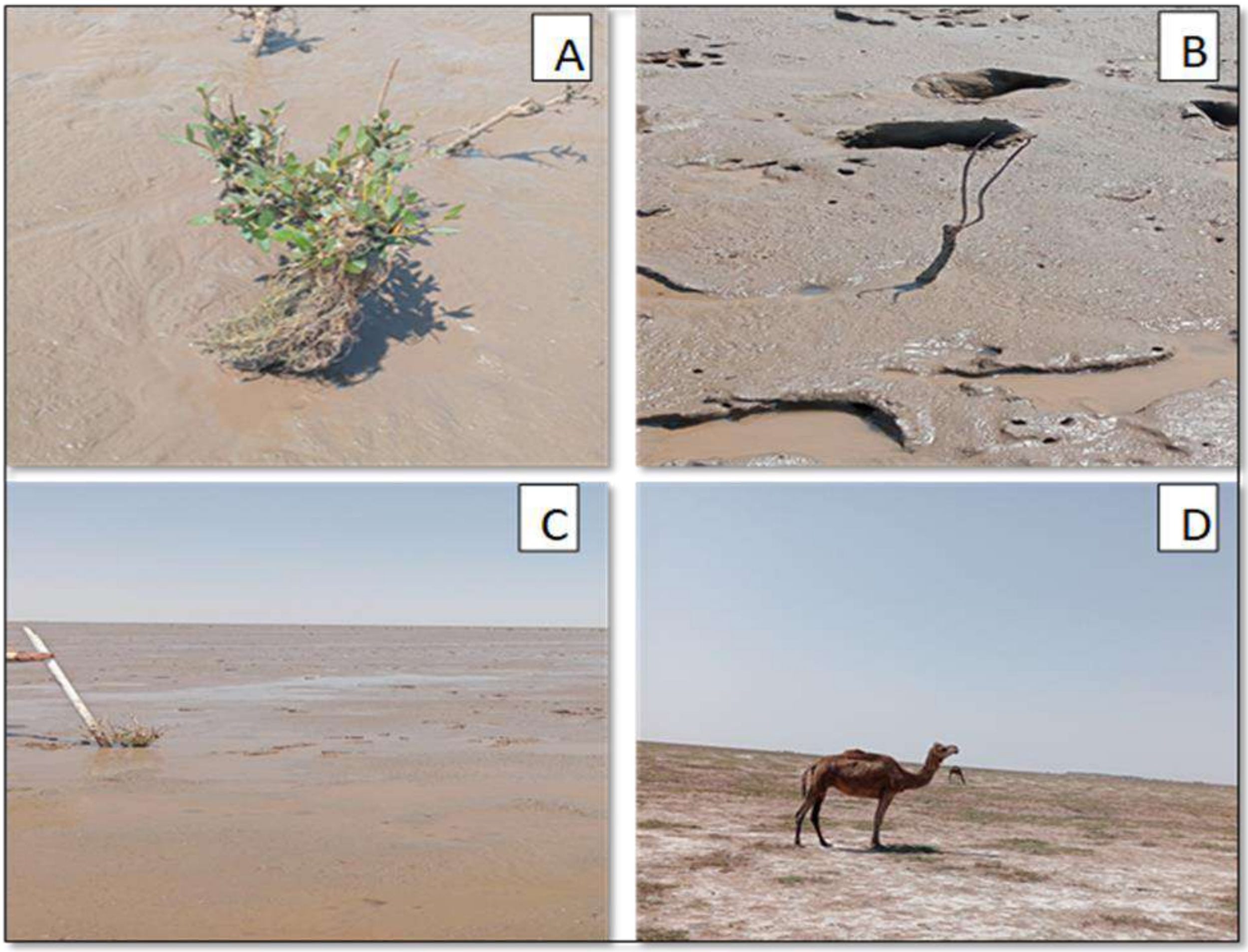

Plate 15. Mangrove Stress factors observed in plantation site during a visit in 2025.

[A-Fishing net; B- Animal foot; C- Sediment deposit; D-Camel grazing]

12. Summary and Discussion

The mangrove monitoring was conducted at sites located in Sat Saida Bet and Nakti Creek (near to Tuna village) in Kandla district as well sites located nearby Kantiyajal, Bharuch district. The sampling occurred at six plantation blocks in Sat Saida Bet, two in Nakti Creek, and five in Kantiyajal for monitoring the mangrove plantations developed over an area of total 1600 ha from 2005 to 2021. The primary objectives of this study included determination of the density and abundance of planted mangroves to estimate the carbon sequestration potential, understanding ecological concerns about the success of the plantation, and recommending appropriate conservation strategies. The sampling points are selected only where the mangroves are present inside the plantation blocks. Extensive field studies performed from February to May of 2025 revealed marked differences in the density and height growth of mangroves over the various sites. Most remarkably, carbon sequestration was the highest at Sat Saida Bet (up to 4043 Mg C ha^{-1}) while Nakti Creek exhibited the greatest concentration of carbon stock in topsoil, averaging 62.81% carbon stock. The monitoring show significant variation in mangrove density and tree height among the sites. At Sat Saida Bet, mangrove density was between 100 to 4000 individuals per hectare and the tree height was between 70 to 240 cm. Nakti Creek reported densities of 400–1,600 individuals per hectare and tree heights of 100–170 cm, while Kantiyajal showed densities of 500–1,600 individuals per hectare and tree heights of 70–140 cm. However, it should be noted that major area of Kantiyajal is empty and under various stresses on mangroves such as grazing pressure by camel, cattle etc.

Soil analysis revealed average carbon stock values (0-30 cm depth) between 39.87% and 62.81%, with Nakti Creek recording the highest percentage. However, Sat Saida Bet demonstrated the highest carbon values overall ranging from 1,920.93 to 4,043.5 Mg C ha^{-1} and also led in CO_2 equivalent values at 31.65, compared to 27.66 at Nakti Creek and 24.97 at Kantiyajal. This study looked at the importance of mangrove ecosystems as blue carbon sinks which absorb carbon dioxide more effectively. Their multifunctional roles provide coastal protection, serve as habitats for various species, sustain fisheries and tourism, aid in climate change mitigation all at the same time. They demonstrate the impact of unsustainable practices as well as habitat destruction. In turn, this creates a need for ongoing restoration and conservation efforts. This report recommends targeted multi-species planting and natural regeneration to improve sparse patches while active long-term management strengthens resilience to ensure sustainability for these ecosystems.

Globally, mangrove rehabilitation and restoration is regarded as one of the most effective management strategies for lost or damaged mangrove forests. Many biotic and abiotic factors such as predation, seed recruitment, soil quality, colonization rates, salinity, and temperature can hamper the overall plantation during various stages of planting. Rather, mangrove restoration projects tend to set specific criteria for success.

In the port development of DPA, we notice an effort that integrates port activity with environmental protection. The monitoring results offered invaluable information with regard to the restoration of mangroves and their relation to climate change, biodiversity as well as human health. The project illustrates the necessity of strategic investment in the conservation of mangroves which aids climate change and coast protective efforts, thereby setting an ecological benchmark in port management. As a source of blue carbon, defenders of coasts and regions abundant in biodiversity, the project highlighted the ecological and economic value of mangroves. Despite the ecological and economic value, the mangroves are still facing threats of habitat loss and unregulated resource extraction, particularly in Kantiyajal site, where the main stress factor on mangrove plantation is camel grazing which is observed. In order to enhance the resilience and sustainability of the critical ecosystems within the port limits, the report recommends of sparse patches with natural regeneration and gap filling as well as constant maintenance. With this, the site selection for mangrove plantation should be done after a scientific and social study of the location.

13. Recommendations in terms of future prospects

On the basis of this study, following recommendations are suggested for current and future plantation activities. This study clearly identified that a few blocks of plantations within Sat-Saida Bet was more promising than other locations for further mangrove plantation efforts. These areas have demonstrated the suitability for expansion of mangroves. Moreover, the availability of space allows for gap-filling, which can further enhance the overall mangrove coverage. To ensure the development of the planted mangroves into a mature and thriving ecosystem, several conservation measures are recommended.

- Appropriate site selection: Identifying suitable locations for mangrove plantations is essential for their survival and growth. Factors such as soil composition, tidal influence, and existing ecological conditions must be thoroughly assessed before selecting a site.

- Monitoring to prevent camel grazing: Continuous monitoring of existing mangrove plantations is necessary to mitigate human activities that may disrupt growth. Grazing by camel is one of main stress in the plantation area at Kantiyajal, which can cause severe damage to young mangrove plants. Implementing protective barriers, enforcing regulations, and engaging local communities in conservation efforts may help safeguard these ecosystems. Or it will better to find different area for further plantations.
- Field observation and high-resolution mapping: The use of both ground-based surveys and advanced mapping techniques is necessary for effective mangrove monitoring, conservation, and management. Field observations provide real-time insights into plant health, while high-resolution mapping helps track vegetation changes over time and detect areas requiring intervention.
- Site-specific plantation techniques: Different mangrove species thrive in varying environmental conditions. Therefore, plantation techniques must be carefully adapted to match the specific hydrogeological features of each site. This includes selecting appropriate planting depths, spacing, and protective measures to prevent high mortality rates among mangrove seedlings.
- Ensuring tidal flushing and inundation: Mangroves rely on a dynamic water exchange system for nutrients and sediment deposition. Regular tidal flushing and controlled inundation must be maintained to sustain optimal soil salinity levels, support biodiversity, and promote natural regeneration. Proper hydrological management will further strengthen the mangrove ecosystem over time.
- Utilizing local seed sources for mangrove plantation: Selecting seed sources from the nearest available areas ensures genetic compatibility with the local environment. This approach accelerates adaptation to site-specific conditions, and strengthens the resilience of the mangrove species.
- Prioritizing restoration over new plantation sites: Instead of creating entirely new plantation sites, efforts should focus on restoring existing mangrove areas that have suffered degradation.
- Preserving natural tidal hydrology and seed dispersal: Mangroves rely on tidal movements for oxygen exchange, sediment deposition, and nutrient supply.

Maintaining the natural water-borne dispersal of seeds helps facilitate regeneration and promotes species diversity.

- Awareness and outreach programs for DPA staff: Strengthening conservation efforts requires active participation from local authorities, environmental organizations, and the general public. Awareness campaigns, training workshops, and stakeholder engagement activities will help develop a collective understanding of mangrove protection. Educating DPA staff and involving communities will encourage responsible stewardship.
- Promoting multispecies plantation for greater ecological benefits: Planting multiple mangrove species fosters biodiversity and enhances ecosystem resilience. A multispecies approach improves the adaptability of the plantation, ensuring long-term sustainability and ecological balance.
- Identification 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.
- Community-based management: Engaging local communities, particularly fishermen can significantly enhance mangrove plantations. Fishermen can be key participants in community-based restoration and conservation.

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Gujarat Institute
Of Desert Ecology

Annexure -B

Environmental Monitoring Report (EMR)

prepared under

"Preparing and monitoring of environmental monitoring and management plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years"

(Monitoring Period: August - September 2025)

Document Ref No.: GEMI/DPA/782(2)(6)/2025/50

Submitted to:

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Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

GEMI Bhavan, 246-247, GIDC Electronic Estate, Sector-25, Gandhinagar-382025

"AN ISO 9001:2015, ISO 14001:2015 AND ISO 45001:2018 Certified Institute"

Certificate

This is to certify that the Monthly Environment Monitoring Report (EMR) for the period 15^{th} August to 14^{th} September 2025 for the work entitled, **"Preparing and Monitoring of Environmental Monitoring and Management Plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years"** has been prepared in line with the work order no. **EG/WK/EMC/1023/2011/iii/239** dated 15/02/2023 allotted by Deendayal Port Authority.

The report has been delivered as per the terms and conditions of the work order Sr. No. 4(2).

S. S. O. & Lab Head

Authorized Signatory

About this Document

Gujarat Environment Management Institute (GEMI) has been assigned with the work of "Preparing and monitoring of Environmental monitoring and Management plan for Deendayal Port Authority (DPA) at Kandla and Vadinar for a period of 3 years" by DPA, Kandla. Under the said project the report titled *"Environment Monitoring Report (August – September 2025)"* is prepared.

- **Name of the Report:** *Environment Monitoring Report (August-September 2025)*
- **Date of Issue:** 12/11/2025
- **Version:** 1.0
- **Report Ref.:** GEMI/DPA/782(2)(6)/2025/50

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List of Abbreviations

A	Acceptable Limits as per IS: 10500:2012
AAQ	Ambient Air Quality
AWS	Automatic Weather monitoring stations
BIS	Bureau of Indian Standards
BOD	Biochemical Oxygen Demand
BQL	Below Quantification Limit
CCA	Consolidated Consent & Authorization
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DO	Dissolved Oxygen
DPA	Deendayal Port Authority
EC	Electrical Conductivity
EMMP	Environmental monitoring and Management Plan
EMP	Environment Management Plan
FPS	Fine Particulate Sampler
FY	Financial Year
GEMI	Gujarat Environment Management Institute
IFFCO	Indian Farmers Fertiliser Cooperative Limited
IMD	India Meteorological Department
IOCL	Indian Oil Corporation Limited
LNG	Liquefied Natural Gas
MGO	Marine Gas Oil
MMTPA	Million Metric Tonnes Per Annum
MoEF	Ministry of Environment & Forests
MoEF&CC	Ministry of Environment, Forest and Climate Change
NAAQS	National Ambient Air Quality Standards
NO_x	Nitrogen oxides
NTU	Nephelometric Turbidity Unit
OOT	Off Shore Oil Terminal
OSR	Oil Spill Response
P	Permissible Limits as per IS: 10500:2012
PAH	Poly Aromatic Hydrocarbons
PM	Particulate Matter
PTFE	Polytetrafluoroethylene
RCC	Reinforced Concrete Cement
RDS	Respirable Dust Sampler
SAR	Sodium Adsorption Ratio
SBM	Single Bouy Mooring
SO_x	Sulfur oxides
STP	Sewage Treatment Plant
TC	Total Coliforms
TDS	Total Dissolved Solids
TOC	Total organic Carbon
TSS	Total Suspended Solids
VOC	Volatile Organic Compounds

CHAPTER 1: INTRODUCTION

1.1 Introduction

Kandla Port, also known as the Deendayal Port is a seaport in Kachchh District near the city of Gandhidham in Gujarat state in western India. Located on the Gulf of Kachchh, it is one of major ports on the western coast, and is located at 256 nautical miles southeast 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. Deendayal Port's journey began in 1931 with the construction of RCC Jetty by Maharao Khengarji. Kandla was constructed in the 1950s as the chief seaport serving western India, after the independence of India. On 31st March 2016, Deendayal Port created history by handling 100 MMT cargo in a year and became the first Major Port to achieve this milestone. Deendayal Port Authority (DPA), India's busiest major port in recent years, is gearing up to add substantial cargo handling capacity with private sector participation. DPA has created new record by handling 137 MMTPA (at Kandla and Vadinar) during the financial year 2022-23. The DPA 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, with a capacity of 54 MMTPA. Further, significant Quantum of infrastructural upgradation has been carried out & excellent maritime infrastructure has been created at Vadinar for the 32 MMTPA Essar Oil Refinery in Jamnagar District.

1.2 Green Ports Initiative

DPA 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 equipment required for monitoring environmental pollution, acquiring dust suppression system, setting up of sewage/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.

DPA had also appointed GEMI as an Advisor for "Making Deendayal Port a Green Port-Intended Sustainable Development under the Green Port Initiatives. DPA 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 DPA. The plantation is being carried out by the Social Forestry division of Kachchh.

1.3 Importance of EMP

Port activities can cause deterioration of air and marine water quality in the surrounding areas due to multifarious activities. The pollution problems usually caused by port and harbour activities can be categorized as follows:

1. Air pollutant emissions due to ship emissions, loading and unloading activities, construction emission and emissions due to vehicular movement.
2. Coastal habitats may be destroyed and navigational channels silted due to causeway construction and land reclamation.
3. Deterioration of surface water quality may occur during both the construction and operation phases.
4. Harbour operations may produce sewage, bilge wastes, solid waste and leakage of harmful materials both from shore and ships.
5. Human and fish health may be affected by contamination of coastal water due to urban effluent discharge.
6. Oil pollution is one of the major environmental hazards resulting from port/harbour and shipping operations. This includes bilge oil released from commercial ships handling non-oil cargo as well as the more common threat from oil tankers.
7. Unregulated mariculture activities in the port and harbour areas may threaten navigation safety.sd

Hence, for the determination of levels of pollution, identification of pollution sources, control and disposal of waste from various point and non-point sources and for prediction of pollution levels for future, regular monitoring and assessment are required during the entire construction and operation phase of a major port. As per the Ministry of Environment, Forest and Climate Change **(MoEF&CC)**, The Environmental Management Plan (EMP) is required to ensure sustainable development in the area surrounding the project. Hence, it needs to be an all encompasses plan consist of all mitigation measures for each item wise activity to be undertaken during the construction, operation and the entire life cycle to minimize adverse environmental impacts resulting from the activities of the project. for formulation, implementation and monitoring of environmental protection measures during and after commissioning of projects. The plan should indicate the details of various measures are taken and proposed to be taken for appropriate management of the environment of Deendayal Port Authority.

It identifies the principles, approach, procedures and methods that will be used to control and minimize the environmental and social impacts of operational activities associated with the port. An EMP is a required part of environmental impact assessment of a new port project but could also be evolved for existing ports. It is useful not only during the construction and operational phases of the new port but also for operation of existing ports to ensure the effectiveness of the mitigation measures implemented and to further provide guidance as to the most appropriate way of dealing with any unforeseen impacts.

It is extremely essential that port and harbour projects should have an Environmental Monitoring and Management Plan (EMMP), which incorporates monitoring of Ambient Air, Drinking Water, Noise, Soil, Marine (water, sediment, ecology) quality along with the collection of online meteorological data throughout the duration of the project.

To ensure the effective implementation of the EMP and weigh the efficiency of the mitigation measures, it is essential to undertake environmental monitoring both during construction and operation period. In view of the above, Gujarat Environment Management Institute (GEMI) has been awarded with the work "**Preparing and Monitoring of Environmental Monitoring and Management Plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years**" vide letter No. EG/WK/EMC/1023/2011/III/239 dated: 15/02/2023 by DPA.

This document presents the Environmental Monitoring Report (EMR) for Kandla and Vadinar for the environmental monitoring done during the period from 16th August -15th September 2025.

1.4 Objectives and scope of the Study

In line with the work order, the key objective of the study is to carry out the Environmental Monitoring and preparation the Management Plan for Kandla and Vadinar for a period of 3 years". Under the project, Environmental monitoring refers to systematic assessment of ambient air, water (drinking and surface), soil, sediment, noise and ecology in order to monitor the performance and implementation of a project in compliance with Environmental quality standards and/or applicable Statutory norms.

The scope of work includes not limited to following:

1. To review the locations/stations of Ambient Air, Ambient Noise, drinking water, and Marine Water, Soil and Sediments monitoring within the impacted region in-and-around DPA establishment, in view of the developmental projects.
2. To assess the Ambient Air quality, quality at 6 stations at Kandla and 2 at Vadinar in terms of gases and particulate matter.
3. To assess the DG stack emissions (gases and particulate matter).
4. To assess Drinking water quality at twenty locations (18 at Kandla and 2 at Vadinar) in terms of Physical, Chemical and Biological parameters viz., Color, Odor, turbidity, conductivity, pH, Total Dissolved Solids, chlorides, Hardness, total iron, sulfate, NH_4, PO_4, and bacterial count on a monthly basis.
5. To assess the Marine water quality in terms of aquatic Flora and Fauna and Sediment quality in terms of benthic flora and fauna.
6. To assess Marine Water Quality and sediment in term of physical and chemical parameter.
7. To assess the trends of water quality in terms of Marine ecology by comparing the data collected over a specified time period.
8. Weekly sample collection and analysis of inlet & Outlet points of the Sewage Treatment Plant (STP) to check the water quality being discharged by DPA as per the CC&A.
9. Carrying out monthly Noise monitoring; twice a day at the representative stations for a period of 24 hours.
10. Meteorological parameters are very important from air pollution point of view; hence precise and continuous data collection is of utmost importance. Meteorological data on wind speed, wind direction, temperature, relative humidity, solar radiation and

rainfall shall be collected from one permanent station at DPA, Kandla and one permanent station at Vadinar.

11. To suggest mitigation measures, based on the findings of this study and also check compliance with Environmental quality standards, Green Port Initiatives, MIV 2030, and any applicable Statutory Compliance.
12. To recommend Environment Management Plans based on Monitoring programme and findings of the study.

CHAPTER 2: METHODOLOGY

2.1 Study Area

Under the study, the locations specified by Deendayal Port Authority for the areas of Kandla and Vadinar would be monitored. The details of the study area as follows:

a. Kandla

Deendayal Port (Erstwhile Kandla Port) is one of the twelve major ports in India and is located on the West Coast of India, in the Gulf of Kutch at 23001'N and 70013'E in Gujarat. The Major Port Authorities Act 2021 is the governing statute for Administration of Major Ports, under which, Deendayal Port Trust (DPT) has become Deendayal Port Authority (DPA). At Kandla, DPA has sixteen (16) cargo berths for handling various types of Dry Bulk Cargo viz, fertilizer, food grains, Coal, sulphur, etc.

- **Climatic conditions of Kandla**

Kandla has a semi-desert climate. Temperature varies from 25°C to 44°C during summer and 10°C to 25°C during winter. The average annual temperature is 24.8 °C. The average rainfall is 410 mm, most of which occurs during the monsoon from the months of June-to-September.

b. Vadinar

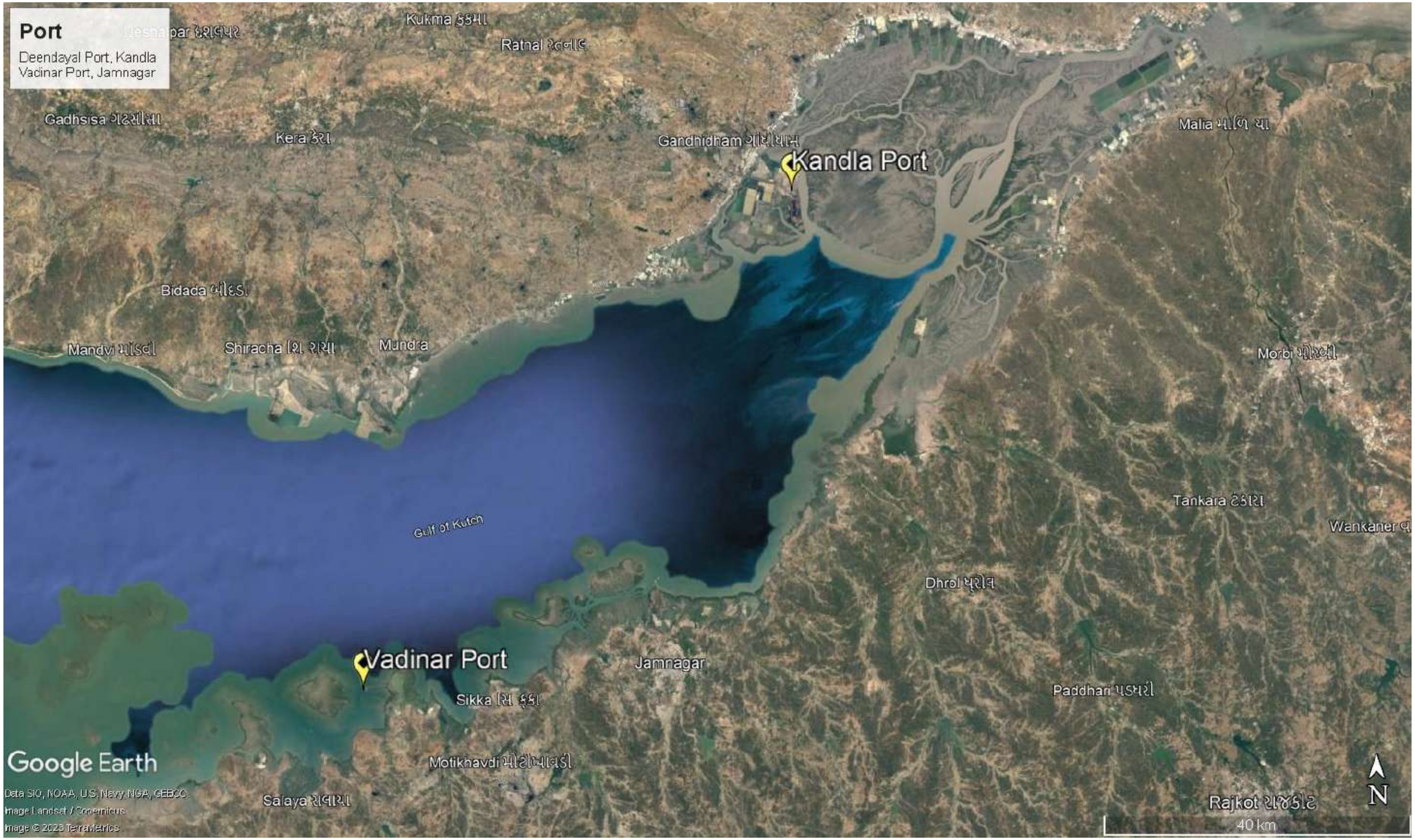
Vadinar is a small coastal town located in Devbhumi Dwarka district of the Gujarat state in India located at coordinates 22° 27' 16.20" N - 069° 40' 30.01”. DPA had commissioned the Off Shore Oil Terminal (OOT) facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, with a capacity of 54 MMTPA. The OOT of the DPA contributes in a large way to the total earnings of this port. Vadinar is now notable due to the presence of two refineries-one promoted by Reliance Industries and Essar Oil Ltd.

DPA also handled 43.30 MMT at Vadinar (which includes transhipment), the containerized cargo crossed 4.50 lakh TEU, grossing a total of 100 MMT overall. Major commodities handled by the Deendayal Port are Crude Oil, Petroleum product, Coal, Salt, Edible Oil, Fertilizer, etc.

- **Climatic conditions of Vadinar**

Vadinar has a hot semi-arid climate. The summer season lasts from March-to-May and is extremely hot, humid, but dry. The climatic conditions in Vadinar are quite similar to that recorded in its district head quarter i.e., Jamnagar. The annual mean temperature is 26.7 °C. Rainy season with extremely erratic monsoonal rainfall that averages around 630 millimetres. The winter season is from October-to-February remains hot during the day but has negligible rainfall, low humidity and cool nights.

The Kandla and Vadinar port have been depicted in the **Map 1** as follows:



Map 1: Locations of Kandla and Vadinar Port

Map 2: Locations of Kandla Port

Map 3: Locations of Vadinar Port

2.2 Environmental Monitoring at Kandla and Vadinar

Regular monitoring of environmental parameters is of immense importance to assess the status of environment during project operation. With the knowledge of baseline conditions, the monitoring programme will serve as an indicator for identifying any deterioration in environmental conditions, thereby assist in recommending suitable mitigatory steps in time to safeguard the environment. Monitoring is as important as that of control of pollution since the efficiency of control measures can only be determined by a well-defined monitoring program. Environmental Monitoring is vital for monitoring the environmental status of the port for sustainable development. The list of main elements for which Environmental monitoring is to be carried out have been mentioned below:

- Meteorology
- Ambient Air
- DG Stack
- Noise
- Soil
- Drinking Water
- Sewage Treatment Plant
- Marine (Surface) water
- Marine Sediments
- Marine Ecology

GEMI has been entrusted by DPA to carry out the monitoring of the various aforementioned environmental aspects at the port, so as to verify effectiveness of prevailing Environment Management plan, if it confirms to the statutory and/or legal compliance; and identify any unexpected changes. Standard methods and procedures have been strictly adhered to in the course of this study. QA/QC procedures were strictly followed which covers all aspects of the study, and includes sample collection, handling, laboratory analyses, data coding, statistical analyses, interpretation and communication of results. The analysis was carried out in GEMI's NABL/MoEF accredited/recognized laboratory.

Methodology adopted for the study

Methodology is a strictly defined combination of practices, methods and processes to plan, develop and control a project along the continuous process of its implementation and successful completion. The aim of the project management methodology is to allow the control of whole process of management through effective decision-making and problem solving. The methodology adopted for the present study is shown in **Figure 1** as given below:

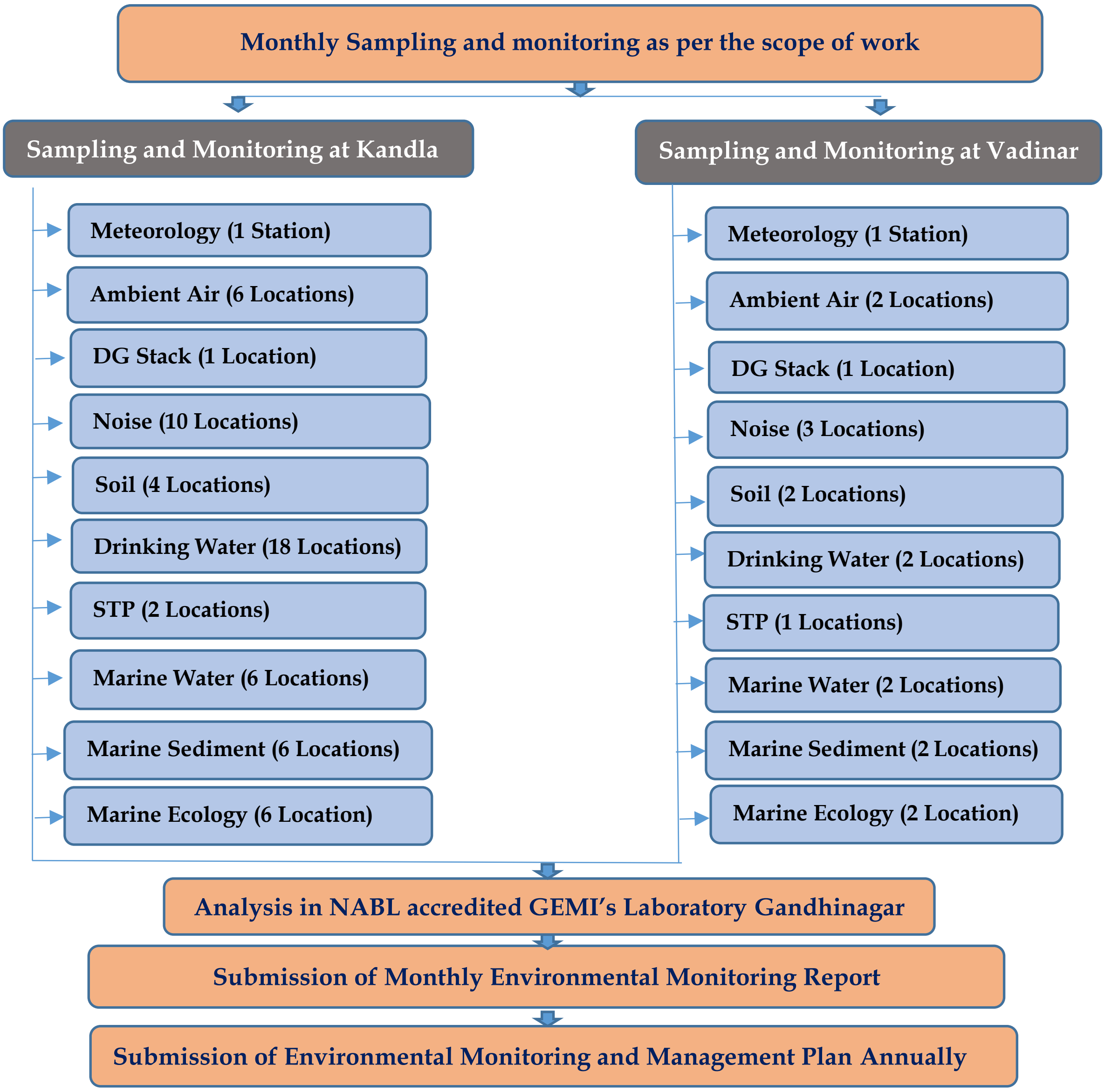


Figure 1: Methodology flow chart

The details of various sectors of Environment monitoring are described in subsequent chapters.

CHAPTER 3: METEOROLOGY MONITORING

3.1 Meteorology Monitoring

Meteorological conditions play a crucial role in dispersion of air pollutants as well as 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. In order to determine the prevailing micro-meteorological conditions at the project site an Automatic Weather Monitoring Stations (AWS) of Envirotech make (Model: WM280) were installed at both the sites of Kandla and Vadinar at 10 m above the ground. The details of the AWS installed have been mentioned in **Table 1** as follows:

Table 1: Details of Automatic Weather Station

Sr. No.	Site	Location Code	Location Name	Latitude Longitude
1.	Kandla	AWS-1	Environment Laboratory (DPA)	23.00996N 70.22175E
2.	Vadinar	AWS-2	Canteen Area	22.39994N 69.716608E

Methodology

During the study, a continuous automatic weather monitoring station was installed at both the sites to record climatological parameters such as Wind speed, Wind Direction, Relative Humidity, Solar Radiation, Rainfall and Temperature to establish general meteorological regime of the study area. The methodology adopted for monitoring meteorological data shall be as per the standard norms laid down by Bureau of Indian Standards (BIS) and the India Meteorological Department (IMD). The details of Automatic Weather Monitoring Station have been mentioned in **Table 2**.

Table 2: Automatic Weather Monitoring Station details

Sr. No.	Details of Meteorological Data	Unit of Measurement	Instrument	Frequency
1.	Wind Direction	degree	Automatic Weather Monitoring Station (Envirotech WM280)	Hourly Average
2.	Wind Speed	Km/hr		
3.	Rainfall	mm/hr		
4.	Relative Humidity	% RH		
5.	Temperature	°C		
6.	Solar Radiation	W/m^2		

The Meteorological parameters were recorded at an interval of 1 hour in a day and the average value for all the Meteorological parameters were summarized for the sampling period of at both the observatory site.

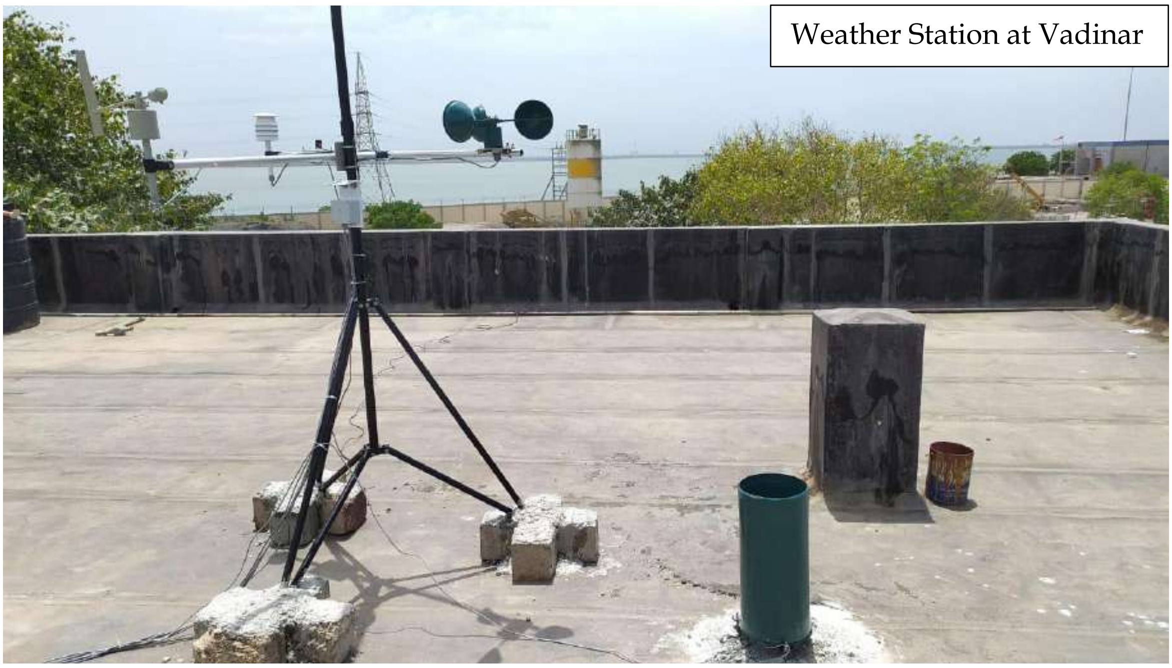


Figure 2: Photographs of Automatic Weather Monitoring Station at Kandla and Vadinar

3.2 Results and discussion

The summary of hourly climatological observations recorded at Kandla and Vadinar during the monitoring period, with respect to significant parameters has been mentioned in **Table 3** as follows:

Table 3: Meteorological data for Kandla and Vadinar

Details of Micro-meteorological data at Kandla Observatory												
Monitoring Period	**Wind Speed (Km/h)**			**Temperature (°C)**			**Relative humidity (%)**			**Solar Radiation (W/m²)**	**Wind Direction (°)**	**Rainfall (mm)**
Stat.	**Mean**	**Max.**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**			
August-September 2025	4.35	64	0.6	30.21	37.9	24.7	74.56	90.4	49.8	66.17	North	0.33
Details of Micro-meteorological data at Vadinar Observatory												
Monitoring Period	**Wind Speed (Km/h)**			**Temperature (°C)**			**Relative humidity (%)**			**Solar Radiation (W/m²)**	**Wind Direction (°)**	**Rainfall (mm)**
Stat.	**Mean**	**Max.**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max.**	**Min**			
August-September 2025	3.62	28	0.6	27	36.3	22.2	79.72	91.5	56.8	67.58	SSW	0.16

3.3 Data Interpretation and Conclusion

- **Temperature**

a. **Kandla:** The ambient temperature for the monitoring period varies between the range of 24.7– 37.9°C for Kandla, with average temperature of 30.21°C.
b. **Vadinar:** The ambient temperature for the monitoring period varies between the range of 22.2-36.3°C for Vadinar, with average temperature of 27°C.

- **Relative Humidity**

a. **Kandla**: The Relative Humidity recorded between the range of 49.8–90.4, with average Humidity of 74.56%.
b. **Vadinar:** During the study period, the Relative Humidity varies between 56.8-91.5%, with average Humidity of 79.72%.

- **Rainfall**

a. **Kandla:** 0.33 mm/hr rainfall was observed at Kandla.
b. **Vadinar:** 0.16 mm/hr rainfall was observed at Vadinar.

- **Wind Speed**

Wind speed and Direction play a significant role in transporting the pollutants and thus decides the air quality.

a. **Kandla:** Wind speed recorded ranges between 0.6–64 Km/hr.
b. **Vadinar:** During the monitoring period, the Wind speed recorded ranges between 0.6-28 Km/hr.

- **Solar Radiation:**

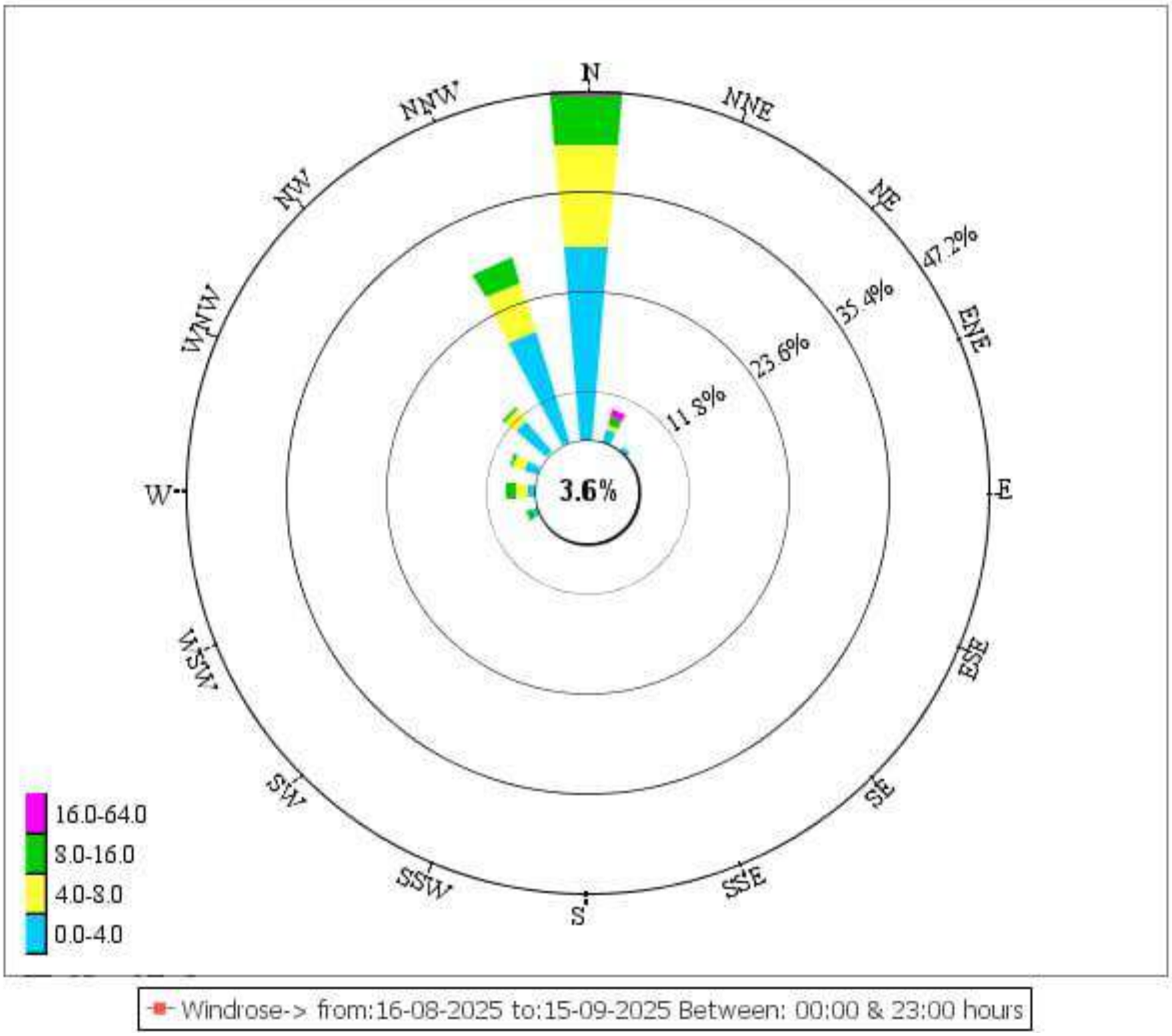
a. **Kandla:** The average Solar Radiation for the monitoring period was recorded as 66.17 W/m^2.
b. **Vadinar:** The average Solar Radiation was recorded as 67.58 W/m^2.

- **Wind rose diagram -**

The wind-rose diagram for the monitoring period has been drawn on the basis of hourly wind speed and direction data.

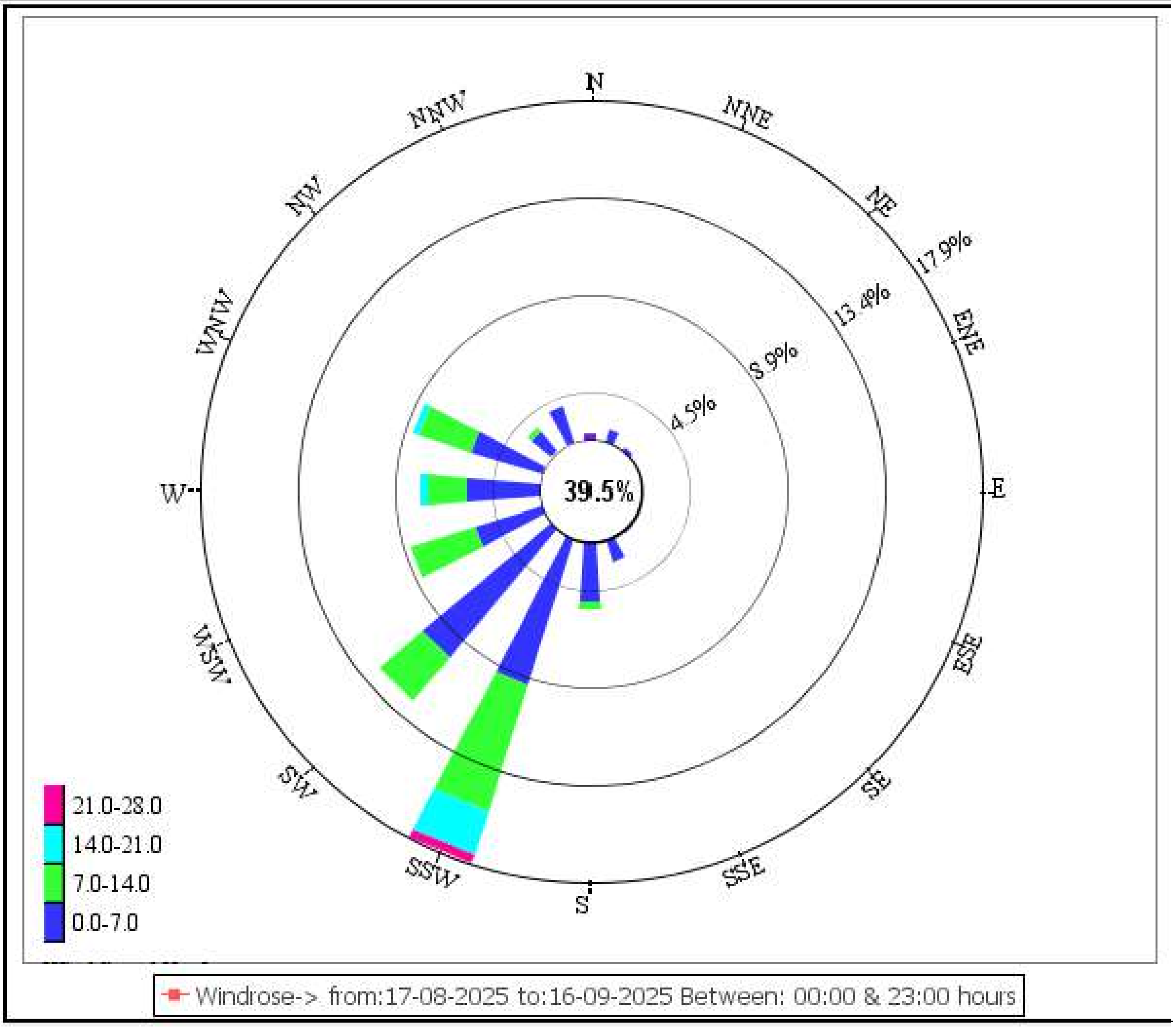
This Wind Rose Diagram reveals that at Kandla and Vadinar, during the monitoring period, the prevailing winds predominantly blow from the North at Kandla. At Vadinar, the winds were observed to blow from South South West Direction.

Wind Rose Plot M/s Deendayal Port Authority Site: Kandla Port (Environment Laboratory)	Display: Wind Direction Wind Speed (Km/hr)



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

Wind Rose Plot M/s Deendayal Port Authority Site: Vadinar Port (Canteen Area)	Display: Wind Direction Wind Speed (Km/hr)



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

CHAPTER 4: AMBIENT AIR QUALITY MONITORING

4.1 Ambient Air Quality

It is necessary to monitor the ambient air quality of the study area, in order to determine the impact of the shipping activities and port operations on the ambient air quality. The prime objective of ambient air quality monitoring is to assess the present air quality and its conformity to National Ambient Air Quality Standards i.e. NAAQS, 2009. Ambient air quality has been monitored from 16th August to 15th September 2025.

Methodology

The study area represents the area occupied by DPA and its associated Port area. The sources of air pollution in the region are mainly vehicular traffic, fuel burning, loading & unloading of dry cargo, fugitive emissions from storage area and dust arising from unpaved village roads. Considering the below factors, under the study, as per the scope specified by DPA eight locations wherein, 6 stations at Kandla and 2 at Vadinar have been finalized within the study area

- Meteorological conditions;
- Topography of the study area;
- Direction of wind;
- Representation of the region for establishing current air quality status
- Representation with respect to likely impact areas.

The description of various air quality stations monitored at Kandla and Vadinar have been specified in **Table 4**.

