DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY
www.deendayalport.gov.in

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

EG/WK/4751/Part (remaining 3 facilities)/ Dated:13/03/2024

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

Sub: Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Authority (Erstwhile: Deendayal Port Trust) at Gandhidham, Kutch, Gujarat – **Submission of Point-wise Compliances of the stipulated conditions in CRZ Recommendations reg.**

Ref.:
1. Letter No. ENV-10-2015-248-E (T-Cell) dated 29/6/2016 of Director (Environment) & Additional Secretary, Forest & Environment Department, GoG
2. DPT letter no. EG/WK/4751/Part (remaining 3 facilities)/78 dated 22 (24)/12/2020 along with point-wise compliance report of the stipulated conditions mentioned in the CRZ Recommendation letter dated 29/6/2016.
3. DPT letter no. EG/WK/4751/Part (remaining 3 facilities)/40 Dated 13/07/2021.
4. DPT letter no. EG/WK/4751/Part (remaining 3 facilities)/150 Dated 8/2/2022.
5. DPA letter no. EG/WK/4751/Part (remaining 3 facilities)/134 Dated 06/07/2022
6. DPA letter no. EG/WK/4751/Part (remaining 3 facilities)/281 Dated 18/04/2023
7. DPA letter no. EG/WK/4751/Part (remaining 3 facilities)/357 Dated 12/09/2023

Sir,

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

In this connection, it is to state that, the Gujarat Coastal Zone Management Authority vide above referred letter dated 29/6/2016 had recommended remaining 3 project activities (Phase I) of Deendayal Port Authority (Erstwhile: Deendayal Port Trust). Subsequently, the MoEF&CC, GoI had accorded the Environmental & CRZ Clearance vide letter dated 18/2/2020. In this regard, DPA vide above referred letters had regularly submitted compliance report of the stipulated conditions, to the Director (Env.) & Member Secretary, GCZMA, F & E Dept., GoG.

Now, as directed under Specific Condition No. 28 mentioned in the CRZ Clearance letter dated 29/6/2016 i.e. ***A six-monthly report on compliance of the conditions mentioned in this letter shall have to be furnished by the DPA on a regular basis to this Department /MoEF&CC, GoI***, please find enclosed herewith compliance report (For Period upto November, 2023) of stipulated conditions along with necessary annexure, for kind information & record please **(Annexure I).**

............Cont.........

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

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

Thanking you.

Yours faithfully,

Encl.: As above

Fr SE (PL) & EMC (I/c)
Deendayal Port Authority

Copy to:

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

Annexure -I

Subject: Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Authority (Erstwhile: Deendayal Port Trust) at Gandhidham, Kutch, Gujarat – **Environmental & CRZ Clearance.**

CURRENT STATUS OF WORK (up to November, 2023)

Sr.No.	Name of Project	Status
1	**Development of Container Terminal at Tuna off-Tekra on BOT Basis:** *(Jetty: T-shape 1100m X 54m, Capacity: 2.19 Million TEUs/Annum, Capital Dredging: 13,56,000 M3, Maintenance Dredging 271200 M3/year, Land Area req.: 84 ha, Break water: Length of 1400 m, with 20 m of height, Estimated Cost: 3097 cr.).*	The Concession Agreement was signed on 25.08.2023. The Project is in the Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024, and the Planned Construction End Date is February 2027.
2	**Providing Railway Line from NH 8A to Tuna Port.** *(Length – 11 km, Estimated cost: 94 cr.)*	**Work completed.**
3	**Construction of Port Craft Jetty & Shifting of SNA Section.** *(Dredging: 27357.00 m3, Estimated Cost: 23.17 cr.)*	**Work completed.**

Annexure 1

COMPLIANCE REPORT (up to November, 2023)

Subject: Compliance of conditions stipulated in CRZ recommendations issued by GCZMA for the proposal "Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Authority (Erstwhile: Deendayal Port Trust) at Gandhidham, Kutch, Gujarat".

CRZ Recommendations: Letter No. ENV-10-2015-248-E (T - Cell) dated 29/6/2016 of Director (Environment) & Member Secretary, GCZMA, Forest & Environment Department, GoG.

Sr. No.	Conditions in CRZ Recommendation Letter	Compliance
	Specific Conditions	
1	The provisions of the CRZ notification of 2011 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.	For a project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in the Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024, and the Planned Construction End Date is February 2027. The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. However, it is assured that DPA will strictly adhere to the provisions of the CRZ Notification, 2011 and no activity other than those permissible in Coastal Regulation Notification, 2011 shall be carried out in the CRZ area.
2	All necessary permissions, under various laws/Rules/Notifications issued there under from different Government Departments/agencies shall be obtained by M/s KPT before commencing any enabling activities for proposed project.	DPA obtained CTE/NOC from the GPCB vide No. PC.CCA-KUTGH-1231(2) I GPCB ID 44000 dated 4/12/2017 (Copy of the same has been communicated with the last compliance report submitted). Further, DPA had obtained CTE validity extension (CTE-125870) from GPCB vide Order dated 27/04/2023 with validity up to 15/11/2025 (**Copy enclosed as Annexure A**). MoEF&CC, GoI accorded EC & CRZ Clearance for the subject proposal of DPA dated 18/2/2020.

3	The KPT shall have to ensure that there shall not be any damage to the existing mangrove area.	For Project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024 and Planned Construction End Date is February 2027. The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. Further, DPA has already prepared a mangrove preservation plan for the entire Kandla area.
4	The KPT shall effectively implement the Mangrove Development, Protection & Management Plan for control of indirect impact on mangrove habitat.	DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005. The copy of the details has already been communicated with the earlier compliance reports submitted. Further, the Study on the present Status, Conservation and Management Plan for Mangroves of Kandla Port region submitted by M/s GUIDE, Bhuj, had already been communicated to the GCZMA & to the MoEF&CC, GoI. In addition to the above, DPA appointed M/s GUIDE, Bhuj for "Regular Monitoring of Mangrove Plantation carried out by DPA" (period 15/9/2017 to 14/9/2018 vide work order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021). The final report submitted by M/s GUIDE, Bhuj, for the years 2017 to 2018 and 2021 to 2022 has already been communicated with the earlier six monthly compliance submitted.
5	The KPT shall have to make a provision that mangrove areas get proper flushing water and free flow of water shall not be obstructed.	It is hereby assured that necessary provisions will be made so that mangrove areas get proper flushing water and free flow of water shall not be obstructed.
6	The KPT shall have to abide by whatever decision taken by the GCZMA for violation of CRZ Notification.	Point noted

7	No dredging, reclamation or any other project related activities shall be carried out in the CRZ area categorized as CRZ I (i) and it shall have to be ensured that the mangrove habitats and other ecologically important and significant areas, if any, in the region are not affected due to any of the project activity.	For Project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024 and Planned Construction End Date is February 2027. The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. DPA had authorised the work to M/s GUIDE, Bhuj for continuous monitoring of Marine Ecology since the year 2017 and the final reports are being submitted from time to time to the Regional Office, MoEF&CC, GoI, Gandhinagar & to the MoEF&CC, GoI, New Delhi along with six monthly compliance reports submitted. Further, DPA issued a work order to M/s GUIDE vide its letter no. EG/ WK/ 4751/ Part (Marine Ecology Monitoring) /11 dated 03/05/2021 for Regular monitoring of Marine Ecology in and around Deendayal Port Authority (Erstwhile Deendayal Port Trust) and continuous Monitoring Program covering all seasons on various aspects of the Coastal Environs for the period 2021-24. The final Report for the period 2020-21 has already been submitted along with compliance report submitted dated 07/10/2021 The final report for the years 2021-2022, 2022-2023 and the Inception report for the years 2023-24 submitted is attached herewith as **Annexure B, Annexure C** and **Annexure D** resp
8	The KPT shall participate financially in installing and operating the Vessel Traffic Management System in the Gulf of Kachchh and shall also take the lead in preparing and operational sing and regularly updating it after getting it vetted by the Indian Coast Guard.	Deendayal Port Authority had already contributed Rs. 41.25 crores for installing and operating the VTMS in the Gulf of Kachchh.
9	The KPT shall strictly ensure that no creeks or rivers are blocked due to any activity at Kandla.	For Project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024 and Planned Construction End Date is February 2027.

		The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed.
10	Mangrove plantation in an area of 50 ha. Shall be carried out by the KPT within 2 years in time bound manner on Gujarat coastline either within or outside the Kandla port Trust area and six monthly compliance reports 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 MoEF&CC, GoI, till date, DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005, which includes 50 Hectares mangrove plantation as per stipulated condition. Further, DPA appointed M/s GUIDE, Bhuj for "Regular Monitoring of Mangrove Plantation carried out by DPA" (period 15/9/2017 to 14/9/2018 vide work order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021). The final report submitted by M/s GUIDE, Bhuj, for the years 2017 to 2018 and 2021 to 2022 have already been submitted in the six monthly compliance communicated vide letter 06/07/2022.
11	No activities other than those permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.	For Project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024 and Planned Construction End Date is February 2027. The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. However, no activities other than those permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.
12	No ground water shall be tapped for any purpose during the proposed expansion modernization activities.	Water requirements will be met through procurement from GWSSB or private tankers. It is hereby assured that no groundwater shall be tapped.
13	All necessary permissions from different Government Departments / agencies shall be obtained by the KPT before commencing the expansion activities.	DPA has already obtained the necessary Environmental & CRZ Clearance for three project activities dated 18/2/2020. Further, Consent to Establish from GPCB had already been obtained from GPCB (CTE – 89537) vide no. PC/CCA-KUTCH-1231 (2)/GPCB ID 44000/429717 dated 4/12/2017. Further, DPA had obtained CTE

		validity extension (CTE-125870) from GPCB vide Order dated 27/04/2023 with validity up to 15/11/2025 (**Copy enclosed as Annexure A**).
14	No effluent or sewage shall be discharged into sea/creek or in the CRZ area and it shall be treated to conform to the norms prescribed by the GPCB and would be reused /recycled within the plant premises.	DPA already has a Sewage Treatment Plant capacity of 1.5 MLD. The treated wastewater is utilized for plantation/gardening purposes. Further, BOT Operator will provide necessary arrangements for a sewage treatment facility.
15	All the recommendations and suggestion given by the Mantec Consultants Pvt. Ltd. in their Comprehensive Environment Impact Assessment report for conservation / protection and betterment of environment shall be implemented strictly by the KPT.	DPA has installed Mist Canon at the Port area to minimize the dust. Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done. For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of 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 E**. For ship waste management, DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" and "Dry Solid Waste (Non- Hazardous)" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars regarding the reception facilities at Swachch Sagar portal. Further, DPA has appointed GEMI, Gandhinagar for the work of "Preparation of Plan for Management of Plastic Wastes, Solid Waste, including C&D waste, E-waste, Hazardous waste, including Biomedical and Non-Hazardous Waste in the Deendayal Port Authority" vide Work Order dated 24/01/2023. The work is in progress. DPA assigned work to M/s GUIDE, Bhuj, for regular monitoring of Marine Ecology since the year 2017 (From 2017 – 2021), and final reports of the same are being submitted regularly to the Regional Office, MoEF&CC, GoI, Gandhinagar as well as to the MoEF&CC, GoI, New Delhi along with compliance reports submitted.

		Further, it is to submit that DPA issued a work order to M/s GUIDE vide its letter no. EG/ WK/ 4751/ Part (Marine Ecology Monitoring) /11 dated 03/05/2021 for Regular monitoring of Marine Ecology in and around Deendayal Port Authority (Erstwhile Deendayal Port Trust) and continuous Monitoring Program covering all seasons on various aspects of the Coastal Environs for the period 2021-24. Final Report for the period 2020-21 has already been submitted along with compliance report submitted dated 07/10/2021 The final report for the year 2021-2022, 2022-2023 and Inception report for the year 2023-24 submitted is attached herewith as **Annexure B, Annexure C** and **Annexure D** resp As already informed, DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares). The work is completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The final report submitted by GUIDE, Bhuj is attached herewith as **Annexure F**. Further, DPA has accorded the work of "Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The same is in process For dredged material management, DPA has been assigning work to M/s GUIDE, Bhuj for analysis of dredged material since the year 2017 and the reports are being submitted from time to time along with compliance reports submitted. The final Report submitted by M/s GUIDE, Bhuj for the period 2022-2023 is attached herewith as **Annexure G.** Further, Dredged Material will be disposed of at designated location as identified by the CWPRS, Pune.

		For energy conservation measures, DPA is already generating 20 MW of Wind energy. In addition to it, DPA has commissioned a 45 kWP Solar Plant at Gandhidham. Further, it is relevant to mention that, two out of four Nos. of Harbour Mobile Crane (HMC) made electric operated. Balance 02 Nos. shall be made electric operated by 2023-2024. Four Nos. of Deisel operated RTGs converted to e-RTGs. Retrofitting of hydrogen fuel cell in Tug Kalinga and Pilot Boat Niharika to be done as a pilot project under the guidance of MoPSW. Also, 14 Nos. of EV cars to be hired in this year and 03 Nos. EV Bus to be procured by the year 2023-24. Further, for Oil Spill Management, DPA is already having Oil Spill Contingency Plan in place and Oil Response System as per the NOS-DCP guidelines.
16	The construction and operational activities shall be carried out in such a way that there is no negative impact on mangroves and other coastal /marine habitats. The construction activities and dredging shall be carried out only under the constant supervision and guidelines of the Institute of National repute like NIOT.	For Project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024 and Planned Construction End Date is February 2027. The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. Further, DPA has already prepared a mangrove preservation plan for the entire Kandla area.
17	The KPT shall contribute financially for any common study or project that may be proposed by this Department for environmental management / conservation / improvement for the Gulf of Kutch.	Point noted.
18	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.	For Project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024 and Planned Construction End Date is February 2027. However, the construction debris and/ or any other waste will not be disposed of into the sea and the debris will be removed from the construction site after construction is over. Further, it is relevant to mention here that, DPA had already issued general circular vide dated 3/9/2019 regarding Construction and Demolition

		Waste Management for strict implementation in DPA (Copy has already been communicated with the last compliance report submitted).
19	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.	For Project at Sr. No. 1, the Concession Agreement was signed on 25.08.2023. The Project is in Conditions Precedent Stage. Both the Parties are fulfilling their respective CPs. The Planned Construction Start Date is February 2024 and Planned Construction End Date is February 2027. However, construction camps with necessary amenities will be located in the already nearby developed areas. Further, due care shall be taken so that the environmental conditions are not deteriorated by the construction labours.
20	The KPT shall regularly updates its Local Oil Spill Contingency and Disaster management Plan in accordance with the National Oil Spill and Disaster Contingency Plan and shall submit the same to the MoEF, GoI and this department after having it vetted through the Indian Coast Guard.	Point noted. ▪ Deendayal Port already has an updated Disaster Management Plan (A copy of the Plan has already been submitted with the earlier compliances). ▪ Further, the Local Oil Spill Contingency Plan is already available with Deendayal Port Authority. ▪ DPA has also executed MOU with Oil Companies, i.e., IOCL, HPCL, BPCL etc., for combating the Oil Spill at Kandla
21	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.	Agreed with the condition
22	The KPT shall take up massive greenbelt development activities in and around Kandla and also within the KPT limits.	DPA has planted about one lakhs trees in roadside dividers, colony areas at Kandla and Gopalpuri, in the greenbelt area of Gandhidham & Adipur Township, Sewage Treatment Plants at Gopalpuri & Kandla and extensive green belt development plans initiated at different locations in Township areas. DPA entrusted work of greenbelt development in and around the Port area to the Forest Department, Gujarat, at the cost of Rs. 352lakhs (Area 32 hectares), and the work is completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The final report submitted by GUIDE, Bhuj is attached herewith as **Annexure F.**

		Further, DPA assigned work to GUIDE, Bhuj vide work order dated 23/06/2023 for "Green belt development in Deendayal Port Authority and its Surrounding Areas (Phase II) (10000 plants). The work is in progress.
23	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 District Collector/District Development Officer.	Already CSR works are being attended to by DPA. The details of CSR activities undertaken/to be undertaken by DPA are placed in **Annexure H.**
24	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.	DPA has already kept Rs. 274 lakhs in B.E. 2023-24 under the scheme "Environmental Services & Clearance thereof".
25	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 is already having Environment Management cell. Further, DPA has also appointed expert agency for providing Environmental Experts from time to time. Recently, DPA appointed M/s Precitech Laboratories, Vapi for providing Environmental Experts vide work order dated 5/2/2021. In addition, it is relevant to submit here that, DPA has appointed Manager (Environment) on contractual basis for the period of 3 years and further extendable to 2 years (Copy of the details has already been communicated with the last compliance report submitted). Further, for monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of 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 E**.
26	An Environmental reports indicating the changes, if any, with respect to the baseline environmental quality in the coastal and marine environment shall be submitted every year by the KPT to this Department as well as to the MoEF&CC,GOI.	For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of 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 E**. DPA has been submitting the environmental monitoring report along with the six-monthly compliance report to IRO, MoEF&CC, GoI.
27	The KPT shall have to contribute financially to support the National Green Corps Scheme being implemented in Gujarat by the GEER Foundation, Gandhinagar, in construction with Forests and Environment Department.	Agreed with the condition.
28	A 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 been regularly submitting six monthly compliance reports of the stipulated conditions to GCZMA and the Regional Office, MoEF&CC, GoI.
29	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.	Agreed with the condition.

Annexure -A

GUJARAT POLLUTION CONTROL BOARD

GPCB

PARYAVARAN BHAVAN, SECTOR 10-A,
GANDHINAGAR - 382010,
(T) 079-23232152

By R.P.A.D

AMENDMENT TO CONSENT TO ESTABLISH (CTE)
CTE-125870

NO: PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / **Date: -**

To,
M/s. Kandla Port Trust,
Developing Integrated Facilities within existing KPT, at Kandla,
Kandla & Tuna area,
Tal : Gandhidham, Dist : Kutch – 370 201

Subject : Consent to Establish (CTE) issued vides CTE - 89537 vide letter no. **PC/ CCA-KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017.**

Reference : 1. Board has issued CTE vide letter **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017.**
2. Your application for CTE validity extension/ CTE Fresh Inward no. 271834 dated 07/01/2023.

Sir,

Without prejudice to the powers of this Board under the Water (Prevention and Control of Pollution) Act-1974, the Air (Prevention and Control of Pollution) Act-1981 and the Environment (Protection) Act-1986 and without reducing your responsibilities under the said Acts in any way. The Board had granted **Consent to Establish (NOC)** vide order no. **CTE – 89537** vide letter no. **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017** for the plant at **Developing Integrated Facilities within existing KPT, at Kandla, Kandla & Tuna area, Ta. Gandhidham, Dist. Kutch.**

The Board has right to review & amend the conditions of the said CTE order. Now considering your application for CTE-Amendment inward no. 271834 dated 07/01/2023 for validity extension of the CTE order dated 27/04/2023, the said order is amended as below:

1. The validity mentioned in the CTE order no- **CTE – 89537** issued vide letter no. **PC/ CCA-KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017 shall be read as CTE order no. CTE-125870 dated 27/04/2023, valid up to 15/11/2025.**
2. The rest of the conditions of Consent to Establish (CTE) order No: **CTE – 89537** issued vide letter no. **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017** shall remain unchanged and industry shall comply with the same judicially.

For and on behalf of
Gujarat Pollution Control Board

(T. C. Patel)
Unit Head

Annexure -B

Final Report

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

Submitted to

DEENDAYAL PORT AUTHORITY
Administrative Office Building
Post Box No. 50, Gandhidham (Kachchh)
Gujarat-370201

Submitted by

GUJARAT INSTITUTE OF DESERT ECOLOGY
P.B. No. 83, Mundra Road, Opp. Changleshwar Temple
Bhuj-Kachchh, Gujarat-370001

May 2022

Final Report

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

Submitted to

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

DEENDAYAL PORT AUTHORITY
Administrative Office Building
Post Box No. 50, Gandhidham (Kachchh)
Gujarat-370201

Submitted by

GUJARAT INSTITUTE OF DESERT ECOLOGY
P.B. No. 83, Mundra Road, Opp. Changleshwar Temple
Bhuj-Kachchh, Gujarat-370001

May 2022

Gujarat Institute
Of Desert Ecology

Dr. V. Vijay Kumar
Director

This is to state that this Final Report of the work entitled **"Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme"** has been prepared as per the work order issued by DPA vide no EG/WIK/4751/Part (Marine Ecology Monitoring)/11, Dt. 03.05.2021 for the year 2021-2022 as per EC and CRZ clearance accorded by the MOEF&CC, GOI dated 19.12.2016,18.2.2020,19.2.2020 and 20.11.2020 with specific conditions xviii, xxiii, xv & iv respectively.

Gujarat Institute of Desert Ecology Bhuj

Authorized Signatory **Institute Seal**

P. O. Box No. # 83, Opp. Changleshwar Temple, Mundra Road, Bhuj (Kachchh) - 370 001, Gujarat (India)
Tel : 02832 - 235025 Tele / Fax : 235027
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Project Team

Project Coordinator

Dr. V. Vijay Kumar, Director

Project Investigators			
Sl No	Name	Designation	Area of Expertise
1	Dr. M. Jaikumar	Senior Scientist	Mudflat Ecology & Seaweed
2	Dr. Durga Prasad Behera	Project Scientist	Plankton Physico-chemical of water Marine Fisheries
3	Dr. L. Prabha Dev	Advisor	Marine Ecology
4	Dr. Nikunj B. Gajera,	Scientist	Avifauna
Co-Principal Investigators			
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6	Dr. R. Kapilkumar Ingle	Project Scientist	Mangrove
7	Dr. Dhara Dixit	Project Scientist	Halophytes & Seaweed
1	Mr. Dayesh Parmar	Project officer	GIS & Remote sensing
Team Members			
2	Mr. Sai Vineeth Perla	Senior Research Fellow	Sediment, Water, Phytoplankton & Mangrove
3	Miss. Pallavi Joshi	Junior Research Fellow	Zooplankton, Phytoplankton
4	Miss.Bhagavati N.Kannad	Junior Research Fellow	Mangrove and sediment

Snapshot

(Monsoon)

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 water front facilities (OJ 8 to 11- Para VIII Marine Ecology, specific condition iv.
2	Deendayal Port letter Sanctioning the Project	DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/11 date 03.05.2021
3	Duration of the Project	Three years-from 24.05.2021 to 23.05.2024
4	Period Of Survey Carried	June 2021 to September 2021 (Monsoon season)
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 DPA port jurisdiction
7	**Components of the report**	
7a	Mangroves	The overall average density of 3198 trees/ha of *A. marina* during monsoon 2021. The highest tree density was reported at S4 in the Kandla creek of Sat saida bet (7851 trees/ha) followed by S7 at Kharo creek near Kandla port (5289 trees/ha) and S5 at Phang creek (4070 trees/ha). The lowest tree density (1433 trees/ha) was reported at S9 followed by S13 (1619 trees/ ha) near the oil jetty (Table). The density of mangrove trees was in the order Kandla creek > Kharo creek> Phang creek > Tuna Creek> Jangi creek> Navlaki creek > Vira coastal area.
7b	Mudflats	The highest TOC values (1.102 ±0.75%) were recorded at station S-13 followed by S-11 (0.35 ±0.11%). Lowest TOC values were reported at site S-3. It is observed that TOC values show a significant difference 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.
7c	Zooplankton	A total of 19 Zooplankton groups and 42 genera were recorded from 15 sampling stations S1 to S15. The highest percentage of composition was Calanoida among the copepods (47.77%) followed by Decapoda (12.7%), Chaetognatha (6.4%) and Malacostraca (6.3%).
7d	Phytoplankton	A total of 23 genera of phytoplankton were recorded from 15 sampling sites phytoplankton belonged to three major groups namely Diatoms (pennales and centrals), dinoflagellates and Cyanophyceae. The Centrales contributed the highest percentage (54.4%) followed by pennales diatoms (36.3%) and dinoflagellates (6.2%) and the rest (3.1%) by Cyanophyceae.
7e	Intertidal Fauna	The intertidal fauna recorded were enlisted into four groups namely Molluscs, Polychaetes, Crabs and “Others”. There were totally 16 species recorded from the intertidal sites of which 7 belongs to molluscs the dominant group followed by polychaetes, crabs, and “Others” each represented with 3 species.
7f	Sub-tidal Macrobenthos	Two major invertebrate groups namely Molluscs and Polychaetes and a few other fauna which are less abundant constituted as “Others”. The molluscs represented by 11genera constituted the most dominant group followed by polychaetes with 6 genera. The group “Others” was formed of 3 genera. The bivalves *Pholas* sp. and *Saccostrea* sp. occurred in 11 sampling stations with a frequency of 73.33% while *Agropectin* sp. 26.67%.
7g	Seaweeds and Seagrasses	No seaweed and seagrass are reported in the DPA coastal area.
7h	Halophytes	Four species of halophytes namely *Sesuvium portulacastrum, Salvadora persica* and *Aeluropus lagopoides* and *Salicornia brachiata* were recorded inside the quadrates during monsoon 2021.
7i	Avifauna	A total of 62 species belonging to 7 orders, 21 families and 45 genera were recorded from the coastal area of DPA during this study. There were 42 aquatic and 20 terrestrial species of which 5 are listed as Near

		Threatened in the IUCN 2021, Red List. Shannon diversity (H') index 3.6 and species richness index 1.4 were recorded. The overall species evenness index value for the study area was 0.79 with Equitability 0.93.
7j	Marine Mammals	The *Sousa plumbea* reported.

(Post-Monsoon)

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 water front facilities (OJ 8 to 11- Para VIII Marine Ecology, specific condition iv.
2	Deendayal Port letter Sanctioning the Project	DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/11 date 03.05.2021
3	Duration of the Project	Three years-from 24.05.2021 to 23.05.2024
4	Period Of Survey Carried	October 2021 to January 2022 (Post-monsoon season)
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 DPA port jurisdiction
7	**Components of the report**	
7a	Mangroves	Overall average density of 3410 trees/ha of A. marina during post- monsoon 2022.the highest tree density was reported at S7 in the Kharo creek area (5524/Ha) followed by Tuna creek. The The lowest tree density at station S-5,1930/Ha (Phang creek) followed by station S-6 ,1970/Ha Jangi creek.
7b	Mudflats	The highest TOC values (0.8%) was recorded at station S-1 followed by S-2 and S-4 (0.68%). Lowest TOC values were reported at site S-14. the TOC values were higher at sampling stations S-1, S-2, and S-4 during the post-monsoon season.

7c	Zooplankton	The zooplankton identified from the 15 stations falls under 11 phyla and 42 genera belonging to the 18 groups. The phylum Arthropoda was the predominant represented with 20 genera including copepods, crabs, shrimps and their larvae. The overall percentage of the various groups of zooplankton varied from 0.28% to 39.39%. The highest percentage was due to the calanoid copepods (39.39%) followed by Decapoda (10.89%) and Harpacticoida (6.98%). The group which contributed the least was Hemichordata (0.28%) followed by *Foraminifera*, *Crustacean larva*e and *Bipinaria larvae* (0.56%) each.
7d	Phytoplankton	Total genera encountered in entire study period was 35 but among the station the generic variation of phytoplankton was varied from 11 to 29 numbers. It include Pennales, Centrales (Bacillariophyceae), Dinophyceae, Cyanophyceae, and Chlorophyceae. The percentage of contribution contributed by a Centric group (52%) followed by Pennales (36%). The Dinophyceae contributed less number contribution (8%) and Chlorophyceae and, Cyanophyceae contributed equally (2%) only in the least number of contributions during the post-monsoon season
7e	Intertidal Fauna and Reptiles	The diversity of intertidal animals in Kandla port area includes twenty-one species, representing Mollusca,(9) , Arthropoda(6), Annelida(3), one each of Nematoda, Nemertea and Chordata. The dominant mollusk species are *Pirenella cingulata, Optediceros breviculum* and *Bakawan rotundata.*
7f	Sub-tidal Macrobenthos	The subtidal benthic animals in Kandla port was composed of twenty-two species of which Mollusca was the most dominant (13) followed by Annelida (6), Arthropoda(2) and Cnidaria.(1). The species *Pirenella cingulata* and *Optediceros breviculum* are the most common molluscs.
7g	Seaweeds and Seagrasses	No seaweed and seagrass are reported in the DPA port and it periphery environment expect some drifted species *Enteromorpha*,*Chaetomprpha* in station S-13 and S-14 of Veera coast.
7h	Halophytes	Four species of halophytes namely *Sesuvium portulacastrum, Salvadora persica* and *Aeluropus lagopoides* and *Salicornia brachiata* were recorded inside the quadrates during Post-monsoon 2021. Among the halophyte species recorded, *Salicornia brachiata* was found to be distributed at almost all the sampling sites. (Table-13 and Plate-8). The percentage of Salicornia

		brachiate was found to be highest at station S-14 (62%) followed by station S-11 (60%).
7i	Avifauna	A total of 84 species belonging to 9 orders, 34 families and 62 genera were recorded from the coastal area of Deendayal Port during this study (Table-14). Among these, 52 species were aquatic and 32 species were terrestrial, which included 7 species listed as Near Threatened in the IUCN 2022, Red List. Order Charadriiformes i.e. aquatic birds (including raptors and most water birds) constituted the predominant groups representing 35% of all species recorded from the study area followed by order Passeriformes (24%), Pelecaniformes (19%) and other six orders formed 22% of the recorded spies.

(Pre-Monsoon)

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 water front facilities (OJ 8 to 11- Para VIII Marine Ecology, specific condition iv.
2	Deendayal Port letter Sanctioning the Project	DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/11 date 03.05.2021
3	Duration of the Project	Three years-from 24.05.2021 to 23.05.2024
4	Period Of Survey Carried	February 2022 to May 2022 (Pre-monsoon season)
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 Deendayal port Authority jurisdiction
7	**Components of the report**	
7a	Mangroves	Overall average density of 4483 trees/ha of *A. marina* during Pre- Monsoon 2022.The highest tree density was reported at S-8&S-9 in the Navlakhi creek (5619/Ha) followed by Kandla creek (5018/Ha). The lowest tree

		density at S-11,3582/Ha Jangi creek station followed by S-5, 3188 trees/Ha (Phang creek) .
7b	Mudflats	The highest TOC values (0.70%) were recorded at station S-1 followed by S-6 and S-4 (0.64&0.63%). The lowest TOC values were reported at site S-12 (0.45%)
7c	Zooplankton	The zooplankton identified from the 15 stations falls under 7 phyla and 35 genera belonging to the 12 groups. The phylum Arthropoda was the predominant represented with 22 genera including copepods, crabs, shrimps and their larvae. The overall percentage of the various groups of zooplankton varied from 0.67% to 39.84%. The highest percentage was due to the calanoid copepods (39.84%) followed by Decapoda (20.01%) and Foraminifera (7.28%). The group which contributed the least was Cyclopoida & Nematoda (0.67%) followed by *Malacostraca* (2.37%) each.
7d	Phytoplankton	Total genera encountered in entire study period was 23 but among the station the generic variation of phytoplankton was varied from 17 to 23 numbers. It include Pennales, Centrales, Dinophyceae, Cyanophyceae . The percentage of contribution contributed by a Pennales group (46.5%) followed by centrales (46.1%). Dinophyceae contributed (4.7%) whereas the Cyanophyceae contributed the least number of contribution (2.7%) during Pre-Monsoon.
7e	Intertidal Fauna	The diversity of intertidal animals in Deendayal port Authority area includes Sixteen species, representing Mollusca,(8) , Arthropoda(5), Annelida(1), Nemertea (1) and Chordata (1). The dominant mollusc species are, *Optediceros breviculum* and *Pirenella cingulate*.
7f	Sub-tidal Macrobenthos	The subtidal benthic animals in Deendayal port Authority composed of twenty-two species of which Mollusca was recorded in which the most dominant Mollusca (13*sp*) followed by Annelida (6 *sp*), Arthropoda(2) and Cnidaria.(1). The species *Optediceros breviculum* and *Glauconome angulata* are the most common molluscs in study area.
7g	Seaweeds, Seagrass and Reptiles	No seaweed and seagrass are reported in the Deendayal Port Authority and it periphery environment expect some drifted species *Enteromorpha*,*Chaetomprpha* in station S-13 and S-14 of Veera coast. Among reptiles saw-scaled viper *Echis carinatus sochureki* was recorded at site S-10 Sat Saida bet
7h	Halophytes	Four species of halophytes namely *Sesuvium portulacastrum, Salvadora persica* and *Aeluropus lagopoides* and *Salicornia brachiata* were recorded inside

		the quadrates during Pre-Monsoon 2022. Among the halophyte species recorded, *Salicornia brachiate*& *Sesuvium portulacastrum* was found to be distributed equally in 5 study station. The percentage of Salicornia brachiate was found to be highest at station S-5 (81%) followed by station S-8 (60%).
7i	Avifauna	A total of 52 species belonging to six orders, 25 families and 41 genera were recorded from the coastal area of Deendayal Port during the present study (Annexure-1) Among these, 29 species were aquatic and 23 species were terrestrial, which included four species listed as Near Threatened in the IUCN 2022, Red List. Order Charadriiformes i.e. aquatic birds (including raptors and most water birds) constituted the predominant groups representing 58% of all species recorded from the study area followed by order Passeriformes (31%), i.e., perching birds (including babblers, drongos, mynas, sunbirds, doves, warblers, larks, chats, wagtails, robins).

Comparison Study of Marine Biodiversity of Deendayal Port Authority (DPA) Since 2017-2022

Habitat/ Groups	Major Taxa/Genera/Species	Year 2017-18		Year 2018-19		Year 2019-2020		Year 2020-2021		Year May 2021- May 2022		
										Pre monsoon	Monsoon	Post Monsoon
Mangroves	*Avicennia marina*, *Ceriops tagal*, *Rhizophora mucronata, Aegiceras corniculatum*	4	4	4	4	4	4	4	4	4	4	4
Intertidal habitat	Gastropods, Bivalves, Crustaceans Polychaetes, fishes, amphipods and Isopods	22	23	20	24	19	10	10	12	16	21	16
Subtidal habitat	Polychaetes, molluscs, crustaceans, echinoderms	27	29	24	31	26	28	30	48	11	22	22
Phytoplankton	*Bacillaria, Navicula, Nitzschia, Chaetoceros, Coscinodiscus, Triceratium, Bidulphia, Melosira, Thassiosira*	9	18	20	24	32	26	23	19	23	35	23
Zooplankton	Copepods, Harpacticoids, Cyclopoids. brachyurans, cirripedes, Bivalve veligers	14	19	23	27	33	36	29	27	42	42	35
Seaweeds	Nil (Drifted tufts only)	Nil	Nil	Nil	Nil	Nil	Nil	drifted	drifted	drifted	drifted	drifted

Sea grasses	Nil (Drifted tufts only)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Halophytes (within quadrate)	*Sesuvium portulacastrum, Salvadora persica, Aeluropus lagopoides, Salicornia brachiata, Suaeda nudiflora* and *Trianthema portulacastrum*	4	9	7	7	3	4	4	4	4	4	4
Avifauna	Charadriiformes, Phoenicopteriformes, Pelecaniformes, Passeriformes	52	91	52	74	49	89	49	69	62	84	52
Fishes	*Mugil cephalus, Harpodon nehereus, Pampus argenteus, Hilsa, Engraulis, Coilia* sp. *Peneaus, Portunus*	11	15	11	11	10	8	5	4	7	5	7
Marine Mammals	Dolphin, *Sousa plumbea*	Nil	1	1	1	1	1	Nil	Nil	1	Nil	Nil
Reptiles in the mangroves	The saw-scaled viper, *Echis carinatus sochureki*	1	1	1	0	1	1	Nil	1	Nil	Nil	1

1. Introduction

Deendayal Port is located at Kandla in the Kachchh district of Gujarat state, operated by Deendayal Port Authority (DPA) 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 includes edible oil, crude oil and other petroleum products. Cargo handling has increased from 117.5 MMT to127 MMT during 2021-2022. Presently, the Port has total 1-16 dry cargo berths for handling dry cargo, 6 oil jetties, and one barge jetty at Bunder basin, dry bulk terminal at Tuna Tekra, barge jetty at Tuna and two SPMs at Vadinar for handling oil. Regular expansion or developmental activities such as the addition of jetties, allied SIPC and ship bunkering facilities are underway in order to cope with the increasing 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 – specific condition no. xxiii.

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

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

As per the environmental clearance requirements to these developmental initiatives, by MoEF & CC, among other conditions, has specified to conduct the continuous monitoring of the coastal environment on various aspects covering 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. 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 the Work

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

- Physico-chemical characteristics of water and sediment
- Detailed assessment of mangrove vegetation structure including density, diversity, height, canopy, and other vegetation characteristics.
- GIS and RS studies to assess different ecological sensitive land use and land cover categories within the Port area such as the extent of dense and sparse mangroves, mudflats, creek systems, and other land cover categories within the port limits.

- Quantitative and qualitative assessment of the intertidal fauna, composition, distribution, diversity, density, and other characteristics.
- Data collection on the species composition, distribution, diversity and density of sub-tidal benthic fauna.
- Estimation of primary productivity at the selected sampling sites located in around the DPA area.
- Investigation of the species composition, distribution, density, and diversity of phytoplankton and zooplankton.
- Recording the occurrence and diversity distribution of halophytes, seagrasses, seaweeds and other coastal flora.
- Investigations on the Avifaunal density, diversity, composition, habitat, threatened and endangered species and characters.
- Fishery Resources – Species composition, diversity, Catch Per Unit Effort (CPUE) and other socio-economic information.

1.3. Study area

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

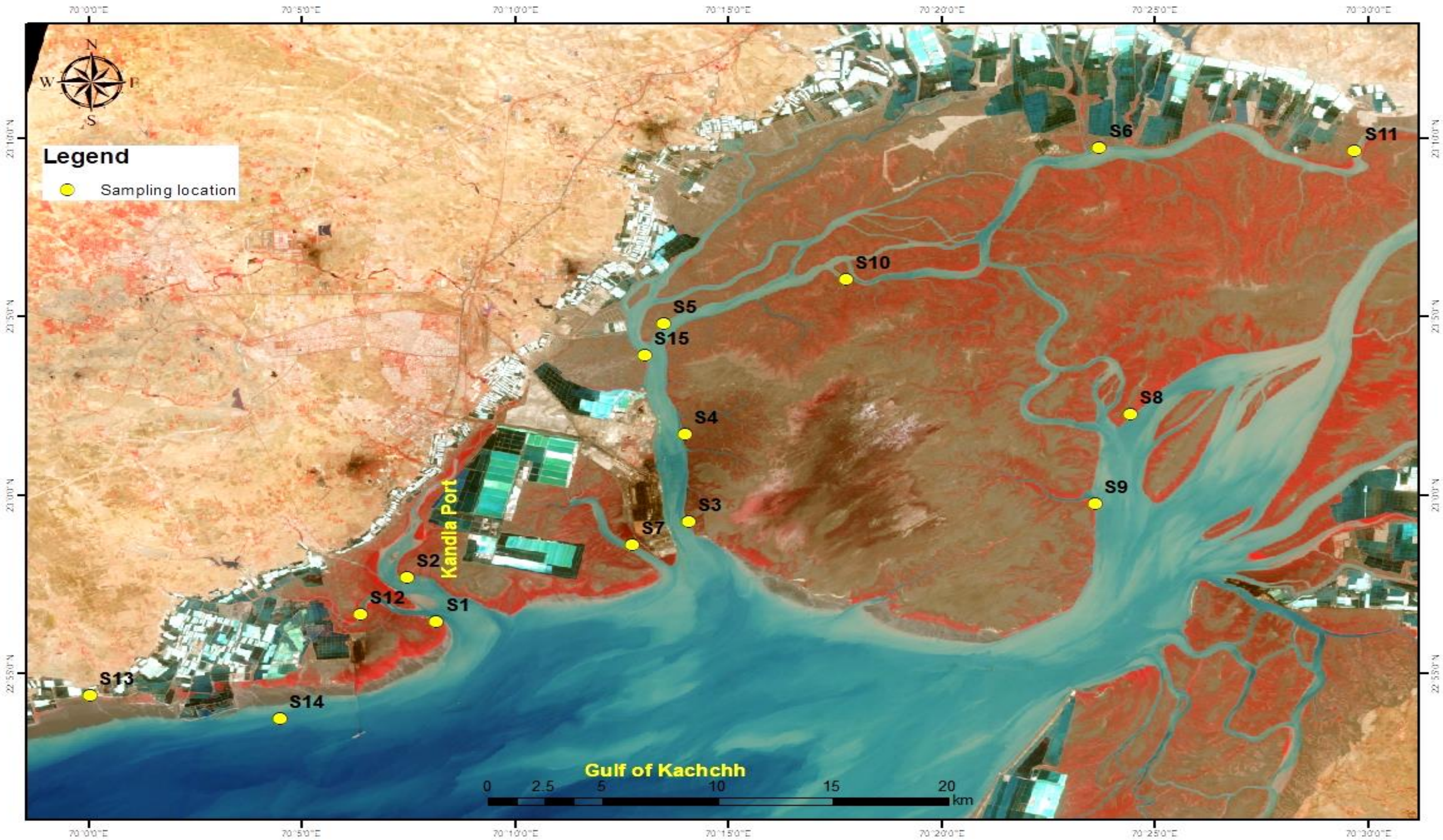


Figure 1. Map showing the proposed sampling locations 2021-2024

2. Land use and Land Cover Changes

In order to understand the spatial and temporal changes in the vicinity of the Deendayal port jurisdiction area, Remote Sensing and GIS technique have been employed. Land cover classification was carried out using digital satellite imageries. Images for the Deendayal Port area acquired for the period of April 2017, December 2019 and March 2020, November 2020, April 2021 and March 2022 were used for the study. These were brought to UTM projection with spheroid and datum named WGS 84 in UTM zone 42 north. The details of the satellite imagery used are given below.

Table 1. Satellite imagery used for Land use and Land Cover Map

Image use	Satellite name	Sensor	Spatial Resolution	Date acquired
2017	IRS-R2A	LISS IV	5.8m	26 April- 2017
2019	IRS-R2A	LISS IV	5.8m	24-DEC-2019
2020	IRS-R2A	LISS IV	5.8m	29-March-2020
2020	IRS-R2	LISS IV	5.8m	17-Nov-2020
2021	IRS-R2	LISS IV	5.8m	10-APR-2021
2022	IRS-R2	LISS IV	5.8m	12-March-2022

2.1. Methodology

Training samples were collected from these imageries. Selecting training samples from these cloud-free mosaics was straightforward due to the very distinctive signature of the mangrove area. High contrast with open water, saltpan and mudflat helped in selecting the training data successfully. Same training samples with slight modifications in each imageries mosaic (addition and removal of a few training samples) were used for the classification of all different date images. Six major classes, *viz*., mangrove, water, mudflat, other vegetation, salt pan and port were delineated. For the tonal variation and pixel values in the imageries, a supervised Maximum Likelihood Classification (MLC) and NDVI (Normalised Differential Vegetative Index) methods were used for the classification.

ERDAS Imagine 9.3 was used for satellite image processing, classification and data transformation, whereas ARC GIS 10.3 was used for the map formation. For graphs and databases processing, MS WORD and MS EXCEL were used. Ground truth study comprises data collection of ground features along with the respective geographical positions in terms of latitudes and longitudes with Garmin e-Trex Vista GPS. Thus, the data were interpreted using all the collected information.

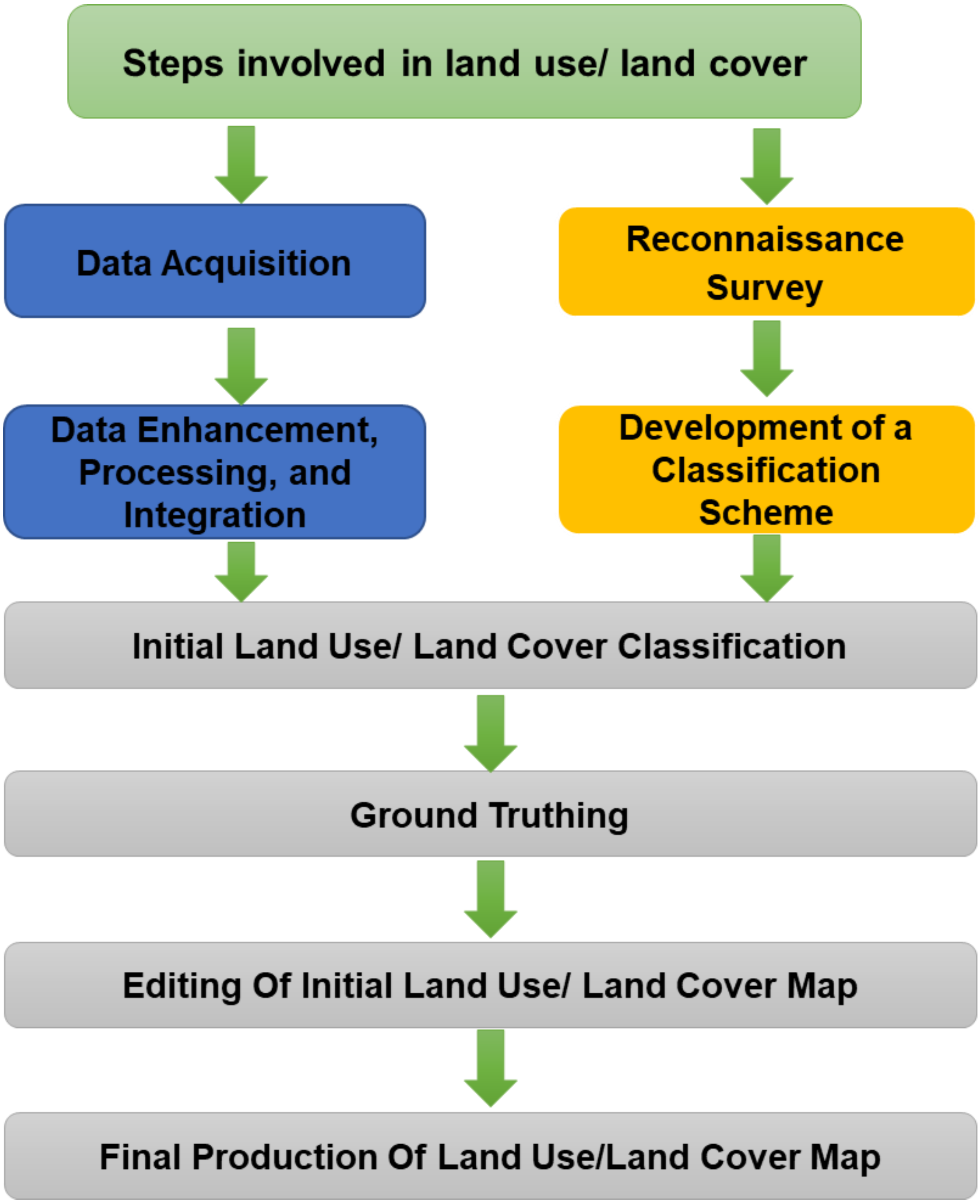


Figure 2. Methodology for land use Land cover

2.1.1. Land use /land cover

Classified imageries are presented in Fig 3 to Fig 4 and detailed presented in table 2 and 3.