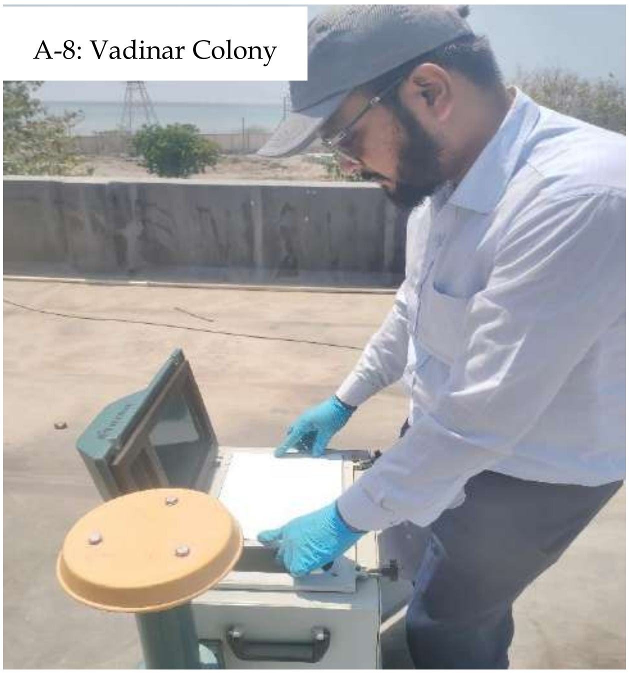
Table 4: Details of Ambient Air monitoring locations

<table>
<tr><th>Sr. No.</th><th colspan="2">Location Code</th><th>Location Name</th><th>Latitude Longitude</th><th>Significance</th></tr>
<tr><td>1.</td><td rowspan="6">Kandla</td><td>A-1</td><td>Oil Jetty No. 1</td><td>23.029361N 70.22003E</td><td rowspan="2">Liquid containers and emission from ship</td></tr>
<tr><td>2.</td><td>A-2</td><td>Oil Jetty No. 7</td><td>23.043538N 70.218617E</td></tr>
<tr><td>3.</td><td>A-3</td><td>Bansal Canteen</td><td>23.027197N 70.195451E</td><td>Vehicular activity and dust emission</td></tr>
<tr><td>4.</td><td>A-4</td><td>Sewa Sadan-3</td><td>23.009945N 70.221745 E</td><td>Construction and vehicular activity, road dust emission,</td></tr>
<tr><td>5.</td><td>A-5</td><td>Coal Storage Area</td><td>23.000190N 70.219757E</td><td>Coal Dust, Vehicular activity</td></tr>
<tr><td>6.</td><td>A-6</td><td>Gopalpuri Hospital</td><td>23.081506N 70.135258E</td><td>Residential area, dust emission, vehicular activity</td></tr>
<tr><td>7.</td><td rowspan="2">Vadinar</td><td>A-7</td><td>Admin Building</td><td>22.441806N 69.677056E</td><td>Vehicular activity</td></tr>
<tr><td>8.</td><td>A-8</td><td>Vadinar Colony</td><td>22.401939N 69.716306E</td><td>Residential Area, burning waste, vehicular activity</td></tr>
</table>

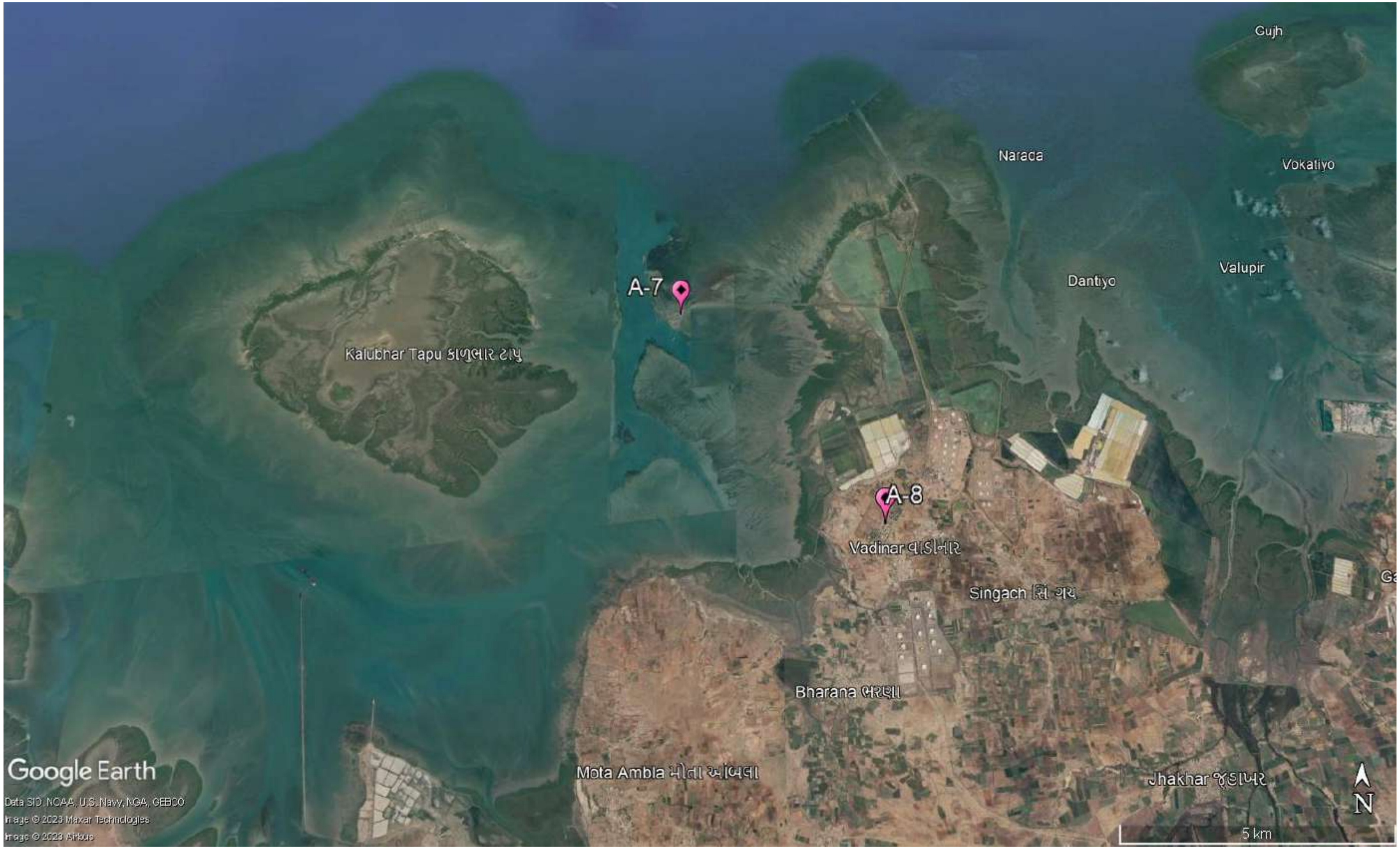
The two ambient air monitoring locations have been changed: Location A-3, previously at Kandla Port Colony, has now been shifted to Bansal Canteen, and Location A-4, earlier at Marine Bhavan, is now relocated to Sew Sadan-3. The monitoring locations at Kandla and Vadinar have been depicted in map in **Map 4 and 5** respectively.

Ambient Air monitoring photos

Kandla	
 A-1: Oil Jetty No. 1	 A-2: Oil Jetty No. 7
 A-3: Bansal Canteen	 A-4: Sewa Sadan-3
 A-5: Coal Storage Area	 A-6: Gopalpuri Hospital

Vadinar	
A-7: Admin Building 	A-8: Vadinar Colony 

Map 4: Locations for Ambient Air Monitoring at Kandla



Map 5: Locations for Ambient Air Monitoring at Vadinar

Frequency

The sampling for Particulate matter i.e. PM_{10} and $PM_{2.5}$ and the gaseous components like SO_x, NO_x, CO as well as the Total VOCs were monitored twice in a week for a period of 24 hours a day. Whereas, the sampling for the components of PAH, Benzene and non-Methane VOCs was conducted on monthly basis.

Sampling and Analysis

The Sampling of the Ambient Air Quality parameters and analysis is conducted as per the CPCB guidelines of National Ambient Air Quality Monitoring. The sampling was performed at a height of 3.5 m (approximately) from the ground level. For the sampling of PM_{10}, calibrated 'Respirable Dust Samplers' were used, where Whatman GF/A microfiber filter paper of size 8”x 10” were utilized, where the Gaseous attachment of the make Envirotech instrument was attached with Respirable Dust Sampler for the measurement of SO_x and NO_x. The Fine Particulate Sampler for collection of $PM_{2.5}$ was utilized for the particulate matter of size <2.5 microns. A known volume of ambient air is passed through the cyclone to the initially pre-processed filter paper. The centrifugal force in cyclone acts on particulate matter to separate them into two parts and collected as following:

- Particles <10 μ size (Respirable): GF/A Filter Paper
- Particles <2.5 μ size (Respirable): Polytetrafluoroethylene (PTFE)

Sampling and analysis of ambient SO_2 was performed by adopting the 'Improved West and Gaeke Method'. The ambient air, drawn through the draft created by the RDS, is passed through an impinger, containing a known volume of absorbing solution of Sodium tetrachloromercurate, at a pre-determined measured flow rate of 1 liter/minute (L/min). Similarly, NO_x was performed by adopting the 'Jacob Hochheister Modified’ (Na arsenite) method. The impinger contains known volume of absorbing solution of Sodium Arsenite and Sodium Hydroxide.

Data has been compiled for PM_{10}, $PM_{2.5}$, SO_x and NO_x samples of 24-hour carried out twice a week. In case of CO, one hourly sample were taken on selected monitoring days using the sensor-based CO Meter. For the parameters Benzene, Methane & Non-methane and Volatile Organic Carbons (VOCs), the Low Volume Sampler is used, where the charcoal tubes are used as sampling media. The sampling in the Low Volume Sampler (LVS) is carried out as per IS 5182 (Part 11): 2006 RA: 2017, where the ambient air flow rate is maintained at 200 cc/min, the volume of air that passes through the LVS during two hours monitoring is approx. 24 L.

The sampling of PAHs is carried out as per IS: 5182 (Part 12): 2004. Where, the EPM 2000 Filter papers are utilized in the Respirable Dust Sampler (RDS). For the parameters, Benzene, PAH & Non-methane VOC’s, monthly monitoring is carried out. The details of the parameters with their frequency monitored are mentioned in **Table 5:**

Table 5: Parameters for Ambient Air Quality Monitoring

Sr. No.	Parameters	Units	Reference method	Instrument	Frequency
1.	PM_{10}	µg/m³	IS 5182 (Part 23): 2006	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-23): 2006	Twice in a week
2.	$PM_{2.5}$	µg/m³	IS:5182 (Part:24):2019	Fine Particulate Sampler (FPS) conforming to IS:5182 (Part-24): 2019	
3.	Sulphur Dioxide (SO_x)	µg/m³	IS 5182 (Part:2): 2001	Gaseous Attachment conforming to IS:5182 Part-2	
4.	Oxides of Nitrogen (NO_x)	µg/m³	IS:5182 (Part-6): 2006	Gaseous Attachment conforming to IS:5182 Part-6	
5.	Carbon Monoxide (CO)	mg/m³	GEMI/SOP/AAQM/11 ; Issue no 01, Date 17.01.2019: 2019	Sensor based Instrument	
6.	VOC	µg/m³	IS 5182 (Part 17): 2004	Low Flow Air Sampler	
8.	PAH	µg/m³	IS: 5182 (Part 12): 2004	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-12): 2004	Monthly
7.	Benzene	µg/m³	IS 5182 (Part 11): 2006 RA: 2017	Low Flow Air Sampler	
9.	Non-methane VOC	µg/m³	IS 5182 (Part 11): 2006	Low Volume Sampler	

4.2 Result and Discussion

The summarized results of ambient air quality monitoring for the study period are presented in **Table-6 to 9** along with the graphical representation from **Graph 1 to Graph 6.** Various parameters monitored during the study have been presented by their maximum, minimum, average and Standard deviation.

Table 6: Summarized results of PM_{10}, $PM_{2.5}$, SO_2, NO_x, VOC and CO for Ambient Air quality monitoring

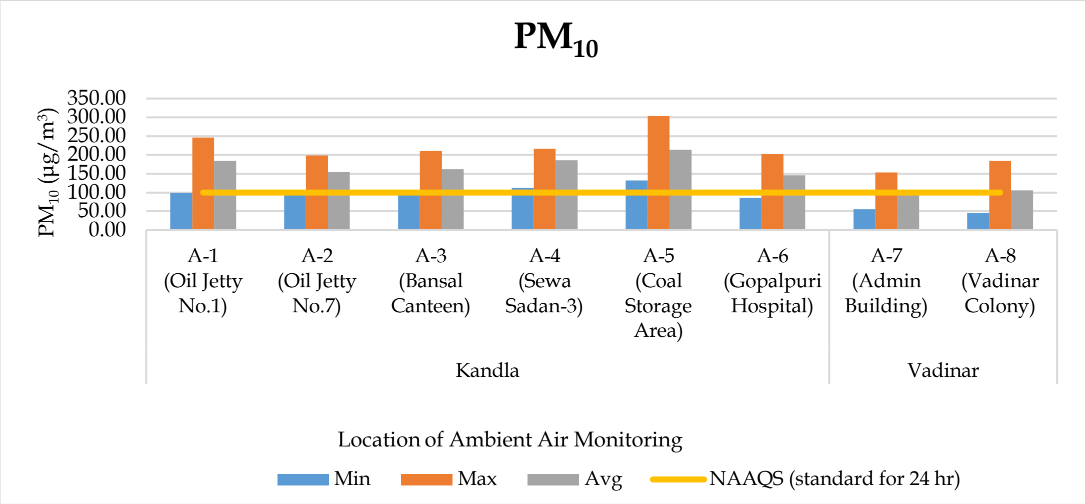
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
A-1: Oil Jetty No.1,	18-08-2025	156.24	31.25	8.36	12.21	0.12	0.81
	20-08-2025	166.33	33.27	9.65	<6	0.08	0.79
	25-08-2025	200.15	40.03	15.62	11.23	0.19	0.85
	28-08-2025	194.26	38.85	22.11	<6	0.21	0.81

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
Kandla	01-09-2025	99.12	19.82	26.54	13.24	0.13	0.82
	02-09-2025	246.58	49.32	6.21	22.05	0.16	0.86
	08-09-2025	210.21	42.04	21.36	<6	0.17	0.88
	10-09-2025	199.52	39.90	8.62	19.21	0.24	0.80
	Minimum	**99.12**	**19.82**	**6.21**	**11.23**	**0.08**	**0.79**
	Maximum	**246.58**	**49.32**	**26.54**	**22.05**	**0.24**	**0.88**
	Average	**184.05**	**36.81**	**14.81**	**15.59**	**0.16**	**0.83**
	Std. Deviation	**43.91**	**8.78**	**7.70**	**4.76**	**0.05**	**0.03**
A-2: Oil Jetty No.7, Kandla	18-08-2025	96.24	19.25	9.46	15.43	0.13	0.84
	20-08-2025	123.52	24.70	6.12	14.11	0.16	0.82
	25-08-2025	154.21	30.84	10.46	18.32	0.17	0.80
	28-08-2025	198.25	39.65	<5	14.33	0.12	0.83
	01-09-2025	162.35	32.47	18.42	<6	0.11	0.85
	02-09-2025	184.23	36.85	13.63	9.27	0.08	0.81
	08-09-2025	164.21	32.84	19.41	12.20	0.15	0.82
	10-09-2025	152.45	30.49	7.68	18.24	0.2	0.84
	Minimum	**96.24**	**19.25**	**6.12**	**9.27**	**0.08**	**0.80**
	Maximum	**198.25**	**39.65**	**19.41**	**18.32**	**0.20**	**0.85**
	Average	**154.43**	**30.89**	**12.17**	**14.56**	**0.14**	**0.83**
	Std. Deviation	**32.32**	**6.46**	**5.17**	**3.22**	**0.04**	**0.02**
A-3: Bansal Canteen , Kandla	18-08-2025	165.24	33.05	15.22	<6	0.22	0.79
	20-08-2025	101.25	20.25	9.45	15.23	0.23	0.82
	25-08-2025	154.65	30.93	18.43	14.28	0.08	0.83
	28-08-2025	177.20	35.44	15.46	<6	0.15	0.82
	01-09-2025	210.33	42.07	<5	16.36	0.12	0.79
	02-09-2025	138.24	27.65	14.53	17.57	0.14	0.84
	08-09-2025	145.22	29.04	7.45	13.43	0.16	0.86
	10-09-2025	205.24	41.05	16.32	12.23	0.07	0.80
	Minimum	**101.25**	**20.25**	**7.45**	**12.23**	**0.07**	**0.79**
	Maximum	**210.33**	**42.07**	**18.43**	**17.57**	**0.23**	**0.86**
	Average	**162.17**	**32.43**	**13.84**	**14.85**	**0.15**	**0.82**
	Std. Deviation	**35.93**	**7.19**	**3.92**	**1.95**	**0.06**	**0.02**
A-4: Sewa Sadan - 3, Kandla	18-08-2025	188.24	37.65	6.31	6.68	0.18	0.81
	20-08-2025	200.33	40.07	<5	<6	0.19	0.80
	25-08-2025	195.44	39.09	6.43	11.23	0.18	0.85
	28-08-2025	216.24	43.25	8.13	<6	0.18	0.80
	01-09-2025	164.27	32.85	10.34	14.55	0.13	0.81
	02-09-2025	206.61	41.32	<5	<6	0.05	0.87
	08-09-2025	112.36	22.47	13.52	15.63	0.08	0.88
	10-09-2025	202.32	40.46	<5	17.69	0.12	0.82
	Minimum	**112.36**	**22.47**	**6.31**	**6.68**	**0.05**	**0.78**
	Maximum	**216.24**	**43.25**	**13.52**	**17.69**	**0.19**	**0.89**

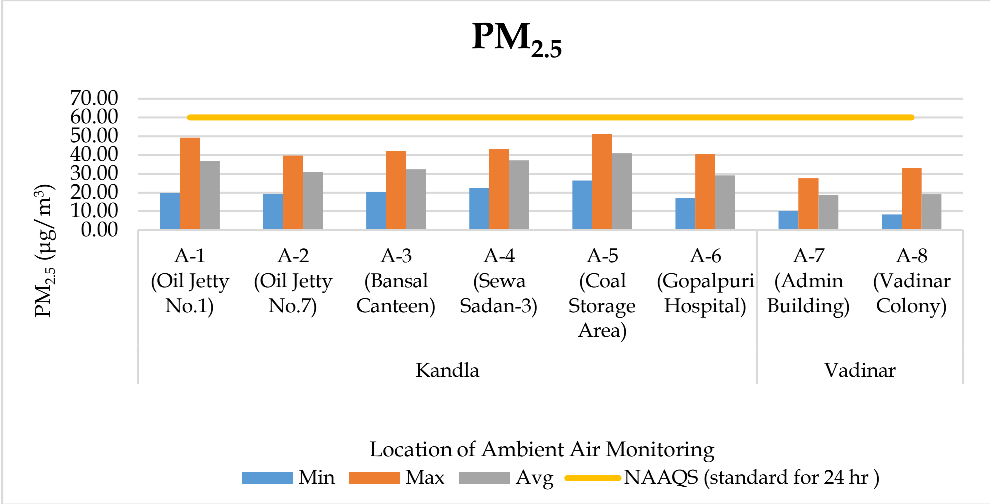
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_X ($\mu g/m^3$)	VOC ($\mu g/m^3$)	CO (mg/m^3)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
	Average	**185.73**	**37.15**	**8.95**	**13.16**	**0.14**	**0.83**
	Std. Deviation	**33.38**	**6.68**	**3.03**	**4.31**	**0.05**	**0.03**
A-5: Coal Storage Area, Kandla	18-08-2025	210.66	42.13	29.54	11.34	0.2	0.81
	20-08-2025	186.32	37.26	14.52	9.22	0.06	0.82
	25-08-2025	132.26	26.45	15.12	18.42	0.26	0.88
	28-08-2025	200.52	40.10	21.21	26.32	0.07	0.90
	01-09-2025	303.45	46.25	21.42	17.17	0.15	0.75
	02-09-2025	212.36	42.47	20.36	26.26	0.15	0.85
	08-09-2025	209.51	41.90	17.54	25.43	0.17	0.86
	10-09-2025	256.44	51.29	12.26	19.43	0.13	0.83
	Minimum	**132.26**	**26.45**	**12.26**	**9.22**	**0.06**	**0.75**
	Maximum	**303.45**	**51.29**	**29.54**	**26.32**	**0.26**	**0.90**
	Average	**213.94**	**40.98**	**19.00**	**19.20**	**0.15**	**0.84**
	Std. Deviation	**49.95**	**7.21**	**5.43**	**6.61**	**0.07**	**0.05**
A-6: Gopalpuri Hospital, Kandla	18-08-2025	86.52	17.30	7.21	<6	0.09	0.71
	20-08-2025	112.22	22.44	9.26	10.32	0.1	0.79
	25-08-2025	132.68	26.54	8.54	16.43	0.14	0.81
	28-08-2025	154.22	30.84	8.23	11.21	0.16	0.85
	01-09-2025	121.32	24.26	6.45	<6	0.09	0.79
	02-09-2025	172.54	34.51	8.02	<6	0.1	0.66
	08-09-2025	202.33	40.47	10.22	<6	0.11	0.84
	10-09-2025	187.41	37.48	<5	12.43	0.15	0.81
	Minimum	**86.52**	**16.14**	**6.12**	**6.45**	**0.09**	**0.79**
	Maximum	**202.33**	**34.47**	**9.76**	**13.46**	**0.16**	**0.84**
	Average	**146.16**	**25.54**	**7.56**	**9.68**	**0.12**	**0.81**
	Std. Deviation	**39.87**	**6.42**	**1.20**	**3.01**	**0.03**	**0.02**
A-7: Admin Building, Vadinar	18-08-2025	91.25	16.42	7.42	13.46	0.04	0.65
	20-08-2025	55.22	10.32	10.25	19.23	0.19	0.63
	25-08-2025	126.21	22.71	32.65	<6	0.13	0.69
	28-08-2025	153.26	27.58	23.21	<6	0.15	0.7
	01-09-2025	84.25	15.16	<5	<6	0.19	0.72
	02-09-2025	101.41	18.25	<5	<6	0.16	0.73
	08-09-2025	122.08	21.55	<5	12.55	0.09	0.72
	10-09-2025	92.35	16.52	6.21	7.22	0.18	0.75
	Minimum	**55.22**	**10.32**	**6.21**	**7.22**	**0.04**	**0.63**
	Maximum	**153.26**	**27.58**	**32.65**	**19.23**	**0.19**	**0.75**
	Average	**103.25**	**18.56**	**15.95**	**13.12**	**0.14**	**0.70**
	Std. Deviation	**30.04**	**5.29**	**11.53**	**4.92**	**0.05**	**0.04**
A-8: Vadinar Colony,	18-08-2025	84.52	15.21	8.26	9.45	0.25	0.70
	20-08-2025	101.22	18.21	12.34	<6	0.2	0.62
	25-08-2025	111.56	20.08	30.21	10.36	0.11	0.59
	28-08-2025	184.13	33.14	15.34	8.45	0.22	0.65

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
Vadinar	01-09-2025	45.21	8.43	5.21	<6	0.15	0.71
	02-09-2025	123.36	22.20	<5	<6	0.14	0.54
	08-09-2025	102.27	18.40	<5	29.51	0.13	0.58
	10-09-2025	95.24	17.14	7.54	9.11	0.14	0.56
	Minimum	**45.21**	**8.43**	**5.21**	**8.45**	**0.11**	**0.54**
	Maximum	**184.13**	**33.14**	**30.21**	**29.51**	**0.25**	**0.71**
	Average	**105.94**	**19.10**	**13.15**	**13.38**	**0.17**	**0.62**
	Std. Deviation	**39.18**	**6.99**	**9.11**	**9.05**	**0.05**	**0.06**

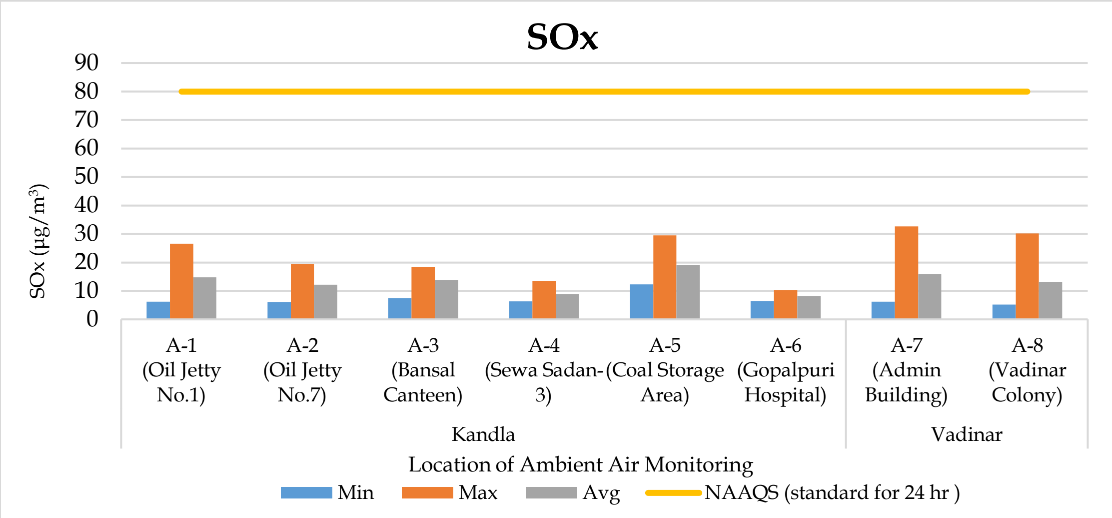
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar)



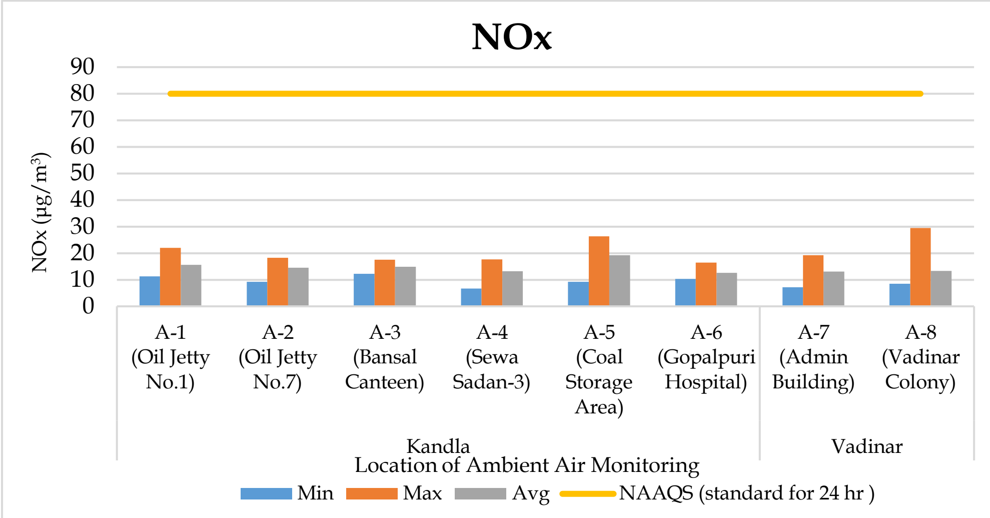
Graph 1: Spatial trend in Ambient PM_{10} Concentration



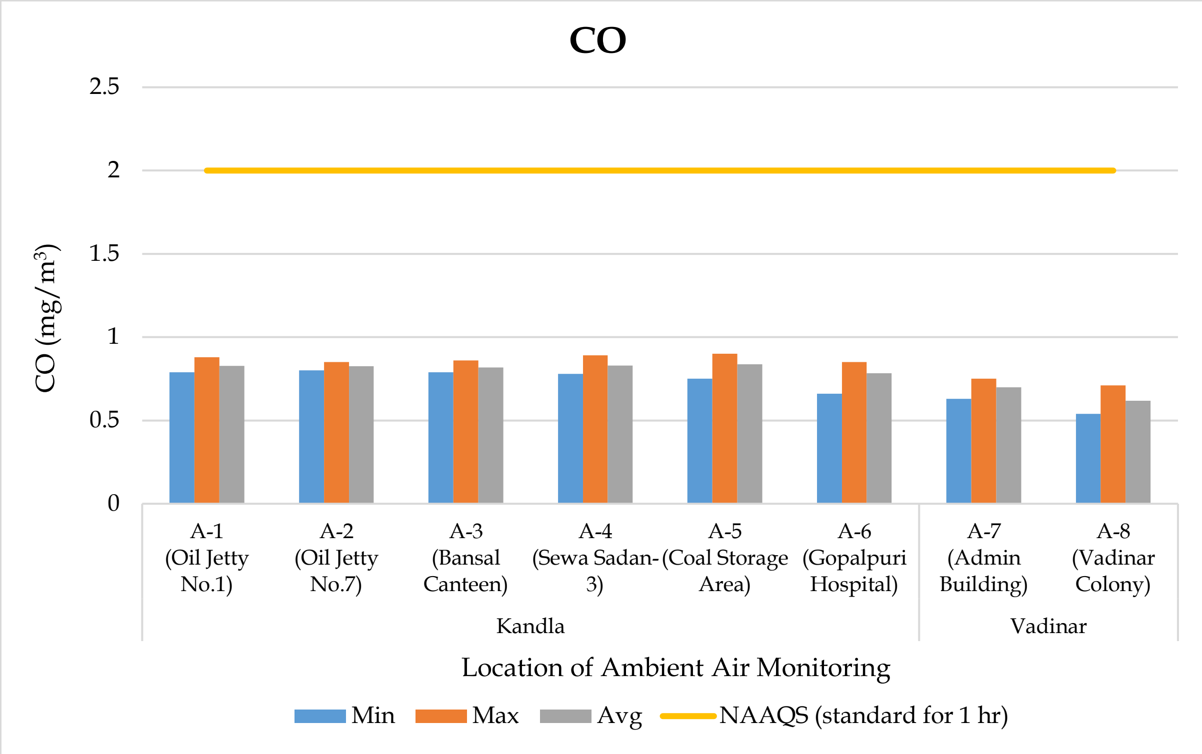
Graph 2: Spatial trend in Ambient $PM_{2.5}$ Concentration



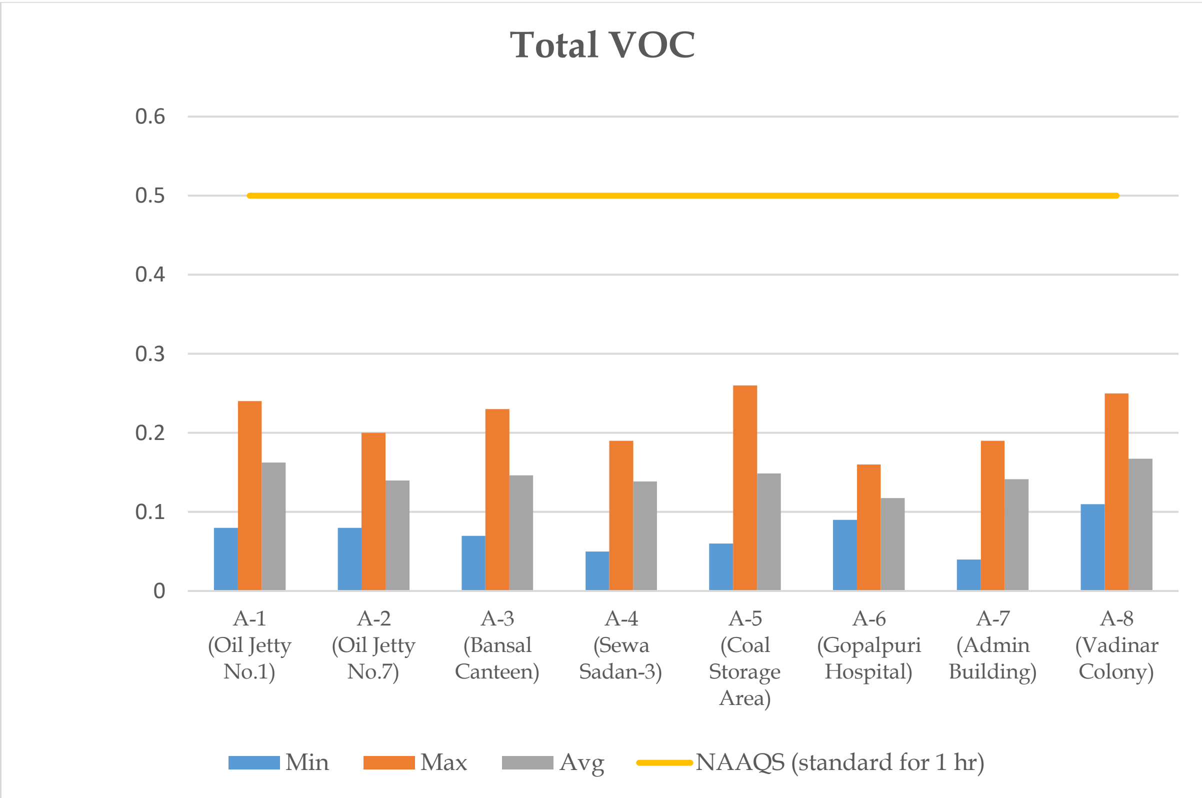
Graph 3: Spatial Trend in Ambient SOx Concentration



Graph 4: Spatial trend in Ambient Nox Concentration



Graph 5: Spatial trend in Ambient CO Concentration



Graph 6: Spatial trend in Ambient Total VOCs

Table 7: Summarized results of Benzene for Ambient Air quality monitoring

Benzene (µg/m³)									
Sr. No	Kandla						Vadinar		NAAQS standards (24 hr)
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	0	0	0	0	0	0	0	0	5 µg/m3

Table 8: Summarized results of Polycyclic Aromatic Hydrocarbons

Sr. No.	Components	Kandla						Vadinar	
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	Napthalene	0.450	0.680	0.180	0.180	1.520	1.170	0.000	0.000
2	Acenaphthylene	0.050	0.090	0.110	0.960	0.460	0.500	0.050	0.000
3	Acenaphthene	0.010	0.040	0.420	0.060	0.650	0.000	0.000	0.000
4	Fluorene	0.500	0.250	0.220	0.240	0.210	0	0.000	0.000
5	Anthracene	0.300	0.360	0.290	0.620	0.330	0.100	0.090	0.000
6	Phenanthrene	0.075	0.075	0.080	0.080	0.000	0.240	0.030	0.000
7	Fluoranthene	0.060	0.840	0.610	0.180	0.600	0.390	0.000	0.000
8	Pyrene	0.085	0.640	0.420	0.720	0.710	0.300	0.060	0.000
9	Chrycene	0.920	1.220	0.620	0.510	0.760	1.120	0.150	0.070
10	Banz(a)anthracene	0.750	1.010	0.490	0.410	0.440	0.880	0.080	0.000
11	Benzo[k]fluoranthene	0.000	0.000	0.000	0.000	0.000	3.200	0.480	0.510
12	Benzo[b]fluoranthene	0.000	0.000	0.000	0.000	0.000	1.250	0.070	0.120
13	Benzopyrene	2.110	3.265	2.020	1.990	3.101	2.210	0.310	0.480
14	Indeno [1,2,3-cd] fluoranthene	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	Dibenz(ah)anthracene	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	Benzo[ghi]perylene	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 9: Summarized results of Non-methane VOC

Sr No	Kandla						Vadinar	
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	0	0	0	0	0	0	0	0

4.3 Data Interpretation and Conclusion

The results were compared with the National Ambient Air Quality Standards (NAAQS), 2009 of Central Pollution Control Board (CPCB).

- The concentration of PM_{10} at Kandla varies in the range of **86.52 to 256.44 µg/m³** with an average value of **172.91 µg/m³**. PM_{10} exceeded NAAQS of all the monitoring locations in Kandla. Whereas, at Vadinar, the concentration varies from **45.21 to 184.13 µg/m³**, with an average value of **104.60 µg/m³**.
- The elevated PM_{10} concentration at location A-5, the Coal Storage Area, can be attributed to several factors. Heavy vehicular traffic in upwind areas significantly contributes to the dispersion of particulate matter into the ambient air. The process of unloading coal directly onto trucks using grabs leads to the emission of coal dust into the air and its subsequent settling on the ground. This settled dust is re-entrained into the atmosphere as trucks travel through the area. Additionally, coal-loaded trucks are often not adequately covered with tarpaulin sheets, which exacerbates the suspension of coal particles during transit from vessels to the storage yard or site. These factors collectively contribute to increased PM_{10} levels in and around the Coal Storage Area and Marine.
- The **$PM_{2.5}$** concentrations at Kandla varies from **17.30 to 51.29 µg/m³** with average **34.58 µg/m³**. The **$PM_{2.5}$** concentration falls within the NAAQS limit for all locations of Kandla. Whereas, at Vadinar its concentration varies from **8.43 to 33.14 µg/m³** with average **18.83 µg/m³**. Also, due to construction and demolition all around the port contributing in increased particulate matter levels.
- The concentrations of **PM_{10}** at the Vadinar sampling locations are exceeding the limits prescribed by the National Ambient Air Quality Standards (NAAQS), primarily due to ongoing construction activities in the Vicinity.
- The concentration of **SO_x** varies from **6.12 to 29.54 µg/m³** with average concentration as **12.84 µg/m³** at Kandla and **5.21 to 32.65 µg/m³** with average as **14.55 µg/m³** at Vadinar. The average concentration of SO_x complies with the prescribed limit of NAAQS (80 µg/m³) for both the monitoring site.
- The concentration of **NO_x** varies from **6.68 to 26.32 µg/m³** with average **14.99 µg/m³** at Kandla and **7.22 to 29.51 µg/m³** with average **13.25 µg/m³** at Vadinar. The concentration of **NO_x** falls within the prescribed limit of NAAQS i.e. 80 µg/m³ at both the monitoring site of Kandla and Vadinar.
- The concentration of **CO** varies from **0.66 to 0.90 µg/m³** with average **0.82 µg/**m³ at Kandla and **0.54 to 0.75 µg /m³** with average **0.66 µg/m³** at Vadinar. The concentration falls within the norm of 2 mg/m³ specified by NAAQS at both the monitoring sites
- The concentration of **Total VOCs** levels was recorded in range of **0.05 to 0.26 µg/m³** at Kandla and **in range of 0.04 to 0.25 µg/m³** at the location of Vadinar respectively. The main source of VOCs in the ambient air may be attributed to the burning of Gasoline and Natural gas in Vehicle exhaust and burning fossil fuels, and garbage that release VOCs into the atmosphere. During the monitoring period, the wind flows towards South direction at Kandla, and hence the wind direction and speed also contribute to increased dispersion of pollutants from the upward areas towards the downward areas.
- **Benzene** was not detected on the location of Kandla & Vadinar.

- **Polycyclic Aromatic Hydrocarbons (PAHs)** are ubiquitous pollutants in urban atmospheres. Anthropogenic sources of total PAHs in ambient air emissions are greater than those that come from natural events. These locations are commercial areas where Vehicular activity and dust emission is common. PAHs are a class of chemicals that occur naturally in coal, crude oil, and gasoline. The higher concentration which results from burning coal, oil, gas, road dust, etc. Other outdoor sources of PAHs may be the industrial plants in-and-around the DPA premises.
- The Ambient air Monitoring location of Kandla recorded the **Non-methane VOC** (NM-VOC) concentration Value to be **0 µg/m³**. While at Vadinar, the concentration of NM-VOC falls is found to be **0 µg /m³** at both the location.

With reference to the Ambient Air Quality monitoring conducted under the study, it may be concluded that the particulate matter PM_{10}, were reported in higher concentration and apparently exceeds the NAAQ
S particularly at locations of Kandla., whereas $PM_{2.5}$ complies with the NAAQS at majority of the locations. For both the ambient air monitoring parameters (PM_{10} and $PM_{2.5}$), the major exceedance was observed at location A-5 i.e. Coal Storage Area. The gaseous pollutants (NO_x, So_x, CO, VOCs etc.) falls within the permissible limit. The probable reasons contributing to these emissions of pollutants into the atmosphere in-and-around the port area are summarized as follows: -

1. **Port Machinery:** Port activities involve the use of various machinery and equipment, including cranes, for lifts, tugboats, and cargo handling equipment. These machines often rely on diesel engines, which can emit pollutants such as NO_x, Particulate matter, and CO. Older or poorly maintained equipment tends to generate higher emissions.
2. **Port Vehicles:** Trucks and other vehicles operating within port and port area contributes to air pollution. Similar to port machinery, diesel-powered vehicles can emit NO_x, PM, CO, and other pollutants such as PAH, VOCs etc. Vehicle traffic and congestion in and around port areas can exacerbate the air quality issues.
3. Apart from that, construction and demolition activities majorly contribute to particulate matter pollution.

4.4 Remedial Measures:

To improve air quality, DPA has implemented a number of precautionary measures, such as maintaining Green zone, initiated Inter-Terminal Transfer 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 unpaved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port. To address air pollution from port shipping activities, various measures that can be implemented are as follows:

- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle-Mask advised in sensitive areas. Covering vehicles with tarpaulin during transportation will help to reduce the suspension of pollutants in air.

- Store fine particulate cargo (e.g., coal, fertilizers) in covered sheds or domes.
- Shrouding shall be carried out in the work site enclosing the dock/proposed facility area. This will act as dust curtain as well achieving zero dust discharge from the site. These curtain or shroud will be immensely effective in restricting disturbance from wind in affecting the dry dock operations, preventing waste dispersion, improving working conditions through provision of shade for the workers.
- Develop green belts using dust-tolerant species along port boundaries and roads.
- Frequent water sprinkling on roads to reduce dust suspension due to vehicular movement, this can be use during transporting coal to avoid suspension of coal dust.
- Use of proper transport methods, such as a conveyor belt, for excavated material and screens around the construction site.
- Temporary pavement of roads in construction site could considerably reduce dust emission. Prohibition of use of heavy diesel oil as fuel could be possibly reduce pollutants. Encouraging use of low-sulfur fuels (viz. Marine Gas Oil (MGO)/Liquefied Natural Gas (LNG), can significantly reduce sulfur and PM emissions from ships.
- Investing in infrastructure for cold ironing allows ships to connect to the electrical grid while docked, reducing the need for auxiliary engines and associated emissions.
- Implementing efficient cargo-handling processes, optimizing logistics to reduce congestion and idling times, and encouraging use of cleaner port machinery and vehicles can all contribute to reducing air pollution in port areas.

CHAPTER 5: DG STACK MONITORING

5.1 DG Stack Monitoring

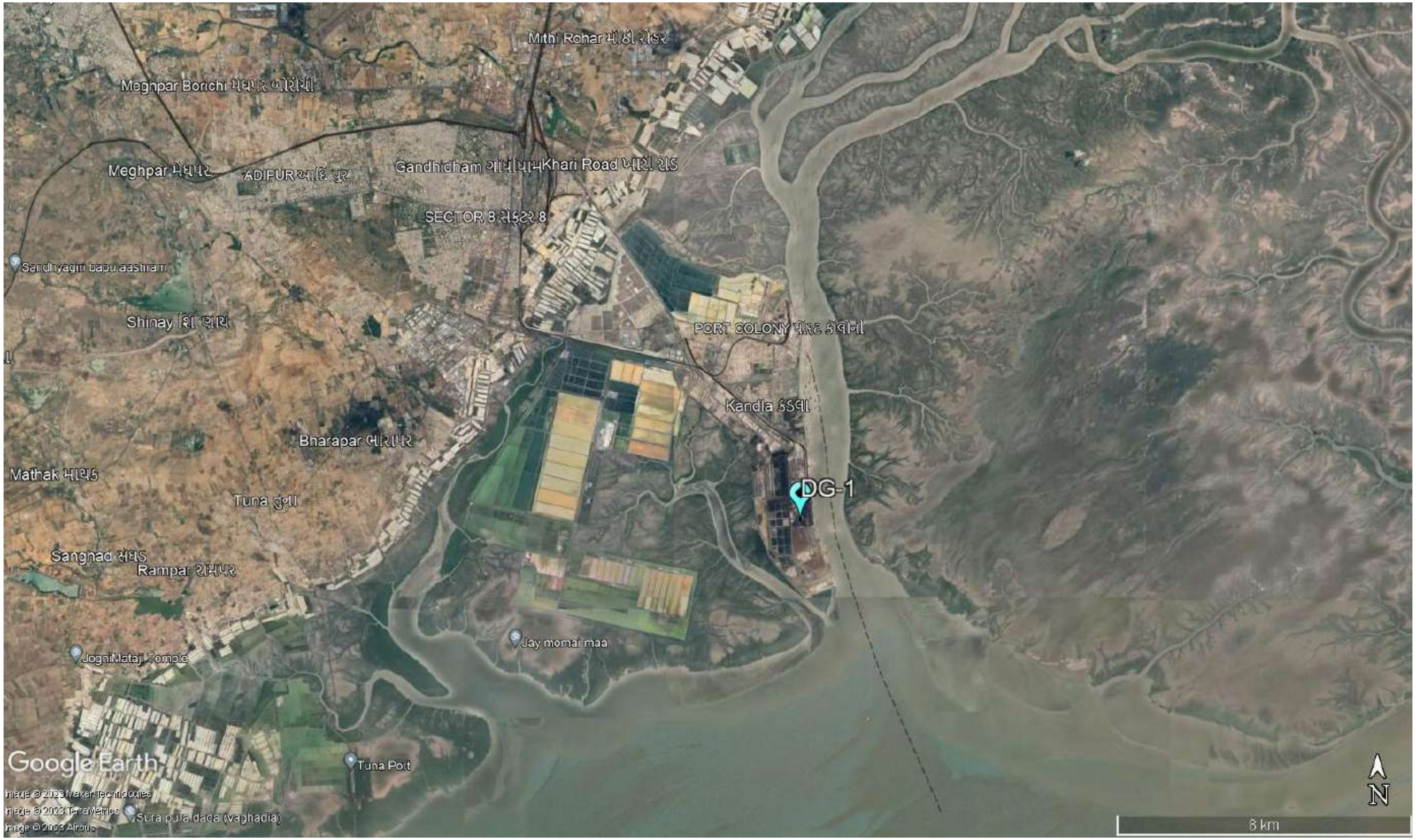
A diesel generator is a mechanical-electrical machine that produces electrical energy (electricity) from diesel fuel. They are used by the residential, commercial, charitable and governmental sectors to provide power in the event of interruption to the main power, or as the main power source. Diesel generating (DG) sets are generally used in places without connection to a power grid, or as an emergency power supply if the grid fails. These DG sets utilize diesel as fuel and generate and emit the air pollutants such as Suspended Particulate Matter, SO_2, NO_x, CO, etc. from the stack during its functioning. The purpose of stack sampling is to determine emission levels from plant processes to ensure they are in compliance with any emission limits set by regulatory authorities to prevent macro environmental pollution. The stack is nothing but chimney which is used to disperse the hot air at a great height, emissions & particulate matters that are emitted. Hence, monitoring of these stacks attached to DG Sets is necessary in order to quantify the emissions generated from it.

As defined in scope by DPA, the monitoring of DG Stack shall be carried out at two locations, one at Kandla and one at Vadinar. The details of the DG Sets at Kandla and Vadinar have been mentioned in **Table 10** as follows:

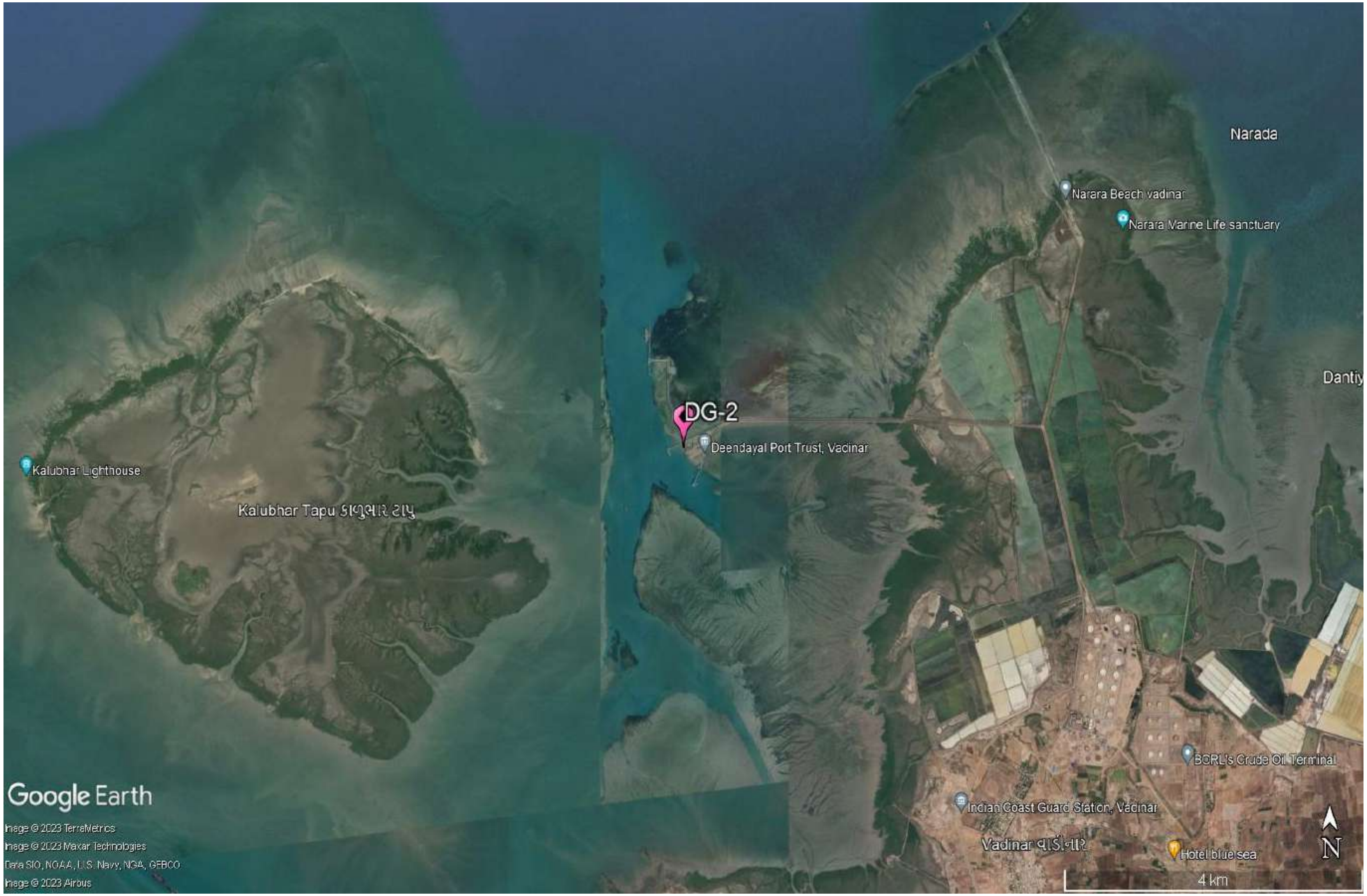
Table 10: Details of DG Stack monitoring locations

Sr. No.	Location Code	Location Name	Latitude/ Longitude
1.	DG-1	Kandla	22.98916N 70.22083E
2.	DG-2	Vadinar	22.44155N 69.67419E

The map depicting the locations of DG Stack Monitoring to be monitored in Kandla and Vadinar have been mentioned in **Map 6 and 7** as follows:



Map 6: Locations for DG Stack monitoring at Kandla



Map 7: Locations for DG Stack monitoring at Vadinar

Methodology:

Under the study, the list of parameters to be monitored under the projects for DG Stack Monitoring has been mentioned in **Table 11** as follows:

Table 11: DG stack parameters

Sr. No.	Parameter	Unit	Instrument
1.	Suspended Particulate Matter	mg/Nm^3	Stack Monitoring Kit
2.	Sulphur Dioxide (SO_2)	PPM	Sensor based Flue Gas Analyzer (Make: TESTO, Model 350)
3.	Oxides of Nitrogen (NO_x)	PPM	
4.	Carbon Monoxide	%	
5.	Carbon Dioxide	%	

The methodology for monitoring of DG Stack has been mentioned as follows:

The monitoring of DG Stack is carried out as per the IS:11255 and USEPA Method. The Stack monitoring kit is used for collecting representative samples from the stack to determine the total amount of pollutants emitted into the atmosphere in a given time. Source sampling is carried out from ventilation stack to determine the emission rates/or characteristics of pollutants. Sample collected must be such that it truly represents the conditions prevailing inside the stack. Whereas the parameters Sulphur Dioxide, Oxides of Nitrogen (NO_x), Carbon Monoxide and Carbon Dioxide, the monitoring is carried out by using the sensor-based Flue Gas Analyzer.