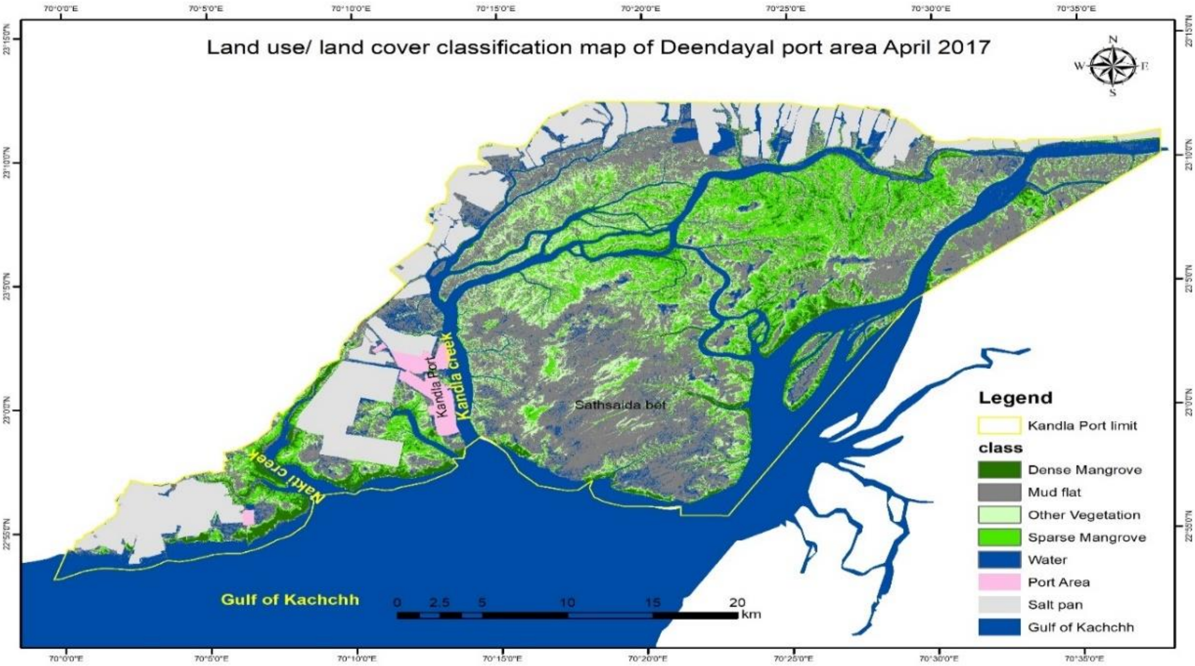


Figure 3. Land use/ Land cover classification in DPA area- April-2017

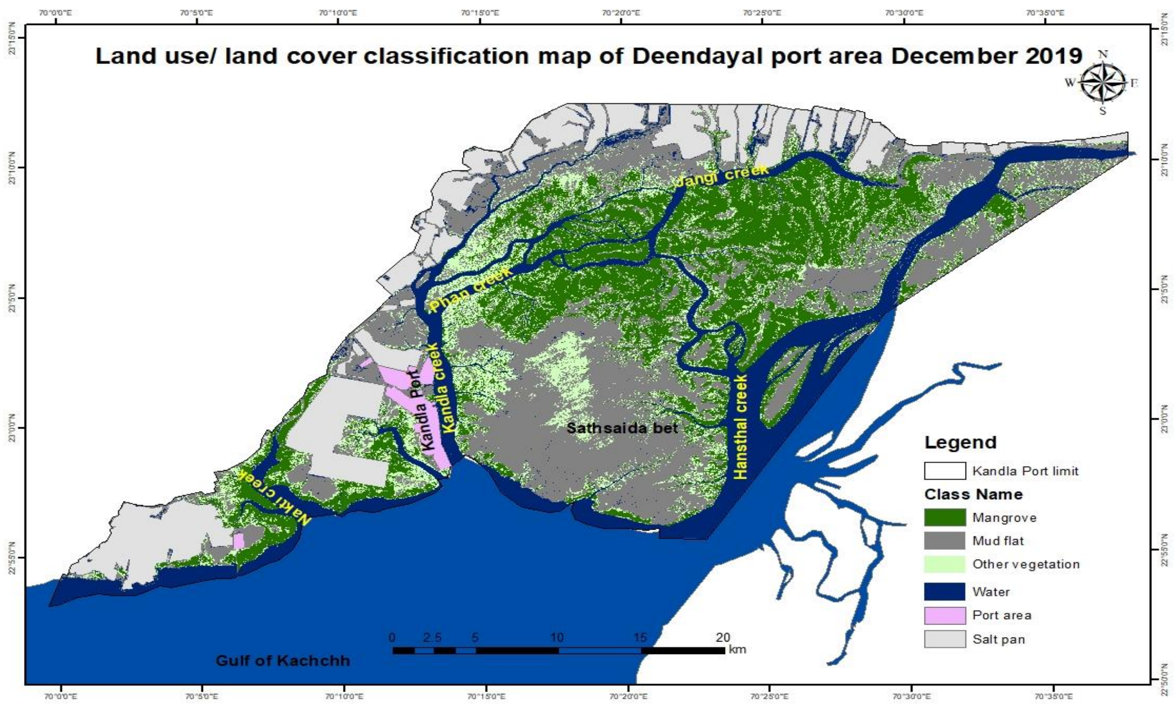


Figure 4. Land use/ land cover classification in DPA area December-2019

Table 2. Land use /Land cover statistics in the DPA area - April-2017

Class Name	Area (ha)	Percentage
Mangrove (Dense + Sparse)	19319.71	19.32
Mudflat	31293.43	31.3
Other veg	12438.8	12.44
Port Area	1243.67	1.24
Salt pan	15016.1	15.02
Water	20674.3	20.68
Total	**99986.01**	**100**

Table 3. Land use /Land cover statistics in the DPA area - December-2019

Class Name	Area (ha)	Percentage
Mangrove	23060.04	23.06
Mudflat	31179.87	31.18
Other vegetation	12333.21	12.33
Water	16953.68	16.96
Port area	1346.21	1.35
Salt pan	15113	15.12
Total	**99986.01**	**100**

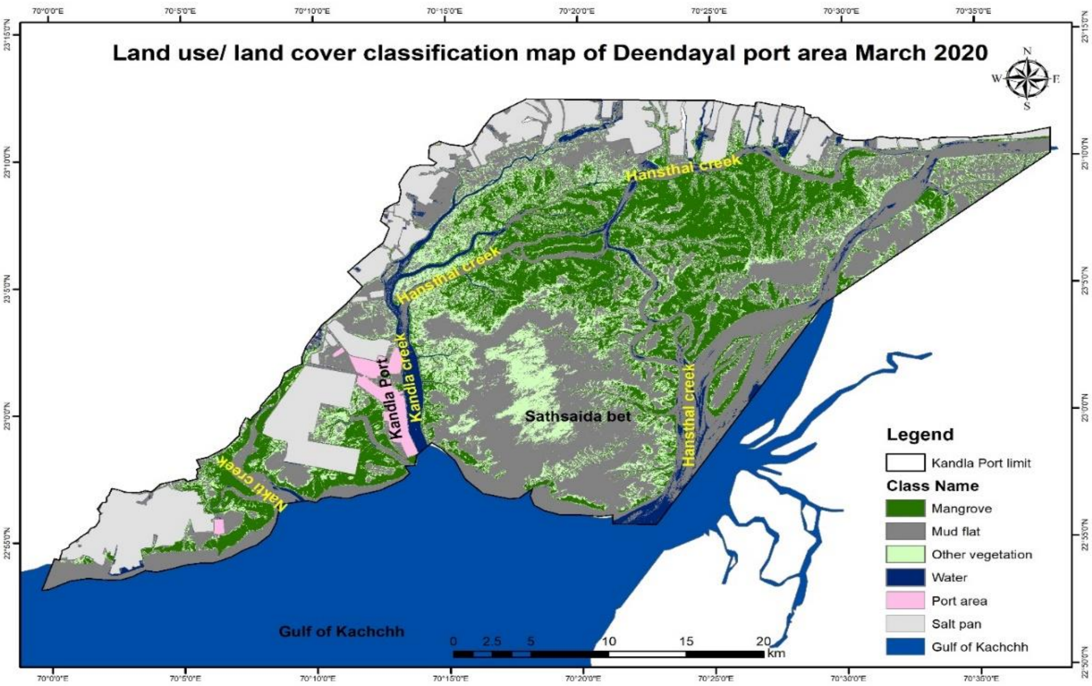


Figure 5. Land use/ land cover classification in DPA area March-2020

Table 4. Land use /land cover statistics in the DPA area- March-2020

Class name	Area (ha)	Percentage
Mangrove	23168.4	23.17
Mudflat	40714.6	40.72
Other vegetation	15991.69	15.99
Port area	1346.21	1.35
Salt pan	15054.5	15.06
Water	3710.61	3.71
Total	**99986.01**	**100**

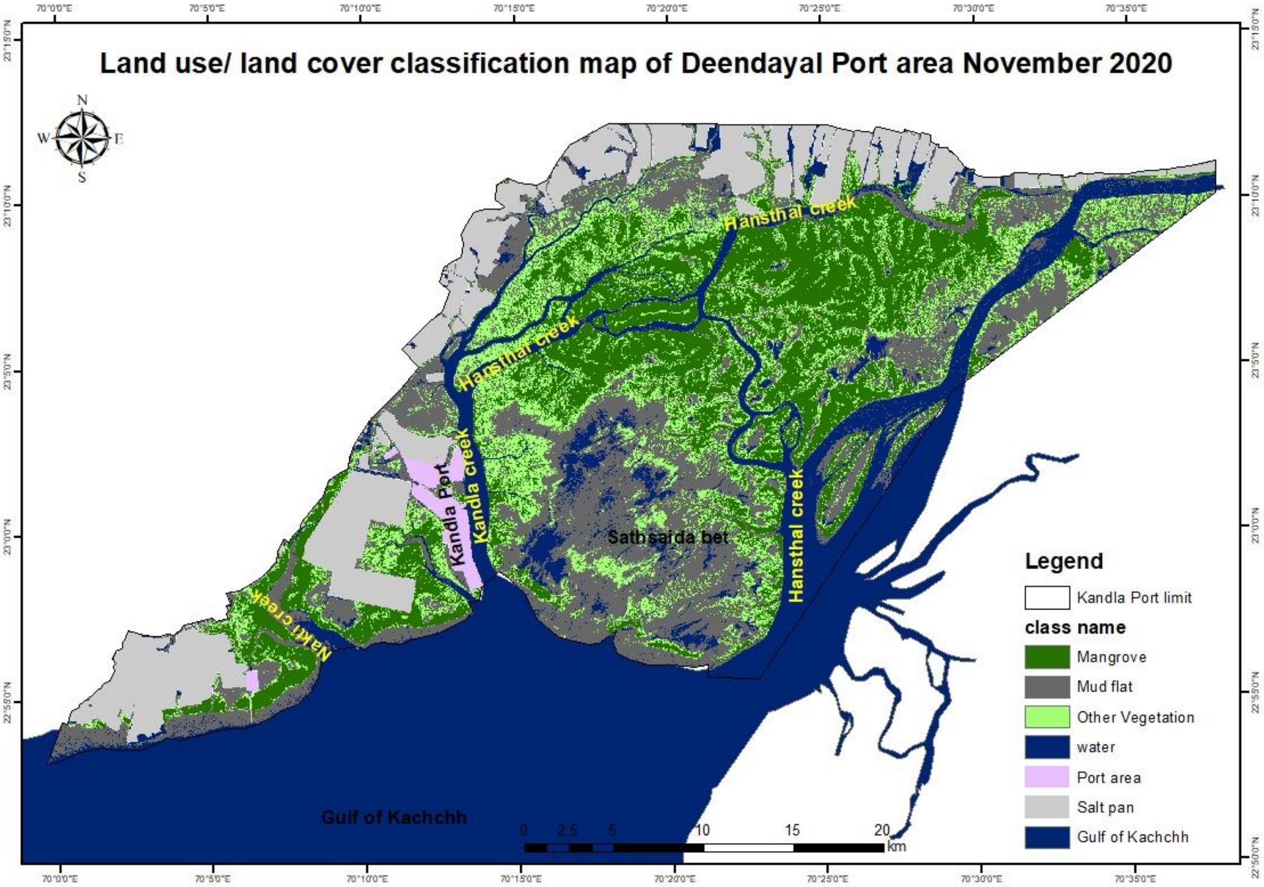


Figure 6. Land use/ land cover classification in Deendayal port area November 2020

Table 5. Land use /land cover statistics in the DPA area- November2020

Class	Area (ha)	Percentage
Mangrove	23856.8	23.86
Mudflat	28764.6	28.77
Other Vegetation	16346.1	16.35
Port area	1346.21	1.35
Salt pan	15193.5	15.2
water	14478.8	14.48
Total	99986.01	100

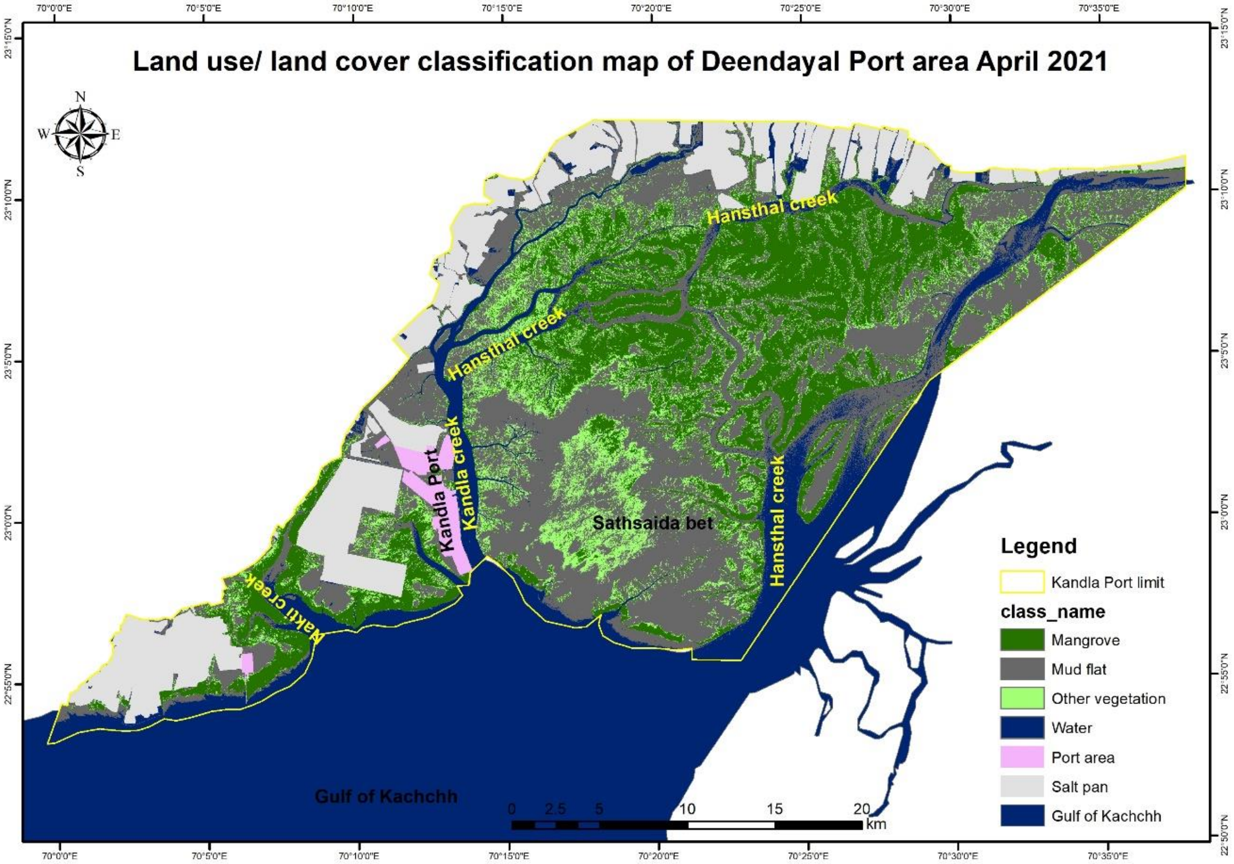


Figure 7. Land use/ land cover classification in Deendayal port area April-2021

Table 6. Land use /land cover statistics in the DPA area April-2021

class name	Area (ha)	Percentage
Mangrove	23967.4	23.97
Mudflat	36909.3	36.91
Other vegetation	11230.4	11.23
Port area	1346.21	1.35
Salt pan	15236.6	15.24
Water	11296.1	11.3
total	**99986.01**	**100**

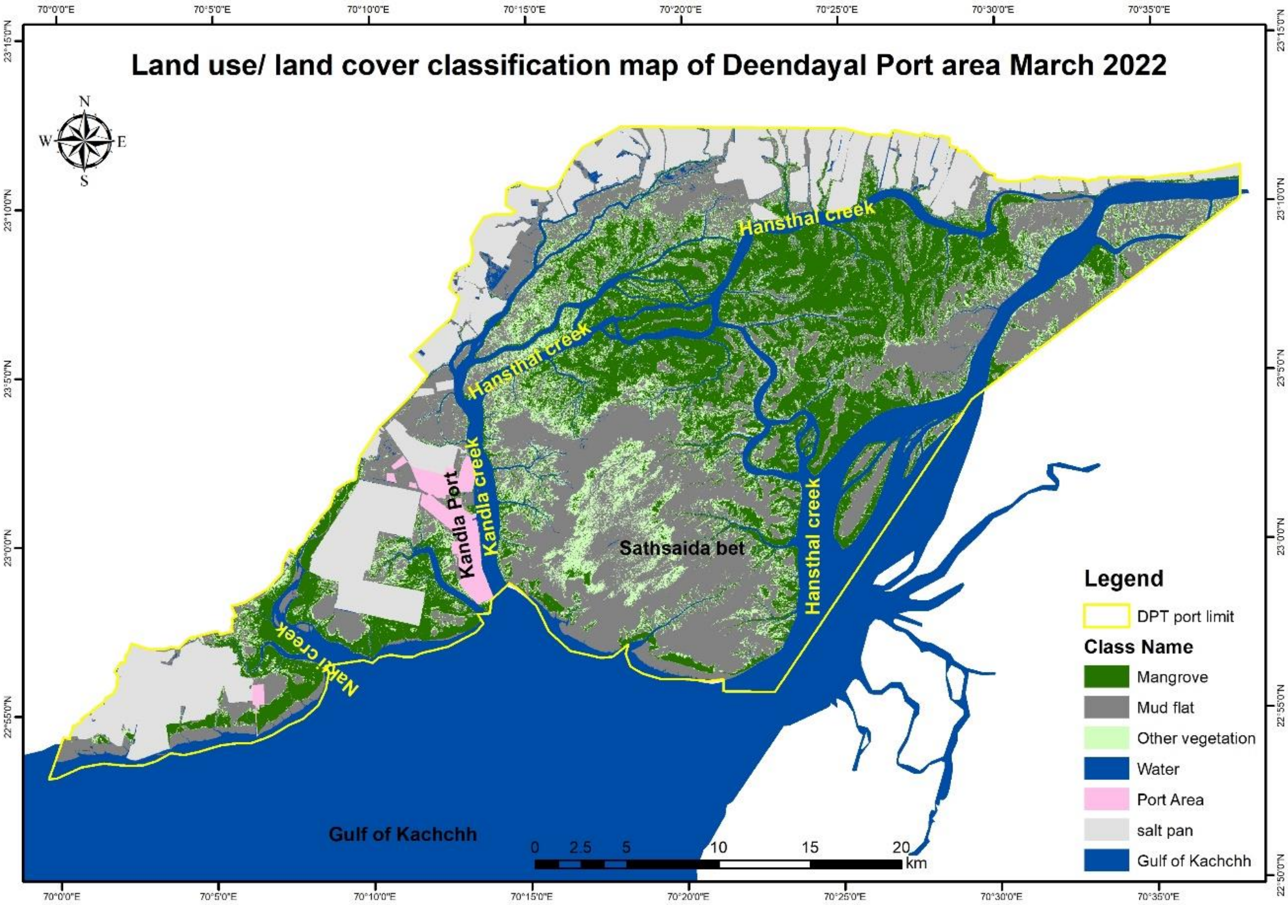


Figure 8.Land use/ land cover classification in Deendayal port area March-2022

Table 7. Land use /land cover statistics in the DPA area March-2022

class name	Area (ha)	Percentage
Mangrove	24328.7	24.33
Mudflat	31089.06	31.09
Other vegetation	11561.2	11.56
Port Area	1436.75	1.44
salt pan	15545.7	15.55
Water	16024.6	16.03
Total	**99986.01**	**100**

2.2.2. Comparative analysis of Land use and Land cover study

From April 2017 to March 2022 the overall mangrove area increased from 19319 ha to 24328 ha, i.e. 5 % of the total area of DPA. Mangrove area is replacing on the mudflat, hence there is a decreasing trend of the mudflat is clearly seen. Since this area comes under the influence of the tidal time mudflat area comes high value in that case water area decrease. But overall trends show mudflat is replaced by mangroves. (Fig3 .7). Good monsoon and favorable environment have positively impacted the mangroves to flourish. The below graph shows clearly, year on year mangrove area in DPA vicinity is increasing, currently, around 24% of the total area of DPA is covered by mangroves.

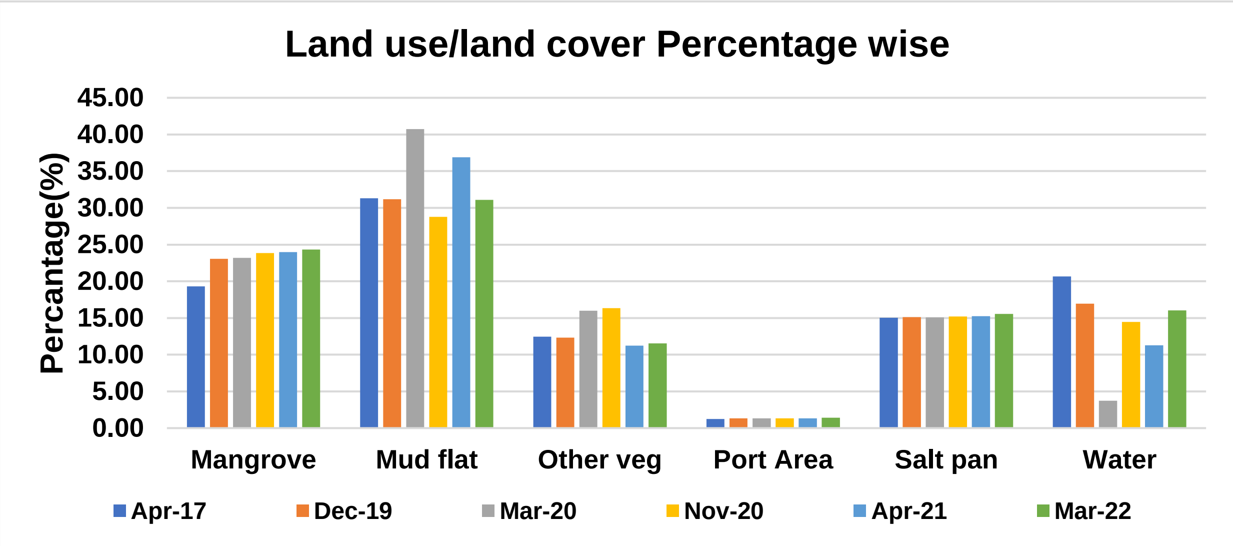


Figure 9. LU/LC Percentage area for the period 2017 to 2022 in Deendayal Port Authority

Table 8. Land use /land cover Percentage wise in the vicinity of DPA area for the study period 2017-2022

Month-Year	**17-Apr**	**19-Dec**	**20-Mar**	**20-Nov**	**21-Apr**	**22-Mar**
Class Name	Area (ha)					
Mangrove	19.32	23.06	23.17	23.86	23.97	24.33
Mudflat	31.3	31.18	40.72	28.77	36.91	31.09
Other veg	12.44	12.33	15.99	16.35	11.23	11.56
Port Area	1.24	1.35	1.35	1.35	1.35	1.44
Salt pan	15.02	15.12	15.06	15.2	15.24	15.55
Water	20.68	16.96	3.71	14.48	11.3	16.03
Total	100	100	100	100	100	100

3. Methodology

3.1. Physico-chemical characteristics of water and sediment

A port is a location on a coast or shore containing one or more harbors where ships can dock and transfer people or cargo to or from land. Port locations are selected to optimize access to land and navigable water, for commercial demand, and for shelter from wind and waves. Harbors can be natural or artificial. An artificial harbor has deliberately constructed breakwaters, sea walls, or jetties, or otherwise, they could have been constructed by dredging, and these require maintenance by further periodic dredging.Ports are economic instruments for trade and a vital component in the nation’s economy. Nevertheless, port activities such as land reclamation, dredging and large-scale construction and its continuous expansion negatively affect the marine ecosystems in its vicinity.

In a port environment, activities like dredging, continuous movement of vessels and humans create major impacts at the marine/coastal environment and the living resources. This will have several impacts on the coastal environmental health which can be reflected by the nature of the physico-chemical characteristics of water which in turn indicates in its productivity. The change in productivity pattern of the marine environment is highly influenced by the flow of nutrients which generally originates from natural and anthropogenic sources. This change in quality of marine water, impacts the composition and availability of aquatic organisms directly and also affects the natural process in the marine ecosystem biological component, coral reefs and seagrass habitats etc. Similar to water, marine sediments also receive pollutants / such as heavy metals, petroleum hydrocarbons, polyaromatic hydrocarbons, polychlorinated biphenyls etc as contaminants from various activities, both off shore and on shore near ports and harbours. Hence assessing the water and sediment characteristics is imperative to understand the environmental changes and to suggest scientific interventions to restore the ecosystem integrity.

3.1.1. Sampling Parameters & Water sample collection

Sampling was carried out for the coastal water (surface) and sediment for the determination of physical and chemical characteristics from the prefixed sampling sites. The biological parameters (benthic and pelagic fauna, flora and productivity) were also estimated (Table 9).

Table-9. Physico-chemical and biological parameters analysed

Parameters		
Water	**Mangrove & Other Flora**	**Intertidal fauna**
▪ pH ▪ Temperature ▪ Salinity (ppt) ▪ Petroleum Hydrocarbon-PHC ▪ Dissolved oxygen ▪ Total Suspended Solids (TSS) ▪ Total Dissolved solids (TDS) ▪ Petroleum Hydrocarbons (PHs) **Nutrients** ➢ Nitrate (NO_3) ➢ Nitrite (NO_2) ➢ Total Nitrogen **Sediment** ✓ Texture ✓ 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)	**Mangrove** Vegetation structure density, diversity, height, canopy cover Other vegetation characteristics. **Halophytes:** Occurrence, Distribution, and diversity **Seagrass and Seaweed** Occurrence Distribution and diversity.	**Intertidal fauna:** composition, distribution, diversity, density and other characteristics. **Avifauna:** Density, diversity, composition, habitat, threatened and endangered species and characters

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

3.1.2. 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.

3.1.3. 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).

3.1.4. 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.

3.1.5. 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.

3.1.6. Turbidity

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

3.1.7. Dissolved Oxygen (DO))

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

3.1.8. 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.

3.1.9. 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).

3.1.10. Total phosphorus

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

3.1.11. Nitrite

Nitrite in 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).

3.1.12 . Nitrate

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

3.2. Sediment characteristic

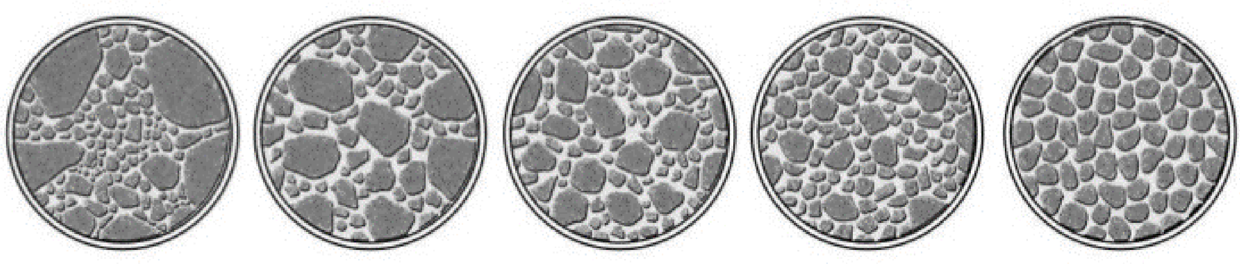
Sediment samples were collected from the prefixed stations by using a Van Veen grab having a mouth area of $0.04m^2$ or by a non-metallic plastic spatula. Sediment analysis was carried out using standard methodologies. In each location (grid), sediment samples were collected from three different locations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

3.2.1. Sediment Texture

For texture analysis, specified unit of sediment sample was sieved through sieves of different mesh size as per Unified Soil Classification System (USCS). Cumulative weight retained in each sieve will be 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 100%.

3.2.2. 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).



3.3. Biological Characteristics of water and Sediment

3.1.1. Primary productivity

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

3.3.2. Phytoplankton

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

3.3.3. Zooplankton

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

3.3.4. Intertidal Fauna

Intertidal faunal assemblages were studied for their density, abundance and frequency of occurrence during monsoon 2021 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; Apte, 2012;2014). Average data at each site were used to calculate the mean density (No/m^2).

3.3.5. Subtidal Macro Benthic Fauna

The sampling methods and procedures were designed in such a way to obtain specimens in the best possible condition, as to maximize the usefulness of the data obtained. For studying the benthic organisms, triplicate samples were collected at each station using Van Veen grab which covered an area of 0.04m2. The wet sediment was passed through a sieve of mesh size 0.5 mm for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with

Rose Bengal dye for the ease of spotting at the time of sorting. The number of organisms in each grab sample was expressed as No. /m2. All the species were sorted, enumerated and identified by following available literature. The works of Fauvel (1953) and Day (1967) were referred for polychaetes; Barnes (1980) and Lyla et al. (1999) for crustaceans; Subba Rao et al. (1991) and Ramakrishna (2003) for molluscs. Further, the data were processed for univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clark and Warwick, 2001).

Plate 1: Estimation of intertidal fauna by the quadrate method

Plate 2: Collection of Plankton and macrobenthos in subtidal habitat

3.4. Mudflats

Mudflats are ecologically and socio-economically vital ecosystems that bring benefits to human populations around the globe. These soft-sediment intertidal habitats, with >10% silt and clay (Dyer 1979), sustain global fisheries through the establishment of food and habitat (including important nursery habitats), support resident and migratory populations of birds, provide coastal defenses, and have aesthetic value. Mudflats are intimately linked by physical processes and dependent on coastal habitats, and they commonly appear in the natural sequence of habitats between subtidal channels and vegetated salt marshes. In some coastal areas, they may be several kilometers 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 prevailing physical conditions of the region. Intertidal mudflats can be separated into three distinct zones such as the lower tidal mudflats, middle mudflats 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 terriginous, marine, atmospheric and anthropogenic sources and are mainly associated with fine grained particles (Wang et.al., 2006)

3.4.1. 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) area and made into composite sample for analysis. The samples were packed in zip lock bags, stored in icebox and shifted to the laboratory for subsequent analysis.

Plate 3: Sediment sample collection at mangrove and mudflat areas

3.4.2. 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 H_2SO_4) by utilizing the heat evolved with the addition of H_2SO_4. 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 is required for blank titration. T = volume of Ferrous ammonium sulfate needed for soil sample. Wt. =weight of soil (g).

3.4.3. 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 soils. 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).

3.5. Mangrove assessment

Mangroves are widely distributed on the Deendayal Port Authority jurisdiction along the Kandla coast. The 15 mangrove sites selected at the different creeks belong to Deendayal Port Authority jurisdiction and all these stations are supposed to be sufficient to represent the mangroves status in Kandla. The mangrove stations in this study were named Tuna, Jangi, Kandla, Phan and Navlakhi which are based on the nearest location to their respective creek system. The Point Centered Quadrate Method (PCQM) was used for the collection of data of mangrove vegetation structure. The data included measurements of density of plants, height variations, canopy and basal area of mangrove trees as per method (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 orientation of the transect line was already fixed, it was easy for movement within the station area for data recording. The distance between trees from the centre of the sampling point for nearest 4 trees of four different directions, height of trees from the ground level , canopy length and conopy width were measured to determine the canopy cover were measured in this study. The equipments utilized in these field were handy and easy to use such as ranging rods, pipes and for measurement of girth at root collar above the ground (GRC) measurement tape was used. The plants with a height <50 cm were considered as regeneration class and >50 cm but <100 cm were 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.

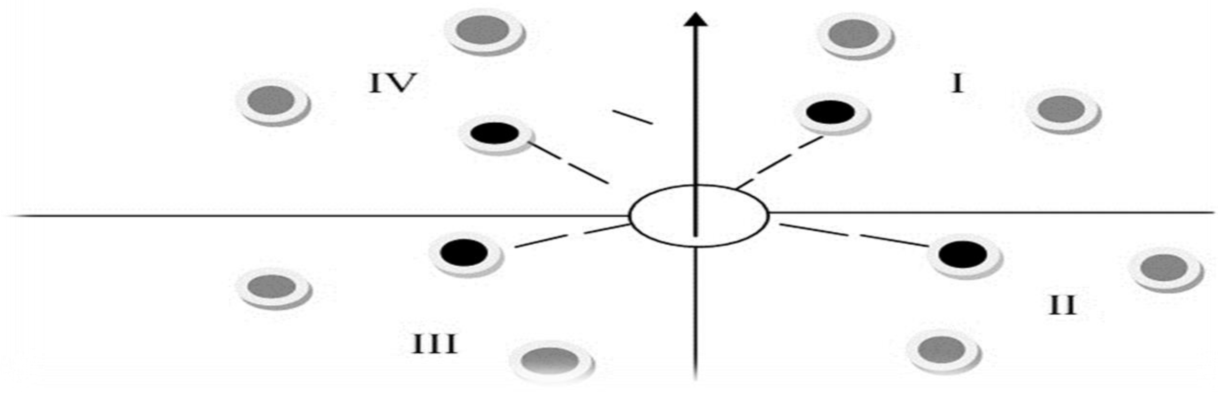


Plate 4: Assessment of mangrove density, height, canopy cover & girth

3.6. Halophytes

To quantify and document the halophytes at Deendayal Port Authority region, quadrate method was followed. At each sampling location quadrates of various sizes have been laid during every seasonal sampling. For recording plant density at each transect, quadrate 1 x 1m have been laid within each tree quadrates were used randomly (Misra,1968; Bonham 1989). Four quadrates each for shrubs and herbs were laid in side each tree quadrate to assess the halophytes and its 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 species were identified using standard keys. Specimens of the species were collected to know more information on habitat and for the preparation of herbarium.

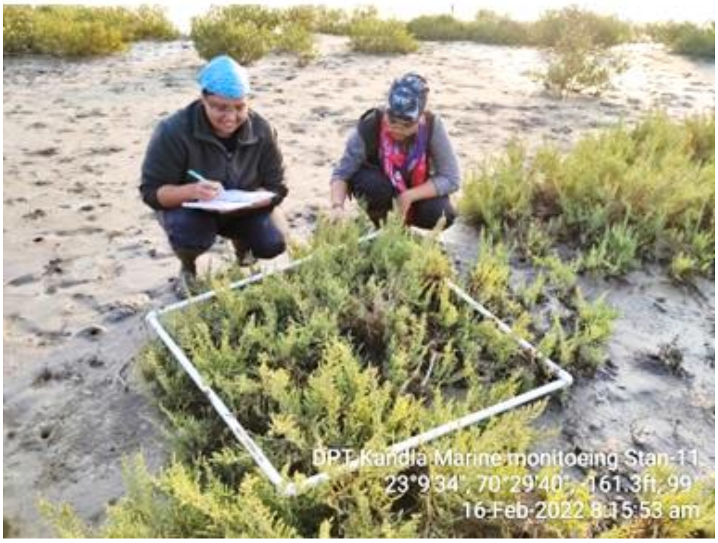


Plate 5: Assessment of halophytes cover

3.7. Marine Fishery

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

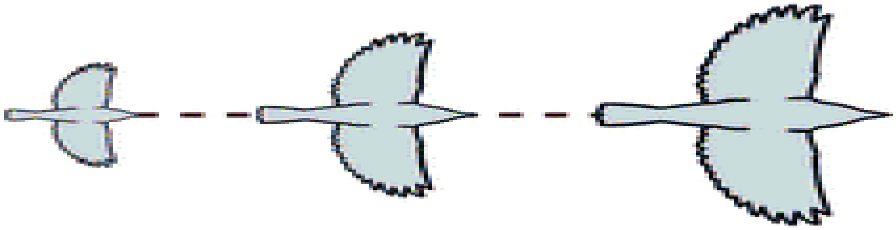
Plate 6: Collection of fisheries information from DPA environment

3.8. Avifauna

The Avifauna along DPA mangrove strands was demarcated into fifteen major stations. In each station creeks were of varying length from 2 to 5 km. These creeks were surveyed by using boat and adopting “line transect” method. A total of fifteen boats transect (one in each site) survey was conducted in the Monsoon (June-September 2021), Post-monsoon (October-January2021-2022) and pre-monsoon season (February-may 2022). Survey was done in both terrestrial habitats like Mangrove plantation adjoining the mudflats waste land, and aquatic habitats like creek area, rivers and wetland.

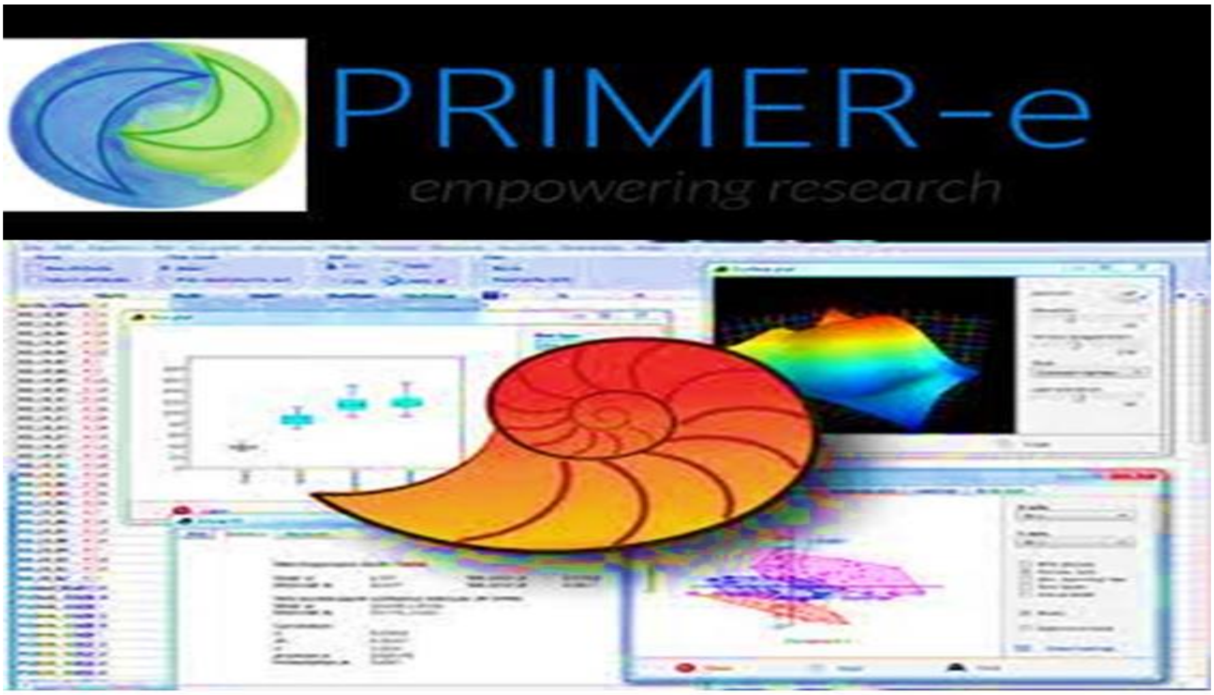
Boat Surveys

Mangrove bird diversity was calculated by using Boat Survey method. Birds were observed from an observation post aboard the boat which was 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 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 Deendayal port Authority.



3.9. Data analysis

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



4. Results

4.1. Physico-Chemical Characteristics of water and Sediment

4.1.1. 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 Table11.

Table-10. Physico-chemical characteristics of coastal waters during the years 2021-2022

Parameter		Monsoon 2021	Post Monsoon 2021	Pre Monsoon 2022	Mean±sd
Temperature	max	31.5	25.5	35	31.5±5
	min	22.9	18.1	25	22±4
pH	max	8.4	8.1	8	8.2±0.2
	min	7.7	7.8	7.2	7.6±0.3
Salinity	max	46.7	44.9	50.7	47.4±3.0
	min	40	36.4	31.9	36.1±4.1
Dissolved oxygen (mg/L)	max	5.9	7.584	7.215	6.9±0.9
	min	3.9	6.24	6.243	5.5±1.9
Total Suspended Solids (TSS) (mg/L	max	1047	223	173	481±491
	min	52	87	103	81±26
Total Dissolved solids (TDS) (mg/L)	max	48056	42086	48922	46355±3722
	min	5069	32088	39004	25387±17932
Turbidity (NTU)	max	72.4	361	186	206±145
	min	14.7	38	29	27±12
Nitrate (NO3) (mg/L)	max	0.02	0.03	0.02	0.02±0.01
	min	0.002	0.007	0.001	0.003±0.003
Nitrite (NO2) (mg/L)	max	0.77	3.53	3.53	2.61±1.59
	min	0.003	0.035	0.04	0.02±0.02
Total Phosphorus (mg/L)	max	3.60	2.27	7.61	4.49±2.78
	min	0.35	0.45	0.17	0.32±0.15
PHs (µg/L)	max	29	42	30	34±7
	min	3	15	14	11±7
Chlorophyll a (mg/L)	max	0.31	0.21	0.99	0.50±0.42
	min	0.002	0.007	0.719	0.243±0.413

Temperature (°C) and pH

The maximum water temperature of the sampling station season-wise varied from 25.5°C to 35°C, with a mean of 31.5±5 for the period May 2021 to May 2022. The minimum water temperature varied from 18.1 °C to 25°C with a mean of 22±4. The seasonal variation of water temperature of all the stations is depleted in figure-10.

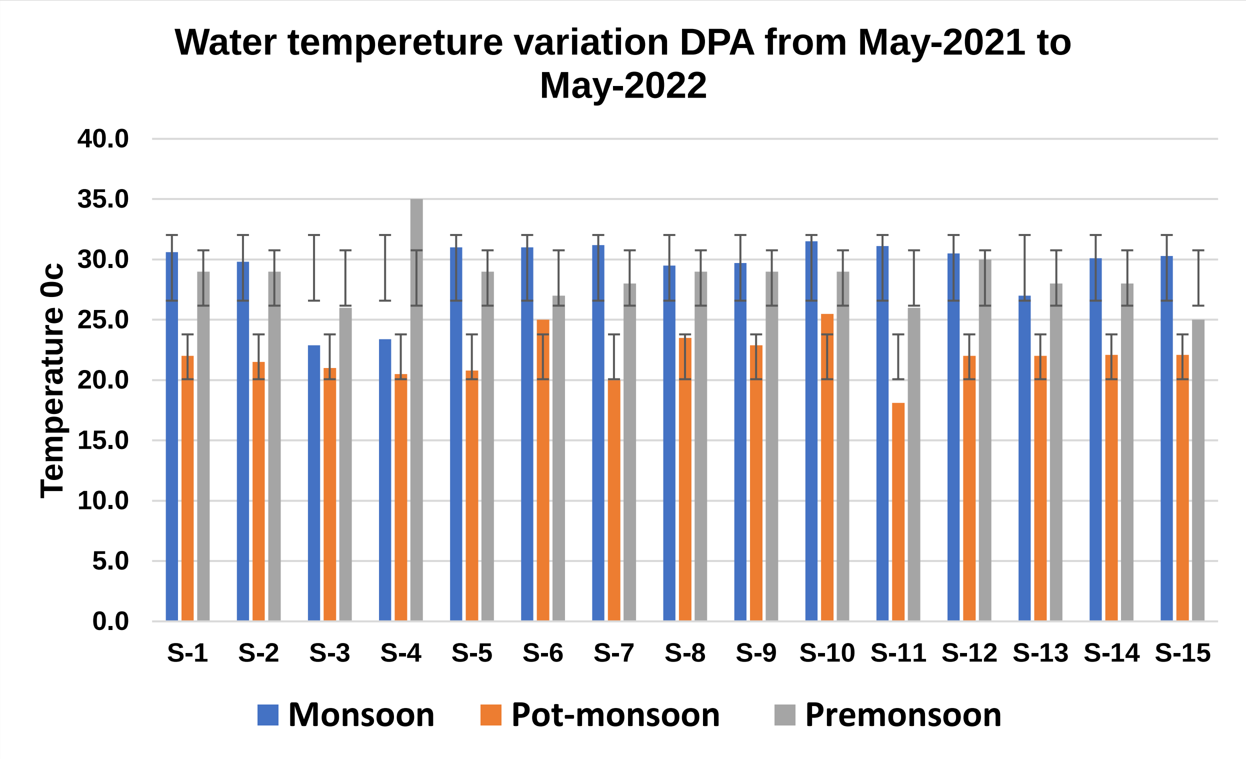


Figure 10. Temperature variation in DPA study sites 2021-2022

From figure 9, it is clearly observed that during the Monsoon highest temperature was observed at station-10 (31.5°C) and the lowest at station S-3(22.9°C). In Post-monsoon highest temperature was observed at S-12 (27°C) and the lowest temperature at S-11 (18.1°C). Similarly, during Pre-monsoon, the highest and lowest temperature were recorded at S-4 (35°C) and S-15 25°C.

pH

The maximum water pH of the sampling station season-wise varied from 8 to 8.4, with a mean of 8.2±0.2. The minimum value of pH season-wise varied from 7.2 ° to 7.7 with a mean of 7.6±0.3. The seasonal variation of the pH at the 15 stations is presented in figure-11

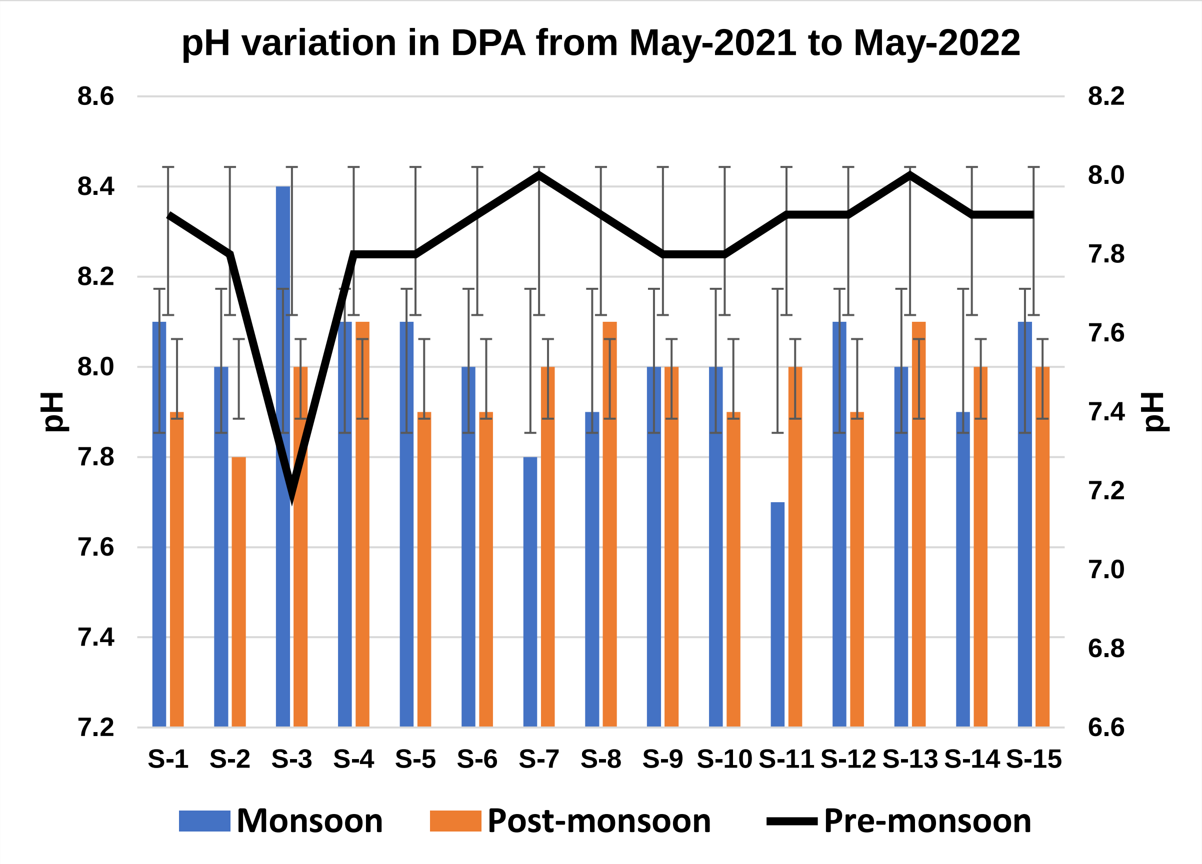


Figure 11. pH variation May 2021 to May 2022 in Deendayal Port Authority

During Monsoon highest pH was observed at S-3 (8.4) and Lowest pH was observed at S-11 (22.9°C). In Post-monsoon highest pH was value was observed at S-8 (8.1) and the the lowest pH was observed at S-2 (7.8). Similarly in Pre-monsoon the highest and lowest pH values were observed at station S-7 (8) and S-3 was 7.3 respectively.

Salinity

The maximum water salinity of the sampling stations season-wise varied from 46.7ppt to 50.7 ppt with a mean of 47.4±3.0 ppt for the period May 2021 to May 2022.The minimum water season-wise varied from 31.9ppt to 40.0 ppt with a mean of 36.1±4.1. The seasonal variation of water salinity among the stations is presented in figure-12

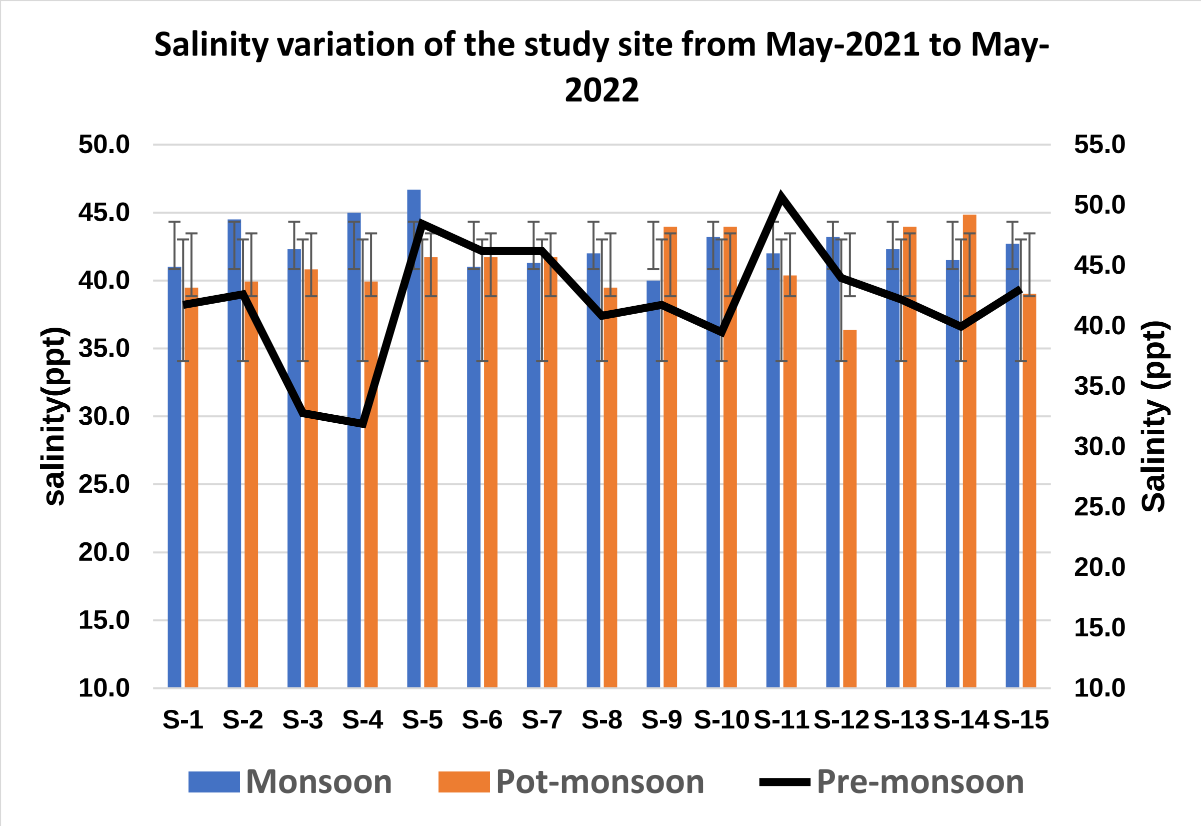


Figure 12. Seasonal variation of salinity during 2021-2022 at DPA

During Monsoon highest salinity was observed at S-5 (46.7 ppt) and the lowest at S-9 (40 ppt). In Post-monsoon highest salinity was 44.9 ppt at S-14 and lowest value at S-12 (36.4 ppt). In Pre-monsoon, the highest and lowest salinity was were 50.7ppt and 31 ppt (S-4), respectively (Table 10).

Dissolved oxygen (DO)

The maximum dissolved oxygen concentration of the sampling station for three seasons varied from 5.9 mg/L to 7.6 mg/L with a mean of 6.9±0.9 mg/L from May 2021 to May 2022. The minimum DO values varied from 3.9 mg/L to 6.2 mg/L with a mean of 5.5±1.4 mg/L. The seasonal variation of water DO among stations is presented in figure-12

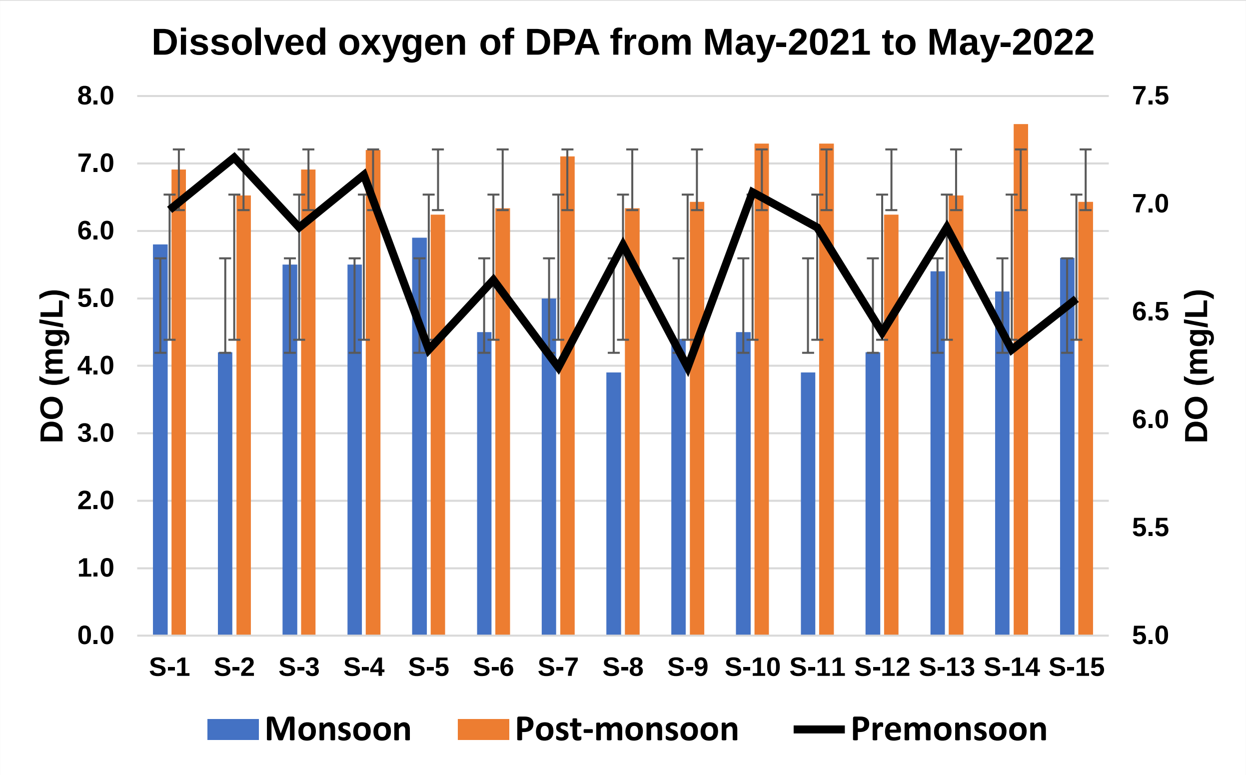


Figure 13. Seasonal variation Dissolved Oxygen (2021 to 2022)

During Monsoon highest dissolved oxygen concentration was observed at station S-5 (5.9 mg/L), and the Lowest dissolved oxygen concentration was observed at S-8 (3.9 mg/L). In Post-monsoon, the highest dissolved oxygen was observed at S-14 (7.6 mg/L) and the lowest value at S-5 (6.2 mg/L). During Pre-monsoon, the highest and lowest DO values were observed at stations S-2 (7.2 mg/L) and S-7 (6.2 mg/L), respectively.

Total Suspended Solids (TSS)

The maximum Suspended Solids value from the period varied from 173 mg/L to 1047 mg/L with a mean of 481±491 mg/L.The minimum Total Suspended Solids (TSS) value in three season-wise varied from 52 mg/L to 103 mg/L with a mean of 81±26 mg/L. The seasonal variation of water Suspended Solids concentration among stations is presented in figure-14

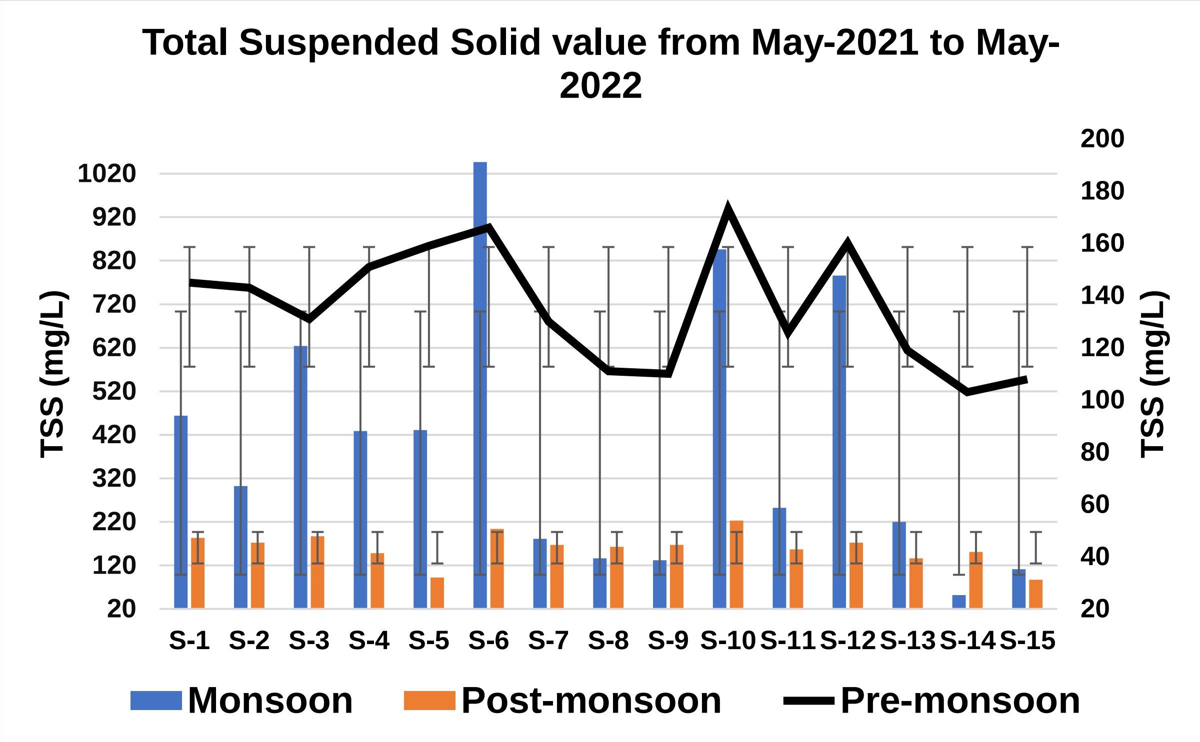


Figure 14. Seasonal variation of TSS during May 2021-May 2022

During Monsoon highest, TSS was observed at station S-6 (1047 mg/L), and Lowest TSS was observed at station S-14 (52 mg/L). In Post-monsoon highest TSS was observed at station S-10 (223 mg/L) and the lowest S-15 (87 mg/L). Similarly, in Pre-monsoon, the highest and lowest TSS was observed at S-10 (173 mg/L), and S-14 was 103 mg/L. The TSS value is relatively high in S-6, S-10, and S-12.

Total Dissolved Solids (TDS)

The maximum Suspended Solids of the sampling station season-wise varied from 42086mg/L to 48922mg/L with a mean of 46355±3722 mg/L for the period May 2021 to May 2022. The minimum Total Suspended Solids (TSS) in the sampling station varied seasonally from 5069 mg/L to 39004 mg/L, with a mean of 25387±17932 mg/L during three seasons. The seasonal variation of water Suspended Solids among stations is presented in figure-15

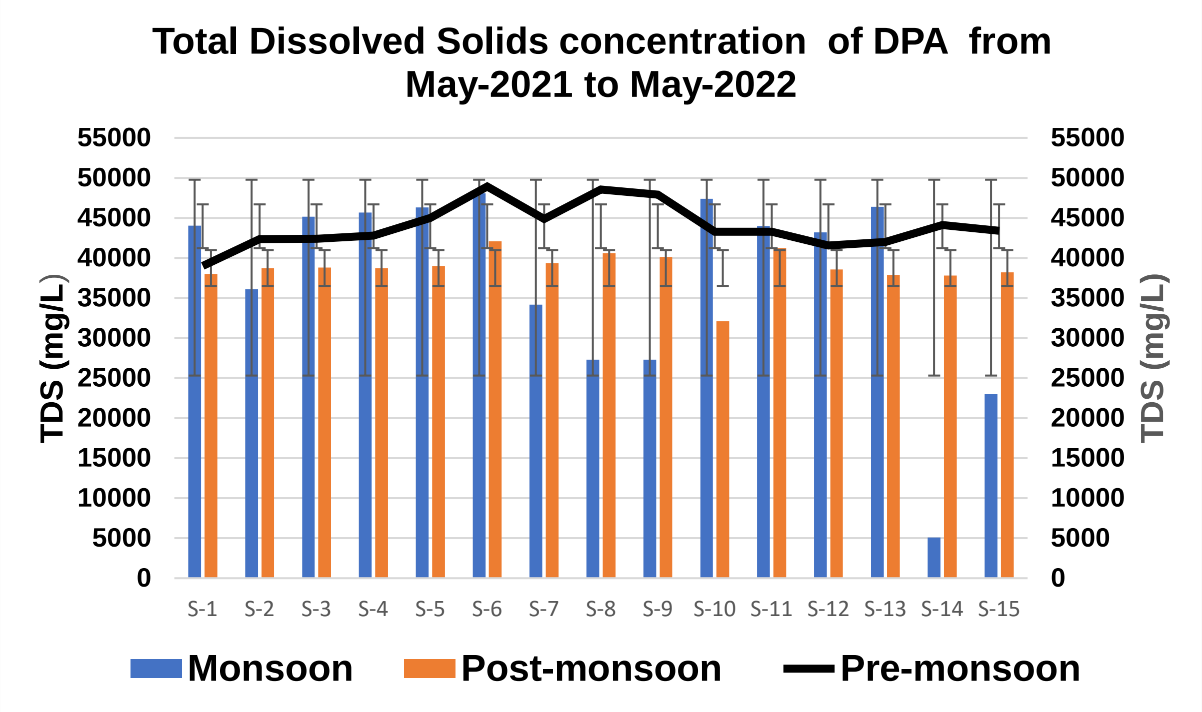


Figure 15. Total Dissolved Solids (TSS) May 2021 to May 2022 in DPA

During Monsoon highest TSS was observed S-6 (48056 mg/L) and Lowest TSS was observed at S-14 (5069 mg/L). In Post-monsoon highest TSS was observed at S-6 (42086 mg/L) and Lowest TSS was observed at S-10 (32088 mg/L). Similarly in Pre-monsoon the highest and lowest TSS was observed at station S-6 (48922 mg/L) and S-14 was 28993 mg/L

Turbidity (NTU)

The maximum Turbidity of the sampling station season wise varied from 72 NTU to 361 NTU with a mean of 206±145 NTU for the period May 2021 to May 2022.The minimum Turbidity in sampling station season-wise varied from 15 NTU to 38 NTU with a mean of 27±12 NTU.The seasonal variation of water Turbidity among the stations is presented in figure-16

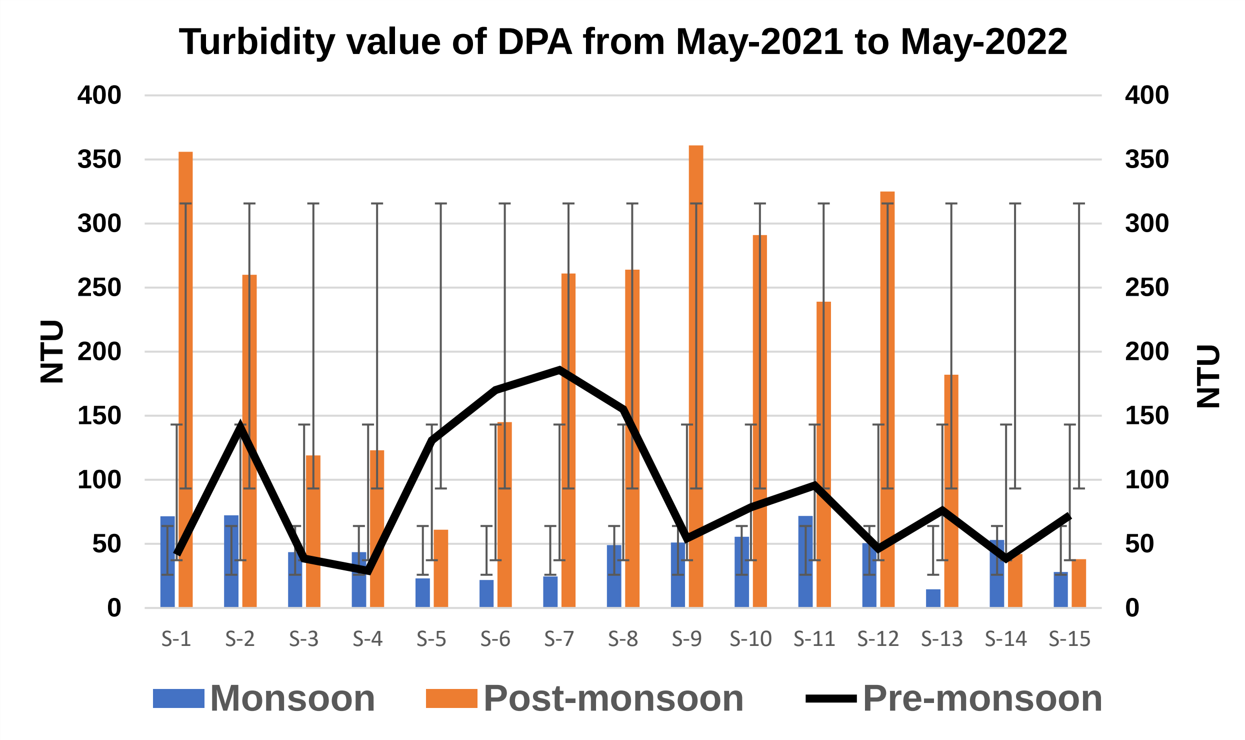


Figure 16. Seasonal variation during Turbidity May 2021 to May 2022

During Monsoon highest Turbidity was observed at S-1&S-2 (72 NTU) and Lowest T at S-13 (15 NTU). In Post-monsoon highest Turbidity was observed at station S-9 (361 NTU) and the Lowest at station S-10 (38 NTU). Similarly in Pre-monsoon, the highest and lowest TSS was observed at S-7 (186NTU), and it was less at S-4 (29 NTU)

Nitrate

The amount of Nitrate in the water sample is relatively low throughout the study period. The maximum Nitrate value for the three seasons was 0.03 mg/L with a mean of 0.02±0.01 mg/L from May 2021 to May 2022. The minimum Nitrate values varied from 0.001mg/L to 0.007mg/L with a mean of 0.003±0.003. The seasonal variation of water Nitrate among the stations is presented in figure-17

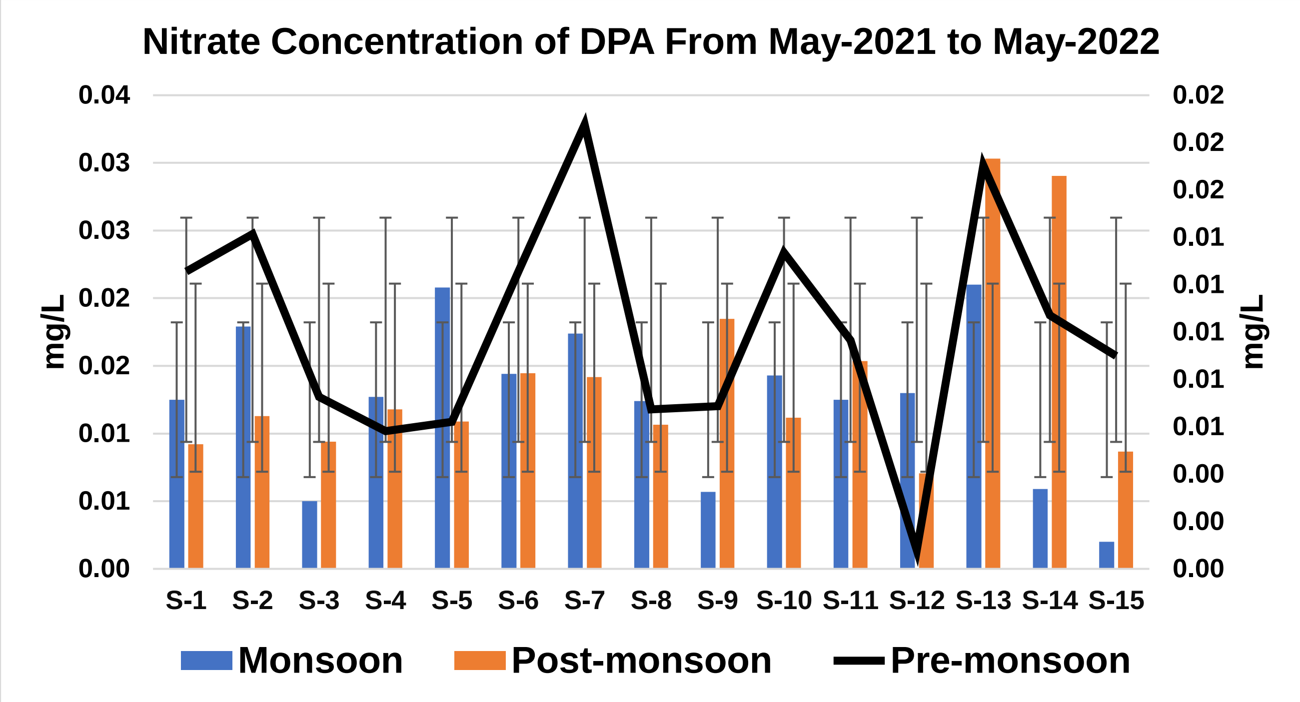


Figure 17. Seasonal variation of Nitrate concentration during May 2021 to May 2022

During Monsoon the highest Nitrate alue observed (0.02mg/L) at station S-2,S-5,S-7 & S-13, and the lowest Nitrate value was 0.002mg/L (station S-15). In Post-monsoon the values were increased and highest Nitrate was observed at S-13 &S-14 (0.03 mg/L) and Lowest at S-15 (0.007mg/L). Similarly in Pre-monsoon the highest and lowest (0.02 mg/L) (0.001 mg/L) were reported S-13&S-14.

Nitrite

The highest seasonal nitrite values were higher than the nitrate values. The maximum nitrite values 3.53 mg/L was observed both Pre-monsoon and Post-monsoon at S-13. The maximum Nitrite values for the season varied from 0.77 mg/L to 3.53 mg/L with a mean of 2.61±1.59 mg/L. The minimum nitrite varied from 0.003mg/L to 0.04mg/L with a mean of 0.02 mg/L. The seasonal variation of Nitrite concentration presented at figure-18

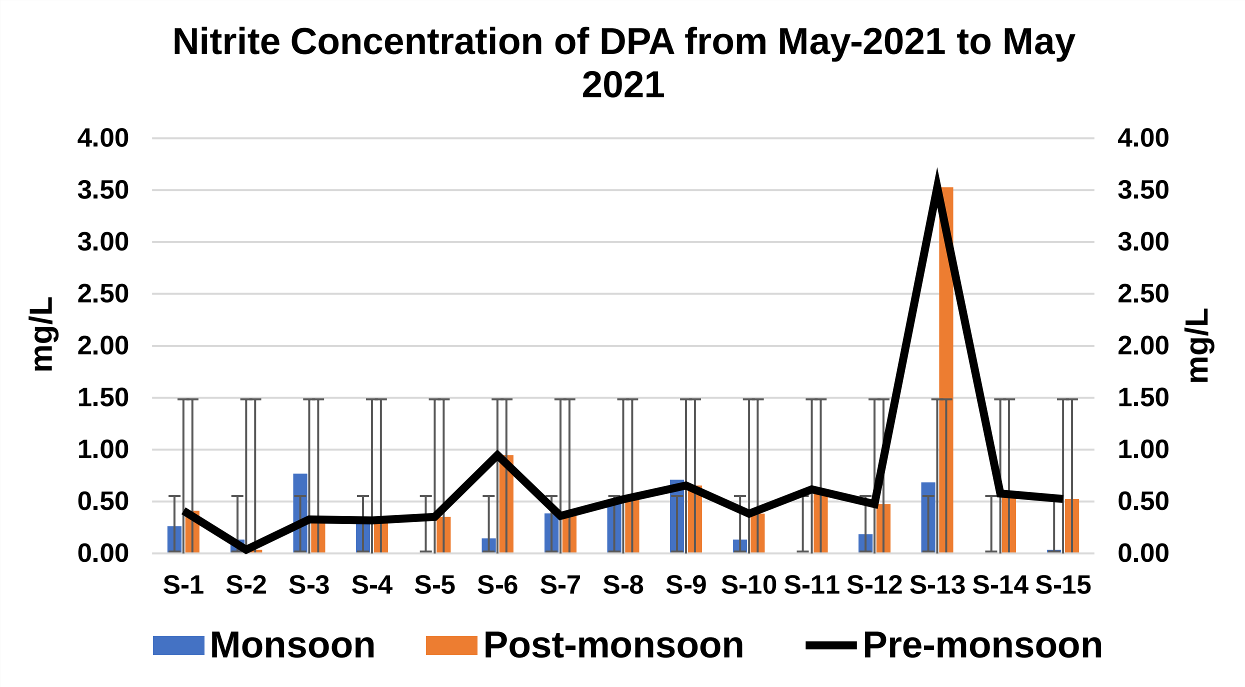


Figure 18. Nitrite concentration May 2021 to May 2022 in Deendayal Port Authority

During Monsoon highest nitrite concentration was S-3 (0.77mg/L) and Lowest was S-11 (0.003mg/L). In Post-monsoon the maximum value was S-13 (3.53 mg/L) and lowest Nitrite was observed at S-2 (0.04) .Similarly (0.035 mg/L) in Pre-monsoon the highest (3.53 mg/L) and lowest (0.04 mg/L).Nitrate was observed at S-13 and S-2 respectively.

Total Phosphorous

The total phosphorous at S-3 was highest during monsoon and pre-monsoon during the period of study. Seasonal observation reveaed that maximum varied between 2.27 mg/L to 7.61 mg/L with a mean of 4.49±2.78 mg/L..The minimum values observed from 0.17mg/L to 0.45 mg/L with a mean of 0.32±0.15.The seasonal variation total phosphorous among stations is presented in figure-19.

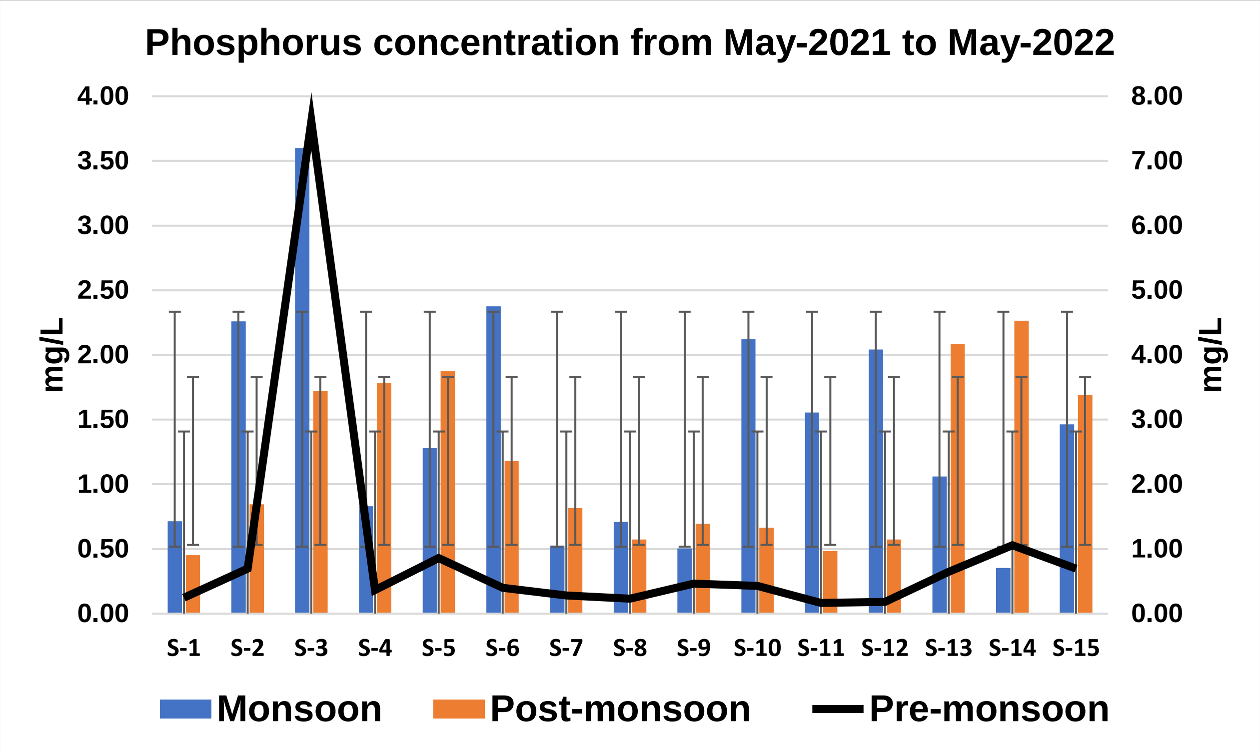


Figure 19. Seasonal variation Total Phosphorous

May 2021 to May 2022

During Monsoon maximum 3.60mg/L (S-3) and lowest 0.35 mg/L. (S-14). In Post-monsoon ranged between 0.45 mg/L at S-1 and 2.27 mg/L at S-14. In Pre-monsoon the highest and lowest values 7.61 mg/L and 0.17 mg/L at S-3 and S-11 respectively.

4.1.2. Petroleum Hydrocarbon (PHs)

The PHs values were comparatively high at S-5 and S-15 during post-monsoon than the other seasons. The Maximum values petroleum Hydrocarbons (PHs) of for the three-season varied from 29 µg/L to 42 µg/L with a mean of 34±7 µg/L. The minimum Petroleum Hydrocarbons from 3 µg/L to 15 µg/L with a mean of 11±7 µg/L.

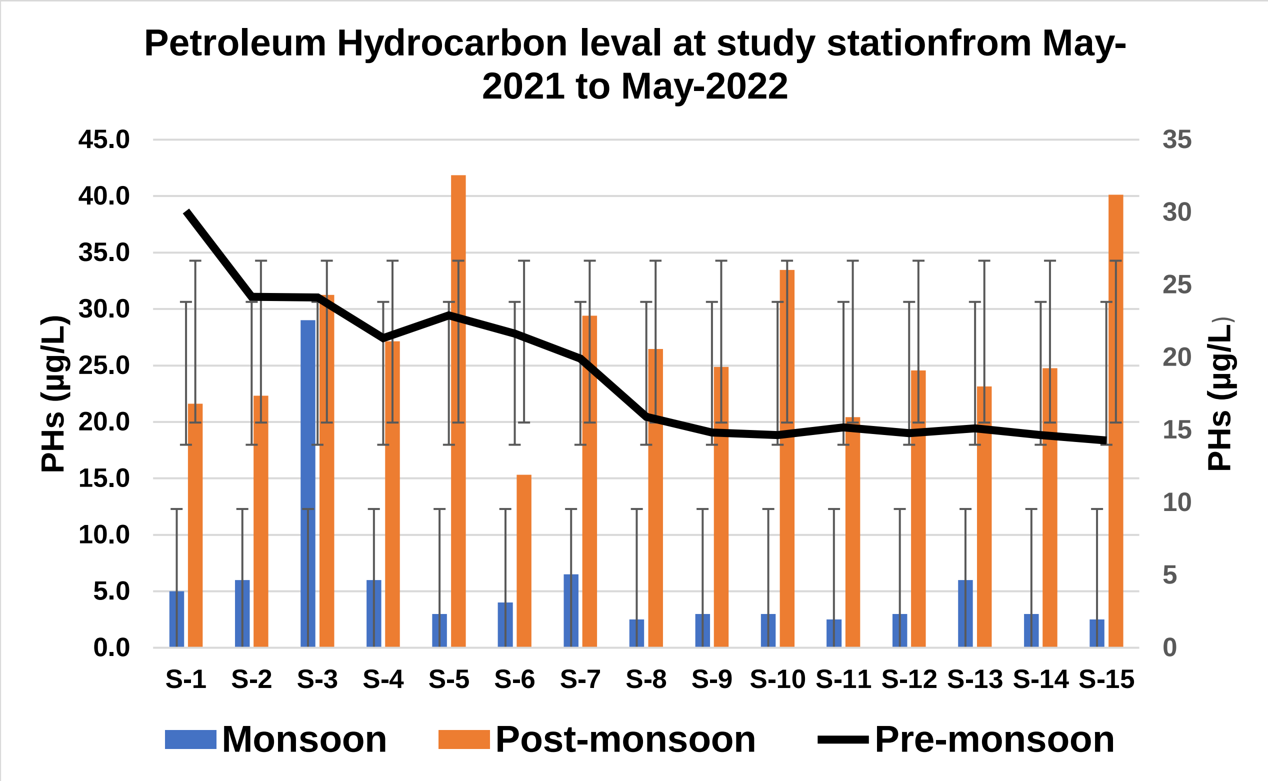


Figure 20. Seasonal Petroleum Hydrocarbon from May 2021 to May 2022

The PHs concentration in general at low level during monsoon. During Monsoon highest PH was observed at S-3 (29 µg/L) and Lowest PHs was observed along maximum S-8 to S-12 (3 µg/L). In Post-monsoon highest PHs value observed at S-4 (42 µg/L) and Lowest PHs was observed S-6 (15 µg/L). Similarly in Pre-monsoon maximum was recorded (30 µg/L) at S-1 and the minimum was (14 µg/L) at S-15.

4.1.3. Sediment

Texture

The nature of soil texture was characterized by the proportion of clay, sand and silt fractions. Soil texture revealed dominance of silty-clay type in all the stations with insignificant variation among them.

During Monsoon the highest percentage of clay (95%) was reported at S-2 at Tuna creek followed by S-7 (90%) in Kharo creek. The highest percentage of sand was reported at S3 in Kandla creek, followed by S-14 and S-15 in Vira coast and S-8 in Navlakhi creek. The percentage of silt content was less in all 15 sampling sites.

There were noticeable variations in the soil fractions, sand, silt and clay among the stations. In the in post-monsooon the highest percentage of clay (85.5%) was reported at S-7 at Kharo creek followed by S-12 (79.7%) in Tuna creek. The highest percentage of sand was observed at S-15 in Kandla creek, followed by S-11 in Jangi creek and S-5 in Phang creek. The percentage of silt content was less compared to clay and sand in all sampling sites. In the pre-monsoon the highest percentage of clay (85.5%) was reported at S-7 at Kharo creek followed by S-12 (79.7%) in Tuna creek. The highest percentage of sand was observed at S-15 in Kandla creek (69.7%), followed by S-11(63.6%) in Jangi creek and S-5(62.1%) in Phang creek.The Soil texture revealed the dominance of silty-clay type in all the stations with less variations among them. This consistently high clay-loam value may be attributed to the winnowing activity of sediment transport system. The absence of perennial flow of freshwater in to the coast along with lack of wave induced sand transport from open sea are the possible reasons for this uniform pattern of soil texture.

4.2. Biological Characteristics of water and Sediment

4.2.1. 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 global primary production being mediated by the activity of microscopic phytoplankton. For the period of May 2021 to May 2022. The maximum Chlorophyll ‘a’ recorded from 0.212 mg/L to 0.989 mg/L with a mean of 0.505±0.422 mg/L. The minimum Chlorophyll ‘a’ values ranged from 0.002 mg/L to 0.719 mg/L with a mean of 0.243±0.413 mg/L.The seasonal variation of Chlorophyll ‘a’ among stations is presented in figure-21.

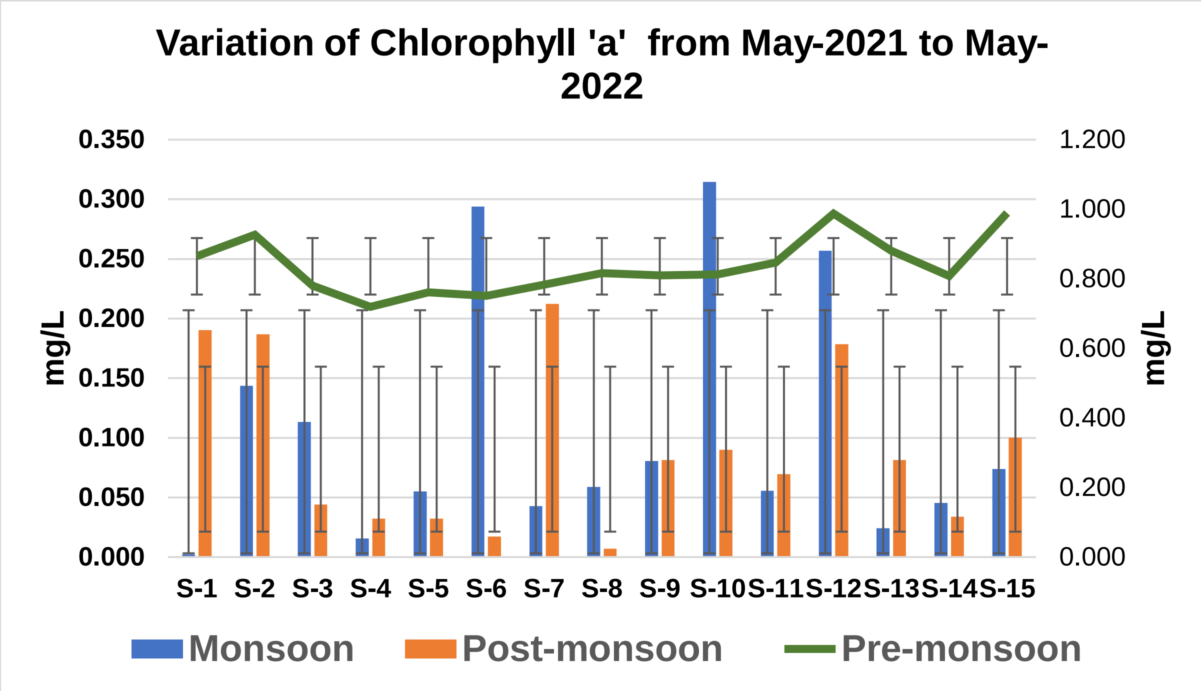


Figure 21. Concentration of Chlorophyl 'a' from May 2021 to May 2022

During Monsoon highest Chlorophyll 'a' was observed at S-10 (0.314 mg/L) and lowest was observed along maximum station as (0.002 mg/L). In Post-monsoon highest Chlorophyll 'a' was observed at station S-7 (0.212 mg/L) and the lowest (0.007 mg/L) at S-8. Similarly in Pre-monsoon the highest and lowest Chlorophyll 'a' was observed at stations S-15 (0.989 mg/L) and S-5 (0.761 mg/L) respectively.

4.2.2. Phytoplankton

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

Generic Status

Season wise the maximum phytoplankton genera varied from 23 to 29 number with average variation of genera was 25±3 number and the minimum genera varied from 11 to 17 number with average variation of genera was 14±3 (Fig.24).

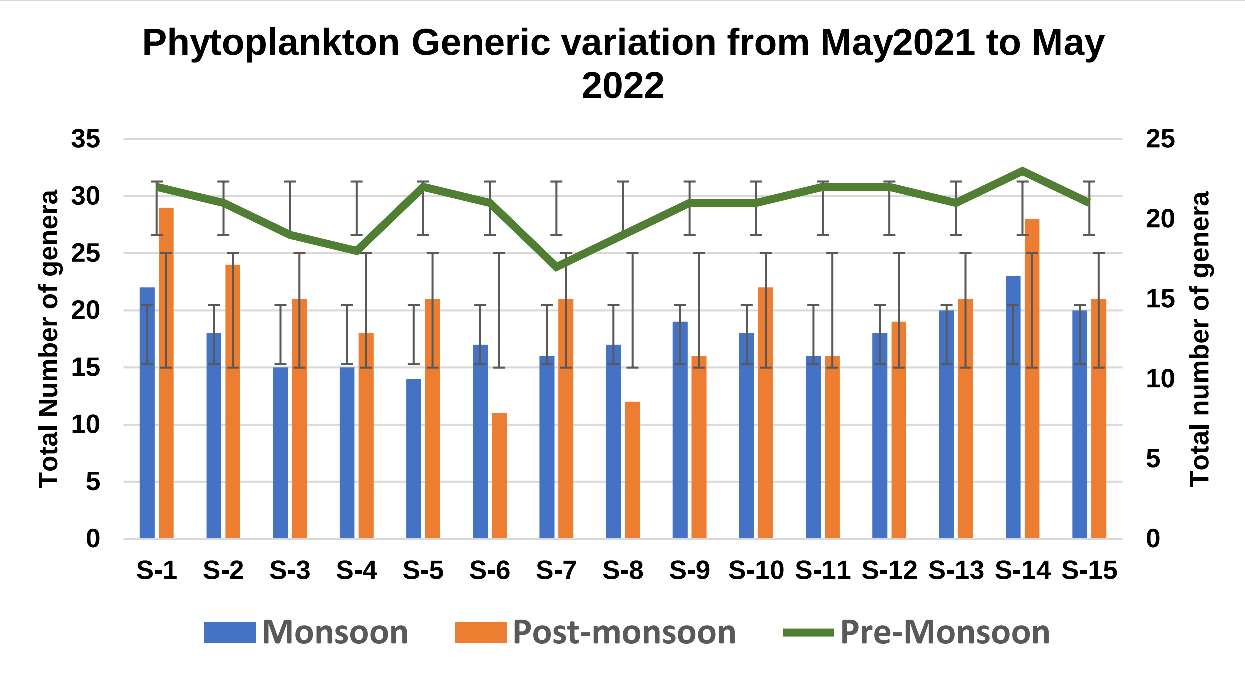


Figure 22. Seasonal variation of Phytoplankton genera from May-2021 to May2022

During monsoon the phytoplankton genera varied from 14 to 23 number and the highest genera was observed at station S-14 (23 no) and lowest genera was observed at station S-5 (14no).In post-monsoon genera varied from 11 to 29 number and the highest genera was observed at station S-1 (29 no) and lowest genera was observed at station S-6 (11).Similarly during pre-monsoon genera 17 to 23 number of genera noticed and the highest numbering genera was observed at S-14 (23) and lowest genera was observed at station S-7 (17).

Percentage composition

The Maximum percentage of phytoplankton composition for the period May 2021 to May 2022 varied from 46 %to 54% and the minimum percentage of phytoplankton was 2%. Five major group such as pennales, centrales, Dinophyceae, Cyanophyceae and Chlorophyceae of phytoplankton was reported for the period 2021 and 2022. The percentage of composition pennales for three season varied from 36% to 46% with average variation of 39±6. The Centrales percentage of composition three season varied from 46% to 54% with average variation of 51±4. In Dinophyceae percentage of composition three seasons varied from 5% to 8% with average variation of 6±2.The phytoplankton group, Cyanophyceae and Chlorophyceae contribute less i.e from 2% to 3% (Fig.25).

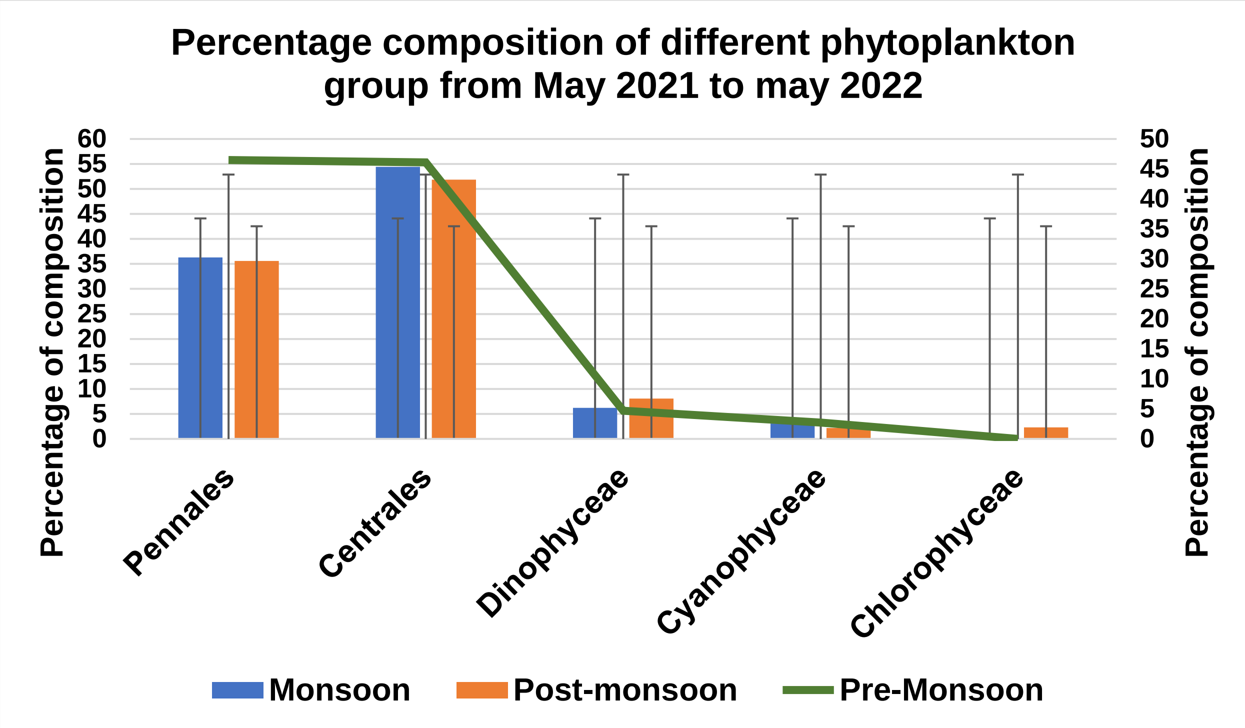


Figure 23. Seasonal variation of Percentage composition of different phytoplankton group

Percentage of Occurrence

Season wise percentage occurrence of the different groups of phytoplankton varied from 13% to 100%. Highest percentage of occurrence was found during the pre-monsoon season which constitute 15 phytoplankton genera (100%) followed by post-monsoon season 3 phytoplankton genera (100%) and monsoon 2 phytoplankton genera (100%). Overall, the occurrence of phytoplankton genera was more in monsoon season (Fig.26). The phytoplankton genera, *Amphora* and *Bacillaria* were found (100%) at all the three seasons.

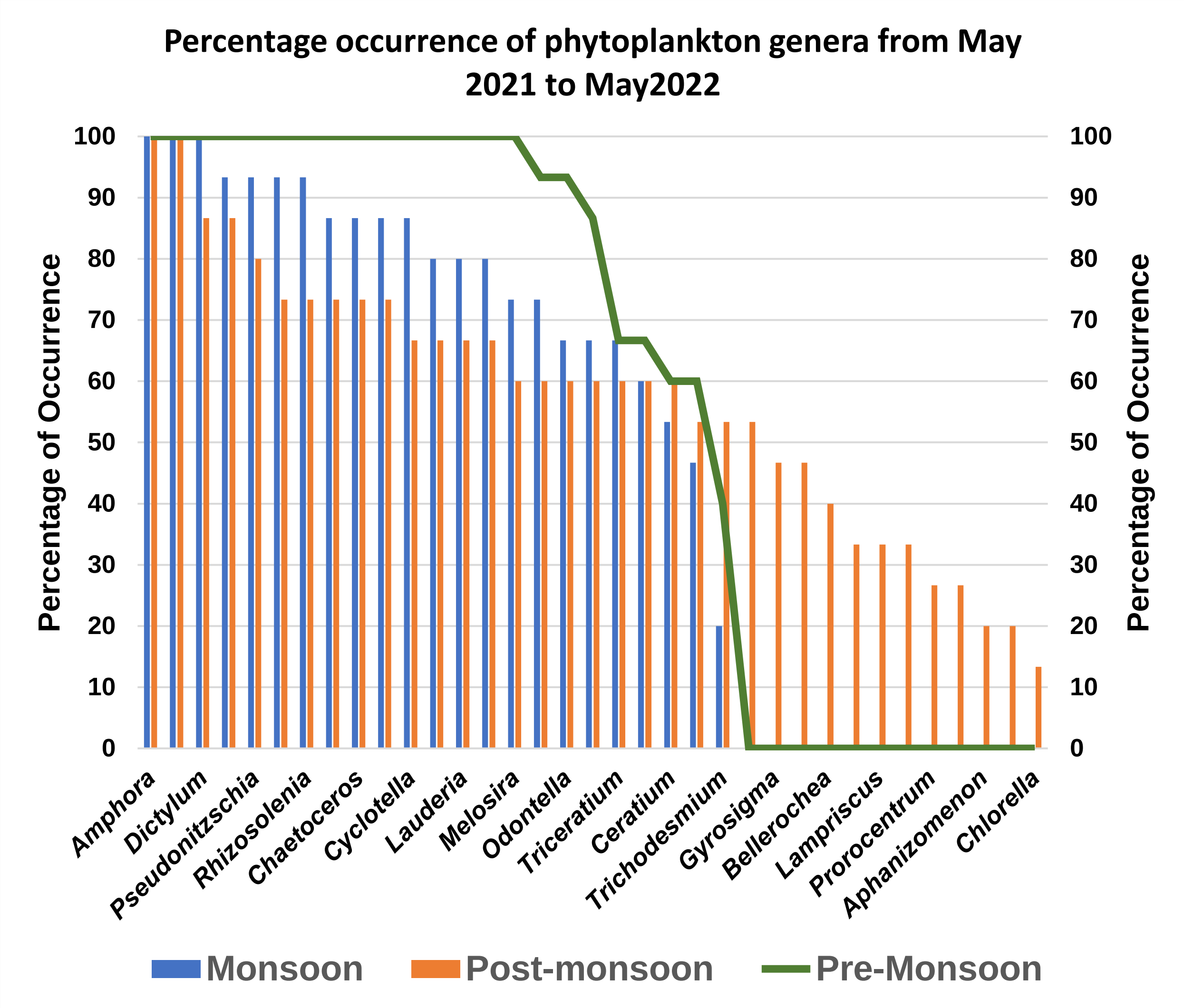


Figure 24. Seasonal variation in the percentage occurrence of phytoplankton genera

Phytoplankton density

The density signifies the abundance of plankton which is measured as cell/ individual/L. The maximum phytoplankton density variation for 3 seasons varied from 22,080 No/L to 26,720 No/L with average variation of 24,587±2342 and the minimum phytoplankton density was varied from 8,160 No/L to 9,440 No/L with average variation of 9173±910 (Fig.27).

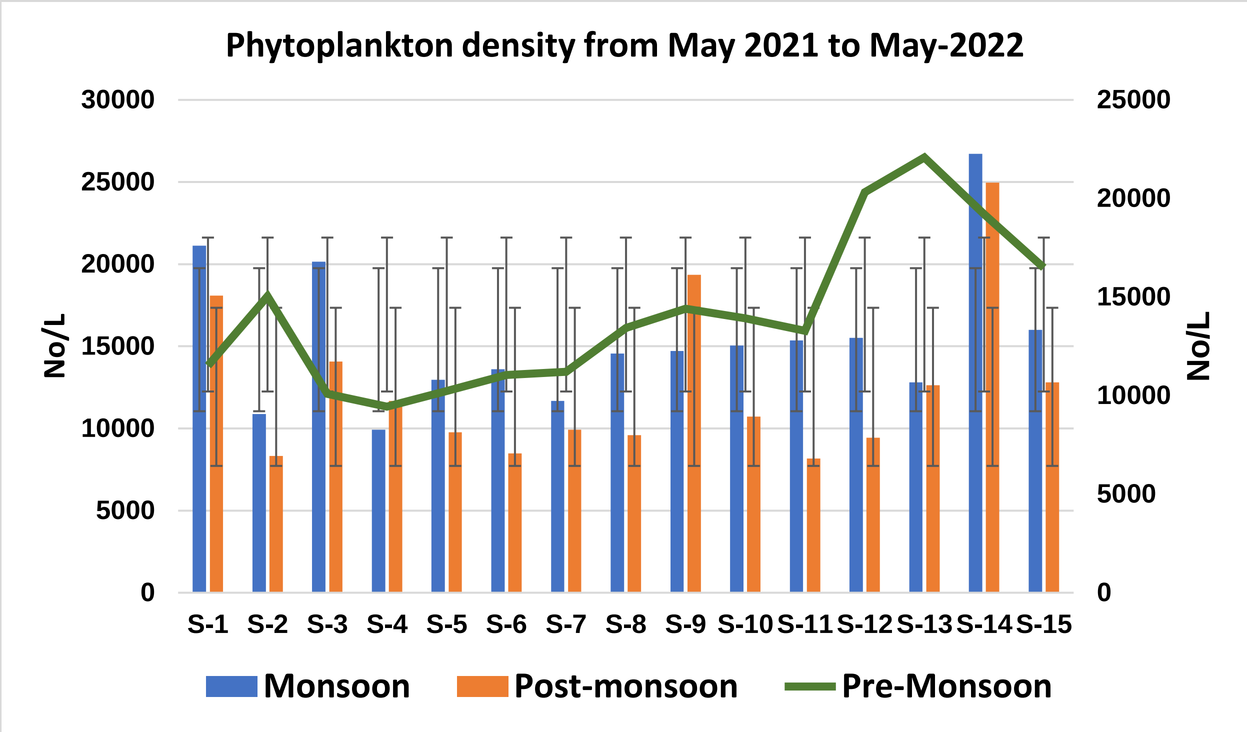


Figure 25. Seasonal variation Phytoplankton density during May 2021 to May 2022

During monsoon the phytoplankton density varied from 9,920 No/L to 26,720 No/L where highest density was observed at S-14 &S-4.In post-monsoon cell density varied from 8,160 No/L (S-14) to 24,960 No/L (S-11).Similarly during pre-monsoon density varied from 9,440 no/L to 22080 no/L and the highest density was observed at S-13 (22,880) and lowest density was observed at S-4 (9440)

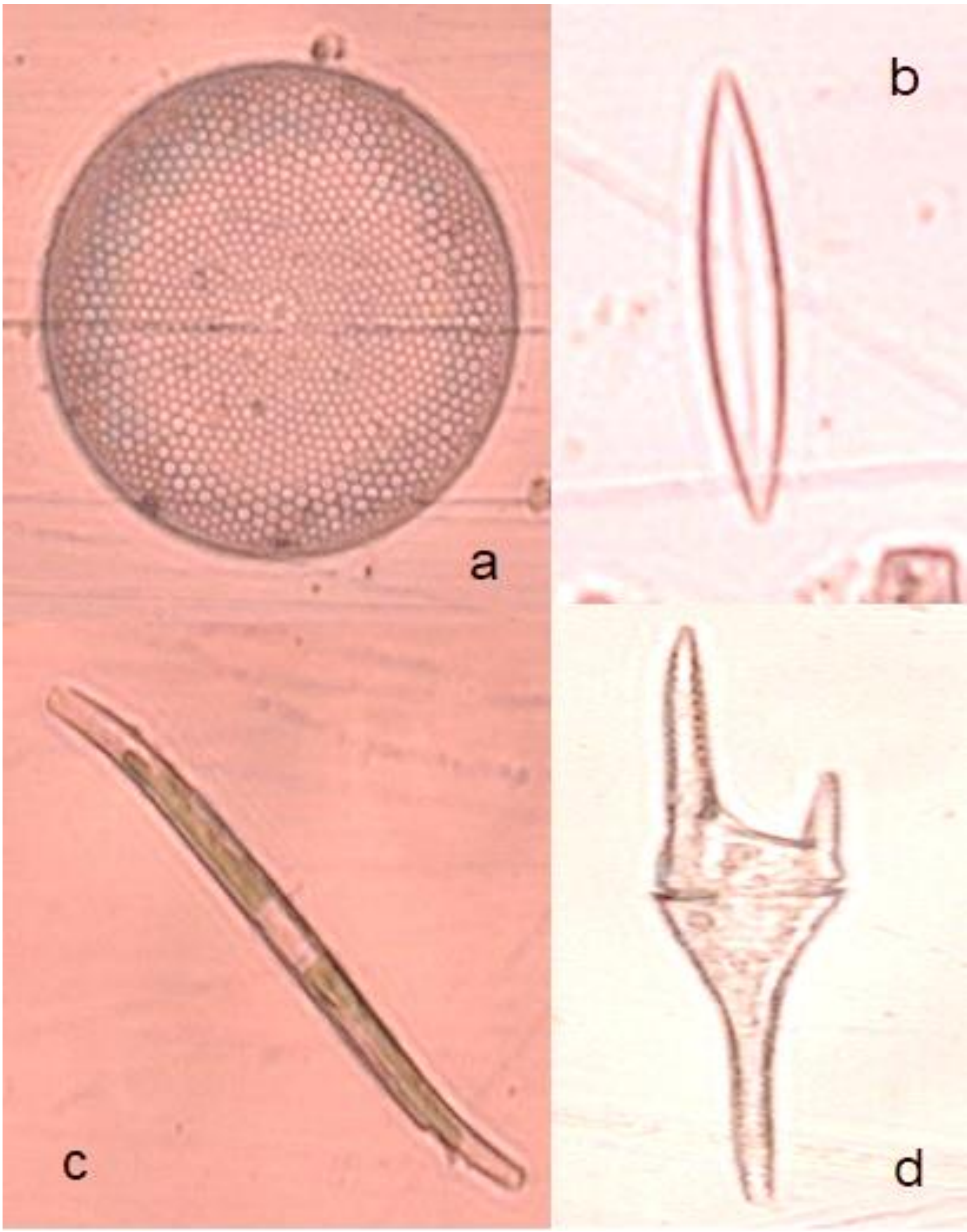


Plate 7: Phytoplankton of Deendayal Port Authority

a. *Coscinodiscus* sp. b. *Navicula* sp. c. *Pluerosigma* sp.

d. *Ceratium* sp.

4.2.3. Zooplankton

The zooplankton fauna of Indian waters is very diverse, which could be due to a series of environmental factors, most significantly ocean currents (Jagadeesan et al., 2013), upwelling (Madhupratap et al., 1990), high primary productivity (Smith & Madhupratap, 2005) and salinity. These studies also recorded species compositions of the plankton community with marked spatial, seasonal, and diurnal fluctuations in both the Bay of Bengal and the Arabian Sea. Zooplanktons are strongly responsive to environmental variables, including light, temperature, salinity, pH, dissolved oxygen, turbulence, and food availability. In recognition of this multifaceted ecological and economic significance of zooplankton in marine environments, there has been a long emphasis on studying their systematics, ecology, and other biological aspects at different spatiotemporal scales.

Zooplankton plays a major role in the functioning and productivity of aquatic ecosystems through its impact on the nutrient dynamics and its unique position in the food web. Many species of zooplankton can be used as biological indicators for water pollution, water quality, and eutrophication. Zooplankton communities are highly influenced by Spatio-temporal variations in hydrochemical parameters and physical forces. The Spatio-temporal variations in zooplankton species composition and distribution in the Arabian Sea and Bay of Bengal have been extensively studied during the past 100 years and with more emphasis since the 1950s. Copepods are the most dominant zooplankton group and the most diverse in species composition in the pelagic realm of the marine environment. The preponderance of copepods among the various taxonomic groups has been reported as a common feature in coastal and oceanic environments. As the study area of DPA is under the influence of various port and cargo handling activities, regular monitoring is highly essential to know the environmental pressures at the Kandla coast and its nearby creek environment with respect to plankton which supports the fishery resources and several ecological services.

Phylum group and generic status

The zooplankton identified from the 15 stations falls under 7-13 phylum and 1-17 group for the period May-2021 to May 2022. In monsoon season 13 phylum and 14 zooplankton group was recorded, similarly, in post-monsoon season 11 phylum and 17 groups have been recorded from the entire study station, likewise in pre-monsoon season 7 phylum and 12 zooplankton were recorded (Fig.28).