Frequency

Monitoring is required to be carried out once a month for both the locations of Kandla and Vadinar.

5.2 Result and Discussion

The sampling and monitoring of DG stack emission was carried out at Kandla and Vadinar and its comparison with CPCB or Indian standards for Industrial Stack Monitoring the flue gas emission from DG set has given in **Table 12.**

Table 12: DG monitoring data

Sr. No.	Stack Monitoring Parameters for DG Sets	Stack Monitoring Limits / Standards As per CPCB	DG- 1 (Kandla)	DG-2 (Vadinar)
1.	Suspended Particulate Matter (SPM) (mg/Nm^3)	150	70.23	34.65
2.	Sulphur Dioxide (SO_2) (PPM)	100	1.03	N.D.
3.	Oxides of Nitrogen (NO_x) (PPM)	50	23.46	13.25
4.	Carbon Monoxide (CO) (%)	1	0.23	0.03
5.	Carbon Dioxide (CO_2) (%)	-	1.12	1.33

5.3 Data Interpretation and Conclusion

The results of DG stack emission are compared with the permissible limits mentioned in the consent issued by GPCB, and have been found within the prescribed limit for all the monitored parameters.

CHAPTER 6: NOISE MONITORING

6.1 Noise Monitoring

Noise can be defined as an unwanted sound, and it is therefore, necessary to measure both the quality as well as the quantity of environmental noise in and around the study area. Noise produced during operation stage and the subsequent activities may affect surrounding environment impacting the fauna and as well as the human population. Under the scope, the noise monitoring is required to be carried out at 10 locations in Kandla and 3 locations in Vadinar. The sampling locations for noise are not only confined to commercial areas of DPA but also the residential areas of DPA.

The details of the noise monitoring stations are mentioned in **Table 13** and locations have been depicted in the **Map 8 and 9** as follow:

Table 13: Details of noise monitoring locations

Sr. No.	Location Code		Location Name	Latitude/ Longitude
1.	Kandla	N-1	Oil Jetty 7	23.043527N 70.218456E
2.		N-2	West Gate No.1	23.006771N 70.217340E
3.		N-3	Canteen Area	23.003707N 70.221331E
4.		N-4	Main Gate	23.007980N 70.222525E
5.		N-5	Main Road	23.005194N 70.219944E
6.		N-6	Marin Bhavan	23.007618N 70.222087E
7.		N-7	Port & Custom Building	23.009033N 70.222047E
8.		N-8	Nirman Building	23.009642N 70.220623E
9.		N-9	ATM Building	23.009985N 70.221715E
10.		N-10	Wharf Area/ Jetty	22.997833N 70.223042E
11.	Vadinar	N-11	Near Main Gate	22.441544N 69.674495E
12.		N-12	Near Vadinar Jetty	22.441002N 69.673147E
13.		N-13	Port Colony Vadinar	22.399948N 69.716608E

Map 8: Locations for Noise Monitoring at Kandla

Map 9: Locations for Noise Monitoring at Vadinar

Methodology:

The intensity of sound energy in the environment is measured in a logarithmic scale and is expressed in a decibel (dB(A)) scale. The ordinary sound level meter measures the sound energy that reaches the microphone by converting it into electrical energy and then measures the magnitude in dB(A). Whereas, in a sophisticated type of sound level meter, an additional circuit (filters) is provided, which modifies the received signal in such a way that it replicates the sound signal as received by the human ear and the magnitude of sound level in this scale is denoted as dB(A). The sound levels are expressed in dB(A) scale for the purpose of comparison of noise levels, which is universally accepted. Noise levels were measured using an integrated sound level meter of the make Envirotech Sound Level Meter (Class-I) (model No. SLM-109). It has an indicating mode of Lp and Leq. Keeping the mode in Lp for few minutes and setting the corresponding range and the weighting network in "A" weighting set the sound level meter was run for one-hour time and Leq was measured at all locations.

Frequency

Monitoring was carried out at each noise monitoring station for Leq. noise level (Day and Night), which was recorded for 24 hours continuously at a monthly frequency with the help of Sound/Noise Level Meter (Class-1). The details of the noise monitoring have been mentioned in **Table 14**.

Table 14: Details of the Noise Monitoring

Sr. No.	Parameters	Units	Reference Method	Instrument
1.	Leq (Day)	dB(A)	IS 9989: 2014	Noise Level Meter (Class-I) model No. SLM-109
2.	Leq (Night)	dB(A)		

Standard for Noise

Ministry of Environment & Forests (MoEF) has notified the noise standards vide the Gazette notification dated February 14, 2000 for different zones under the Environment Protection Act (1986). The day time noise levels have been monitored from 6.00 AM to 10.00 PM and night noise levels were measure from 10.00 PM to 6.00 AM at all the thirteen locations (10 at Kandla and 3 at Vadinar) monthly. The specified standards are as mentioned in **Table 15** as follows:

Table 15: Ambient Air Quality norms in respect of Noise

Area Code	Category of Area	Noise dB(A) Leq	
		Daytime	Night time
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

6.2 Result and Discussion

The details of the Noise monitoring conducted during the monitoring period have been summarized in the **Table 16** as below:

Table 16: The Results of Ambient Noise Quality

Sr. No.	Station Code	Station Name	Category of Area	Standard	Day Time			Standard	Night Time		
					Max.	Min.	Leq dB(A) Total		Max.	Min.	Leq dB(A) Total
1	N-1	Oil Jetty 7	A	75	55.8	42.5	49.4	70	41.7	34.2	45
2	N-2	West Gate No.1	A	75	61.4	46.2	53.9	70	47.5	41.2	46.2
3	N-3	Canteen Area	B	65	59.2	47.4	52.6	55	49.2	34.6	45.8
4	N-4	Main Gate	A	75	57.9	46.8	52	70	45.2	38.2	45.5
5	N-5	Main Road	A	75	56.2	45.6	50.9	70	43.2	36.2	45.1
6	N-6	Marin Bhavan	B	65	59.1	41.6	51.4	55	47.1	34.6	45.4
7	N-7	Port & Custom Building	B	65	56.2	40.3	49.5	55	45.1	37.4	45.2
8	N-8	Nirman Building	B	65	56.4	41.6	49.3	55	42.6	35.4	45.1
9	N-9	ATM Building	B	65	55.7	42.2	50.5	55	49.7	38.9	45.9
10	N-10	Wharf Area/ Jetty	A	75	58.6	41.2	51.6	70	48.7	36.2	45.5
11	N-11	Near Main Gate	A	75	63.5	54.2	58.8	70	54.3	43.8	49.0
12	N-12	Near Vadinar Jetty	A	75	62.4	56.9	59.8	70	54.7	49.4	52.0
13	N-13	Port Colony Vadinar	C	55	42.9	36.7	39.8	45	38.6	31.7	35.1

6.3 Data Interpretation and Conclusion

The noise level at both the locations (Kandla and Vadinar) was compared with the standard limits specified in NAAQS by CPCB. During the Day Time, the average noise level at all 10 locations at Kandla ranged from **40.3 dB(A) to 61.4 dB(A)**, while at Vadinar, he noises levels for the three-location ranged from **36.7 dB(A) to 63.5 dB(A).** Whereas, during Night Time the average Noise Level ranged from **34.2 dB(A) to 49.7 dB(A)** at Kandla and **31.7 dB(A) to 54.7 dB(A)** at Vadinar. In some locations at the Kandla site, spikes in noise levels were observed due to construction and demolition activities.

6.4 Remedial Measures

Though, the noise levels detected at the locations of Kandla and Vadinar, are found within the prescribed norms, the noise can further be considerably reduced by adoption of low noise equipment or installation of sound insulation fences. Green belt of plants can be a good barrier. If noise exceeds the applicable norms, then the working hours may be altered as a possible means to mitigate the nuisances of construction activities.

CHAPTER 7: SOIL MONITORING

7.1 Soil Quality Monitoring:

The purpose of soil quality monitoring is to track changes in the features and characteristics of the soil, especially the chemical properties of soil occurring at specific time intervals under the influence of human activity. Soil quality assessment helps to determine the status of soil functions and environmental risks associated with various practices prevalent at the location.

As defined in scope by Deendayal Port Authority (DPA), Soil Quality Monitoring shall be carried out at Six locations, four at Kandla and two at Vadinar. The details of the soil monitoring locations within the Port area of DPA are mentioned in **Table 17:**

Table 17: Details of the Soil quality monitoring

Sr. No.	Location Code		Location Name	Latitude Longitude
1.	Kandla	S-1	Oil Jetty 7	23.043527N 70.218456E
2.		S-2	IFFCO Plant	23.040962N 70.216570E
3.		S-3	Khori Creek	22.970382N 70.223057E
4.		S-4	Nakti Creek	23.033476N 70.158461E
5.	Vadinar	S-5	Near SPM	22.400026N 69.714308E
6.		S-6	Near Vadinar Jetty	22.440759N 69.675210E

Methodology

As per the defined scope by Deendayal Port Authority (DPA), the sampling and analysis of Soil quality has been carried out on monthly basis.

The samples of soil collected from the locations of Kandla and Vadinar and analyzed for the various physico-chemical parameter. Collection and analysis of these samples was carried out as per established standard methods and procedures. The samples were analyzed for selected parameters to get the present soil quality status and environmental risks associated with various practices prevalent at the location. GEMI has framed its own guidelines for collection of soil samples titled as ***'Soil Sampling Manual'***. Soil samples were collected from 30 cm depth below the surface using scrapper, filled in polythene bags, labelled on-site with specific location code and name and sent to GEMI's laboratory, Gandhinagar for further detailed analysis. The samples collected from all locations are homogeneous representative of each location. The list of parameters to be monitored under the projects for the Soil Quality Monitoring been mentioned in **Table 18** as follows:

Frequency

Monitoring is required to be carried out once a month for both the locations of Kandla and Vadinar.

Table 18: Soil parameters

Sr. No.	Parameters	Units	Reference method	Instruments
1.	TOC	%	Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934)	Titration Apparatus
2.	Organic Carbon	%		
3.	Inorganic Phosphate	Kg/Hectare	Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017 Determination of Available Phosphorus in Soil	UV-Visible Spectrophotometer
4.	Texture	-	Methods Manual Soil Testing in India January 2011,01	Hydrometer
5.	pH	-	IS 2720 (Part 26): 1987	pH Meter
6.	Conductivity	µS/cm	IS 14767: 2000	Conductivity Meter
7.	Particle size distribution & Silt content	-	Methods Manual Soil Testing in India January 2011	Sieves Apparatus
8.	SAR	meq/L	Procedures for Soil Analysis, International Soil Reference and Information Centre, 6th Edition 2002 13-5.5.3 Sodium Absorption Ratio (SAR), Soluble cations	Flame Photometer
9.	Water Holding Capacity	%	NCERT, Chapter 9, 2022-23 and Water Resources Department Laboratory Testing Procedure for Soil & Water Sample Analysis	Muffle Furnace
10.	Aluminium	mg/Kg	EPA Method 3051A	ICP-OES
11.	Chromium	mg/Kg		
12.	Nickel	mg/Kg		
13.	Copper	mg/Kg	Methods Manual Soil Testing in India January, 2011, 17a	
14.	Zinc	mg/Kg	Methods Manual Soil Testing in India January, 2011, 17a	
15.	Cadmium	mg/Kg	EPA Method 3051A	
16.	Lead	mg/Kg		
17.	Arsenic	mg/Kg		
18.	Mercury	mg/Kg		

The map depicting the locations of Soil Quality Monitoring to be monitored in Kandla and Vadinar have been mentioned in **Map 10 and 11** as follows:

Map 10: Locations for Soil Quality Monitoring at Kandla

Map 11: Locations for Soil Quality Monitoring at Vadinar

7.2 Result and Discussion

The analysis results of physical analysis of the soil samples collected during environmental monitoring mentioned in **Table 19** are shown below:

Table 19: Soil Quality for the sampling period

Sr. No	Location / Parameters	Unit	Kandla				Vadinar	
			S-1 (Oil Jetty 7)	S-2 IFFCO Plant)	S-3 (Khori Creek)	S-4 (Nakti Creek)	S-5 (Near SPM)	S-6 (Near Vadinar Jetty)
1	pH	-	9.21	8.85	9.23	8.33	8.16	8.45
2	Conductivity	µS/cm	6548	4265	654	9578	155	298
3	Inorganic Phosphate	Kg/ha	1.26	0.88	1.68	1.1	0.24	0.18
4	Organic Carbon	%	0.26	0.44	0.44	0.28	0.65	0.56
5	Organic Matter	%	0.33	0.56	1.1	0.47	0.72	0.26
6	SAR	meq/L	8.56	9.12	1.35	13.25	0.16	0.2
7	Aluminium	mg/Kg	13562.26	10255.68	6587.16	12365.33	28563.35	21472.38
8	Chromium	mg/Kg	65.32	55.21	45.16	60.25	82.14	55.21
9	Nickel	mg/Kg	31.26	27.54	18.62	22.15	28.54	25.11
10	Copper	mg/Kg	45.21	55.47	32.51	42.13	66.21	72.14
11	Zinc	mg/Kg	53.33	60.21	22.14	42.18	42.15	59.21
12	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	3.65	2.11	4.21	6.25	0.55	0.29
14	Arsenic	mg/Kg	0.2	0.07	1.01	2.12	BQL	BQL
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	60.13	50.24	38.52	51.23	55.12	62.54
17	Sand	%	32.08	57.51	62.12	48.21	66.21	69.57
18	Silt	%	42.31	38.23	33.36	23.14	26.14	28.21
19	Clay	%	25.61	4.26	4.52	28.65	7.65	2.22
20	Texture	-	slit sandy	Sandy loam	sandy loam	Loam	sandy loam	Sandy loam

7.3 Data Interpretation and Conclusion

Soil samples were collected from 6 locations (4 at Kandla and 2 at Vadinar) and further analysed for its physical & chemical characteristics. Each of the parameters have been given an interpretation based on the observations as follows:

- The value of **pH** ranges from **8.21 to 9.23,** highest at location S-3 (Khori Creek) and lowest at S-4 (Nakti Creek); while the average pH for Kandla was observed to be **8.905**.

Whereas, at Vadinar the pH value observed at S-5 i.e., **Near SPM (8.16)** and at S-6 i.e., **Near Jetty Area (8.45).** As per the observation the pH was found to be **moderately to strongly alkaline** both the monitoring station of Kandla and Vadinar**.**

- At entire monitoring locations of Kandla the value of **Electrical Conductivity** ranges from **654-9578 µs/cm**, highest at location S-4 (Nakti Creek) with the average as 5261.25 **µs/cm**. Whereas, at Vadinar the range of conductivity was between the range of **155 to 298 µs/cm** with an average value of 226.5 **µs/cm**.

- At Kandla, the concentration of **Inorganic Phosphate** varied from **0.88-1.68 Kg/ha**, with average **1.23 Kg/ha**. Whereas, at the locations of Vadinar, the Inorganic Phosphate was observed at S-5 i.e., Near SPM (**0.24 Kg/ha**) and detected at S-6 i.e., near Jetty Area (**0.18 Kg/ha**). The phosphorus availability in soil solution is influenced by a number of factors such as Organic matter, clay content, pH, temperature, etc.

- The concentration of **Total Organic Carbon** ranges from **0.26 to 0.44 %** while the average TOC at Kandla was detected as **0.35 %.** Whereas, at Vadinar the average TOC was found to be **0.60%** where the observed TOC value found at S-5 i.e. Near SPM (**0.65%**) and S-6 i.e. near Jetty Area to be **0.56 %** respectively.

- The concentration of **Water Holding Capacity** in the soil samples of Kandla and Vadinar varies from **38.52-60.13 %** and **55.12-62.54 %** respectively.

- The concentration of **Sodium Adsorption Ratio** ranges from **1.35–13.25 meq/L** with an average value **8.07 meq/L** at Kandla. Whereas, at Vadinar, the concentration of Sodium Adsorption Ratio ranges from 0.16 to 0.20 **meq/L** with an average SAR was found to be **0.18 meq/L**. A component of conductivity is the SAR. A high SAR indicates a large concentration of sodium ions in the soil, which raises conductivity.

Sandy loam, loamy sand, and silty sand were the soil textures observed at all the monitoring locations of Kandla and Vadinar.

Heavy Metals

For the sampling period, the concentration of **Aluminium** varied from **6587.16 to 13562.26 mg/kg** at Kandla and **21472.38 to 28563.35 mg/kg** at Vadinar and the average value was observed to be **10692.61 and 25017.87 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Chromium** varied from **45.16 to 65.32 mg/kg** at Kandla and **55.21 to 82.14 mg/kg** at Vadinar and the average value was observed to be **56.48 and 68.67 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Nickel** varied from **18.62 to 31.26 mg/kg** at Kandla and **25.11 to 28.54 mg/kg** at Vadinar and the average value was observed to be **24.89 and 26.82 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Zinc** varied from **22.14 to 60.21 mg/kg** at Kandla and **42.15 to 59.21 mg/kg** at Vadinar and the average value was observed to be **44.46 and 50.68 mg/kg** at Kandla and Vadinar monitoring station, respectively

- The concentration of **copper** varied from **32.51 to 55.47 mg/kg** at Kandla and **66.21 to 72.14 mg/kg** at Vadinar and the average value was observed to be **43.83 and 69.17 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Arsenic** varied from 0.07 **to 2.12 mg/kg** at Kandla and the average value was observed to be **0.85** at Kandla while at Vadinar the average value was observed to be **BQL**.

- The concentration of **Lead** varied from **2.11 to 6.25 mg/kg** at Kandla and the average value was observed to be **4.05** at Kandla while at Vadinar the average value was observed to be **0.42 mg/kg**.

- While other heavy metals in the Soil i.e., **Mercury, Cadmium** were observed "Below Quantification Limit" for majority of the soil samples collected at Kandla and Vadinar.

CHAPTER 8: DRINKING WATER MONITORING

8.1 Drinking Water Monitoring

It is necessary to check with the drinking water sources regularly so as to know whether water quality conforms to the prescribed standards for drinking. Monitoring the drinking water quality is essential to protect human health and the environment. With reference to the scope specified by DPA, a total of 20 locations (18 at Kandla and 2 at Vadinar) were monitored to assess the Drinking Water quality. The DW-2 location was replaced by Shramdeep due to demolition of past sampling location (port & custom building)

The details of the drinking water sampling stations have been mentioned in **Table 20** and the locations have been depicted through Google map in **Map 12 and 13.**

Table 20: Details of Drinking Water Sampling Locations

Sr. No.	Location Code		Location Name	Latitude/ Longitude
1.	Kandla	DW-1	Oil Jetty 7	23.043527N 70.218456E
2.		DW-2	Shramdeep	23.009631N, 70.220877E
3.		DW-3	North Gate	23.007938N 70.222411E
4.		DW-4	Workshop	23.009372N 70.222236E
5.		DW-5	Canteen Area	23.003707N 70.221331E
6.		DW-6	West Gate 1	23.006771N 70.217340E
7.		DW-7	Sewa Sadan -3	23.009779N 70.221838E
8.		DW-8	Nirman Building	23.009642N 70.220623E
9.		DW-9	Custom Building	23.018930N 70.214478E
10.		DW-10	Port Colony Kandla	23.019392N 70.212619E
11.		DW-11	Wharf Area/ Jetty	22.997833N 70.223042E
12.		DW-12	Hospital Kandla	23.018061N 70.212328E
13.		DW-13	A.O. Building	23.061914N 70.144861E
14.		DW-14	School Gopalpuri	23.083619N 70.132061E
15.		DW-15	Guest House	23.078830N 70.131008E
16.		DW-16	E- Type Quarter	23.083306N 70.132422E
17.		DW-17	F- Type Quarter	23.077347N 70.135731E
18.		DW-18	Hospital Gopalpuri	23.081850N 70.135347E
19.	Vadinar	DW-19	Near Vadinar Jetty	22.440759N 69.675210E
20.		DW-20	Near Port Colony	22.401619N 69.716822E

Map 12: Locations for Drinking Water Monitoring at Kandla

Map 13: Locations for Drinking Water Monitoring at Vadinar

Methodology

The water samples were collected from the finalized sampling locations and analysed for physico-chemical and microbiological parameter, for which the analysis was carried out as per APHA, 23rd Edition and Indian Standard method in GEMI's NABL Accredited Laboratory, Gandhinagar. GEMI has followed the CPCB guideline as well as framed its own guidelines for the collection of water/wastewater samples, under the provision of Water (Preservation and Control of Pollution) Act 1974, titled as '**Sampling Protocol for Water & Wastewater**'; approved by the Government of Gujarat vide letter no. ENV-102013-299-E dated 24-04-2014. The samples under the study were collected and preserved as per the said Protocol. The parameters finalized to assess the drinking water quality have been mentioned in **Table 21** as follows:

Table 21: List of parameters for Drinking Water Quality monitoring

Sr. No.	Parameters	Units	Reference method	Instrument
1.	pH	-	APHA, 23rd Edition (Section-4500-H^+B):2017	pH Meter
2.	Colour	Hazen	APHA, 23rd Edition, 2120 B:2017	Color Comparator
3.	EC	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
4.	Turbidity	NTU	APHA, 23rd Edition (Section -2130 B):2017	Nephlo Turbidity Meter
5.	TDS	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with filtration assembly and Oven
6.	TSS	mg/L	APHA, 23rd Edition, 2540 D: 2017	
7.	Chloride	mg/L	APHA, 23rd Edition (Section-4500-Cl-B):2017	Titration Apparatus
8.	Total Hardness	mg/L	APHA, 23rd Edition (Section-2340 C):2017	
9.	Ca Hardness	mg/L	APHA, 23rd Edition (Section-3500-Ca B):2017	
10.	Mg Hardness	mg/L	APHA, 23rd Edition (Section-3500-Mg B):2017	
11.	Free Residual Chlorine	mg/L	APHA 23rd Edition, 4500	
12.	Fluoride	mg/L	APHA, 23rd Edition (Section-4500-F-D):2017	UV- Visible Spectrophotometer
13.	Sulphate	mg/L	APHA, 23rd Edition (Section 4500-SO4-2-E):2017	
14.	Sodium	mg/L	APHA, 23rd Edition (Section-3500-Na-B):2017	Flame Photometer
15.	Potassium	mg/L	APHA,23rd Edition, 3500 K-B: 2017	
16.	Salinity	mg/L	APHA, 23rd Edition (section 2520 B, E.C. Method)	Salinity /TDS Meter
17.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3- B: 2017	UV- Visible Spectrophotometer

Sr. No.	Parameters	Units	Reference method	Instrument
18.	Nitrite	mg/L	APHA, 23rd Edition, 4500 NO2-B: 2017	
19.	Hexavalent Chromium	mg/L	APHA, 23rd Edition, 3500 Cr B: 2017	
20.	Manganese	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES
21.	Mercury	mg/L	EPA 200.7	
22.	Lead	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
23.	Cadmium	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
24.	Iron	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
25.	Total Chromium	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
26.	Copper	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES
27.	Zinc	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
28.	Arsenic	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
29.	Total Coliforms	MPN/ 100ml	IS 15185: 2016	LAF/ Incubator

8.2 Result and Discussion

The drinking water quality of the locations at Kandla and Vadinar and its comparison with the to the stipulated standard (Drinking Water Specifications i.e., IS: 10500:2012) have been summarized in **Table 22** as follows:

Table 22: Summarized results of Drinking Water quality

Sr. No.	Parameters	Units	Standard values as per IS		Kandla																		Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
1.	pH	-	**6.5-8.5**	**-**	7.55	7.92	7.50	7.62	7.42	7.36	7.22	7.56	7.12	6.56	7.01	6.95	7.21	7.54	6.92	7.26	7.30	7.15	6.94	7.36
2.	Colour	Hazen	**5**	**15**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.	EC	µS/ cm	-	-	238	20.3	32.6	26.5	40.2	65.8	29.4	36.6	75.4	132.3	155.4	125.8	55.4	49.7	142	16.3	29.7	96.5	232	75.2
4.	Salinity	PSU	-	-	0.16	0.05	0.03	0.03	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.06	0.03	0.02	0.08	0.03	0.03	0.05	0.15	0.02
5.	Turbidity	NTU	**1**	**5**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
6.	Chloride	mg/L	**250**	**1000**	45.63	3.56	10.25	16.24	8.45	15.27	8.13	9.34	22.36	29.57	40.23	29.37	20.13	16.44	36.36	11.05	13.25	25.27	42.45	13.25
7.	Total Hardness	mg/L	**200**	**600**	6	BQL	5	5.5	6	8	3	2.5	5	18	18	23	2.5	3.5	18	BQL	2	6	132	20
8.	Ca Hardness	mg/L	**-**	**-**	2	BQL	3	3.5	3.5	6	2.5	1.5	2	10	9	12	1.5	3	8	BQL	1	4	67	9
9.	Mg Hardness	mg/L	**-**	**-**	4	BQL	2	2	2.5	2	BQL	1	3	8	9	11	1	BQL	10	BQL	BQL	2	65	11
10.	Free Residual Chlorine	mg/L	**0.2**	**1**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
11.	TDS	mg/L	**500**	**2000**	132	12	16	18	20	31	15	17	32	52	82	62	26	30	74	18	21	60	180	38
12.	TSS	mg/L	**-**	**-**	BQL	BQL	4	BQL	BQL	BQL	BQL	3	BQL	BQL	4	BQL	BQL	3	BQL	BQL	1	BQL	BQL	BQL
13.	Fluoride	mg/L	**1.0**	**1.5**	0.42	BQL	0.39	BQL	0.41	0.25	0.31	BQL	0.42	0.38	0.39	0.35	0.26	0.31	0.394	0.39	0.30	0.31	0.65	0.29
14.	Sulphate	mg/L	**200**	**400**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	21.25	BQL
15.	Nitrate	mg/L	**45**	**-**	7.65	BQL	BQL	BQL	BQL	BQL	BQL	BQL	1.54	BQL	BQL	BQL	1.10	BQL	BQL	BQL	BQL	BQL	1.65	BQL
16.	Nitrite	mg/L	**-**	**-**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17.	Sodium	mg/L	**-**	**-**	36.21	BQL	2.12	3.95	1.92	1.85	1.24	2.21	3.62	4.11	4.23	6.54	4.69	3.12	9.52	1.02	1.52	3.67	19.54	BQL
18.	Potassium	mg/L	**-**	**-**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

Sr. No.	Parameters	Units	Standard values as per IS		Kandla																		Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
19.	Hexavalent Chromium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	TON	**Agreeable**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	**0.01**	**0.05**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	**0.003**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	**0.05**	**1.5**	BQL	BQL	0.010	BQL	0.005	BQL	BQL	BQL	0.004	0.020	0.004	0.018	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.011
24.	Iron	mg/L	**0.3**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
25.	Lead	mg/L	**0.01**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
26.	Manganese	mg/L	**0.1**	**0.3**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
27.	Mercury	mg/L	**0.001**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
28.	Total Chromium	mg/L	**0.05**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Zinc	mg/L	**5**	**15**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Total Coliform*	MPN/ 100ml	**Shall not be detected**		60	20	50	BQL	BQL	100	BQL	80	BQL	BQL	30	BQL	15	BQL	BQL	40	BQL	BQL	BQL	40

A: Acceptable, P:Permissible, BQL: Below Quantification limit; Turbidity (QL=0.5 NTU), Free Residual Chlorine (QL=2 mg/L), Total Suspended Solids (QL=2 mg/L), Fluoride (QL=0.3 mg/L), Sulphate (QL=10 mg/L), Nitrate as NO_3 (QL=1 mg/L), Nitrite as NO_2 (QL=0.1mg/L), Sodium as Na (QL=5mg/L), Potassium as K (QL=5mg/L), Hexavalent Chromium (QL=0.01 mg/L), Arsenic (QL=0.005 mg/L), Cadmium (QL=0.002 mg/L), Copper (QL=0.005 mg/L), Iron (QL=0.1mg/L), Lead (QL=0.002 mg/L), Manganese (QL=0.04 mg/L), Mercury (QL=0.0005 mg/L), Total Chromium (QL=0.005 mg/L), Zinc (QL=0.5 mg/L), Total Coliforms (QL=1 MPN/ 100ml)

AQL: Above Quantification Limit; Total Coliforms (QL=1000000)

*Note: For Total Coliform, one MPN is equivalent to one CFU. The use of either method; MPN or CFU for the detection of bacteria are considered valid measurements for bacteria limits.

8.3 Data Interpretation and Conclusion

Drinking water samples were taken at 20 locations (18 at Kandla and 2 at Vadinar), and their physical and chemical properties were analyzed. The analysis's results were compared with standard values as prescribed in IS 10500:2012 Drinking Water Specification.

- **pH:** The pH values of drinking water samples in Kandla were reported to be in the range of **6.56 to 7.92** with an average pH of **7.28.** In Vadinar, its values ranged from **6.94 to 7.36,** with an average pH of **7.15.** remarkably, the pH values at project locations are within the permissible range of 6.5 to 8.5 specified under IS: 10500:2012.
- **Colour:** The value of Color in Drinking water sample at Kandla is found to be **1 Hazen** in each sample. In Vadinar the Color value is found to be **1 Hazen** in both the locations.
- **Turbidity:** At the drinking water locations of Kandla & Vadinar, the turbidity was reported **BQL** for All the monitoring location.
- **Total Dissolved Solids (TDS):** Monitoring TDS is crucial because it provides an indication of overall quality of the water. During the monitoring period, the TDS concentrations in Kandla were observed to vary in a wide range i.e., between **12 to 132 mg/L,** with an average concentration of **39.88 mg/L**. while in Vadinar, it ranged from **38 to 180 mg/L,** with average at **109 mg/L.**
  It is important to note that the TDS concentrations in both Kandla and Vadinar fall well within the acceptable limit of 500 mg/L.
- **Electrical Conductivity (EC):** It is a measure of the ability of a solution to conduct electric current, and it is often used as an indicator of the concentration of dissolved solids in water. During the monitoring period, the EC values for samples collected in Kandla were observed to range from **16.3 to 238 µS/cm**, with an average value of **75.99 µS/cm**. In Vadinar, the EC values showed variation from **75.2 to 232 µS/cm,** with an average value of **153.60 µS/cm**. It's important to regularly monitor EC levels in drinking water as it can provide valuable information about water quality and presence of dissolved substances.
- **Chlorides:** The concentrations in the drinking water samples collected from Kandla and Vadinar were within acceptable limits, as specified by the BIS. The chloride in Kandla varied from **3.56 to 45.63 mg/L**, with an average value of **20.05 mg/L**. In Vadinar, it ranged from **13.25 to 42.45 mg/L**, with an average value of **27.85 mg/L.** It's important to note that all the recorded chloride concentrations in both Kandla and Vadinar were well below the acceptable limit of 250 mg/L.
- **Total Hardness (TH):** Total Hardness varied from **2 to 23 mg/L**, with the average value as **8.25 mg/L**. While at Vadinar, the variation was observed from **20 to 132 mg/L**; with the average conc. at **76 mg/L**. It's important to note that all the recorded chloride concentrations in both Kandla and Vadinar were well below the acceptable limit of 200 mg/L.
- **Sulphate:** During monitoring period in Kandla and Vadinar, the sulphate concentrations were found to be within the acceptable limits i.e., 200 mg/L as per the specified norms. In Kandla, the sulphate concentrations Was found to be **Below Quantification Limit** at all Monitoring locations. In Vadinar, the sulphate

concentration was observed at DW-19 is **21.25 mg/L &** DW-20 is **Below Quantification Limit.**

- **Sodium:** During the monitoring period, at Kandla variation in the concentration of sulphate was observed to be in the range of **1.02 to 36.21 mg/L**, with the average concentration of **5.38 mg/L**. While at Vadinar, the Sodium concentration was Observed to be in range of **BQL to 19.54 mg/L**, with the average Concentration of **19.54 mg/L.**
- **Nitrate:** During the monitoring period, at Kandla & Vadinar variation in the concentration of Nitrate was observed to be in the range of **1.10 to 7.65 mg/L**, with the average concentration of **3.43 mg/L** also majority of the location recorded as "**BQL".** While at Vadinar, the concentration was observed at DW-19 is **1.658 mg/L &** DW-20 is **Below Quantification Limit.**
- **Fluoride:** The concentration was found to be in the range of **0.253 to 0.421** mg/**L** with an average concentration of **0.354 mg/L** at all the monitoring location at Kandla. While at Vadinar the concentration was found to be in the range of **0.298 to 0.658 mg/L** with an average concentration of **0.48 mg/L** for both the monitoring location.
- **Nitrite:** The Concentration was found to be **BQL** in all the monitoring location at Kandla. While at Vadinar its value also reported to be BQL for both the Monitoring location.
- **Iron:** The Concentration was found to be **BQL** in all of the monitoring location for location at Kandla While at Vadinar, the Concentration recorded as Below Quantification Limit.
- **Copper:** During the monitoring period, at Kandla variation in the concentration of copper was observed to be in the range of **0.004 to 0.020 mg/L**, with the average concentration of **0.010 mg/L**. While at Vadinar, the concentration was observed at DW-19 is **Below Quantification limit &** DW-20 is **0.011**
- **TSS:** The Concentration was found to be **BQL** in most of the monitoring location except for location DW-3 (North Gate) i.e. 4 mg/L, DW-8 (Nirman Building) i.e. 3 mg/L and DW-11 (Wharf Jetty Area) i.e. 4 mg/L and more locations at Kandla. While at Vadinar, the Concentration was observed at DW-19 & DW-20 is **Below Quantification limit.**
- **Free Residual Chlorine:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration recorded at both location is found Below Quantification Limit.
- **Lead:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla. While at Vadinar, the Concentration recorded as Below Quantification Limit at all the Monitoring locations.
- **Potassium:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration was found to be BQL in both Location.
- **Manganese:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration was found to be BQL in both Location.
- **Zinc:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration was found to be BQL in both Location.

- **Arsenic:** The concentration was found to be **Below Quantification Limit** in all of the Monitoring Location at Kandla. While at Vadinar was Observed **Below Quantification Limit** at both the locations.
- The parameters such **as Hexavalent Chromium**, and **the metals Arsenic, Cadmium, Total Chromium** were all observed to have concentrations "Below the Quantification Limit (BQL)" at majority of the locations during the monitoring period.
- **Total Coliforms:** During the monitoring period, at Kandla variation in the concentration of Total coliform was observed to be in the range of **BQL to 100 MPN/100ml**. While at Vadinar, the concentration recorded at DW-19 is **Below Quantification Limit** and at DW-20 is **40 MPN/100ml.**

8.4 Remedial Measures

Appropriate water treatment processes should be administered to eradicate coliform bacteria. The methods of disinfection such as **chlorination, ultraviolet (UV), or ozone** etc, apart from that, filtration systems can also be implemented to remove bacteria, sediment, and other impurities.

The following steps can be implemented to ensure that the water being supplied is safe for consumption:

- Regular monitoring should be carried out to assess the quality of drinking water at various stages, including the source, purification plants, distribution network, and consumer endpoints would help in early detection of coliform bacteria or other contaminants in the drinking water.
- It is necessary to carry out a system assessment to determine whether the drinking-water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets identified targets. This also includes the assessment of design criteria of the treatment systems employed.
- Identifying control measures in a drinking-water system that will collectively control identified risks and ensure that the health-based targets are met. For each control measure identified, an appropriate means of operational monitoring should be defined that will ensure that any deviation from required performance (water quality) is rapidly detected in a timely manner.
- Management and communication plan should be formulated describing actions to be taken during normal operation as well as during incident conditions (such as drinking water contamination) and documenting the same.

CHAPTER 9: SEWAGE TREATMENT PLANT MONITORING

9.1 Sewage Treatment Plant (STP) Monitoring:

The principal objective of STP is to remove contaminants from sewage to produce an effluent that is suitable to discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. As defined in the scope by Deendayal Port Authority (DPA), Kandla, the STP Monitoring is to be carried out weekly at three locations, one at Kandla, one at Gopalpuri and one STP at Vadinar. The samples from the inlet and outlet of the STP have been collected weekly. The details of the locations of STP to be monitored for Kandla and Vadinar have been mentioned in **Table 23** as follows:

Table 23: Details of the monitoring locations of STP

Sr. No.	Location Code		Location Name	Latitude Longitude
1.	Kandla	STP-1	STP Kandla	23.021017N 70.215594E
2.		STP-2	STP Gopalpuri	23.077783N 70.136759E
3.	Vadinar	STP-3	STP at Vadinar	22.406289N 69.714689E

The Consolidated Consent and Authorization (CC&A) issued by the GPCB were referred for the details of the STP for Kandla and Gopalpuri. The CC&A of Kandla and Gopalpuri entails that the treated domestic sewage should conform to the norms specified in **Table 24**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

Table 24: Treated effluent Standards (as per CC&A of Kandla STP)

Sr. No.	Parameters	Prescribed limits
1.	pH	6.5-8.5
2.	BOD (3 days at 27°C)	30 mg/L
3.	Suspended Solids	100 mg/L
4.	Fecal Coliform	< 1000 MPN/100 ml

The detailed process flow diagram of the Kandla and Gopalpuri STP have been mentioned in **Figure 3 and 4** as follows:

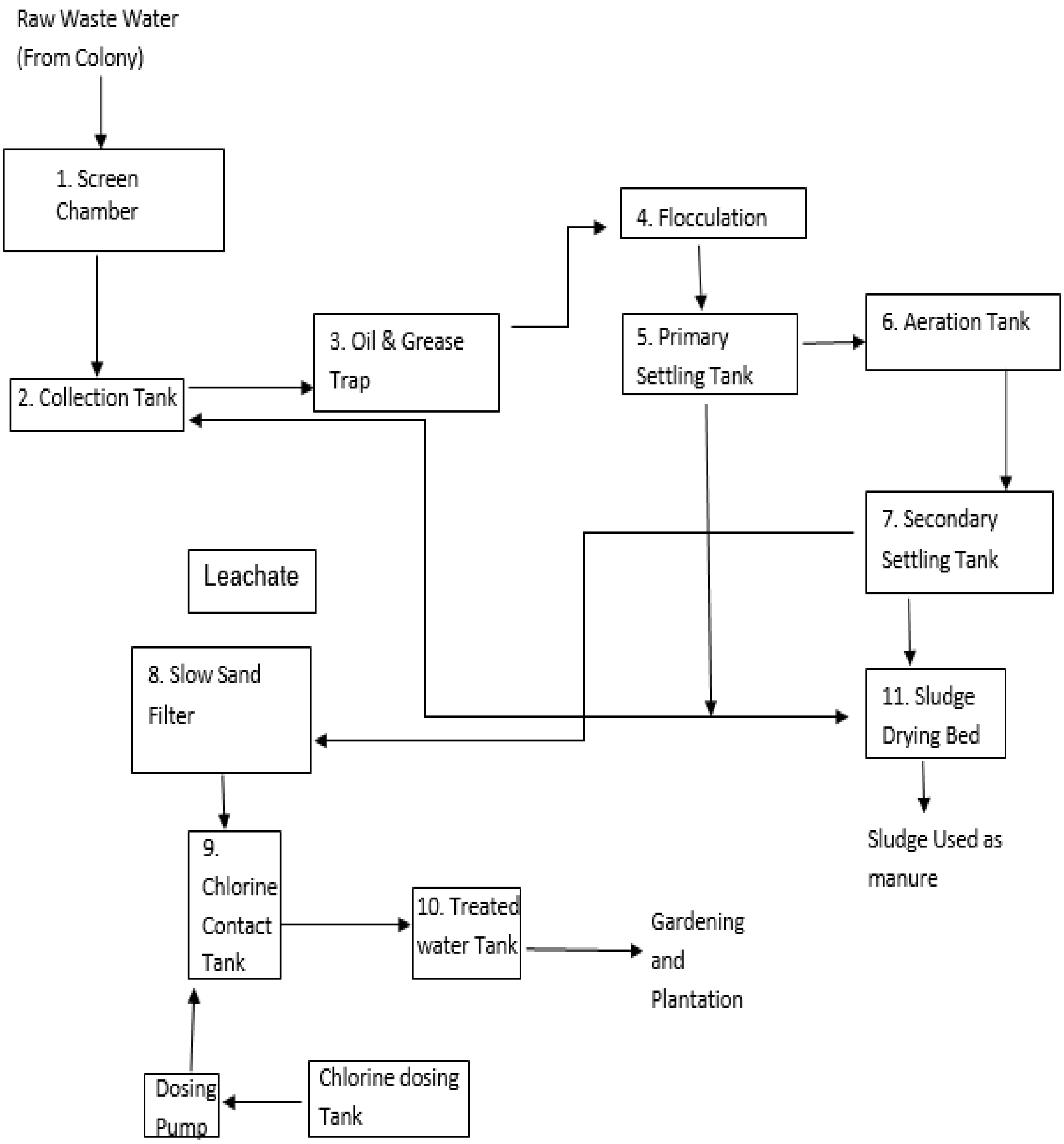


Figure 3: Process flow diagram of STP at Kandla

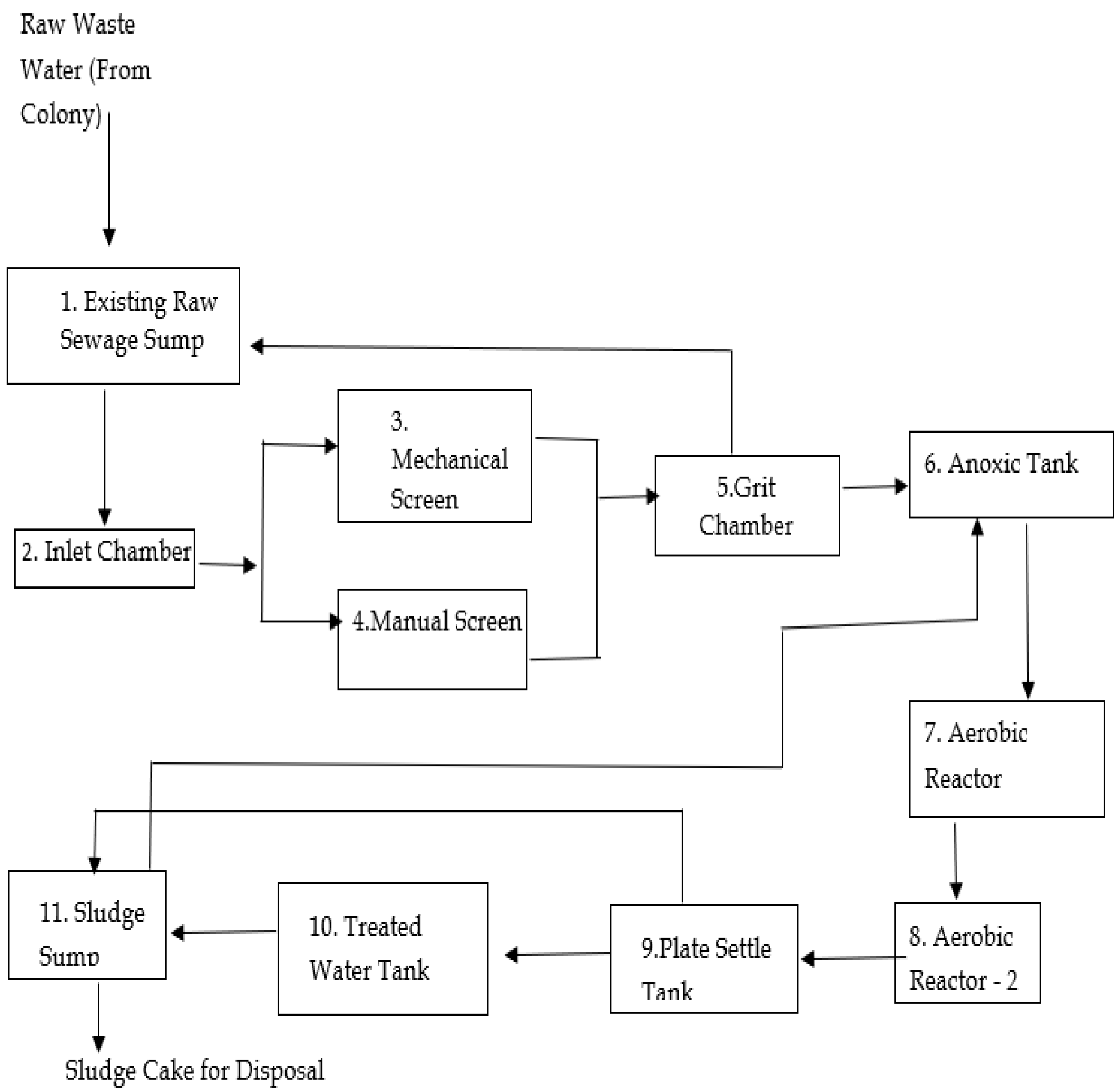


Figure 4: Process flow diagram of STP at Gopalpuri

STP at Vadinar

The STP at Vadinar has been built with a treatment capacity of 450 KLD/day. The Consolidated Consent and Authorization (CC&A) issued by the GPCB has been referred for the details of the said STP. The CC&A of the Vadinar STP suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 25**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

Table 25: Norms of treated effluent as per CC&A of Vadinar STP

Sr. No.	Parameters	Prescribed limits
1.	pH	5.5-9
2.	BOD (3 days at 27°C)	10 mg/L
3.	Suspended Solids	20 mg/L
4.	Fecal Coliform	Desirable 100 MPN/100 ml Permissible 230 MPN/100 ml
5.	COD	50 mg/L

The detailed process flow diagram of the Vadinar STP have been mentioned in **Figure 5** as follows:

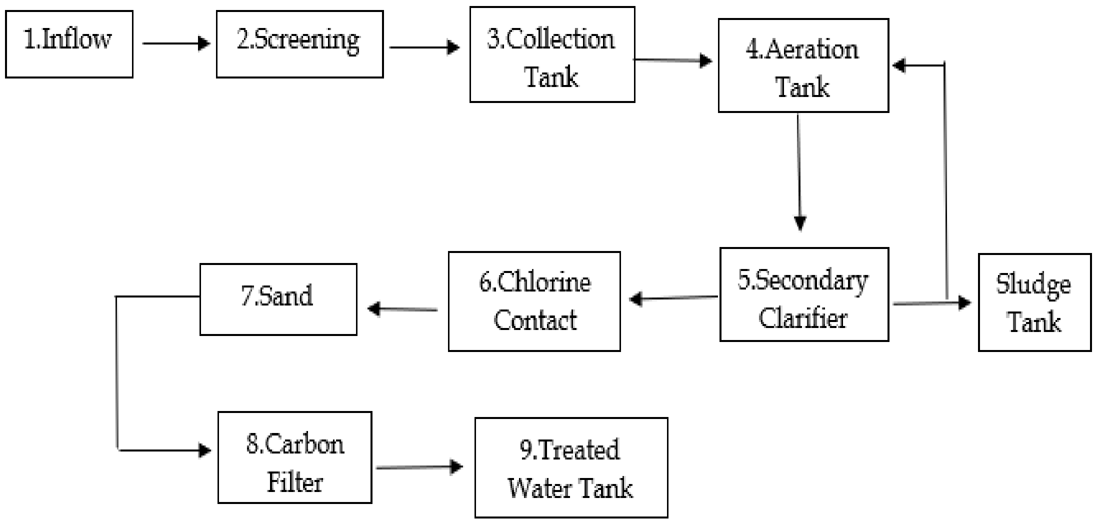
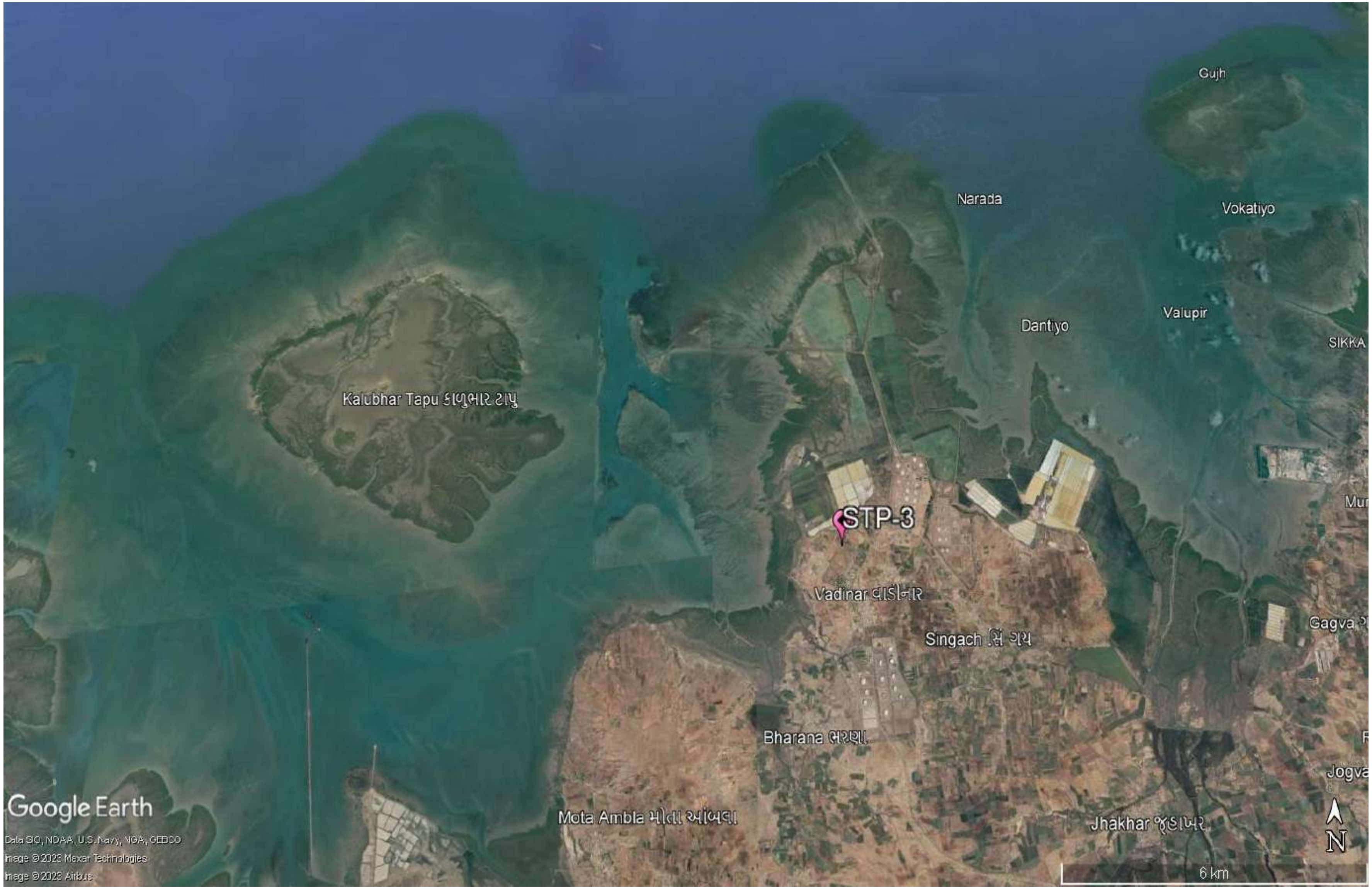


Figure 5: Process flowchart for the STP at Vadinar

The map depicting the locations of STP to be monitored in Kandla and Vadinar have been shown in **Map 14 and 15** as follows:

Map 14: Locations for STP Monitoring at Kandla



Map 15: Locations for STP Monitoring at Vadinar

Methodology

As per the defined scope by DPA, the sampling and analysis of water samples from the inlet and outlet of the STP's of Kandla and Vadinar are carried out once a week, i.e., four times a month.

The water samples were collected from inlet and the outlet of the STP's and analyzed for physico-chemical and microbiological parameter. Collection and analysis of these samples was carried out as per established standard methods and procedures for the examination of water. The samples were analyzed for selected parameters to establish the existing water quality of the inlet and outlet points of the STP. GEMI has framed its own guidelines for collection of water/wastewater samples titled as 'Sampling Protocol for Water & Wastewater'; which has been approved by the Government of Gujarat vide letter no. ENV-102013-299-E dated 24-04-2014 under the provision of Water (Preservation and Control of Pollution) Act 1974. The sample collection and preservation are done as per the said Protocol. Under the project, the list of parameters to be monitored for the STP have been mentioned in **Table 26** as follows:

Frequency

Monitoring is required to be carried out once a week for monitoring location of Kandla and Vadinar i.e., two STP station at Kandla and one STP station at Vadinar.

Table 26: List of parameters monitored for STP's at Kandla and Vadinar

Sr. No.	Parameters	Units	Reference method	Instruments
1.	pH	-	APHA, 23rd edition, 4500- H^+ B, 2017	pH Meter
2.	TDS	mg/L	APHA, 23rd Edition, 2540 C: 2017	Vacuum Pump with filtration assembly and Oven
3.	TSS	mg/L		
4.	DO	mg/L	APHA, 23rd Edition, 4500 C: 2017	Titration Apparatus
5.	COD	mg/L	APHA, 23rd Edition, 5220 B: 2017	Titration Apparatus plus Digester
6.	BOD	mg/L	IS-3025, Part 44, 1993	BOD Incubator plus Titration Apparatus
7.	SAR	meq/L	IS 11624: 2019	Flame Photometer
8.	Total Coliforms	MPN/100ml	IS 1622: 2019	LAF/ Incubator

9.2 Result and Discussion

Analytical results of the STP samples collected from the inlet and the outlet of the STP's of Kandla and Vadinar have been summarized in **Table 27 & 28**. Further it was compared with the standard norms specified in the CC&A of the respective STPs.

Table 27: Water Quality of inlet and outlet of STP of Kandla

Sr No.	Parameter	Units	GPCB Norms (Kandla)	Kandla															
				Week 3 of August				Week 4 of August				Week 1 of September				Week 2 of September			
				STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)
1.	pH	-	**6.5-8.5**	7.50	7.21	7.04	7.25	7.12	7.02	6.96	7.24	7.62	7.41	7.51	7.10	7.22	7.18	7.35	7.22
2.	TDS	mg/L	**-**	1354	1289	1268	1516	1423	1254	1438	1516	1321	1220	1126	1023	1365	1254	865	821
3.	TSS	mg/L	**100**	30	15	92	16	39	28	56	14	65	28	96	45	45	25	101	22
4.	COD	mg/L	**-**	132	55.2	206.5	68.8	198	112	227.6	36.6	112.3	58.4	71.1	28.3	122.0	60.0	111.0	41.0
5.	DO	mg/L	**-**	BQL	2.1	BQL	2.1	BQL	3.5	BQL	2.8	BQL	3.9	BQL	4.2	BQL	3.6	BQL	4.1
6.	BOD	mg/L	**30**	30.26	18.5	61.95	8.60	20.36	12.25	68.28	4.58	36.58	12.25	40.26	19.25	29.54	12.36	40.23	15.69
7.	SAR	meq/L	**-**	14.56	5.55	5.83	4.71	5.23	2.2	12.11	13.03	10.65	4.22	6.35	4.25	6.24	2.36	3.25	1.52
8.	Total Coliforms	MPN/ 100ml	**<1000**	1600	210	500	23	1600	120	1600	20	1600	50	1600	120	1600	220	1600	23

Table 28: Water Quality of inlet and outlet of STP of Vadinar

Sr No.	Parameter	Units	GPCB Norms (Vadinar)	Vadinar							
				Week 3 of August		Week 4 of August		Week 1 of September		Week 2 of September	
				STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)
1.	pH	-	**5.5-9**	6.98	7.01	7.64	7.60	7.06	7.08	7.34	7.99
2.	TDS	mg/L	**-**	406	378	368	332	448	390	418	330
3.	TSS	mg/L	**20**	10	10	10	4	14	4	12	10
4.	COD	mg/L	**50**	100.8	36.3	96.8	36.3	94.9	39.5	105.7	28.5
5.	DO	mg/L	**-**	4.6	6.1	3.8	4.0	2.8	5.3	4.1	7.5
6.	BOD	mg/L	**10**	15.12	4.54	12.10	4.54	17.79	4.94	19.82	3.56
7.	SAR	meq/L	**-**	2.19	2.38	1.76	1.84	3.01	2.19	3.02	2.38
8.	Total Coliforms	MPN/100ml	**100-230**	1600	100	1600	50	1600	20	1600	23

BQL: Below Quantification limit; Total Suspended Solids (QL=2), Dissolved Oxygen (QL=0.5), Biochemical Oxygen Demand (QL=3 mg/L)

9.3 Data Interpretation and Conclusion

For physicochemical analysis, the treated sewage water was gathered from the Kandla STP, Gopalpuri STP, and Vadinar STP and the analytical results were compared with the standards mentioned in the Consolidated Consent and Authorization (CC&A) by GPCB.

- The **pH** of treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) conform to their respective stipulated norms of **7.02 to 7.41** at Kandla and **7.01 to 7.99** at Vadinar respectively.
- The **TDS** of treated sewage at Kandla was ranges from **821 to 1516 mg/L**, whereas for Vadinar it ranges from **330 to 390 mg/L**.
- The **TSS** of the Treated effluent for the STP-1 and STP-2 at Kandla and STP-3 at Vadinar falls within the stipulated norms of 14 **to 45 mg/L and 4 to 10 mg/L** respectively as mentioned in their respective CCA.
- **COD** value for Kandla was observed in the range of **28.30 to 112 mg/L**. Whereas for Vadinar the value of COD falls within the range of **28.50 to 39.50 mg/L**.
- The value of **DO** was observed in the range of **2.10 to 4.20 mg/L** at Kandla, whereas for Vadinar it was observed in the range of **4.00 to 7.50 mg/L.**
- The **BOD** of the outlet for the STPs of Kandla and Vadinar falls within the stipulated norms.
- The value of **SAR** for Kandla was observed in the range of **1.52 to 13.03 meq/L**, whereas for Vadinar, it was observed in the range of **1.84 to 2.38 meq/L**.
- The value of **Total Coliforms** for Kandla was observed in the range of **20 to 220 MPN/100 ml**, whereas for Vadinar, it was observed in the range of **20 to 100 MPN/100 ml**.

During the monitoring period, only Total Coliforms were observed to be exceeding the limits at STPs of Kandla and Vadinar while rest of the treated sewage parameters for STP outlet were within norms as specified under the CCA at both the monitoring sites. Regular monitoring of the STP performance should be conducted on regular basis to ensure adequate treatment as per the norms.

9.4 Remedial Measures:

- The quantum of raw sewage (influent) entering the STP should be monitored by installation of the flow meter. If the quantity of the sewage exceeds the treatment capacity of the treatment plant, then provision of additional capacity of collection sump should be provided.
- The adequacy and efficacy of the stages of Sewage treatment units shall be conducted.
- The results show the presence of total coliforms; hence the method of disinfection (Chlorination) sodium or calcium Hypochlorite can be used.
- Effectiveness of any technology depends on factors such as the specific pollutants in the wastewater, plant size, local regulations, and available resources. There are several processes that may be implemented such as - Advanced oxidation process involve using strong oxidants to break down complex organic compounds. Methods like Fenton's

reagent (hydrogen peroxide and iron catalyst) and UV/H_2O_2 treatment can help in reducing COD through oxidation.

- Electrochemical processes like Electrocoagulation (EC) and Electrooxidation (EO) that involve the application of an electric current to facilitate the removal of pollutants through coagulation, flocculation, and oxidation. These methods can be useful for treating sewage containing various pollutants.

CHAPTER 10: MARINE WATER QUALITY MONITORING

10.1 Marine Water

Deendayal Port is one of the largest ports of the country and thus, is engaged in wide variety of activities such as movement of large vessels, oil tankers and its allied small and medium vessels and handling of dry cargo several such activities whose waste if spills in water, can cause harmful effects to marine water quality.

Major water quality concerns at ports include wastewater and leakage of toxic substances from ships, stormwater runoff, etc. This discharge of wastewater, combined with other ship wastes which includes sewage and wastewater from other on-board uses, is a serious threat to the water quality as well as to the marine life. As defined in the scope by DPA, the Marine Water sampling and analysis has to be carried out at a total of eight locations, six at Kandla and two at Vadinar. The marine water sampling has been carried out with the help of Niskin Sampler with a capacity of 5L. The Niskin Sampler is a device used to take water samples at a desired depth without the danger of mixing with water from other depths. Details of the locations to be monitored have been mentioned in **Table 29:**

Table 29: Details of the sampling locations for Marine water

Sr. No.	Location Code		Location Name	Latitude Longitude
1.	Kandla	MW-1	Near Passenger Jetty One	23.017729N 70.224306E
2.		MW-2	Kandla Creek (nr KPT Colony)	23.001313N 70.226263E
3.		MW-3	Near Coal Berth	22.987752N70.227923E
4.		MW-4	Khori Creek	22.977544N 70.207831E
5.		MW-5	Nakti Creek (nr Tuna Port)	22.962588N 70.116863E
6.		MW-6	Nakti Creek (nr NH-8A)	23.033113N 70.158528E
7.	Vadinar	MW-7	Near SPM	22.500391N 69.688089E
8.		MW-8	Near Vadinar Jetty	22.440538N 69.667941E

The map depicting the locations of Marine Water to be sampled and analysed for Kandla and Vadinar have been mentioned in **Map 16 and 17** as follows:

Map 16: Locations for Marine Water Monitoring at Kandla

Map 17: Locations for Marine Water Monitoring at Vadinar

Methodology

The methodology adopted for the sampling and monitoring of Marine Water was carried out as per the '**Sampling Protocol for Water & Wastewater'** developed by GEMI. The water samples collected through the Niskin Sampler are collected in a clean bucket to reduce the heterogeneity. The list of parameters to be monitored under the project for the Marine Water quality have been mentioned in **Table 30** along with the analysis method and instrument.

Frequency:

As defined in the scope by DPA, the sampling and analysis of Marine Water has to be carried out once in a month at the eight locations (i.e., six at Kandla and two at Vadinar).

Table 30: List of parameters monitored for Marine Water

Sr. No	Parameters	Units	Reference method	Instrument
1.	Electrical Conductivity	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
2.	Dissolved Oxygen (DO)	mg/L	APHA, 23rd Edition, 4500 O C, 2017	Titration Apparatus
3.	pH	-	APHA, 23rd Edition (Section-4500-H^+B):2017	pH meter
4.	Color	Hazen	APHA, 23rd Edition, 2120 B: 2017	Color comparator
5.	Odour	-	IS 3025 Part 5: 2018	Heating mantle & odour bottle
6.	Turbidity	NTU	IS 3025 Part 10: 1984	Nephlo Turbidity Meter
7.	Total Dissolved Solids (TDS)	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with Filtration Assembly and Oven
8.	Total Suspended Solids (TSS)	mg/L	APHA, 23rd Edition, 2540 D: 2017	
9.	Particulate Organic Carbon	mg/L	APHA, 23rd Edition, 2540 D and E	TOC analyser
10.	Chemical Oxygen Demand (COD)	mg/L	IS-3025, Part- 58: 2006	Titration Apparatus plus Digester
11.	Biochemical Oxygen Demand (BOD)	mg/L	IS-3025, Part 44,1993,	BOD Incubator plus Titration apparatus
12.	Silica	mg/L	APHA, 23rd Edition, 4500 C, 2017	UV- Visible Spectrophotometer
13.	Phosphate	mg/L	APHA, 23rd Edition, 4500 P-D: 2017	
14.	Sulphate	mg/L	APHA, 23rd Edition, 4500 SO4-2 E: 2017	
15.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3-B: 2017	

<table>
<tr><th>Sr. No</th><th>Parameters</th><th>Units</th><th>Reference method</th><th>Instrument</th></tr>
<tr><td>16.</td><td>Nitrite</td><td>mg/L</td><td>APHA, 23rd Edition, 4500 NO2- B: 2017</td><td></td></tr>
<tr><td>17.</td><td>Sodium</td><td>mg/L</td><td>APHA, 23rd Edition, 3500 Na-B: 2017</td><td rowspan="2">Flame photometer</td></tr>
<tr><td>18.</td><td>Potassium</td><td>mg/L</td><td>APHA, 23rd Edition, 3500 K-B: 2017</td></tr>
<tr><td>19.</td><td>Manganese</td><td>µg/L</td><td>APHA, 23rd Edition, ICP Method 3120 B: 2017</td><td rowspan="3">ICP-OES</td></tr>
<tr><td>20.</td><td>Iron</td><td>mg/L</td><td>APHA, 23rd Edition, ICP Method 3120 B: 2017</td></tr>
<tr><td>21.</td><td>Total Chromium</td><td>µg/L</td><td rowspan="2">APHA, 23rd Edition, 3500 Cr B: 2017</td></tr>
<tr><td>22.</td><td>Hexavalent Chromium</td><td>µg/L</td><td>UV- Visible Spectrophotometer</td></tr>
<tr><td>23.</td><td>Copper</td><td>µg/L</td><td rowspan="5">APHA, 23rd Edition, ICP Method 3120 B: 2017</td><td rowspan="6">ICP-OES</td></tr>
<tr><td>24.</td><td>Cadmium</td><td>µg/L</td></tr>
<tr><td>25.</td><td>Arsenic</td><td>µg/L</td></tr>
<tr><td>26.</td><td>Lead</td><td>µg/L</td></tr>
<tr><td>27.</td><td>Zinc</td><td>mg/L</td></tr>
<tr><td>28.</td><td>Mercury</td><td>µg/L</td><td>EPA 200.7</td></tr>
<tr><td>29.</td><td>Floating Material (Oil grease scum, petroleum products)</td><td>mg/L</td><td>APHA, 23rd Edition, 5520 C: 2017</td><td>Soxhlet Assembly</td></tr>
<tr><td>30.</td><td>Total Coliforms (MPN)</td><td>MPN/ 100ml</td><td>IS 1622: 2019</td><td>LAF/ Incubator</td></tr>
</table>

10.2 Result and Discussion

The quality of the Marine water samples collected from the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 31**. The said water quality has been represented in comparison with the standard values as stipulated by CPCB for Class SW-IV Waters.

Table 31: Results of Analysis of Marine Water Sample for the sampling period

Sr. No.	Parameters	Unit	Primary Water Quality Criteria for Class SW-IV Waters	Kandla						Vadinar	
				MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8
1.	Density	kg/m³	-	1.02	1.021	1.022	1.023	1.021	1.02	1.023	1.022
2.	pH	-	6.5-9.0	7.23	7.54	7.84	7.72	7.48	7.92	7.77	7.51
3.	Color	Hazen	No Noticeable	1	1	1	1	1	1	5	5
4.	EC	µS/cm	-	51,300	51,700	51,400	51,300	51,500	51,100	52,100	52,900
5.	Turbidity	NTU	-	142	156	174	155	98	75	12.36	8.21
6.	TDS	mg/L	-	37,168	37,256	37,214	37,159	37,145	36,847	35,264	34,156
7.	TSS	mg/L	-	251	232	255	210	210	199	242	286
8.	COD	mg/L	-	36.2	61.1	40.7	30.5	72.3	50.8	60.54	41.23
9.	DO	mg/L	3.0 mg/L	6.9	6.2	7.1	6.9	6.1	6.6	7.3	6.9
10.	BOD	mg/L	5.0 mg/L	3.2	3.5	3.3	BQL	BQL	4.1	BQL	BQL
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	2568.3	2654.8	2695.1	2415.3	2587.6	2459.3	2514.62	2856.37
13.	Nitrate	mg/L	-	3.255	3.369	3.568	3.321	3.125	3.198	1.569	1.328
14.	Nitrite	mg/L	-	BQL	BQL	0.156	BQL	BQL	BQL	BQL	BQL
15.	Phosphate	mg/L		BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
16.	Silica	mg/L	-	4.56	4.21	4.22	4.01	3.58	4.10	1.52	1.02
17.	Sodium	mg/L	-	3,562	3,965	4,235	6,154	4,802	3,826	>10000	>10000
18.	Potassium	mg/L	-	121.0	136.0	145.0	212.0	169.0	154.0	524.0	658.00
19.	Hexavalent Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	-	-	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
24.	Iron	mg/L	-	1.489	1.548	1.266	1.85	1.269	0.514	0.189	BQL
25.	Lead	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
26.	Manganese	mg/L	-	0.060	0.073	0.050	0.065	0.039	0.022	BQL	BQL
27.	Total Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
28.	Zinc	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Mercury	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Particulate Organic Carbon	mg/L	-	1.25	1.45	1.69	1.39	1.2	0.41	0.09	BQL
31.	Total Coliforms	MPN/ 100ml	500/100 ml	4	8	4	2	8	16	18	22

Sr. No.	Parameters	Unit	Primary Water Quality Criteria for Class SW-IV Waters	Kandla						Vadinar	
				MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8
32.	Floating Material (Oil grease scum, petroleum products)	mg/L	10 mg/L	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

10.3 Data Interpretation and Conclusion

The Marine water quality of Deendayal Port Harbor waters at Kandla and Vadinar has been monitored for various physico-chemical and biological parameters during the monitoring period. The detailed interpretation of the parameters in comparison to the Class SW-IV for Harbour Waters is as follows:

- **Density** at Kandla was observed in the range of **1.02 to 1.023 kg/m³**, with the average of **1.02 kg/m³.** Whereas for the location of Vadinar, it was observed **1.023 kg/m³** at MW-7 and **1.022 kg/m³** at MW-8, with the average of **1.023 kg/m³**.
- **pH** at Kandla was observed in the range of **7.23 to 7.92,** with the average pH as **7.62**. Whereas for the locations of Vadinar, it was observed in the range of be **7.51 to 7.77**, with the average pH as **7.64**. For the monitoring location of both the study areas, pH was found to comply with the norms of 6.5-8.5.
- **Color** range varied from **1 Hazen** at all the monitoring locations in Kandla, and for Vadinar, it found **5 Hazen** for the both of the location.
- **Electrical conductivity (EC)** was observed in the range of **51,100 to 51,700 µS/cm**, with the average EC as **51,383.3 µS/cm** for the locations of Kandla, whereas for the locations of Vadinar, it was observed in the range of **52,100 to 52,900 µS/cm**, with the average EC as **52,500 µS/cm**.
- For all monitoring locations of Kandla the value of **Turbidity** was observed in the range of **75 to 174 NTU**, with average value of **133.33 NTU**. For Vadinar it ranges from **8.21 to 12.36 NTU**, with average of **10.28 NTU**. Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and microscopic organisms. Turbidity affects the amount of light penetrating to the plants for photosynthesis.
- For the monitoring locations at Kandla the value of **Total Dissolved Solids (TDS)** ranged from **36,847 to 37,256 mg/L**, with an average value of **37,131.50 mg/L**. Similarly, at Vadinar, the TDS values ranged from **34,156 to 35,264 mg/L**, with an average value of 34,710 **mg/L**.
- **TSS** values in the studied area varied between **199 to 255 mg/L** at Kandla and **242 to 286 mg/L** at Vadinar, with the average value of **226.17 mg/L and 264 mg/L** respectively for Kandla and Vadinar.

- **COD** varied between **30.5 to 72.3 mg/L** at Kandla and **41.23 to 60.54 mg/L** at Vadinar, with the average value as **48.60 and 50.88 mg/L** respectively for Kandla and Vadinar.
- **DO** level in the studied area varied between **6.1 to 7.1 mg/L** at Kandla and **6.9 to 7.3 mg/L** at Vadinar, with the average value of **6.63 mg/L and 7.10 mg/L** respectively for Kandla and Vadinar. Which represents that the marine water is suitable for marine life.
- **BOD** observed was observed in the range of **3.2 to 4.1 mg/L**, with average of **3.53 mg/L** for the location of Kandla and for the locations of Vadinar, it was detected **Below Quantification Limit** for all sampling locations.
- **Sulphate** concentration in the studied area varied between **2415.36 to 2695.12 mg/L** at Kandla and **2514.62 to 2856.37 mg/L** at Vadinar. The average value observed at Kandla was **2563.44 mg/L**, whereas **2685.49 mg/L** was the average value of Vadinar. Sulphate is naturally formed in inland waters by mineral weathering or the decomposition and combustion of organic matter.
- **Nitrate** in the study area was observed in the range of **3.125 to 3.568 mg/L**, with the average of **3.31 mg/L**. Whereas for the Vadinar, recorded value was observed in the range of **1.328 to 1.569 mg/L**, with the average of **1.449 mg/L.**
- In the study area of Kandla the concentration of **Potassium** varied between **121 to 212 mg/L** and **524 to 658 mg/L** at Vadinar, with the average value as **156.17 mg/L and 591 mg/L** respectively for Kandla and Vadinar.
- **Silica** in the studied area varied between **3.58 to 4.56 mg/L**, with the average of **4.11 mg/L**, at Kandla. Vadinar, observed value was found to be **1.52 mg/L** at location MW-7 and **1.02 mg/L** at MS-8 location.
- **Sodium** in the study area varied between **3562 to 6154 mg/L**, with average of **4424 mg/L**, at Kandla whereas at Vadinar the sodium concentration value was detected to be **more than 10,000 mg/L** at both locations.
- **Odour** was observed **1** for all locations of Kandla and Vadinar.
- **Copper** in the study area, was detected **below the quantification limit (BQL)" at** Kandla and whereas Vadinar was detected **below the quantification limit (BQL)"** for the all-sampling location.
- **Iron** in the studied area varied between **0.514 to 1.85 mg/L**, with the average of **1.32 mg/L,** at Kandla, and for Vadinar value were recorded **0.189 mg/L** for location MW-7 and **Below Quantification Limit** for location MW-8.
- **Lead** concentration at Kandla was detected **below the quantification limit (BQL)"** for the all-sampling location. and whereas Vadinar was detected **below the quantification limit (BQL)"** for the all-sampling location.
- **Manganese** in the studied area varied between **0.022 to 0.073 mg/L**, with the average of 0.052 mg/ L, at Kandla and whereas Vadinar was detected **below the quantification limit (BQL)"** for the all-sampling location.
- **Particulate Organic Carbon** in the study area was observed in the range of **0.41 to 1.69**, with the average value of **1.23**. Whereas for the Vadinar, the value observed was **0.09** at MW-7 and **Below Quantification Limit** at MW-8.

- **Oil & Grease, Nitrite, Phosphate, Hexavalent Chromium, Arsenic, Cadmium, Total Chromium, Zinc, Mercury and Floating Material (Oil grease scum, petroleum products)** were observed to have concentrations **"Below the Quantification Limits (BQL)"** for most of the locations of Kandla and Vadinar.
- **Total Coliforms** were detected complying with the specified norm of 500 MPN/100ml for all the locations of Kandla and Vadinar.

During the Monitoring period, marine water samples were analysed and found in line with Primary Water Quality criteria for class-IV Waters (For Harbour Waters).

However, as a safeguard towards marine water pollution prevention, appropriate regulations on ship discharges and provision of reception facilities are indispensable for proper control of emissions and effluent from ships. Detection of spills is also important for regulating ship discharges. Since accidental spills are unavoidable, recovery vessels, oil fences, and treatment chemicals should be prepared with a view to minimizing dispersal. Proper contingency plans and a prompt reporting system are keys to prevention of oil dispersal. Periodical clean-up of floating wastes is also necessary for preservation of port water quality.

CHAPTER 11: MARINE SEDIMENT QUALITY MONITORING

11.1 Marine Sediment Monitoring

Marine sediment, or ocean sediment, or seafloor sediment, are deposits of insoluble particles that have accumulated on the seafloor. These particles have their origins in soil and rocks and have been transported from the land to the sea, mainly by rivers but also by dust carried by wind. The unconsolidated materials derived from pre-existing rocks or similar other sources by the process of denudation are deposited in water medium are known as sediment. For a system, like a port, where large varieties of raw materials and finished products are handled, expected sediment contamination is obvious.

The materials or part of materials spilled over the water during loading and unloading operations lead to the deposition in the harbour water along with sediment and thus collected as harbour sediment sample. These materials, serve as receptor of many trace elements, which are prone to environment impact. In this connection it is pertinent to study the concentration and distribution of environmentally sensitive elements in the harbour sediment. 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.

Methodology

As defined in the scope by DPA, the Marine Sediment sampling is required to be carried out once in a month at total eight locations, i.e., six at Kandla and two at Vadinar. The sampling of the Marine Sediment is carried out using the Van Veen Grab Sampler (make Holy Scientific Instruments Pvt. Ltd). The Van Veen Grab sampler is an instrument to sample (disturbed) sediment up to a depth of 20-30 cm into the sea bed. While letting the instrument down on the seafloor, sediment can be extracted. The details of locations of Marine Sediment to be monitored under the study are mentioned in **Table 32** as follows:

Table 32: Details of the sampling locations for Marine Sediment

Sr. No	Location Code		Location Name	Latitude Longitude
1.	Kandla	MS-1	Near Passenger Jetty One	23.017729N 70.224306E
2.		MS-2	Kandla Creek	23.001313N 70.226263E
3.		MS-3	Near Coal Berth	22.987752N 70.227923E
4.		MS-4	Khori Creek	22.977544N 70.207831E
5.		MS-5	Nakti Creek (near Tuna Port)	22.962588N 70.116863E
6.		MS-6	Nakti Creek (near NH-8A)	23.033113N 70.158528E
7.	Vadinar	MS-7	Near SPM	22.500391N 69.688089E
8.		MS-8	Near Vadinar Jetty	22.440538N 69.667941E

The map depicting the locations of Marine Sediment sampling at Kandla and Vadinar have been mentioned in **Map 18 and 19** as follows:

Map 18: Location of Marine Sediment Monitoring at Kandla

Map 19: Locations of Marine Sediment Monitoring at Vadinar

The list of parameters to be monitored under the projects for the Marine Sediment sampling been mentioned in **Table 33** as follows:

Table 33: List of parameters to be monitored for Sediments at Kandla and Vadinar

Sr. No.	Parameters	Units	Reference method	Instruments
1.	Texture		Methods Manual Soil Testing in India January 2011,01	Hydrometer
2.	Organic Matter	%	Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934)	Titration apparatus
3.	Inorganic Phosphates	mg/Kg	Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017	UV- Visible Spectrophotometer
4.	Silica	mg/Kg	EPA METHOD 6010 C & IS: 3025 (Part 35) – 1888, part B	
5.	Phosphate	mg/Kg	EPA Method 365.1	
6.	Sulphate as SO^{4-}	mg/Kg	IS: 2720 (Part 27) - 1977	
7.	Nitrite	mg/Kg	ISO 14256:2005	
8.	Nitrate	mg/Kg	Methods Manual Soil Testing in India January, 2011, 12	
9.	Calcium as Ca	mg/Kg	Methods Manual Soil Testing in India January 2011, 16.	Titration Apparatus
10.	Magnesium as Mg	mg/Kg	Method Manual Soil Testing in India January 2011	
11.	Sodium	mg/Kg	EPA Method 3051A	Flame Photometer
12.	Potassium	mg/Kg	Methods Manual Soil Testing in India January, 2011	
13.	Aluminium	mg/Kg	EPA Method 3051A	ICP-OES
14.	Chromium	mg/Kg		
15.	Nickel	mg/Kg		
16.	Zinc	mg/Kg		
17.	Cadmium	mg/Kg		
18.	Lead	mg/Kg		
19.	Arsenic	mg/Kg		
20.	Mercury	mg/Kg		

11.2 Result and Discussion

The quality of Marine Sediment samples collected from the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 34.**

Table 34: Summarized result of Marine Sediment Quality

Sr No.	Parameters	Unit	Kandla						Vadinar	
			MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Inorganic Phosphate	kg/ ha	1.02	4.23	2.65	1.56	0.91	0.94	0.91	0.62
2.	Phosphate	mg/Kg	321.25	512.36	436.51	320.16	265.21	220.14	423.65	303.54
3.	Organic Matter	%	1.2	1.96	1.56	1.12	1.45	1.20	1.45	1.72
4.	Sulphate as SO^{4-}	mg/Kg	303.21	108.51	110.36	85.46	100.25	92.17	125.36	136.28
5.	Calcium as Ca	mg/Kg	4200.00	1800.00	2200.00	1600.00	1900.00	1700.00	2300.00	1900.00
6.	Magnesium as Mg	mg/Kg	795.00	958.00	1475.00	745.00	1023.00	841.00	982.00	1265.40
7.	Silica	g/Kg	421.31	326.24	169.46	326.42	315.41	421.28	200.25	259.64
8.	Nitrite	mg/Kg	1.15	1.09	1.2	1.01	1.03	1.12	0.45	0.26
9.	Nitrate	mg/Kg	6.12	5.21	4.13	5.23	6.42	6.31	15.24	8.29
10.	Sodium	mg/Kg	2861	2215	2856	2036	3014	3954	7546	8952
11.	Potassium	mg/Kg	1956	1854	1926	2136	2525	3067	1347	3256
12.	Copper	mg/Kg	38.22	42.57	45.56	32.17	42.1	29.53	16.25	22.31
13.	Aluminium	mg/Kg	35268.4	36529.5	37514.6	25187.6	35268.6	29543	15423.61	25146.25
14.	Chromium	mg/Kg	72.36	74.65	71.39	72.55	62.58	51.36	40.26	35.28
15.	Nickel	mg/Kg	29.35	25.21	22.59	21.85	36.27	21.26	20.24	30.58
16.	Zinc	mg/Kg	101.26	268.54	362.14	101.22	85.36	79.58	18.25	39.41
17.	Cadmium	mg/Kg	BQL	BQL	BQL	0.54	BQL	BQL	0.006	BQL
18.	Lead	mg/Kg	7.31	10.25	19.24	12.33	9.51	6.22	3.26	8.47
19.	Arsenic	mg/Kg	4.12	3.62	6.28	7.26	4.26	3.2	2.59	5.21
20.	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21.	Texture	-	Silt Loam	Sandy Loam	Silt Loam	Loam	Silt Loam	Silt Loam	Sandy Loam	Loam

11.3 Data Interpretation and Conclusion

The Marine sediment quality at Kandla and Vadinar has been monitored for various physico-chemical parameters during the monitoring 2024. The detailed interpretation of the parameters is given below:

- **Inorganic Phosphate** for the sampling period was observed in range of **0.91 to 4.23** Kg/ha for Kandla. Whereas for Vadinar the value observed at location MS-7 (Nakti creek) is 0.91 Kg/ha and MS-8 (Near Vadinar Jetty) is 0.62 Kg/ha. For Kandla and Vadinar the average value of Inorganic Phosphate was observed 1.89 and 0.77 Kg/ha respectively.
- The concentration of **Phosphate** was observed in range of **220.14 to 512.36 mg/Kg** for Kandla and for Vadinar the value observed at location MS-7 (Nakti creek) as 423.65 mg/Kg and MS-8 (Near Vadinar Jetty) as 303.54 mg/Kg. For Kandla and Vadinar the average concentration of Phosphate was observed 345.94 and 363.60 mg/Kg respectively.

- The **Organic Matter** for the sampling period was observed in the range of **1.12 to 1.96%** for Kandla with the average value of 1.42% and for Vadinar the value recorded at location MS-7 and MS-8 was observed 1.45% & 1.72% respectively, with average concentration as 1.59 %.
- The concentration of **Sulphate** was observed in the range of **85.46 to 303.21 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 125.36 mg/Kg and at MS-8 is 136.28 mg/Kg. For Kandla and Vadinar the average value of Sulphate was observed 133.33 and 130.82 mg/Kg respectively.
- The value of **Calcium** was observed in the range of **1600 to 4200 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 2300 mg/Kg and at MS-8, is 1900 mg/Kg. The average value of Calcium for the monitoring period was observed 2233.33 mg/Kg and 2100 mg/Kg at Kandla and Vadinar, respectively.
- The value of **Magnesium** for the sampling period was observed in the range of **745 to 1475 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 982 mg/Kg and at MS-8, is 1265.40 mg/Kg. For Kandla and Vadinar the average value of Magnesium was observed 972.83 mg/Kg and 1123.70 mg/Kg respectively.
- For the sampling period **Silica** was observed in the range of **169.46 to 421.31 mg/Kg** for Kandla with average value 330.02 mg/Kg and for Vadinar the value observed to be 200.25 and 259.64 mg/Kg at MS-7 and MS-8, respectively with average 229.95 mg/Kg.
- The value of **Nitrate** was observed in the range of **4.13 to 6.42 mg/Kg** for Kandla with average value 5.57 mg/Kg and for Vadinar the value observed to be 15.24 and 8.29 mg/Kg at MS-7 and MS-8, respectively with average 11.77 mg/Kg.
- The value of **Nitrite** was observed in the range of **1.01 to 1.20 mg/Kg** for Kandla with average value 1.10 mg/Kg and for Vadinar the value observed to be 0.45 and 0.26 mg/Kg at MS-7 and MS-8, respectively with average 0.36 mg/Kg.
- The value of **Sodium** was observed in the range of 2036 **to 3954 mg/Kg** for Kandla with average value 2822.67 mg/Kg and for Vadinar the value observed to be 7546 and 8952 mg/Kg at MS-7 and MS-8, respectively with average 8249 mg/Kg.
- The value of **Potassium** was observed in the range of **1854 to 3067 mg/Kg** for Kandla with average value 2244 mg/Kg and for Vadinar the value observed to be 1347 and 3256 mg/Kg at MS-7 and MS-8, respectively with average 2301.50 mg/Kg.
- The value of **Aluminium**, was observed in the range of **25187.6 to 37514.6 mg/Kg** for Kandla with average value 33218.62 mg/Kg and for Vadinar the value observed to be 15423.61 and 25146.25 mg/Kg at MS-7 and MS-8, respectively with average 20284.93 mg/Kg.
- The value of **Mercury** was observed "Below the Quantification Limit" at all the eight-monitoring location of Kandla and Vadinar.
- Texture was observed to be "**Sandy Loam**" and "Slit Loam" at location MS-1, MS-2, MS-3, MS-4, MS-5, MS-6 in Kandla. "**Sandy Loam**" at location MS-7 & "**loam"** at location MS-8 in Vadinar during sampling period.

Heavy Metals

The sediment quality of Kandla and Vadinar has been compared with respect to the Average Standard guideline applicable for heavy metals in marine sediment specified by EPA have been mentioned in **Table 35.**

Table 35: Standard Guidelines applicable for heavy metals in sediments

Sr. No.	Metals	Sediment quality (mg/kg)			Source
		Not polluted	Moderately polluted	Heavily polluted	
1.	As	<3	3-8	>8	EPA
2.	Cu	<25	25-50	>50	
3.	Cr	<25	25-75	>75	
4.	Ni	<20	20-50	>50	
5.	Pb	<40	40-60	>60	
6.	Zn	<90	90-200	>200	
7.	Cd	-	<6	>6	
ND = Not Detected					

(Source: G Perin et al. 1997)

Table 36: Comparison of Heavy metals with Standard value in Marine Sediment

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Arsenic	mg/Kg	4.12	3.62	6.28	7.26	4.26	3.2	2.59	5.21
2.	Copper	mg/Kg	38.22	42.57	45.56	32.17	42.1	29.53	16.25	22.31
3.	Chromium	mg/Kg	72.36	74.65	71.39	72.55	62.58	51.36	40.26	35.28
4.	Nickel	mg/Kg	29.35	25.21	22.59	21.85	36.27	21.26	20.24	30.58
5.	Lead	mg/Kg	7.31	10.25	19.24	12.33	9.51	6.22	3.26	8.47
6.	Zinc	mg/Kg	101.26	268.54	362.14	101.22	85.36	79.58	18.25	39.41
7.	Cadmium	mg/Kg	BQL	BQL	BQL	0.54	BQL	BQL	0.006	BQL

- **Arsenic** was observed in the range of **3.2 to 7.26 mg/Kg** for Kandla with average value 4.79 mg/Kg and for Vadinar the value observed to be 2.59 and 5.21 mg/Kg at MS-7 and MS-8, respectively with average 3.90 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to arsenic falls in moderately polluted class.
- **Copper** was observed in the range of **29.53 to 45.56 mg/Kg** for Kandla with average value 38.36 mg/Kg and for Vadinar the value observed to be 16.25 and 22.31 mg/Kg at MS-7 and MS-8, respectively with average 19.28 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to copper falls in Moderately polluted class.
- **Chromium** was observed in the range of 71.39 **to 99.39 mg/Kg** for Kandla with average Value 79.03 mg/Kg and for Vadinar the value observed to be 40.26 and 35.28 mg/Kg at MS-7 and MS-8, respectively with average 37.77 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to chromium falls under moderately polluted class.

- **Nickel** was observed in the range of **21.26 to 36.27 mg/Kg** for Kandla with average value 26.09 mg/Kg and for Vadinar the value observed to be 20.24 and 30.58 mg/Kg at MS-7 and MS-8, respectively with average 25.41 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to nickel falls in moderately polluted class.
- **Lead** was observed in the range of **6.22 to 19.24 mg/Kg** for Kandla with average value 10.81 mg/Kg and for Vadinar the value observed to be 3.26 and 8.47 mg/Kg at MS-7 and MS-8, respectively with average 5.87 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to lead falls in Not polluted class.
- **Zinc** was observed in the range of **79.58 to 195.43 mg/Kg** for Kandla with average value 119.21 mg/Kg and for Vadinar the value observed to be 18.25 and 39.41 mg/Kg at MS-7 and MS-8, respectively with average 28.83 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to zinc falls in moderately polluted class
- **Cadmium** was observed BQL for all locations at Kandla and Vadinar except MS-7 during sampling period. With reference to the guidelines mentioned in table 35, the sediment quality with respect to cadmium falls in non-polluted class.

Analysis of the sediments indicates moderate pollution. However, it may be noted that, the sediments are highly dynamic being constantly deposited and carried away by water currents. Hence maintaining the quality of sediments is necessary as it plays a significant role in regulating the quality of the marine water and the marine ecology.

The presence of anthropic activity in the coastal areas has an effect upon the marine water and sediment. One of the primary risks associated with contaminated sediments is bioaccumulation in benthic organisms, which is a route of entry into the food chain. Generally adopted sediment remediation approaches include dredging, capping of contaminated areas, and monitored natural recovery (MNR). Dredging can remove contaminated sediments, but it requires large areas of land for sediment disposal. It is expensive and may cause secondary contamination of the water column during re-suspension. MNR relies on ongoing naturally occurring processes to decrease the bioavailability or toxicity of contaminants in sediment. These processes may include physical, biological, and chemical mechanisms that act together to reduce the environmental risks posed by contaminated sediments. MNR require longer monitoring time and can be even more expensive than for dredging and capping. Capping consists of in situ covering of clean or suitable isolating material over contaminated sediments layer to limit leaching of contaminants, and to minimize their re-suspension and transport. Hence appropriate remedial measures for the polluted sediment sites may be implemented, to reduce the concentration of the heavy metals.

CHAPTER 12: MARINE ECOLOGY MONITORING

12.1 Marine Ecological Monitoring

The monitoring of the biological and ecological parameters is important in order to assess the marine environment. 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. Deendayal Port and its surroundings have mangroves, mudflats and creek systems as major ecological entities.

As defined in the scope by DPA, the Marine Ecological Monitoring is required to be carried out once a month specifically at eight locations, six at Kandla and two at Vadinar. The sampling of the Benthic Invertebrates has been carried out with the help of D-frame nets, whereas the sampling of zooplankton and phytoplankton has been carried out with the help of Plankton Nets (60 micron and 20 micron). The details of the locations of Marine Ecological Monitoring have been mentioned in **Table 37** as follows:

Table 37: Details of the sampling locations for Marine Ecological

Sr. No.	Location Code		Location Name	Latitude Longitude
1.	Kandla	ME-1	Near Passenger Jetty One	23.017729N 70.224306E
2.		ME-2	Kandla Creek (near KPT Colony)	23.001313N 70.226263E
3.		ME-3	Near Coal Berth	22.987752N 70.227923E
4.		ME-4	Khori Creek	22.977544N 70.207831E
5.		ME-5	Nakti Creek (near Tuna Port)	22.962588N 70.116863E
6.		ME-6	Nakti Creek (near NH - 8A)	23.033113N 70.158528E
7.	Vadinar	ME-7	Near SPM	22.500391N 69.688089E
8.		ME-8	Near Vadinar Jetty	22.440538N 69.667941E

The map depicting the locations of Marine Ecological monitoring in Kandla and Vadinar have been mentioned in **Map 20 and 21** as follows:

Map 20: Locations of Marine Ecological Monitoring at Kandla

Map 21: Locations of Marine Ecological Monitoring at Vadinar

The various parameters to be monitored under the study for Marine Ecological Monitoring are mentioned in **Table 38** as follows:

Table 38: List of parameters to be monitored for Marine Ecological Monitoring

Sr. No.	Parameters
1.	Productivity (Net and Gross)
2.	Chlorophyll-a
3.	Pheophytin
4.	Biomass
5.	Relative Abundance, species composition and diversity of phytoplankton
6.	Relative Abundance, species composition and diversity of zooplankton
7.	Relative Abundance, species composition and diversity of benthic invertebrates (Meio, Micro and macro benthos)
8.	Particulate Oxidisable Organic Carbon
9.	Secchi Depth

Methodology

- **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.

- **Phytoplankton Estimation**
Phytoplankton 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*). Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as Cyanophytes (Bluegreen 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 Estimation**

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. 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.

- **Benthic Organisms Estimation**

Benthic macroinvertebrates are small aquatic animals and the aquatic larval stages of insects. They include dragonfly and stonefly larvae, snails, worms, and beetles. Use of benthic macroinvertebrates has been in vogue as indicator organisms for water quality monitoring since long. Traditional methods of water quality monitoring incorporates mostly monitoring of physicochemical parameters. Benthic macroinvertebrates are majorly insects that dwell on the floor of water bodies. They are found in all water bodies, as they have a wide range of pollution tolerance among various species. The benthic macro-invertebrate's community structure depends on the exposure to pollution it receives. Benthic macroinvertebrates have been used as indicator organisms to measure the water quality of water bodies across the world. Evaluating the abundance and variety of benthic macroinvertebrates in a waterbody gives us an indication of the biological condition of that waterbody. Generally, waterbodies in healthy biological condition support a wide variety and high number of macroinvertebrate taxa, including many that are intolerant of pollution. Samples yielding only pollution–tolerant species or very little diversity or abundance may indicate a less healthy waterbody. Biological condition is the most comprehensive indicator of waterbody health. When the biology of a waterbody is healthy, the chemical and physical components of the waterbody are also typically in good condition.

- **Diversity Index**

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.

1. **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. Shannon-Wiener's index (H) reproduces community parameters to a single number by using an equation are as follow:

$$H' = \sum p_i * \ln(p_i)$$

Where, $\sum$ = Summation symbol,

pi = Relative abundance of the species,

ln = Natural logarithm

More diverse ecosystems are considered healthier and more resilient. Higher diversity ecosystems typically exhibit better stability and greater tolerance to fluctuations. e.g., The Shannon diversity index values between 2.19 and 2.56 indicate relatively high diversity within the community compared to communities with lower values. It suggests that the community likely consists of a variety of species, and the species are distributed somewhat evenly in terms of their abundance.

2. **Simpson's index:**

A reasonably high level of dominance by one or a small number of species is indicated by the range of **0.89 to 0.91**. The general health and stability of the ecosystem may be impacted by this dominance. Community disturbances or modifications that affect the dominant species may be more likely to have an impact. The dominating species determined by the Simpson's index can have big consequences on how the community is organised and how ecological interactions take place.

The formula for calculating D is presented as:

$$D = 1 - \sum (p_i \hat{} 2)$$

Where, $\sum$ = Summation symbol, pi = Relative abundance of the species

3. **Margalef's diversity index:**

The number of species is significantly related to the port’s vegetation cover surface, depth, and photosynthetic zone. The habitat heterogeneity is a result of these three elements. Species richness is related to the number of distinct species present in the analysed area. Margalef's index has a lower correlation with sample size. Small species losses in the community over time are likely to result in inconsistent changes.

Margalef’s index D_{Mg}, which is also a measure of species richness and is based on the presumed linear relation between the number of species and the logarithm of the number of individuals. It is given by the formula:

$$D_{Mg} = \frac{S-1}{lnN}$$

Where, N = total number of individuals collected

S = No. of taxa or species or genera

4. **Berger-Parker index:**

This is a useful tool for tracking the biodiversity of deteriorated ecosystems. Environmental factors have a considerable impact on this index, which accounts for the dominance of the most abundant species over the total abundance of all species in the assemblage. The preservation of their biodiversity and the identification of the fundamental elements influencing community patterns are thus critical for management and conservation. Successful colonising species will dominate the assemblage, causing the Berger-Parker index to rise, corresponding to well-documented successional processes. The environmental and ecological features of the system after disturbance may therefore simply but significantly determine the identity of the opportunistic and colonising species through niche selection processes.

The Berger-Parker index is a biodiversity metric that focuses on the dominance or relative abundance of a single species within a community. It provides a measure of the most abundant species compared to the total abundance of all species present in the community. Mathematically, it can be represented as follows:

$$d = \frac{N_{max}}{N_i}$$

Where, N_{max} = Max no of individuals of particular genera or species

$\sum N_i$ = Total no of individuals obtained.

The resulting value of the Berger-Parker index ranges between 0 and 1. A higher index value indicates a greater dominance of a single species within the community. Conversely, a lower index value suggests a more even distribution of abundance among different species, indicating higher species diversity. The range of the Berger-Parker index can be interpreted as when the index value is close to 0, it signifies a high diversity with a more even distribution of abundances among different species. In such cases, no single species dominates the community, and there is a balanced representation of various species.

5. **Evenness index–**

Evenness index determines the homogeneity (and heterogeneity) of the species' abundance. Intermediate values between 0 and 1 represent varying degrees of evenness or unevenness in the distribution of individuals among species. Value of species evenness represents the degree of redundancy and resilience in an ecosystem. High species evenness = All species of a community can perform similar ecological activities or functions= even utilization of available ecological niches = food web more stable = ecosystem is robust (resistant to disturbances or environmental changes). Intermediate values between 0 and 1 represent variable degrees of evenness or unevenness.

$$EI = \frac{H}{\ln(S)}$$

Where, H= Shannon value

ln(S) = the natural logarithm of the number of different species in the community

Relative Abundance: The species abundance distribution (SAD) from disturbed ecosystems follows even/ uneven pattern. E.g., If relative abundance is 0.15, then the found species are neither highly dominant nor rare.

$$RA = \frac{No.of\ Individuals\ of\ Sp.}{Total\ no.of\ Individual} * 100\%$$

The basic idea of 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. Biodiversity is commonly expressed through indices based on species richness and species abundances. 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.