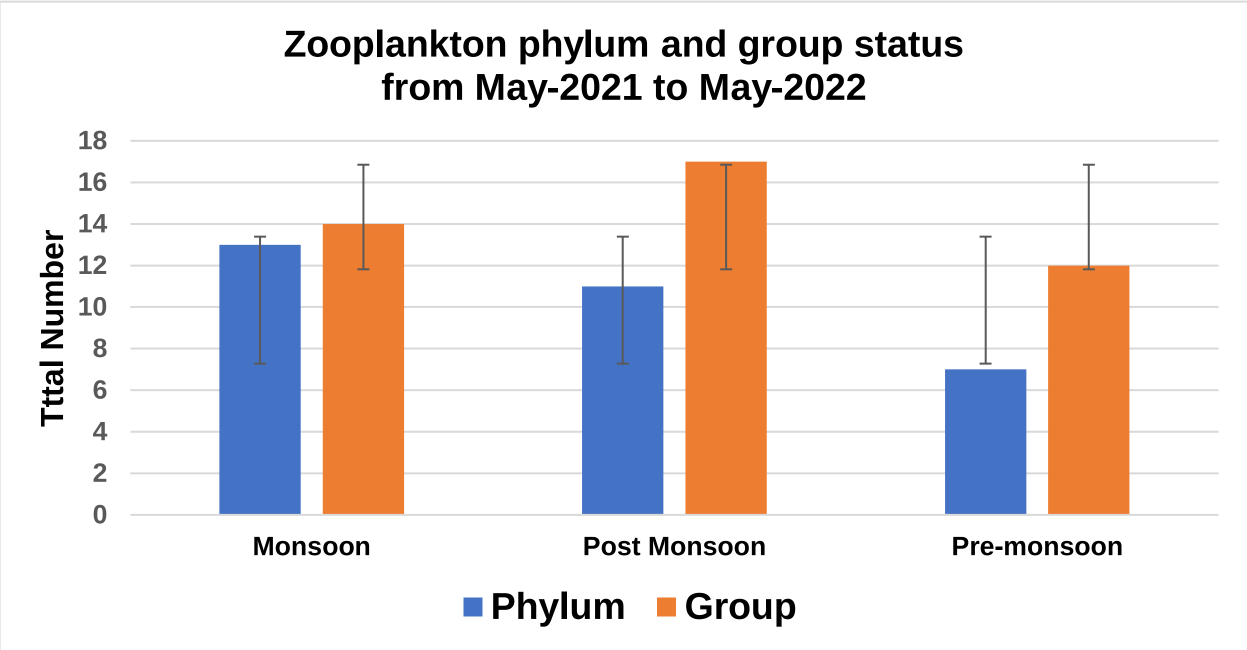


Figure 26. Details of Zooplankton Phylum and group status

The phylum Arthropoda was the predominant represented 5 groups in monsoon,6 group each in post-monsoon and pre-monsoon which mainly include Copepoda, Harpacticoida, Cyclopoida, Decapoda, Crab larvae and Malacostraca. Maximum number zooplankton genera among the stations DPA area varied from 27 to 32 with an average variation of 30±2, and the minimum zooplankton genera varied from 19-24 with an average variation of 21±2. During monsoon season highest and lowest genera were observed at the S-14 (32 no) and S-8 (19 no).In post-monsoon, the highest genera were observed at S-2, S-4 and S-11, and the minimum genera were observed at S-13. Likewise, in pre-monsoon, the highest and lowest genera were observed at stations S-15 (30no) and S-13 (24), which is presented in figure 27.

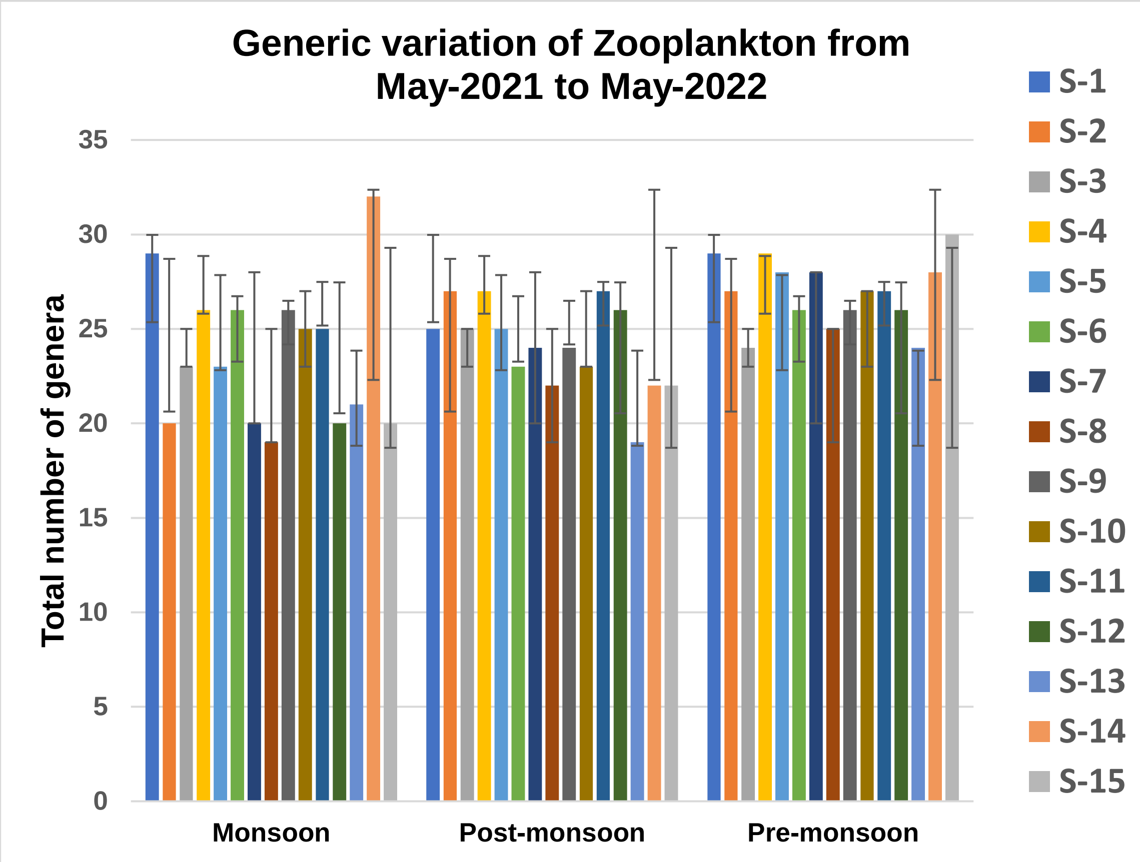


Figure 27. Generic status of Zooplankton during May 2021 to May 2022

Percentage of composition

The maximum percentage of composition of zooplankton ranged from 39.4% to 47.8% and the minimum percentage composition of zooplankton ranged from 0.3% to 0.7%.In monsoon, the highest percentage of composition was contributed by the Copepoda group (47.8%) followed by Decapoda (12.7%) and Sagita (6.4%).In post-monsoon the highest percentage of contributed by Copepoda (39.4%) followed by Decapoda (10.9%) and Cyclopoida (8.4%). Similarly, in the pre-monsoon season, the highest percentage of composition was due to the Copepoda group (39.8%) followed by Decapoda (20%) and Foraminifera (7.3%), as presented in figure 28.

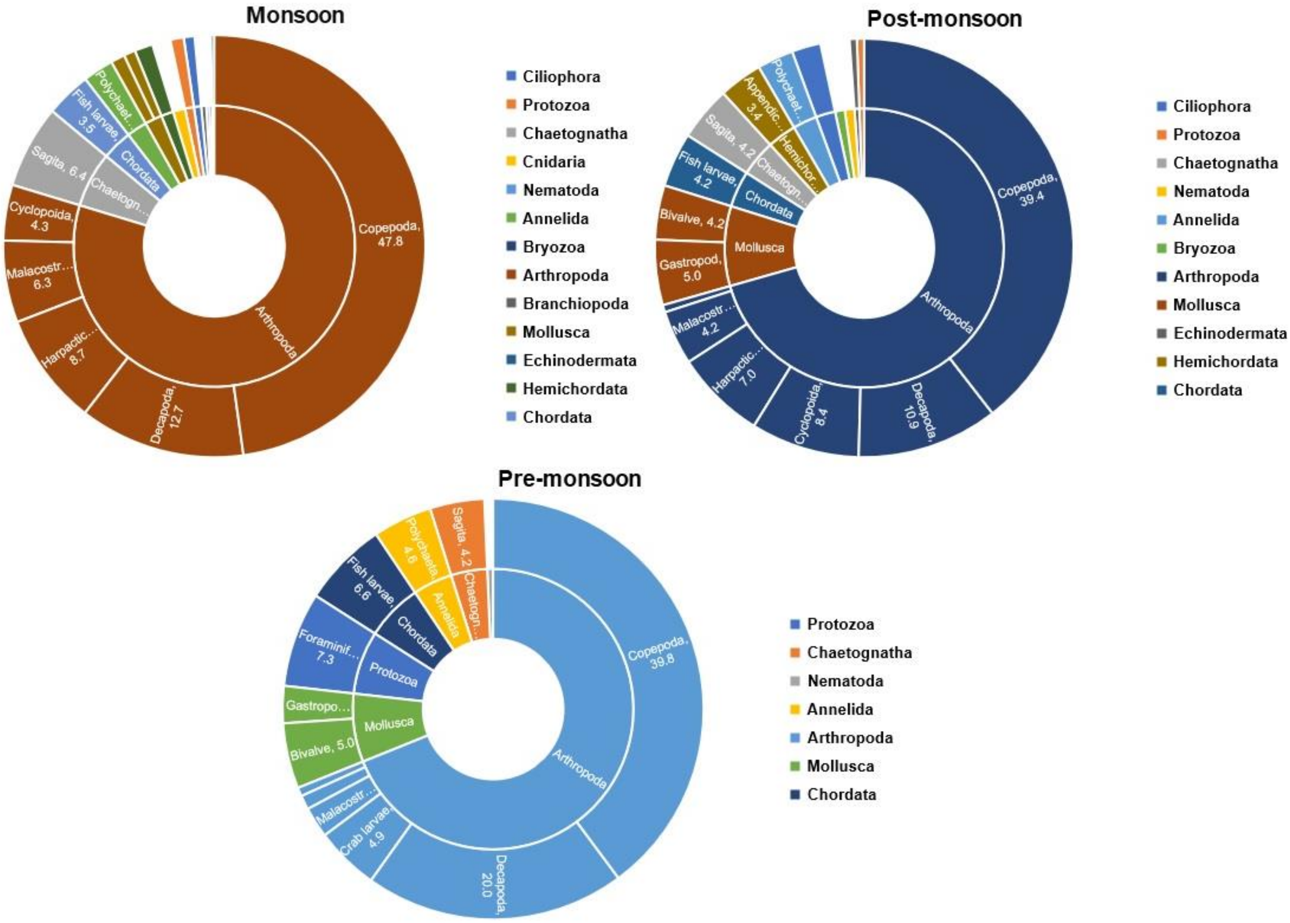


Figure 28. Percentage composition of Zooplankton during May-2021 to May2022

Percentage of occurrence

Percentage occurrence of zooplankton genera varied from 7-100%. In the monsoon season, the maximum percentage of occurrence was contributed by *Paracalanus sp* (100%) followed by *Brachyuran larvae*, *Microsetella*, *Sagitta sp*. (93%) and the least percentage of occurrence was contributed by Tornaria larvae (7%). In post-monsoon maximum percentage of occurrence contributed by *Bivalve larvae, Brachyuran larvae, Fish larvae, Labidocera sp. Oithona sp. Oncaea sp.& Temora sp.* (100%) and the least percentage occurrence contributed by Tornaria larvae (7%). Siimilarly in pre-monsoon maximum percentage of occurrence contributed by *Acartia sp,Acrocalanus sp,Aetideus sp. Calanus sp. Caridean larvae,Eucalanus sp.,Euphausia sp.,Fish larvae , Gastropod larvae, Globigerina sp., Labidocera sp.,Paracalanus sp. Polychaete larvae, Sagitta sp* (100%) and it is presented in figure 29,

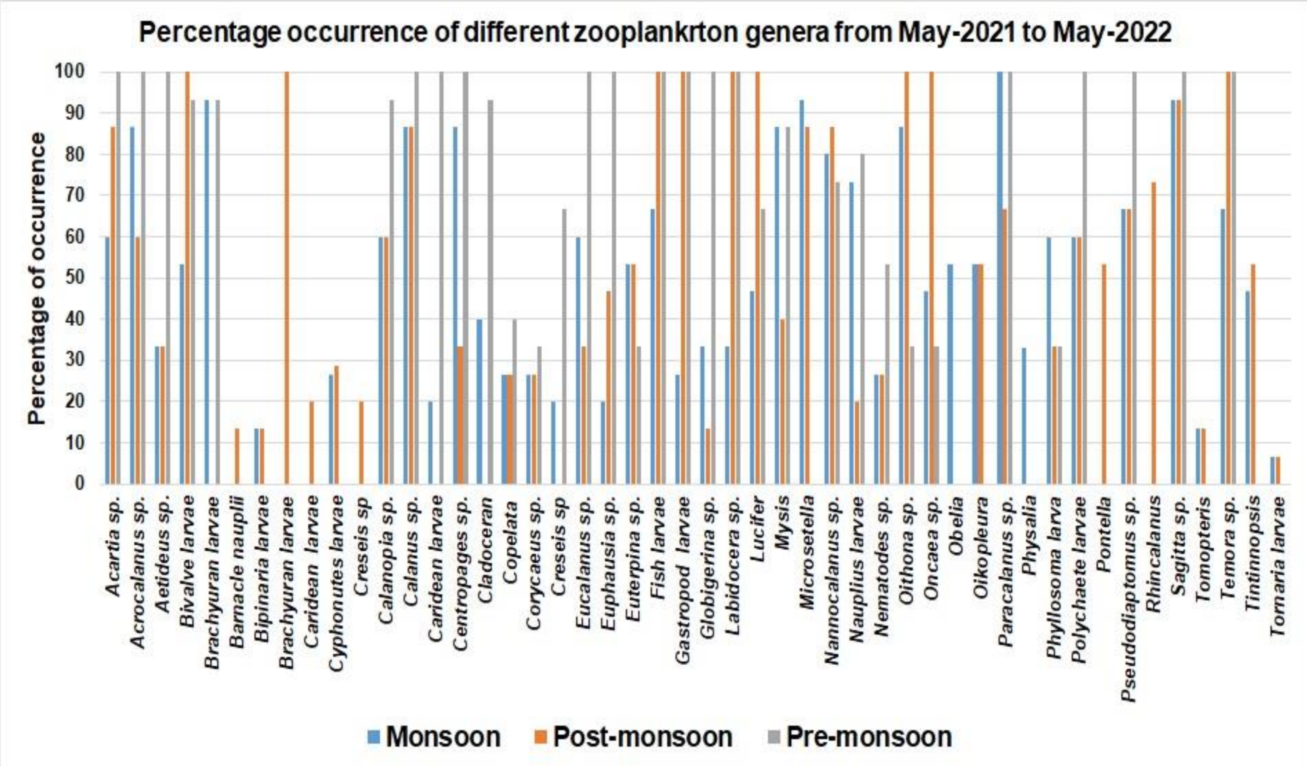


Figure 29. Percentage occurrence of Zooplankton in Deendayal Port Authority May-2021 to May-2022

Zooplankton density

During monsoon the phytoplankton density varied from 12,960 no/L to 23,840 no/L where highest density was observed at station S-14 (23,840 no/L) and lowest density was observed at station S-13 (12,960 no/L).In post-monsoon the density varied from 8,120 no/L to 16,240 no/L where the highest density was observed at station S-14 (16,340) and lowest genera was observed at station S-7 (8120 no/L).Similarly during pre-monsoon genera varied from 12,800 no/L to 22,560 no/L where the the highest density was observed at station S-5 (22,560) and lowest density was observed at station S-13 (12800),whis is depleted in figure 30.

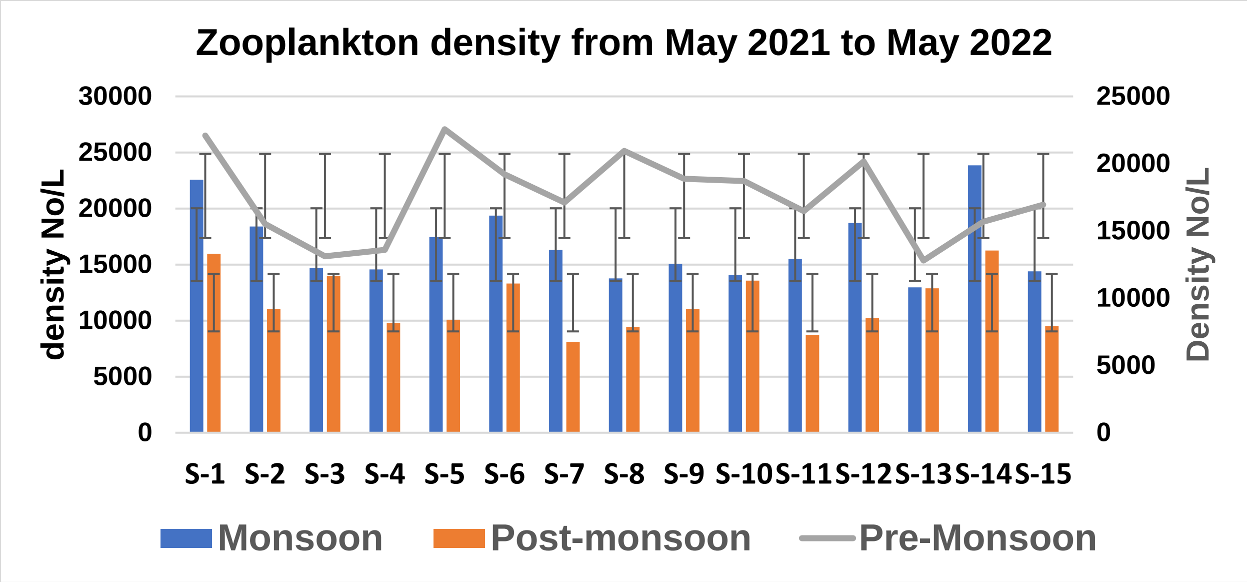
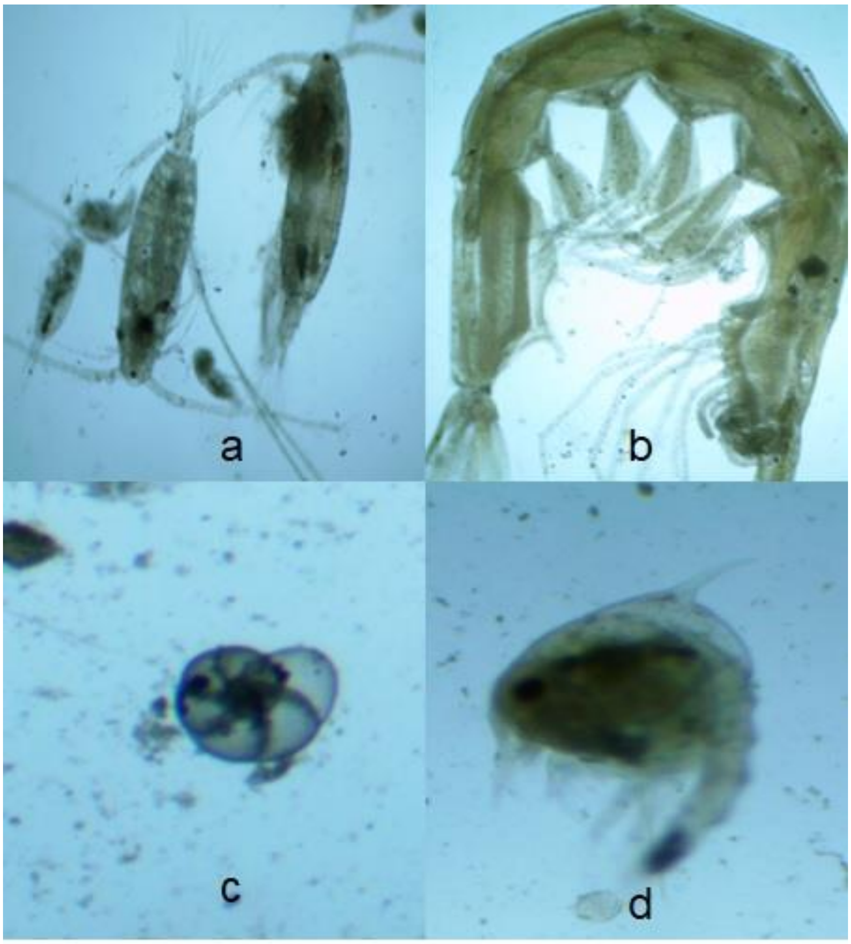


Figure 30. Density Zooplankton in Deendayal Port Authority May-2021 to May-2022



a. Calanoida sp b. Mysis larvae c. Foraminifera sp d. Brachurian larvae

Plate 8: Zooplankton of Deendayal Port Authority

4.2.4. Intertidal fauna

The intertidal habitats are found along the margins of the oceans and include estuaries, mudflats, salt marshes and rocky shores (Chakraborty 2017). This intertidal zone is rich in diversity because high concentrations of nutrients drift from the land. Although these habitats differ in many respects, they share the common feature that organisms living in them experience enormous changes in their abiotic environment caused by the tidal cycle. The tide rises roughly every 12.5 h, and during this time, intertidal organisms can be exposed to marine-like temperature and salinity conditions. The Gulf of Kachchh (GoK), occupying an area of 7300 km2, is biologically one of the most productive environments with diversified habitats along the west coast of India. The southern shore has numerous Islands and inlets which harbour vast areas of mangroves and coral reefs. The northern shore with numerous shoals and creeks also sustains large stretches of mangroves. A variety of marine wealth existing in the Gulf includes algae, mangroves, corals, sponges, molluscs, prawns, fishes, reptiles, birds and mammals.

The marine environment is a complex system influenced by various physical, chemical and biological processes and harbours broad assemblages of diversified Fauna. Intertidal Fauna represents species of invertebrates and chordates. They have an essential role in the pelagic and benthic food chain at different trophic levels in the coastal environment. Hence, periodic environmental monitoring to assess the abundance and diversity of macrofauna in this habitat is inevitable. The intertidal Fauna was comparatively less mortality based on the condition of their habitat, and many environmental impacts can be identified by following the changes in the assemblages of intertidal Fauna. Activities of organisms influence sedimentation and erosion and sediment physical and chemical nature. Tidal flats occur mainly in areas where saline and freshwater mix. Benthic organisms occur here usually in high densities because estuaries are among the most productive regions in the sea. Nutrient input by freshwater discharges sustains a relatively high primary production by phytoplankton and micro-and macro flora. Living on the tidal flats provides food for this abundant animal life. Moreover, there is a high input of organic matter (food) from rivers. However, as the organisms must tolerate rapid tidal and seasonal changes in salinity, the number of benthic species is usually lower than in the open sea and freshwater. Therefore, the macrofauna of the intertidal area worldwide has received considerable attention in recent years. Rapid coastal industrialisation in recent years has underlined the importance of complete understanding and continuous monitoring of marine environments, especially coastal stretches where human activity is intense, to evaluate their stability and functioning. In ports, activities like dredging, frequent vessel movement, and human interference in large numbers have a significant impact on the living organisms in the intertidal zone. Assessment of these effects has usually targeted bottom substrata and the associated benthic Fauna. Hence benthic communities are logical targets whose density, diversity, community structure and seasonal shift will be a powerful tool for understanding any marine environment.

Phylum wise diversity

The survey of the intertidal Fauna of DPA Kandla area recorded the presence of 6 phyla (Nematoda, Nemertea, Annelida, Arthropoda, Mollusca and Chordata), including 27 species. The species diversity was the highest for phylum Mollusca (12 species), followed by Arthropoda (9species), Annelida (3 species) and Nematoda, Nemertea, Chordata (1) species, respectively (Fig.33).

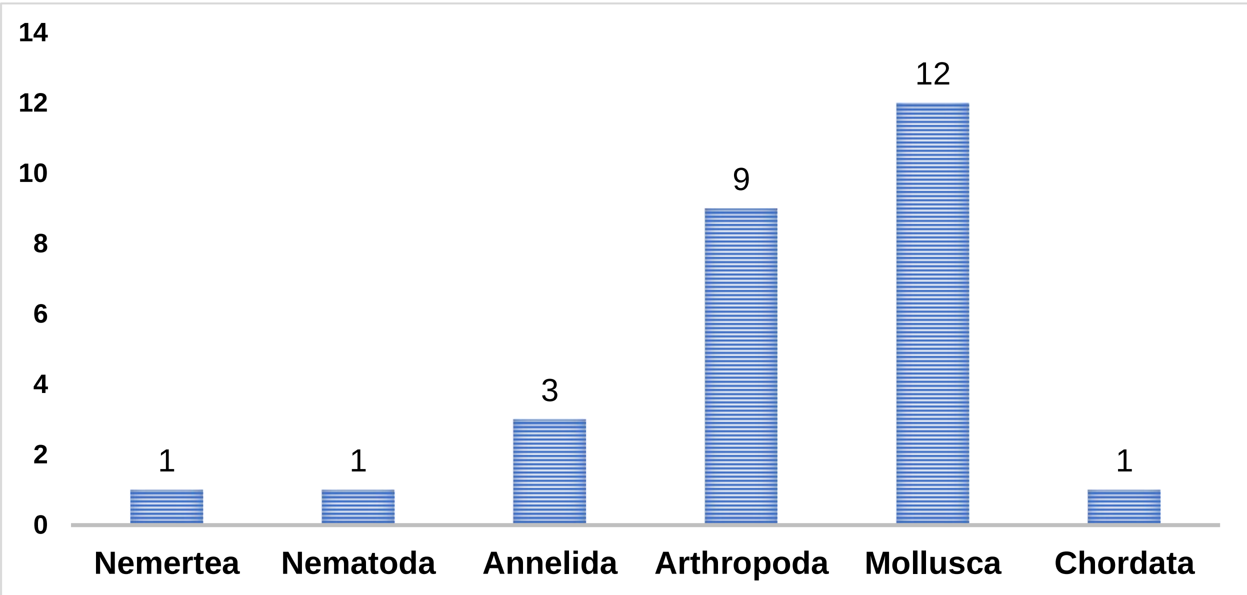


Figure 31. Phylum wise intertidal faunal diversity during May-2021 to May-2022

Density variation of intertidal fauna

The occurrence of intertidal animals was documented during the three seasons. The highest number of organisms was documented from the pre-monsoon season (2015), followed by Post-monsoon (1882) and Monsoon (914), respectively. The intertidal fauna of DPA Kandla survey recorded the presence of 27 species classified under six phyla (Nemertea, Nematoda, Annelida, Arthropoda, Mollusca and Chordata). The mollusc diversity was very high in all the seasons; during the pre-monsoon (9 species), Post-monsoon and Monsoon (7 species), respectively. The second most dominant phyla, Arthropoda sharing (7 Species) in the pre-monsoon period, Post-monsoon period (6 species) and Monsoon (5 species). The least diversity was documented by Chordata, Nemertea, and Nematoda (1 species) (Fig.34).

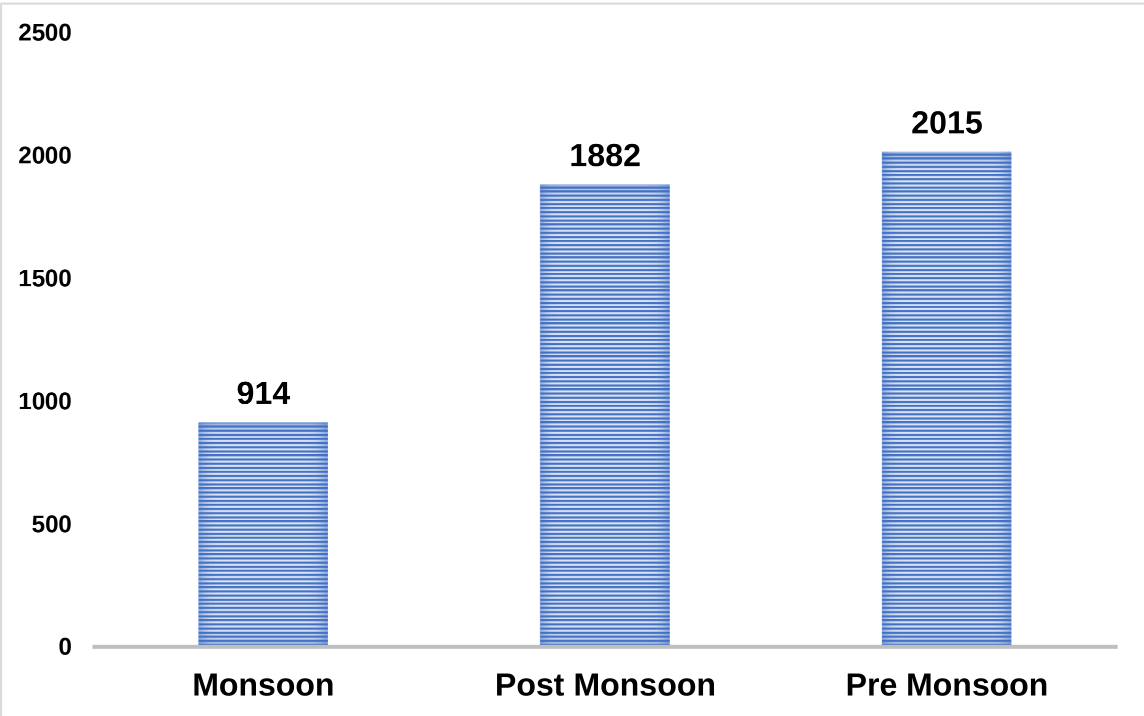


Figure 32. Season wise intertidal population density (No/m^2) during May-2021 to May-2022

Phylum wise and season wise intertidal diversity

During the Premonsoon period, the highest number of animals was documented from stations S-2, S-4, and S-15 and the least were documented from S-10. During the Post-monsoon period, the highest number of animals was RECORDED from stations. S-3, 11, and 15 and the least were documented from S-10. During the monsoon period, the highest number of animals was documented from stations S-2 and 14 and the least were documented from S-1 and S-13. The least no animals were documented during the Monsoon period (Fig.35).

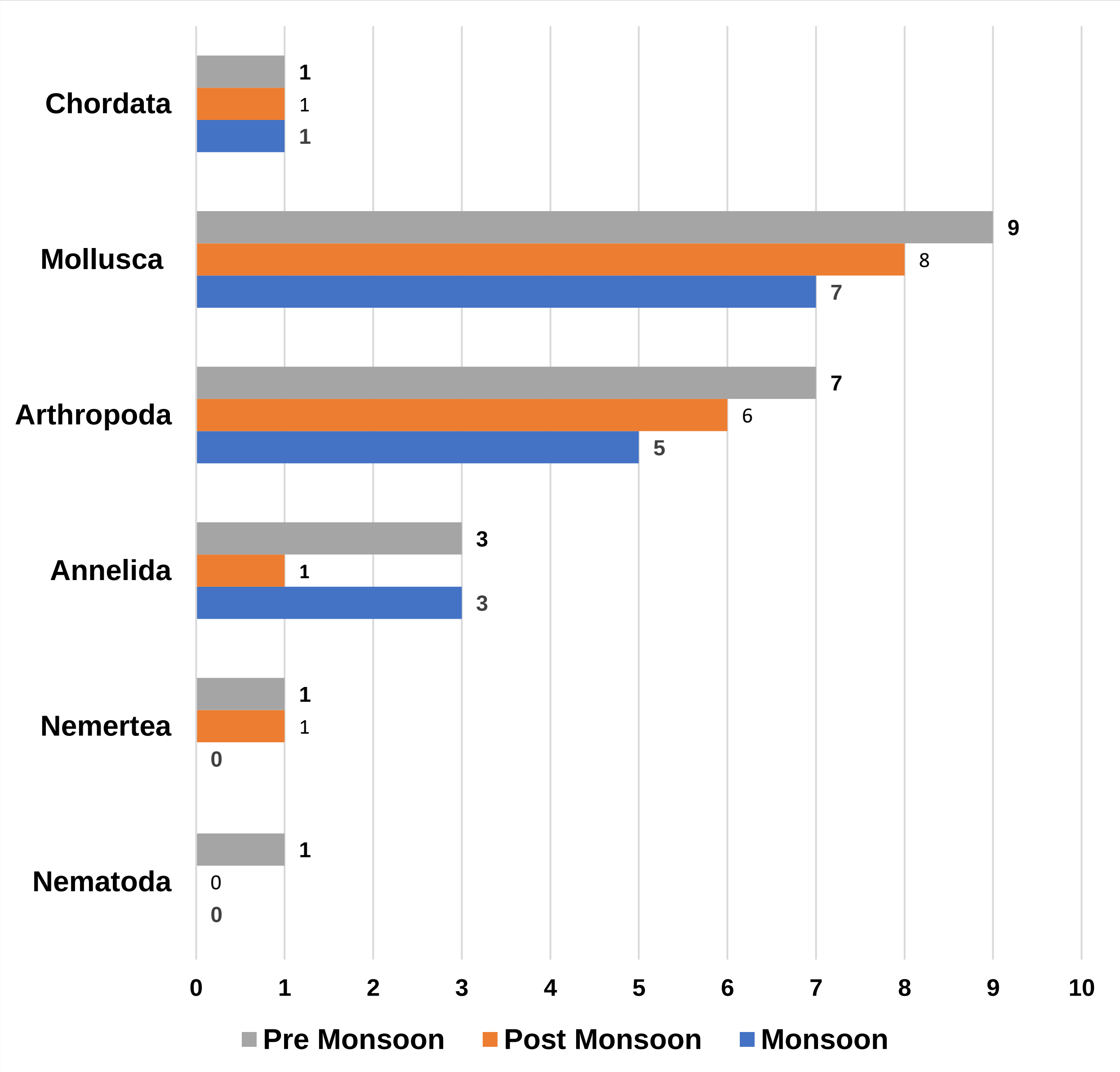


Figure 33. Season wise intertidal faunal diversity during May-2021 to May-2022

Station wise Intertidal Fauna density (No/m^2)

The occurrence of intertidal animals was documented during the three seasons. The highest no of organisms was documented from the pre-monsoon season (21), followed by Post-monsoon (16) and Monsoon (16), respectively. The most common species were the molluscs such as *Pirenella cingulata*, *Optediceros breviculum*, and *Bakawan rotundata*. The lowest density noticed was that of *Indothais lacera* and *Metaplax indica*.(Fig.36).

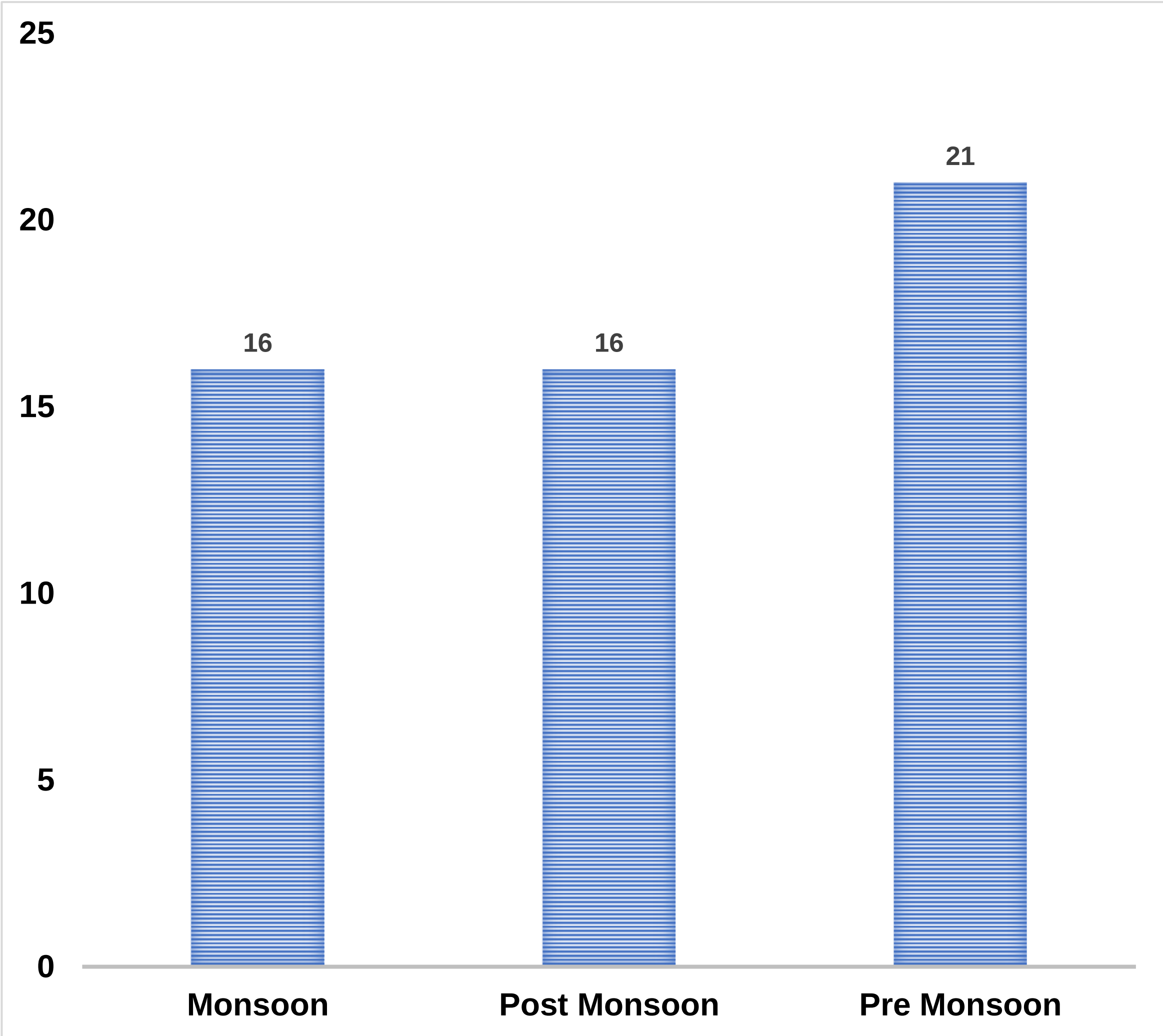


Figure 34. Season wise intertidal faunal diversity during May-2021 to May-2022

Metopograpsus messor

Scylla serrata

Metaplax indica

Austruca sindensis

Austruca iranica

Amphibalanus amphitrite

Plate 9: Intertidal Arthropods fauna of Deendayal Port Authority

Table11. Intertidal faunal distribution (No/m^2) at the selected station in Deendayal Port authority during monsoon 2021

	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
Annelida															
Nereis sp.	3	0	0	7	2	0	0	4	0	0	0	4	0	0	1
Nephtys sp.	0	4	3	0	0	4	0	0	3	0	3	0	0	3	0
Notomastus sp.	0	0	0	2	0	0	3	0	0	2	0	0	1	0	0
Arthropoda															
Scylla serreta	0	1	0	0	4	0	2	0	0	0	3	0	0	3	0
Uca sp.	0	21	9	0	12	19	0	13	4	25	0	11	0	37	0
Amphipods	0	8	0	0	0	9	4	0	0	14	8	5	0	5	0
Isopods	8	0	7	0	5	0	0	4	4	12	0	0	11	0	0
Metopograpsus messor	0	23	0	31	21	0	0	42	0	0	0	14	0	0	14
Mollusca															
Anadara sp.	2	0	5	0	4	0	0	0	3	0	0	0	2	0	3
Piranella cingulata	0	0	24	2	0	0	23	0	9	0	9	0	12	0	0
Optediceros breviculum	12	0	0	11	0	32	0	0	12	0	32	44	0	0	12
Natica sp.	0	2	0	4	0	5	0	5	0	0	0	4	0	0	0
Pholas sp.	5	12	0	0	7	0	12	0	0	13	0	0	8	7	13
Telescopium telescopium	4	0	0	1	0	0	1	0	0	0	1	2	0	0	0
Purpura bufo	0	0	3	0	3	0	2	0	0	0	4	0	0	4	3
Chordata															
Periophthalmus waltoni	0	4	0	7	0	6	11	0	17	0	12	0	0	8	9
Total No/m^2	34	75	51	65	58	75	58	68	52	66	72	84	34	67	55

Table 12. Intertidal faunal distribution (No/m^2) at the selected station in Deendayal Port Authority during Post-monsoon 2021

Arthropoda															
Scylla olivacea	0	1	0	0	4	0	2	0	0	0	3	0	0	3	0
Austruca variegata	0	12	4	7	1	0	13	21	5	8	11	14	0	3	14
Austruca iranica	0	22	0	0	0	0	0	0	0	3	0	7	0	1	1
Metaplax indica	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Tubuca dussumieri	0	1	2	7	11	0	0	13	0	0	0	6	0	0	9
Metopograpsus messor	15	17	22	19	26	31	23	14	15	19	11	17	9	11	19
Amphibalanus amphitrite	0	23	0	31	21	0	0	42	0	0	0	14	0	0	14
Mollusca															
Pirenella cingulata	0	0	111	23	0	6	26	0	5	0	13	0	45	6	0
Telescopium telescopium	0	0	3	5	0	0	11	0	6	0	7	0	7	0	3
Indothais lacera	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0
Bakawan rotundata	6	0	11	0	3	0	37	0	0	0	56	0	0	9	3
Platevindex martensi	0	0	3	0	3	0	2	0	0	0	4	0	0	4	3
Optediceros breviculum	23	11	35	11	0	32	0	0	12	0	32	44	0	0	12
Anadara inaequivalvis	0	2	0	4	0	5	0	5	0	0	0	4	0	0	0
Pholas orientalis	5	12	0	0	7	0	12	0	0	13	0	0	8	7	13
Sheldonella lateralis	4	0	0	1	0	0	1	0	0	0	1	2	0	0	0
Chordata															
Periophthalmus waltoni	0	4	0	7	0	6	11	0	17	0	12	0	0	8	9
Total	129	121	194	130	84	141	141	101	172	45	186	117	70	65	186

Table13. Intertidal faunal distribution (No/m^2) at the selected station in Deendayal Port Authority during pre-monsoon 2022

Intertidal Fauna	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Nemertea															
Nemertea sp.	0	0	0	1	0	1	0	0	0	0	0	0	0	0	5
Annelida															
Nereis sp.	3	0	2	5	4	1	0	0	0	0	0	0	0	0	2
Arthropoda															
Scylla olivacea	0	3	0	0	5	0	6	0	0	0	5	0	0	3	4
Austruca variegata	0	17	6	8	11	0	18	23	12	15	19	17	0	4	9
Austruca iranica	0	2	0	0	0	0	0	0	0	1	0	2	0	1	2
Metopograpsus messor	23	43	34	32	21	17	18	22	11	9	43	28	27	0	21
Tubuca dussumieri	3	2	1	6	9	1	2	1	8	2	1	6	0	0	5
Amphibalanus amphitrite	0	23	0	56	11	0	0	38	0	0	0	21	0	0	14
Mollusca															
Pirenella cingulata	2	8	123	19	0	11	35	0	12	0	8	0	31	6	0
Telescopium telescopium	0	0	2	3	0	0	6	0	2	0	5	0	2	0	1
Bakawan rotundata	8	0	5	0	2	0	15	0	0	0	12	0	0	2	8
Platevindex martensi	0	0	1	0	2	0	0	0	0	0	5	0	0	2	1
Optediceros breviculum	35	42	52	12	7	42	0	0	34	0	15	25	0	0	19
Anadara inaequivalvis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pholas orientalis	2	8	0	0	0	0	0	0	0	0	0	0	0	2	8
Sheldonella lateralis	1	0	0	0	0	0	1	0	0	0	1	2	0	0	0
Chordata															
Periophthalmus waltoni	25	11	15	21	12	7	8	9	11	4	2	9	11	8	5
Total	144	204	246	199	76	131	108	100	154	30	151	156	71	33	212

Piranella cingulata

Optediceros breviculum

Platevindex martensi

Bakawan rotundata

Telescopium telescopium

Umbonium vestarium

Plate.11. Intertidal Molluscs fauna of Deendayal Port Authority

Percentage of composition

In Monsoon the highest percentage composition of intertidal macrofauna was shared by the gastropod *Optediceros breviculum* (16.92%), common mangrove crab *Metopograpsus messor* and juveniles (15.83%) followed by the fiddler crab *Austruca variegata* (16.48 %). The most negligible percentage of diversity was documented from the commercially important crab *Scylla serreta* (1.64%), gastropod *Telescopium telescopium* (0.98%) and the polychaete *Notomastus sp*. (0.87%). Similarly in Post-monsoon the highest percentage composition of intertidal macrofauna was shared by the gastropod *Optediceros breviculum* (30.07%), *Metopograpsus messor* (14.24%), Pirenella cingulata (12.49%) and *Austruca variegata* (6.00%). The lowest percentage of diversity was documented from the *Metaplax indica* (0.05%), *Indothais lacera* (0.37%), *Notomastus* sp (0.43%), *Sheldonella lateralis* (0.48%), Nemertea sp (0.64%) and *Scylla serrata* (0.69%). In Pre-monsoon the highest percentage composition of intertidal macrofauna was shared by the gastropod *Optediceros breviculum* (35.14%) and *Metopograpsus messor* (17.32%). The lowest percentage of diversity was documented from the *Anadara inaequivalvis* (0.05%), *Sheldonella lateralis* (0.25%), *Nemertea* sp (0.35%), *Austruca iranica* (0.40%), *Platevindex martensi* (0.55%), *Nereis* sp(0.84%) and *Pholas orientalis* (0.99%) (figure 35).

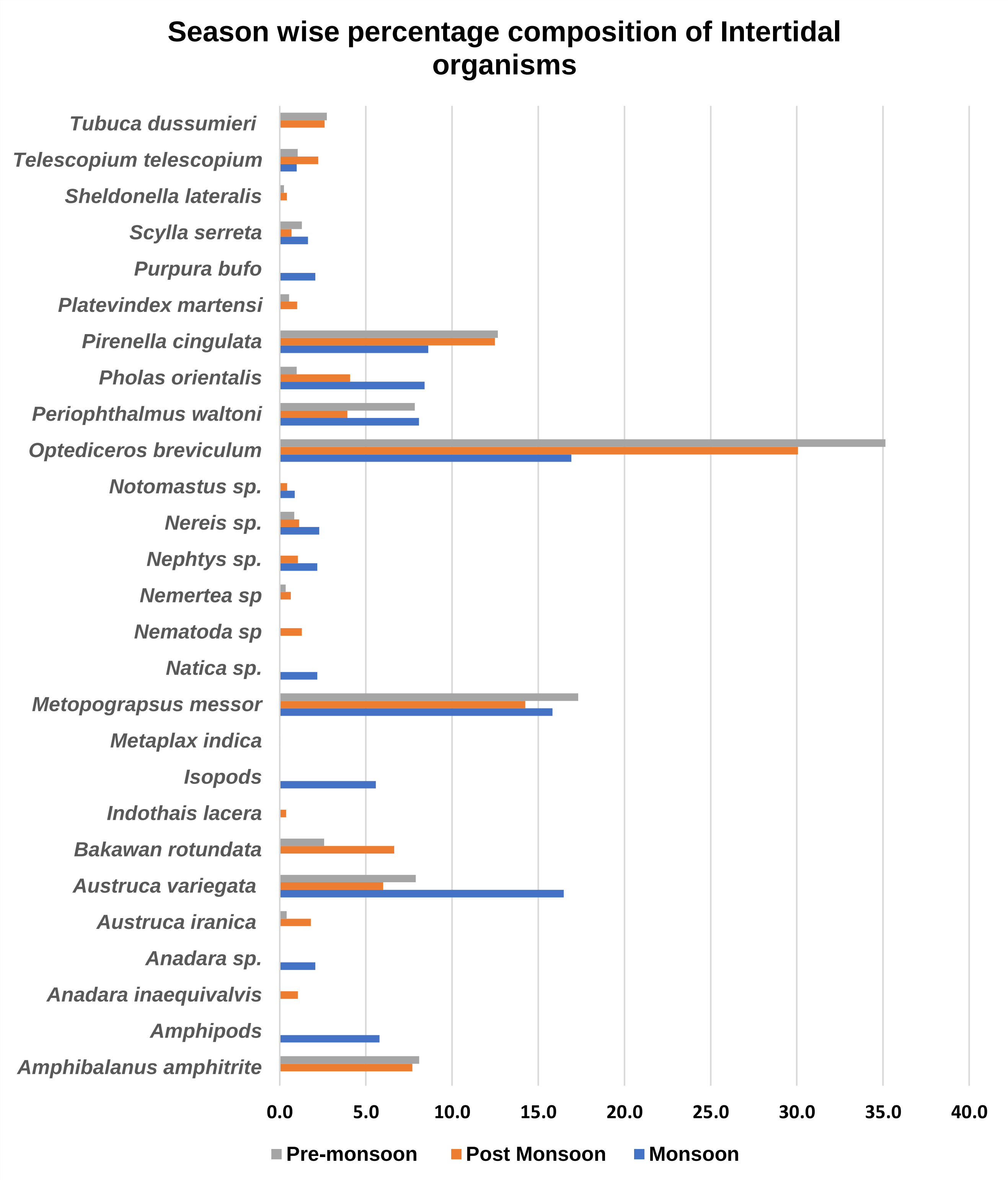


Figure 35. Season wise Percentage composition intertidal faunal diversity May-2021 to May-2022

4.2.5. Subtidal Fauna

Intertidal and subtidal environments may be composed of parts of both estuarine systems and marine systems (Aquatic Ecosystems Task Group, 2012; Cowardin et al., 1979). Subtidal benthic habitats are essential for estuarine and marine life since marine species depend directly or indirectly on the seafloor for food, hide, rest or reproduction and nutrient recycling. The Seasonal difference in rainfall, salinity, nutrients and light intensity might be a remarkable succession in the subtidal diversity. Subtidal ecosystems are permanently submerged owing to tidal influence. However, intertidal ecosystems are found among the high tide and low tide, facing the regular fluctuations and influences from the land and sea (Karleskint, 1998; Levinton, 1995; Pitcher et al., 2007; Rees, 2009). The intertidal and subtidal mangrove forests are important nurseries for the breeding ground of many species of fishes and crustaceans. They provide food and shelter for the larval and juvenile stages. Most soft bottom subtidal animals are dominated by infaunal or burrowing invertebrates such as polychaetes, crustaceans, and molluscs. These organisms associated with soft bottom subtidal environments provide various environmental services, such as nutrient recyclers, deposit feeders and microorganisms living within the sediments (Chaves and Bouchereau, 1999; Vendel et al., 2002).

Phylum wise and season wise density of subtidal fauna

The subtidal Fauna of the DPA Kandla survey recorded the presence of 5 phyla (Cnidaria, Annelida, Arthropoda, Mollusca, and Chordata), including 32 species. The species diversity was the highest in phylum Mollusca (21species), followed by Annelida (6 species), Arthropoda (3 species), and Cnidaria, Chordata 1 species, respectively. The occurrence of intertidal animals was documented during the three seasons. The highest no of organisms was documented from the Monsoon season (459), followed by Post-monsoon (411) and Pre-monsoon (410), respectively (Fig.38 &39).

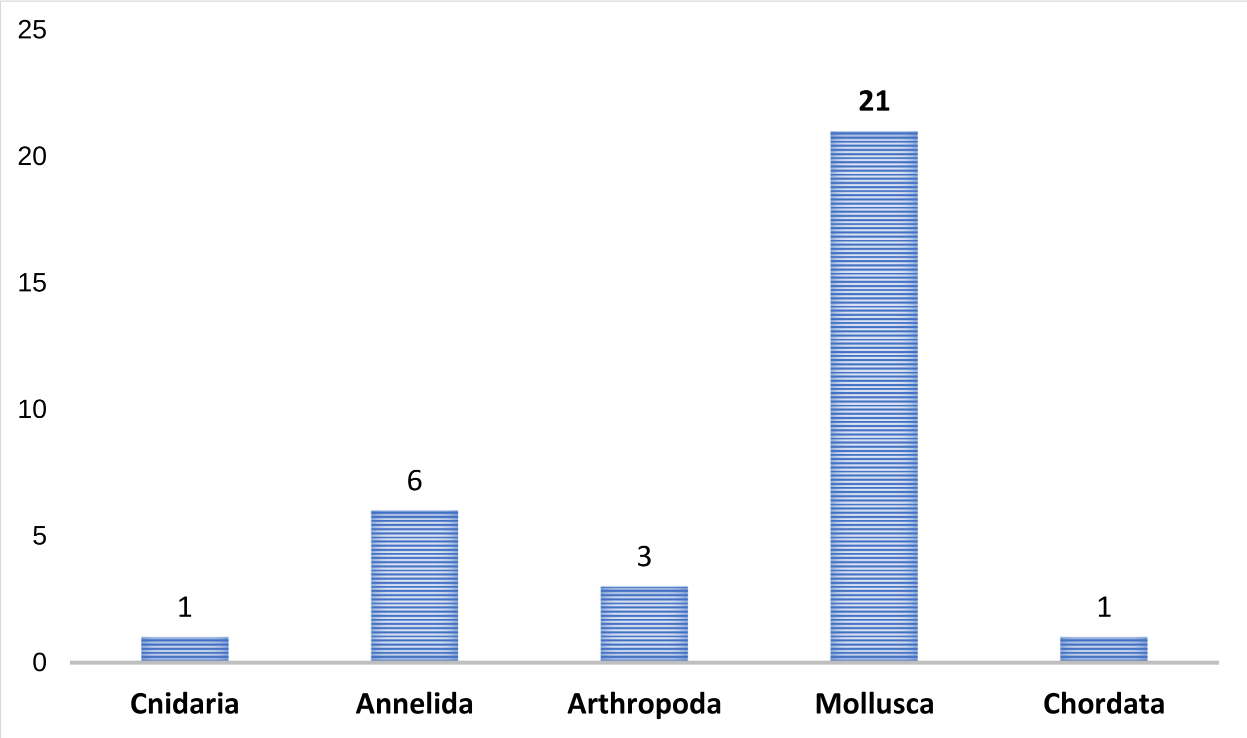


Figure 36. Phylum wise subtidal faunal diversity during May-2021 to May-2022

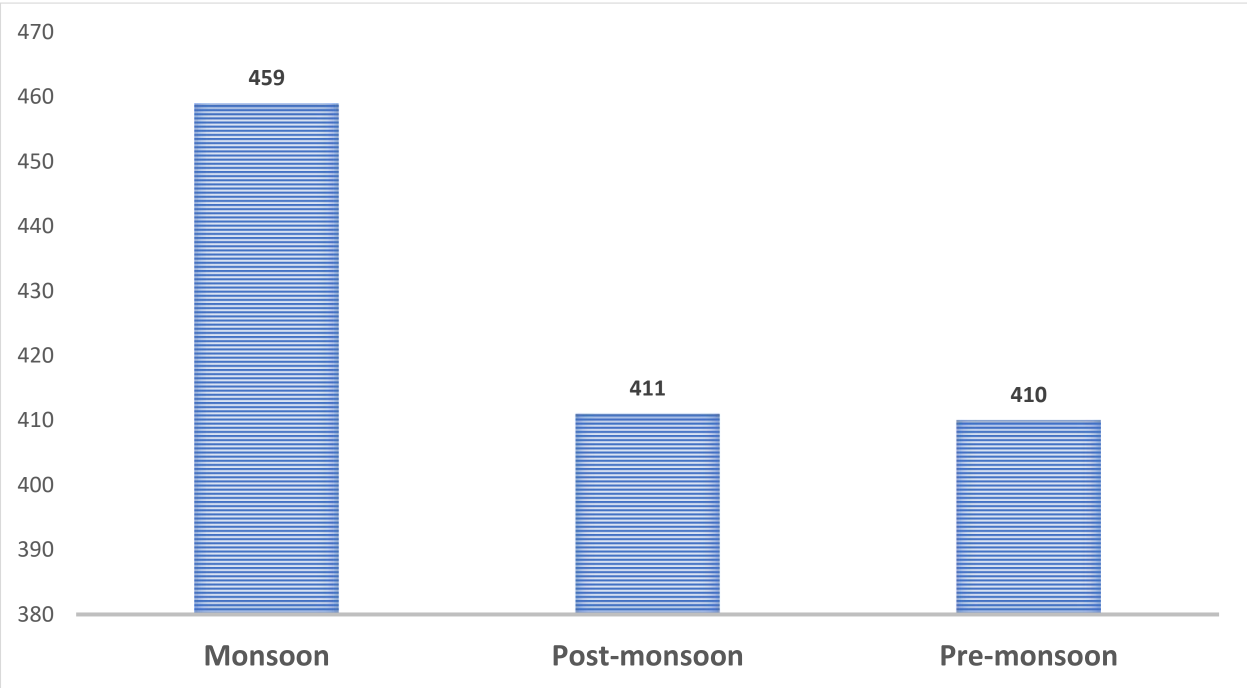


Figure 37. Season wise subtidal species density (No/m^2) during May-2021 to May-2022

Phylum wise and season wise subtidal diversity

The subtidal Fauna of the DPA Kandla survey recorded 32 species classified under five phyla (Cnidaria, Annelida, Arthropoda, Mollusca, and Chordata). Mollusc diversity was very high (21species) in all the seasons; during the pre-monsoon and post-monsoon (13 species), and Monsoon (11 species), respectively. The second most dominant phyla, Annelida sharing (6 Species) in all seasons. The least diversity was documented in the other phyla, such as Chordata and Cnidaria (1 species), respectively (Fig.40). Post-monsoon period, the highest number of animals was documented from stations S- 14, and the least were documented from S-8 and S-12. During the monsoon period, the highest number of animals was documented from stations S-9, and the least were documented from S-15. S-3, 11, and 15 and the least were documented from S-10. Pre-monsoon period, the highest number of animals was documented from stations S- 6, and the least were documented from S-1 and S-10. While comparing the three seasons Post-monsoon period, the least number of animals was documented from all the stations (Fig.41). The occurrence of subtidal animals was documented during the three seasons. The highest number of organisms was documented from the pre-monsoon season and Post-monsoon (22 species), and Monsoon (21). The most common species were the molluscs such as Pirenella cingulata and Optediceros breviculum; the lowest density noticed was that of *Stephensonactis* sp. and *Dosinia sp* (Fig.42)

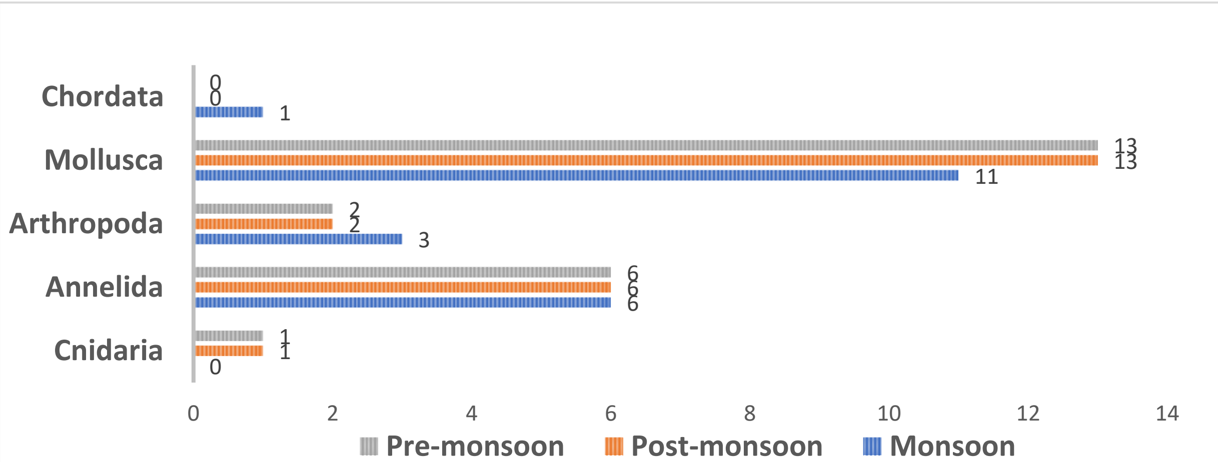


Figure 38. Seasonal variation in phyla diversity during May-2021 to May2022

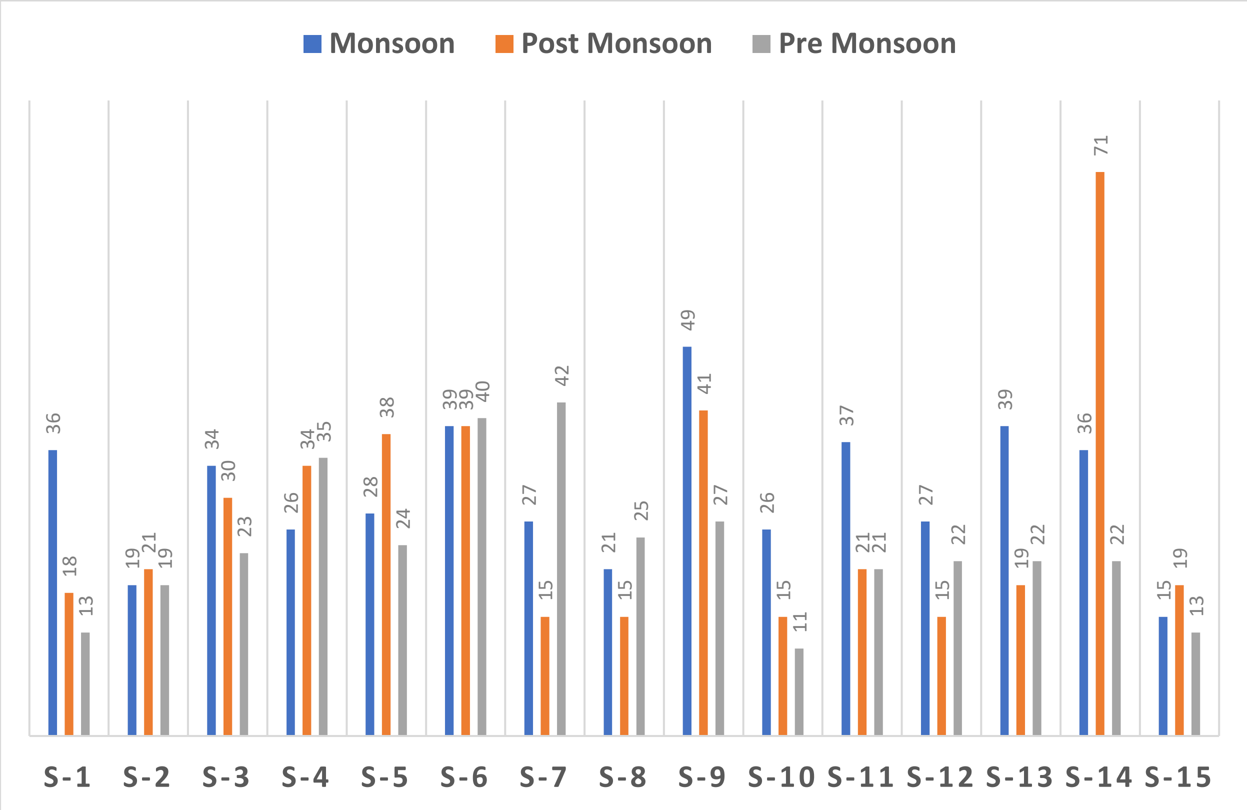


Figure 39. Subtidal Fauna density variation between the stations during (2021-2022)

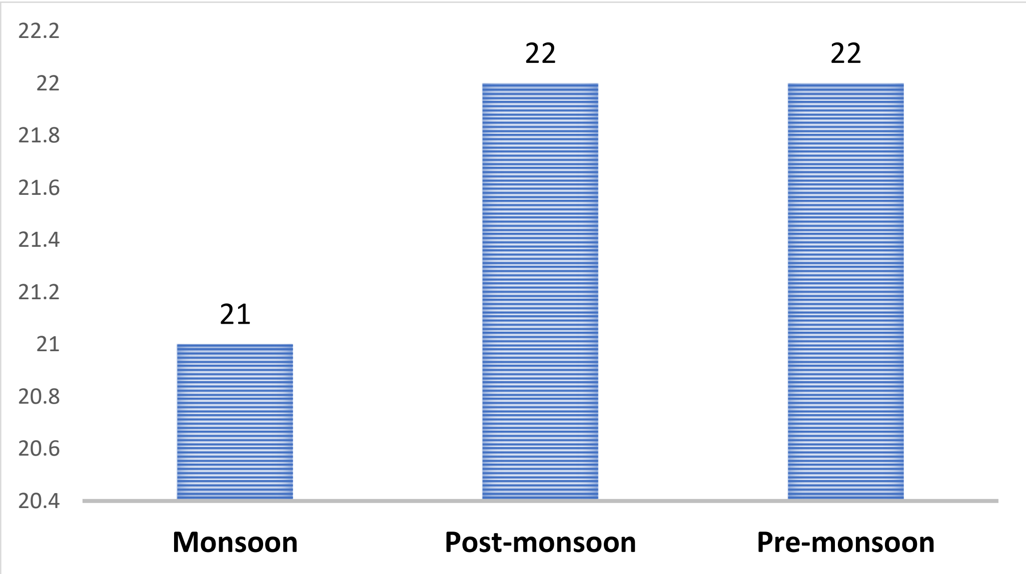


Figure 40. Season wise variation in subtidal organism

Table 14. Subtidal faunal distribution (No/m^2) at the selected stations during post-monsoon 2021

	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	Total
Annelida																
Capitella sp.	0	3	0	0	3	0	0	0	5	4	3	1	0	3	0	46.67
Glycera sp.	0	1	0	0	0	0	2	0	2	0	0	0	3	0	0	26.67
Lumbrineries sp.	1	0	4	3	0	0	1	0	0	2	0	2	2	0	2	53.33
Nephtys sp.	5	0	2	0	0	3	0	2	3	0	0	0	0	1	0	40
Nereis sp.	0	3	1	1	0	4	0	0	3	1	4	0	0	0	3	60
Notomastus sp.	2	0	0	2	0	3	0	0	2	0	0	0	4	0	0	33.33
Arthropoda																
Ampithoe sp.	0	0	0	0	2	0	0	1	3	0	0	2	0	2	0	33.33
Angliera sp.	1	0	3	0	0	2	0	0	1	0	2	1	0	0	0	40
Penaeus sp.	0	2	0	0	1	4	0	0	3	0	2	0	2	1	3	53.33
Mollusca																
Anadara sp	1	3	0	0	3	0	0	0	5	5	3	1	0	3	0	53.33
Argopectn sp.	0	1	0	0	0	0	2	0	2	0	0	0	3	0	0	26.67
Barbatia sp.	2	0	4	5	2	0	2	0	0	0	3	0	0	7	0	46.67
Cerithidea sp	2	0	2	2	0	0	0	0	1	2	0	1	3	0	1	53.33
Crassostrea sp.	3	0	2	3	0	0	2	2	0	3	2	0	0	0	0	46.67
Meretrix veliger	2	0	2	4	0	3	0	2	4	0	2	2	0	0	0	53.33
Pholas sp.	12	0	7	0	13	12	14	9	11	0	11	8	15	12	0	73.33
Placenta sp.	0	0	2	1	0	0	0	2	0	1	1	4	0	0	0	40
Saccostrea sp.	1	2	0	3	2	1	4	0	2	3	0	0	5	2	3	73.33
Telescopium sp.	3	4	3	2	0	6	0	0	0	3	1	5	0	5	0	60
Turritella sp.	0	0	1	0	0	1	0	0	2	0	0	0	2	0	3	33.33
Chordata																

Fish larvae	1	0	1	0	2	0	0	3	0	2	3	0	0	0	0	40
Total	36	19	34	26	28	39	27	21	49	26	37	27	39	36	15	
Total No/m2	900	475	850	650	700	975	675	525	1225	650	925	675	975	900	375	

Table 15. Subtidal faunal distribution (No/m2) at the selected sites during Post-monsoon

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	% of Occurrence
Stephensonactis sp.	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	6.6
Capitella sp.	0	3	0	0	3	0	0	0	5	4	3	1	0	3	0	46.6
Glycera sp.	0	1	0	0	0	0	2	0	2	0	0	0	3	0	0	26.6
Lumbrineries sp.	1	0	4	3	0	0	1	0	0	2	0	2	2	0	2	53.3
Nephtys sp.	5	0	2	0	0	3	0	2	3	0	0	0	0	1	0	40
Nereis sp.	0	3	1	1	0	4	0	0	3	1	4	0	0	0	3	53.3
Notomastus sp.	2	0	0	2	0	3	0	0	2	0	0	0	4	0	0	33.3
Ampithoe sp.	0	0	0	0	2	0	0	1	3	0	0	2	0	2	0	33.3
Penaeus sp.	0	2	0	0	1	4	0	0	3	0	2	0	2	1	3	53.3
Umbonium vestiarium	1	0	0	2	0	3	0	1	0	1	0	0	0	3	0	40
Mitrella blanda	0	0	0	0	0	0	0	0	0	0	2	0	0	7	0	13.3
Clypeomorus bifasciata	0	0	0	0	0	0	0	2	12	0	2	3	0	6	1	33.3
Natica sp	0	0	0	1	0	0	0	0	0	0	0	0	1	12	0	20
Optediceros breviculum	4	5	6	4	11	2	3	2	1	0	0	0	0	5	3	73.3
Pirenella cingulata	5	0	5	6	7	11	1	2	3	1	5	4	3	1	2	93.3
Turritella sp	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	6.6
Marcia sp.	0	0	3	2	0	1	2	3	0	0	0	1	2	11	2	60
Glauconome angulata	0	2	7	11	14	8	6	2	0	6	3	2	0	0	0	66.6
Dosinia sp	0	0	2	2	0	0	0	0	0	0	0	0	0	3	0	20

Gafrarium divaricatum	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	20
Meretrix sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	6	1	20
Solen sp.	0	0	0	0	0	0	0	0	4	0	0	0	0	6	0	13.3
Total	18	21	30	34	38	39	15	15	41	15	21	15	19	71	19	
Total No/m^2	450	525	750	850	950	975	375	375	1025	375	525	375	475	1775	475	

Table 16. Subtidal faunal distribution (No/m2) at the selected sites during Pre-monsoon 2022

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	% Of Occurrence
Cnidaria																
Stephensonactis sp.	0	0	0	0	1	1	0	1	0	0	0	2	0	0	0	26.6
Annelida																
Capitella sp.	0	2	0	0	0	0	0	3	3	1	4	0	0	4	0	40
Glycera sp.	1	1	0	0	0	0	1	0	0	0	1	1	0	0	0	33.3
Lumbrineries sp.	0	1	0	0	0	1	0	0	1	2	2	2	2	0	0	46.6
Nephtys sp.	2	0	0	0	0	0	2	0	1	1	1	0	3	1	0	46.6
Nereis sp.	0	2	1	1	1	1	1	0	0	3	0	0	0	0	2	53.3
Notomastus sp.	1	0	0	1	0	1	3	2	0	0	0	0	1	0	0	53.3
Arthropoda																
Ampithoe sp.	3	0	0	0	0	2	0	0	0	0	0	2	2	3	0	33.3
Penaeus sp.	0	3	1	2	0	1	2	0	0	0	0	2	1	0	0	46.6
Mollusca																
Umbonium vestiarium	0	0	0	1	0	3	5	3	2	0	0	0	0	7	0	40
Mitrella blanda	0	0	0	2	0	2	0	2	1	0	2	0	0	7	0	40
Clypeomorus bifasciata	0	0	0	2	0	1	0	1	9	0	3	3	0	9	2	53.3
Natica sp	0	0	0	1	0	0	4	2	0	0	1	1	0	11	0	86.6
Optediceros breviculum	4	5	11	6	9	2	3	2	2	1	0	2	0	6	1	86.6

Pirenella cingulata	2	0	2	4	6	8	2	2	6	0	2	2	1	3	3	86.6
Turritella sp	0	0	0	1	1	1	1	0	0	0	0	0	0	4	0	33.3
Marcia sp.	0	0	1	0	1	2	6	5	0	0	0	5	0	7	2	53.3
Glauconome angulata	0	2	5	9	4	12	2	1	0	2	4	1	0	2	0	40
Dosinia sp	0	0	1	2	0	1	1	0	0	0	0	2	0	1	0	40
Gafrarium divaricatum	0	1	0	1	0	1	4	0	0	0	0	0	1	2	1	46.6
Meretrix sp.	0	2	1	2	1	0	3	1	0	1	0	0	0	2	2	60
Solen sp.	0	0	0	0	0	0	2	0	2	0	1	1	0	11	0	33.3
Total	13	19	23	35	24	40	42	25	27	11	21	22	22	22	13	26.6
Total No/m^2	325	475	575	875	850	1000	1050	625	675	275	525	550	550	550	325	

Percentage of composition

During monsoon the highest percentage composition was shared by the common bivalve *Pholas orientalis* (27.01%) and *Telescopium telescopium* (6.97%). A minuscule percentage of diversity was documented from the *Argopectn* sp. (1.74%), *Glycera* sp. (1.74%) and Turritella sp. (1.96%). The post-monsoon the highest percentage composition of subtidal macrofauna was shared by the muddy shore bivalve *Glauconome angulata* (14.84%), *Optediceros breviculum* (11.19%), *Pirenella cingulata* (13.63%). The lowest percentage of diversity was documented from the muddy associated sea anemone *Stephensonactis* sp. (0.49%), *Turritella* sp. (0.49%) and *Gafrarium divaricatum* (1.22%) In Pre-monsoon the highest percentage composition of intertidal macrofauna was shared by the microgastropod *Optediceros breviculum* (13.17%) and muddy shore associated gastropods *Clypeomorus bifasciata* (7.32%), *Pirenella cingulata* (10.49%) and the bivalve *Glauconome angulata* (10.73%). The lowest percentage of diversity was documented from the sediment associated sea anemone *Stephensonactis* sp. (1.22%), *Glycera* sp. (1.22%), *Turritella* sp. (1.95%) and *Dosinia* sp. (1.95%) respectively. (Fig.43).

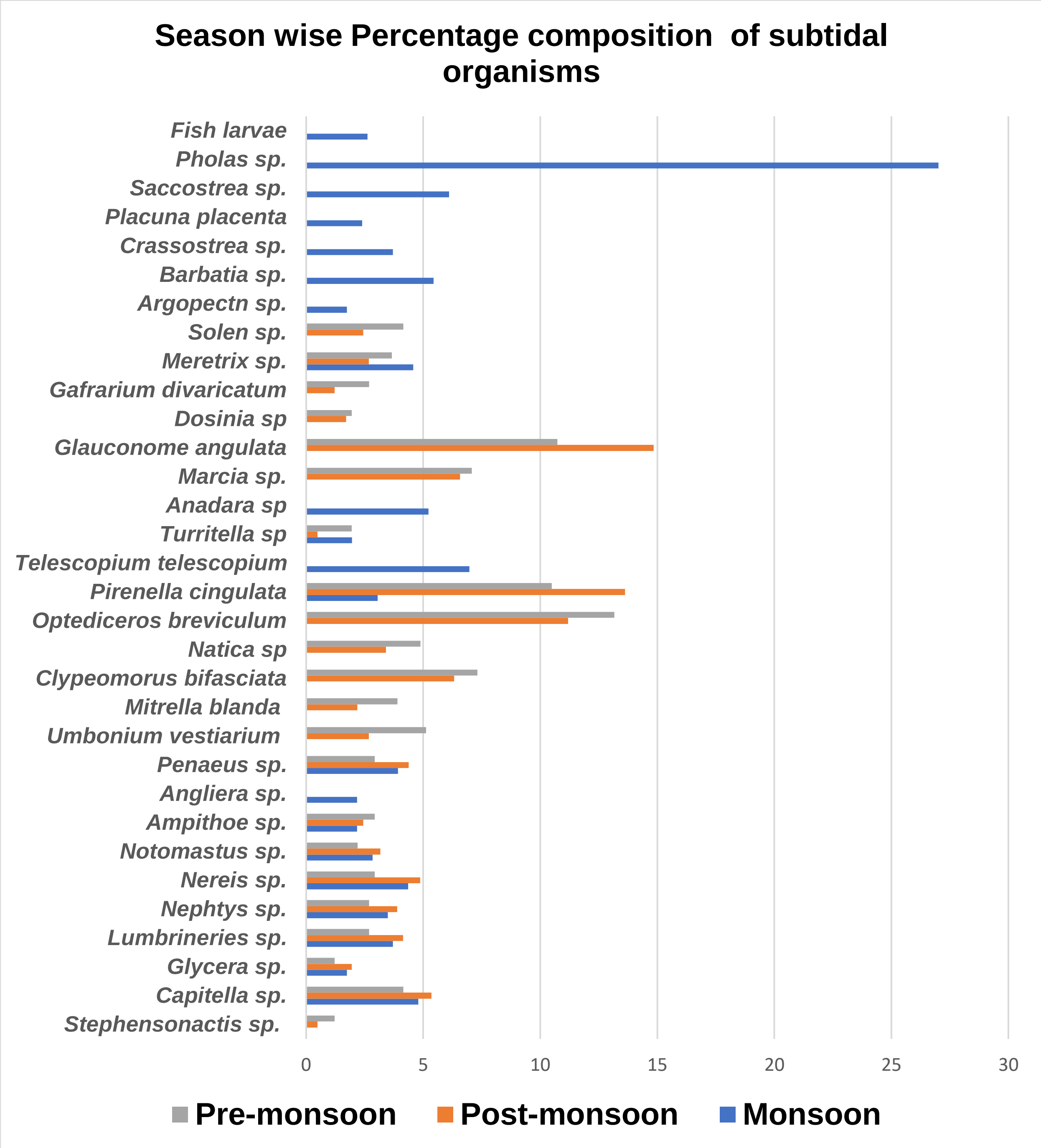


Figure 41 Percentage composition of subtidal organisms from May 2021 to May 2022

4.3. Mudflats

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 a direct indicator of mudflat productivity and blue carbon sequestration.

4.3.1. Bulk density of the sediment

The data on the bulk density of the sediment samples are presented (Fig.44). Among the station of DPA port area the maximum bulk density ranges from 1.27 g/cm^3 to 1.58 g/cm^3 and the minimum bulk density ranges was 1.01 g/cm^3 to 1.39 g/cm^3. Station wise the highest bulk density was recorded at station S-13 both in post-monsoon and pre-monsoon season (1.58 g/cm^3), whereas lowest bulk density was recorded in station S-7 during pre-monsoon (1.01 g/cm^3.).

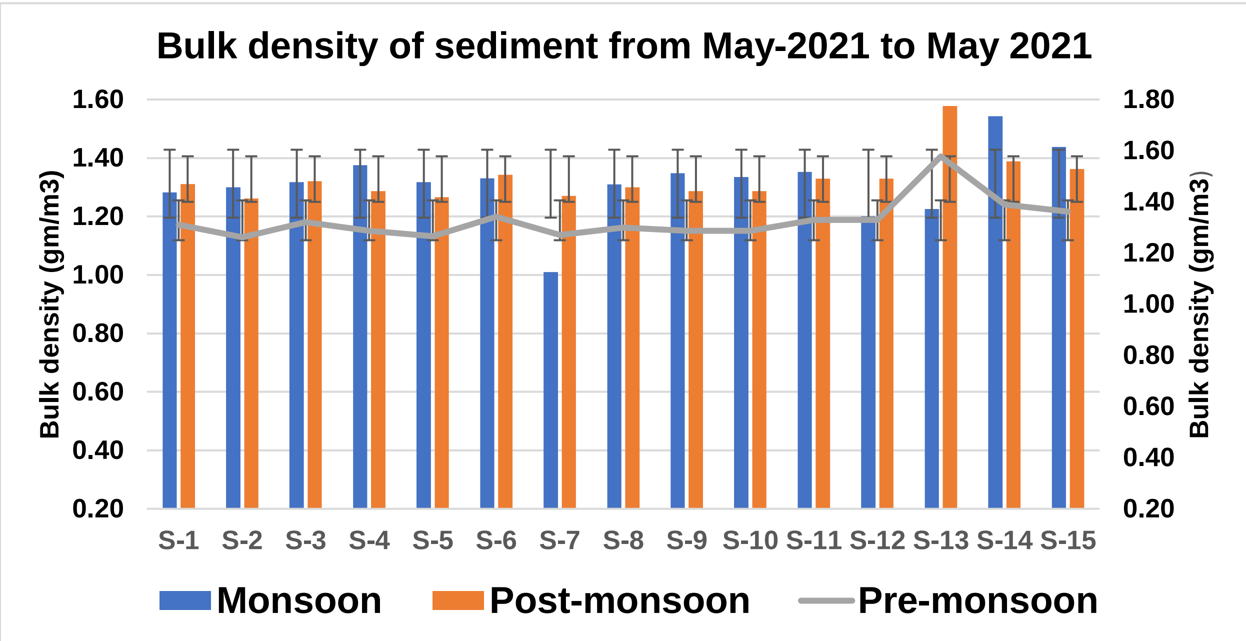


Figure 42 Bulk density of sediment from May 2021 to May 2022

4.3.2. Total Organic Carbon (TOC)

The data on the total organic carbon of the sediment samples are presented (Fig.45).Among the station of DPA port area the maximum sediment carbon ranges from 0.48% to 1,10% to and the minimum sediment carbon ranges was 0.10% to 0.56%. Station wise the highest sediment carbon was recorded at station S-13 during monsoon (1.10%), whereas lowest bulk density was recorded in station S-3 during same season (0.14%.).

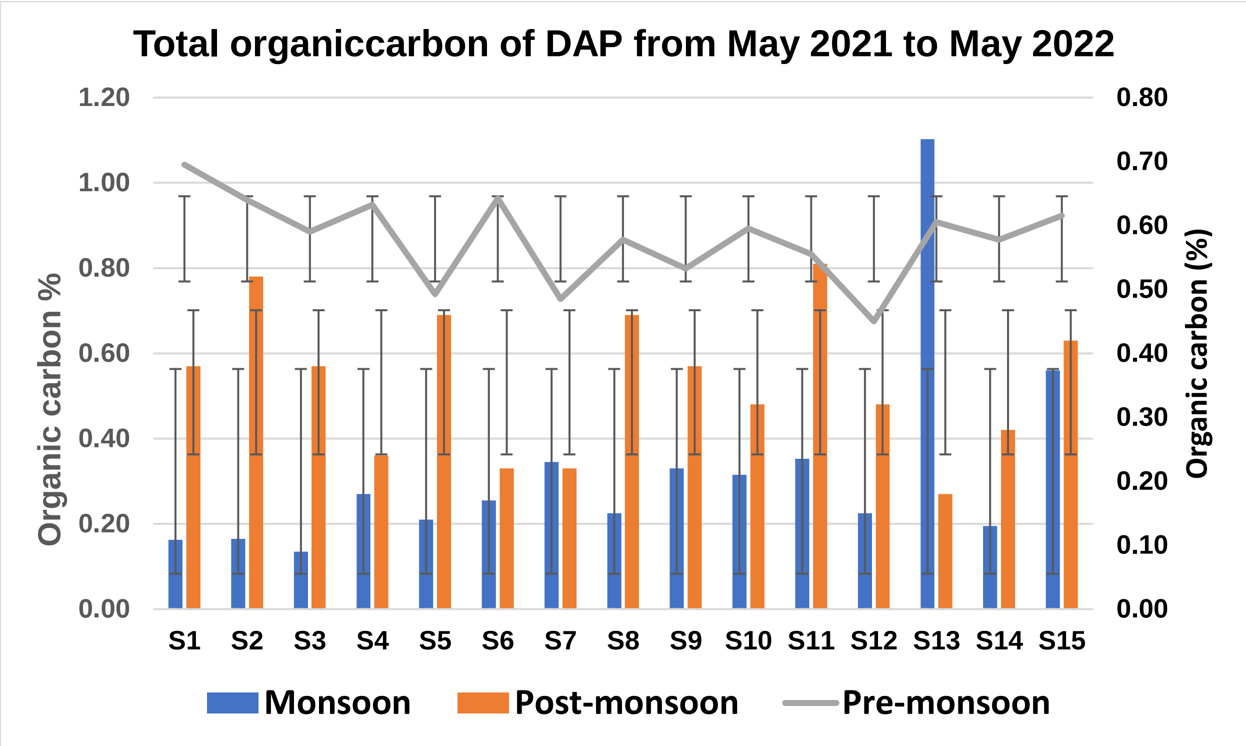


Figure 43. Percentage of organic carbon in sediment from May 2021 to May 2022

4.4. Mangroves

Mangroves are the diverse group of plants which show a common ability to survive and grow in saline waterlogged soils of coastal areasHowever, the existance of mangrove at the certain location is dependent on a few environmental factors such as climatic conditions, salinity, level, tidal fluctuation, soil characteristics and wind velocity (Vaghela et al., 2021). Temperature range of 15–25 C can be suitable for them to thrive, bellow or up to this range can affect their growth rate and even overall survival. The rise in temperature can effect on the mangrove growth as photosynthesis process get declined. Mangrove ecosystem is one of the most important salt tolerant evergreen forest ecosystems found in the tropical and subtropical intertidal regions worldwide. It shows its present in 123 countries with various species composition, biophysical and geomorphological features. The worldwide extent of mangrove is 10 to 24 million hectors which lays between 32_ N and 38_ S latitude (FAO, 2010). Although they play an important role global environment by providing various ecological services (Kumari et al., 2020) such as habitat for many terrestrial and marine organisms (Nagelkerken et al., 2008), various resources including food, shelter and habitat, breeding sites for aquatic fauna; they are under severe threats from a range of causes (Hai et al., 2020). In case of India, mangroves account only for 4% of its worldwide distribution with an extent of 4975 km^2. As the Gujarat state of India has largest coastal area, it accounts approximately 23 % of Indian mangrove (1177 km^2) under mangrove and which make it second largest in the country. In Gujarat, Gulf of Kachchh (GOK) account major mangrove density, however, it is dominated by single species *Avicennia marina*. As mangroves are adapted to various extreme environmental conditions like higher salinity and high temperature levels, they can be suitable candidates in the area of Katchchh. This area features various environmental settings such as arid hinterland, extreme evapotranspiration rate, and annual rainfall is lowest (approximately 348 mm). As *A. marina* has higher saline tolerance capability among other mangrove species, it is dominated in this area, however, three more true mangrove species occasionally can be observed which are, *Rhizophora mucronata, Ceriops tagal* and *Aegiceras corniculatum.*

With these mangrove species, the coastal areas of Kachchh also habitat to various halophytes and mangrove associate plants such as *Salvadora oleoides, Suaeda* *fruticosa, Suaeda nudiflora*. Mangrove cover accounts almost 798 km^2 which is 1.75% of total geographical area of Kachchh (FSI, 2017). The DPA Kandla project region has a long intertidal zone with many creeks and an presence of mangroves. Such mangroves should be monitored to understand the changes in their features to get the idea about their responses to climatic changes and anthropogenic activites. This can further help in the management plans for the protection of mangrove ecosystems and their sustainable use (Medeiros and Sampaio, 2008). In this project, the mangrove vegetation attributes at 13 sampling stations within the DPA port area for the analysis of various vegetation attributes including density, diversity, plant height, girth, canopy cover etc of mangroves. With this, the impacts of physical processes which are influencing the mangrove ecosystem in port area were also summarized. The importance of study is to draw a holistic preservation and management plan and the end users of this document will be the port authorities.

4.4.1. Tree Density

During the monsoon season a total of 14 sampling sites were surveryed and overall average density was recorded as 3198 plants/ha (fig.46). Station wise study, the hightest mean plant density was at Kandla creek area (5444/ha) followed by Kharo creek (5289/ha) and Phang creek (3631/ha). The lowest tree density (1433 trees/ha) was reported at S9. The density of mangrove trees was in the order Kandla creek > Kharo creek> Phang creek > Tuna Creek> Jangi creek> Navlaki creek > Vira coastal area. From this, it could be concluded that the variability in mangrove formation was in accordance to the geomorphology and environmental characteristics of the Kandla coastal regions.

During the post-monsoon 2021, S-13 in Veera creek and S-1 in Tuna creek were not surveyed due to certain reasons. Among surveyed total 13 stations, the mean plant density was maximum at Tuna creek (3915/ ha), followed by Navlakhi creek (3644/ Ha). The highest average tree density was reported at S7 in the Kharo creek area (5524/Ha) andlowest density in individual site is recorded in the site S-5 at Phang creek.

Similar to post-monsoon survey, for pre-monsoon 2022 study, total 13 sites (From S-2 to S-12 and S-14 and S-15) were surveyed for recoding the plant growth parameters. The highest mean plant density was maximum at Navlakhi creek (6519/Ha), followed by Kandla creek (5018/Ha). Considering the sampling sites individually the highest tree density was reported at S4 in the Kandla creek area (8318/Ha). The lowest average tree density (3188 trees/Ha) was reported in Phang creek, however, the lowest density in individual site is recorded in the site S-15 at Kandla creek.

As the sampling points of mangroves chosen for all these three seasonal studies (monsoon, post-monsoon, and pre-monsoon) were not exactly the same location and had been selected randomly to represent the whole area. With this, the responsible environmental factors show difference in the vegetation structure of mangroves at sampling stations.

Finally in summary, the overall average density of trees for monsoon 3241 plants/ ha, for post-monsoon 3410 plants/ha and pre-monsoon 4483 plants/ha were recorded.

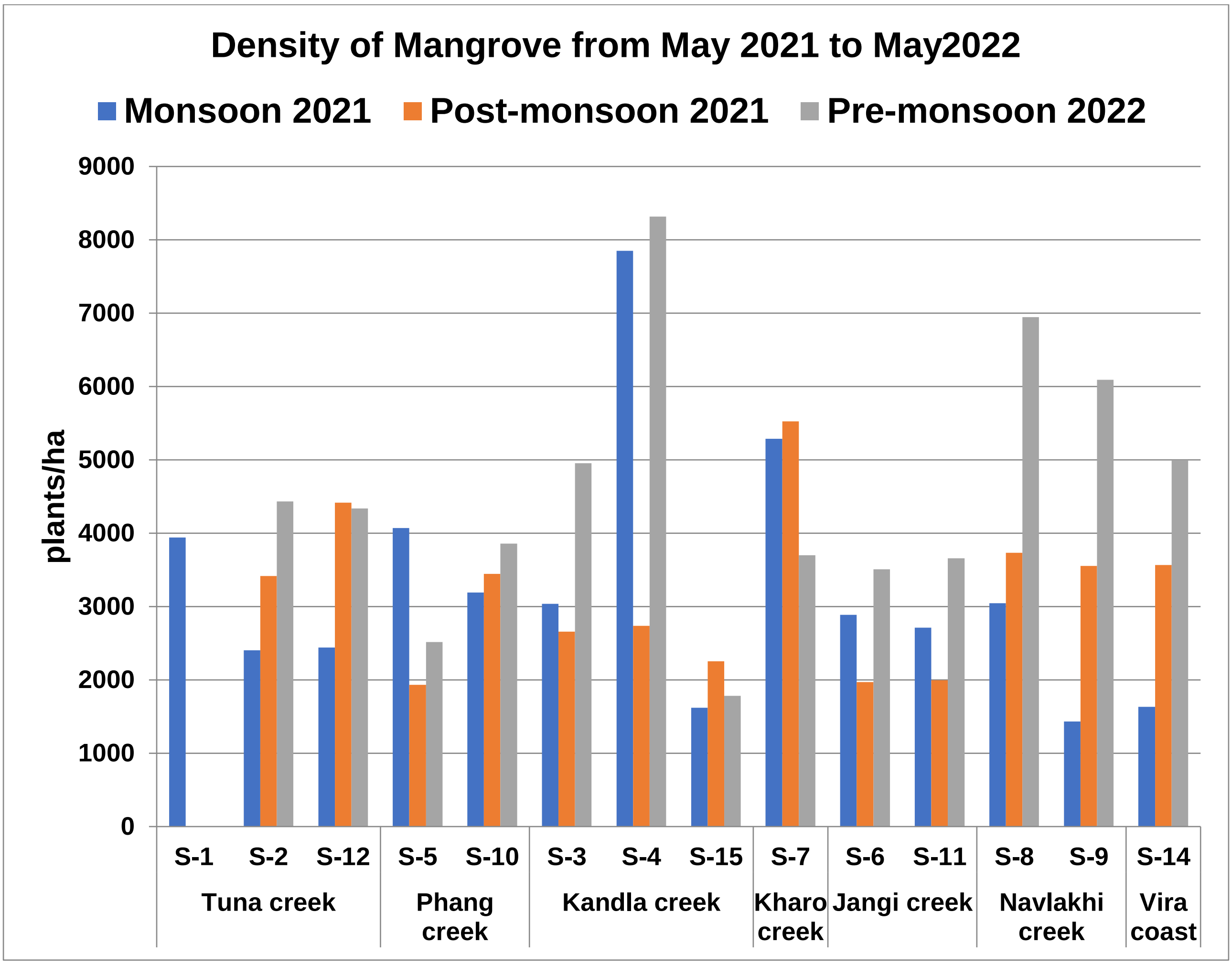


Figure 44. Density of mangrove from in Deendayal Port Authority area

4.4.2. Tree Height

In three seasons, mangroves had been found with the mean height 1.36 m, 1.13 m and 1.01 m for monsoon 2021, post-monsoon 2021-22 and pre-monsoon 2022, respectively (Fig.47). An increase in the plant height was noticed during monsoon of 2021. The height of mangroves at various stations were found in between 1 m to 4.7 m during monsoon. However, during the post-monsoon season, tree height varied from 0.5 m to 1.6 m in various stations. During the pre-monsoon 2022, the overall mean height of the mangroves was found 101 cm. The highest average tree height was found at Navlakhi creek area (214 cm) followed by Tuna creek (119 cm). The hightest tree height was recorded in station S-9 of Navlakhi creek. Finally in summary, the overall average height of trees for monsoon 129 cm, for post-monsoon 110 cm and for pre-monsoon, 101 cm were recorded.

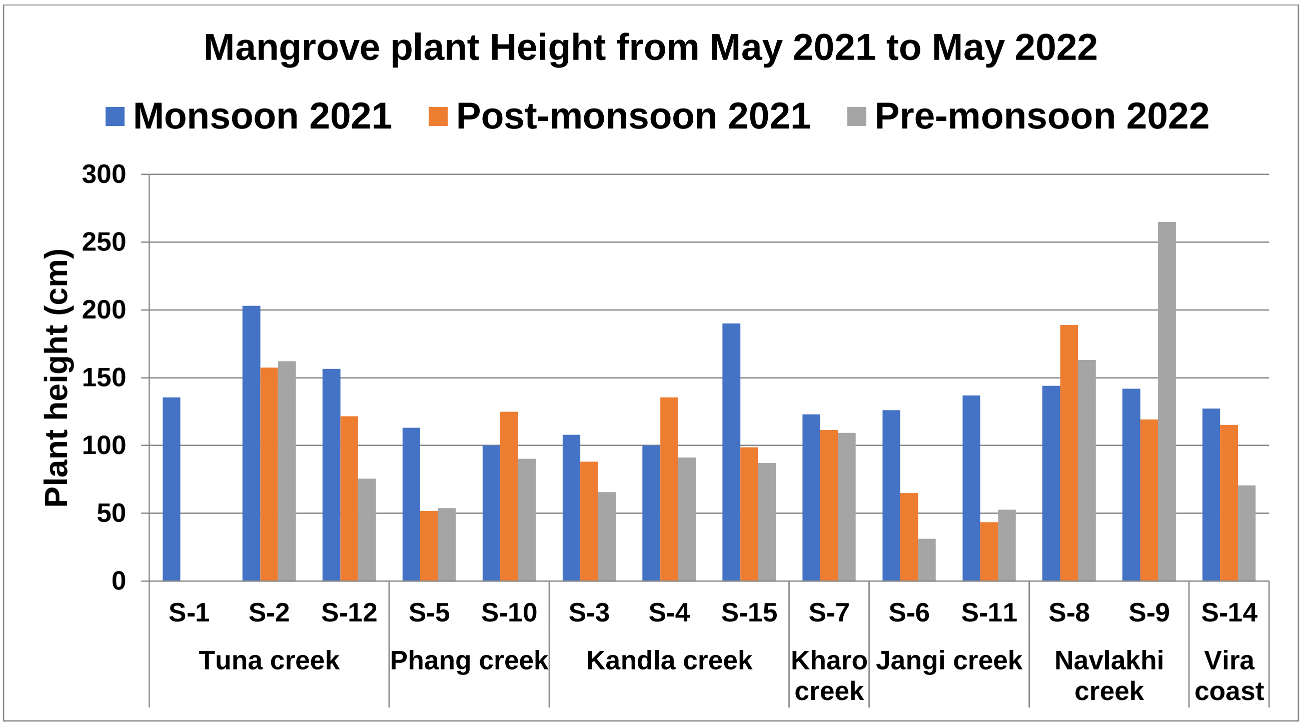


Figure 45. Mangrove plant height from in Deendayal Port Authority

4.4.3. Canopy Crown Cover

There were wide variations observed in the mangrove tree canopy cover in all stations during three seasons. During the monsoon, the canopy cover was found larger compared to other seasons. During monsoon of 2021, it was 2.97 m2 (overall mean), however reduced in the post-monsoon 2021 to 2.06 m2. During the pre-monsoon of 2022, it was again reduced to 1.29 m2. During monsoon, the widest canopy cover was observed at S-13 station near the oil jetty (35.33 m) and stations S-3 and S-5 also showed relatively large canopy cover. However, the station S-1 of Tuna creek showed lowest canopy cover ranging from 0.16m to 2.89 m. During post-monsoon, stations S-2, S-4 and S-8 showed relatively larger canopy cover and stations S-14, S-6, and S-3 showed lower canopy cover (Fig.48). However, the lowest canopy cover was reported at S-7 ranging from 0.2 to 5.06 m^2. During pre-monsoon of 2022, the stations S-2, S-8 and S-15 showed relatively large canopy cover, however, S-3, S-12,, and S-7 stations show lower canopy cover. Among the creek environments of DPA. The mean mangrove canopy was maximum at Kandla (19.13m) followed by Phang creek (18.85m) during monsoon, however, during post-monsoon, the maximum canopy cover was found at Navlakhi (26.63 m) followed by Phang creek (23.20 m^2).

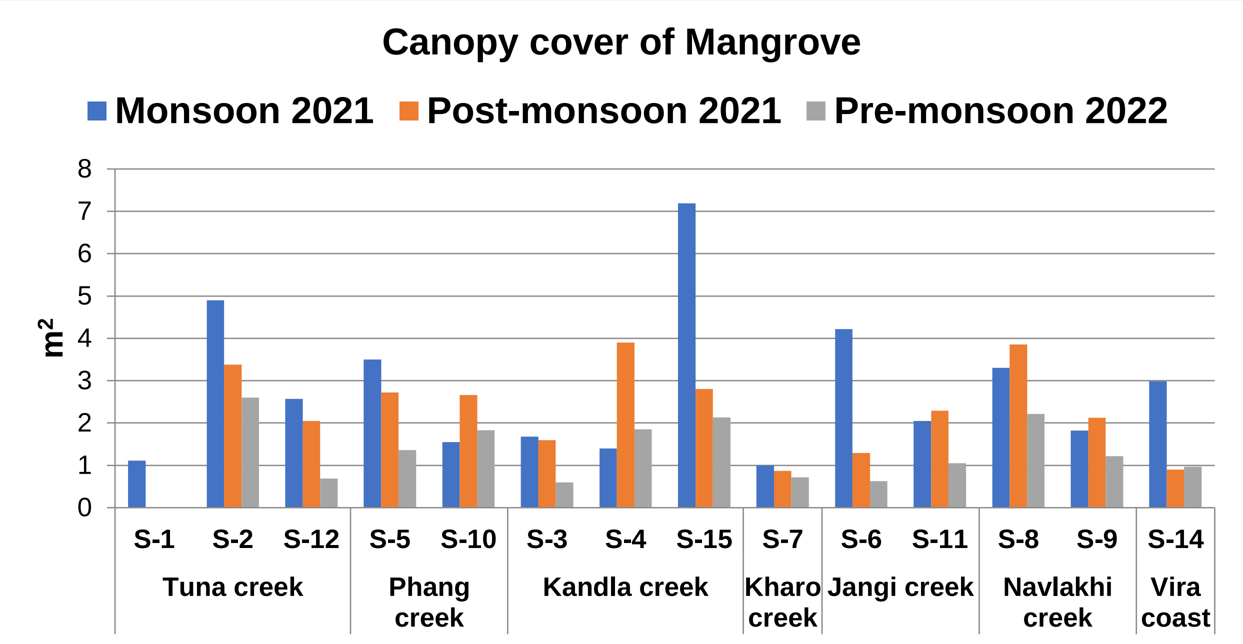


Figure 46. Station wise average tree canopy cover of mangroves from May 2021 to May 2022

4.4.4. Basal Area (Girth)

During monsoon, the overall average basal area of the mangroves trees in the DPA area was 16.57cm and it reduced to 10.46 cm and 7.18 cm during post-monsoon of 2021 and pre-monsoon of 2022 respectively. During monsoon, the station wise the largest mean basal area (103 cm) was found at station S-5 in Phang creek and S-13 near oil jetty (89 cm). However, during post-monsoon, the largest mean basal area (137 cm) was recorded at site S-8 in Navlakhi creek followed by S-2 in Tuna creek (120 cm). In summary, the overall average basal area (girth) of mangroves surveyed for monsoon was 16 cm, for post-monsoon 10.6 cm and the pre-monsoon 7.2 cm were recorded (Fig.49).

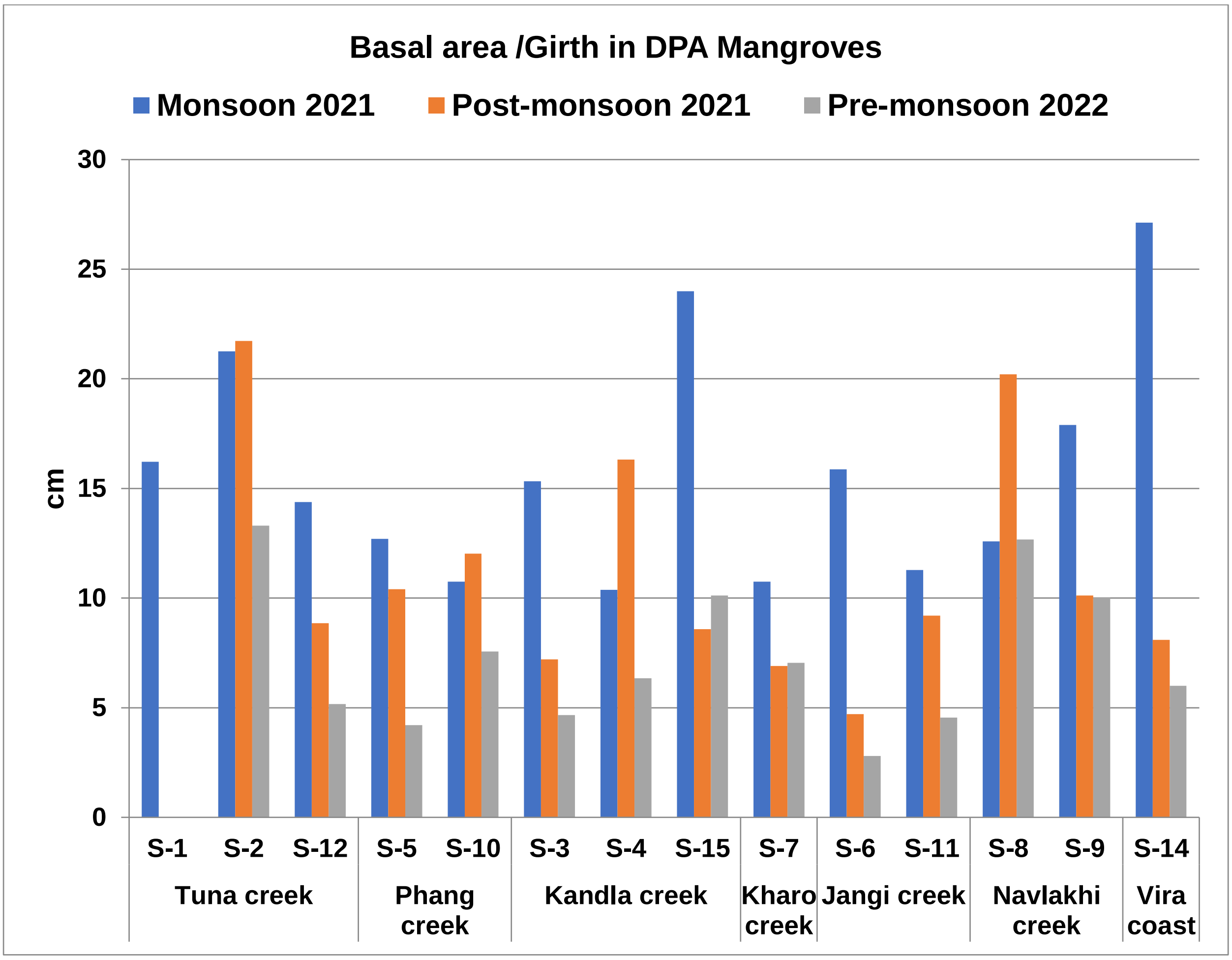


Figure 47. Station wise average tree girth of mangroves in during May 2021 to May 2022

4.4.5. Regeneration and Recruitment Class

During monsoon, the overall average ratio of absolute tree density to regeneration class observed was7.1 and regeneration to recruitment class ratio was 3.3. The overall average regeneration class density was 51,045 plants/ha and that of recruitment class 19,757 plants/ha. The highest regeneration class density was 85,000 plants/ha at Kharo creek (S-7) and same density at Tuna creek. The recruitment class density was relatively high at Tuna creek (34,794 plants/ha) and the overall mean density of recruitment class was 19,757 plants/ha for the monsoon.