12.2 Result and Discussion

The details of Marine Ecological Monitoring conducted for the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 39.**

Table 39: Values of Biomass, Net Primary Productivity (NPP), Gross Primary Productivity (GPP), Pheophytin and Chlorophyll for Kandla and Vadinar

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
1.	Biomass	mg/L	202	89	55	120	65	101	91	112
2.	Net Primary Productivity	mg/L/hr	BQL	0.42	BQL	BQL	0.26	BQL	BQL	BQL
3.	Gross Primary Productivity	mg/L/hr	0.21	0.32	1.02	1.31	1.21	0.36	0.71	1.02
4.	Pheophytin	mg/m^3	BQL	1.12	0.72	1.29	1.08	0.62	1.05	1.32
5.	Chlorophyll-a	mg/m^3	3.16	1.2	1.35	1.18	1.22	1.16	1.48	1.62
6.	Particulate Oxidisable Organic Carbon	mg/L	1.52	1.25	0.35	0.79	1.02	0.91	0.6	0.78
7.	Secchi Depth	ft	0.72	0.62	0.45	0.81	0.91	0.76	1.26	1.33

- **Biomass:**
  With reference to the **Table 39**, the concentration of **Biomass** reported from location ME-1 to ME-6 in range between **55 to 202 mg/L** where lowest biomass presents in ME-3 (Near Coal Berth) and highest biomass present in ME-1 (Near Passenger Jetty One) during sampling period. In Vadinar, the value of biomass was observed **91 mg/L** at ME-7 (Near SPM) and **112 mg/L** in ME-8 (Near Vadinar Jetty) monitoring station.

- **Productivity (Net and Gross)**
  Gross primary productivity (GPP) is the rate at which organic matter is synthesised by producers per unit area and time (GPP). The amount of carbon fixed during photosynthesis by all producers in an ecosystem is referred to as gross primary productivity. The monitoring location of Kandla reported GPP value in range between 0.21 to 1.31 mg/L/ Hr where the highest value recorded for ME-4 (khori Creek)) and lowest recorded at ME-1 (Near Passenger Jetty One). In Vadinar, the value of GPP was observed 0.71 at ME-7 (Near SPM) and 1.02 at ME-8 (Near Vadinar Jetty) monitoring station.

  Net primary productivity, is the amount of fixed carbon that is not consumed by plants, and it is this remaining fixed carbon that is made available to various consumers in the ecosystem. The Net primary productivity of the monitoring location at Kandla from (ME-1 to ME-6) has been recorded in as **BQL (Below Quantification Limit) except ME-2 and ME-5.** While in Vadinar, the value of **NPP** was observed **BQL (Below Quantification Limit).** at ME-7 (Near SPM) and ME-8 (Near Vadinar Jetty) monitoring station.

- **Pheophytin**
  The level of Pheophytin was detected in the range from **0.62 to 1.29 mg/m³** where the highest value observed at ME-4 (Khori Creek) and the lowest value observed at ME-1 (Near Passenger Jetty One). While in Vadinar, the value of Pheophytin was observed 1.05 mg/m3 at ME-7 and **1.32 mg/m³** at ME-8 monitoring station.

- **Chlorophyll-a**

In the sub surface water, the value of Chlorophyll-a reported in range from **1.16 to 3.16 mg/m^3**. The highest value observed at ME-1 (Near Passenger Jetty One) while the lowest value observed at ME-6 (Nakti Creek (near NH - 8A)). In Vadinar, the value of chlorophyll-a was observed **1.48 mg/m^3** at ME-7 (Near SPM) and **1.62 mg/m^3** in ME-8 (Near Vadinar Jetty) monitoring station.

- **Particulate Oxidisable Organic Carbon**

  During the sampling period, the particulate oxidisable organic carbon falls within the range of **0.35 to 1.52 mg/L** from monitoring location ME-1 to ME-6 at Kandla, whereas for Vadinar, the value of POC observed **0.60 mg/L** at ME-7 (Near SPM) and **0.78 mg/L** in ME-8 (Near Vadinar Jetty) monitoring station.

- **Secchi Depth**

  In monitoring station of Kandla (ME-1 to ME-6) the level of Secchi Depth was observed between **0.45 to 0.91 ft** whereas at Vadinar, the value recorded at ME-7 i.e. Near SPM is **1.26 ft** and in Near Vadinar Jetty is **1.33 ft**.

Ecological Diversity

Phytoplankton: For the evaluation of the Phytoplankton population in DPA Kandla and Vadinar within the immediate surroundings of the port, sampling was conducted during the study period. Total 8 sampling locations were studied i.es. sampling locations (6 from Kandla and two from Vadinar).

The details of variation in abundance and diversity in phytoplankton communities are mentioned in **Table 40**.

Table 40: Phytoplankton variations in abundance and diversity in sub surface sampling stations

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Bacillaria sp.	156	136	-	-	212	-	-	-
Biddulphia sp.	-	-	231	122	-	-	133	148
Chaetoceros sp.	185	-	-	-	132	-	-	-
Chlamydomonas sp.	-	147	-	184	-	121	-	-
Cyclotella sp.	172	-	194	-	156	-	-	-
Coscinodiscus sp.	-	176	-	189	-	148	184	200
Ditylum sp	256	-	152	176	-	-	-	-
Fragilaria sp.	-	-	-	-	-	235	-	188
Bacteriastrum sp.	168	-	136	157	185	-	238	195
Pleurosigma sp.	-	185	-	-	-	152	182	-
Navicula sp.	212	-	189	-	-	-	-	-
Merismopedia sp.	-	201	-	158	-	174	-	-
Synedra sp.	-	-	-	-	145	-	-	141
Skeletonema sp.	-	194	-	-	-	222	-	166
Oscillatoria sp.	-	-	137	-	165	-	210	-
Thallassiosira	142	169	-	198	-	201	-	232
Gomphonema sp.	-	-	213	-	194	-	247	-
Density-Units/L	**1291**	**1208**	**1252**	**1184**	**1189**	**1253**	**1194**	**1270**
No. of genera	**7**	**7**	**7**	**7**	**7**	**7**	**6**	**7**

The phytoplankton community of the sub surface water in the Kandla and Vadinar was represented by, Diatoms, green algae and filamentous Cynobacteria. Diatoms were represented by 14 genera; green algae were represented by 1 genera and filamentous Cynobacteria were represented by 2 genera during the sampling period.

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from **1184 to 1291 units/L,** while for Vadinar its density of phytoplankton observed **1194 units/L at ME-7 and 1270 units/L at ME-8.** During the sampling, phytoplankton communities were dominated, *Bacteriastrum sp., Chlamydomonas sp., Cyclotella sp, Thallassiosira , Gomphonema sp, in* Kandla, while *Biddulphia sp., Bacteriastrum sp., Cosinodiscus sp.* in Vadinar.

The details of Species richness Index and Diversity Index in Phytoplankton are mentioned in **Table 41**.

Table 41: Species richness Index and Diversity Index in Phytoplankton

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	7	7	7	7	7	7	6	7
Individuals	1291	1208	1252	1184	1189	1253	1194	1270
Shannon diversity	1.93	1.88	1.90	1.85	1.86	1.89	1.71	1.92
Simpson 1-D	0.85	0.86	0.85	0.83	0.85	0.85	0.83	0.85
Species Evenness	0.99	0.97	0.98	0.95	0.96	0.97	0.95	0.99
Margalef richness	0.84	0.85	0.84	0.85	0.85	0.84	0.71	0.84
Berger-Parker	0.20	0.17	0.18	0.17	0.18	0.19	0.21	0.18
Relative abundance	0.54	0.58	0.56	0.59	0.59	0.56	0.50	0.55

- **Shannon- Wiener's Index (H)** of phytoplankton communities was in the range of **1.85 to 1.93** between selected sampling stations from ME-1 to ME-6 with an average value of **1.89** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of phytoplankton communities recorded to be **1.71** at location ME-7 and **1.92** at ME-8 with an average value of **1.82**. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla.

- **Simpson diversity index (1-D)** of phytoplankton communities was ranged between **0.83 to 0.86** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.85** Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was **0.83** at location ME-7 and **0.85** at ME-8 with an average of **0.84**.

- **Margalef's diversity index** (Species Richness) of phytoplankton communities in Kandla and nearby creeks sampling stations was varying from **0.84 to 0.85** with an average of **0.85** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of phytoplankton communities observed **0.71** at ME-7 and **0.84** at ME-8 with an average value of **0.78**

- **Berger-Parker Index (d)** of phytoplankton communities was in the range of **0.17 to 0.20** between selected sampling stations from ME-1 to ME-6 with an average value of **0.18** at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of **0.18 to 0.21** with an average value of **0.20**. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.95 to 0.99** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed **0.95** at location ME-7 & **0.99** at ME-8 location.

- During the sampling period, **Relative Abundance** of phytoplankton communities was in range of **0.54 to 0.59** between selected sampling stations from ME-1 to ME-6 with an average value of **0.57** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **0.50** at ME-7 and **0.55** at ME-8 with an average value **0.53**, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

The details of variation in abundance and diversity in zooplankton communities are mentioned in **Table 42**.

Table 42: Zooplankton variations in abundance and diversity in sub surface sampling stations

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Acartia sp.	-	1	1	-	2	2	-	1
Acrocalanus	2	-	-	1	1	1	2	-
Amoeba	-	2	2	-	-	2	-	-
Brachionus sp.	1	-	-	2	2	-	-	1
Calanus sp.	2	-	-	1	-	-	-	1
Cladocera sp.	-	2	1	-	2	-	2	-
Cyclopoid sp.	-	-	2	-	1	-	-	-
Copepod larvae	1	-	-	2	-	2	-	2
Diaptomus sp.	2	1	-	-	-	1	2	-
Eucalanus sp.	-	-	2	1	1	-	1	1
Mysis sp.	1	2	1	-	-	1	-	-
Paracalanus sp.	-	-	-	1	-	-	2	2
Density Unit/L	**9**	**8**	**9**	**8**	**9**	**9**	**9**	**8**
No. of genera	**6**	**5**	**6**	**6**	**6**	**6**	**5**	**6**

A total of 12 zooplankton genera were recorded in Kandla and Vadinar during the study period. The zooplankton community was mainly composed of *Acartia sp., Acrocalanus, Cladocera sp., Copepod larvae, and Mysis sp.*, which showed the highest occurrence across stations. From **ME-1 to ME-6** (Kandla), the density of zooplankton ranged between **8 to 9 units/L**. In Vadinar (**ME-7 and ME-8**), the density ranges from **8 to 9 units/L**. At Kandla stations, *Acartia sp., Cladocera sp., Brachiomus sp., Copepod larvae, and Mysis sp* were the most frequently observed genera, while *Acrocalamus, Diaptomus sp., Cladocera sp. and paracalanus sp.* also had strong representation at Vadinar stations.

The details of Species richness Index and Diversity Index in Zooplankton communities are mentioned in **Table 43**.

Table 43: Species richness Index and Diversity Index in Zooplankton

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	6	5	6	6	6	6	5	6
Individuals	9	8	9	8	9	9	9	8
Shannon diversity	1.74	1.49	1.74	1.65	1.74	1.74	1.58	1.65
Simpson (1-D)	0.92	0.89	0.92	0.93	0.92	0.92	0.89	0.93
Species Evenness	0.97	0.93	0.97	0.92	0.97	0.97	0.98	0.92
Margalef	2.28	1.92	2.28	2.4	2.28	2.28	1.82	2.4
Berger-Parker	0.22	0.25	0.22	0.25	0.22	0.22	0.22	0.25
Relative abundance	66.67	62.5	66.67	75	66.67	66.67	55.56	75

- **Shannon- Wiener's Index (H)** of zooplankton communities was in the range of **1.49 to 1.74** between selected sampling stations from ME-1 to ME-6 with an average value of **1.68** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of zooplankton communities recorded to be **1.58** at ME-7 and **1.65** at ME-8 with an average value of 1.61**.** The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Near SPM (Vadinar).

- **Simpson diversity index (1-D)** of zooplankton communities was ranged between **0.89 to 0.93** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.91.** Similarly, for Vadinar Simpson diversity index (1-D) of zooplankton communities was **0.89** ME-7 and **0.93** at ME-8 with an average of **0.91.**

- **Margalef's diversity index** (Species Richness) of zooplankton communities in Kandla and nearby creeks sampling stations was varying from **1.92 to 2.40** with an average of **2.24** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of zooplankton communities observed **1.82** at ME-7 and **2.40** at ME-8 with an average value of **2.11**.

- **Berger-Parker Index (d)** of zooplankton communities was in the range of **0.22 to 0.25** between selected sampling stations from ME-1 to ME-6 with an average value of **0.23** at Kandla creek and nearby creeks. Berger-Parker Index (d) of zooplankton communities in the sampling stations of Vadinar, was observed **0.22** at ME-7 and **0.25** at ME-8 with an average value of **0.23**. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.92 to 0.97** for all the six-monitoring station of Kandla whereas, for the Vadinar the species evenness was observed **0.98** at ME-7 and **0.92** at ME-8 the locations**,** during the monitoring month.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of **62.5 to 75** between selected sampling stations from ME-1 to ME-6 with an average value of **67.36** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **55.56** at ME-7 and **75** at ME-8 with an average value **65.28**, thus it can be concluded that the studied species is stated as neither highly dominant nor rare.

The details of variation in abundance and diversity in **Benthic organism** are mentioned in **Table 44.**

Table 44: Benthic Fauna variations in abundance and diversity in sub surface sampling

Family/Class	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Thiaridae	2	-	-	-	2	-	1	2
Mollusca	-	1	1	1	-	2	-	-
Odonata	-	-	2	2	-	1	1	-
Lymnidae	1	-	-	1	1	-	-	-
Planorbidae	-	2	1	-	-	1	-	-

Family/Class	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Talitridae	1	-	-	-	-	-	1	2
Trochidae	2	1	1	1	1	1		1
Atydae	-	-	1	2	-	-	1	2
Gammaridae	-	-	-	-	1	1	-	-
Portunidae	-	1	-	-	-	-	-	-
Turbinidae	2	2	2	1	1	2	2	1
Palaemonidae	-	-	-	-	-	-	1	-
Density-Units/l	**8**	**7**	**8**	**8**	**6**	**8**	**7**	**8**
No of Class	**5**	**5**	**6**	**6**	**5**	**6**	**6**	**5**

Few benthic organisms were observed in the collected samples using Van-Veen grabs at Deendayal Port (Kandla and Vadinar). The dominant macro-benthic groups included *Thiaridae, Mollusca, Trochidae, Atydae, and Turbinidae,* which were present across multiple stations. *Turbinidae* was observed at all sites (**ME-1 to ME-8**). While *Mollusca sp and Trochidae* occurred at most of the locations, indicating their broad distribution. The number of benthic families/classes varied between 5 to 6 across all stations.

At ME-1, the most dominant groups were *Thiaridae, Turbinidae and Trochidae* each with a density of **2 units/L**. The least represented benthic fauna included *Lymnidae and Talitridae* which was observed only at ME-1 with a Density of **1 units/L**.

The details of Species richness Index and Diversity Index in Benthic Organisms are mentioned in **Table 45.**

Table 45: Species richness Index and Diversity Index in Benthic Organisms

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	5	5	6	6	5	6	6	5
Individuals	8	7	8	8	6	8	7	8
Shannon diversity	1.56	1.47	1.73	1.73	1.39	1.73	1.65	1.56
Simpson 1-D	0.89	0.9	0.93	0.93	0.93	0.93	0.95	0.89
Species Evenness	0.97	0.91	0.97	0.97	0.86	0.97	0.92	0.97
Margalef's	1.92	2.06	2.4	2.4	2.23	2.4	2.57	1.92
Berger-Parker	0.25	0.29	0.25	0.25	0.33	0.25	0.29	0.25
Relative abundance	62.5	71.43	75	75	83.33	75	85.71	62.5

- **Shannon- Wiener's Index (H)** of benthic organism was in the range of **1.39 to 1.73** between selected sampling stations from ME-1 to ME-6 with an average value of **1.60** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of benthic organism recorded to be **1.65** at ME-7 & **1.56** at ME-8 location with an average value of **1.60**. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Vadinar.

- **Simpson diversity index (1-D)** of benthic organism was ranged between **0.89 to 0.93** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0**.91. Similarly, for Vadinar Simpson diversity index (1-D) of benthic organism was **0.95** at ME-7 and **0.89** at ME-8 location with an average of **0.92.**

- **Margalef's diversity index** (Species Richness) of benthic organism in Kandla and nearby creeks sampling stations was varying from **1.92 to 2.40** with an average of **2.23** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of benthic organism observed to be **2.57** at ME-7 and **1.92** at ME-8 location with an average of **2.24**.

- **Berger-Parker Index (d)** of benthic organism was in the range of **0.25 to 0.33** between selected sampling stations from ME-1 to ME-6 with an average value of **0.27** at Kandla creek and nearby creeks. Berger-Parker Index (d) of benthic organism in the sampling stations of Vadinar, was observed to be **0.29** at ME-7 and **0.25** at ME-8 location with an average value of **0.27**. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.86 to 0.97** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of **0.92** at ME-7 and 0.97 at ME-8.

- During the sampling period, **Relative Abundance** of Benthic organisms was **62.5 to 83.33** between selected sampling stations from ME-1 to ME-6 with an average value of **73.71** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **85.71** at ME-7 and **62.5** at ME-8 location, with an average value **74.11**, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla

STP Monitoring

Noise Monitoring

Soil Monitoring

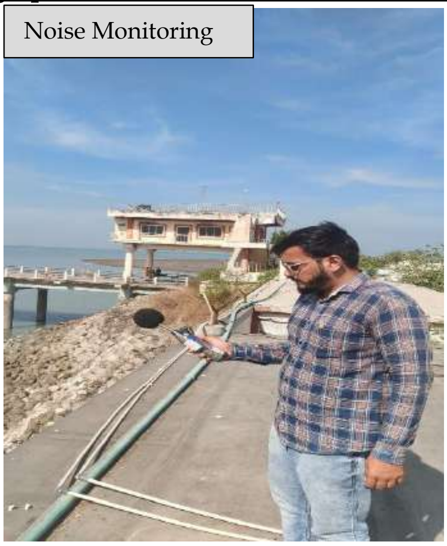
Marine Monitoring

Air Monitoring

Drinking Water Monitoring

Annexure 2: Photographs of the Environmental Monitoring conducted at Vadinar

Air Monitoring



Noise Monitoring

STP Monitoring

Drinking water Monitoring

Marine Monitoring

Soil Monitoring

Source: GEMI

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"We Provide Environmental Solutions"

Annexure -C

Monsoon Report
(June to September, 2024)

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

Submitted to

DEENDAYAL PORT AUTHORITY
ISO 9001:2008 | ISO 14001 | ISPS compliant port

Submitted by

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Abstract

Monsoon (June 2024 to September 2024)

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. (v) EC& CRZ clearance granted by MoEF CC , GOI dated 1/1/2024 augmentation of iquid cargo handling facility specific condition no XXV
2	Deendayal Port letter sanctioning the project	DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/72
3	Duration of the project	Three years-from 2024-2027
4	Period of the survey carried	First Year Monsoon season (June 2024 to September 2024)
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	Among the 15 sampling locations, Tuna Creek had the highest mean plant density with 2535 trees/ha, followed by Kharo Creek with 2486 trees/ha. However, in Kharo creek only one station is located. Regarding individual sample locations, the S-6 had the highest tree density (3,673 trees/ha), followed by S-1 (3,522 trees/ha). The S-15 (1,027 trees/Ha) and S-11 (1,221 trees/Ha) had the lowest average tree density.
7b	Mudflats	The highest TOC value (3.1%) was recorded at S-13 followed by S-1 and lowest TOC value was reported at site S-10 dependent on the living life forms and variations in the living object in the mudflats. The bulk density of mangrove soil at

		Deendayal Port Authority coastal region ranged from 1.30 g/cm3 to 1.61 g/cm3. The highest bulk density was recorded at S-13 sites followed by S-14. The lowest bulk density was recorded at S-5 located at Janghi creek.
7c	Phytoplankton	The phytoplankton density varied from 11,200 No/L to 20,480 No/L with the average 15,019 No/L. The highest phytoplankton density was observed at station S-13 (20,480 No/L) followed by S-14 (19,480 No/L), whereas the lowest 11,200 No/L at S-12. *Dictylum ,Nitzschia, Pseudonitzschia, Pleurosigma, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix, Navicula, Gyrosigma* which are distributed at all the stations.
7d	Zooplankton	The zooplankton identified from the 15 stations falls under 7 phyla and 28 genera belonging to the 13groups. Zooplankton population density v during the Monsoon 2024 at the 15 sampling sites ranged from 8,400 No/L to14,420No/L with an overall average of 10,491No/ L . 12 zooplankton genera that exhibited 100% of occurrence.
7e	Intertidal Fauna	The species diversity of the invertebrate phyla showed the maximum for phylum Mollusca (8 species), which is followed by Arthropoda (4species). The overall percentage composition of the three groups of intertidal fauna at the 15 station ie Arthropoda (67.09%), Mollusca (22.11%), and Chordata (10.8%),
7f	Sub-tidal Macrobenthos	macro benthic species of the various groups recorded (Fig.20) & Table 6 from the DPA port environment includes Mollusca (10) and Annelida (4) Arthropoda (2). The percentage composition of the three phyla that occurred during the monsoon. The phylum Mollusca is represented by maximum (65%) share of the subtidal Fauna, followed by Annelida (25.5%), Arthropoda (9.8%)
7g	Seaweeds	NO
7h	Seagrass	NO.
7i	Marine reptiles	NO
7j	Marine mammals	NO
7k	Halophytes	The halophytes sp *Salicornia brachiata* as mesure dominance
7l	Avifauna	A total of 53 species (32 species terrestrial and 21 aquatic bird) representing 9 order, 22 families and 37 genera were recorded during the study period
7m	Physicochemical	This is purely dynamic varies according to tidal current and condition gulf environment and influence to entire creek system.

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1. Introduction

Deendayal Port is located at Kandla in the Kachchh district of Gujarat state, operated by Deendayal Port Authority (DPA) (constituted under the major port Authority Act and the administrative control of ministry of ports shipping & water way GOI)is India's busiest major port in recent years and is gearing to add substantial cargo handling capacity with private participation. DPA being one of the 12 major ports in India is situated at latitude 22°59'4.93N and longitude 70°13'22.59 E on the Kandla creek at the inner end of Gulf of Kachchh (GoK). 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 viz. chemicals, edible oil, crude oil and other petroleum products etc. DPA has handled 132.3 MMTPA during the year 2023-2024. Presently, the Port has total 1-16 dry cargo berths for handling dry cargo, 7 oil jetties, and one barge jetty at Bunder basin, dry bulk terminal at Tuna Tekra, barge jetty at Tuna and two SPMs (2 local & 1 Nayara energy Limited and two product berths-Nayara energy Limited) at Vadinar for handling crude oil & petroleum product. Regular expansion or developmental activities such as the addition of jetties, allied SIPC and ship bunkering facilities oil jetty No 8 and container terminal at Tuna Tekra are underway in order to cope with the increasing the 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 shape 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 (Stage I) with in existing Kandla port – specific condition no. xxiii.

(iii) EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 (1)Setting of oil jetty No7 (2) Setting up barrage jetty at jafarawadi (3) Setting up barrage port at Veera (4) Admirative office building at Tuna Tekra (5) Road connecting from Veera barrage jetty to Tuna gate by M/s DPA -specific condition no. xv.

(iv) EC & CRZ clearance granted by the MoEF &CC, GoI dated 20/11/20 – expansion of port by creation of water front facilities (Oil jetty 8,9,10 and 11) and development of land area 554 acres for associated facilities for storage at old

Kandla , Gandhidham, Kachchh by Ms.Dpa Para VIII Marine Ecology, specific condition iv.

(v)Development of 7 integrated facilities (Stage I) within the existing Kandala port CRZ clearance MoEFcc ,GOI dated 19/12/2016-Specific condition (ii),(iii) and (iv) the project proponent ensure that ,not damage the mangrove patch without disturbing creek water circulation ,there is no blocking of creek or rivers of project area and shoreline also not damaged and it periodically monitored .

(vi) EC& CRZ clearance granted by MoEF CC , GOI dated 1/1/2024 augmentation of liquid cargo handling facility specific condition no XXV.

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 all 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 an 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 faunal 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 and further extended to another 3 years i.e from May 2024 to May 2027 with specific condition XXV for augmentation of liquid cargo handling facility . The study covers all the seasons as specified by specific condition of the Ministry of Environment, Forest and Climate Change (MoEF&CC). The present study is designed considering the scope of 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 & 1.1.2024 with specific conditions xviii, xxiii, xv, iv and xxv respectively. A detailed holistic approach to different components of 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 the period May 2024 to May 2025 as follows:

- Physico-chemical characteristic of water and sediment will be analysed.
- 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.
- To study the intertidal faunal composition, distribution, diversity, density and other characteristics, other mega faunal components such as mammals, reptiles and amphibians.
- To investigate the species composition, distribution, diversity, density of sub-tidal benthic fauna.
- To estimate the primary productivity selected sampling sites located in around DPT area.
- Investigate the species composition, distribution, density and diversity of phytoplankton and zooplankton.
- To study the distribution of halophytes, sea grasses, seaweeds and other coastal flora, their occurrence, distribution, abundance and diversity.
- To study the Avifaunal Density, diversity, composition, habitat, threatened and endangered species and characters.
- Fishery Resources - Common fishes available, composition, diversity, Catch Per Unit Effort (CPUE) and other socio-economic information.

This study in short attempts the following, to i) developing a strong long term monitoring of the port marine environment from the biological perspective which could be used to monitor changes in the future, and ii) formulating a management plan based on the baseline data in order to ensure long-term ecological health of the port environment. A better understanding of the marine ecology of the port and its processes has been attempted in this study which will assist in better management and conservation decisions to promote marine environmental health within the port limits.

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 (Table1) .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 (Fig1). 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).

Locations	GPS coordination	
	Latitude	Longitude
S-1	22.9410	70.1358
S-2	22.9616	70.1244
S-3	22.9876	70.2345
S-4	23.0285	70.2331
S-5	23.0804	70.2245
S-6	23 9'19.99	7024'1.47
S-7	22.9771	70.2125
S-8	23.0378	70.4070
S-9	22.9960	70.3932
S-10	23.1007	70.2961
S-11	23.1608	70.4948
S-12	22.9446	70.1062
S-13	23° 6'58.69"	70°21'8.77"
S-14	22.89590	70.07450
S-15	23.0654	70.2172

Table 1 . Sampling locations (2024-2025)

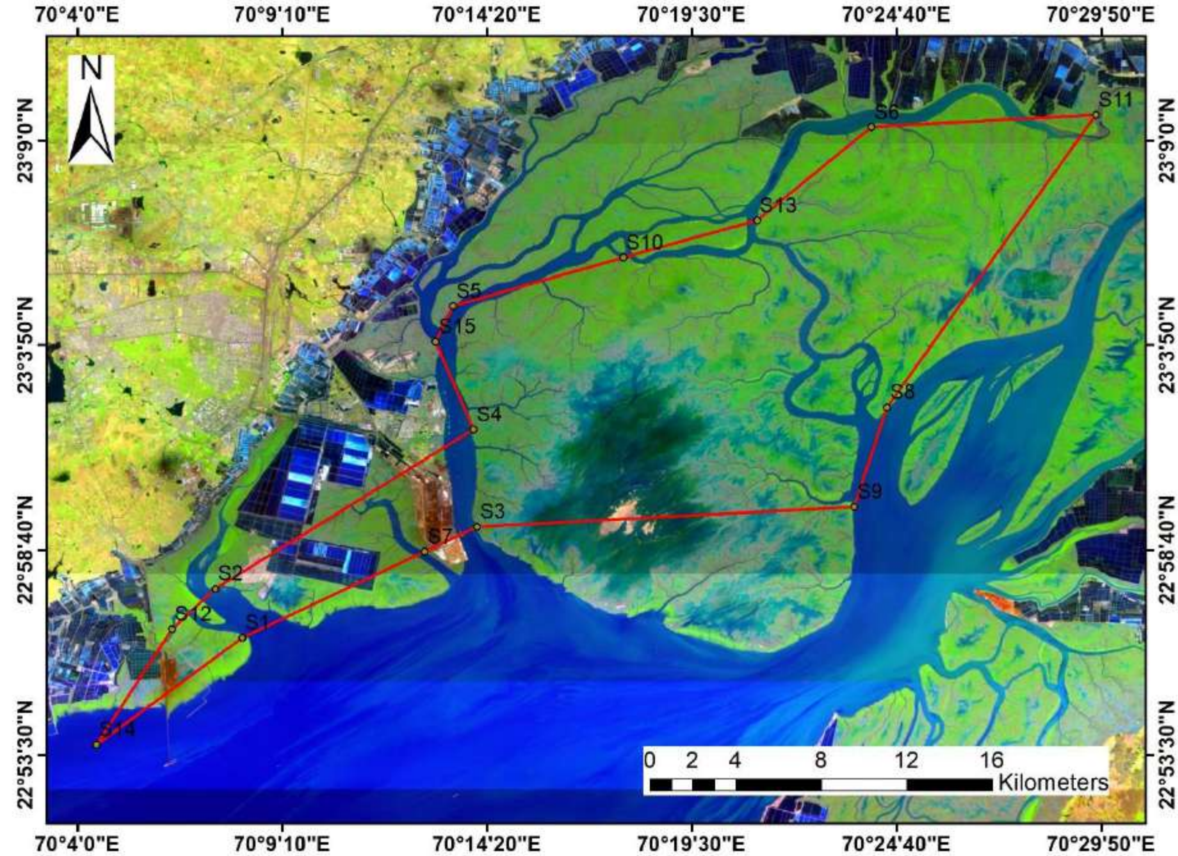


Figure 1. Sampling location of Study area

Gujarat Institute Of Desert Ecology

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.2).

Table 2: Physico-chemical and biological parameters analysed

Parameters	
Water	**Mangrove & Other Flora**
pH	**Mangrove**
Temperature	Vegetation structure, density
Salinity (ppt)	Diversity
Dissolved oxygen	Height
Total Suspended Solids (TSS)	Canopy and other vegetation characteristics
Total Dissolved solids (TDS	**Halophytes:**
Turbidity	Percentage of distribution and cover
Nutrients	Diversity
Nitrate (NO_3)	**Seagrass and Seaweed**
Nitrite (NO_2)	Occurrence, distribution, and diversity
Phosphate	**Intertidal fauna**
Silicate	Composition, distribution, diversity, density and other characteristics
Petroleum Hydrocarbon (PHs)	**Mammals**
Sediment	**Avifauna**
Texture	Density, diversity, composition, habitat,
Bulk density	Threatened and endangered species and characters
Total organic carbon (TOC)	
Biological Parameters	
Phytoplankton- Genera, abundance, diversity and biomass	
Productivity-Chlorophyll a	
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 the 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

Methodology

2.1.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 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).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.

Silicate

The determination of dissolved silicon compounds in natural waters is based on the formation of a yellow silicomolybdic acid when an acid sample is treated with a molybdate solution. It is Spectrophotometrically measured by absorbance (810 nm for maximum absorbance and 660 for about 40% by adopting method of s Grasshoff et.al 1999**.**

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 sampling

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 passed through sieves of different mesh size as per Unified Soil Classification System (USCS). Cumulative weight of the fraction 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).

2.2. 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 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 the 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.

Intertidal Fauna

Intertidal faunal assemblages were studied for their density, abundance and frequency of occurrence during Monsoon 2024 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; 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).

Sub tidal 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. /10cm^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 (2017), Ravinesh *et al*. (2021) and Edward *et al*, (2022) for molluscs. Statistical analyses such as diversity indices and Univariate measures such as Shannon-Wiener diversity index (H'), Margalef's species richness (d), Simpson's dominance (D) were determined using 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

2.3. 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 reflects the 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).

Plate 3. Sediment sample collection at mangrove and mudflat areas

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.

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).

2.4. Mangrove assessment

Mangroves are widely distributed on the Deendayal Port Authority jurisdiction area along the Kandla coast. The 15 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 closeness of the location to the respective creek system. The Point Centered Quadrate Method (PCQM) was used for the collection of data of the mangrove vegetation structure. The data included, measurements of density of plants, height variations, canopy and basal girth 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 to the 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

2.5. 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 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 halophyte

2.6. 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 (Plate 6). For effective sampling, points were fixed at distances within the 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

2.7. 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, 2024). 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.

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 Table3.

Temperature (°C) and pH

The water temperature at the sampling sites ranged from 23°C to 30°C.The maximum temperature of seawater was reported at S-7 and the minimum at S-6 in Janghi creek. The pH of seawater ranged from 7.7 to 8.1. The highest pH reported from majority of the stations was 8.0 to 8.1 and the lowest value 7.7 was noticed at S-8 S-11 in Navlaki creek & Janghi . The overall temperature fluctuation minimum which might be due to monsoon water but the pH of the water did not show remarkable variations 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 34 ppt to 42 ppt with the average value of 38 ppt. Minimum salinity was observed at S-3 and maximum at S-8 & S-10 also.

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 2.9 mg/L to 8.2 mg/L. The highest DO concentration was observed at station S-4 and lowestvalue reported at S-7.

Suspended Solids (TSS)

The total suspended solids (TSS) concentration at the 15 sampling sites ranged from 205 mg/L to 729 mg/L with the average of 419 mg/L. The highest TSS values was reported at S-6 followed by 658 mg/L in S-3 opposite oil jetty. The minimum TSS value 205 mg/L was recorded at S-13.

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 26,876mg/L 1,39,862mg/L with an average of 84,352 mg/L. The maximum value was reported from S-10.

Turbidity

The turbidity of the water samples from the study sites ranged between 20 NTU and 160 NTU with the average of 59 NTU. The lowest value was noticed at S-8 and the highest value at S-6 followed by S-7 (142 NTU).

Dissolved nutrients (Nitrate, Nitrite, Total Phosphorus and Silicate)

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 0.001 mg/L to 0.003 mg/L with an average of 0.002 mg/L.. There was no remarkable variation in the concentration of nitrate among the study stations. Similarly, nitrite values varied between 0.001 mg/L to 0.173 mg/L. The highest concentration was observed at station S-9 and lowest value at station S-14. The Total phosphorus values among the study station ranged from 36 mg/L to 73 mg/L with an average of 54 mg/L. The highest phosphorus concentration was observed at station S-6 near Janghi creek and lowest at station S-3 opposite to oil jetty . During this season the highest concentration over limit might be due to leaching of phosphatic fertilizer while handling in the cargo port area and other cargo discharge . Likewise, the silicate concentration varied from 0.012 mg/L to 0.058 mg/with the average of 0.035 mg/L.The highest concentration of Silicate was observed at S-15 and lowest value at S-14. The variations in the concentration of silicate in correlated with the production of diatoms and siliceous planktonic species which are invoved in the in the export of carbon from surface of open sea towards creek system of Kandla and the particulate matter to the bottom sediment.

Petroleum Hydrocarbons (PHs)

Petroleum Hydrocarbons (PHs) are widely recognized as the most extensively utilized fossil fuels in commercial applications (Kuppusamy et al., 2020). PHs serve as crucial raw materials across various industries and function as primary sources of energy (Varjani, 2017). However, their pervasive use has led to their identification as a major concern in terms of environmental contamination, posing significant threats to ecosystems due to their inherent stability and resilience. The category of PHs encompasses diverse components, including Polycyclic aromatic hydrocarbons (PAHs), alkanes, paraffin, cycloalkanes, organic pollutants, and non-hydrocarbon elements such as phenol, sulfur compounds, thiol, metalloporphyrin, heterocyclic nitrogen, naphthenic acid and asphaltene. The introduction of PHs into an ecological niche or ecosystem promptly alters its composition, leading to a decline in overall functionality and inducing weathering processes. This weathering, in turn, initiates various influences, encompassing chemical reactions (auto-oxidation/photo-oxidation), physical changes (dispersion), physico-chemical alterations (sorption, dissolution, evaporation), and biological transformations (microbial and plant catabolism of hydrocarbons) (Truskewycz et al., 2019).The presence of PHs significantly impacts marine organisms, with bioaccumulation of harmful PHs in the aquatic food chain persisting for extended periods. This, in consequence, affects primary producers, primary consumers, and secondary consumers. Notably, approximately 90% of PH discharges are attributed to anthropogenic activities, particularly oil spills, occurring in both terrestrial and marine environments. Reports indicate an alarming annual discharge of around 8.8 million metric tonnes of oil into aquatic environments (Periathamby and Dadrasnia, 2013).

In the current study, the presence of PHs in water samples collected along all the 15 sampling locations were detected and estimated. The PHs ranged from 1.2 µg/L to 10.1 µg/L.. The highest concentration of the PHs was noticed at S-4 (in front of oil jetty) (10.1 µg/L while the lowest was noted at S-5 (1.2 µg/L) (Phang creek) with average variation of 4.6 2 µg/L among the different station . Overall the PHs in al station little higher which might be due to cargo handling activity.

Table 3: Physico-chemical& Biological characteristics of the waters at the study sites during Monsoon 2024

Parameter	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) (Water)	24	25	25	25	26	23	30	25	25	24	29	24	25	26	23
pH	8.1	8.0	8.1	8.0	8.0	8.1	8.1	7.7	7.9	7.9	7.7	8.0	8.1	8.1	8.0
Salinity (ppt)	36	38	34	39	37	36	41	42	38	42	38	36	40	38	36
Dissolved oxygen (mg/L)	4.3	6.2	5.5	8.2	7.6	7.4	2.9	7.2	6.4	7.0	5.2	5.8	4.1	3.6	5.3
(TSS) (mg/L)	302	599	658	467	346	729	503	329	365	390	346	468	205	259	323
(TDS) (mg/L)	56812	138585	88083	59045	116696	77160	83011	47680	98899	139862	89974	26876	96345	87131	59128
Turbidity (NTU)	58	45	58	74	42	160	142	20	47	60	44	47	31	28	33
Nitrate (NO_3) (mg/L)	0.003	0.002	0.002	0.002	0.002	0.003	0.001	0.002	0.003	0.003	0.002	0.002	0.002	0.002	0.003
Nitrite (NO_2) (mg/L)	0.050	0.038	0.031	0.053	0.050	0.064	0.079	0.061	0.173	0.018	0.062	0.094	0.083	0.001	0.052
Silicate (mg/L)	0.043	0.039	0.030	0.034	0.037	0.028	0.022	0.021	0.053	0.047	0.054	0.027	0.018	0.012	0.058
Total Phosphorus (mg/L)	48.24	61.18	36.18	68.53	62.94	73.24	46.18	51.18	37.06	53.82	42.35	46.18	53.53	67.35	62.94
PHs (µg/L)	7.15	6.35	3.49	10.1	1.2	6.5	2.05	7.85	8.7	2.75	1.75	3.9	3.45	1.4	2.45
TOC	3.12	2.55	2.88	2.715	3.03	2.82	2.91	2.955	2.7	2.43	2.775	2.85	2.67	2.52	2.73
(Biological) Chlorophyll a (mg/L)	0.18	0.27	0.13	0.00	0.04	0.11	0.46	0.89	0.59	0.00	0.21	0.47	0.17	0.20	0.08

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.2.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-1 followed by S-4. The highest percentage of sand was observed at S-14 followed by S-11 . As per the observations, the percentage of silt content showed wide fluctuations between stations when compared to the clay and sand The nature of soil texture was characterized by the proportion of clay, sand and silt fractions. The Soil texture revealed the dominance of clay-sandy type while the sandy type substratum was very much dominated as compared to silt. This feature of the bottom sediment might be attributed to the activity of sediment transport in the creek 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.

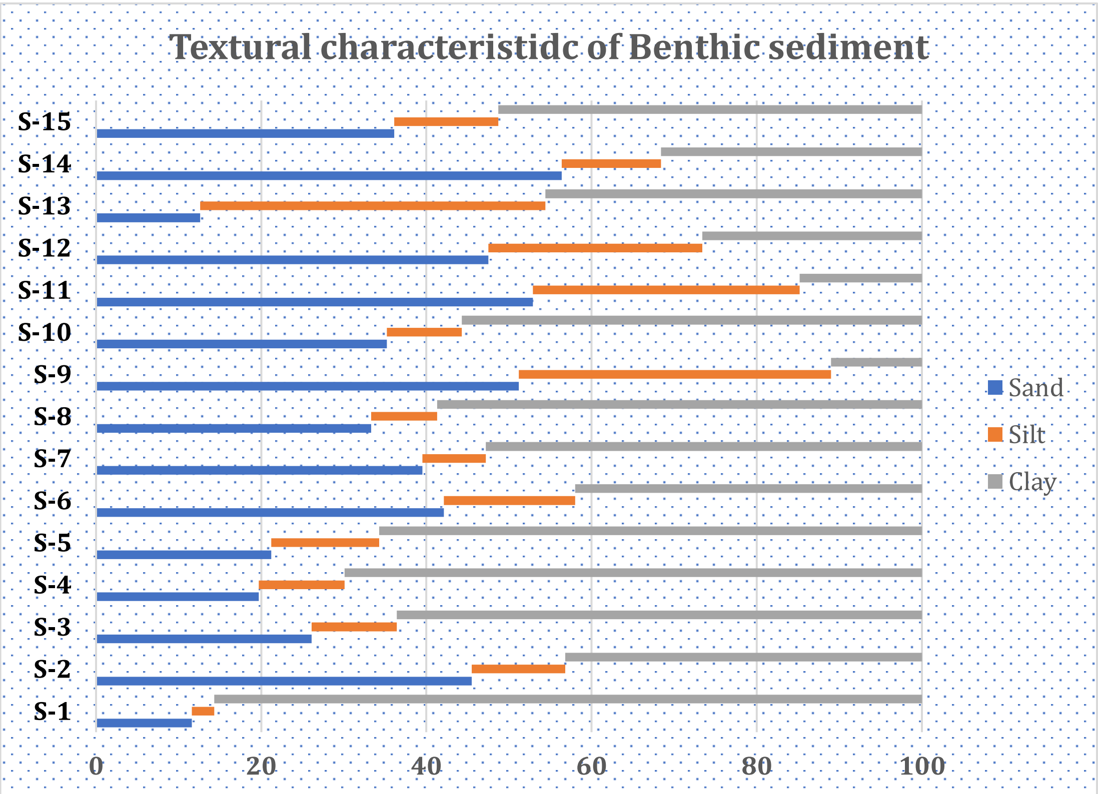


Figure 2: Characteristics of sediment at the study stations in Monsoon 2024

Total Organic Carbon (TOC)

In the present study, the total organic carbon content varied from 2.4% to 3.1% (Fig.3). The highest values of TOC were reported at S-1 followed by S-5 &S-8. The lowest TOC value was recorded at S-10. The distribution of total organic carbon closely followed the distribution of sediment type in general i.e., sediment low in clay content contained relatively low organic carbon. But in the Kandla creek system is associated with Mangroves which holds the organic particles derived from the plants and the fauna undergo decomposition and mixed with the sediment during the the mixing process which would have facilitated the adherence of particulate matter in the soft substratum as most of the stations showed more organic carbon load during monsoon .

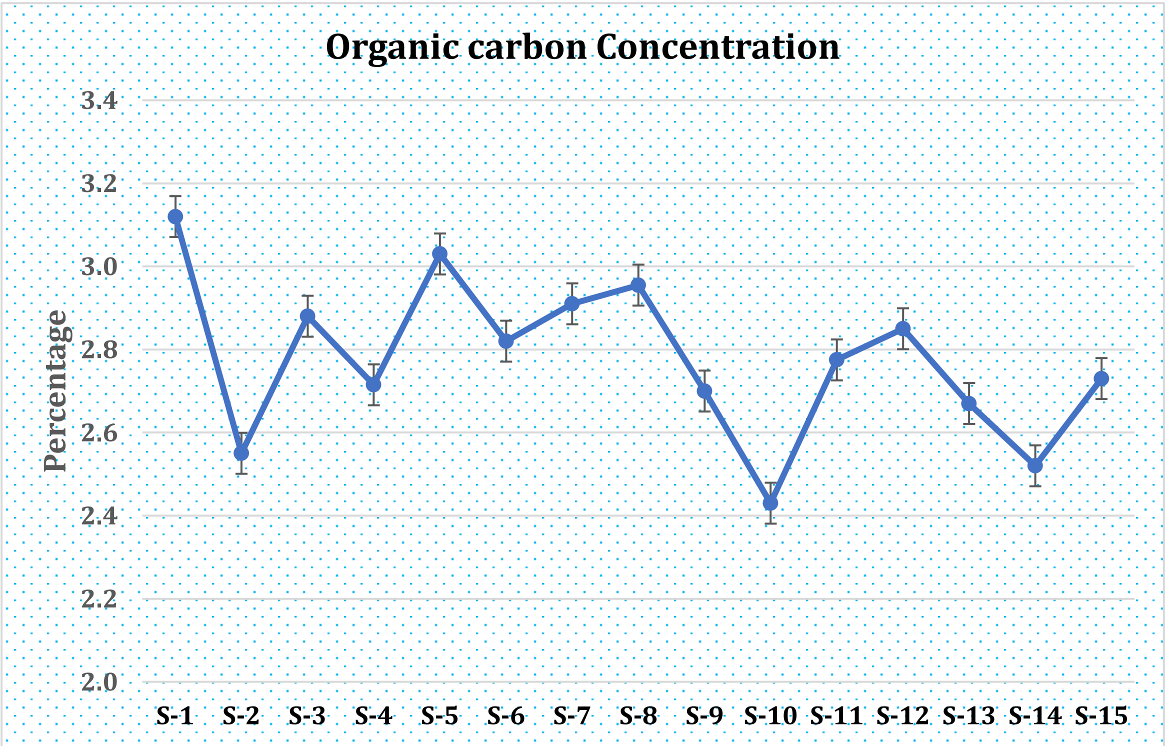


Figure 3: Total Organic Carbon content (%) in the sediment during Monsoon 2024

3.3. Biological characteristics

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 arbitrated by the activity of microscopic phytoplankton.

At present , the Chlorophyll 'a' concentration ranged from 0.01 mg/L to 0.89 mg/L with average variation among the station was 0.26 mg/L . The highest concentration 0.89 mg/L was reported at S-8 (Fig.4) followed by S-9 (0.59mg/L). The photosynthetic pigment chlorophyll a which is a measure of the population density of phytoplankton during the monsoon period showed minor variations among the sites. The Chlorophyll 'a' content was very low at S-4 (Table 2).

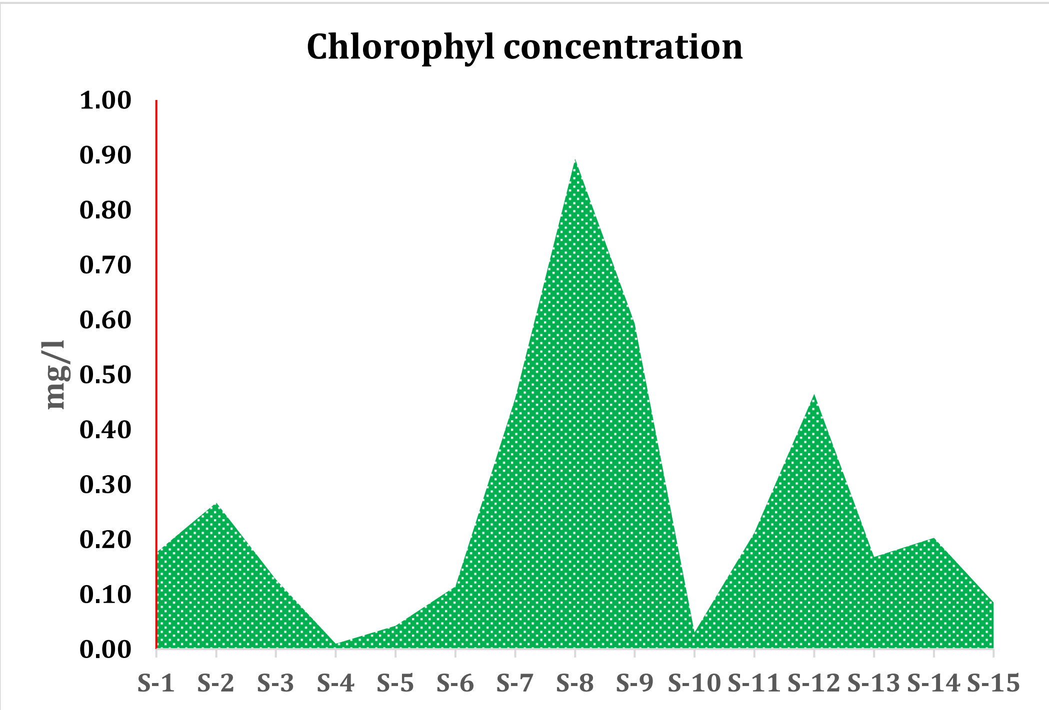


Figure 4: Chlorophyll 'a' concentration at the study stations in Monsoon 2024

3.4. Phytoplankton

Phytoplankton are a key component of the ocean and freshwater ecosystems and provide many ecosystem services including oxygenation through photosynthesis which is estimated to be about half of the Earth's oxygen. Thus, they are important component of the functioning of ecosystems and climate regulation (Jacqueline et al.,2018). The carbon assimilation during photosynthesis by the phytoplankton enables the transfer of atmospheric carbon dioxide into the biomass which is stored in the cells and later pass on to the food chains and being cycled through the food webs. These microscopic producer community has been influenced by the negative impact from human developments and activities, and hence the service provision afforded by them should be accounted for in marine management processes (Jacqueline et al.,2018). Phytoplankton growth depends on the availability of carbon dioxide, sunlight, and nutrients. Phytoplankton, like land plants, require nutrients such as nitrate, phosphate, silicate, and calcium at various levels depending on the species. Some phytoplankton can fix nitrogen and can grow in areas where nitrate concentrations are low. They also require trace amounts of iron which limits phytoplankton growth in large areas of the ocean because iron concentrations are very low. Other factors influence phytoplankton growth rates, including water temperature and salinity, water depth, wind, and what kinds of predators are grazing on them (Lindsey and Scott,2010).

The numerous species of phytoplankton are the primary producers form the basis of marine food-webs, supporting production of higher trophic levels (a provisioning ES), and act as a sink of carbon dioxide. The spatial distributions of phytoplankton and rates of primary productivity are generally subject to bottom-up control, due to the tight coupling between light, temperature and nutrients. understanding of the spatial and temporal variability in phytoplankton parameters are accounted in marine management as these are correlated with physical and chemical factors of the water. The diatoms form the bulk of phytoplankton and the dinoflagellates are scarce. The phyto-plankton in the Gulf of Kachchh shows a primary peak in September and secondary peaks in January or June are instances of local blooms of more than one genus and species of diatoms.The detailed genera and percentage of phytoplankton presented in table -4.