4.4.6. Tree Density

During post-monsoon, the overall average regeneration class density was 44,988 plants/ha and that of recruitment class 6628 plants/ha. The highest ratio for tree density to recruitment class was observed at S-11 (1:5.3). At the S-4 site, there were no recruitment class plants found. The pre-monsoon 2022, the overall average density was 78,896 plants/ha and 10,393 plants/ha found for regeneration and recruitment class respectively. If the ratio of regeneration to recruitment class is comparatively lower of specific station to other stations, it indicates the possibilities of any disturbance for the seed distribution, establishment and even survival of mangroves. In same way, higher in the ratio of tree density to regeneration class means higher in the rates of seed productivity and possibilities of settlement within the stand. The detailed study of seed production rate with its distribution pattern within the stand, seed predation, wash-out by the wave action, re-settlement pattern, chances of successful establishment, rate of sapling dislodgment etc., are the responsible factors which determine establishment of the mangrove stands naturally.

The environmental factors such as complex hydro-edaphic conditions, infrequent tidal coverage and high evapotranspiration rate etc influence the mangrove struture in area. Because such conditions, leads to low soil-water potential and ionic imbalance, they create stress on the mangroves which affect their growth. In DPA Kandla area such conditions are responsible for the dominance of *Avicennia marina*. Although, other mangrove species such as *Ceriops tagal, Aegiceras corniculatum* and *Rhizophora mucronata* were also reported in a few stations, there presence is very rare.

Table 17. Density of mangroves in the DPA vicinity during monsoon (2021)

Sampling stations	Density (Tree/Ha)	Tree height (m)			Canopy cover (m^2)			Basal area (cm)		
		Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Tuna creek										
S-1	3940	1.00	1.85	1.36	0.16	2.89	1.11	7.00	39.00	16.22
S-2	2403	1.10	4.10	2.03	0.20	30.80	4.90	7.00	75.00	21.25
S-12	2442	1.00	2.85	1.57	0.20	9.30	2.57	7.00	43.00	14.38
Mean	2928	1.03	2.93	1.65	0.19	14.33	2.86	7.00	52.33	17.28
Phang creek										
S-5	4070	1.10	3.70	1.13	0.42	33.30	3.50	7.00	103.00	12.70
S-10	3192	1.00	2.00	1.00	0.26	4.40	1.55	6.00	27.00	10.75
Mean	3631	1.05	2.85	1.07	0.34	18.85	2.53	6.50	65.00	11.73
Kandla creek										
S-3	3036	1.00	3.70	1.08	0.40	33.00	1.68	7.00	66.00	15.33
S-4	7851	1.00	2.51	1.00	0.20	5.25	1.40	6.00	43.00	10.38
Mean	5444	1.00	3.11	1.04	0.30	19.13	1.54	6.50	54.50	12.86
Kharo Creek										
S-7	5289	1.00	1.90	1.23	0.20	5.00	1.00	6.00	25.00	10.75
Near Oil Jetty (Incorporated in Kandla creek with rename S-15)										
S-13	1619	1.10	4.70	1.90	0.42	35.38	7.19	6.00	89.00	24.00
Jangi creek										
S-6	2887	1.10	2.70	1.26	0.42	12.60	4.22	7.00	44.00	15.88
S-11	2713	1.00	2.10	1.37	0.40	13.60	2.05	7.00	40.00	11.28
Mean	2800	1.05	2.40	1.32	0.41	13.10	3.14	7.00	42.00	13.58
Navlakhi creek										
S-8	3044	1.10	2.40	1.44	0.42	10.88	3.30	5.00	46.00	12.58
S-9	1433	1.10	2.10	1.42	0.20	6.75	1.82	6.00	77.00	17.90
Mean	2239	1.10	2.25	1.43	0.31	8.82	2.56	5.50	61.50	15.24

Vira coast										
S-14	1633	1.00	1.65	1.27	0.53	5.14	2.98	7.33	49.00	27.12
Overall average	**3198**	**1.04**	**2.72**	**1.36**	**0.34**	**14.97**	**2.97**	**6.48**	**54.79**	**16.57**

Table 18. Regeneration and Recruitment class plants during monsoon (2021)

Sampling location	Tree density No/ha (1)	Regeneration Density-No/ha (2)	Recruitment class density-No/ha (3)	Ratio of 1:3	Ratio of 2:3
Tuna Creek					
S-1	3940	17333	38667	1 : 9.81	0.45 : 1
S-2	2403	85000	44286	1 : 18.43	1.92 : 1
S-12	2442	65714	21429	1 : 8.78	3.07 : 1
Average	2928	56016	4794	1 : 12. 34	1.82 : 1
Kandla Creek					
S-3	3036	60476	12857	1 : 4.23	4.70 : 1
S-4	7851	28571	34762	1 : 4.43	0.82 : 1
Average	5444	44524	23810	1 : 4.33	2.76 : 1
Kharo Creek					
S-7	5289	85000	14286	1 : 2.70	5.95 : 1
Near oil Jetty					
S-13	1619	63889	11667	1 : 7.21	5.48 : 1
Phang Creek					
S-5	4070	62857	18571	1 : 4.56	3.38 : 1
S-10	3192	15714	16429	1 : 5.15	0.96 : 1
Average	3631	39286	17500	1 : 4.85	2.17 : 1
Jangi area					
S-6	2887	28000	5000	1 : 1.73	5.60 : 1
S-11	2713	55714	39286	1 : 14.48	1.42 : 1

Average	2800	41857	22143	1 : 8.11	3.51 : 1
Navlakhi Creek					
S-8	3044	67857	29286	1 : 9.62	2.32 : 1
S-9	1433	15714	16429	1 : 11.46	0.96 : 1
Average	2239	41786	22858	1 : 10.54	1.64 : 1
Vira coast					
S-14	1633	36000	11000	1 : 6.74	3.27 : 1
Overall average	**3198**	**51045**	**19757**	1 : 7.10	**3.32** : 1

Table 19. Density of mangroves in the DPA vicinity during post-monsoon season 2021

Sampling stations	**Density (Tree/Ha)**	**Tree height (cm)**			**Canopy cover (m)**			**Basal Area (cm)**		
		Min	**Max**	**Avg.**	**Min**	**Max**	**Avg.**	**Min**	**Max**	**Avg.**
Tuna creek										
S-2	3415.42	100.00	390.00	157.50	0.10	21.62	3.38	7.00	120.00	21.73
S-12	4414.96	110.00	280.00	121.69	0.20	12.80	2.05	7.00	35.00	8.85
Mean	3915.19	110.00	326.67	160.27	0.20	13.22	2.44	7.00	61.67	14.14
Phang creek										
S-5	1930.67	100.00	310.00	51.63	0.56	26.40	2.72	7.00	103.00	10.41
S-10	3443.98	100.00	340.00	125.00	0.20	20.00	2.66	7.00	90.00	12.03
Mean	2687.33	100.00	325.00	88.31	0.38	23.20	2.69	7.00	96.50	11.22
Kandla creek										
S-3	2657.54	100.00	200.00	88.13	0.20	9.90	1.59	7.00	37.00	7.20
S-4	2737.97	100.00	500.00	135.63	0.20	26.40	3.90	7.00	103.00	16.31
S-15	2252.23	100.00	300.00	98.69	0.42	18.00	2.80	7.00	40.00	8.59
Mean	2549.24	100.00	333.33	107.48	0.27	18.10	2.77	7.00	60.00	10.70
Kharo Creek										
S-7	5524.11	100.00	330.00	111.38	0.20	5.06	0.87	7.00	37.00	6.90

Jangi creek									
S-6	1970.70	100.00	240.00	64.88	0.20	9.60	1.29	7.00	35.00	4.71
S-11	1996.38	110.00	350.00	43.56	0.56	22.08	2.29	7.00	95.00	9.20
Mean	1983.54	105.00	295.00	54.22	0.38	15.84	1.79	7.00	65.00	6.96
Navlakhi creek										
S-8	3734.57	120.00	540.00	188.88	0.20	40.30	3.86	7.00	137.00	20.21
S-9	3553.99	100.00	340.00	119.13	0.20	12.95	2.13	7.00	90.00	10.13
Mean	3644.28	110.00	440.00	154.00	0.20	26.63	2.99	7.00	113.50	15.17
Vira coast										
S-14	3567.10	100.00	200.00	115.13	0.06	4.40	0.90	7.00	27.00	8.10
Overall average	**3410.14**	**103.57**	**321.43**	**112.97**	**0.24**	**15.21**	**2.06**	**7.00**	**65.81**	**10.46**

Table 20. Regeneration and Recruitment of Mangrove along the DPA Kandla area during post-monsoon season 2021

Sampling location	Tree density- No/ha (1)	Regeneration density- No/ha (2)	Recruitment density- No/ha (3)	Ratio of 1:3	Ratio of 2:3
Tuna creek					
S-2	3415	94000	7000	1 : 2.0	13.43 : 1
S-12	4415	49500	5250	1 : 1.2	9.43 : 1
Average	3915	71750	6125	1 : 1.6	11.7 : 1
Kandla creek					
S-3	2658	97500	5500	1 : 2.1	17.73 : 1
S-4	2738	47000	0	0	0
S-15	2252	66000	1125	1 : 0.5	58.67 : 1
Average	2549	70167	2208	1 : 0.9	31.77 : 1
Kharo creek					
S-7	5524	21000	6750	1 : 1.2	3.11 : 1

Phang creek					
S-5	1931	24000	2000	1 : 1.0	12.00 : 1
S-10	3444	63000	10625	1 : 3.1	5.93 : 1
Average	2687	43500	6313	1 : 2.3	6.89 : 1
Jangi creek					
S-6	1971	17500	5375	1 : 2.7	3.26 : 1
S-11	1996	63000	10625	1 : 5.3	5.93 : 1
Average	1984	40250	8000	1 : 4.0	5.03 : 1
Navlakhi creek					
S-8	3735	90000	14875	1 : 4.0	6.05 : 1
S-9	3554	47500	9125	1 : 2.6	5.21 : 1
Average	3644	68750	12000	1 : 3.3	5.73 : 1
Vira coast					
S-14	3567	27000	5000	1 : 1.4	5.40 : 1
Overall average	**3410**	**48917**	**6628**	**1 : 27**	**10 : 1**

Table 21. Density of mangroves in the DPA vicinity during Pre-monsoon (2022)

Sampling stations	**Density (Tree/Ha)**	**Tree height (cm)**			**Canopy cover (m^2)**			**Basal Area (cm)**		
		Min	**Max**	**Avg.**	**Min**	**Max**	**Avg.**	**Min**	**Max**	**Avg.**
Tuna creek										
S-2	4435.20	0.00	370.00	162.25	0.00	24.00	2.60	0.00	65.00	13.30
S-12	4335.38	0.00	310.00	75.63	0.00	7.50	0.69	0.00	30.00	5.16
Mean	4385.29	0.00	340.00	118.94	0.00	15.75	1.64	0.00	47.50	9.23
Phang creek										
S-5	2517.95	0.00	240.00	53.81	0.00	24.00	1.36	0.00	40.00	4.21
S-10	3859.04	0.00	400.00	90.25	0.00	21.60	1.83	0.00	63.00	7.56

Mean	3188.50	0.00	320.00	72.03	0.00	22.80	1.59	0.00	51.50	5.89
Kandla creek										
S-3	4955.75	0.00	250.00	65.63	0.00	8.06	0.60	0.00	36.00	4.66
S-4	8318.00	0.00	170.00	91.25	0.00	24.00	1.86	0.00	25.00	6.35
S-15	1782.72	0.00	280.00	87.13	0.00	18.80	2.13	0.00	60.00	10.13
Mean	5018.82	0.00	233.33	81.33	0.00	16.95	1.53	0.00	40.33	7.05
Kharo creek										
S-7	3699.42	0.00	205.00	109.25	0.00	4.84	0.72	0.00	22.00	7.05
Jangi creek										
S-6	3508.60	0.00	220.00	31.06	0.00	6.75	0.63	0.00	30.00	2.80
S-11	3657.25	0.00	260.00	52.75	0.00	9.86	1.05	0.00	50.00	4.55
Mean	3582.92	0.00	240.00	41.91	0.00	8.31	0.84	0.00	40.00	3.68
Navlakhi creek										
S-8	6944.44	0.00	320.00	163.25	0.00	17.10	2.21	0.00	45.00	12.68
S-9	6092.73	0.00	340.00	265.00	0.00	14.00	1.22	0.00	65.00	10.03
Mean	6518.59	0.00	330.00	214.13	0.00	15.55	1.72	0.00	55.00	11.35
Vira coast										
S-14	4990.03	0.00	300.00	70.63	0.00	6.75	0.96	0.00	30.00	6.00
Overall average	**4483.37**	**0.00**	**281.19**	**101.17**	**0.00**	**12.99**	**1.29**	**0.00**	**40.90**	**7.18**

Table 22. Regeneration and Recruitment class plants during Pre-monsoon (2022)

Station	Tree density-No/ha (1)	Regeneration density-No/ha (2)	Recruitment density-No/ha (3)	Ratio of 1:3	Ratio of 2:3
Tuna creek					
S-2	4435.20	139000	21250	1: 4.79	6.54 : 1
S-12	4335.38	146000	21125	1: 4.87	6.91 : 1

Mean	4385.29	142500	21188	1: 4.83	6.73 : 1
Phang creek					
S-5	2517.95	49500	125	1: 0.05	396.00 : 1
S-10	3859.04	103000	5500	1: 1.43	18.73 : 1
Mean	3188.50	76250	2813	1: 0.88	207.36 : 1
Kandla creek					
S-3	4955.75	29500	5125	1: 1.03	5.76 : 1
S-4	8318.00	9500	2375	1: 0.29	4.00 : 1
S-15	1782.72	57500	2250	1: 1.26	25.56 : 1
Mean	5018.82	32167	3250	1: 0.65	9.90 : 1
Kharo creek					
S-7	3699.42	62857	23750	1: 6.42	2.65 : 1
Jangi creek					
S-6	3508.60	39500	6250	1: 1.78	6.32 : 1
S-11	3657.25	72000	6000	1: 1.64	12.00 : 1
Mean	3582.92	55750	6125	1: 1.71	9.10 : 1
Navlakhi creek					
S-8	6944.44	140000	13250	1: 1.91	10.57 : 1
S-9	6092.73	73500	12500	1: 2.05	5.88 : 1
Mean	6518.59	106750	12875	1: 1.98	8.29 : 1
Vira coast					
S-14	4990.03	76000	2750	1: 0.55	27.64 : 1
Overall average	**4483**	**78896**	**10393**	1: **2.44**	39.08 : 1

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

Plate 11. Mangrove Species of DPA Port Authority

4.5. Halophytes

The holophytes are the plants that are adopted in coastal estuaries and salt marshes. It is common in arid and desert milieu which often have substantial salt accumulation in salt. Technically this plant which has tolerance to moderate to high salt concentration in its growth substrate. Halophytes are plants that survive to reproduce in environments where the salt concentrations around 200 mM NaCl or more, constitute about 1% of the world's flora. (Timothy et.al 2008). Halophytes are classified based on their growth conditions as obligate halophytes, facultative halophytes, and habitat-indifferent halophytes. During the period of May 2021 to May 2022 four major halophytes were recorded along the selected study stations of Deendayal Port Authority sites during the 3 seasons, were *Salicornia brachiata*, *Aeluropus lagopoides*, *Salvadora persica* and *Sesuvium portulacastrum*. Maximum percentage coverage of halophytes ranges from 16% to 32 % and the species *Salicornia brachiate* shared highest percentage of coverage (32%) in monsoon period followed by post-monsoon (19.7%) and pre-monsoon (12.5%). The percentage cover of different halophytes cover was depleted in figure 48.

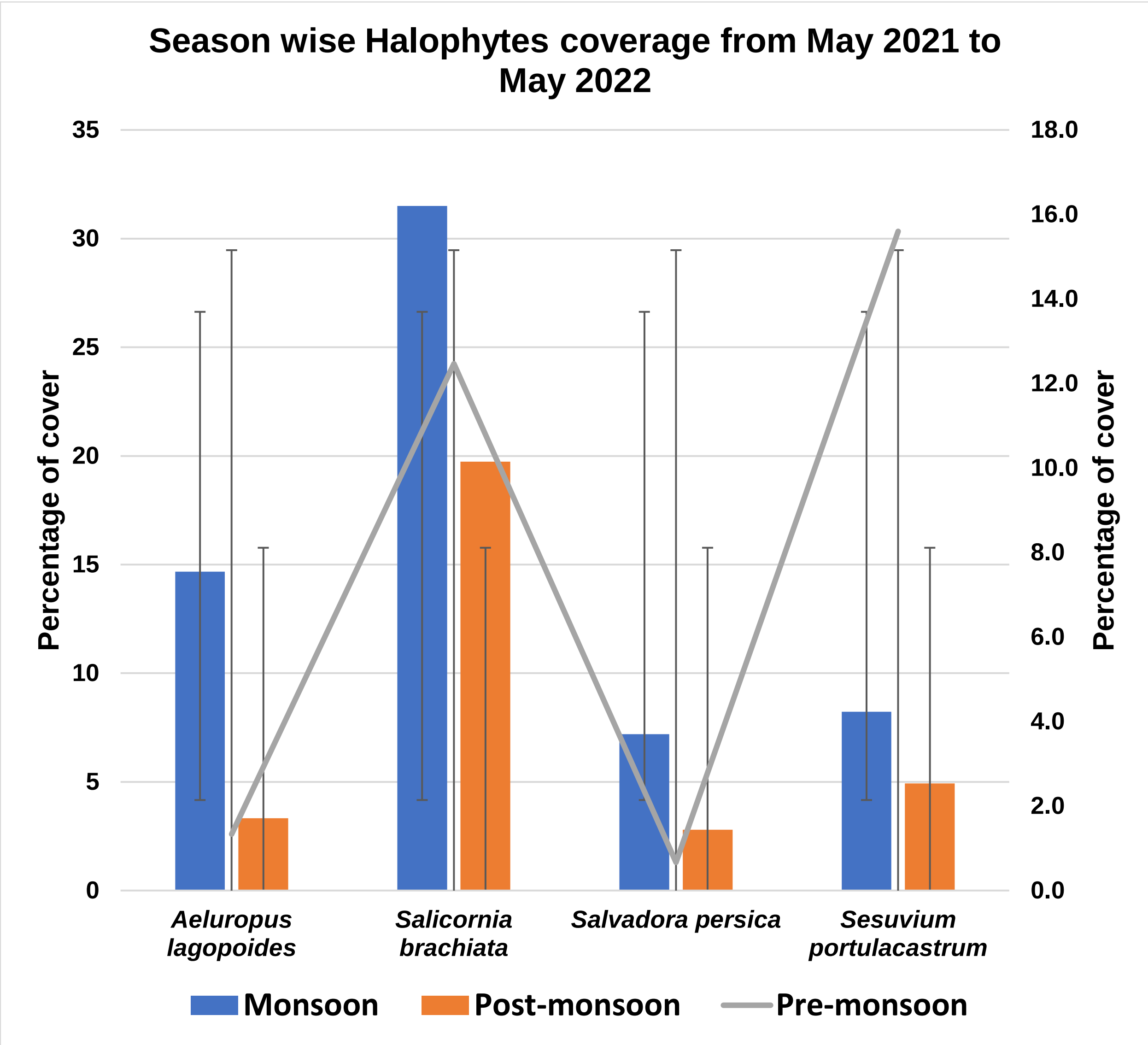


Figure 48. Percentage cover of halophytes reported during May 2021 to May 2022

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

Plate 12: Halophyte species on the intertidal zone

4.6. Seaweed and Seagrass

Seaweeds are an integral part of coastal ecosystems and offer invaluable ecosystem services supporting the life of many marine forms. The economic value of seaweeds significantly contributes to the sustainable development of rural coastal regions. Seaweeds are consumed as food in some Asian countries, but their utilization for the production of phycocolloids is widespread across the globe, with an estimated value of more than one billion US$. In India, seaweeds have been utilized exclusively for the production of phycocolloids but recently they are used for the production of plant growth stimulants for agricultural applications. The domestic agar and alginate industry totally depend on the supplies from natural seaweed beds with some occasional imports. According to Oza and Zaidi (2001) compilation secondary data and report, the total seaweed species was 844 which constituted 434, 194, and 216 species of red, brown, and green seaweeds, respectively.

The recent inventory from the Indian region documented the presence of approximately 865 seaweed taxa so far (Mantri et al., 2020). Various studies have been conducted since last few decades with respect to the distribution and diversity of seaweed from various parts of the Indian coast and few dotted pieces of literature available. Along the Gujarat coast which is represented by 1600 km coastline, harbours 198 species of which 109 species from 62 genera belonging to Rhodophyta, 54 species from 23 genera to Chlorophyta, and 35 species from 16 genera to Ochrophyta (Jha et.al.,2009). According to Mantri et.al. (2020) 13 potential sites have been identified for the occurrence of seaweed density and diversity.

The survey CSIR-CSMCRI (Jha et.al., 2009) confirmed the presence of industrially important taxa, namely, *Gelidiella acerosa*, *Gelidium micropterum*, *G. pusillum*, *Ahnfeltia plicata*, *Gracilaria dura*, *G. debilis*, Gracilariopsis longissima (formerly *G. verrucosa), Hypnea musciformis*, Meristotheca papulosa, Porphyra sp, Asparagopsis taxiformis (Rhodophyta), *Sargassum tenerrimum*, *S. plagiophyllum*, *S. swartzii*, *Turbinaria ornate* (Ochrophyta), *Ulva prolifera* (formerly *Enteromorpha prolifera*), *Ulva compressa* (formerly *Enteromorpha compressa*), and *Ulva flexuosa* (formerly *Enteromorpha tubulosa*) (Chlorophyta) from the coastal waters of Gujarat. In the present study, an attempt was made to describe the occurrence, diversity and other ecological features of seaweeds within Deendayal Port jurisdiction. It was found that except for some drifted species Enteromorpha, Chaetomprpha in stations S-13 and S-14 of Veer coast no natural seaweed beds are seen in the different locations within DPA environment.

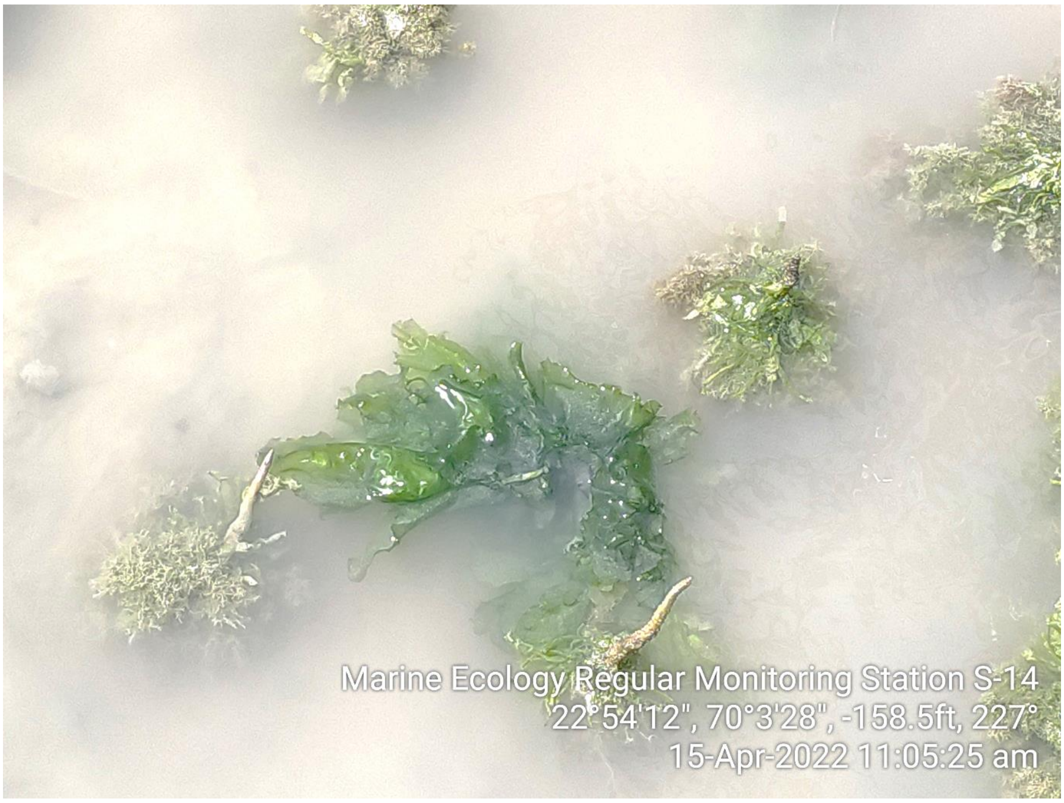


Plate 13: Drifted seaweeds intertidal zone

Seagrass

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

4.7. Marine fisheries

In northern gulf of Kachchh total fish production estimated was 4,29,41 metric tons which include the 28 major commercial and and miscellaneous item contain 2,47,33 metric tons and it all total production during this financial year was 67674 metric tons (Gujarat State fisheries report 2021) (Figure 49).

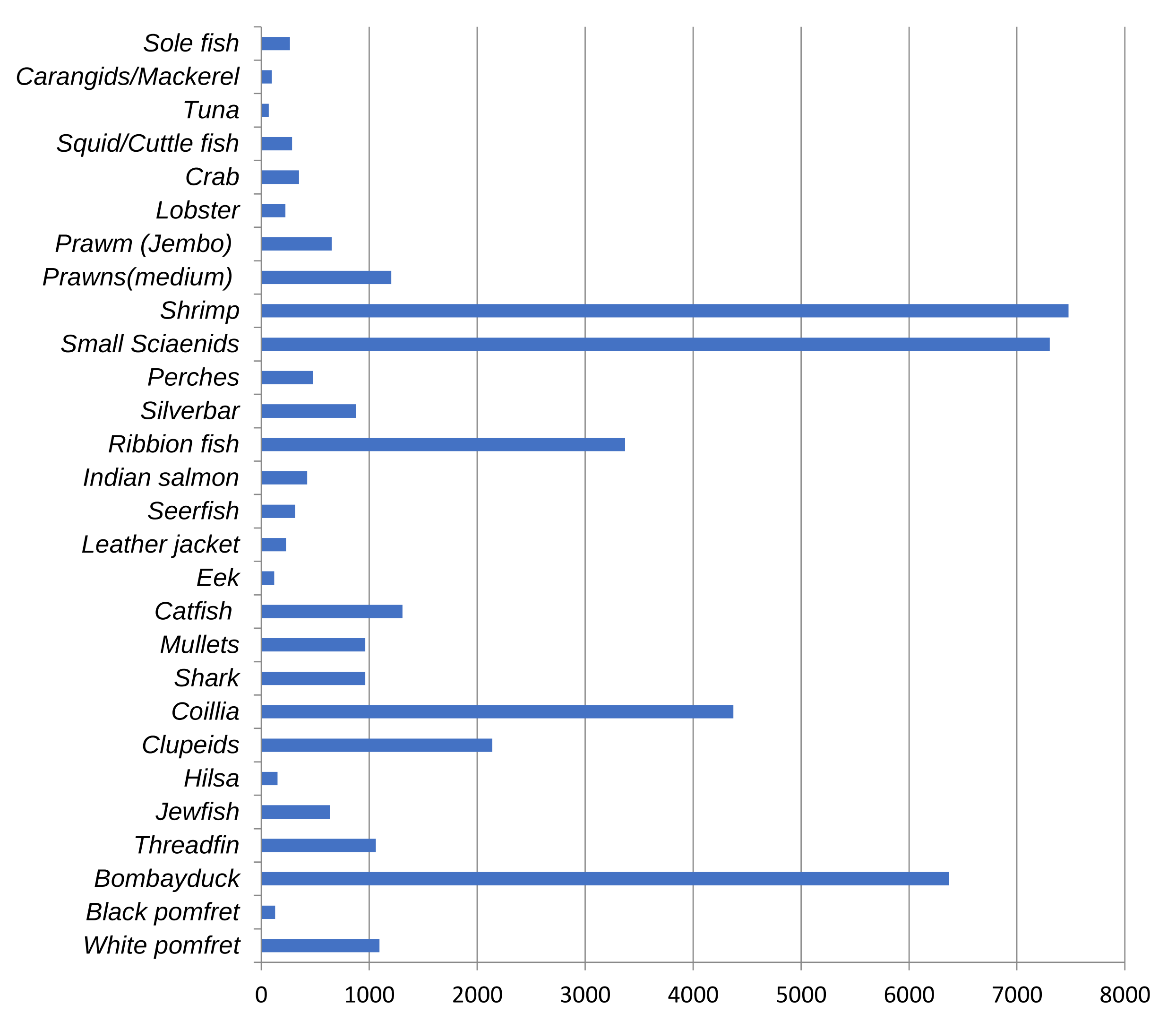


Figure 49. Major fisheries of Gulf of Kachchh

Major fisheries in Kandla and its periphery environment

The Ichthyofauna diversity in specific to Kandla and its periphery environment mostly connected to Sikka coast of Jamnagar where 112 ichthyofauna species belonging to 50 families, 12 orders, and 84 genera has been reported (Katira & Kardani 2017). Similarly the locality of Jamnagar Marine National Park, Gulf of Kachchh reported 109 ichthyofauna species belonging to 58 families, 19 orders, and 93 genera (Brahmane et al. 2014).Apart from this, a recent study conducted by Sidat et,al (2021) and reported 96 species which include 20 order and 47 families.

The major fish catch activity is carried out in extensive creek systems of Khari creek, Tuna creek, Navalakhi creek and Jhangi creek. For the period of period 2021, cast net was operated in different creek system of Kandla and major fish catch was include the species *Penaeus indicus,Chanos chanos, Mudskipper, Therapon fish, Portunus pelagicus Other crab species* of total quantity was 1.8 kg (Figure 50)

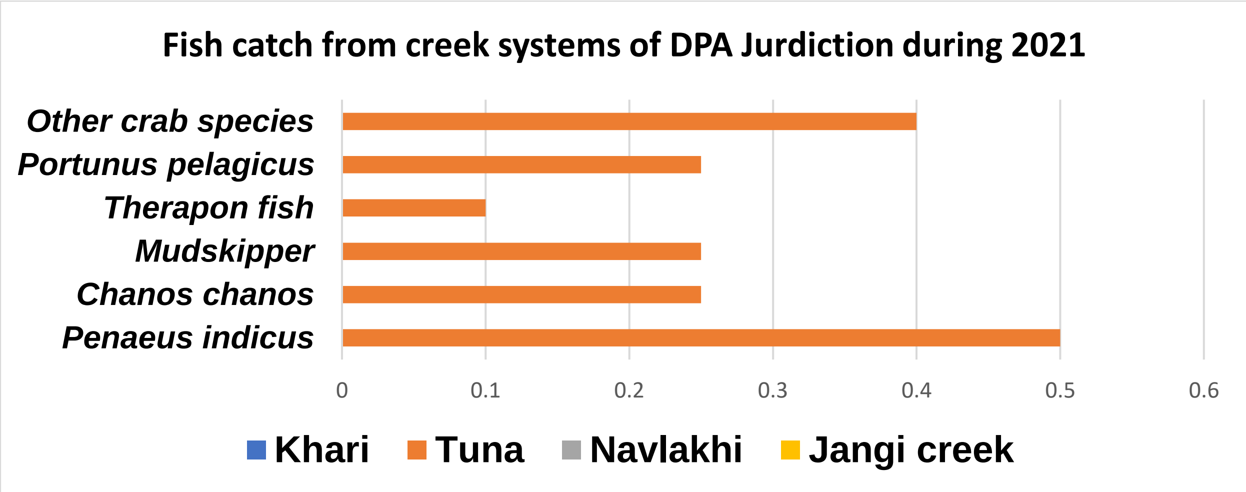


Figure 50. Experimental fish catch in Tuna creek system

In year 2022 experimental fish catch was conducted along all the creek system of DPA jurisdictions and total catch was 39.68 kg contributing by *Chanos chanos ,Mudskipper, Therapon fish, Scylla serrata, Planiliza planiceps, Arius jella*, *Eletheronema tetradactylum, Brachirus orientalis* (Fig.53).

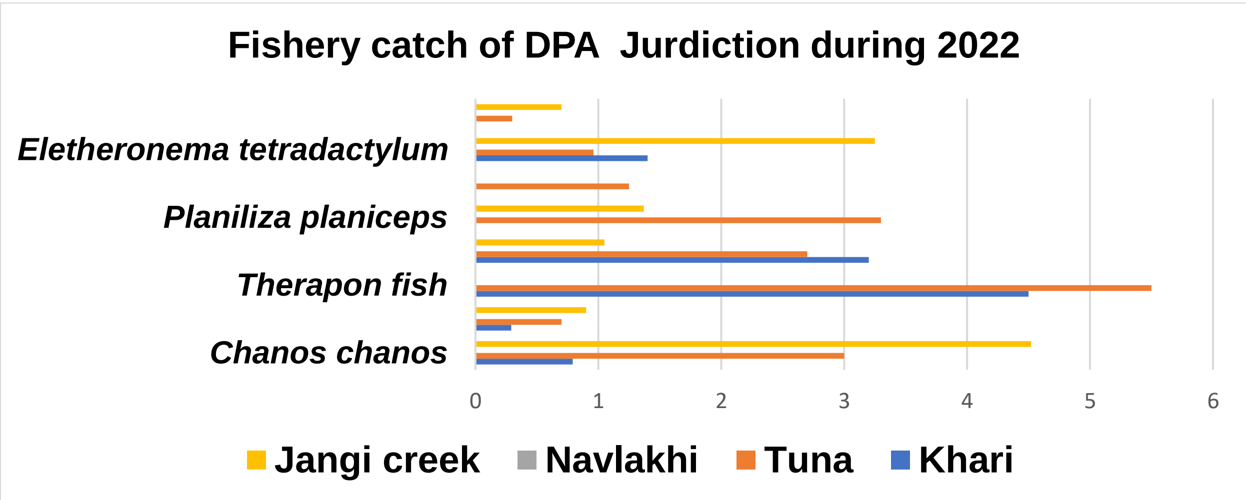


Figure 51. Experimental fish catch in different creek system of DPA Jurisdiction

Plate 14: Fisheries of DPA Jurisdiction

4.8. Marine Mammals

Marine mammals play critical ecological roles as predators (mainy hunts fish) and prey, both for sharks and other, larger marine mammals (Roman & Estes2018).Dolphins are highly intelligent marine mammals and are part of the toothed whales, including orcas and pilot whales. They are distributed worldwide, mostly living on shallow seas of the continental shelves, and are carnivores, mostly eating fish and squid(Thomas 2009).The *Sousa plumbea* (plate.15),commonly known as the Indian Ocean humpback dolphin, is listed as “Endangered” by the International Union for the Conservation of Nature (IUCN 2022) and was documented from the Kandla waters. These dolphins have a more uniform dark-grey (plumbeous or lead coloured) colour with white mottling interspersed with slight pink pigmentation in specific individuals. The belly or the ventral surface of the body is lighter. These dolphins are found close to the shore and around larger creeks and the open sea.Indian Ocean humpback dolphins mainly feed on fish like mullet, mackerel, sardines and pomfrets found along with the estuarine areas (Thomas et al., 2012).

Plate 15: Marine Mammals of DPA Jurisdiction

4.9. Reptiles

India has the highest incidence of deaths due to snakebites in the world. *Echis carinatus* (EC) is known as a saw-scaled viper, and its bite causes one of themost mortality and morbidity in the Indian subcontinent (Daniels2002, Rudresha et al., 2021). During the Pre-monsoon period of 2022 field surveys, the saw-scaled viper *E. carinatus* (Fig), was recorded at S-10, located Northern part of Sat Saida bet along the Phan creek. This species was spotted on the branches of mangrove trees, on top of the *Salvadora persica* and bottom of the mangrove trees and halophytes. The colour pattern consists of a pale buff, greyish, reddish, olive or pale brown ground colour. This snake, during the daytime, does not active, and hides in the bottom of the trees, branches of mangrove trees, associated with halophytes and mangrove litter.

Plate 16: Marine reptiles of DPA Jurisdiction

4.10. Avifauna

Mangrove forest habitats play host to a number of bird species around the world. Detailed investigations of bird ecology in the mangrove forest habitats are sparse. Birds were known to pollinate mangrove representatives of the genus Sonneratia (Coupland et al., 2006), whereas, Pelliciera rhizophorae a mangrove species was pollinate only by the hummingbird Amazilia tzacatl De la Lave of Triana and Planch in Central America (Prahl, 1987). Onuf et al. (1977) confirmed that birds nesting in mangrove forest habitats are an important source of inorganic nitrogen for Rhizophora plants. The common birds found in the mangrove forest habitats are of the family Ardeidae, Charadriidae, Laridae, Ciconidae, Accipitridae and Alcedinidae. Migratory birds visiting the mangroves may fly long distances to find food and nesting places there (Parrish and Sherry, 1994). This may be particularly true in the neotropics (Confer and Holmes, 1995; Lefebvre and Poulin, 1996; Panitz, 1997).

Mangrove forests are extremely essential for the survival of many species of birds (Subramanian and Sethuraman, 1998; Sethuraman, 2000; Kathiresan, 2000), but information on birds associated with mangroves in India is scanty (Mukherjee, 1969; Samant, 1985; Rashid and Scott, 1988; Sampath, 1989; Sethuraman and Subramanian, 1997). A checklist of some birds associated with the mangroves of Ratnagiri has been prepared by Samant (1985) and in the same area Apate et al. (2005) reviewed the potential and prospects of estuarine ecotourism with special emphasis on mangrove birds. Deshmukh (1990) has recorded 147 bird species from the mangrove swamps of Vikhroli, near Mumbai. Kulkarni (2000) reported that Thane creek mangroves of Mumbai supports over 1, 00,000 birds during winter. The reported species are the Lesser Flamingo Phoenicopterus minor, Greater Flamingo Phoenicopterus ruber, Asian Openbill Anastomus oscitans, White Stork Ciconia ciconia, Pied Avocet Recurvirostra avosetta, Eastern Golden Plover Pluvialis dominica, Ruddy Turnstone Arenaria interpres and Dunlin Calidris alpina. Similarly, smaller waders particularly Little Stints Calidris minutus and Temminck's Stints C. temminckii were also been recorded in several thousands (Nitsure 2002).

Comparative status of avifaunal species diversity over three seasons

A total of 84 species belonging to 9 orders, 34 families and 62 genera were recorded from the coastal area of Deendayal Port during this study (Annexure 1). Among these, 52 species were aquatic and 32 species were terrestrial, which included 7 species listed as Near Threatened in the IUCN 2022, Red List.

Order Charadriiformes i.e. aquatic birds (including raptors and most water birds) constituted the predominant groups representing 35% of all species recorded from the study area followed by order Passeriformes (24%), Pelecaniformes (19%) and other six orders formed 22% of the recorded species. The families with more number of species were Scolopacidae (13 spp.), Ardeidae (8 spp.), Charadriidae (6 spp.), Laridae (6 spp.), Alcedinidae, Hirundinidae, Threskiornithidae each family having (three spp.), six families each having 2 species and eight families each having one species. From the recorded species, 27 species were migrants, 14 species were local migrants or resident migrants, 43 species were breeding resident.

Thirteen (13) kinds of feeding guilds, viz., aquatic invertebrate-feeder, piscivore, insectivore, granivore, frugivore, reptile-feeder, amphibian feeder, nectarivore, weedivore, plankton-feeder, herbivore, carrion-feeder and predatory were identified; among the bird species observed (Ali & Ripley 1987). Here, the aquatic invertebrate guild is the most frequent one with thirty six percent incidence and 31 species occurring under this shared category. Whereas, omnivore, frugivore, granivore, and plankton-feeder guilds are the least frequent with only one species observed in each.

Overall mean bird species is 84 calculated from the study area. The overall Shannon diversity (H') is 4.1 with overall species richness index for study area is 10.4. The overall species evenness index value for study area is 0.72 with overall Equitability is 0.92 (Tabe a&b)

Table 23. Comparative status of avifaunal species diversity over three Seasons in the study area.

Diversity Indices	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon
	No. of Species			Individuals			Shannon_H		
S - 1	36	37	61	130	141	227	3.384	3.247	3.889
S - 2	34	32	57	197	201	278	3.215	3.201	3.759
S - 3	22	25	37	94	97	163	2.844	2.745	3.249
S - 4	21	24	36	68	66	120	2.865	2.768	3.436
S - 5	17	15	34	41	36	141	2.625	2.524	3.005
S - 6	24	26	41	101	106	173	2.904	2.875	3.561
S - 7	27	21	48	107	112	311	3.095	2.931	2.835
S - 8	24	23	44	104	110	206	2.913	2.956	3.5
S - 9	28	29	49	134	131	275	2.95	2.991	3.368
S - 10	27	31	47	115	105	197	3.021	3.121	3.595
S - 11	26	28	43	121	101	187	3.054	3.152	3.493
S - 12	18	19	33	72	82	156	2.621	2.722	3.104
S - 13	20	21	40	65	115	141	2.865	2.945	3.53
S -14	25	24	37	101	72	164	3.095	2.865	3.307
S -15	19	NA	46	104	NA	214	3.021	NA	3.551
Total SA	52	62	84	1554	1475	2953	3.676	3.845	4.104

Table 24. Comparative status of avifaunal species diversity over three Seasons in the study area.

Diversity Indices	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon
	Evenness_e^H/S			Species Richness			Equitability_J		
S - 1	0.819	0.864	0.801	3.157	3.208	4.049	0.944	0.91	0.946
S - 2	0.732	0.777	0.7526	2.422	2.473	3.419	0.911	0.877	0.9297
S - 3	0.78	0.825	0.6966	2.269	2.32	2.898	0.919	0.885	0.8999
S - 4	0.835	0.88	0.8633	2.547	2.598	3.286	0.941	0.907	0.959
S - 5	0.812	0.857	0.5937	2.655	2.706	2.863	0.926	0.892	0.8522
S - 6	0.76	0.805	0.8588	2.388	2.439	3.117	0.913	0.879	0.959
S - 7	0.818	0.863	0.3547	2.61	2.661	2.722	0.939	0.905	0.7323
S - 8	0.767	0.812	0.7526	2.353	2.404	3.066	0.916	0.882	0.9249
S - 9	0.682	0.727	0.5923	2.419	2.47	2.955	0.885	0.851	0.8654
S - 10	0.759	0.804	0.7751	2.518	2.569	3.349	0.916	0.882	0.9338
S - 11	0.815	0.86	0.7647	2.364	2.415	3.144	0.937	0.903	0.9287
S - 12	0.763	0.808	0.6756	2.121	2.172	2.642	0.906	0.872	0.8878
S - 13	0.835	0.863	0.8531	2.547	2.598	3.369	0.941	0.907	0.9569
S -14	0.818	0.88	0.7378	2.61	2.661	2.889	0.939	0.905	0.9158
S -15	0.759	NA	0.7574	2.518	NA	3.144	0.916	NA	0.9274
Total SA	0.7593	0.8043	0.721	1.453	1.504	1.546	0.9303	0.8963	0.9262

Plate 17. Avifauna status of Deendayal Port Area

5. Discussion

5.1. Physico-chemical status of Deendayal Port Authority Environment

Water quality of coastal water reveals the state of the overall environment. The quality of water determines the biological and other resources in the marine environment. However, water quality parameters in marine environment vary to a great extent, which becomes difficult to explain, especially when we lack a benchmark study. They are influenced by many geographical factors. The geophysical and geo-chemical factors such as shape and size of the coastal areas, prevailing currents, temperature, salinity, tidal impacts, directions of prevailing winds and influx of fresh water influence the quality of water in a marine environment. The above factors affect the various inputs that are being added into the harbour water. Hence, we may not be able to analyse the overall impact of these inputs over the marine water quality. The shifting nature of water column makes the task more difficult for the analysis. Nonetheless, water quality indicators are fair enough to reveal the state of environment in a marine area in case of harbour environment. The pollution indicators in the water column can also give an indication of the impacts that are likely to occur both in near future as well as in the long term at the present rate of occurrence.

Temperature and pH

Water temperature in DPA port area generally varies in the range 18.1°C 35.0°C. However, the present study shows a reduced range of water temperature in Kandla DPA port. Water temperature Port region varies between 18.1 °C and 25.5 °C in the post-monsoon. The temperature rises marginally during pre-monsoon and ranges between 25,5 °C and 35.0 °C. The summer water temperature has been recorded as high (35°C). There is no vertical variation in temperature of marine water in Kandla Port area due to lack of thermal stratification in Creek (NIO,1998). This is because of the strong currents, high tidal impact and low depth of the harbour areas. The currents influence vertical mixing and restrict the stratification of water layer in the harbour area. The low temperature could be attributed to the heavy rainfall received during monsoon season temperature reduction in water depends mainly on the intensity of rainfall received on monsoon and less air temperature, Since the DPA port region falls under the arid zone, evaporation exceeds precipitation in a year. There is very little esupply of fresh water into the port area, which results in uniform water temperature vertically from surface to bottom. It is true in case of temperatures variation across the stations. However, a seasonal variation of water temperature is significant in Kandla Port area (Saravana,2002).

pH

The pH of seawater of DPA Port area varied in the range of 7.6 to 8.4. Generally, the pH of seawater is controlled by Carbonate and biocarbonate system and falls in the narrow range of (0.2-0.3). pH was alkaline during summer and showed downward pattern up to monsoon and remained alkaline during postmonsoon, (Vajravelu et.al 2018). Changes in pH will depend on the factor like the removal of CO2 by photosynthesis through bicarbonate degradation, fresh water influx, reduction in salinity and temperature and decomposition of organic matter (Rajasegar et al., 2002).

Salinity

As temperature influences the salinity of marine water in the tropics, water in DPA region has higher salinity in the range of 36.1ppt 50.7 ppt. Highest salinity observed during pre-monsoon (50.7ppt) at station S-11. The higher salinity towards inner regions around S-11, S-5, S-14 indicates localized effects of seepage of high saline (brine) water from salt marshes and saltpans of salt industries (Zingde& Anand ,1996). Hundreds of salt industries in and around Kandla Port use seawater with salinity in the range of 35 to 39 ppt. They release 'bittern' remains of salt after manufacturing, which has salinity as high as 250 ppt in Kandla Creek, thereby increasing the salinity in isolated regions of port areas (Chhaya, & Chhaya, 1997). Lack of fresh water from catchments coupled with higher evaporation is the cause of higher salinity in Kandla Port area. In the Little Gulf of Kuchchh water salinity has been recorded as high as 50 ppt (NIO,1998).

Dissolved oxygen

DO is consumed in marine ecosystem by the respiration and decaying organic matter in the water column. Loads of high organic matters may deplete the DO to its minimum level, which can be detrimental for the aquatic life. A severe depletion of DO may lead to 'Eutrophication' in an aquatic system. However, no such event has been reported in Kandla port region so far. DO in marine water of Kandla Port region has been found in the range of 4.93 mg/l and 7.6 mg/1 for in 3 seasons. During post-monsoon and pre-monsoon the dissolved oxygen varies from 6.2 mg/1 to 7.6 mg/1 and 6.2 mg/1 to7.2 mg/1. The current range of dissolved oxygen in the marine water of Kandla Port region

conforms to the designated best use for Salt pans, Shell fishing, Mariculture and Ecologically Sensitive Zone. For ecologically sensitive zone not less than 3.5mg/l at any time in a year (or 5.0 mg/1 at 60 percent saturation level) of DO is essential for the protection of aquatic life.

Total Suspended Solids

Suspended solids in Deendayal port area varied in the range 52 mg/1 to 1047 mg/1. Generally, the suspended solids in the Deendayal region are high and vary to a great extent from the inner port region to the out harbour region and further towards outer Gulf. The suspended solids, however, decrease substantially in the outer Gulf and are below 52mg/l (station S-14) away from the coastal areas. The higher value of suspended solids and their variations across the stations in the inner Gulf including Kandla Port regions results from the dispersion of sediment loads due to strong currents and tidal influence Zingde& Anand (1996)

Turbidity

Since Kandla Port areas fall under inner Gulf of Kuchch, there is a high turbulence in the· Creek, due to strong a ocean currents and tidal influence. Therefore, the turbidity of tropical seas is higher than other tropical and subtropical seas. The marine water turbidity is expressed in Nephelo Turbidity Unit (NTU). Water turbidity in DPA Port region has been recorded in the range of 15 NTU to 361 NTU.

Generally, water turbidity is high due to high organic load of mud and silt. (Omprakash, 1997) Higher turbidity of marine water at the DPA Port regions may also be associated with the washed sediment from mangrove environment and partially dredging activities, which is done on a regular basis along the Kandla Creek.

Nutrients

Plant nutrients in marine water such as Nitrate and Nitrite are present in low concentration, however, they are very crucial for the marine life. Their increase in concentration enhances the primary productivity in marine water. Nonetheless, excessive concentration sometimes can be detrimental to the aquatic life especially in creeks, estuaries and bays where there is a restricted water exchange. These increased nutrients lead to an excessive growth of algae resulting in eutrophication in some extreme cases (NIO,1998). In a pristine coastal marine water that is unaffected by any anthropogenic activities, it is expected that the level of concentration of phosphorous should be lower than that of the ammonia. However, in case of Kandla creek the result is quite reverse. The relatively higher concentration of phosphorous in Kandla Creek (Station S-3) 7.61 mg/L suggests that there is an input of phosphorous into the Kandla Creek might be handling of cargo phosphatic fertilizer.

Petroleum Hydrocarbon (PHs)

Petroleum hydrocarbons in the water column of Deendayal port area have been found in the range of 3 µg/l to 42 µg/l. The high range of petroleum hydrocarbon (S-5) 42 µg/l. results from the spills and leakage during the handling of crude petroleum products at the Port especially at oil terminals (NIO2002).

5.2. Biological status of Deendayal Port Authority Environment

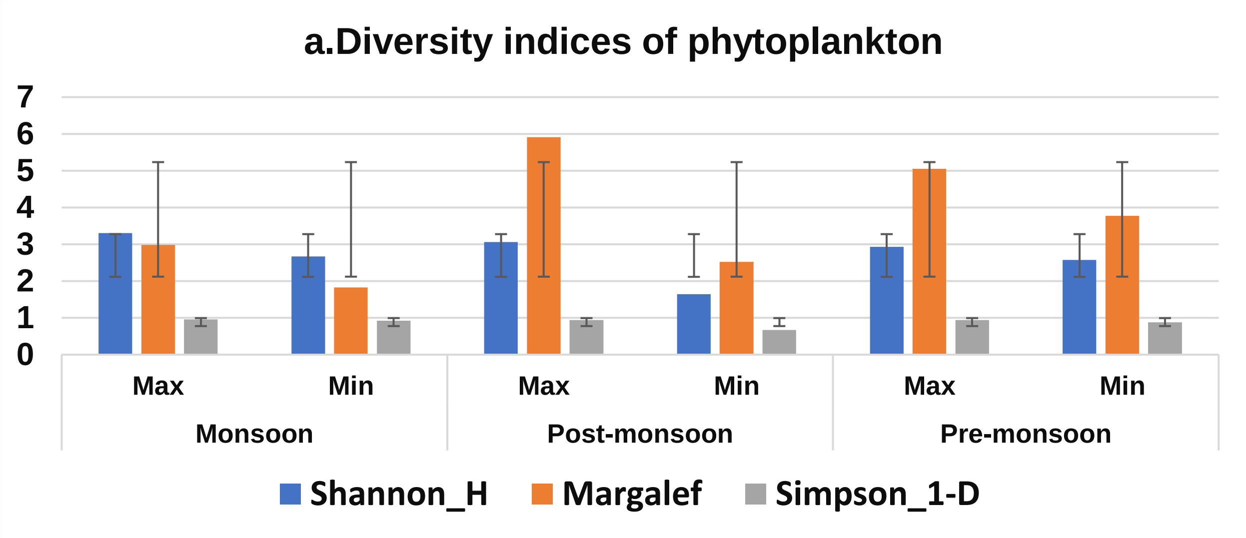
Biological resources of a marine area reflect the overall environment of the region in question. The coastal areas especially bays, creeks and estuaries are rich in biota and are habitat of many marine species. Usually, ports are also built in these areas for their geographical advantages. The port and harbour activities in these locations disturb the habitat of many marine biota. However, in the process many habitats are also created for marine biota. The Gulf of Kachchh is an example of such habitat and has been considered to be rich in biodiversity. Kandla port has been built right in the gulf and has been serving this region nearly seventy years.