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), and Cyanophyceae. The number of genera recorded during the monsoon period was 17 to 22 at the sampling stations with variations in respect to the composition. The maximum number (22) genera were observed at S-13 and the minimum from S-12 representing 17 genera. As far as generic status is concerned the Pennales diatom contributed a smaller number of genera (13) followed by Centrales (9) (Fig.5 & Table 4). Among the 4 groups of phytoplankton, the genera *Pleurosigma* , *Thalassionema, Coscinodiscus* and *Odontella* was highly dominated.

Percentage composition of phytoplankton

The cumulative percentage composition of the five groups of phytoplankton from all the study sites is presented in Fig.6. The percentage composition varied from 0.14 % to 14.35 % of which the pennales and centrales are the dominant constituting 65% and 34% respectively. The diatoms pennales and centrales together formed 99% of the phytoplankton population by number of genera as well as number of individuals while the rest is constituted by Cyanophyceae (1%) during the monsoon 2024.

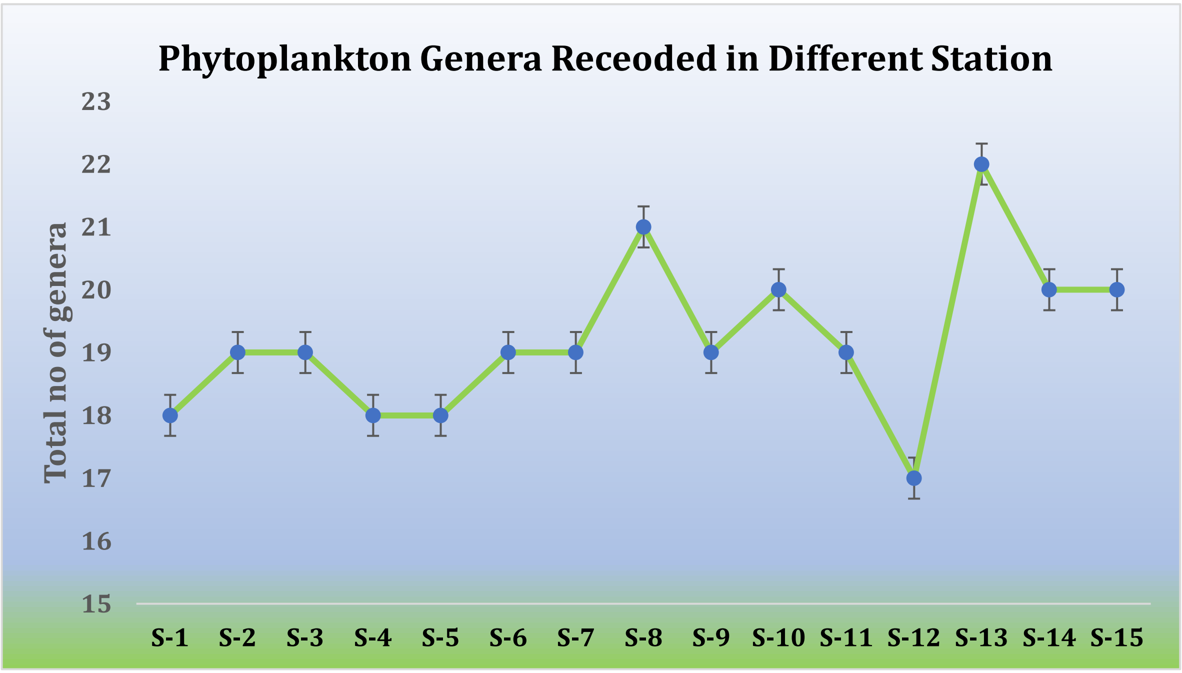


Figure 5: Number of Phytoplankton genera in Monsoon 2024

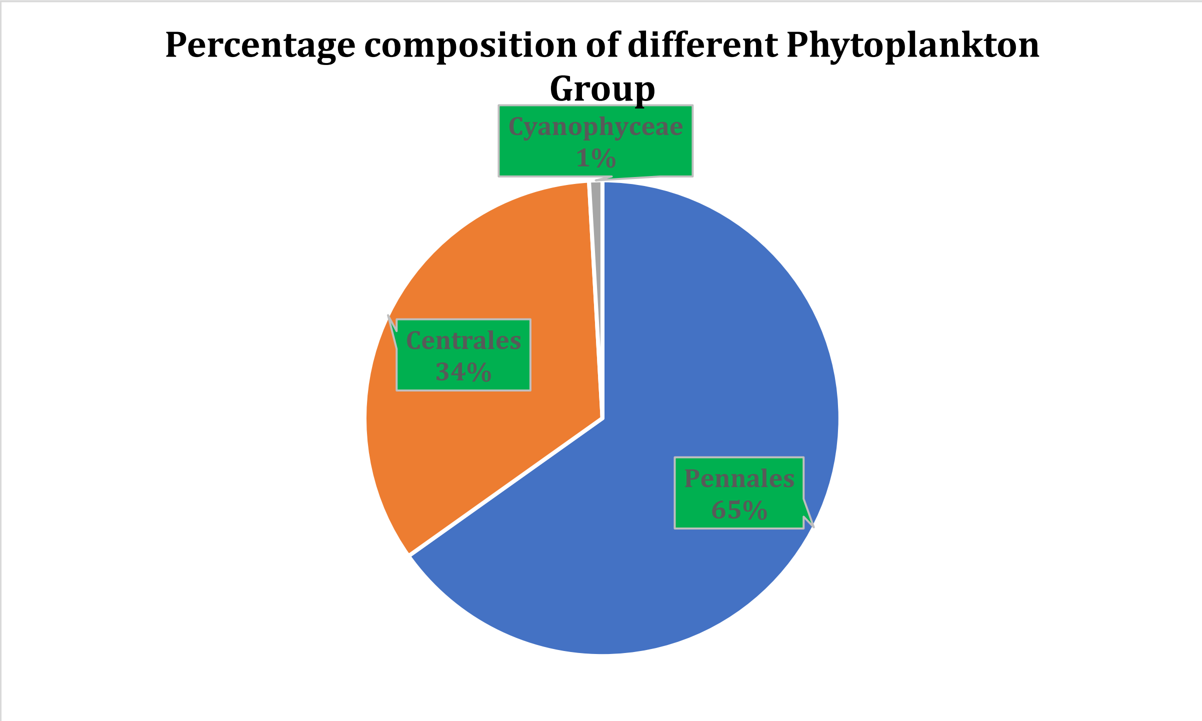


Figure 6: Percentage composition of phytoplankton groups in Monsoon 2024

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 13% to 100% with an average of 83%. i.e 15 genera of diatoms occurred at all the stations i.e *Dictylum ,Nitzschia, Pseudonitzschia, Pleurosigma, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix, Navicula, Gyrosigma* (fig 7) followed by *Triceratium* and *Noctiluca* (73%) during the monsoon season.

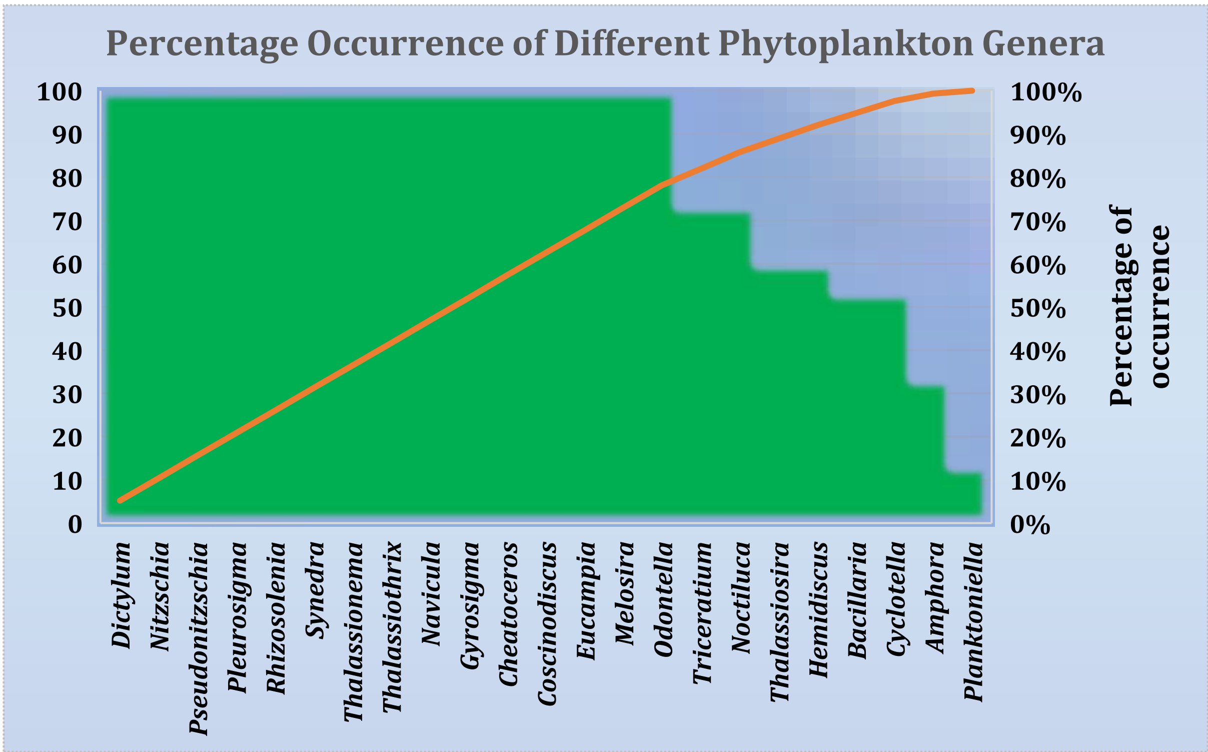


Figure 7: Percentage occurrence of phytoplankton genera in Monsoon 2024

Phytoplankton density and diversity

The density signifies the abundance of plankton which is measured as cell/ individual/L. The phytoplankton density varied from 11,200 No/L to 20,480 No/L with the average 15,019 No/L. The highest phytoplankton density was observed at station S-13 (20,480 No/L) followed by S-14 (19,480 No/L), whereas the lowest 11,200 No/L at S-12 (fig.8). 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 17 to 22 (Table-3). During monsoon the Margalef and Menhinik richness indices were maximum as(2.1& 0.2). The Shannon diversity index was maximum 2.7 and minimum 2.5 a. The Simpson index clearly reflexes the species dominance (genera) at all station (fig 9).

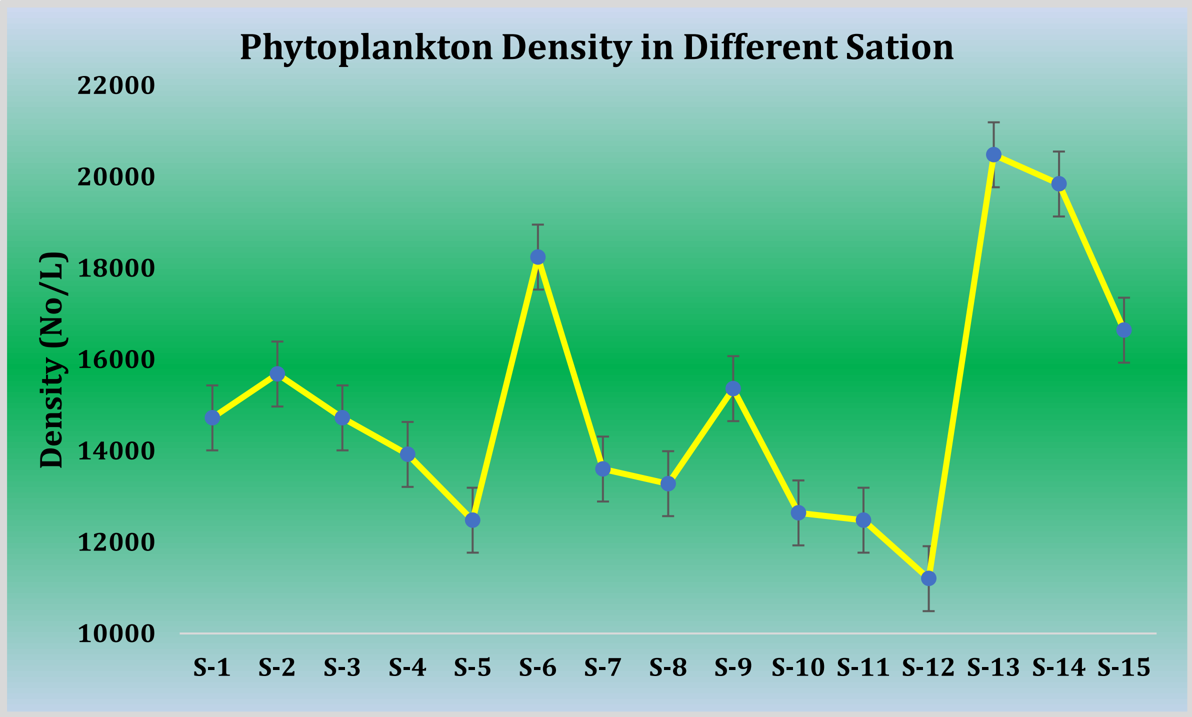


Figure 8: Phytoplankton density in Monsoon 2024

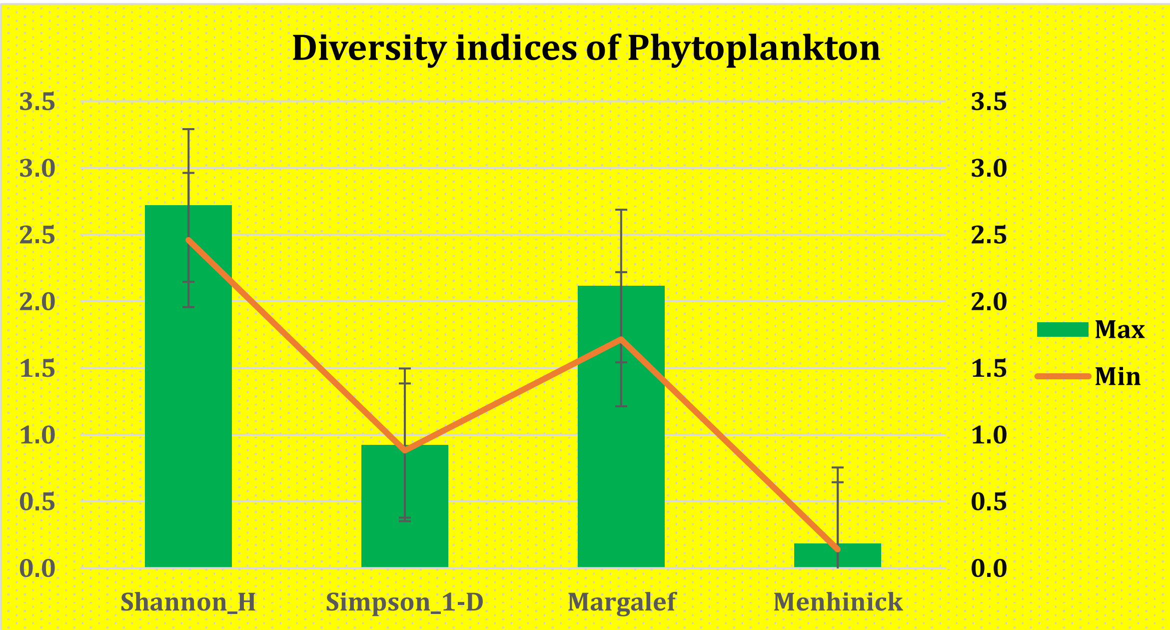


Figure 9: Different diversity indices a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index

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 the cargo movements. Accordingly, species diversity decreases at sites with poor water quality. As presumed from the Shannon diversity index values between 2.60 to 2.93 representing the moderate quality of environmental status dominated by majority of the genera such as *Dictylum ,Nitzschia, Pseudonitzschia, Pleurosigma, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix, Navicula, Gyrosigma* which are distributed at all the stations . A community dominated by relatively few species indicates environmental stress (Plafkin *et al.,* 1989). However, during the monsoon period the many genera appeared and flourish due to the suitable environmental condition in the water. According to Staub *et. al* (1970) species diversity index value between 3.0 to 4.5 represents slightly polluted and the lightly polluted environment shows the index value between 2.0-3.0, and the , 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. Which might be due to the industrial development and salt pan activity along the periphery environment of DPA port authority.

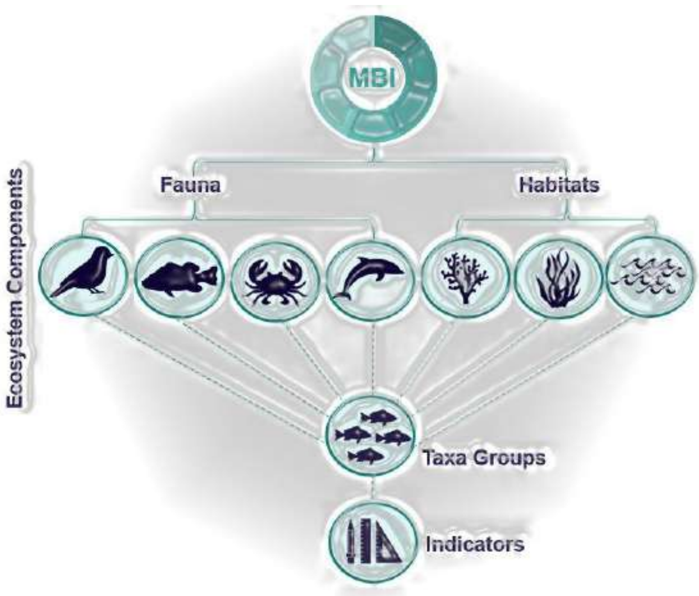


Table 4: Phytoplankton density, percentage composition and occurrence during Monsoon 2024

Group	Genera	Station																
		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**	**PC**	**PO**
Pennales	*Amphora*	0	0	0	0	0	160	0	0	160	0	0	160	160	0	160	0.36	33
	Bacillaria	160	0	0	160	0	0	0	160	160	160	0	0	160	160	160	0.57	53
	Dictylum	480	320	160	480	320	320	160	320	480	640	800	480	320	480	960	2.98	100
	Nitzschia	1280	1440	1120	480	960	1440	1280	480	800	480	640	480	640	480	800	5.68	100
	Pseudonitzschia	480	640	800	480	800	480	640	480	800	480	480	320	640	960	480	3.98	100
	Pleurosigma	320	480	640	800	480	1440	1600	1920	1440	480	1280	1440	3360	3040	1760	9.09	100
	Rhizosolenia	1120	480	640	960	480	1280	480	1120	960	480	800	480	1440	1120	1440	5.89	100
	Synedra	1920	2400	2400	1440	1280	1920	320	320	320	480	640	640	2880	1920	480	8.59	100
	Thalassionema	1280	1440	1760	1920	1600	2880	3360	480	2400	2560	1440	1120	2080	4320	3680	14.35	100
	Thalassiothrix	480	1120	1440	480	1120	1440	480	1280	800	960	480	640	480	320	160	5.18	100
	Navicula	800	1280	480	640	800	480	640	1280	1120	960	480	640	800	480	1280	5.40	100
	Gyrosigma	480	320	480	320	160	480	320	320	480	160	160	480	320	160	160	2.13	100
	Thalassiosira	160	160	320	0	320	0	160	160	320	0	0	0	160	320	0	0.92	60
Centrales	*Cheatoceros*	800	640	480	320	480	800	480	640	800	1120	1440	480	800	480	640	4.62	100
	Coscinodiscus	2880	1440	1600	1920	1280	1920	1440	1920	2240	1440	1600	320	2400	3200	640	11.65	100
	Cyclotella	0	0	0	160	0	0	160	160	0	160	320	0	160	160	320	0.71	53
	Eucampia	320	320	480	640	320	480	320	640	480	320	640	320	480	640	800	3.20	100
	Melosira	480	480	320	480	640	800	480	160	320	480	320	640	480	320	800	3.20	100
	Odontella	960	1120	960	1920	960	1280	800	800	1120	640	480	2240	2080	960	1760	8.03	100
	Planktoniella	0	0	0	0	0	160	0	0	0	160	0	0	0	0	0	0.14	13
	Triceratium	320	160	320	160	160	320	320	160	0	0	160	320	160	0	0	1.14	73
	Hemidiscus	0	1280	160	0	0	160	160	320	0	160	160	0	320	160	0	1.28	60
Cyanophyceae	*Noctiluca*	**0**	160	160	160	320	0	0	160	160	320	160	0	160	160	160	0.92	73
Total Density (No/L)		**14720**	**15680**	**14720**	**13920**	**12480**	**18240**	**13600**	**13280**	**15360**	**12640**	**12480**	**11200**	**20480**	**19840**	**16640**		
Total Genera		**18**	**19**	19	18	18	19	**19**	**21**	**19**	**20**	**19**	**17**	**22**	**20**	**20**		

PC: Percentage of Composition

PO: Percentage of Occurrence

3.5. Zooplankton

These are the primary consumers that depends on phytoplankton for their feeding and constitute a second trophic level in food chain of marine ecosystem. The size of the zooplankton members varies greatly from microscopic to macroscopic occupying different depths in the pelagic realm. They constitute the primary food for several higher trophic level organisms which includes fishes, crustaceans and mollusks. Zooplankton provides the required amount of protein to the cultured fishes and crustaceans (Koli and Mule, 2012) as well. The zooplankton species quickly respond to the environmental changes and thus are used as bio-indicators for the assessment of aquatic environments (Sharma et al., 2007). Thus, zooplankton are of great ecological significance as they play important role of transferring organic matter from primary producer to secondary consumers like fishes (Kehayias et al., 2013). Zooplankton in the Gulf of Kachchhis dominated by copepods (Saravanakumar et al.,2017) while the microzooplankton is represented by Cilio-phora and Forminifera (Patel et al., 2017). Ramaiah (1997) stated that studies on zooplankton communities, especially copepods are of key importance in assessing the health of coastal ecosystems. The distribution of living organism is controlled by the variation in salinity of water and its variation caused by dilution and evaporation is most likely to influence the fauna in the coastal ecosystem (Sridhar et al. 2006). The density of zooplankton was found to be high during postmonsoon and premosoon period, bimodal distribution, the primary peak occurring either in October or April and the secondary peak in March or December (Bhaskaran and Gopalakrishnan,2011). Similarly, there occurs gradual increase in number of organisms towards the offshore area with concomitant increase in diversity. The larval forms of echinoderms, cephalopods and brachiopods are usually confined to the offshore (Govindan et al.,1980). The detailed genera and percentage of phytoplankton presented in table- 5

Phylum, group and generic status

The zooplankton identified from the 15 stations falls under 7 phyla and 28 genera belonging to the 13groups (Table 5). The phylum Arthropoda was the predominant, represented with 20 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 9 genera of copepods in the samples. Among copepods, the Calanoida ranked first in terms of generic representation particularly *Acartia* sp, *Acrocalanus* sp, *Calanopia* sp. and *Calanus* sp. (figure-10).

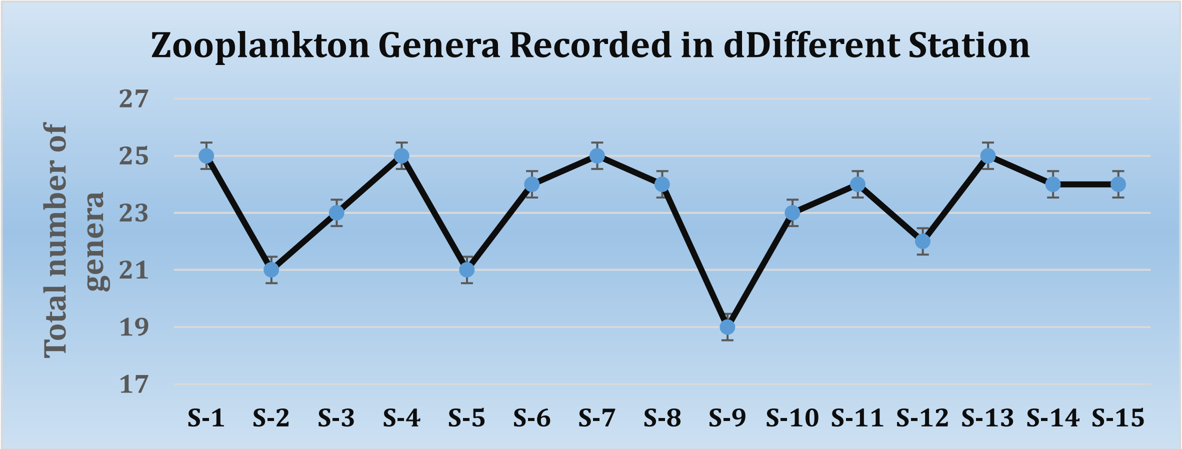


Figure 10: Generic status of zooplankton during Monsoon 2024

Percentage composition

The overall percentage of the various groups of zooplankton varied from 0.4% to 25.8%. The highest percentage was due to the calanoid copepods (25.8%) followed by *Malacostraca* (Brachyuran larvae) (19.9%) and Tintinnida (12.7%). (Fig.11). Among the zooplankton groups calanoid group predominated at all sites.

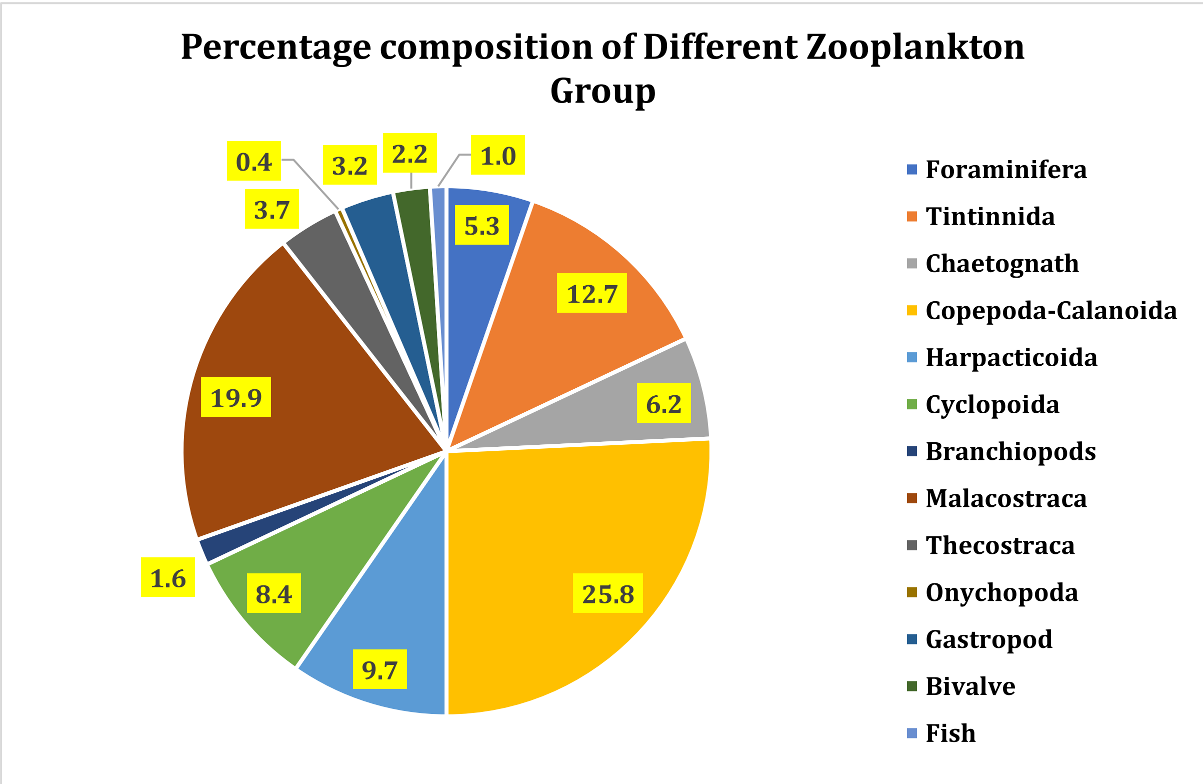


Figure 11: Percentage composition of zooplankton during Monsoon 2024

Percentage occurrence of zooplankton

The percentage occurrence of zooplankton communities(genera) varied from 33% to 100 %. There were 12 zooplankton genera that exhibited 100% of occurrence (Fig.12) followed by the *Euterpina*, *Oithona* and *Oncaea* (93%)and *Calanopia, Nannocalanus* (87%) from the study sites (Table5).

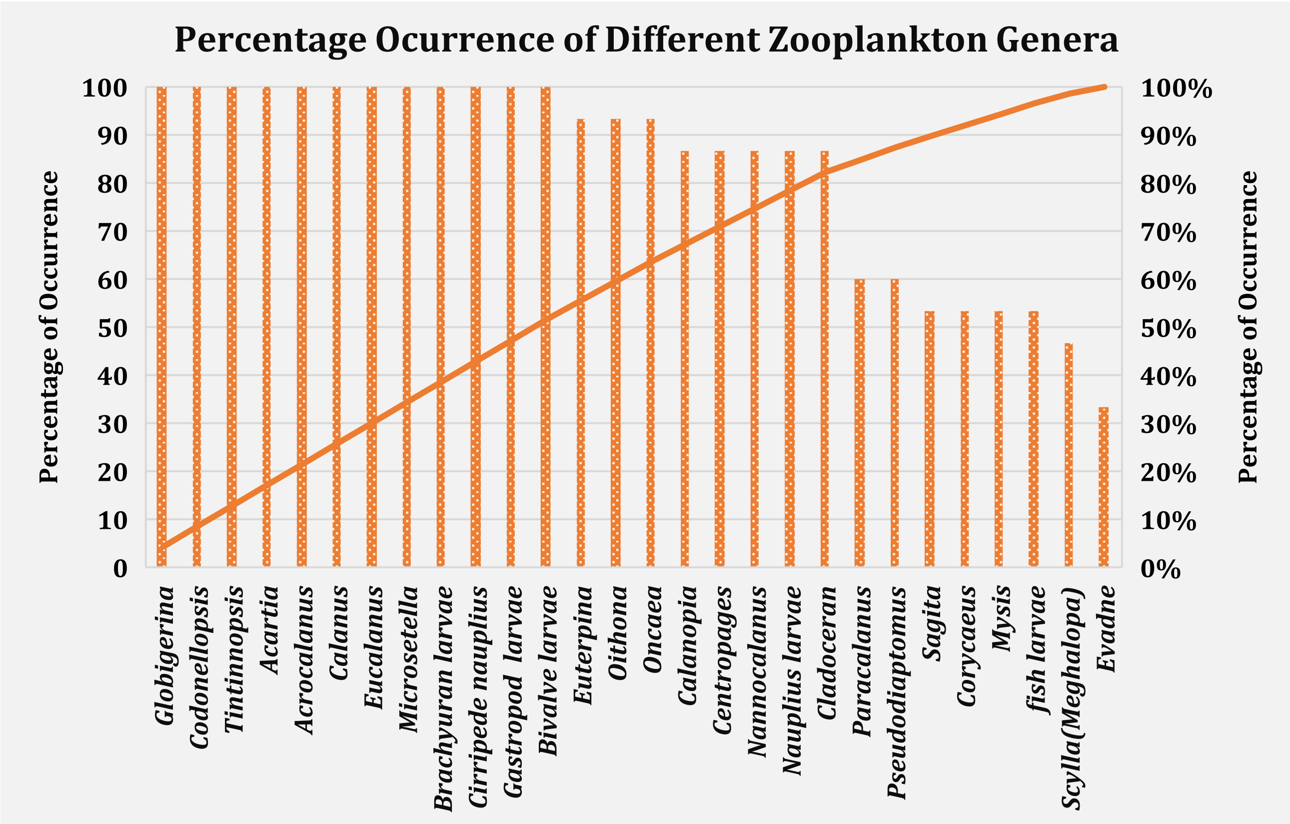


Figure 12: Percentage occurrence of Zooplankton groups during Monsoon 2024

Density of zooplankton

Zooplankton population density v during the Monsoon 2024 at the 15 sampling sites ranged from 8,400 No/L to14,420No/L with an overall average of 10,491No/ L (Table 5). Station-wise, the highest density of 14,420 No/ L was recorded in S-1 followed by S-6 (12,320 No/ L) and lowest density was reported at S-11 (8,400 No/ L) (Figure 13).

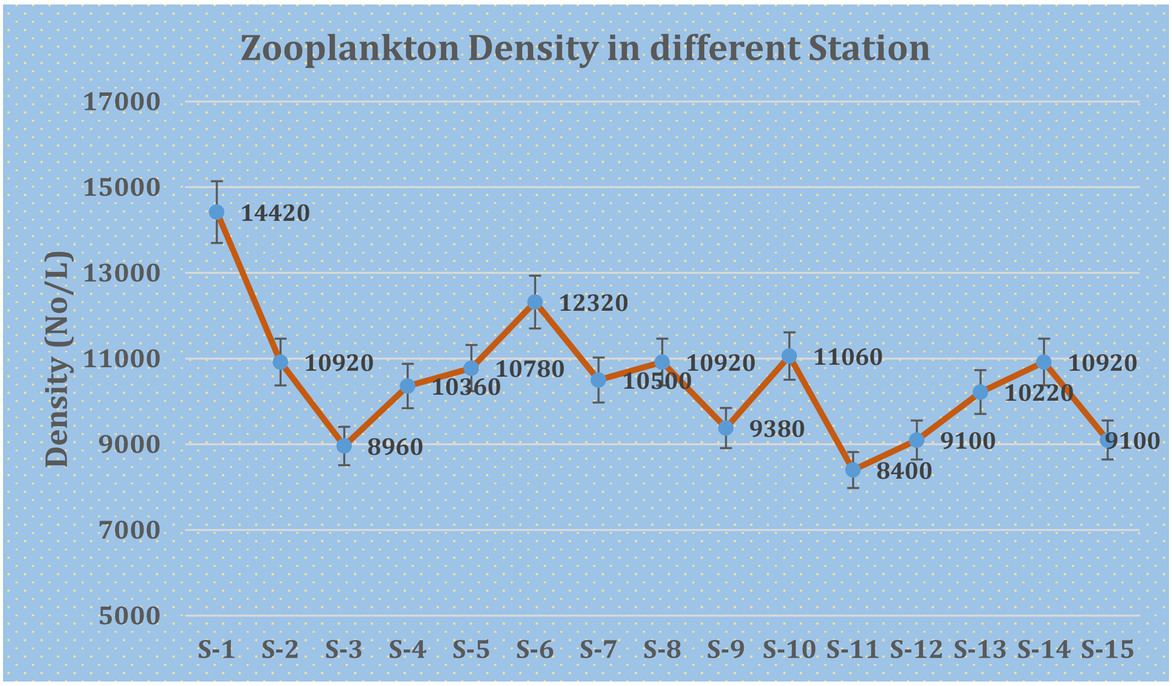


Figure 13: Zooplankton Density in the different stations during Monsoon 2024

Diversity Index

The Shannon diversity index of the zooplankton ranged between 2.44 to 3.01. Similarly, Margalef and Menhinick species richness index also varied from 2.60 to 1.97 and 0.20 to 0.26 respectively representing the moderate quality of the environment. (fig.14).

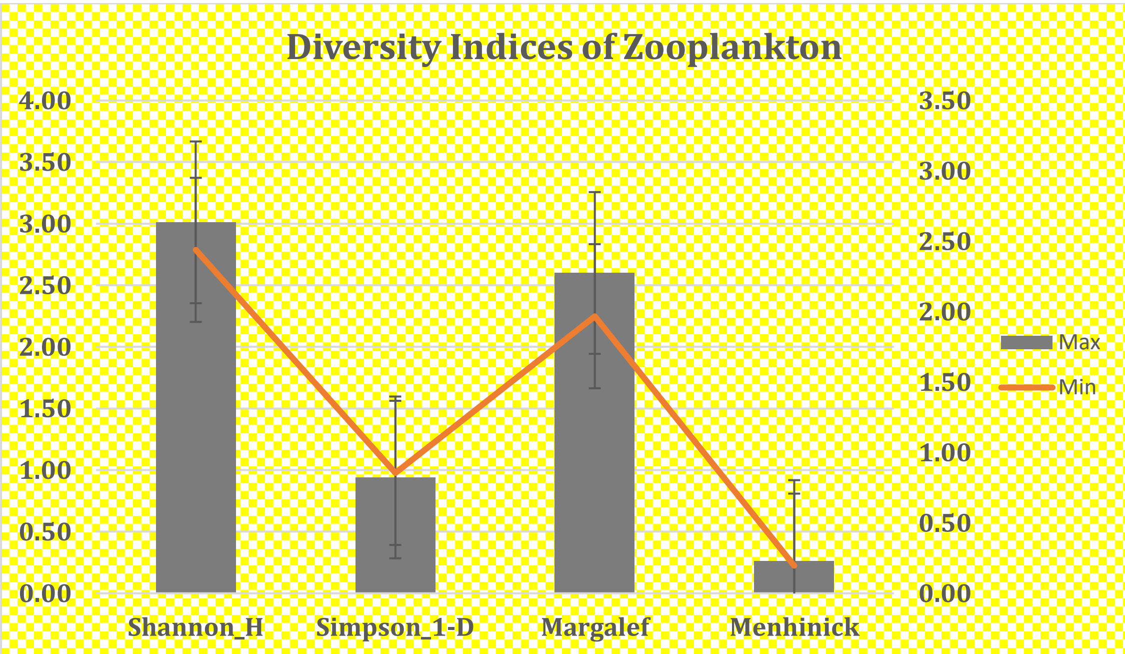


Figure 14: Zooplankton Density indices Monsoon 2024

Table 5: Zooplankton generic status during Monsoon 2024 in Deendayal Port Authority area

Groups	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	PC	PO
Foraminifera	Globigerina	980	1120	280	420	560	800	420	1120	420	700	420	280	420	280	140	5.31	100
Tintinnida	Codonellopsis	420	700	980	420	560	480	280	700	420	280	420	560	980	840	420	5.38	100
	Tintinnopsis	1120	420	700	980	420	800	560	420	1120	420	140	1400	420	1260	980	7.09	100
Chaetognath	Sagita	2800	0	980	1680	2100	1280	700	140	0	0	140	0	0	0	0	6.24	53
Copepoda-Calanoida	Acartia	280	420	140	280	140	640	280	140	140	420	560	280	140	420	560	3.08	100
	Acrocalanus	420	560	280	560	700	480	280	140	420	140	280	560	420	280	140	3.60	100
	Calanopia	420	280	0	280	0	320	140	420	280	420	280	700	980	280	420	3.32	87
	Calanus	700	420	980	420	560	800	420	280	140	420	280	140	420	280	140	4.07	100
	Centropages	420	280	0	140	420	320	420	280	0	140	420	280	560	420	140	2.69	87
	Eucalanus	700	420	280	140	280	960	700	980	420	560	420	280	420	280	560	4.70	100
	Nannocalanus	140	280	560	280	420	160	140	0	0	140	140	280	420	280	140	2.15	87
	Paracalanus	0	140	280	0	0	0	140	140	0	140	280	140	0	140	280	1.07	60
	Pseudodiaptomus	280	140	0	280	0	160	140	0	140	280	0	0	140	0	280	1.17	60
Harpacticoida	Corycaeus	0	0	420	0	0	320	0	420	560	0	0	140	700	280	420	2.07	53
	Euterpina	560	280	420	560	280	480	560	280	420	980	0	140	140	280	420	3.69	93
	Microsetella	840	980	420	420	280	160	420	280	140	280	420	560	280	420	280	3.93	100
Cyclopoida	Oithona	280	0	140	280	420	160	420	700	560	280	420	140	420	280	140	2.95	93
	Oncaea	280	420	140	140	420	320	140	140	0	280	140	140	280	420	140	2.16	93
	Nauplius larvae	140	0	140	280	420	320	140	280	140	0	140	140	280	140	140	1.72	87
	Mysis	140	0	140	0	140	160	140	0	0	0	140	280	140	0	0	0.81	53
	Scylla(Meghalopa	280	140	140	140	0	0	0	140	0	0	140	0	140	0	0	0.71	47
Branchiopods	Cladoceran	280	140	280	140	140	0	280	140	140	280	140	0	280	140	140	1.60	87
Malacostraca	Brachyuran larva	1680	2940	420	1260	1680	1760	2380	2940	3080	3780	1820	1540	1260	2660	2100	19.89	100
Thecostraca	Cirripede naupliu	420	280	560	420	280	480	560	280	420	280	700	420	280	280	140	3.69	100
Onychopoda	Evadne	0	0	0	140	0	0	140	0	0	140	140	0	0	140	0	0.44	33
Gastropod	Gastropod larvae	280	280	140	280	420	320	280	420	280	420	280	420	280	560	420	3.23	100
Bivalve	Bivalve larvae	420	280	140	280	140	320	420	140	140	140	0	280	140	420	280	2.25	100
Fish	fish larvae	140	0	0	140	0	320	0	0	0	140	140	0	280	140	280	1.00	53
Total Density (No/L)		**14420**	**10920**	**8960**	**10360**	**10780**	**12320**	**10500**	**10920**	**9380**	**11060**	**8400**	**9100**	**10220**	**10920**	**9100**		
Total Genera		**25**	**21**	**23**	**25**	**21**	**24**	**25**	**24**	**19**	**23**	**24**	**22**	**25**	**24**	**24**		

PC: Percentage of Composition PO: Percentage of Occurrence

3.6. Intertidal Fauna

The intertidal zone, the interface between terrestrial and marine environments, represents one of the most dynamic and ecologically multifaceted ecosystems. Globally, the increasing utilization of the littoral zone for several developmental projects and human activities have contributed increasing level of habitat transformation and consequently degradation of this fragile ecosystem. Such degradation is manifested in the rapid loss of biodiversity, which poses a significant threat to the ecosystem's products and services (Liang et al 2024).

The intertidal zone is often referred as the littoral zone is the area where the land is submerged temporarily due to the tidal water inundation, and where the benthic region of the ocean begins and below this zone is the sublittoral (shelf) zone, extending from the low tide mark to the shelf break, is permanently submerged. The Intertidal zone can include rocky ledges, sandy beaches, mudflats, salt marshes, and mangrove swamps and the benthic region has a variety of physical conditions, including depth, light penetration, and pressure. The intertidal zone is a marine habitat that experiences extreme and rapidly changing environmental conditions such as water Temperature, salinity, tidal amplitude, turbidity, along with substratum composition and organic matter and carbon content and the vegetation characteristics which are very much correlated with the fauna population density and distribution along the intertidal zone.

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 Mollusca (8 species), which is followed by Arthropoda (4species). The phylum Chordata was represented by one species (Table 6& Fig.15).Among the station the intertidal genera varied from 4 to 9 number higher number of genera recorded at S-6, S-10 and S-13 (9) and least number of genera recoded at S-15 .

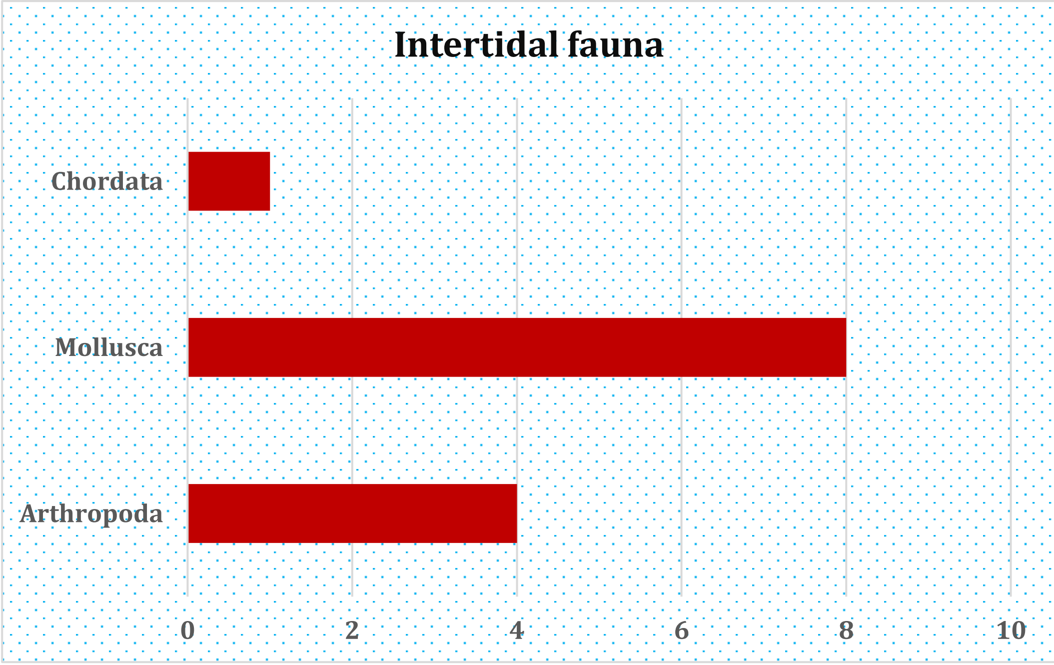


Figure 15: Number of genera of intertidal fauna during in Monsoon 2024

Percentage composition of Intertidal Fauna

The overall percentage composition of the three groups of intertidal fauna at the 15 station ie Arthropoda (67.09%), Mollusca (22.11%), and Chordata (10.8%), as shown in figure 16&17. The cumulative percentage of intertidal fauna varied from 0.1% to 23.5%.

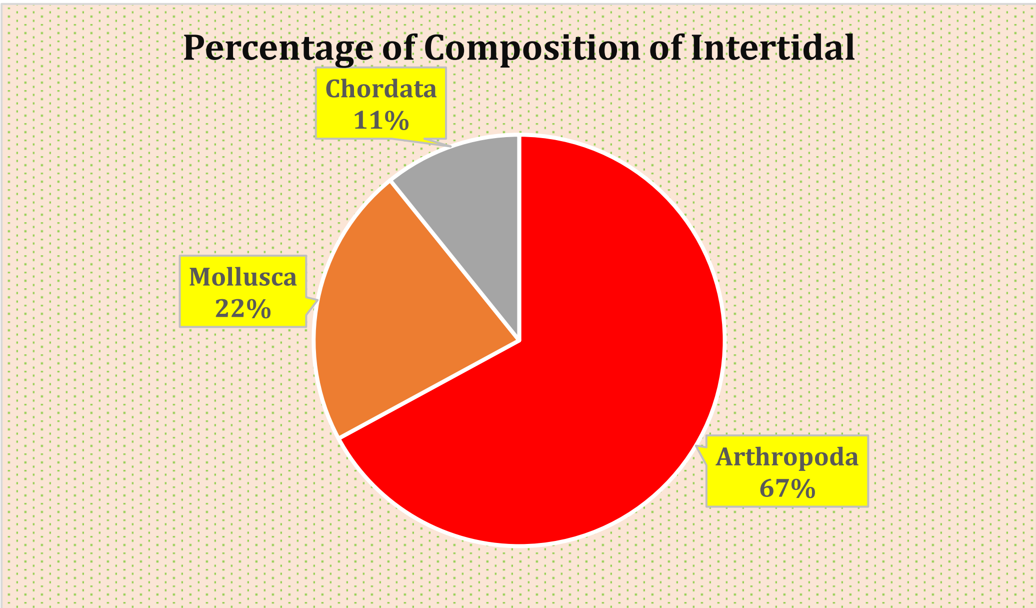


Figure 16: Percentage composition of intertidal fauna during Monsoon 2024

Highest percentage of organism contributed by *Austruca iranica* followed by *Austruca variegata* and least number of organism contributed by *Indothais lacera* , *Optediceros breviculum*.

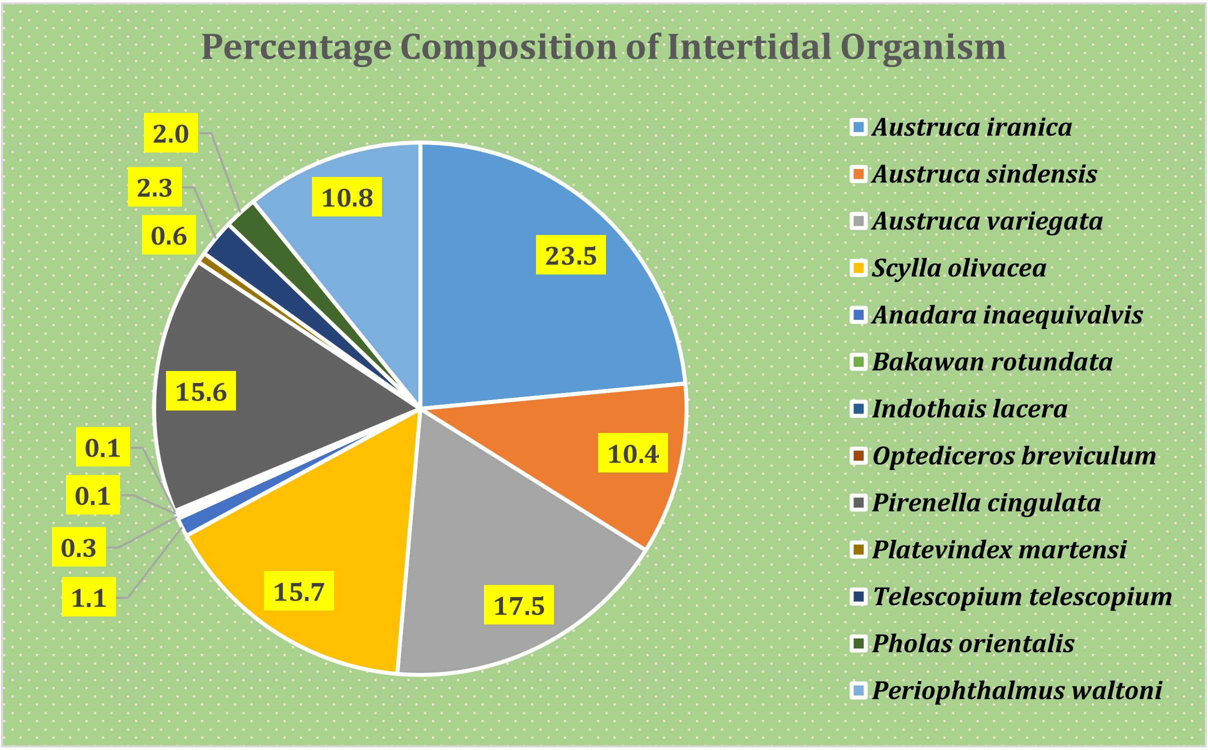


Figure 17: Cumulative % composition of intertidal fauna during Monsoon 2024

Intertidal Fauna density (No/m²)

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 at S- 2 and the least from S-11.

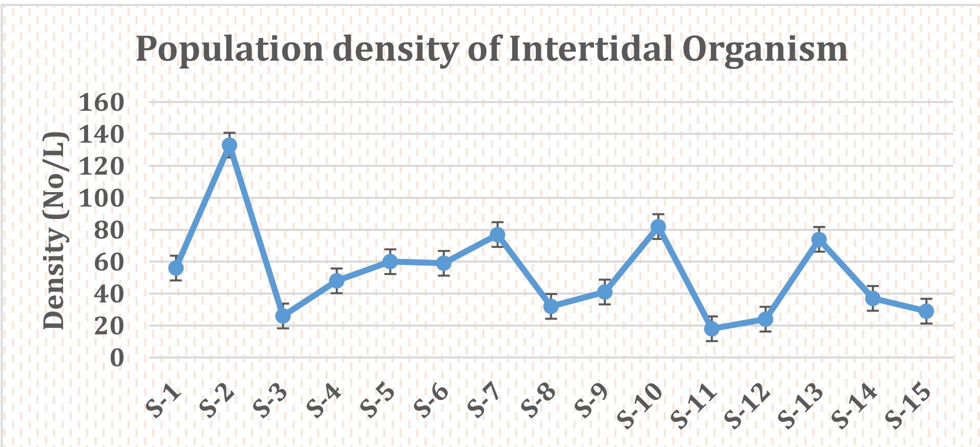


Figure 18: Density of intertidal fauna during Monsoon 2024

The Intertidal faunal diversity documented during the monsoon period of 2024 has shown that the highest number of animals were collected from S-2, and the lowest was from S-11. The most common species are the crustaceans such as *Austruca iranica* and Austruca variegata and among the Mollusca *Pirenella cingulata* (Table.5) and figure 17 represents the various diversity indices calculated for the different fauna recorded from the 15 sites adjoining the DPA port area as presented in figure 19.

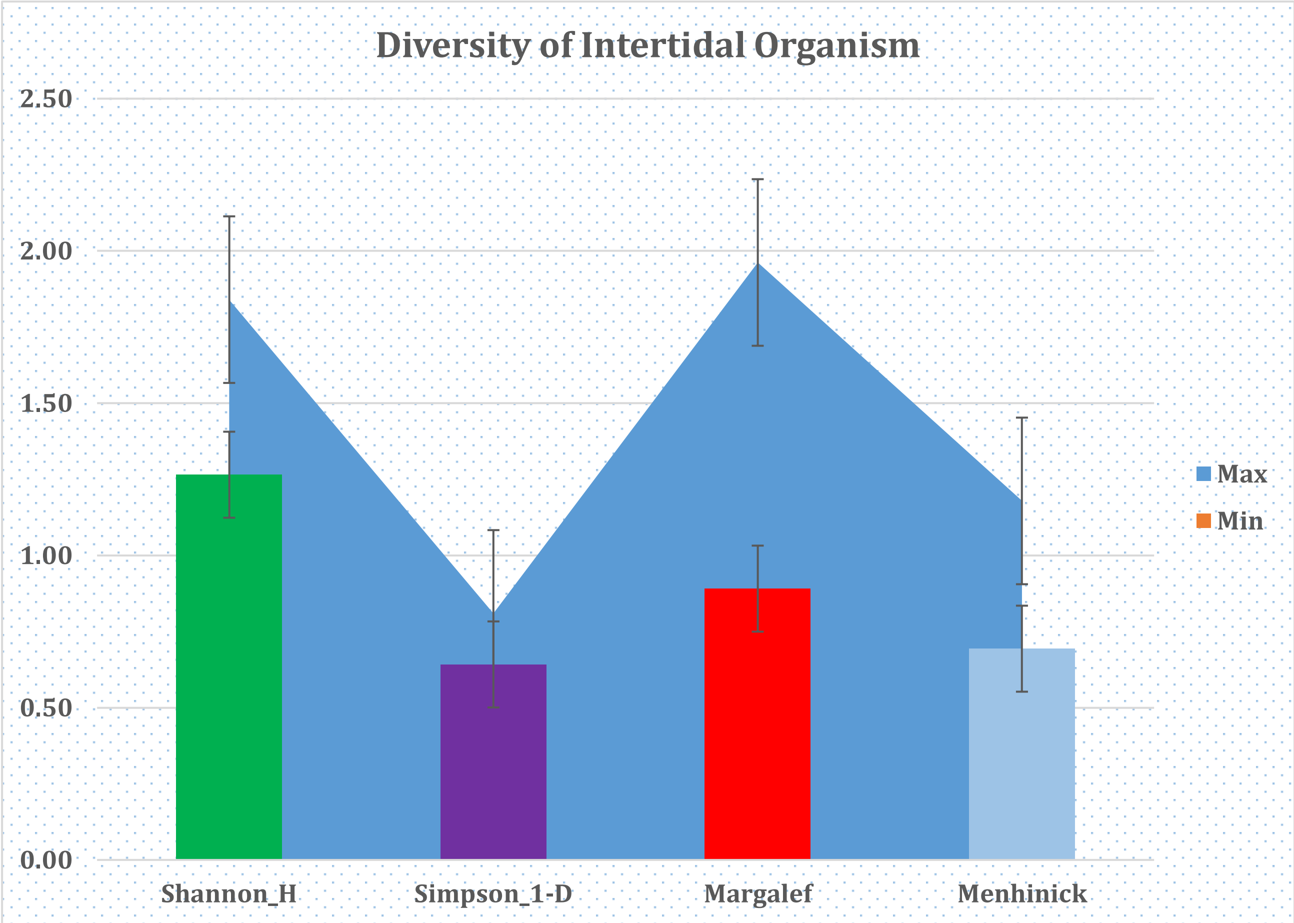


Figure 19. Diversity indices of Intertidal fauna

The maximum and minimum diversity is represent 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). The intertidal diversity of organisn represent in poor conditions.

Table 6: Intertidal faunal distribution along Deendayal Port Authority area during Monsoon 2024

Phyla	Grpup	Station															
		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**	PC
Arthropoda	*Austruca iranica*	21	25	14	20	27	18	10	10	12	10	2	6	2	5	5	23.49
	Austruca sindensis	0	3	0	0	3	6	6	5	12	4	10	6	7	17	4	10.43
	Austruca variegata	12	42	2	7	10	12	10	10	10	3	2	2	5	2	10	17.46
	Scylla olivacea	5	25	2	10	5	10	10	3	3	30	2	0	2	8	10	15.70
Mollusca	*Anadara inaequivalvis*	0	0	2	1	0	2	0	0	0	2	0	0	2	0	0	1.13
	Bakawan rotundata	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25
	Indothais lacera	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.13
	Optediceros breviculum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13
	Pirenella cingulata	15	35	5	0	0	0	29	0	0	0	0	0	40	0	0	15.58
	Platevindex martensi	0	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0.63
	Telescopium telescopium	0	1	0	0	1	1	2	0	0	7	0	0	6	0	0	2.26
	Pholas orientalis	0	1	1	0	4	2	0	2	2	2	0	0	2	0	0	2.01
Chordata	*Periophthalmus waltoni*	0	0	0	10	10	7	10	2	2	20	2	10	8	5	0	10.80
Total Density of population (No/m2)		**56**	**133**	**26**	**48**	**60**	**59**	**77**	**32**	**41**	**82**	**18**	**24**	**74**	**37**	**29**	
Total genera		**5**	**8**	**6**	**5**	**7**	**9**	**7**	**6**	**6**	**9**	**5**	**4**	**9**	**5**	**4**	

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. Benthic fauna is an important component of marine ecosystems, providing key services including secondary production and remineralization. Being sedentary or having only limited mobility, benthic communities are particularly vulnerable to variations in environmental and ecological factors. As a result, they exhibit distinct spatial and temporal distribution patterns on small and large scales. Coastal areas are naturally highly dynamic, with several distinct habitat types coexisting nearby (e.g., estuaries and intertidal habitats) and supporting high biodiversity (Cowie and Woulds,2011) . The abiotic factors structuring benthic communities include salinity, temperature, sediment characteristics, and oxygen availability, however, their relative importance varies among the different habitats. On a fine scale, biotic factors such as competition for food and space, predation, reproductive strategies, and life-history traits influence the distribution and abundance of individual species, in turn determining community structure. Moreover, coastal habitats are also the most impacted by anthropogenic pressures, from climate change-related warming and acidification to habitat degradation and pollution. Benthic fauna, through their diverse feeding modes and lifestyles, not only are affected by conditions in the sediment environment, but also actively influence sediment textural and geochemical properties, the flow regime of bottom waters, and, through exchange of particles and solutes between water and sediments, also regulate properties in overlying waters (Meysman et al., 2006)

All marine sediments are anoxic below a certain depth from the sediment surface and, consequently, sulphidic sediments have a worldwide distribution. Organic sediment enrichment occurs through vertical and advective accumulation of organic carbon from the decomposition of the organic matter . On bottoms where accumulation of organic matter happens and leading to the reduction of oxygen at low concenlration. The oxygen deficiency may very well be the most widespread anthropogenically induced delelerious effect in me marine environment that causes localized mortality of benthic macrofauna. Also there is a complicated interplay between oxygen concentration and sediment geochemistry that regulates the response of organisms to declining dissolved oxygen concentrations. The physio-biochemical system of estuary is regulated by benthic faunal through burrowing and feeding activities. Benthic communities are the useful tools for biomonitoring and gathering large amount of data in relation to coastal marine health of marine ecosystem. It is important to identify which are the primary causal factors for degradation of coastal ecosystem for design the proper management system at the coastal region..

Distribution and composition of subtidal macrobenthos

The number of macro benthic species of the various groups recorded (Fig.20) & Table 6 from the DPA port environment includes Mollusca (10) and Annelida (4) Arthropoda (2). The percentage composition of the three phyla that occurred during the monsoon is shown in (Fig 20 & table 6) The phylum Mollusca is represented by maximum (65%) share of the subtidal Fauna, followed by Annelida (25.5%), Arthropoda (9.8%) in the total benthic samples collected (Fig.21).

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 22. The density of the Fauna was high at S-14 (700/m^2), and the lowest number (175/m^2) was noticed at S-9 during the monsoon 2024.

Diversity index

The figure 22 represent the subtidal microbenthic faunal diversity documented in the monsoon 2024. The highest number of species diversity was documented from stations S-14, S-9, S-3 and S-13. The most common species are *Optediceros breviculum, Glauconome angulata and Pirenella cingulata.* The least diversity was documented for *Solen* sp were found significantly less diversity. The figure 24 represents the various diversity indices calculated for the different fauna recorded from the 15 sites adjoining the DPA port area. Invariabily the minimum and maximum index values of the three indices were observed at S-8&9 and S 14 respectively. Shannon diversity index varied , from 1.00 to 2.00 Simpson index ranged between 0.56 and 0.85 and the Margalef index ranged from 1.03 and 3.30**.**

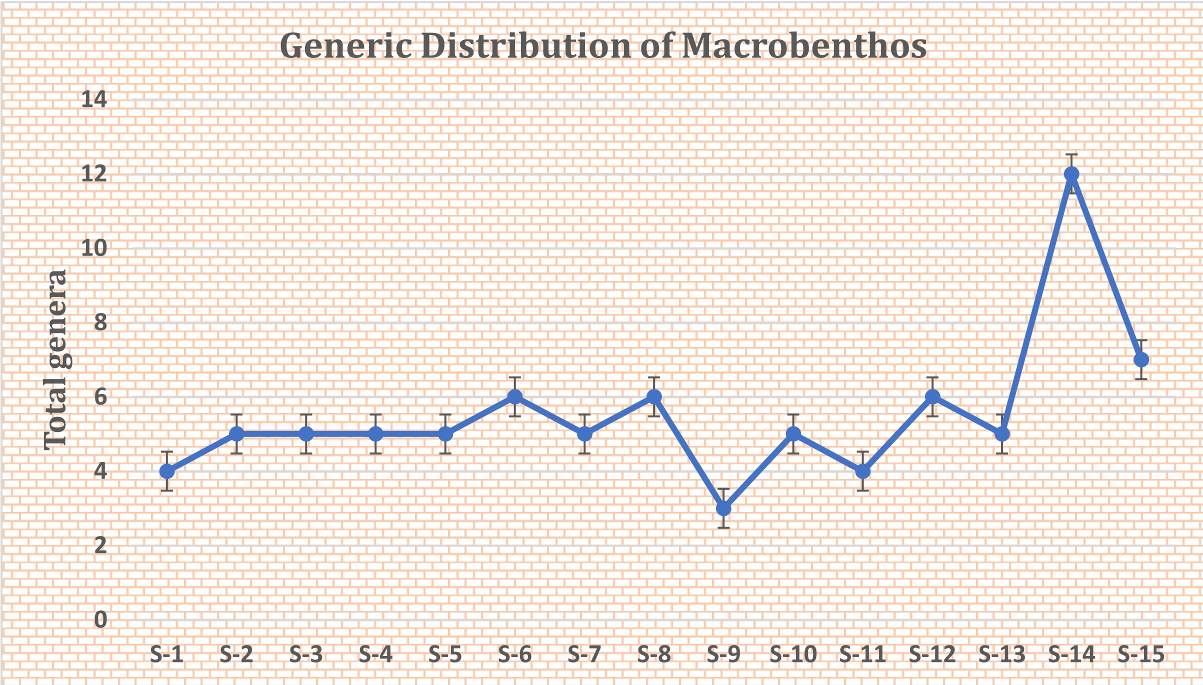


Figure 20. Number of genera of macrobenthos during Monsoon 2024

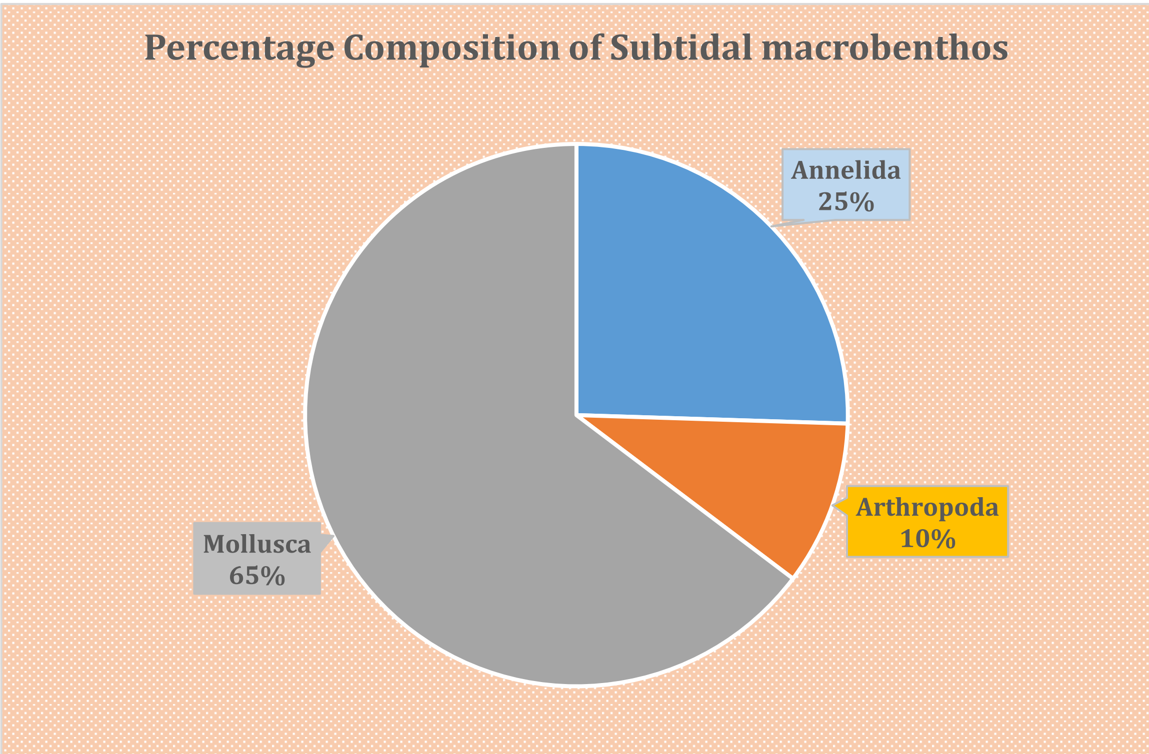


Figure 21. Percentage composition of macrobenthos during Monsoon 2024

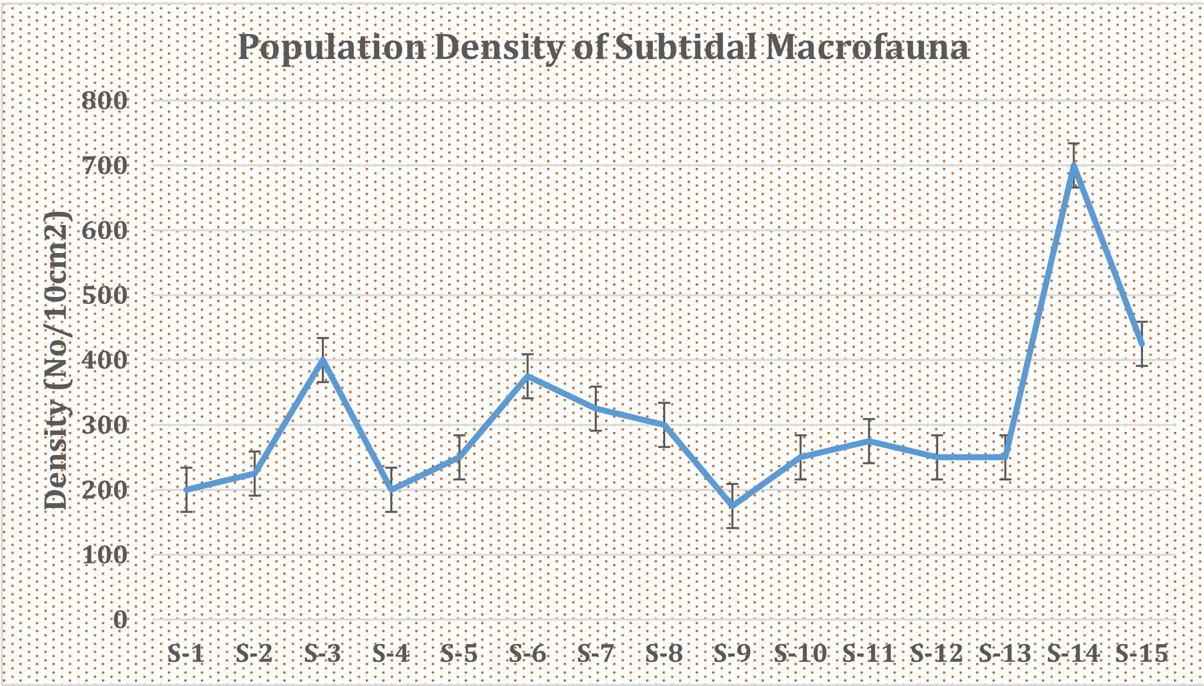


Figure 22. Subtidal fauna density during Monsoon 2024

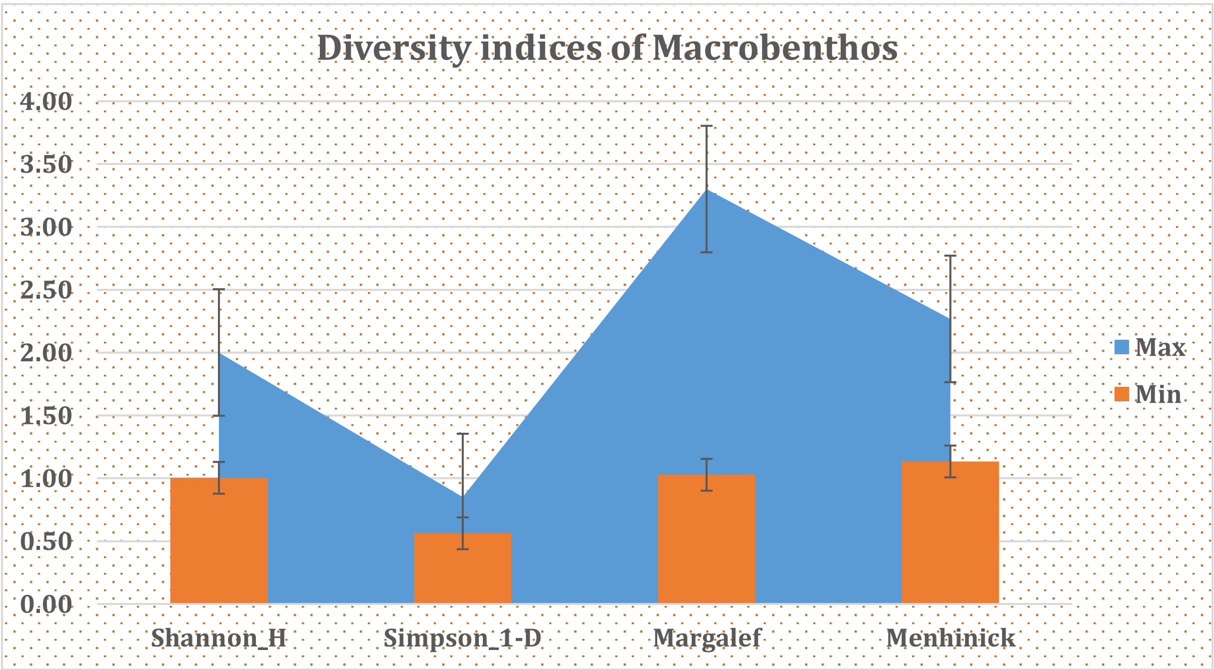


Figure 23. Subtidal macrofaunal diversity indices

Table 7: Macro-benthic faunal distribution during Monsoon 2024 in Deendayal Port Authority

Phyla	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	PC
Annelida	*Capitella sp.*	0	1	0	0	3	0	0	0	1	0	3	1	0	1	0	5.4
	Lumbrineries sp.	1	0	4	0	0	0	1	0	0	2	0	2	2	0	2	7.6
	Nephtys sp.	1	0	2	0	0	0	0	2	3	0	0	0	0	1	0	4.9
	Nereis sp.	0	3	1	0	0	1	0	0	0	1	4	0	1	0	3	7.6
Arthropoda	*Ampithoe sp.*	0	0	0	0	2	0	0	1	0	0	0	2	0	2	0	3.8
	Penaeus sp.	0	2	0	0	1	1	0	0	0	0	2	0	2	0	3	6.0
Mollusca	*Mitrella blanda*	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	1.6
	Natica sp	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1.1
	Optediceros breviculum	1	0	0	2	2	2	3	2	0	0	0	0	0	1	3	8.7
	Pirenella cingulata	5	0	0	0	0	2	1	2	3	1	0	2	3	12	2	17.9
	Turritella sp	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1.1
	Marcia sp.	0	0	0	2	0	1	2	3	0	0	0	1	2	1	2	7.6
	Glauconome angulata	0	2	7	1	2	8	6	2	0	6	0	2	0	0	0	19.6
	Dosinia sp	0	0	2	2	0	0	0	0	0	0	0	0	0	3	0	3.8
	Gafrarium divaricatum	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	2.7
	Solen sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.5
Total Population		8	9	16	8	10	15	13	12	7	10	11	10	10	28	17	
Density No/m2		**200**	**225**	**400**	**200**	**250**	**375**	**325**	**300**	**175**	**250**	**275**	**250**	**250**	**700**	**425**	
Total genera		4	5	5	5	5	6	5	6	3	5	4	6	5	12	7	

8. Seaweeds

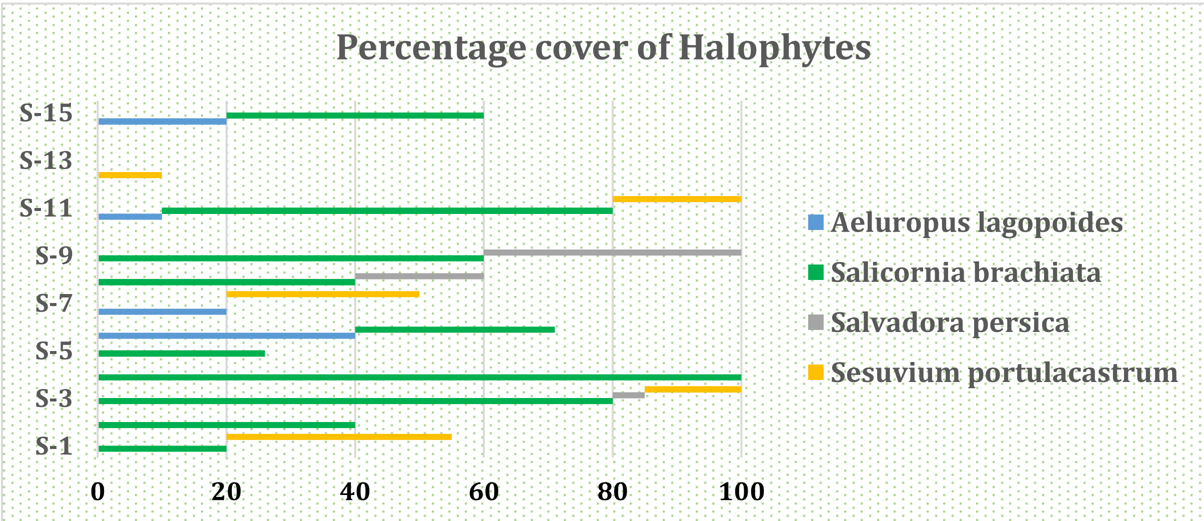
There is no observation of seaweed during the study period

3.9. Seagrass

Similar to seaweed seagrass also not encounter during present observation

3.10. Halophytes

The halophytes are the plants that are adapted to live in coastal estuaries and salt marshes. It is common in arid and desert milieu which often have substantial salt accumulation. Technically these are the plants which have tolerance to moderate to high salt concentration in its growth substrate. Halophytes, that survive and reproduce in environments where the salt concentration is 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, *Salicornia brachiata* (a), *Aeluropus lagopoides* (c), *Salvadora persica* (d) and *Sesuvium portulacastrum*(b) (Plate-7) were recorded along the selected Deendayal Port Authority sites during the monsoon sampling. Among the halophyte species recorded, *Salicornia brachiata* alone was found at ten sampling locations. (Fig.24) and the percentage of cover was found to be the highest at S-4 (100%) and the lowest at S-2 &S-8(40%).



Fifure24.Halophytes diversity of Deendayal Port Authority

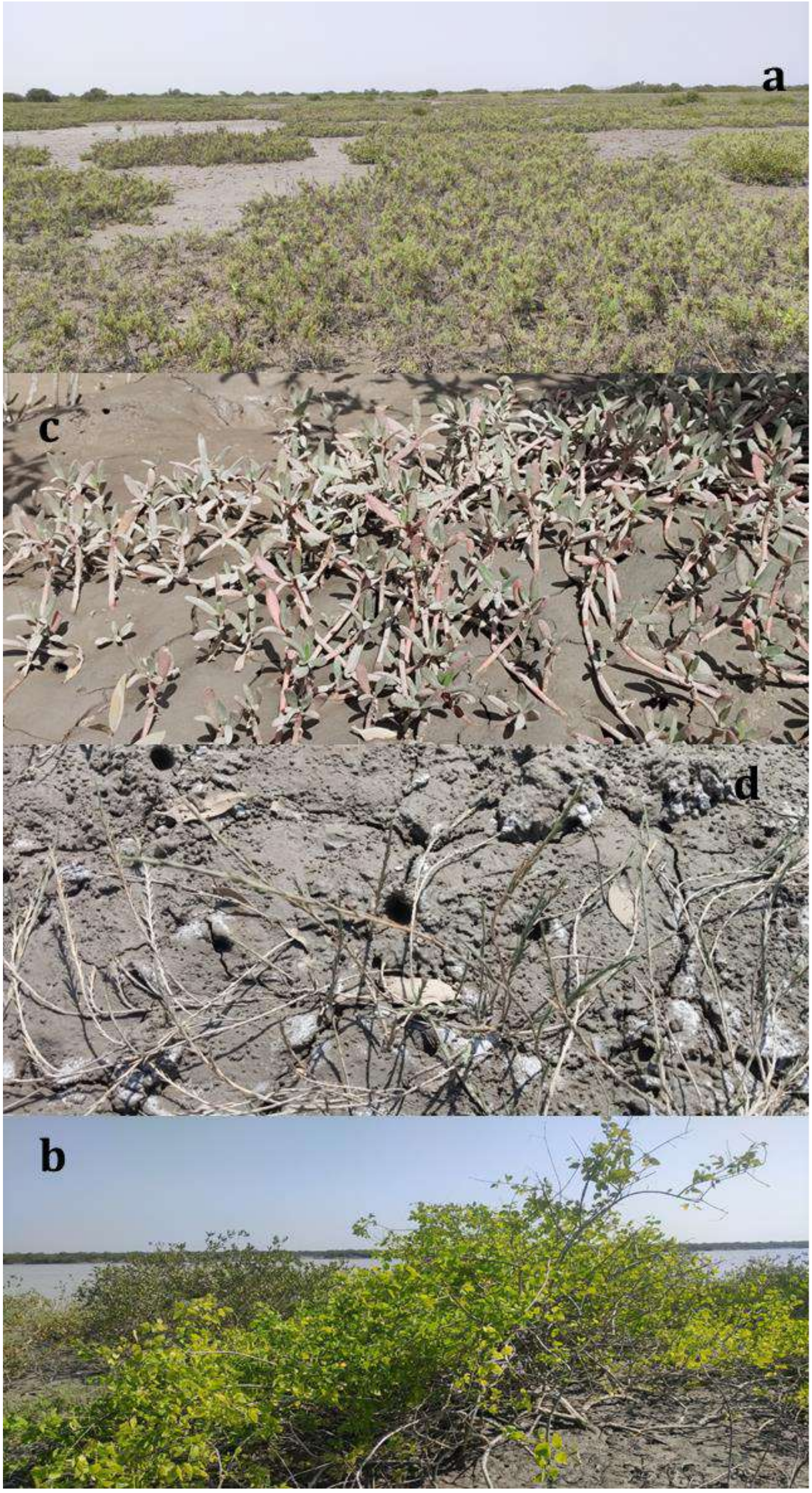


Plate 7. Halophyte species on the intertidal zone of Deendayal Port Authority area

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

3.11. Mangroves

Mangroves in Gujarat are distributed across four main regions: Kachchh, Gulf of Kachchh, Saurashtra, Gulf of Khambhat including South Gujarat. Kachchh and Gulf of Kachchh have the largest mangrove forests, which are meticulously studied and documented by the Gujarat Institute of Desert Ecology (GUIDE). The GUIDE research reveals the unique vegetation characteristics, species composition, ecological importance, and conservation status of these crucial coastal ecosystems. Mangroves serve as critical habitats for a wide variety of marine and terrestrial species, playing a significant role in coastal protection, biodiversity conservation, and local livelihoods. The efforts to study and conserve these ecosystems highlight their importance and the need for sustainable management

Tree Density

During the 2024 monsoon, 15 mangrove sites were selected in and around the Deendayal port Authority to undertake assessment on plant density and growth parameters such as height, girth, and canopy cover. The overall average tree density from the study sites along the DPA, was recorded as 2,189 trees/ha during the monsoon of 2024. However, the area under mangrove cover is shrinking due to increase in the anthropogenic activities such as salt pan formation and other developmental interferences. Among the 15 sampling locations, Tuna Creek had the highest mean plant density with 2535 trees/ha, followed by Kharo Creek with 2486 trees/ha. However, in Kharo creek only one station is located. Regarding individual sample locations, the S-6 had the highest tree density (3,673 trees/ha), followed by S-1 (3,522 trees/ha). The S-15 (1,027 trees/Ha) and S-11 (1,221 trees/Ha) had the lowest average tree density. The varying status of the mangroves across different locations (as illustrated in Fig. 25) reflect the seasonal changes in the local geomorphology as well as the distinct biological and environmental characteristics of each site.

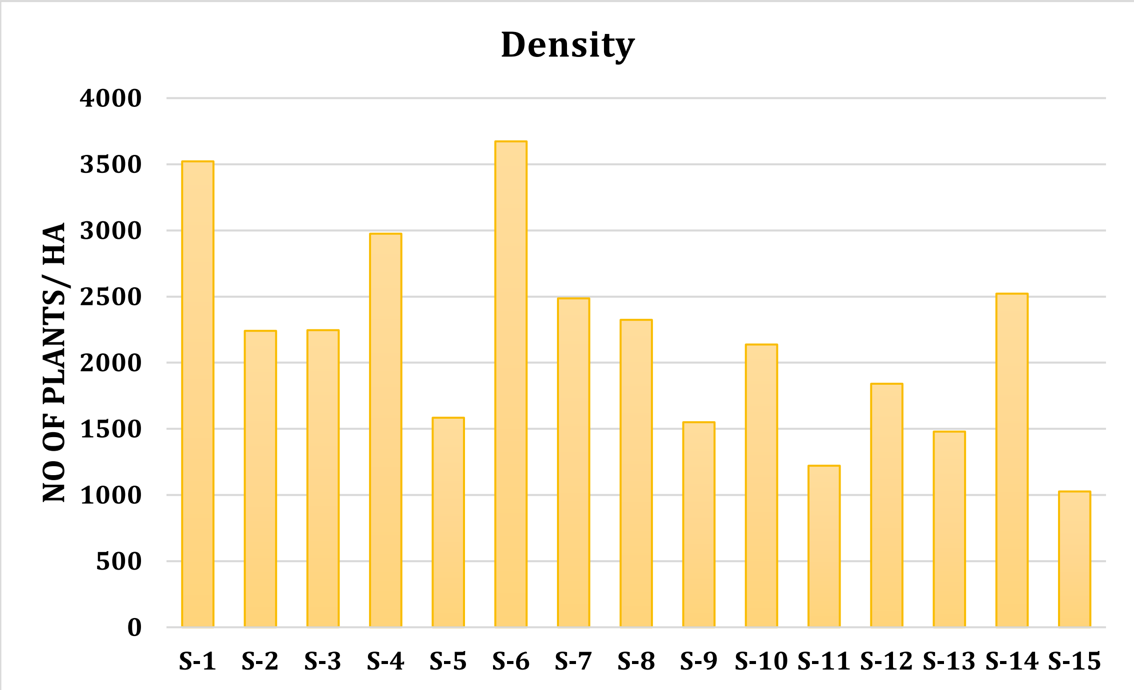


Figure 25. Plant density during monsoon 2024

Height

The overall mean height of the mangroves from the DPA, Kandla environment was 1.8 m during the monsoon of 2024. The highest average tree height was 2 m, recorded at Veera coast area followed by Tuna and Phang creek (1.8 m). In Veera area, only one station (S-14) is located. While considering the sites individually, the average tree height was 2.4 m at S-10 located at Phang creek, followed by site S-12 (2.3 m) located at Tuna creek (Fig.26). During the study, it was observed that the average tree height at several sites varied between 1.3 m and 2.4 m. Height is a crucial factor since it indicates whether trees are developing normally or exhibiting stunted growth. Height also contributes to the complexity of the habitat. Taller mangroves provide better protection against storm surges and high waves. They act as a buffer, reducing the energy of waves before they reach inland areas, thus protecting coastal communities from flooding and erosion. S

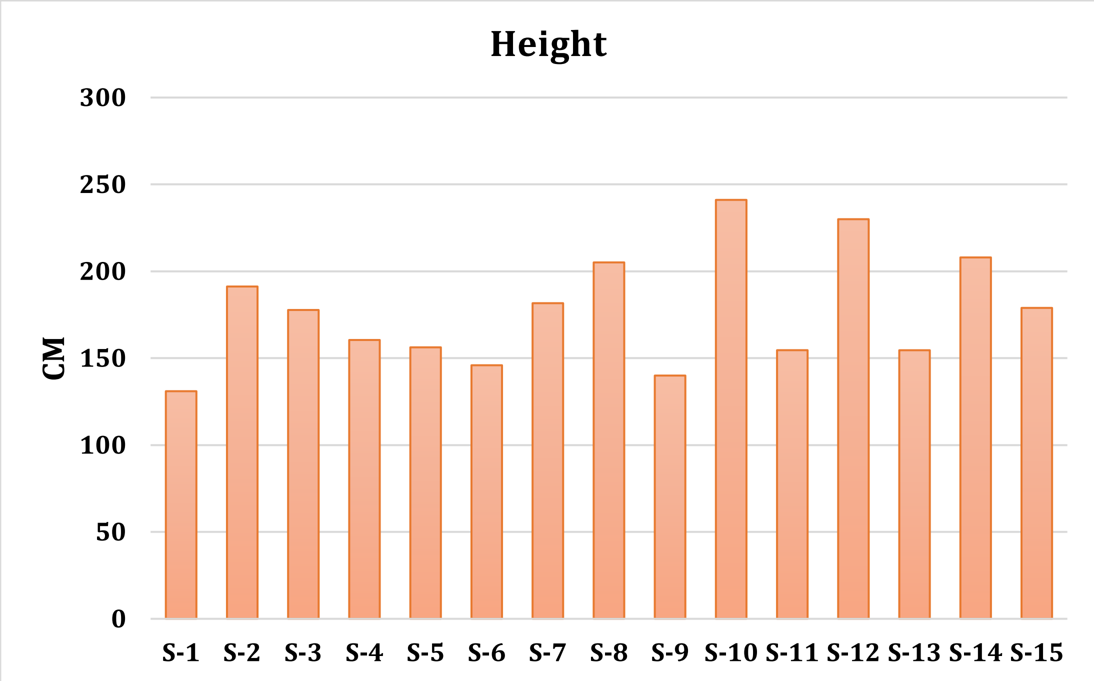


Figure 26. Plant height during monsoon 2024

Canopy Crown Cover

The survey conducted during the 2024 monsoon revealed that the average canopy cover across the mangrove study sites was 3.8 m^2. The figure 27 reflects the overall extent of the mangrove canopy, which plays a vital role in providing habitat for diverse species, stabilizing shorelines, and maintaining ecological balance. The station S-10 at Phang Creek and S-15 at Kandla Creek are noted for having higher average canopy covers compared to other locations. Navlakhi Creek had the highest average canopy cover at 5.2 m^2, followed by Phang Creek at 4.5 m^2, while, S-1 at Tuna Creek, and S-4 at Kandla Creek had comparatively lower average canopy cover. These variations in canopy cover across different sites in the Kandla sample region underscore significant differences influenced by local environmental and biological factors.

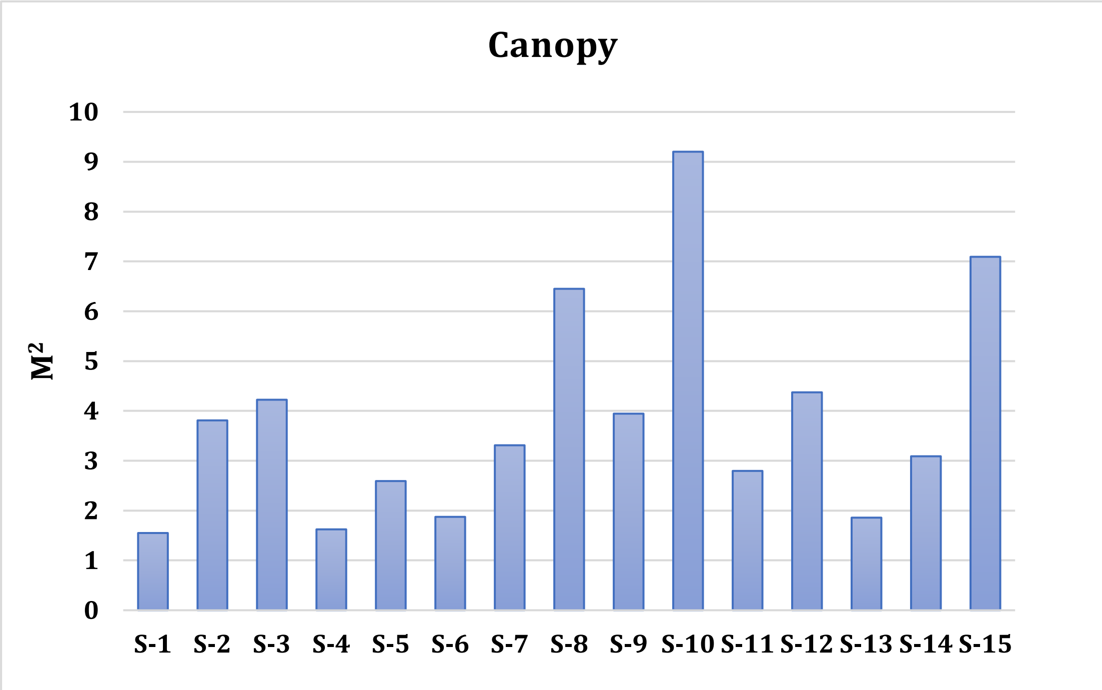


Figure 27. Mangrove canopy cover during monsoon 2024

Basal Girth

The average basal girth of the mangroves at the DPA sampling sites was reported to be 13 cm during the monsoon of 2024. Among the individual sampling sites, the highest average basal girth was recorded at site S-10 (22 cm) and site S-8 (18 cm), located in Phang Creek and Navlakhi Creek respectively (Fig.28). The lowest average basal girth was reported at site S-6 and S-9 (8 cm) in Janghi Creek and Navlakhi Creek, respectively. In the DPA Kandla area, as in other parts of Gujarat and the entire Gulf of Kutch, Avicennia marina is predominant, characterized by its multiple stem pattern. However, some larger trees in a few sites exhibit the higher basal girth measurements

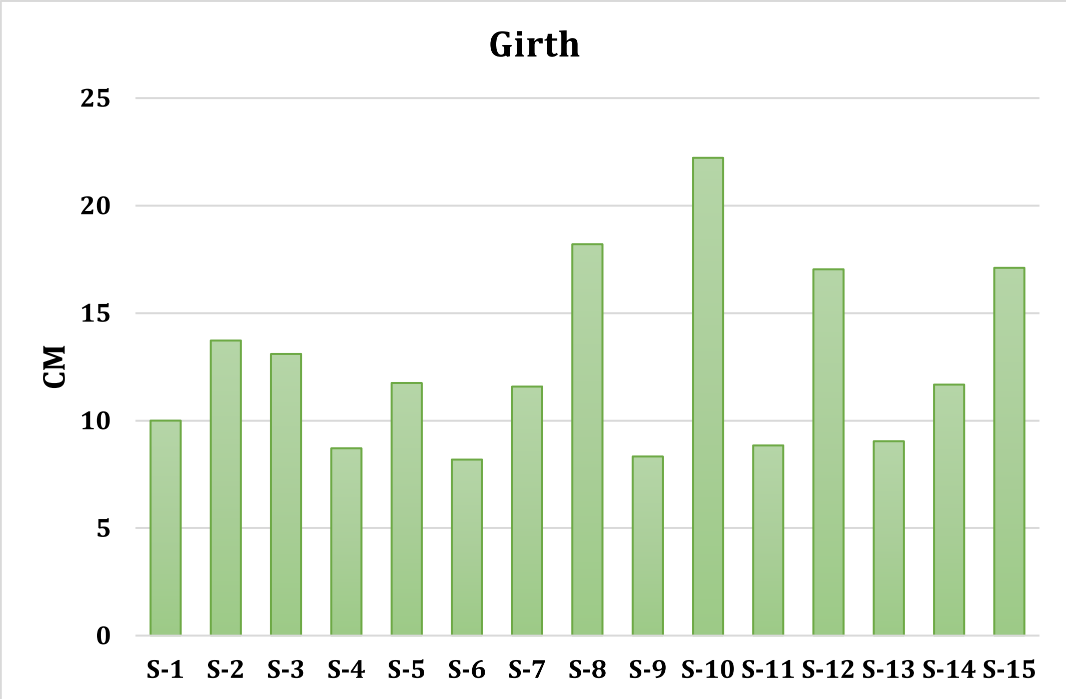


Figure 28. Basal girth of mangrove

Regeneration and recruitment class

The mangrove density and growth parameters were recorded during the survey conducted in the monsoon season of 2024 in the DPA Kandla area. The overall average regeneration class density was recorded as 29,692 plants/ha and the overall average recruitment class density was recorded as 5,308 plants/ha. In site-wise observations, the highest average regeneration class plants were recorded at site S-8 (73,000 plants/ha) which is followed by S-9 (52,000 plants/ha) both located along the Navlakhi creek area, For the recruitment class, the maximum plant density (average) was (11,750 plants/ha) at site S-7 located in the Kharo creek during this survey. Younger class mangroves can assure future availability of matured plants of full-grown trees in the area. Young mangroves help to stabilize soil and trap sediments, preventing coastal degradation and maintaining water quality. As they grow, these young plants will eventually contribute to the various ecosystem services and enhance the coastal protection offered by mature mangroves, shielding shorelines from erosion and storm surges.

a **b**

c **d**

Plate 8: Mangrove species recorded along the Deendayal Port area

a. Rhizophora mucronate b. Aegiceras corniculatum c. Ceriops tagal d. Avicennia marina

3.12. Marine Reptiles

The saw-scaled viper *Echis carinatus sochureki* normally encounter in while visit in mangrove survey but during the present observation in all the 15 study location there is no single encounter in study area. 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 in previous record .

3.13. Marine Mammals

Sousa plumbea (Cuvier, 1829) is commonly referred to as the Indian Ocean humpback dolphin. 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). During the field surveys, the Indian Ocean humpback dolphin (Sousa plumbea) was not cited in monsoon season.

3.14. Marine Fishery

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 localitynear the Marine National Park, in Jamnagar, 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*, (Plate 9) the maximum during monsoon. Around 2kg of Mugil was catch in 10 minutes of in 1 km stretch.

Plate 9 Fish catch along the Deendayal Port Authority in monsoon 2024

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 bulk density (or apparent density) is defined as the density of a large volume of porous material powder including the pore spaces within the material particles in the measurement volume. The data on the bulk density of the sediment samples are presented in (Fig.29). The bulk density of mangrove soil at Deendayal Port Authority coastal region ranged from 1.30 g/cm^3 to 1.61 g/cm^3. The highest bulk density was recorded at S-13 sites followed by S-14. The lowest bulk density was recorded at S-5 located at Janghi creek.

Total Organic Carbon (TOC)

The highest TOC value (3.1%) was recorded at S-13 followed by S-1 and lowest TOC value was reported at site S-10 (Fig.30). 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.