Chlorophyll 'a' , Phytoplankton and Zooplankton

In general the basic parameters of marine biota like Chlorophyll 'a' and Phytoplankton are observed to be moderate in their values but similar to those prevailing along the coastal waters of India (NIO,2002).The index value of both phytoplankton and Zooplankton of 3 season shows moderate environmental status (**Figure 52 a &b).**

Natural geographical processes such as strong currents and higher tidal influence have been responsible for the high turbidity and suspended solids which in turn reduce the light penetration thereby reducing the growth of Plankton and primary productivity.The seasonal distribution of phytoplankton was 8160 No./l to 26,720 No./l and Zooplankton density ranges from 8120 No./l to 23,840 No./l .

As per Shannon Wiener's rules the aquatic environment i.e both soil and water 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 DPA port and its periphery environment has been influenced by contaminants deposited from industries and the cargo movements. Accordingly, species diversity decreases at sites with poor water quality. As deduced from the Shannon diversity index values between 3-4 overall 3 season representing the moderate quality of environmental status dominated by the few genera such as Coscinodiscus sp. and Synedra sp,and copepod sp. A community dominated by relatively few species indicates environmental stress (Plafkin et al., 1989). According to Staub et. al (1970) species diversity index value between 3.0 to 4.5 represents slightly polluted and the lightly polluted environment, the index value characterizes 2.0-3.0, similarly, moderately polluted environment shows index value of 1.0-2.0 and finally, the heavily polluted environment index value is 0.0-1.0. While considering the overall index values it is inferred that the study sites can be included under the category of lightly polluted environment.



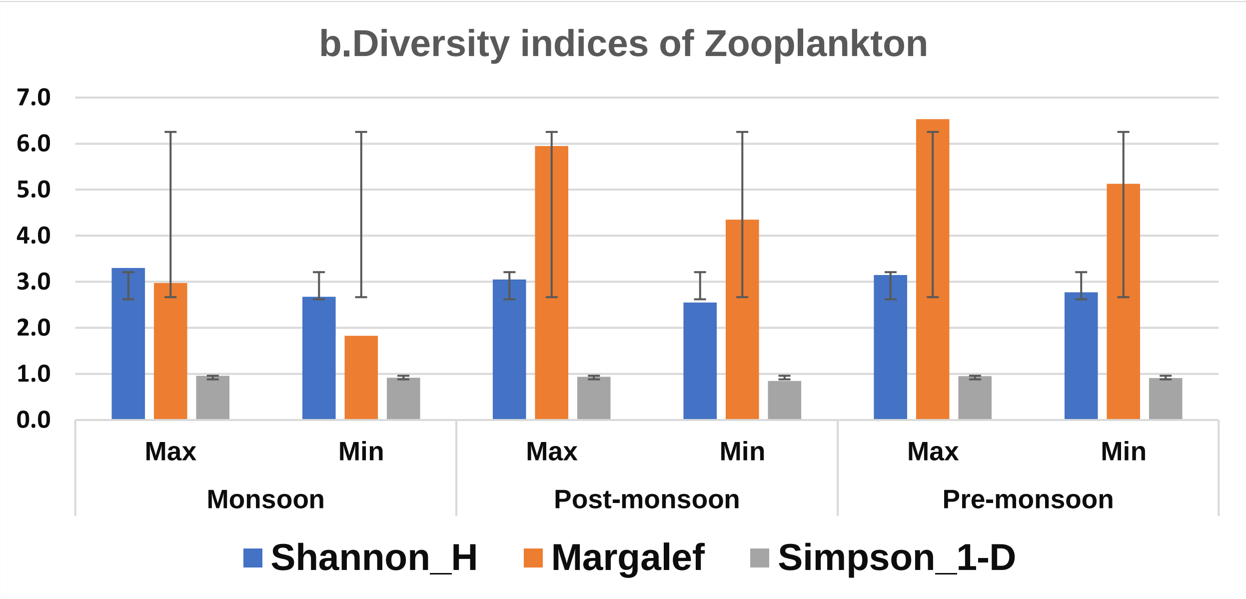


Figure 52 Diversity indices of Phytoplankton and Zooplankton

Intertidal Fauna

Macrofaunal communities did not show much spatial and temporal variation in their components at 15 sampling locations. The distribution of intertidal Fauna seems to be entirely governed by the environmental parameters like Physico-chemical and biological characteristics of the ambient milieu. Generally, intertidal Fauna on the Kachchh coast scope a harsher environment with relatively high salinity, wide temperature fluctuations, seasonal fluctuation of different hydrological parameters and a high sedimentation rate. The water suspended solids (SS) were generally found due to the dispersion of fine sediment from the bed and the intertidal mudflats due to tidal movements at the mouth of the Kachchh coast (Kandla).

An earlier study by Saravanakumar et al. (2007) revealed the presence of five intertidal Fauna in the mangrove environments along the Kachchh coast, with a diversity index ranging from 1.84 to 2.45. The species composition and diversity indices reported during 2018-2019, 2019-2020, 2020-21, and 2021-2022 did not vary significantly in the DPA port environment. It was understood that the intertidal fauna community in the Kachchh mangrove had not varied much in terms of its species diversity. An earlier study by Saravanakumar et al. (2007) revealed the presence of five intertidal Fauna in the mangrove environments along the Kachchh, with a diversity index ranging from 1.84 to 2.45. During (the 2021 to 2022) monsoon season diversity index values ranged from 1.14 to 1.80; pre-monsoon from 0.73 to 2.27; Post-monsoon from 0.39 to 2.41, respectively. The maximum diversity was documented during Post-monsoon and pre-monsoon, and the least diversity was documented during the Monsoon. The species richness is dominant in Post-monsoon 0. 0.53 to 2.72, Pre-monsoon 0. 0.37 to 2.72 and ranged from 0.95 to 1.72, ranging from the monsoon period. The Evenness values are average in the monsoon period, 0.61 to 0.84 and Post-monsoon 0.36 to 0.83 and pre-monsoon 0.39 to 0.88, respectively (Table 25-27). According to Magurran (1991), the Shannon diversity index of >3.0 indicates a healthy coastal environment. However, diversity indices around the DPA coastal environment were <3.0, indicating that the moderate faunal diversity..In the present observation, the species composition of the benthic macrofauna showed dominance in the Phyla Molluscs, Arthropoda, Annelida, Nematoda, Nemertea and Chordata. Previously, Ansari et al. (1986), Mohammed (1995) and Kumar (2001) recorded the presence of the Molluscs, Arthropoda, Annelida, and Chordata in various parts of Indian coastal waters. In the present study, the intertidal faunal density ranged from 34 ind/m2 to 84 ind/m2 during the monsoon period, 45 ind/m2 to 196 ind/m2 from Post-monsoon to 30 ind/m2 204 ind/m2 during the Premonsoon Period. The intertidal Fauna diversity was low in the DPA port area with their lower population density during the seasonal study throughout the stations

Subtidal Fauna

In the present observation, the species composition of the benthic macrofauna showed dominance in the Phyla Mollusca, Arthropoda, Annelida, Cnidaria and Chordata. The subtidal Fauna of the DPA Kandla survey recorded 32 species classified under five phyla (Cnidaria, Annelida, Arthropoda, Mollusca, and Chordata). Mollusc diversity was very high (21species) in all the seasons; during the pre-monsoon and Post-monsoon (13 species), and Monsoon (11 species), respectively. The second most dominant phyla, Annelida sharing (6 Species) in all seasons. The least diversity was documented in the other phyla, such as Chordata and Cnidaria (1 species). The highest number of organisms was documented from the pre-monsoon season and Post-monsoon (22 species), and Monsoon (21). The most common species were the molluscs such as *Pirenella cingulata* and *Optediceros breviculum*; the lowest density noticed was that of *Stephensonactis s*p. and *Dosinia sp*. Previously, Ansari et al. (1986), Mohammed (1995) and Kumar (2001) recorded the presence of the Molluscs, Arthropoda, Annelida, and Chordata in various parts of Indian coastal waters. The subtidal faunal diversity was low in the DPA port area with their lower population density during the seasonal study throughout the stations. Mahapatro et al. (2011) documented the macrofaunal diversity in Bhitarkanika (Odisha coast) mangroves, and the diversity ranged from 1870 No/m2. Ramakrishna et al. (2011) recorded the population structure and density of macrofaunal from the Andaman and Nicobar Islands and documented diversity from 1015 No/m2 in the. In the Gulf of Katchh, Saravanakumar et al. (2007) documented that from 1999 to 2000, the diversity indices ranged from 1.84 to 2.45, the richness varied between 0.82 and 0.98, and the evenness varied between 0.64 to 0.81. The present study observed the diversity indices ranged from 1.49 to 2.56, the richness varied between 1.37 and 4.01, and the evenness varied between 0.61 and 0.94. The results obtained from this study represent moderate environmental status. However, they provide baseline information on which further studies on biodiversity and conservation strategies might be based. There is a need for an in-depth study of Fauna and their interactions in mangrove ecosystems. Also, practices directed at managing mangrove resources should go hand in hand with conservation strategies.

Table 25. Diversity indices intertidal Fauna of Deendayal Port Authority during monsoon 2021

Indices	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Shannon	1.62	1.72	1.49	1.58	1.80	1.51	1.65	1.14	1.73	1.43	1.65	1.45	1.34	1.46	1.71
Evenness	0.84	0.70	0.74	0.61	0.76	0.75	0.65	0.62	0.81	0.84	0.65	0.61	0.77	0.61	0.79
Margalef	1.42	1.62	1.27	1.68	1.72	1.16	1.72	0.95	1.52	0.95	1.64	1.35	1.13	1.43	1.50

Table 26. Diversity indices intertidal fauna of Deendayal Port Authority during Post-monsoon 2021

Indices	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Shannon	1.36	2.23	0.99	2.32	2.15	1.35	1.73	1.78	1.43	0.39	1.63	1.89	0.81	2.17	2.41
Evenness	0.65	0.77	0.45	0.68	0.71	0.55	0.63	0.74	0.84	0.74	0.57	0.73	0.56	0.88	0.79
Margalef	1.34	2.17	0.98	2.59	2.26	1.50	1.72	1.30	1.06	0.37	1.64	1.66	0.73	2.30	2.72

Table 27. Diversity indices intertidal fauna of Deendayal Port Authority during Pre-monsoon 2022

Indices	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Shannon	1.45	1.83	1.18	1.72	2.04	1.02	1.69	1.02	1.54	0.93	1.98	1.65	0.73	1.89	2.27
Evenness	1.60	1.89	1.50	1.64	1.93	1.21	1.55	0.70	1.14	0.97	2.10	1.36	0.53	2.10	2.72
Margalef	0.53	0.62	0.36	0.62	0.86	0.46	0.68	0.69	0.77	0.63	0.73	0.75	0.69	0.83	0.74

Mangroves

For three seasons, the mangrove biodiversity assessment had been carried out for total 15 stations (S-1 to S-15) during 2021-22. However, the sampling station S-13 were offshore (out of area) and not carried the mangrove survery. In first season (monsoon-2021), although the station name mentioned as S-13 for the station nearby oil jetty, was incorporated to Kandla creek and considered as station S-15 for further analysis. With this, first station (S-1) was surveyed only one season (monsoon). In this way, total 13 stations were surveyed for season 2nd (post-monsoon 2021) and 3rd (pre-monsoon 2022). All these stations were located in total five sampling sites namely Tuna, Phan, Kandla, Jangi and Navlaki which were fixed for the collection of relevant phyto-sociological parameters. The overall plant characteristics were surveyed, in three classes of plants which are regeration class, recruitment class and tree class. The parameters considered for tree class were density, height, girth, plant height, canopy cover. During the monsoon season we found density was comparitively low to other two seasons, but post-monsoon of 2021 and premonsoon of 2022, it was increasing. It might be possible because the sampling stations were same for these survey but coordinates were taken randomly, although the results represented the same stations. Second interesting result was observed that, the height, canopy cover and girth of trees were reducing from monsoon to further seasons. From these four characteristics it might be possible that, the recruitment class plants present in the first survey (monsoon) grown and counted in tree class in further surveys.

As per year analysis, the average density was found higher in Kharo creek, followed by Navlakhi creek, and then Kandla creek. However, in the Kharo creek, only one station was surveyed. There were possibilities of fresh water availability for the mangroves of the stations located in Kharo creek, and Navlakhi creek. However, stations S-6 and S-11 located in Janghi creek had no such possibility of fresh water and that resulted in the less density of trees. Although the density was recorded higher in Kharo creek stations mangroves, they show smaller canopy cover compare to all other stations mangroves. Tree hight and girth were found more in Navlakhi creek mangroves compare to other station mangroves, throughout the year analysis.

For better growth, mangroves need a nutrient-rich, hypoxic, and muddy soil. They also need variations in salinity instead of always uniform condition of salinity. The freshwater incursion is important for the growth of mangrove. It may possible that Navlakhi, Tuna creek mangrove gets freshwater and they grow more compare to other locations. Of course, other parameters such as physico-chemical conditions also play important role in the growth of mangroves. Generally, sedimentation provides good substrates for mangrove seeds, nutrient rich environment for their germination. Sediments in the mangrove area is generally originated from marine alluviam which further get deposited on the coastal areas. With this, rivers also carry mud to sea and get deposited on the coast. Slit and clay parts of sediment forms the mud which is nutrient rich and supportive to mangrove growth. Mangrove species are adapted for a certain level of changes in such parameters and hence, complexity in the environmental factors determines the composition and structure of mangrove forest and further its species distribution in overall area. The conditions in the DPA Kandla were perfect for the A. marina species and that's why, it was showing its wide distribution throughout all locations. However, a few speceis can be also found rarely in the area, probably came there by floating with tides from the plantation areas and germinated in the area of DPA Kandla.

6. Impact identification and Evaluation

Direct and Indirect Impact on Ecologically Sensitive Ecosystems (Impact-I)

Location of the Deendayal port Site in the close vicinity of ecologically sensitive terrestrial ecosystem (Sanctuary, National Park, Biosphere Reserve and migratory route, breeding and nesting sites of avifauna) may impact the overall biodiversity values due to project associated activities.

A. Habitat degradation due to pollution

B. Loss of habitat and population of faunal groups

C. Overall impact on biodiversity of the protected area

Evaluation: The coastal ecosystems investigated during 2021 to 2022 are located within the jurisdiction of Deendayal Port surrounded by the port associated industrial sectors and predominately salt industries. There are no ecologically sensitive ecosystems (Protected Areas) located within the 10 km radius of the project site. As per the existing land use no impact on the protected areas was foreseen. Further, the study area is not identified as migratory route of any major animal group as well as nesting and breeding sites of avifauna.

Impact II. Direct loss of inter-tidal habitat will impact the floral and faunal species

Loss of inter-tidal habitat (mangrove) and degradation due to project associated activities will affect the overall population status of threatened aquatic avifauna

Evaluation: As per land use land cover study, the project area dominated by intertidal habitats like, Mangrove, creeks and salt pans. The study area reported total 2534 birds belong to 89 species (Annexure 1). However, this list includes only seven threatened species (Painted Stork – 24, Lesser flamingo 68, bar tailed Godwit – 18, Black-tailed Godwit- 11, Black-headed Ibis, 38, Darter 6 and Eurasian Curlew -1) belong to Near threatened category and counted few individuals within study area.

Since the study area beyond 5 km supports large extent of similar (Inland wetlands & Sal pans) habitat types and supports large number of aquatic birds, the overall impact on few aquatics threatened avifauna reported in the study area would be minimal (Annexure 1). In spite of that, implementing, proper mangrove plantation activity can take care of this minimal impact. Further, no endangered aquatic birds reported in the study area.

7. Mitigation and management plan

Direct and Indirect Impact on Ecologically Sensitive Ecosystems

The Deendayal Port area is surrounded by a large number of port associated industries and salt industries. Since no Protected Area exists within 10 km radius of the DPA port Jurisdiction, impacts on sensitive ecosystem was not visualized.

Loss of Inter-tidal habitats

The project proponent should take up compensatory mangrove and associated plantation in and around the project area.

- The plantation needs to be carried out with fourfold density of seedlings compared to the natural mangrove density of the Kandla creek area.
- This mangrove plantation is expected to support mangrove associated bird species and thereby enhance the avifauna diversity of the local environment.
- Since the intertidal (mangrove and creeks) and salt pan habitats support few thousands of aquatic and migratory bird species, the project proponent should plan the establishment /construction activities (if any) other than the migratory season (November – February) to avoid disturbance to the migratory species.
- The above suggested mangrove plantation needs to be monitored for next five years till it attains maturity. The growth rate, enhancement and assemblage of associated faunal species should be studied.
- Since the intertidal habitat and adjacent areas support thousands of aquatic avifauna, the project proponent should take up long-term (five years) ecological monitoring program of the adjacent creek, mangrove and salt pan habitats to assess the change in avifaunal diversity due to any developmental activities taking place in the future.

8. Conservation and management of marine Biodiversity od Deendayal Port Authority

Conservation of biodiversity is considered as the key component for administration of natural assets. Biodiversity is an all-encompassing concept that describes the magnitude of ecological diversity addressing the wide range of life associated with different types ecosystems. The warnings to biodiversity involve: habitat fragmentation, stressing the already squeezed natural resources, deforestation; annexation of invasive species and climate alternation (Khan et al., 2019a,b). Biodiversity conservation is the protection and management of the biotic ad abiotic resources for sustainable development and existence and preservation of the diverse species, Sustainable utilization of species in the ecosystem along with the maintenance of the life-supporting systems are essential for the functioning of the various ecological processes. It is an integral part of any commercial activity and infrastructure development in the marine environment. Emphasis is given towards the reinstatement of the physical, chemical and biological characteristics of the coastal ecosystem which are much complex and vulnerable on which the human is highly dependent. Management of the marine biodiversity is the prime concern in the development of Ports and harbours which occupy the fragile continental shelf which is highly productive and harbors numerous living resources. Hence Environmental Management Plan (EMP) is considered as an important component in any developmental activity with sustainable management goals which are to be fulfilled within a time frame. Thus, EMP aims to suggest concrete measures that would mitigate the impacts paving way for maintaining the integrity of the project environment.

Development of ports involves effective management plan towards environmental wellbeing that guarantees both sustainable port growth and a healthy ecosystem functioning in its vicinity. There is a need for innovative solutions for port development which are in harmony with the ecosystem and which are robust or adaptable under change. The recent trends like growth of global trade, increasing vessel movements and size, modernize port facilities, driving urgent investments in ports has been negatively impact water quality and marine flora and fauna. This simultaneously calls for sustainable and inclusive development which ensures productive nature of its marine environment.

The port authorities mandate to their activities environmentally sustainable and benign need to understand the marine ecological setting of their ports including water quality, biotic components and the factors that impact them. In spite of all the pressures, the ecosystem continues to deliver many services which are often intangible. In order to maintain these services intact, it is imperative that different biotic and abiotic components of the port environment are sustainably managed in the long run.

Accordingly Deendayal Port has initiated several environmental management measures as mandated by the MoEF &CC from time to time with the purpose of maintaining and preservation of its terrestrial and coastal environmental integrity. The following measures have been taken by the port authorities:

Ongoing Environment Management Measures by DPA

A holistic and comprehensive study on the marine ecology of the port including different marine faunal and floral components and preparation of management plan has been initiated as per the specific condition No. xviii of the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016. The results of the seasonal observations on the environmental characteristics and biodiversity of the intertidal zones have been compiled along with the conservation plan recommendation for three consecutive years (2017 to 2021). ii. Mangrove plantation has been carried out to the tune of 900 ha in Sat Saida Island, 150 ha in Nakti creek, 450 ha in Kantiyajal (Table 26) by Deendayal Port. The black mangrove *Avicennia marina* was used in these plantation activities as this species is more suitable to the existing environmental condition in this coast.

Based on the information gathered through the seasonal studies on the different biotopes and the biodiversity along with the mangrove, macrofauna, plankton density and diversity, productivity of mudflat and avifauna for the period 2018-2022 within the limits of the Deendayal port, it is evident that the impact is insignificant since management action plans are showing positive responses to a large extent in spite of the climate change induced impacts on the marine ecosystem. This project aims to draw a holistic management framework for conserving the Marine Biodiversity and Ecology of the DPA port marine environment which include many biotopes such as mangroves, intertidal and subtidal realms, mudflats and salt marshes, each serving as an abode for a variety of fauna and flora. Given the economic importance of DPA port and the increasing national and global demand for sustainability, it is planned to study the marine ecology of this port seasonally, with the long term objective of rendering the port existence and operations environmentally sustainable.The proceeding section outlines management initiatives to be undertaken by the port authorities for holistic management of marine biodiversity within the port limits envisaging several facilities will be built within port premises in the future.

Intertidal and Subtidal Biodiversity Management

The intertidal zone constitutes the coastal environment where land and sea meet, i.e., the area between extreme high-water springs (EHWSs) and extreme low water springs (ELWSs). The subtidal zone lies below the lowest water level beyond the intertidal zone. Both this zone provides numerous ecosystems for marine fauna and needs to be managed effectively for the overall wellbeing of the ecosystem. In addition, ecosystems located in the intertidal zone are experiencing degradation and an accelerating loss of biodiversity, which might potentially affect ecosystem goods and services and human well-being. In the DPA vicinity, intertidal and subtidal zones are mostly muddy-silt in nature lacking rocky or sandy formations. Intertidal belts of the study area support many biological elements indicating overall ecosystem health. The intertidal zone may be susceptible to natural and anthropogenic pressures such as soil erosion, industrial pollution, continuous dredging and sedimentation. Intervention is often required to mitigate or support the natural recovery of the intertidal zone in a port environment

The marine biodiversity study conducted from MAY 2021 to MAY-2022

The results showed the crustaceans (crabs) and mudskippers are the dominant groups throughout the year along the intertidal zone at all the sampling sites. It's imperative to take measures to conserve and promote the intertidal biodiversity of DPA coastal / creek environments. The majority of the intertidal fauna were associated in the mangrove and halophyte habitats and many of them are true mangrove species. Mangroves provide natural habitats for variety of intertidal macrofauna likes crabs, gastropods, saw scale viper and avifauna. Hence, promoting mangrove plantation or increasing mangrove cover would help to conserve the intertidal macrofauna.

Soil erosion is another major threat to the intertidal habitats in DPA port jurisdiction. Often the threat of erosion is severe in a port environment due to vessel movement, altered hydrological regime and other natural causes. During the present study it was noticed that few creeks stretch in Kandla are susceptible to erosion due to high water currents and tides. The dual purpose of controlling erosion and promoting intertidal biodiversity could be best achieved by installation of artificial reef structures. Artificial coastal structures are cheap and installation is easy and adaptable and for better results it can be supplemented with the addition of a substrate that will support marine organisms as that of the natural intertidal and sub tidal environment. The structural diversity of the artificial reef will determine the diversity of marine organisms utilizing the created habitat. Artificial reefs once built will last for decades and would enrich marine biodiversity in short period of time by providing ideal habitat. Natural materials such as dead gastropod and bivalve shells may be used for building artificial reefs and these materials are environment-friendly. Reef balls are another form of artificial reef increasingly used in western waters to create sustainable marine reef habitat which may be easily attempted in Deendayal port. Both reef balls and artificial reefs being inexpensive and locally available, can be built in different creek systems of the port.

Plankton and Productivity

Planktonic community and productivity were studied in creek waters of Deendayal port jurisdiction. Diversity and density of phytoplankton community in DPA port creek environment is moderate as only 30 and 24 genera were reported during monsoon, post-monsoon and winter, respectively**.** Similarly, 35 genera of zooplankton have been reported during post-monsoon and winter. The productivity of the water column is low as indicated by the Chlorophyll 'a' pigment concentration, due to the prevalence of high rate of suspended solids which prevents the photosynthesis. However, the observed species diversity is moderate and support the biodiversity of the creek system.

Mangrove Management

DPA has around 23.967km^2 of mangroves cover in their jurisdiction which consists of many major and minor creek systems within its limit, port infrastructure occupies only ~1% of the total area. Establishment of facilities is a continuous process and the expansion of infrastructure over the coming years will bring remarkable changes in the landscape and seascape in and around the port area. Long term human centered activity of this magnitude will have repercussions on its natural resources and ecosystems. Mangroves, mudflats and intertidal creeks are the major ecological entities within the port boundary and they function in close synchrony with each other, thus their conservation and management call for a holistic approach.

Conservation of Island

Islands support a rich marine fauna, flora and avifauna diversity and deserve special conservation efforts. Land cover classification of Sat Saida Island using GIS tool revealed sparse and dense mangroves, mudflats and halophytic vegetation other than mangroves are other prominent land cover categories. Though equipped with all the features to support a dense mangrove formation, the mangroves of Sat Saida Island are rather sparse and scrubby and confined mostly to creek banks. Different elevation features of the Island render the tidal flooding and hydroperiod in the interior region poor resulting in sparse and open mangrove formations. This Island could be an ideal site for mangrove plantations while implementing ministry's mandated plantation activities, other mangrove restoration and rehabilitation activities with biophysical amendments such as desilting existing creeks, joining existing minor creeks could be taken up which will increase the mangrove cover in this Island. These physical activities in the mangrove lined minor creeks will increase tidal flooding and hydro-period and convert sparse mangroves into dense mangroves in due course of time. Deendayal port has already carried out 1400 ha of mangrove plantation since 2006 with good success rate in various locations and additional 100 ha is in progress.

Co-Management with the Community

Management program for mangroves is feasible in the case of Deendayal port since all the mangrove formations are under its legal control and hence any management program could be implemented without any sectoral conflicts with forest or any other government departments. It was proven in many instances that involving the stakeholder communities in the surrounding villages will yield better results in mangrove management. Though the population in the port surroundings has different livelihood activities, fishermen community could be targeted to involve in community based mangrove management.

The fishermen communities living in the villages such as Vera, Khari Rohar, and Tuna close to the port could be involved by forming "Samithies" for the conservation of mangroves with possible funding resources. The community-based organization (Samithi), whose responsibilities and roles are well defined in the specific task of conserving mangrove patches in their vicinity, could play a seminal role in conserving these mangrove patches. Their resource dependency, perception of mangroves, and level of involvement in such resource management activities are to be assessed before forming such a community based organization. They could be assigned the specific task of conserving these mangroves by involving them in mangrove plantation/restoration activities, physical protection and other conservation measures. This could be taken up as part of the port's CSR activity.

Physical Protection

The most common method of conserving mangrove ecosystem is by creation of protected areas. Presently, the whole port limit is under the protection of Central Industrial Security Force (CISF). Thus, CISF personnel could be imparted with the ecological significance of mangroves through special awareness program and mangrove patrolling by them can be instituted for physical protection to mangroves. Employees of Deendayal Port environmental and ecological significance of mangroves and other coastal resources. Licenses for salt works and other port allied industries are awarded by port authorities without understanding the ecological and environmental rules and regulations governing them which often lead to legal and environmental bottleneck at a later stage. Short term awareness programs to port employees by marine/mangrove ecologists will be beneficial in several counts,

Identification of Stress Factors

Mangrove environment will continue to be stable and balanced if there are no external stressors such as change in hydrology, elevation and slope, soil and water salinity and pH, soil texture and wave energy are maintained in a natural condition without alteration. In addition, human centered stress factors such as resource collection, tree felling and other habitat modification activities will act as major stressors.

Changes in Hydrology and water quality management

The most important factor in conserving any mangrove formation seems to be maintaining the original hydrology and tidal flow, including depth, duration and frequency of tidal flooding. Understanding the existing mangrove hydrology at the micro-level and applying this knowledge to protect mangroves and cost-effective restoration and regeneration is important. In most mangrove degradation instances, it is the modified hydrology and the resultant reduced tidal flushing and subsequently the critical period of dryness and flushing that determine the health of a mangrove forest. Mostly, micro-topography controls the distribution and well-being of mangroves, and physical processes play a dominant role in the formation and functioning of the mangrove ecosystem. Even disturbed by human impact, mangrove forest has got the ability to self-repair over a period of time provided that the normal tidal hydrology is not disrupted and the availability of water borne seeds are not blocked. Regular monitoring of mangrove hydrology through simple scientific methods will go a long way in maintaining ecosystem balance.

Management plan to improve marine water quality in the port area

- The drains and outfall should be cleaned regularly to avoid anaerobic decomposition and also for proper flow of water/wastewater. This will also enable the characterization of wastewater and calculation of waste load.
- Domestic and canteen wastewater should be discharged only after proper treatment.
- The solid waste generated from the canteen and other diffused sources should be collected and disposed off properly.
- The discharge of oil waste into the sea from the following main sources should be controlled

1. Discharge of oil waste from liquid chemical corridor area. This liquid waste is generated during tanker cleaning, and oil spills during filling operations,
2. Oil spills at berth during unloading operations.
3. Tanker ballast discharge from ships.

- Bulk material should not be disposed into the sea. All drains and roads should be cleaned before the rainy season to avoid runoff from land to sea carrying a myriad of pollutants, including chemicals that may be imposed for oily discharges in and around the port

Promoting Natural Regeneration

Promoting natural regeneration where the mangrove stand has the capacity to self-sustain will ensure the wellbeing of the stand. The natural regeneration capacity of the stand is to be assessed by quantifying the degree and extent of the entrance of younger classes such as saplings into the mature tree category. The ratio between these different size classes will indicate the dynamic state of the mangrove forest. The observation that natural seedling recruitment is commonly occurring will indicate that the system is functioning normally. Only if the natural seedling recruitment is not occurring does the system requires an assisted recovery by plantation and physical amendments. The present study shows that natural regeneration in the studied mangrove formations is expected, as indicated by the entry of younger classes into adult categories.

Mangrove Biodiversity Enhancement

Deendayal port is regularly undertaking mangrove plantation in a massive manner since 2006. However, only *A.marina* plantation was attempted due to adverse environmental conditions. Within DPA limits, three additional mangrove species have been recorded sporadically namely, *Rhizophora mucronata, Ceriops tagal* and *Aegiceras corniculatum*. It is strongly recommended that in all future plantation efforts, these additional species which are naturally occurring in this region could be used in large scale. Planting these additional species is expected to create a seed bank for these species, converting the stand into multispecies formation in due course of time.

Management Plan for Marine Fisheries

Regular dredging activities in the Port area can impact marine fauna through physical contact with dredging equipment and indirectly through changes to noise and vibrations levels, water quality and loss of habitat and food sources. The most important potential impact would be the rise in suspended solid load, which hinders the photosynthesis of the producer communities, especially the phytoplankton and affects the food chain. The high turbidity due to heavy suspended solids load during dredging and reclamation can result in clogging of the gills of the filter, thereby causing asphyxiation. But since fishes in the water column are free swimming in nature, they will tend to avoid turbid areas and move to safer zones. Once the turbidity increase gets reversed due to sedimentation and dispersion by current and wave influences, the fishes are expected to come back. Hence, there will be virtually no impact on fish due to dredging in the long term. As the area does not have any breeding ground for fisheries, no significant impact on marine ecology is anticipated during the dredging phase.

Management Plan for mammals and reptiles

A single species the common dolphin, *Sousa plumbea* are found along the creek waters of Deendayal port during the field investigations. The reptile, saw-scaled viper, *Echis carinatus* sochureki is commonly seen in the mangroves of DPA port jurisdiction

Seaweeds, Sea grasses and Corals

Along the coastal environment of DPA port jurisdiction corals, seaweeds and seagrass formations were not observed. The intertidal area of Kandla is largely muddy in nature. Coral growth in the sub-tidal region is unlikely in view of the high suspended solids in the water column and also not conducive for the growth of the benthic macro algae which need hard substratum to attach the rhizoids. The seagrasses also prefer sand admixed soil and shallow bottom with low suspended matter in the water. The texture of the soil in the study sites were dominated with clay fraction which may not support the growth of sea grass communities.

9. Summary and Conclusion

Intertidal Fauna

Intertidal faunal composition, density and diversity were studied at 15 representative sampling locations within the Deendayal port limits. A total of 10 genera of intertidal macrofauna were recorded during 2020. The intertidal fauna belonged to five groups: crustaceans, gastropods, bivalves, polychaetes and fishes (mudskipper). Among these, crustaceans were the dominant group constituted by 5 species, followed by Mollusca (3 species), Polychaeta (1 species) and mudskipper (1 species). Among the crustaceans, *Metopograpsus messor, Scylla serreta, Uca* sp. and *Bolepthalamus* sp. were distributed in all the sampling locations. However, gastropods *Piranella cingulata* and the *Nassarius* sp. were distributed in four sampling locations. Nereis sp. (Polychaete) was present at sites S-4 and S-5. Similarly, in winter 2021, a total of 12 genera belonging to four groups Crustaceans, Gastropods, Polychaete and fishes (Mudskipper) were observed. Among the groups, Crustaceans and gastropods were dominant with 6 and 4 species, respectively, while Fishes and polychaetes were represented with single species. The mangrove tree trunk crab *M. messor* and *Uca lactea annulipes* were distributed at all the 12 sampling sites.

In the present study, the highest Shannon diversity index was recorded at S-7 and the lowest at S-1. The highest species evenness (0.94) was noticed at S-7, while the lowest (0.54) from site S-1. The highest species richness was recorded at S-4 (1.47) while it was 0.63 at site S-10. During winter, the highest Shannon diversity index was reported at S-1 (1.54) followed by S-3 (1.53) and S-11 (1.50) while the lowest indices were at S-5. In general, the intertidal macrofaunal communities at the Deendayal Port environment showed uneven distribution patterns and species diversity. Shannon diversity indices ranging >4 indicate high, 4-3 indicate good, 3-2 indicate moderate, and 2-1 indicate poor water quality. The overall benthic fauna diversity indices for the three seasons reveal the influence of the water and sediment characteristics on the distribution of the different categories of the benthic fauna, which determines their abundance and survival in the intertidal zone.

Subtidal Fauna

During the present study, three main groups of benthic organisms, polychaetes, molluscs, and crustaceans, were noticed, along with a few organisms that are infrequent in the samples, considered as: others" The group "others" was formed of the larvae of the crabs and fishes. In the post-monsoon 2020, the molluscs (9) constituted the dominant group, followed by polychaetes (7), crustaceans (4), and "Others" (2). The bivalve, *Pholas* sp., The gastropod *Telescopium* sp., and the polychaete *Gonaida* sp., occurred at 66.67% of the samples, indicative of their environmental success. During the winter 2021collections also, the molluscs were followed by the phyla Annelids and Arthropods.

The Shannon diversity indices values varied from 1 to 3 during the seasonal study which to with the maximum at station S-1 and minimum at S-2. Margalef index, which is a measure of the richness of forms that take into account both the number of taxa and the number of individuals in taxa, ranged from 1.85 to 3.40, with the maximum at S-1 and minimum at S-2. The evenness values varied from 0.59 to 0.96, with the maximum in S-7 and minimum in S-4. Concerning winter 2021, the Shannon diversity varied from 1.49 to 2.31 with a maximum at station S-2 and minimum at S-7, evenness ranged from 0.50 to 0.92 with a maximum at S-8 and minimum at S-10 and Margalef richness ranged between 2.87 and 3.68 with a maximum at S-2 and minimum at S-8

Mangrove Environment

Mangroves in Kachchh are constituted by four true species namely, Avicennia marina, Ceriops tagal, Rhizophora mucronata and Aegiceras corniculatum. Among them, A. marina was the dominant. The remaining three species occur sporadically in few places at Sat Saida Bet. During the post-monsoon 2020, the A. marina tree density ranged from 1687 trees/ha (S-5) to 4352 trees/ha (S-7). On the contrary, during winter 2021, the tree density ranged from 2260 trees/ha (S-6) to 5020 trees/ha at S-7 in the Khari creek.

Seaweeds, Seagrasses and Coral habitat

Seaweeds are usually found in coastal stretches characterized by low turbidity and suspended sediment load in the water column with high nutrients content contrary to conditions prevailing in the study site. Hence, the present field survey was conducted during winter (March 2021). A few species of drifted (due to wave action) macroalgae namely, Enteromorpha sp., Ulva lactuca, Ulva rigida, Ulva reticulate and Sargassum wightii were observed in the intertidal belt near Kandla creek and Khari creek near DPA port. Coral ecosystem is not present in the northern shore of Gulf of Kachchh. The study site located at the Nakti creek in Kandla region is at the inner portion of the Gulf with high turbidity and suspended sediment load in the water column rendering it highly unsuitable for coral formation

Halophytes

Halophytes are predominantly present in the premises of Deendayal Port since habitat conditions are suitable for halophytes at the inner part of Gulf of Kachchh. Halophytes are mostly found beyond highest high tidal levels where spring tides reach occasionally and pore-water salinity often reaches >90 ppt. Their presence is widely noticed intermingled with mangrove formations in all the mudflats. During period of May 2021 to May 2022, 4 halophyte species, respectively were recorded within the quadrates from 12 sampling locations.

Mudflats

Mudflats are a major ecological entity within DPA Port limits next to mangroves covering 31% of the total area as per GIS-RS study. Often they are an integral part of mangrove system. The current study focuses on the productivity of the mudflat using Total organic carbon (TOC) as an indicator. The highest TOC values (0.42 ±0.03%) were recorded at station S-5 followed by S-8 (0.35 ±0.03%). Lowest TOC values were reported at site S-3 and S-9. It is observed that TOC values show a significant difference 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. During the winter 2021, the highest percentage of TOC value was reported at S-7 (0.99±0.47%) followed by S-1 (0.84±0.56%). Likewise, lowest TOC values was reported at S-5 (0.27±0.03%) followed by S-4 (0.46±0.59%). Shannon diversity indices ranging >4 indicates high, 4-3 indicates good, 3-2 indicates moderate, 2-1 indicates poor and.

Conclusion

It is imperative to create strong baseline data on the marine environment in the port vicinity in tune with the spatial extent of developmental activities. Continuous marine ecological monitoring study since May 2017 focused on the biological and productivity of mudflats. Based on the detailed investigations of marine ecological components and the possible impacts of the DPA port environment, it could be concluded that the effects on the various biotic components are minimal and confined to high activity areas only with limited impacts on the surroundings. From 2017-2018, 2018-2019, 2019-2020 and 2020-2021 studies conducted by GUIDE, it was inferred that there was no significant variation with respect to taxa/genera/species composition as well as faunal density in all the sampling locations in the Deendayal port Authority and its surroundings.

During the period May 2021 to May 2022, covering the seasons' Monsoon, Post-monsoon and Pre-monsoon, the overall density of mangroves during Monsoon (*A. marina*) was 3198 trees/ha, which increased in post-monsoon to 3410 trees/ha and it again further increased to 4483 trees/ha. The tree height, canopy cover and girth were reduced from Monsoon to further season, representing recruitment class (*A. marina*) in the first survey (Monsoon) was grown and counted in tree class in the further survey. The planktonic community structure was increased in post-monsoon and decreased in pre-monsoon, which was dynamic in nature and depended on various environmental and climatic factors. The intertidal and subtidal fauna such as Mollusca, Arthropoda and Annelida represent major groups. The seaweed was not observed in Monsoon, but the drifted fragment of seaweed *Chaetomorpha* sp. and *Enteromorpha* sp. was cited at S-13 and S-14, which might be drifted from the gulf environment. Four species of halophytes, namely *Sesuvium portulacastrum*, *Salvadora persica*, *Aeluropus lagopoides* and *Salicornia brachiata* were recorded inside the quadrates from May 2021 to May 2022. Among the halophyte species recorded, *Salicornia brachiate* & *S. portulacastrum* as major dominance in the majority of the study area.

A total of 84 species belonging to 9 orders, 34 families and 62 genera were recorded from the coastal area of Deendayal Port during this study. In order to ward off the predicted impacts on specific components of the marine biota, appropriate mitigation and management plan is suggested. Given the vastness of the Gulf, the predicted impact will be negligible, and the baseline background limits of different parameters will be regained on the secession of dredging and disposal activities in and around the port area.

In addition to biological parameters, the port authorities also cover essential Physico-chemical parameters like water turbidity, suspended load, sediment texture, soil organic carbon for bottom sediment and water nutrients like nitrate, nitrite, silicate and phosphate and including heavy metals and petroleum hydrocarbons in the port environment for the period May 2021 to May 2022. Both biological and Physico-chemical data on every season would be helpful in providing more insight into the ecological status of the Deendayal Port Authority. Hence it is recommended to continue the regular monitoring of the ecological status of the coastal and the adjoining land, inclusive of the Port adjoining peripheral land cover areas, to have an integrated management plan to fulfil the green port mission successfully.

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Annexure-1

Sl No	Order	Family	Common Name	Species	MS	Habitat	FG	IUCN-2022
1	Accipitriformes	Pandionidae	Osprey	*Pandion haliaetus*	RM	T	P	LC
2	Accipitriformes	Accipitridae	Black-winged Kite	*Elanus caeruleus*	R	T	C	LC
3	Accipitriformes	Accipitridae	Western Marsh Harrier	*Circus aeruginosus*	M	T	P,A,	LC
4	Accipitriformes	Accipitridae	Shikra	*Accipiter badius*	R	T	C	LC
5	Caprimulgiformes	Apodidae	Indian House Swift	*Apus affinis*	M	T	I	LC
6	Charadriiformes	Scolopacidae	Black-tailed Godwit	*Limosa limosa*	M	A	IN	NT
7	Charadriiformes	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	R	A	IN	LC
8	Charadriiformes	Scolopacidae	Whimbrel	*Numenius phaeopus*	M	A	IN	LC
9	Charadriiformes	Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis*	M	A	IN	LC
10	Charadriiformes	Burhinidae	Eurasian Thick-knee	*Burhinus oedicnemus*	R	A	IN	LC
11	Charadriiformes	Charadriidae	Common Ringed Plover	*Charadrius hiaticula*	RM	A	IN	LC
12	Charadriiformes	Scolopacidae	Dunlin	*Calidris alpina*	M	A	IN	LC
13	Charadriiformes	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	R	A	IN	LC
14	Charadriiformes	Charadriidae	Yellow-wattled Lapwing	*Vanellus malabaricus*	R	T	I,IN	LC
15	Charadriiformes	Charadriidae	Red-wattled Lapwing	*Vanellus indicus*	R	T	I,IN	LC
16	Charadriiformes	Scolopacidae	Little Stint	*Calidris minuta*	M	A	IN	LC
17	Charadriiformes	Scolopacidae	Sanderling	*Calidris alba*	RM	A	P	LC

18	Charadriiformes	Laridae	River Tern	*Sterna aurantia*	R	A	P	LC
19	Charadriiformes	Laridae	Lesser Black-backed Gull	*Larus fuscus*	M	A	P	LC
20	Charadriiformes	Recurvirostridae	Pied Avocet	*Recurvirostra avosetta*	M	A	IN	LC
21	Charadriiformes	Charadriidae	Little Ringed Plover	*Charadrius dubius*	M	A	IN	LC
22	Charadriiformes	Charadriidae	Lesser Sand Plover	*Charadrius mongolus*	M	A	IN	LC
23	Charadriiformes	Charadriidae	Greater Sand Plover	*Charadrius leschenaultii*	M	A	IN	LC
24	Charadriiformes	Scolopacidae	Eurasian Curlew	*Numenius arquata*	RM	A	IN	NT
25	Charadriiformes	Scolopacidae	Bar-tailed Godwit	*Limosa lapponica*	M	A	IN	NT
26	Charadriiformes	Scolopacidae	Spotted Redshank	*Tringa erythropus*	M	A	IN	LC
27	Charadriiformes	Scolopacidae	Common Greenshank	*Tringa nebularia*	M	A	IN	LC
28	Charadriiformes	Scolopacidae	Common Redshank	*Tringa totanus*	M	A	IN	LC
29	Charadriiformes	Scolopacidae	Wood Sandpiper	*Tringa glareola*	M	A	IN	LC
30	Charadriiformes	Dromadidae	Crab-plover	*Dromas ardeola*	M	A	IN	LC
31	Charadriiformes	Laridae	Black-headed Gull	*Chroicocephalus ridibundus*	M	A	IN	LC
32	Charadriiformes	Laridae	Little Gull	*Hydrocoloeus minutus*	M	A	IN	LC
33	Charadriiformes	Laridae	Little Tern	*Sternula albifrons*	M	A	IN	LC
34	Charadriiformes	Laridae	Caspian Tern	*Hydroprogne caspia*	M	A	IN	LC
35	Columbiformes	Columbidae	Rock Pigeon	*Columba livia*	R	T	G	LC
36	Columbiformes	Columbidae	Laughing Dove	*Streptopelia senegalensis*	R	T	G	LC

37	Columbiformes	Columbidae	Eurasian Collared Dove	*Streptopelia decaocto*	R	T	G	LC
38	Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*	R	A	P,A,IN	LC
39	Coraciiformes	Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	R	A	P,A,IN	LC
40	Coraciiformes	Alcedinidae	Pied Kingfisher	*Ceryle rudis*	R	A	P,A,IN	LC
41	Coraciiformes	Meropidae	Green Bee-eater	*Merops orientalis*	R	T	I	LC
42	Coraciiformes	Coraciidae	Indian Roller	*Coracias benghalensis*	M	T	I,RP	LC
43	Coraciiformes	Coraciidae	European Roller	*Coracias garrulus*	M	T	I,RP	LC
44	Gruiformes	Rallidae	Watercock	*Gallicrex cinerea*	R	A	IN	LC
45	Gruiformes	Rallidae	Common Moorhen	*Gallinula chloropus*	R	A	H,I,IN	LC
46	Gruiformes	Rallidae	Common Coot	*Fulica atra*	R	A	IN,W,H	LC
47	Passeriformes	Corvidae	House Crow	*Corvus splendens*	R	T	O	LC
48	Passeriformes	Dicruridae	Black Drongo	*Dicrurus macrocercus*	R	T	I	LC
49	Passeriformes	Estrildidae	Indian Silverbill	*Euodice malabarica*	R	T	G	LC
50	Passeriformes	Passeridae	House Sparrow	*Passer domesticus*	R	T	G	LC
51	Passeriformes	Ploceidae	Baya Weaver	*Ploceus philippinus*	R	T	G	LC
52	Passeriformes	Muscicapidae	Indian Robin	*Saxicoloides fulicatus*	R	T	I	LC
53	Passeriformes	Sturnidae	Rosy Starling	*Pastor roseus*	M	T	O	LC
54	Passeriformes	Sturnidae	Common Myna	*Acridotheres tristis*	R	T	O	LC
55	Passeriformes	Hirundinidae	Wire-tailed Swallow	*Hirundo smithii*	R	T	I	LC
56	Passeriformes	Hirundinidae	Red-rumped Swallow	*Cecropis daurica*	R	T	I	LC

57	Passeriformes	Hirundinidae	Dusky Crag Martin	*Ptyonoprogne concolor*	R	T	I	LC
58	Passeriformes	Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	R	T	FU,I, H	LC
59	Passeriformes	Pycnonotidae	White-eared Bulbul	*Pycnonotus leucotis*	R	T	FU,I	LC
60	Passeriformes	Cisticolidae	Plain Prinia	*Prinia inornata*	R	T	I	LC
61	Passeriformes	Alaudidae	Crested Lark	*Galerida cristata*	R	T	G,I	LC
62	Passeriformes	Nectariniidae	Purple Sunbird	*Cinnyris asiaticus*	R	T	N	LC
63	Passeriformes	Motacillidae	Western Yellow Wagtail	*Motacilla flava*	RM	A	I	LC
64	Passeriformes	Motacillidae	Citrine Wagtail	*Motacilla citreola*	RM	A	I	LC
65	Passeriformes	Motacillidae	White-browed Wagtail	*Motacilla maderaspatensis*	M	A	I	LC
66	Passeriformes	Hirundinidae	Streak-throated Swallow	*Petrochelidon fluvicola*	M	T	I	LC
67	Pelecaniformes	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*	R	A	P	LC
68	Pelecaniformes	Phalacrocoracidae	Indian Cormorant	*Phalacrocorax fuscicollis*	R	A	P	LC
69	Pelecaniformes	Ardeidae	Grey Heron	*Ardea cinerea*	RM	A	P,A	LC
70	Pelecaniformes	Ardeidae	Great Egret	*Ardea alba*	RM	A	P,A	LC
71	Pelecaniformes	Ardeidae	Little Egret	*Egretta garzetta*	R	A	I,P,A	LC
72	Pelecaniformes	Ardeidae	Cattle Egret	*Bubulcus ibis*	R	T	I,P,A	LC
73	Pelecaniformes	Ardeidae	Indian Pond Heron	*Ardeola grayii*	R	A	I,P,A	LC
74	Pelecaniformes	Ardeidae	Purple Heron	*Ardea purpurea*	RM	A	P,A, OP	LC
75	Pelecaniformes	Ardeidae	Intermediate Egret	*Ardea intermedia*	R	A	I,P,A	LC

76	Pelecaniformes	Ardeidae	Western Reef Egret	*Egretta gularis*	R	A	I,P,A	LC
77	Pelecaniformes	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*	RM	A	A,IN, I,W	NT
78	Pelecaniformes	Threskiornithidae	Indian Black Ibis	*Pseudibis papillosa*	R	T	I,G,R P	LC
79	Pelecaniformes	Threskiornithidae	Eurasian Spoonbill	*Platalea leucorodia*	RM	A	A,IN, I,W	LC
80	Pelecaniformes	Ciconiidae	Painted Stork	*Mycteria leucocephala*	RM	A	P,IN	NT
81	Pelecaniformes	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	R	A	P	LC
82	Pelecaniformes	Anhingidae	Oriental Darter	*Anhinga melanogaster*	R	A	P.A, OP	NT
83	Phoenicopteriformes	Phoenicopteridae	Lesser Flamingo	*Phoeniconaias minor*	RM	A	PL	NT
RM= Resident Migrant; R=Resident; M=Migretory; T=Terrestrial; A= Aquatic; FU=Frugivore; N=Nectorivore; P=Piscivore; G=Granivore; C=Carnivore; I=Insect and other terrestrial invertebrate feeder; PL=Plankton Feeder; IN=Aquatic Inverstibrate feeder; A=Amphibian feeder; OP=Ophidiovore; RP=Reptile feeder; W= weedivore; H=Herbivore;PD=Predatory;NT= Near Threatened; LC= Least Concern								

Annexure -C

Final Report

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

Submitted to

DEENDAYAL PORT AUTHORITY
Administrative Office Building
Post Box No. 50, Gandhidham (Kachchh)
Gujarat-370201

Submitted by

GUJARAT INSTITUTE OF DESERT ECOLOGY
P.B. No. 83, Mundra Road, Opp. Changleshwar Temple
Bhuj-Kachchh, Gujarat-370001

May 2023

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Bhuj-Kachchh, Gujarat-370001

May 2023

Dr. V. Vijay Kumar
Director

Gujarat Institute
of Desert Ecology

CERTIFICATE

This is to state that this final report of work entitled "**Regular monitoring of Marine ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme**" has been prepared as per the work order issued by DPA vide no EG/WIK/4751/Part (Marine Ecology Monitoring)/11, Dt,03.05.2021 for the 2022-2023 as per EC and CRZ clearance accorded by the MOEF& CC, GOI dated 19.12.2016,18.2.2020,19.2.2022 and 20.11.2020 with specific conditions xvii, xxiii, xv & iv respectively.