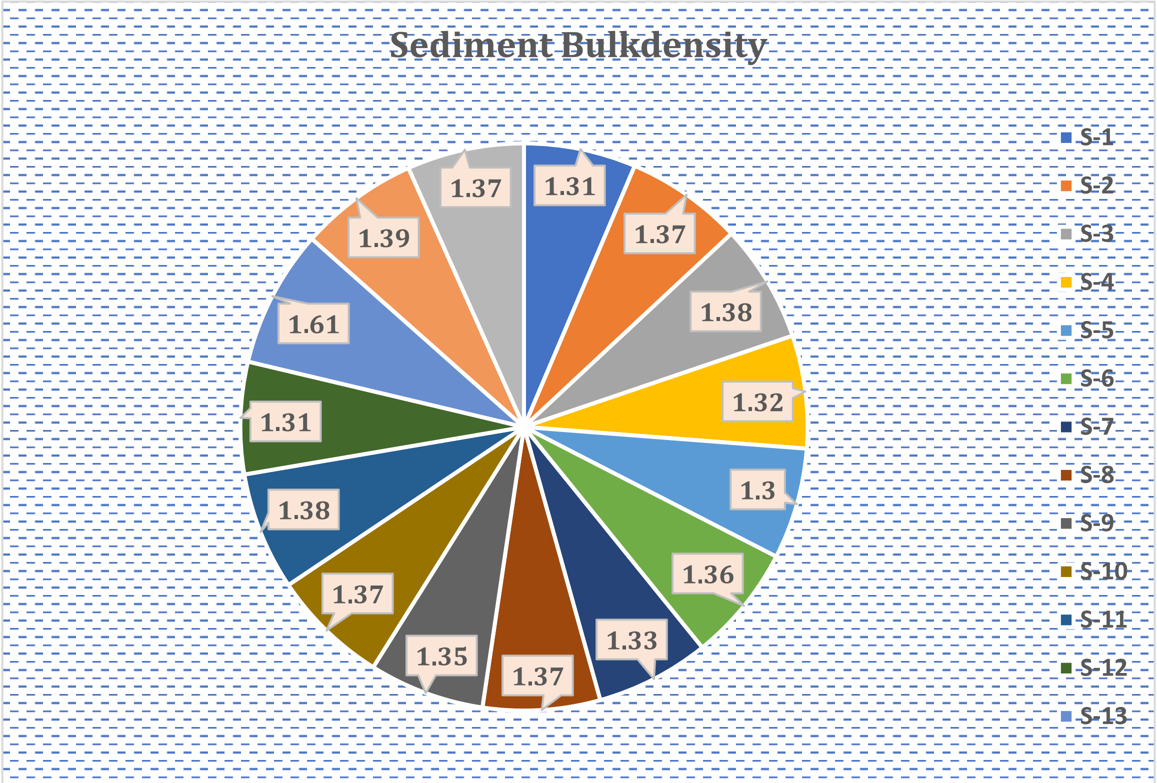


Figure 29: Bulk density of mudflat sediment during Monsoon 2024

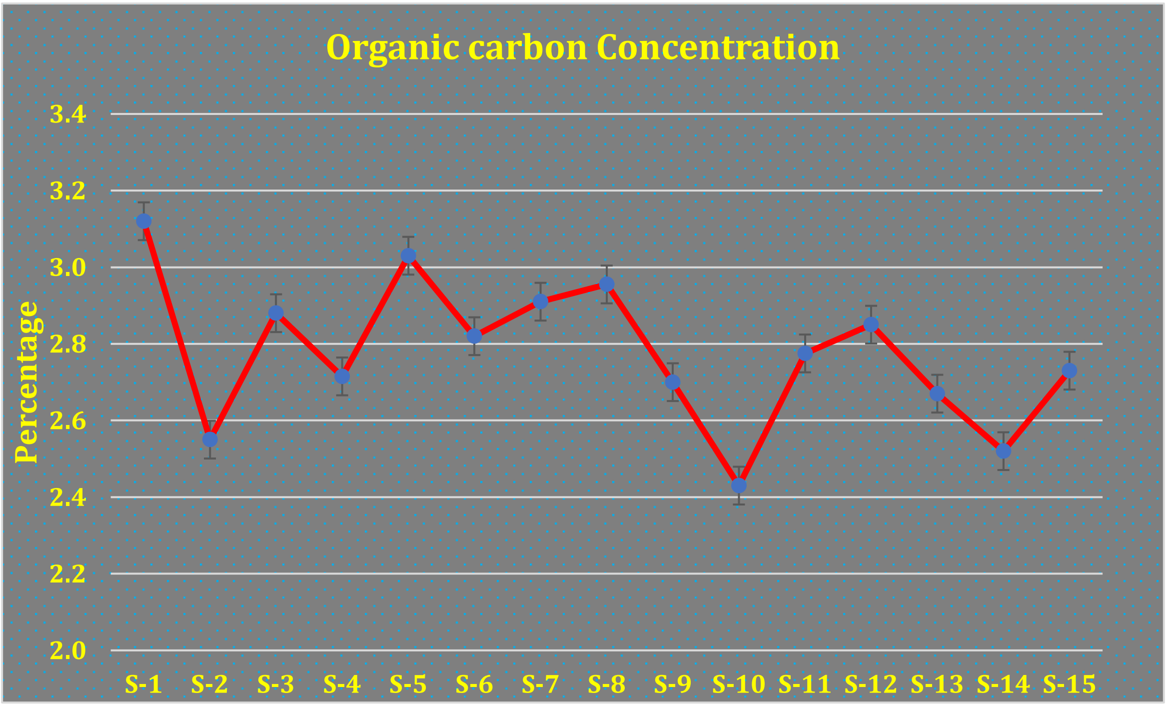


Figure 30: Mudflat sediment Organic Carbon during Monsoon 2024

5. Avifauna

Globally, avifauna has the highest level of diversity. Indian subcontinent comprehends around 1340 species of birds which contribute more than 15% of the world's bird species (Ali and Ripley 1987, Manakadan and Pittie 2001, Grimmett *et al.* 2011, Cox 2010). Thus, understanding the diversity and structure of bird communities to describe the importance of regional or local landscapes for avian conservation and assessment of avian diversity has become an important tool in biodiversity conservation (Safiq *et al.* 1997). The baseline data on diversity, distribution and species composition plays a significant role for identifying priority areas and formulating the species-specific conservation plan (Peterson *et al.* 2000, Colin 2000) and evaluate the habitat quality (Chettri *et al.* 2005, Manjunath and Joshi 2012). While, numerous bird species use their foraging ecology to sustain a trophic level, making birds another key animal group in an ecosystem. Scavenging carcasses, eliminating vermin and insect pests, cycling nutrients, dispersing seeds, pollination, and pest control are some of these services. As scavengers and possible pollinators, they have a functional role in the ecosystem and are appropriately referred to as bio-indicators (Bruford 2002, Gregory *et al.* 2003, Parmar *et al.* 2016, Maznikova *et al.* 2024). The aim of the present study was to understand the occurrence and distribution of avifauna in the coastal areas of the Deendayal Port Authority, Kandla, India (Fig. 31).

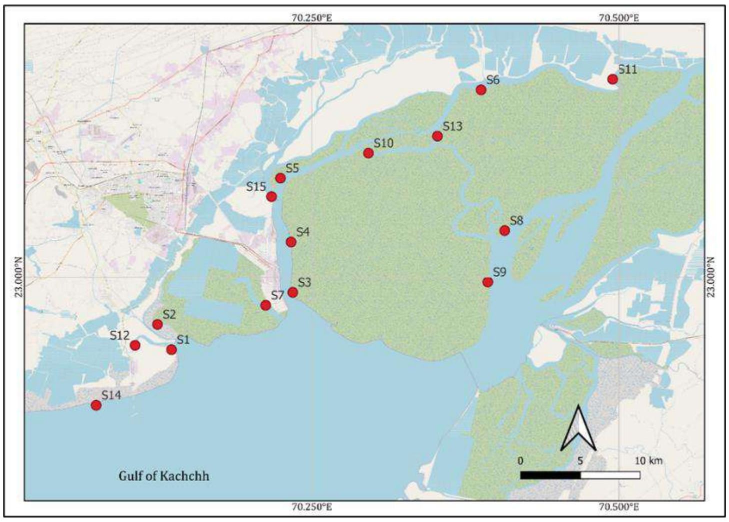


Figure 31. Permanent study sites at Deendayal Port Authority, Kandla, India

Gujarat Institute Of Desert Ecology

Status, Diversity and Distribution of avifauna in different station

The status and diversity of avifauna was studied in coastal areas of Deendayal Port Authority, Kandla, India for the monsoon season. The entire survey was comprehensively carried out by boat survey and walking along the fixed sampling station, for documentation of avifauna. A total of 53 species (32 species terrestrial and 21 aquatic bird) representing 9 order, 22 families and 37 genera were recorded during the study period **(See Annexture 1& Plate 10,11).** Scolopacidae (nine species) were the most dominant family in terms of species richness followed by Ardeidae (seven species), whereas Columbidae and Laridae (five species), whereas others represent less species (Fig.32)

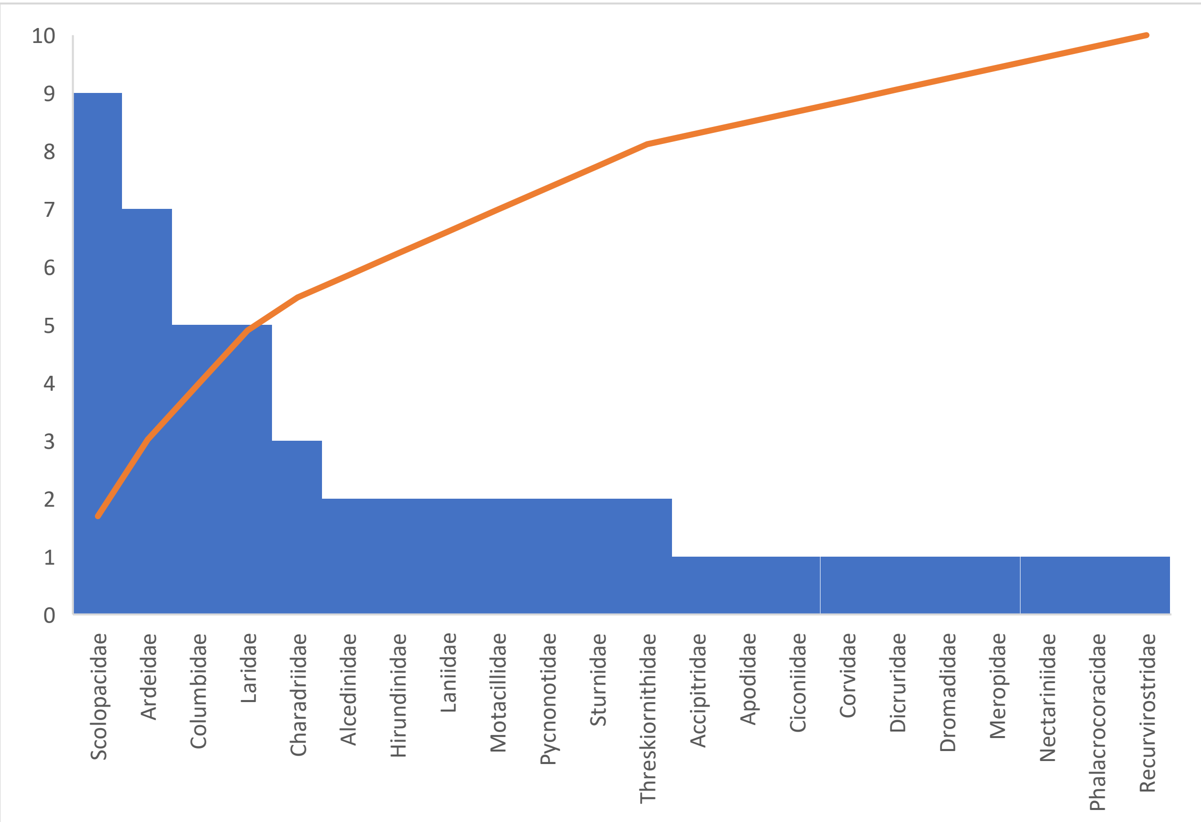


Figure 32 Distribution of families and species at the Deendayal Port Authority

Among the survey station, site 13 (53 species) were the most dominant with 37 genera and 22 families species richness followed by site 5 and 12 (45 species), and site 1 have 44 species and other sites have less species composition **(**Fig. 33).

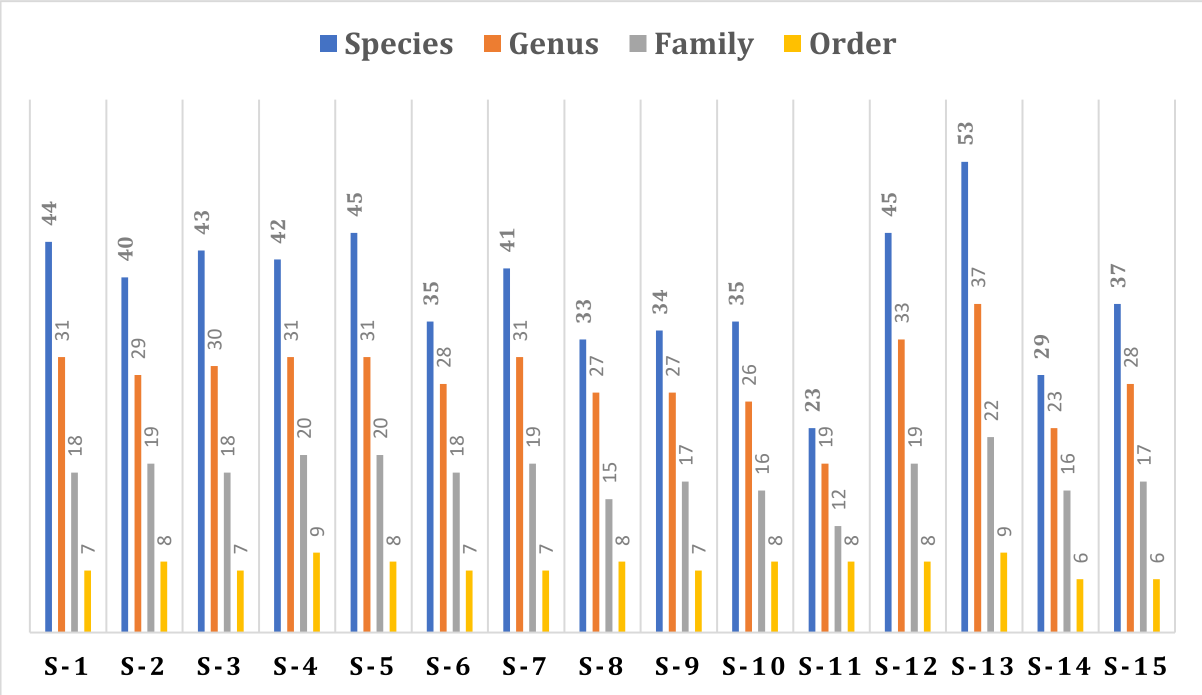


Figure 33 Site wise distribution of Avifauna recorded during monsoon season from the Deendayal Port Authority

The Shannon–Wiener diversity indices shows that site 13 (H=3.738), followed by site 12 (H=3.61), site 5 and 1 (H=3.57), whereas others represent less diversity (Table 7). Based on the movement pattern 36 species (68%) of birds were residence, 14 (26%) are migratory and three (6%) species are regional migratory (Annexure 1, Fig. 34). Considering the abundance of the species during the study period, 32 taxa were recorded from terrestrial, 21 from aquatic habitat. Among 53 species, only five species viz. Painted Stork Mycteria leucocephala (Pennant, 1769), Black-headed Ibis Threskiornis melanocephalus (Latham, 1790), Glossy Ibis Plegadis falcinellus (Linnaeus, 1766), Black-tailed Godwit Limosa limosa (Linnaeus, 1758) and Eurasian curlew Numenius arquata (Linnaeus, 1758) are under the Near Threatened (NT), whereas, River Tern Sterna aurantia (Gray, JE, 1831) is under vulnerable (VU) categories of IUCN Red List of Threatened Species. Moreover, two species (4%) River Tern Sterna aurantia (Gray, JE, 1831) and Common Greenshank Tringa nebularia (Gunnerus, 1767) were under the

Schedule I, and species (96%) were under Schedule II categories of Wild Life (Protection) Act, 1972 **(**Fig 35)

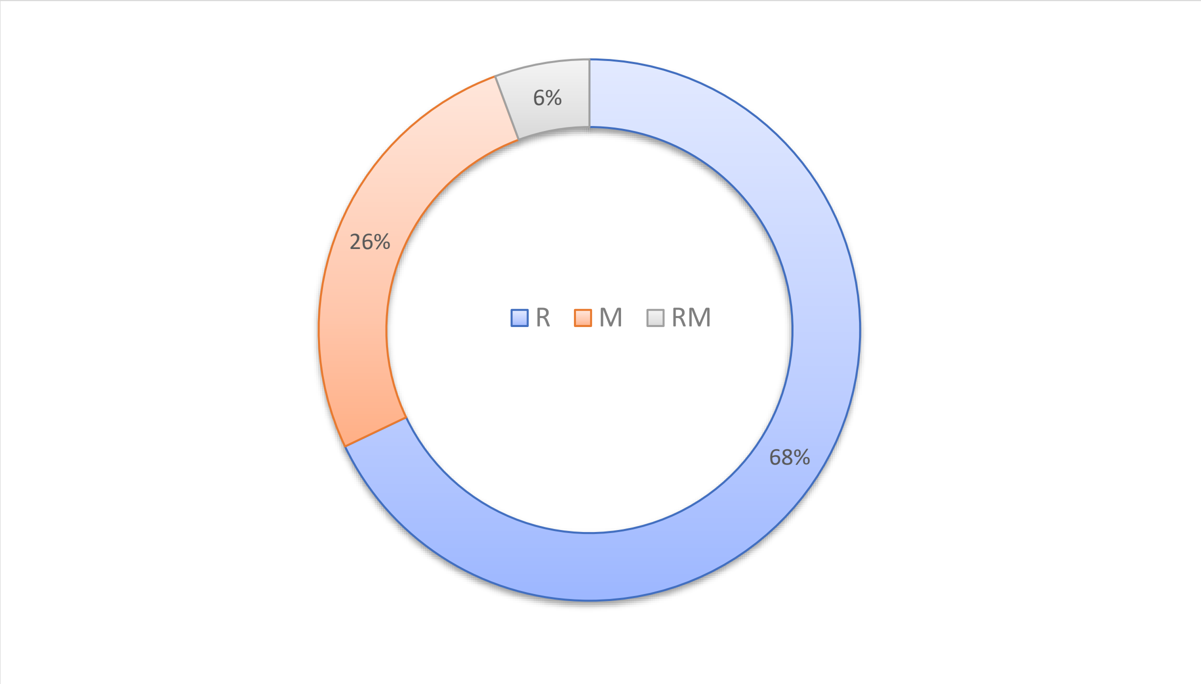


Figure 34 Behavioral status of avifauna from the Deendayal Port Authority,

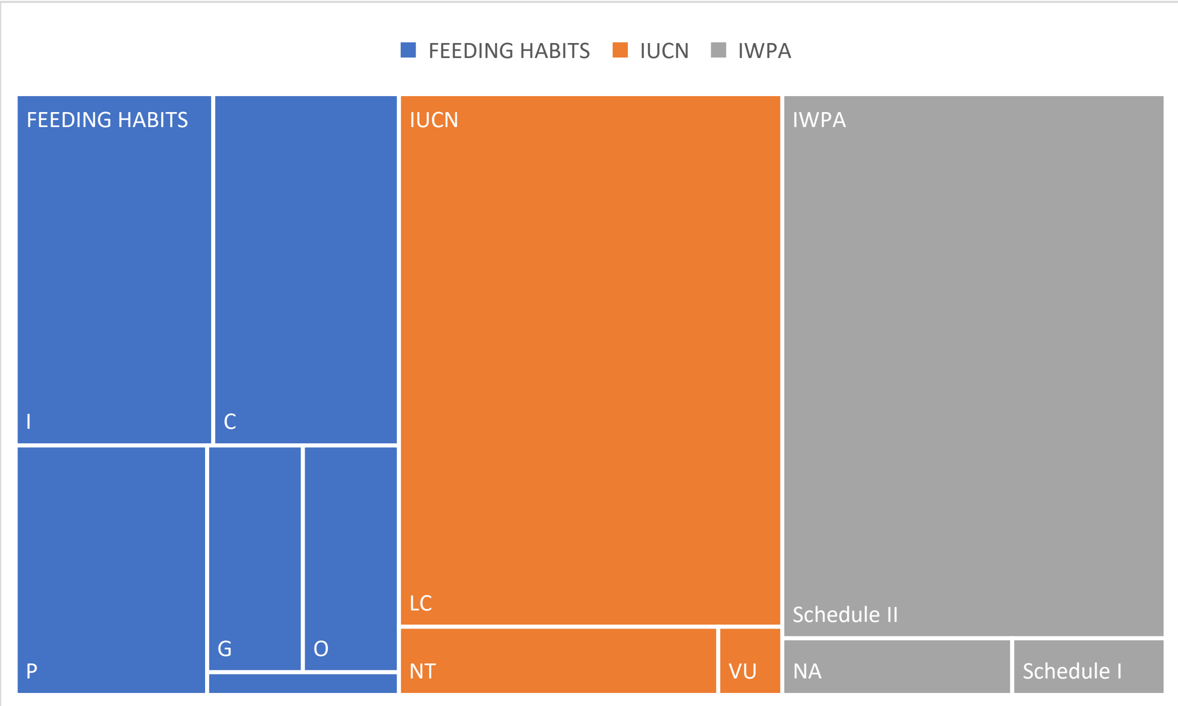


Figure 35 Status of foraging guild and threatened species recorded from Deendayal Port Authority,

Table 8. Site wise diversity indices recorded from DPA in Monsoon 2024

Site	Species	Individuals	Shannon_H	Evenness_e^H/S	Margalef	Equitability_J
S-1	44	115	3.60	0.84	9.06	0.95
S-2	40	126	3.55	0.87	8.06	0.96
S-3	43	170	3.49	0.76	8.18	0.93
S-4	42	185	3.61	0.88	7.85	0.96
S-5	45	172	3.62	0.83	8.55	0.95
S-6	35	105	3.39	0.85	7.31	0.95
S-7	41	159	3.58	0.87	7.89	0.96
S-8	33	95	3.41	0.92	7.03	0.98
S-9	34	91	3.41	0.89	7.32	0.97
S-10	35	136	3.39	0.84	6.92	0.95
S-11	23	62	2.96	0.84	5.33	0.94
S-12	45	171	3.66	0.86	8.56	0.96
S-13	53	218	3.75	0.80	9.66	0.94
S-14	29	74	3.22	0.86	6.51	0.96
S-15	37	96	3.47	0.87	7.89	0.96

Plate 10 Critical Mangroves and Mudflat habitats of birds at Deendayal Port Authority, Kandla (A-F)

Plate 11 . Common and migratory birds from the Deendayal Port Authority, Kandla. (A) Lesser black-backed gull Larus fuscus Linnaeus, 1758 (B) Caspian gull Larus cachinnans Pallas, 1811 (C) Western Reef Heron Egretta gularis (Bosc, 1792) (D) Crab-plover Dromas ardeola Paykull, 1805 (E) Black Headed Ibis Threskiornis melanocephalus (Latham, 1790) (F) Eurasian curlew Numenius arquata (Linnaeus, 1758).

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Annexture 1. Checklist of Avifauna recorded during the monsoon season from the Deendayal Port Authority, Kandla, India.

Sl. No.	Order, Family, Common & Scientific Name	MS	FS	IUCN	IWPA	Habitat
A	**CHARADRIIFORMES**					
1	**Charadriidae**					
1	Little ringed plover *Charadrius dubius* Scopoli, 1786	R	C	LC	Schedule II	A
2	Red-wattled Lapwing *Vanellus indicus* (Boddaert, 1783)	R	I	LC	Schedule II	T
3	Yellow-wattled Lapwing *Vanellus malabaricus* (Boddaert, 1783)	R	I	LC	Schedule II	T
2	**Dromadidae**					
4	Crab-plover *Dromas ardeola* Paykull, 1805	M	C	LC	Schedule II	A
3	**Laridae**					
5	Common tern *Sterna hirundo* Linnaeus, 1758	RM	P	LC	Schedule II	A
6	Little tern *Sternula albifrons* (Pallas, 1764)	R	P	LC	Schedule II	A
7	River Tern *Sterna aurantia* (Gray, JE, 1831)	R	P	V	Schedule I	A
8	Caspian gull *Larus cachinnans* Pallas, 1811	M	P	LC	Schedule II	A
9	Lesser black-backed gull *Larus fuscus* Linnaeus, 1758	M	C	LC	Schedule II	A
4	**Recurvirostridae**					
10	Black Winged Stilt *Himantopus himantopus* (Linnaeus, 1758)	R	C	LC	Schedule II	A
5	**Scolopacidae**					
11	Black-tailed Godwit *Limosa limosa* (Linnaeus, 1758)	M	O	NT	Schedule II	T
12	Common Greenshank *Tringa nebularia* (Gunnerus, 1767)	M	I	LC	Schedule I	T
13	Common Redshank *Tringa tetanus* (Linnaeus, 1758)	M	I	LC	Schedule II	A
14	Common Sandpiper *Actitis hypoleucos* (Linnaeus, 1758)	M	I	LC	Schedule II	A
15	Eurasian curlew *Numenius arquata* (Linnaeus, 1758)	M	C	NT	Schedule II	A
16	Green Sandpiper *Tringa ochropus* Linnaeus, 1758	M	I	LC	Schedule II	T
17	Marsh Sandpiper *Tringa stagnatilis* (Bechstein, 1803)	M	C	LC	Schedule II	T
18	Temminck's stint *Calidris temminckii* (Leisler, 1812)	M	C	LC	Schedule II	T
19	Whimbrel *Numenius phaeopus* (Linnaeus, 1758)	M	P	LC	Schedule II	A
B	**COLUMBIFORMES**					
6	**Columbidae**					

20	Blue Rock Pigeon *Columba livia* (Gmelin, JF, 1789)	R	G	LC	NA	T
21	Spotted Dove *Spilopelia chinensis* (Scopoli, 1786)	R	G	LC	Schedule II	T
22	Eurasian Collared Dove *Streptopelia decaocto* (Frivaldszky, 1838)	R	G	LC	Schedule II	T
23	Laughing Dove *Spilopelia senegalensis* (Linnaeus, 1766)	R	G	LC	Schedule II	T
24	Red Collared Dove *Streptopelia tranquebarica* (Hermann, 1804)	R	G	LC	Schedule II	T
C	**CORACIIFORMES**					
7	**Alcedinidae**					
25	Common Kingfisher *Alcedo atthis* (Linnaeus, 1758)	R	P	LC	Schedule II	A
26	White-throated Kingfisher *Halcyon smyrnensis* (Linnaeus, 1758)	R	C	LC	Schedule II	T
8	**Meropidae**					
27	Green Bee-eater *Merops orientalis* Latham, 1801	R	I	LC	Schedule II	T
D	**PELECANIFORMES**					
9	**Ardeidae**					
28	Cattle Egret *Bubulcus ibis* (Linnaeus, 1758)	R	C	LC	Schedule II	T
29	Great Egret *Ardea alba* (Linnaeus, 1758)	R	P	LC	Schedule II	A
30	Indian Pond Heron *Ardeola grayii* (Sykes, 1832)	R	C	LC	Schedule II	A
31	Intermediate Egret *Ardea intermedia* (Wagler, 1829)	R	P	LC	Schedule II	A
32	Little Egret *Egretta garzetta* (Linnaeus, 1766)	R	C	LC	Schedule II	A
33	Grey Heron *Ardea cinerea* Linnaeus, 1758	R	P	LC	Schedule II	T
34	Western Reef Heron *Egretta gularis* (Bosc, 1792)	RM	P	LC	Schedule II	A
10	**Threskiornithidae**					
35	Black Headed Ibis *Threskiornis melanocephalus* (Latham, 1790)	R	C	NT	Schedule II	A
36	Glossy Ibis *Plegadis falcinellus* (Linnaeus, 1766)	R	C	NT	Schedule II	T
E	**CICONIIFORMES**					
11	**Ciconiidae**					
37	Painted Stork *Mycteria leucocephala* (Pennant, 1769)	R	C	NT	Schedule II	A
F	**PASSERIFORMES**					
12	**Corvidae**					
38	House Crow *Corvus splendens* (Vieillot, 1817)	R	O	LC	NA	T

13	**Dicruridae**					
39	Black Drongo *Dicrurus macrocercus* Vieillot, 1817	R	I	LC	Schedule II	T
14	**Hirundinidae**					
40	Barn Swallow *Hirundo rustica* (Linnaeus, 1758)	RM	I	LC	Schedule II	T
41	Wire-tailed Swallow *Hirundo smithii* Leach, 1818	R	I	LC	Schedule II	T
15	**Laniidae**					
42	Bay-backed Shrike *Lanius vittatus* Valenciennes, 1826	R	I	LC	Schedule II	T
43	Brown shrike *Lanius cristatus* Linnaeus, 1758	R	I	LC	Schedule II	T
16	**Motacillidae**					
44	White Wagtail *Motacilla alba* Linnaeus, 1758	M	I	LC	Schedule II	T
45	Yellow Wagtail *Motacilla flava* Linnaeus, 1758	M	I	LC	Schedule II	T
17	**Nectariniidae**					
46	Purple Sunbird *Cinnyris asiaticus* (Latham, 1790)	R	N	LC	Schedule II	T
18	**Pycnonotidae**					
47	White Eared Bulbul *Pycnonotus leucotis* (Gould, 1836)	R	O	LC	Schedule II	T
48	Red-vented Bulbul *Pycnonotus cafer* (Linnaeus, 1766)	R	O	LC	Schedule II	T
19	**Sturnidae**					
49	Common Myna *Acridotheres tristis* (Linnaeus, 1766)	R	O	LC	Schedule II	T
50	Brahminy Starling *Sturnia pagodarum* (Gmelin, JF, 1789)	R	I	LC	Schedule II	T
G	**SULIFORMES**					
20	**Phalacrocoracidae**					
51	Little Cormorant *Microcarbo niger* (Vieillot, 1817)	R	P	LC	Schedule II	A
H	**Apodiformes**					
21	**Apodidae**					
52	House Swift *Apus nipalensis* (Hodgson, 1837)	R	I	LC	Schedule II	
I	**ACCIPITRIFORMES**					
22	**Accipitridae**					
53	Black Kite *Milvus migrans* (Boddaert, 1783)	R	C	LC	Schedule II	T

Gujarat Institute of Desert Ecology
Mundra Road, Bhuj 370 001, Kachchh, Gujarat
E-mail: desert_ecology@yahoo.com
www.gujaratdesertecology.com

Annexure -D

Inception Report

On

Greenbelt Development in Deendayal Port Authority (DPA) and its surrounding areas (Phase-III) along with two years maintenance

Submitted to

Deendayal Port Authority

Administrative Office Building

Post Box No.50, Gandhidham (Kachchh)

Gujarat-370201

Prepared by

Gujarat Institute of Desert Ecology

Mundra Road, Bhuj-370 001, Kachchh, Gujarat

E-mail: desert_ecology@yahoo.com

www.gujaratdesertecology.com

Inception Report

on

Greenbelt Development in Deendayal Port Authority (DPA) and its surrounding areas (Phase-III) along with two years maintenance

Co-ordinator
Dr. V. Vijay Kumar, *Director*

Principal Investigator
Dr. Jayesh B. Bhatt, *Scientist*

Co-Principal Investigator
Mr. Bhagirath Paradva, *Project Fellow*
Mr. Rakesh Popatani, *Project Fellow*

Team Member
Mr. Vivek Chauhan, *Junior Research Fellow*

Submitted by

Gujarat Institute of Desert Ecology
Opp. Changleshwer Temple, Mundra Road
Bhuj-370 001, Kachchh, Gujarat
www.gujaratdesertecology.com

Content

Introduction

A greenbelt is a designated area of undeveloped, wild, or agricultural land surrounding urban areas, intended to limit urban sprawl, protect natural environments, improve air quality, and promote biodiversity. Greenbelt development involves creating and maintaining these areas, often through strategic planting of trees, shrubs, or other vegetation to form natural barriers between urban and rural landscapes.

Thus, greenbelt offers a number of benefits for population. Vegetation absorbs various pollutants from the environment and thus help in effective pollution control. However, economic development like industrialization, mining, infrastructural development, etc. have exerted pressure and led to reduction and fragmentation of natural vegetation cover day-by day across the globe. Industrial and infra-structural developmental activities are likely to pollute the environment with varying magnitudes. Nevertheless, the pre-eminence of resistance of each of the organisms helps themselves to overcome the hazards caused by such pollutants.

Therefore, the general concept of greenbelt has evolved to develop vegetation or green spaces alongside of industries, mines, thermal power stations, roadsides, and other developmental unit is an effective measure to rejuvenate the environment through vital vegetation cover that safeguard the health of human and other living organisms. Greenbelts in and around urban and industrial areas are important to the ecological health of any given region.

Rationale

GUIDE team visited the proposed Greenbelt development site at Kandla port with the officials from Kandla Port as part of site selection. Based on the field observation and its landscape, environment and ecology of the area, suitable plant species were identified to improve the local environment and for the Greenbelt development at the port area.

Project Site

Based on observation made by the GUIDE team and officials from Deendayal Port Authority, a site at Roadside Over Bridge (RoB) to oil jetty road and Gopalpuri The area proposed for green development of Deendayal Port is barren land without any vegetation. The soil of the area is black muddy and is high saline soil with saline ground water. The area is very dry and hot during the summer.

Scope of Work

The overall objective is to Development Greenbelt at Deendayal Port Area. The following activities under the Greenbelt development have been carried out:

1. Inventories the suitable sites for greenbelt development in and around the Deendayal Port at Kandla.
2. Carryout Soil and Moisture Conservation (SMC) of the selected sites.
3. Identify suitable plant species as per site scenario for the greenbelt plantation.
4. Adopting plantation technique and soil/manure amendments.
5. Regular monitoring (survival and growth) of the plantation.
6. Suggest measures for management and improvement of the greenbelt.

Approach and Methodology for Greenbelt Development

Following steps have been adopted for greenbelt development:

1. **Planning Phase**:

- Involves site selection, environmental assessments, and choosing appropriate plant species based on local ecosystems.
- DPA officials and environmental experts collaborate to design sustainable spaces that support biodiversity and recreation.
- Selecting native trees/suitable to the condition and local environment to ensure ecological compatibility and resilience.

2. **Implementation Phase**:

- Includes land preparation (clearing and levelling), planting trees and shrubs, and constructing pathways or recreational facilities.
- Sustainable practices are prioritized to minimize environmental disruption.

3. Maintenance Phase:

- Focuses on long-term care such as watering, pruning, pest control, and replanting.
- Regular monitoring ensures the health of vegetation and ecosystems.
- Community involvement and education are key to sustaining the greenbelt

Plantation techniques:

- Site development for a plantation includes clearance for weeds and it involves, bush cutting, soil and moisture conservation works and marking of pits for planting of saplings, etc.
- After clearing the land sites for pits, plantation have been marked on ground using a measuring tape to ensure the desired spacing.
- Pits of the size 45 cm x 45 cm and 45 cm depth have been dug for tree plantation. Pits have been deep enough to ensure that the roots of the plants do not curl up once the planting material is placed in it.
- Since the soil is highly saline, a fertile soil around 06 dumpers have been added for better survival.
- Charcoal have been added for better moisture conservation and survival.
- The pit has been filled a little above the ground level so that after the earth settles the upper surface of the pit is at same level as that of ground thus avoiding any water logging.
- The plantation has been carried out in two phases (1^{st} in Gopal pruri-200 plants & 2^{nd} Roadside Over Bridge (RoB)-Oil jetty road side-5000 plants)

Selection of Plant Species for Plantation: Various indigenous tree species suitable for the area have been identified and selected for plantation areas based on soil quality, available water facility, and other environmental parameters.

Management and Monitoring of Greenbelt: The plantation within the identified site will be managed and monitored for a minimum period of two years after the plantation. The management of plantation includes watering at regular intervals, during summer and winter periods and if required even during monsoon with dry spells.

Fig. Map of Plantation Area at Gopalpuri

Fig. Map of Plantation Area RoB to Oil Jetty Road

Fig. Digging Out Trench for Plantation

Fig. Transportation of Plants to Site

Fig. Fertile Soil for Better Survival of Plants

Fig. Fertile Soil Filling to the pits

Fig. Addition of Charcoal for moisture conservation

Fig. Regular Watering of the Plants by Tanker

Annexure I
List of Plants for Plantation at site for Greenbelt Development
Site: Gopalpuri

Sr. No	Scientific name	Local name	No. of plants
Fruit Plants			
1	*Achras sapotta*	Chiku	3
2	*Citrus limonum*	Limbu	3
3	*Citrus medica*	Bijora	3
4	*Cocos nucifera*	Nariyel	3
5	*Eugenia jambolana*	Jambu	3
6	*Ficus carica*	Anjir	3
7	*Morus indica*	Shetur	5
8	*Phyllanthus emblica*	Amla	3
9	*Psidium guajava*	Jamfal	3
10	*Punica granatum*	Dadam	3
11	*Terminalia catappa*	Badam	5
12	*Pithecellobium dulce*	Gorsamli	3
13	*Tamarindus indica*	Khatiamli	5
14	*Carissa carandas*	Karmda	5
15	*Moringa oleifera*	Mitho sargavo	5
16	*Limonia acidissima*	Kothi	3
Medicinal Plant			
17	*Murraya koenigii*	Mitho limdo	5
18	*Plumbago zeylanica*	Chitrak	5
19	*Vitex negundo*	Nagod	8
20	*Nyctanthes arbor-tristis*	Parijat	8
21	*Justicia adhatoda*	Ardusi	5
22	*Butea monosperma*	Khakharo	5
23	*Hibiscus rosa-sinensis*	Jasud	5
24	*Bauhinia variegata*	Kanchnar	5
25	*Terminalia arjuna*	Arjun	5
26	*Azadirachta indica*	Limdo	5
27	*Ficus racemosa*	Umaro	5
28	*Aegle marmelos*	Bili	5
Air purifying plant			
29	*Cestrum diurnum*	Divsno raja	5
30	*Nerium odorum*	Karen	8
31	*Plumeria rubra*	Khadchampo	8
32	*Thespesia lampas*	Parspipalo	8
33	*Alstonia scholaris*	Saptaparni	8
34	*Plumeria rubra*	Kadam	5

Sr. No	Scientific name	Local name	No. of plants
35	*Ficus elastica*	Rabarplant	3
36	*Livistona chinensis*	Fenpalm	3
37	*Polyalthia longifolia*	Asopalav	8
38	*Roystonea regia*	Roayalpalm	2
39	*Pongamia glabra*	Karanj	8
40	*Delonix regia*	Gulmhor	5
41	*Ficus benjamina*	Ficus	5

Site: RoB to Oil Jetty Road

Sr. No.	Scientific Name	Local Name	No. of plants
1	*Conocarpus lancifolius*	*Conocarpus*	1700
2	*Peltophorum pterocarpum*	Peltophorum	660
3	*Millettia pinnata*	Karanj	660
4	*Delonix regia*	Gulmahor	660
5	*Tabubia rosea*	Tabubia	660
6	*Senna siamea*	*Kasid*	660

Annexure E

List of CSR Works for the year 2025(April to Till November-2025)		
Sr.No	**Name of work**	**Approved cost (Rs in Lakhs)**
1	Request for construction of relocatable of sports arena at Gandhidham Military Station,HQ 98 Artillery Brigade Military Station Gandhidham	₹ 28.00
2	Proposal for construction of Police Community Hall at Police Headquarters Shinay.Office of the Superintendent of Police, East – Kutch Gandhidham.	₹ 100.00
3	Proposal for providing AWG system at their check posts located in the Runn of Kutch,Commandant BSF Station Gandhidham	₹ 82.70
4	Proposal for providing 4000 pieces of Tripal/Tarpaulin,Matri Sena Charitable Trust	₹ 32.00
5	Proposal for Upgrading Satellite Eye Hospital at Bhuj.1.Request for financial support for the addition of cornea and retina outpatient departments (OPD), a spectacle dispensing unit, and a medicine counter as part of our OPD activities, & equipment purchase.	₹ 35.08
6	Proposal for financial assistance for purchase of C Arm and OT table to start Orthopedic at St. Joseph's Hospital Gandhidham,ST. Joseph's Hospital Trust, Gandhidham.	₹ 28.78
7	Proposed to establish a women empowerment center, through Ujjas Mahila Sangh,Gandhidham	₹ 119.48
8	CSR Grant for 'Strengthening of School Ecosystem at Primary School Level in Kachchh District,Ladies Environment Action Foundation (LEAF), Gandhinagar	₹ 50.00
9	Proposal for recharge Ponds and Solar based initiatives.Providing solar street lights, home lighting and solar lights for boats, specially targets sea farming families in the Tuna & Vandi village within Gandhidham block of Kutch district,Baif Institute for sustainable livelihoods and development, (BISLAD)Pune- Maharashtra.	₹ 30.00
10	Proposal for the Financial assistance for Ramakrishna Mission Centre for Human Excellance and Social Sciences also called 'Viveka Thirtha', New Town Kolkata. Human Excellence building ,Ramakrishna Mission, West Bengal	₹ 150.00
11	Funding for Distribute Biomass Green Cook Stove free of cost across Gujarat state.,Ramdas Athawale Foundation Ahemdabad	₹ 27.00
12	Request to Allotment of Fund for Development of School premises and providing furniture etc from CSR Fund.,Shree J.H Shukla Madhyamik Shala	₹ 25.92
13	Re-accreditation of sport academy under Khelo India Scheme.Request for Infrastructure for the proposals i) seating gallery & amenities ii) up gradation of existing hostel for elite athletes iii) surrounding road & infrastructure, etc.,Usha School Athletics, Kerala.	₹ 69.00
14	Proposal for Skill Development Training Program for Unemployed and Underprivileged Youth under CSR Initiative of Deendayal Port Authority (DPA) through Centre of Excellence in Maritime and Shipbuilding (CEMS),Mumbai	₹ 124.00
15	Submission of application along with requisite documents for construction of Kabrastan and fund for basic amenities under CSR,Etihadul Muslemin E Hind Trust, Anjar	₹ 50.00
16	Request Letter for the purchase of stainless steel Water Cooler with filter and dispenser for the school,Sunflower School, Gandhidham	₹ 3.19
17	Proposal for Placement Linked Skill and Capacity Building Training on Tourism and Hospitality Request for funding under Corporate social Responsibility (CSR) initiative,Pragati Edutech, Guwahati	₹ 50.00
18	Fund for establishment of New Facilities and upgradation of existing facilities at 'Adhar Sankul (Excluding cost of Building Construction.),'Adhar Sankul' Manav Seva Trust, Gandhidham.	₹ 75.00
19	Earnest Appeal to Contribute under CSR Activities for the construction of sainik school at silvassa in the name of NETAJI CHANDRA BOSE MILITARY ACEDEMY,VidhyaBharti Gujarat Pradesh, Ahemdabad.	₹ 445.23
20	Construction of an educational and social purpose building having 28 rooms & 2 halls.Shree Akhil Kutch Samasta Meghvanshi Gurjar Meghwal Charitable Trust, Bhuj.	₹ 75.00
21	Request to allotment of fund for development of school premises and providing furniture from CSR fund.Sunrise Global School, Gandhidham	₹ 12.60
22	Financial assistance to construction of Building Mind Power development centre for specially visually impaired children. With Equipments, Furniture CCTV, Airconditioner etc.,Shri Navchetan Adhjan Mandal, Madhapar	₹ 107.00

23	Proposal for DPA support Kutch Muslim Shifa Hospital,Muslim Shifa Medical Trust-Bhuj	₹	200.00
24	Request for help from CSR for providing Kits to the Children . List of government schools in khambhaliya taluka,for school Bags/Kits etc. They have requested for 1000 kits ,District Primary Education Officer, Devbhumi Dwarka-Khambhaliya	₹	4.00
25	Project proposal is for Education,Health and Livelihood project in kutch area Electric vehicle project for migrant community school,mobile health van project proposal, school structure project,tailoring training project, computer class for bhadreshwar centre, school-toilet-project, vermin compose unit, fisherman livelihood project.Yusuf Meherally Centre, Bhadreshwar-Kutch	₹	97.67
26	Request for renovation and construction of the shed work above G.F. slab, both side jali for shed, repairing work, painting.Missionaries of Charity, Bhachau (Mother Teresa's distitudi's home)	₹	55.00
27	River Reincarnation Project of the Bhukhi River.Krushi Research Innovation and Development Association, Mumbai (KRIDA)	₹	400.00
28	Providing Financial Assistance to R.D.S Kalavad Taluka Meghwar Seva samaj Education and Charitable Trust, Kalavad,SWA Ramji Daya Somaiya Shri Kalavad Taluka Meghwar Seva Samaj Education and Charitable trust, Kalavad	₹	75.00
29	CSR funding towards cure of Baby Aasmika Das diagnosed with Spinal Muscular Atrophy (SMA Type-1).	₹	20.00
30	CSR Funding for Providing Nutrition Kit to T.B. Patients under TB Mukat Bharat Abhiyan as Nishyray Mitra.	₹	14.02
31	Financial assistance under the CSR initiative to facilitate the urgent upgradation of the training and parade ground at the 176 BN BSF campus, Bhuj, Frontier Headquarters, Border Security Force (BSF)	₹	171.90
32	Financial assistance under the CSR initiative for Construction of a Martyr’s Column at the 176 BN BSF campus, Bhuj, Frontier Headquarters, Border Security Force (BSF)	₹	32.20

Annexure F

दीनदयाल पोर्ट प्राधिकरण
DEENDAYAL PORT AUTHORITY

Office of the Dy. Chief Engineer
(EMC & I/c), Ground Floor,
Administrative Office Building
Post Box No. 50, Gandhidham-Kachchh
Email: scplkpt@gmail.com,
www.deendayalport.gov.in

****

No: EG/WK/4783/VII/ 143 **Date:**04**/10/2024**

To,
M/s. Precitech Laboratories Pvt. Ltd.
1st floor, Bhanujyot Complex,
Plot no. C5/27, B/h. Pachratna Complex,
Near GIDC Char Rasta,
VAPI-396195
Mail – vapi@precitechlab.com

WORK ORDER

Sub: "Strengthening of Existing Environmental Management Cell of Deendayal Port Authority: Appointment of Environment Expert for two years and further extendable for one years."

Ref: 1) Tender dated 28/12/20223 submitted by M/s Precitech Laboratories Pvt. Ltd., Vapi.
2) LOA No. EG/WK/5375/171 dated 19/09/2024.
3) Performance Guarantee submitted by M/s. Precitech Laboratories Pvt Ltd in the form of Bank Guarantee of Rs. 9,45,000.00 vide Bank Guarantee no. 1102924BG0B00238 dated 30.09.2024 issued by State Bank India, Commercial Branch, Vapi.

Sir,

Kindly refer above cited Letter of Acceptance dated 19/09/2024.

1) 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.
2) Please submit the agreement of contract as per Tender Conditions.
3) Kindly commence the work on or before 07/10/2024.

Please note that the time period for providing Consultancy service for the subject work will be Initially for Two years and further extendable for one year on mutual consent as per tender condition.

Accordingly, a copy of Form-III is enclosed herewith for information and necessary action please.

Encl: Form – III

04/10/24
Dy. Chief Engineer (PL) & EMC (I/c),
Deendayal Port Authority

CC: 1. TPA to CE - For kind information to Chief Engineer, please.
2. RAO, DPA
3. Sr. DD (EDP) with a request to hoist this work order in website of DPA.

4. A.M.(W/A)

दीनदयाल पोर्ट प्राधिकरण

DEENDAYAL PORT AUTHORITY

KANDLA

SAGARMALA

Office of the Dy. Chief Engineer
(EMC & I/c), Ground Floor,
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Post Box No. 50, Gandhidham-Kachchh
Email: seplkpt@gmail.com,
www.deendayalport.gov.in

****

No: EG/WK/4783/VII/ **Date: 4 /~~09~~ 10/2024**

FORM – III

(Under rule 21(2) of the Contract Labour (Regulation and Abolition) Central Rules,1970; and Rules 7(3) of the Inter-State Migrant Workmen (Regulation of Employment and Conditions of Service) Central Rules, 1980)

CERTIFICATE BY PRINCIPAL EMPLOYER FOR OBTAINING LICENCE FROM ASSISTANT LABOUR COMMISSIONER (C); GOPALPURI.

Certified that:

I have engaged the applicant "Precitech Laboratories Pvt Ltd. 177, 1st floor, Bhanujyot Complex, Plot no. C5/27, B/h. Pachratna Complex,Near GIDC Char Rasta,VAPI-396195. as a contractor in my establishment for the work **"Strengthening of Existing Environmental Management Cell of Deendayal Port Authority: Appointment of Environment Expert for two years and further extendable for one years."** to be carried out for **24 months** (as per tender) and the work will be commenced on or before **07/10/2024.**

1) I undertake to be bound by all the provisions of the Contract Labour (Regulations and Abolition) Act, 1970 (37 of 1970) and the Contract Labour (Regulations and Abolition) Central Rules, 1971 The inter-State Migrant Workman (Regulation of Employment and Conditions of Service) Act, 1979 (30 of 1979) and the Inter State Migrant Workmen (Regulation of Employment and Conditions of Service) Central Rules, 1980* in so far as the provisions are applicable to me in respect of the employment of Contract Labour/inter-state migrant workmen by the applicant in my establishment.

2) The engagement of contract labour in the said work is not prohibited under sub-section (1) of section 10 of the Contract Labour (Regulation and Abolition) Act, 1970 (37 of 1970) or an award or a settlement.

04/10/24

Dy. Chief Engineer (PL) & EMC (I/c),
Deendayal Port Authority

Annexure G

CE

May posted in Civil Engineering Deptt/ Chairman's office, after observance & due formalities there.

25/8/2025

Date: 25th August

To,

The Secretary,
Deendayal Port Authority,
Gandhidham, Kutch

Subject: Duty Report for the post of Chief-Manager (Environment & Safety) on contractual basis at DPA – reg.

Sir,

I Dr. Utkarsh S. Mukkannawar, have been selected and offered the position of Chief Manager (Environment & Safety) on contractual basis under professional functionaries category vide Letter No. GA/PS/4292(PF)/2025/1347 with effective from 12th August'2025.

As per terms clause no 19, I "have to report for medical examination before the Chief Medical Officer, DPA at Gopalpuri Hospital……"

Accordingly, I hereby submit and enclose my medical examination Report as clinically healthy and "FIT to Join".

Further, I hereby submit my duty report today i.e., 25th August 2025 (FN) along with duly signed acceptance copy of Offer Letter, the original copy of the medical report enclosing clinical documents and two passport size photos for your kind perusal.

Thanking you,

Yours faithfully,

25/08/25

Dr. Utkarsh Mukkannawar
Mob: 9822077507

CE

May be posted in Civil Engineering Department, after due observance of formalities as per T&C of engagement, under intimation to GAD please.

Date: 10th September 2025

10/9/2025

Secretary.

To,

The Secretary,

Deendayal Port Authority,

Gandhidham, Kutch

Subject: Duty Report for the Port of Manager (Environment & Safety) on contractual basis at DPA – reg.

Sir,

I Ms. Neha Chandrashekhar Dekate, have been selected and offered the position of Manager (Environment & Safety) on contractual basis under professional functionaries' category vide letter no. GA/PS/4292 (PF)/2025/1349 with effective from 12th August'2025.

As per clause no. 19, "I have to report for medical examination before the Chief Medical Officer, DPA at Gopalpuri Hospital……. "

Accordingly, I hereby submit and enclose my medical examination report as clinically healthy and "FIT to Join".

Further, I hereby submit my duty report today i,e. 10th September 2025 (FN) along with duly signed acceptance copy of Offer letter, the original copy of the medical report enclosing clinical documents and two passport size photos for your kind perusal.

Thanking you,

Yours faithfully,

Neha Dekate

Ms. Neha Dekate

Mob: 9096069665

CG/Sr AS

May be posted in Environment Cell of Civil Engineering Deptt., subject to observance of due formalities as per terms & conditions of engagement in DPA on contract, please.

3/9/2025
Secretary

To,

The Secretary

Administrative Building

Deendayal Port Authority

Date: 03/09/2025

SUBJECT: **Duty Report for Contractual Engagement as Manager – Environment & Safety in Deendayal Port Authority (DPA)**

Ref.: DPA letter GA/PS/4292(PF)/2025/1348 dated 12/08/2025

Sir,

With reference to the above referred letter dated 12/08/2025 I am hereby pleased to submit my Duty Report and I confirm to join the organization with effect from today i.e.03/09/2025.

Thanking You

Yours Faithfully

Rajeshwari Sharma