Authorized signatory

Gujarat Institute of Desert Ecology
Bhuj

Institute seal

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Project Team

Project Coordinator

Dr. V. Vijay Kumar, Director

Project Investigators			
Sl No	**Name**	**Designation**	**Area of Expertise**
1	Dr. Durga Prasad Behera	Scientist	Plankton Physico-chemical of water Marine Fisheries
Project team			
2	Dr. Nikunj B. Gajera,	Scientist	Avifauna
3	Dr. L. Prabha Dev	Advisor	Marine Ecology
4	Dr. R. Kapilkumar Ingle	Project Scientist	Mangrove
5	Dr. Dhara Dixit	Project Scientist	Halophytes & Seaweed
6	Mr. Dayesh Parmar	Project officer	GIS & Remote sensing
Team Members			
3	Miss. Pallavi Joshi	Junior Research Fellow	Zooplankton, Phytoplankton Sediment, Water

Snapshot May-2022 to May 2023

S. No	Components of the Study	Remarks
1	MoEF & CC Sanction Letter and Details	(i). EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/12/16 Dev. of 7 integrated facilities – specific condition no. xviii. (ii).EC & CRZ clearance granted by the MoEF &CC, GoI dated 18/2/2020 Dev. Remaining 3 integrated facilities – specific condition no. xxiii. (iii).EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 -specific condition no. xv. (iv). EC & CRZ clearance granted by the MoEF &CC, GoI dated 20/11/20 – Creation of waterfront facilities (OJ 8 to 11- Para VIII Marine Ecology, specific condition iv.
2	Deendayal Port letter Sanctioning the Project	DPT work Order: WK/4751/Part/ (Marine Ecology Monitoring)/11 date 03.05.2021
3	Duration of the Project	Three years-from 24.05.2021 to 23.05.2024
4	Period Of Survey Carried out	May 2022-May 2023
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 DPA port jurisdiction
7	**Components of the report**	
7a	Mangroves	In DPA Kandla, during the period 2022-2023, the overall plant characteristics were surveyed, in which three classes of plants were found such as regeneration, recruitment and tree. The parameters considered for the tree class were density, height, basal girth and canopy cover. In this survey, during the monsoon, the tree class density was higher than other two seasons in the various creeks. The average plant density was found higher in Navlakhi creek, followed by Kharo creek where only one station was fixed. The anthropogenic pressure in Navlakhi creek is less than the

		other creeks which could be the probable reason for the good condition of the mangrove plants.
7b	Mudflats	The sediment bulk density values varied between the lowest 1.23 g/cm^3 and the maximum 1.52 g/cm^3 . Similarly the organic carbon content in the sediment during th different seasons showed maximum value between 0.8% to 2.4% and the minimum range was 0.6% to 2.0%. Station wise the highest sediment carbon was recorded at S-14 during pre-monsoon (2.4%), whereas lowest (0.6%.) at S-7 and S-15 during monsoon and pre-monsoon seasons.
	Zooplankton	The zooplankton identified belongs to 8-11 phylum and 12-19 group for the period May-2022 to May **202**3. In monsoon season 11 phylum and 12 zooplankton group and in post-monsoon season 8 phylum and 16 groups have been recorded from the entire study station. Likewise in pre-monsoon season 10 phylum and 19 zooplankton were noticed. The maximum percentage of the different groups encountered ranged from 36.9% to 40.4% and the minimum varied between 1.6% to 2.8%. Highest percentage was contributed by the Copepoda .
7c	Phytoplankton	The number of phytoplankton genera recorded varied with seasons the maximum number varied between 26 to 37 number with average variation 24-32 while the minimum number of genera varied from 21 to 27. Five major group such as pennales, centrales, Dinophyceae, Cyanophyceae and Chlorophyceae of phytoplankton was reported for the period 2022 to 2023. The Maximum percentage of the groups ranged between 41 % and 64% and the minimum was 5%.
7d	Intertidal Fauna and Reptiles	The intertidal fauna of DPA Kandla area are listed under 6 phyla (Nematoda, Nemertea, Annelida, Arthropoda, Mollusca and Chordata), including 26 species. The species diversity was the highest for phylum Mollusca (22), followed by Arthropoda (19), Annelida (4) and Nematoda, Nemertea, Chordata (1) respectively for the period of study. During monsoon period, the highest number of individuals was the *Parasesarma plicatum* (crab) while it was *Pirenella cingulata* (gastropod) in post-monsoon. Similarly in pre-monsoon the *Austruca variegata*. The overall intertidal diversity was high in monsoon and low number of organism was found in pre-monsoon.

7e	Sub-tidal Macrobenthos	The subtidal fauna recorded are 26 species belonging to 4 phyla (Cnidaria, Annelida, Arthropoda and Mollusca,), The species diversity was the highest for phylum Mollusca(42 no) followed by Annelida (14 species), Arthropoda (5 species), and Cnidaria (3 species) for the three seasons. The animal density was high during the post-monsoon in the study sites, The bivalve mollusc *Glauconome angulata* showed the highest density (51 no) followed by *Pirenella cingulata* (48 no) in post-monsoon. Similarly In pre-monsoon the species *Pirenella cingulata* (43 no) dominated in the number of individuals which was followed by *Glauconome angulata* (38 no). During monsoon the species *Optediceros breviculum* (35 no) followed by *Pirenella cingulata* (27 no) showed high density in the sediment. In general, *Pirenella cingulata* dominated in all the seasons at the sub-tidal benthic system.
7f	Seaweeds and Seagrasses	No species of sea weeds and sea grass was recorded from the the stations sampled.
7g	Halophytes	During the period of May 2022 to May 2023 four major halophytes *Sesuvium portulacastrum, Salvadora persica* and *Aeluropus lagopoides* and *Salicornia brachiata* were recorded along the selected study stations. The maximum percentage of coverage was shown by the species *Salicornia brachiata* particularly in post-monsoon & pre-monsoon period (100%).
7h	Fisheries	The major fish catch activity is carried out in extensive creek systems of Khari creek, Tuna creek, Navalakhi creek and Jhangi creek. For the period of period 2022-2023, cast net was operated in different creek system of Kandla and major fish catch was include the species Penaeus indicus,Chanos chanos, Mudskipper, Therapon fish, Portunus pelagicus,Lobester Other crab species of total quantity was 295 kg (Figure 50). The fish catch was observed in Tuna creek followed by Navlaki and Janghi creek system.
7i	Avifauna	Total fifteen sites were surveyed for three seasons, of which the maximum number of species (79 spp.) was found in Post monsoon. At Site 1 the highest number of species (57 spp.) was sighted while Site 2 (55 spp.), Site 9 (46 spp.) and Site 7 (45 spp.) showed comparatively less number. The number of birds was minimum (49 spp) in monsoon season,however, Site 1 &2 recorded highest number (33 spp.) than Site 9 (27 spp.) and Site 10 (26 spp.). Site 5 recorded the least richness during all the seasons.

Comparison Study of Marine Biodiversity of Deendayal Port Authority (DPA) Since 2019-2023

Habitat/ Groups	Major Taxa/Genera/Species	Year 2019-2020		Year 2020-2021		Year May 2021- May 2022			Year May 2022- May 2023		
		Pre Monsoon	Post monsoon	Pre monsoon	Post monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon	Pre monsoon
Mangroves	*Avicennia marina, Ceriops tagal, Rhizophora mucronata, Aegiceras corniculatum*	4	4	4	4	4	4	4	4	4	4
Intertidal Habitat	Gastropods, Bivalves, Crustaceans Polychaetes, fishes, amphipods and Isopods	19	10	10	12	21	16	16	14	14	13
Subtidal Habitat	Polychaetes, molluscs, crustaceans,echinoderms	26	28	30	48	22	22	11	14	21	32
Phytoplankton	*Bacillaria, Navicula, Nitzschia, Chaetoceros, Coscinodiscus, Triceratium, Bidulphia, Melosira, Thassiosira*	32	26	23	19	35	23	23	24-33	22-26	21-26
Zooplankton	Copepods, Harpacticoids, Cyclopoids. brachyurans, cirripedes, Bivalve veligers	33	36	29	27	42	35	42	41	45	40
Seaweeds	Nil (Drifted tufts only)	Nil	Nil	drifted	drifted	drifted	drifted	drifted	NIL	NIL	NIL

Habitat/ Groups	**Major Taxa/Genera/Species**	**Year**		**Year**		**Year**			**Year**		
		2019-2020		**2020-2021**		**May 2021- May 2022**			**May 2022- May 2023**		
		PRE-M	**POST-M**	**Pre-0M**	**Post-M**	**Monsoon**	**PM**	**Pre-M**	**Monsoon**	**PM**	**Pre-M**
Sea grasses	Nil (Drifted tufts only)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Halophytes	*Sesuvium portulacastrum, Salvadora persica, Aeluropus*	3	4	4	4	4	4	4	4 Salicrnia dominance	4 Salicrnia dominance	5 Salicrnia dominance
Avifauna	Charadriiformes, Phoenicopteriformes, Pelecaniformes, Passeriformes	49	89	49	69	62	84	52	49	79	53
Fishes	*Mugil cephalus, Harpodon nehereus, Pampus argenteus, Hilsa, Engraulis, Coilia* sp. *Peneaus,Portunus,lobester*	10	8	5	4	7	5	7		160 kg	50 kg
Marine Mammals	Dolphin, *Sousa plumbea*	1	1	Nil	Nil	1	Nil	Nil	1	1	Nil
Reptiles in the	The saw-scaled viper, *Echis*	1	1	Nil	1	Nil	Nil	1	1	1	Nil

LIST of PLATES

Introduction

Deendayal Port is located at Kandla in the Kachchh district of Gujarat state, operated by Deendayal Port Authority (DPA) 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 the states such as Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana and Gujarat. Because of its proximity to the Gulf countries, large quantities of crude petroleum are imported through this port. About 35% of the country's total export takes place through the ports of Gujarat in which the Deendayal port has a considerable contribution. Assortments of liquid and dry cargo are being handled at DPA Port. The dry cargo includes fertilizers, iron and steel, food grains, metal products, ores, cement, coal, machinery, sugar, wooden logs etc. The liquid cargo includes edible oil, crude oil and other petroleum products. Cargo handling has increased from 127 MMT to135 MMT during 2022-2023. 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 at Vadinar for handling oil. Regular expansion or developmental activities such as the addition of jetties, allied SIPC and ship bunkering facilities are underway in order to cope with the increasing demand for cargo handling during the recent times.

A developmental initiative of this magnitude is going on since past 7 decades, which will have its own environmental repercussions. Being located at the inner end of the 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 the North-South trending Kandla creek at an aerial distance of 90 km from the mouth of the 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. The 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 – specific condition no. xxiii.

(iii) EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/12/16 Development of 7 integrated facilities specific condition no. xviii.

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

As per the environmental clearance requirements to these developmental initiatives, by MoEF & CC, among other conditions, has specified to conduct the continuous monitoring of the coastal environment on various aspects covering 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, the DPA has consigned the project on 'Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme" to Gujarat Institute of Desert Ecology (GUIDE), Bhuj during May, 2021. Further, Deendayal Port authorities has entrusted Gujarat Institute of Desert Ecology (GUIDE) to continue the study for another three years, *i.e.,* 2021 – 2024. The study covers all the seasons as specified by 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 the Work

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

- Physico-chemical characteristics of water and sediment
- Detailed assessment of mangrove vegetation structure including density, diversity, height, canopy, and other vegetation characteristics.
- GIS and RS studies to assess different ecological sensitive land use and land cover categories within the Port area such as the extent of dense and sparse mangroves, mudflats, creek systems, and other land cover categories within the port limits.
- Quantitative and qualitative assessment of the intertidal fauna, composition, distribution, diversity, density, and other characteristics.
- Data collection on the species composition, distribution, diversity and density of sub-tidal benthic fauna.

- Estimation of primary productivity at the selected sampling sites located in around the DPA area.
- Investigation of the species composition, distribution, density, and diversity of phytoplankton and zooplankton.
- Recording the occurrence and diversity distribution of halophytes, seagrasses, seaweeds and other coastal flora.
- Investigations on the Avifaunal density, diversity, composition, habitat, threatened and endangered species and characters.
- Fishery Resources – Species composition, diversity, Catch Per Unit Effort (CPUE) and other socio-economic information.

1.3. 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 and salt-encrusted landmass which form the major land components. The surrounding environment in the 10 km radius from the port includes built-up areas, salt pans, human habitations and port related structures on the west and north creek system, mangrove formations and mudflats in the east and south. The nearest major habitation is Gandhidham town located about 12 km away on the western part with a population of 2,48,705 (as per 2011 census**).**

Figure 1. Map showing the proposed sampling locations 2021-2024

2.1. Land use and Land Cover Changes

In order to understand the spatial and temporal changes in the vicinity of the Deendayal port jurisdiction area, Remote Sensing and GIS technique have been employed. Land cover classification was carried out using digital satellite imageries. The images of the Deendayal Port area acquired for the period of April 2017, December 2019 and March 2020, November 2020, April 2021, March 2022 and March 2023 were used for the study. These were brought to UTM projection with spheroid and datum named WGS 84 in UTM zone 42 North.

Table 1. Satellite imagery used for Land use and Land Cover Map

Image use	Satellite name	Sensor	Spatial Resolution	Date acquired
2017	IRS-R2A	LISS IV	5.8m	26 April- 2017
2019	IRS-R2A	LISS IV	5.8m	24-DEC-2019
2020	IRS-R2A	LISS IV	5.8m	29-March-2020
2020	IRS-R2	LISS IV	5.8m	17-Nov-2020
2021	IRS-R2	LISS IV	5.8m	10-APR-2021
2022	IRS-R2	LISS IV	5.8m	12-March-2022
2023	IRS-R2	LISS IV	5.8m	31-March-2023

2.2. Methodology

Training samples were collected from the imageries. Selecting training samples from the cloud-free mosaics was straightforward due to the very distinctive signature of the mangrove area. High contrast with open water, saltpan and mudflat helped in selecting the training data successfully. Similar training samples with slight modifications in each imageries mosaic (addition and removal of few training samples) were used for the classification of the images for tha different dates. Six major classes *viz.*, mangrove, water, mudflat, other vegetation, salt pan and port were delineated. For the tonal variation and pixel values in the imageries, NDVI (Normalised Differential Vegetative Index) and a supervised Maximum Likelihood Classification (MLC) methods were used for the classification.

ERDAS Imagine 9.3 was used for satellite image processing, classification and data transformation, whereas ARC GIS 10.3 was used for the map formation. For graphs and databases processing, MS WORD and MS EXCEL were used. Ground truth study comprises data collection of ground features along with the respective geographical positions in terms of latitudes and longitudes with Garmin e-Trex Vista GPS. Thus, the data were interpreted using all the collected information

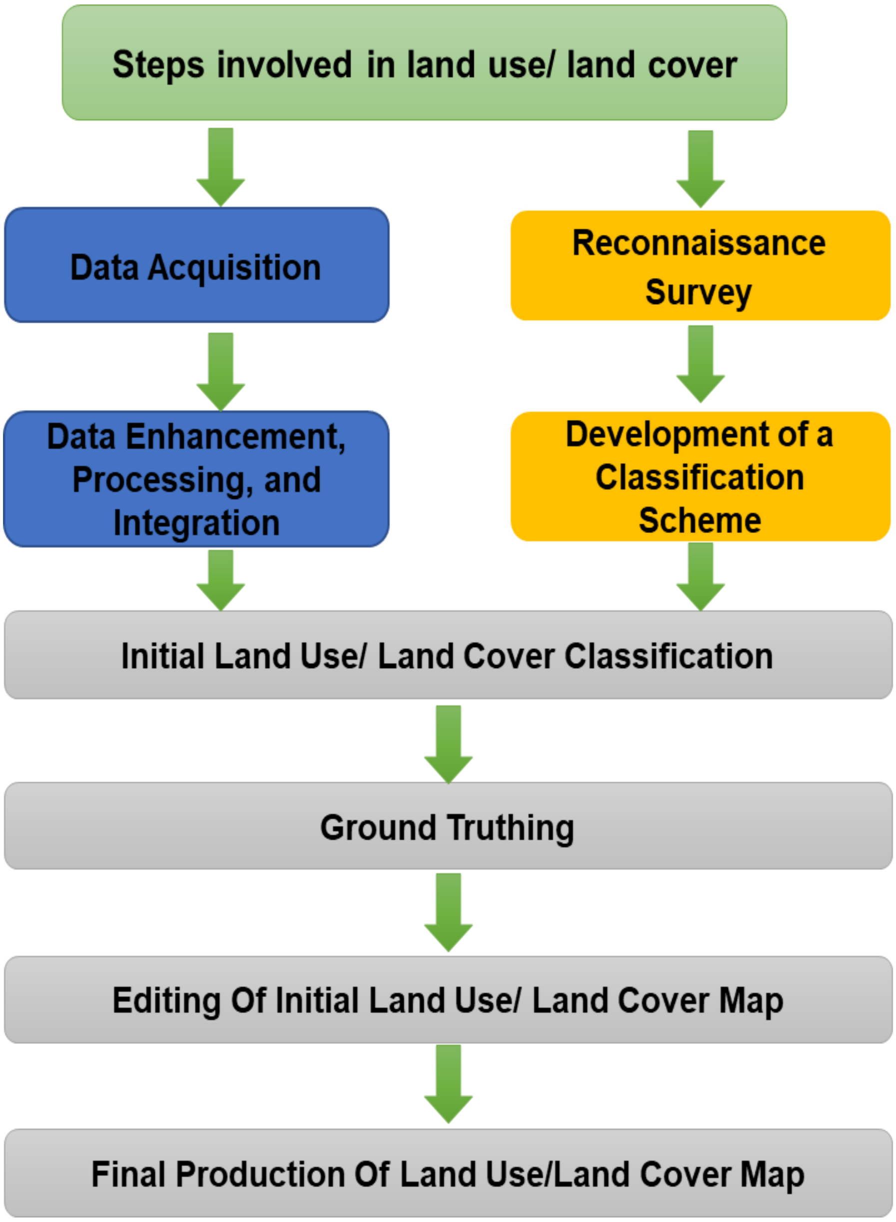

Figure 2. Methodology for land use Land cover

2.3. Land use /land cover

Classified imageries are presented in Fig 3 to10 and the details are presented in table 2 and 9.

Figure 3. Land use/ Land cover classification in DPA area- April-2017

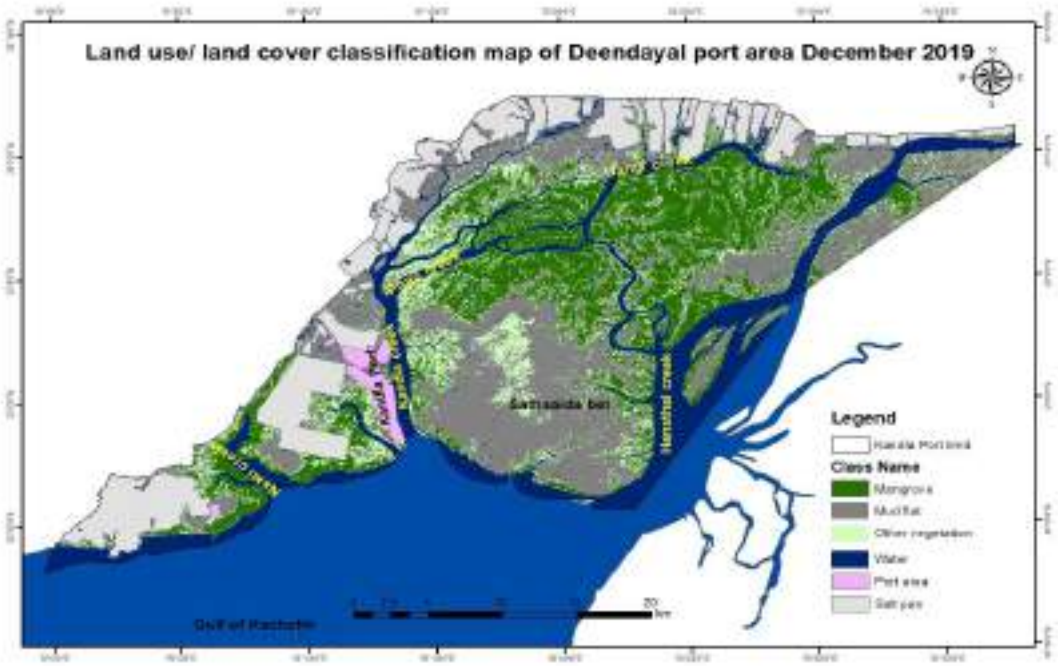

Figure 4. Land use/ land cover classification in DPA area December-2019

Table 2. Land use /Land cover statistics in the DPA area - April-2017

Class Name	Area (ha)	Percentage
Mangrove (Dense + Sparse)	19319.71	19.32
Mudflat	31293.43	31.3
Other veg	12438.8	12.44
Port Area	1243.67	1.24
Salt pan	15016.1	15.02
Water	20674.3	20.68
Total	**99986.01**	**100**

Table 3. Land use /Land cover statistics in the DPA area - December-2019

Class Name	Area (ha)	Percentage
Mangrove	23060.04	23.06
Mudflat	31179.87	31.18
Other vegetation	12333.21	12.33
Water	16953.68	16.96
Port area	1346.21	1.35
Salt pan	15113	15.12
Total	**99986.01**	**100**

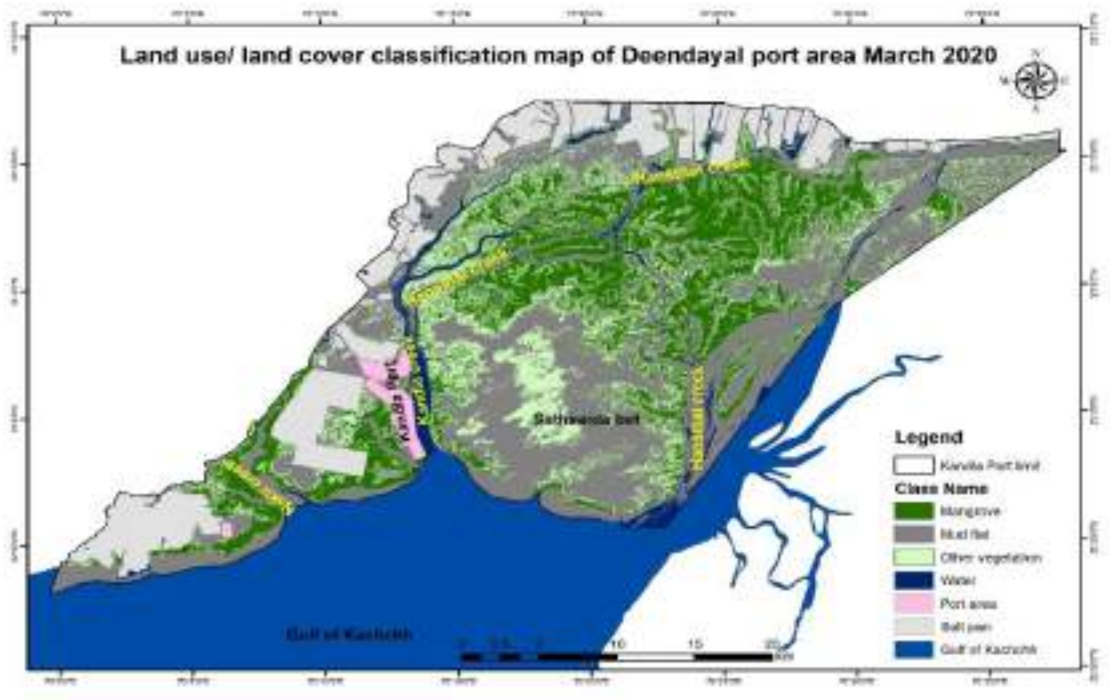

Figure 5. Land use/ land cover classification in DPA area March-2020

Table 4. Land use /land cover statistics in the DPA area- March-2020

Class name	Area (ha)	Percentage
Mangrove	23168.4	23.17
Mudflat	40714.6	40.72
Other vegetation	15991.69	15.99
Port area	1346.21	1.35
Salt pan	15054.5	15.06
Water	3710.61	3.71
Total	**99986.01**	**100**

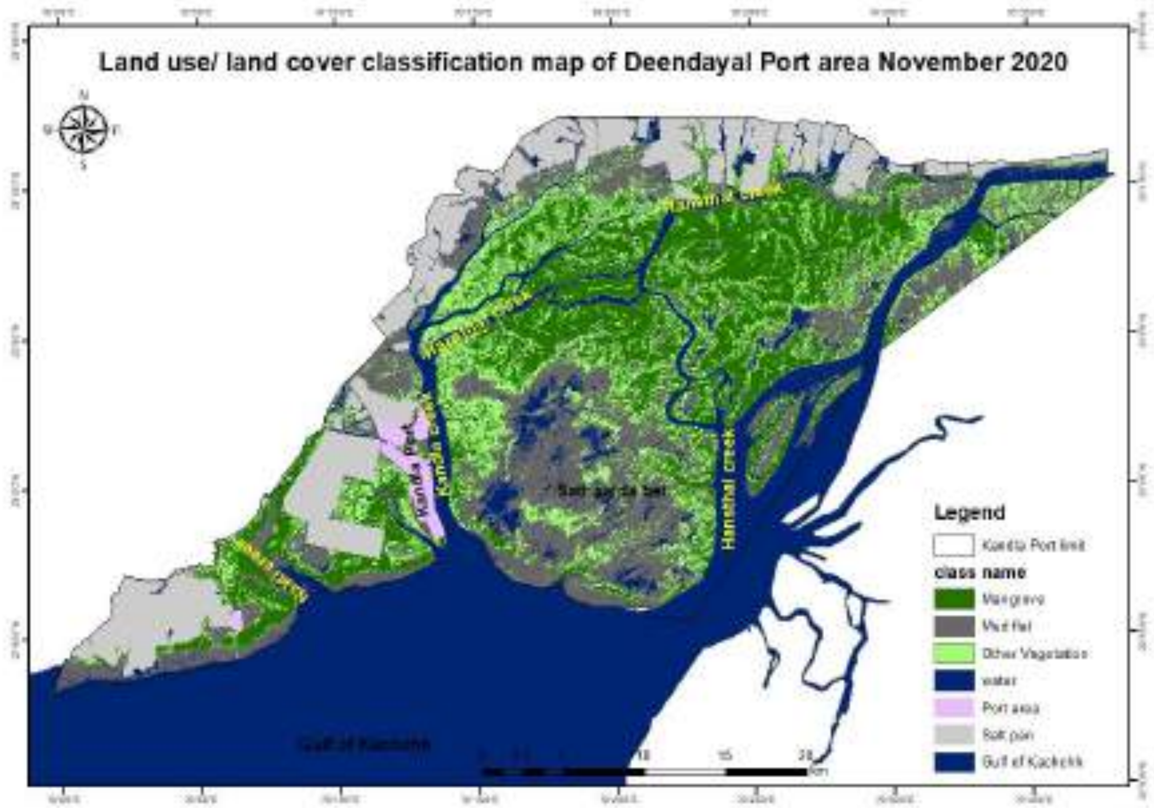

Figure 6. Land use/ land cover classification in Deendayal port area November 2020

Table 5. Land use /land cover statistics in the DPA area- November2020

Class	Area (ha)	Percentage
Mangrove	23856.8	23.86
Mudflat	28764.6	28.77
Other Vegetation	16346.1	16.35
Port area	1346.21	1.35
Salt pan	15193.5	15.2
water	14478.8	14.48
Total	99986.01	100

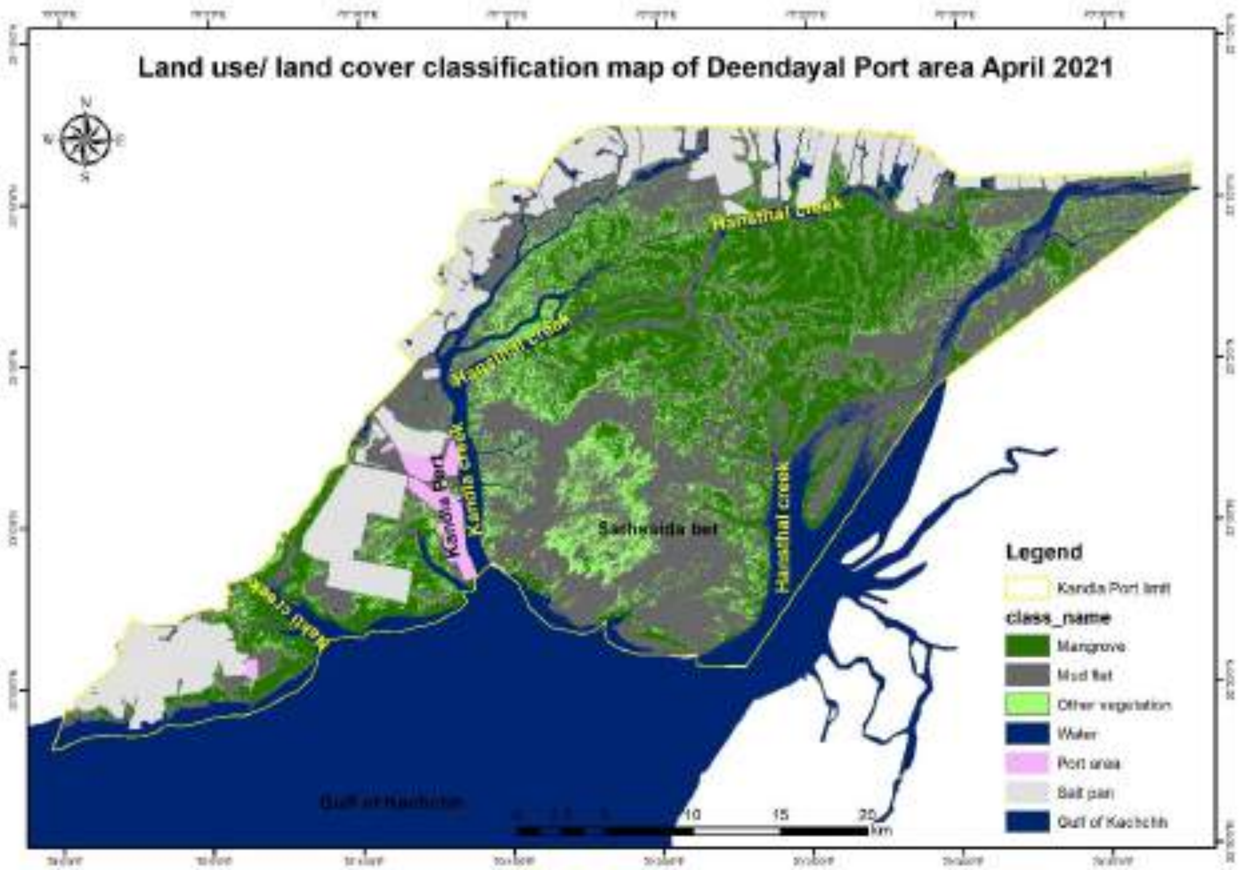

Figure 7. Land use/ land cover classification in Deendayal port area

April-2021

Table 6. Land use /land cover statistics in the DPA area April-2021

class name	Area (ha)	Percentage
Mangrove	23967.4	23.97
Mudflat	36909.3	36.91
Other vegetation	11230.4	11.23
Port area	1346.21	1.35
Salt pan	15236.6	15.24
Water	11296.1	11.3
total	**99986.01**	**100**

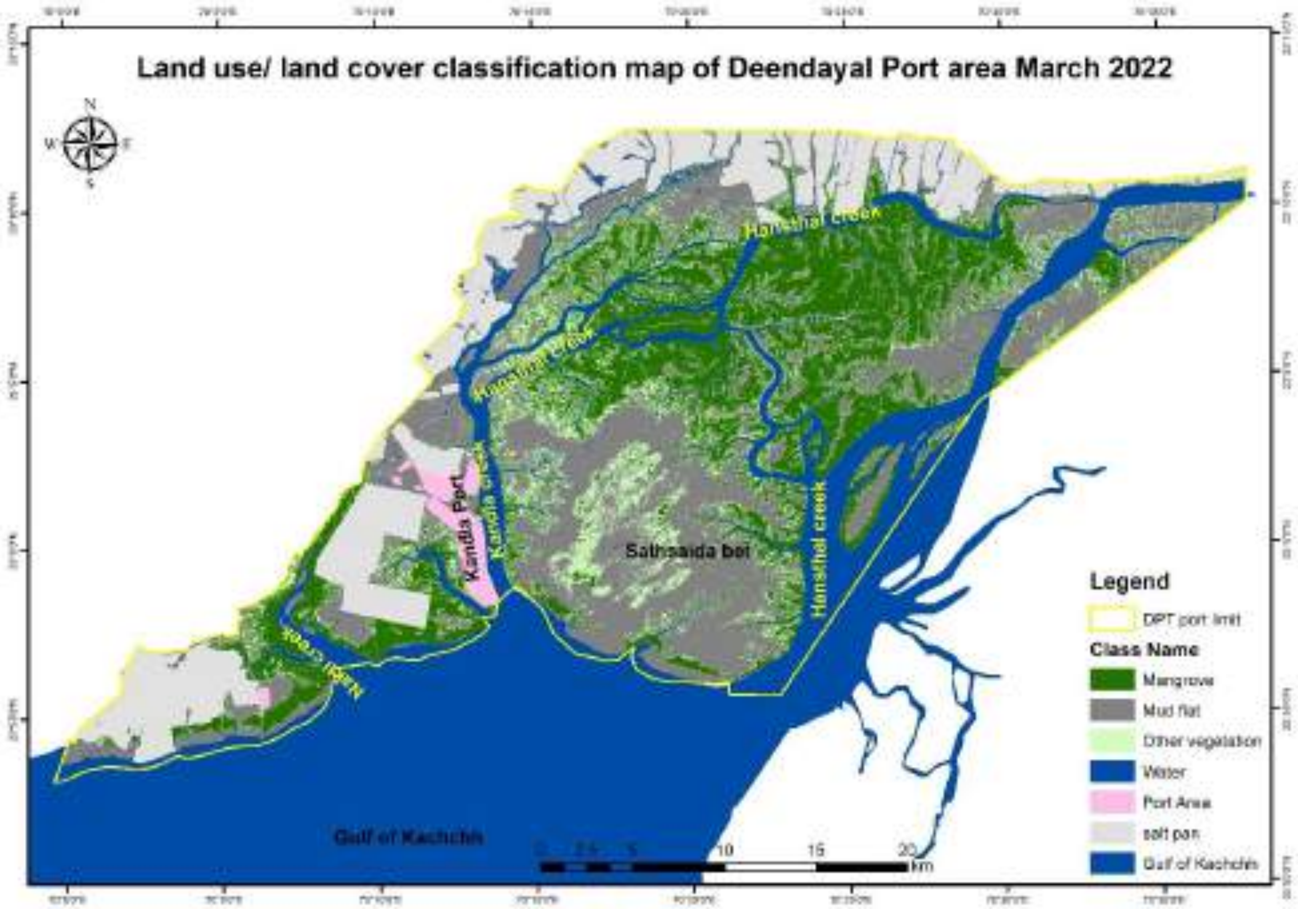

Figure 8.Land use/ land cover classification in Deendayal port area March-2022

Table 7. Land use /land cover statistics in the DPA area March-2022

class name	Area (ha)	Percentage
Mangrove	24328.7	24.33
Mudflat	31089.06	31.09
Other vegetation	11561.2	11.56
Port Area	1436.75	1.44
salt pan	15545.7	15.55
Water	16024.6	16.03
Total	**99986.01**	**100**

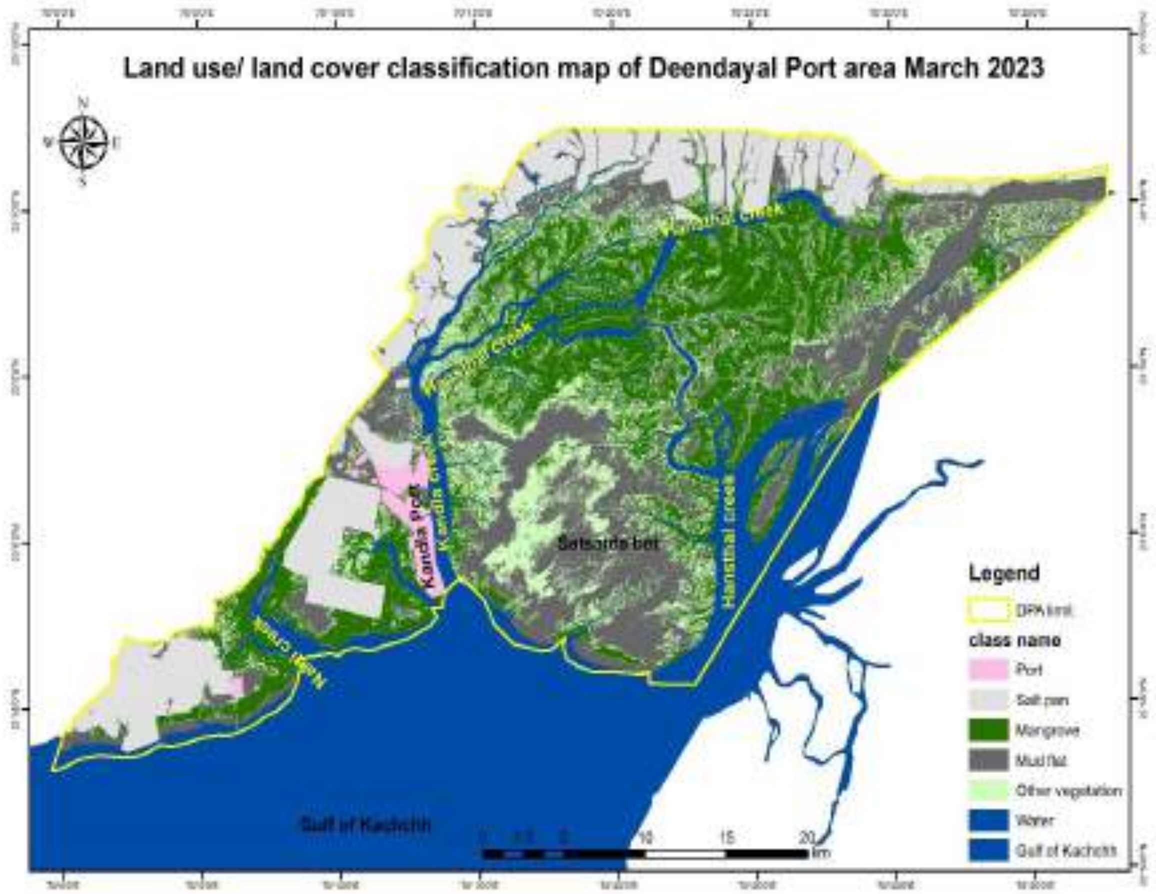

Figure 9. Land use/ land cover classification in Deendayal port area March-2023

Table 8 .Land use /land cover statistics in the DPT area for March-2023

class name	Area (ha)	Percentage
Mangrove	26520.56	26.52
Mud flat	27547.90	27.55
Other vegetation	15969.90	15.97
Port	1436.75	1.44
Salt pan	16094.80	16.10
Water	12416.10	12.42
Total	**99986.01**	**100.00**

2.2.2. Comparative analysis of Land use and Land cover study

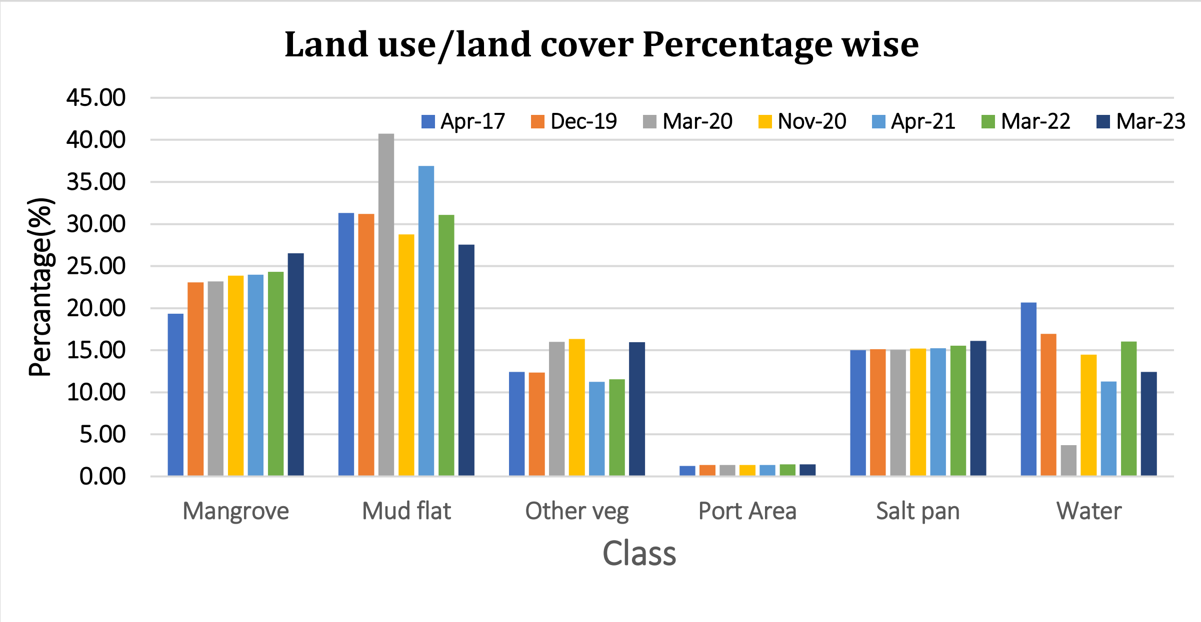

Figure 10. LU/LC Percentage area for the period 2017 to 2023 in Deendayal Port Authority

From April 2017 to March 2023 the overall mangrove area increased from 19319 ha to 26520.5 ha, i.e. 7.2 % of the total area of DPA (Fig 10). It was observed that the mangrove area is replacing mostly the mudflat, hence there is a distinct decreasing trend observed during the period 2022 2023 even though both these areas are influenced by the tides daily. The availability of good monsoon in the recent years and favorable environment have positively impacted the mangroves to flourish. Currently the imageries have shown clearly that mangrove area in DPA vicinity has increased and formed around 26.52% of the total area of DPA jurisdiction.

Table 9. Land use /land cover Percentage wise in the vicinity of DPA area for the study period 2017-2023

Month-Year	**Apr-17**	**Dec-19**	**Mar-20**	**Nov-20**	**Apr-21**	**Mar-22**	**Mar-23**
Class Name	Area (ha)						
Mangrove	19.32	23.06	23.17	23.86	23.97	24.33	26.52
Mudflat	31.30	31.18	40.72	28.77	36.91	31.09	27.55
Other veg	12.44	12.33	15.99	16.35	11.23	11.56	15.97
Port Area	1.24	1.35	1.35	1.35	1.35	1.44	1.44
Salt pan	15.02	15.12	15.06	15.20	15.24	15.55	16.10
Water	20.68	16.96	3.71	14.48	11.30	16.03	12.42
Total	100	100	100	100	100	100	100

3. Methodology

3.1. Physico-chemical characteristics of water and sediment

A port is a location on a coast or shore containing one or more harbors where ships can dock and transfer people or cargo to or from land. Port locations are selected to optimize access to land and navigable water, for commercial demand, and for shelter from wind and waves. Harbors can be natural or artificial. An artificial harbor has deliberately constructed breakwaters, sea walls, or jetties, or otherwise, constructed by dredging. Ports are economic instruments for trade and a vital component in the nation's economy. Nevertheless, port activities such as land reclamation, dredging and large-scale construction as part of its expansion negatively affect the marine ecosystems in its vicinity.

In a port environment, activities like dredging, continuous movement of vessels and humans create major impacts at the marine/coastal environment and the living resources. The port's continuous expansion activities impact the coastal environmental health which can be reflected by the nature of the physico-chemical characteristics of water which in turn indicates in its productivity. The change in productivity pattern of the marine environment is highly influenced by the flow of nutrients which generally originates from natural and anthropogenic sources. This change in quality of marine water, influences the composition and availability of aquatic organisms, particularly the plankton communities, other biological components such as , coral reefs and seagrass habitats etc. Similar to water, marine sediments also receive pollutants / such as heavy metals, petroleum hydrocarbons, polyaromatic hydrocarbons, polychlorinated biphenyls etc as contaminants from various activities, both off shore and on shore near ports and harbours. Hence assessing the water and sediment characteristics is imperative to understand the environmental changes and to suggest scientific interventions to restore the ecosystem integrity.

3.1.1. Sampling methods and Parameters

Sampling of coastal water (surface) and sediment for the determination of physical and chemical characteristics was carried from the prefixed sites. The samples for the estimation of biological parameters (benthic and pelagic fauna, flora and productivity) were also collected from the same sites(Table 10). The samples were collected during three seasons,monsoon, postmonsoon and premonsoon. Each year.

Table-10. Physico-chemical and biological parameters analysed

<table>
<tr><th colspan="3">Parameters</th></tr>
<tr><th>Water</th><th>Mangrove & Other Flora</th><th>Sub -tidal fauna</th></tr>
<tr><td>▪ pH
▪ Temperature(^{0}C)
▪ Salinity (ppt)
▪ Dissolved oxygen
▪ Total Suspended Solids (TSS)
▪ Total Dissolved solids (TDS)
▪ Petroleum Hydrocarbons (PHs)</td><td rowspan="7">Mangrove
Vegetation structure density, diversity, height, canopy cover, Other vegetation characteristics.
Halophytes:
Occurrence,
Distribution, and diversity
Seagrass and Seaweed
Occurrence
Distribution and diversity.</td><td rowspan="7">Macro- fauna
composition, distribution, diversity, density and other characteristics.

Avifauna: Density, diversity, composition, habitat, threatened and endangered species and characters</td></tr>
<tr><td>Nutrients</td></tr>
<tr><td>➢ Nitrate (NO_3)
➢ Nitrite (NO_2)
➢ Total Nitrogen
➢ Total Phosphatee
➢ Total phosphorus</td></tr>
<tr><td>Sediment</td></tr>
<tr><td>✓ Texture
✓ Total organic carbon (TOC)</td></tr>
<tr><td>Biological Parameters</td></tr>
<tr><td>✓ 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)</td></tr>
</table>

The water samples were collected into and pre- cleaned and labelled 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 distillation assembly.

3.1.2. 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.

3.1.3. Salinity

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

3.1.4. 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.

3.1.5. 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**.**

3.1.6. Turbidity

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

3.1.7. Dissolved Oxygen (DO))

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

3.1.8. 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.

3.1.9. 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).

3.1.10. Total phosphorus

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

3.1.11. 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).

3.1.12 . Nitrate

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

3.2. Sediment characteristics

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

3.2.1. Sediment Texture

For texture analysis, specified unit of sediment sample was sieved through sieves of different mesh size as per Unified Soil Classification System (USCS). Cumulative weight retained in each sieve were 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 100%.

3.2.2. 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 the excess acid was titrating against Ferrous ammonium sulphate using Ferroin as an indicator (Walkley and Black, 1934).

3.3. Biological Characteristics of water and Sediment

3.3.1. 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 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 pa,per 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).

3.3.2. Phytoplankton

Phytoplankton samples were collected from the prefixed 15 sampling sites from the coastal water in and around DPA 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 and transferred to a pre-cleaned and labeled container and preserved with 5% neutralized formaldehyde and stored for further analysis. The Quantitative analysis of the phytoplankton (cell count) was carried out using a Sedgewick-Rafter counting chamber. The density (No/l) was calculated using the formula: N=n×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).

3.3.3. Zooplankton

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

3.3.4. Intertidal Fauna

Intertidal faunal assemblages were studied for their density, abundance and frequency of occurrence during monsoon 2021 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 (Apte, 2012;2014, Ravinesh et al. 2021; Edward et al., 2022). The average density of the different groups at each site was calculated and expressed as mean density (No/m^2).

Plate 1: Estimation of intertidal fauna by the quadrate method

3.3.5. Subtidal Macro Benthic Fauna

The sampling methods and procedures were designed in such a way to obtain specimens in the best possible condition, as to maximize the usefulness of the data obtained. For studying the benthic organisms, triplicate samples were collected at each station using Van Veen grab which covered an area of 0.04m2. The wet sediment was passed through a sieve of mesh size 0.5 mm for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal dye for the ease of spotting at the time of sorting. The number of organisms in each grab sample was expressed as No /m^2. All the species were sorted, enumerated and identified by following available literature. The works of Fauvel (1953) and Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; Subba Rao *et al*. (1991) and Ravinesh et al. 2021 for molluscs. Further, the data were processed for univariate statistical methods in PRIMER (Ver. 6.)

Plate 2: Collection of Plankton and macrobenthos in the subtidal habitat

3.4. Sampling at the 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 ,2000) sustaim 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, they may be several kilometers 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 prevailing physical conditions of the region. Intertidal mudflats can be separated into three distinct zones such as the lower tidal mudflats, middle mudflats 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 occur 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.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

3.4.1. Sampling locations

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

Plate 3: Sediment sample collection at mangrove and mudflat areas

3.4.2. 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 H_2SO_4) by utilizing the heat evolved with the addition of H_2SO_4. The unreacted dichromate is determined by back titration with Ferrous ammonium sulphate (redox titration) using Ferroin as indicator. 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 is required for blank titration.

T = volume of Ferrous ammonium sulfate needed for soil sample. Wt. =weight of soil (g).

3.4.3. 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 and organic matter status of soils. The 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 (Holmes et al., 2012;Rudiyanto et al., 2016).

3.5. Mangrove assessment

Mangroves are widely distributed at the Deendayal Port Authority jurisdiction along the Kandla coast. The 15 mangrove sites selected at the different creeks belong to Deendayal Port Authority jurisdiction area 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, Phang and Navlakhi which are based on the nearest location to their respective creek system. The Point Centered Quadrate Method (PCQM) was used for the collection of data of mangrove vegetation structure. The data included are measurements of density of plants, height variations, canopy and basal girth of mangrove trees as per the method of Cintron and Novelli (1984). In this method, a transect of a maximum of 200 m was applied mostly perpendicular or occasionally parallel to the creek.

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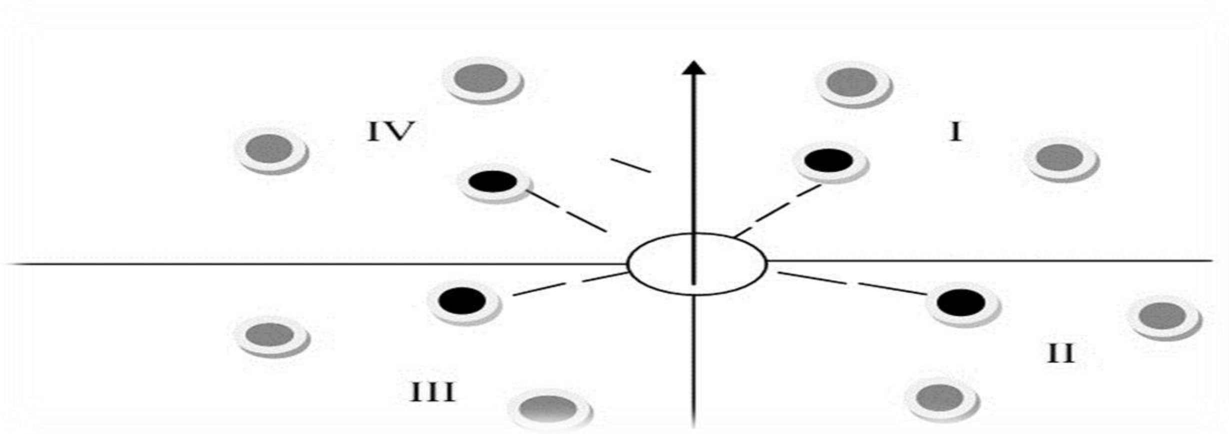


Figure 11. Point Centered Quadrate Method (PCQM)

The sampling points considered were fixed at an interval of 10 m and the vegetation structure of that area were recorded. As the orientation of the transect line was already fixed, it was easy for movement within the station for data recording. The distance between trees from the centre of the sampling point for the nearest 4 trees of four different directions, height of trees from the ground level , canopy length and conopy 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 the measurement of girth at root collar (GRC) above the ground, a measuring tape was used. The plants with a height <50 cm were considered as regeneration class and >50 cm but

<100 cm were considered as recruitment class. Along the transects, sub-plots of 1×1 m^2 were fixed for counting the regeneration class and 2×2 m^2 were laid randomly for recruitment class

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

3.6. Halophytes

To quantify and document the halophytes at Deendayal Port Authority region, quadrate method was followed. At each sampling location quadrates of various size have been laid during every seasonal sampling. For recording the plant density at each transect, 1 x 1m quadrate has been laid within each tree transect randomly (Bonham 1989).Four quadrates each for shrubs and herbs were laid in side each tree quadrate to assess the halophytes and its 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 species were identified using standard keys. Specimens of the species were collected to know more information about the habitat and for the preparation of herbarium.

Plate 5: Assessment of halophyte cover

3.7. Marine Fishery

Fishery resources and diversity were assessed from the selected sampling sites. Finfish and shellfish samples were collected using a gill net with 10 mm mesh size. The cast net was operated onto the water from a canoe or by a person standing in waist deep water during the high tide. For effective sampling, points were fixed at regular distance interval within the 15 offshore sites for deploying fishing nets in order 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, District Fisheries department, Government gazette and other research publications.

Plate 6: Methods of fish capture from DPA environment

3.8. Avifauna

The data on the Avifauna along DPA mangrove stands was collected from the fifteen demarcated major stations at an interval of 2 to 5 km with in each creek. These creeks were surveyed by using boat and adopting "line transect" method (Fig.12). A total of fifteen boat transect (one in each site) survey was conducted in the Monsoon pre-monsoon and Post-monsoon. The survey was done in both terrestrial habitats like mangrove plantation adjoining the mudflats, waste lands and aquatic habitats like creek area, rivers and marshes.

Boat Surveys

Mangrove bird diversity was calculated by using Boat Survey method. Birds were observed from an observation post onboard the boat which was 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 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 jurisdiction area.

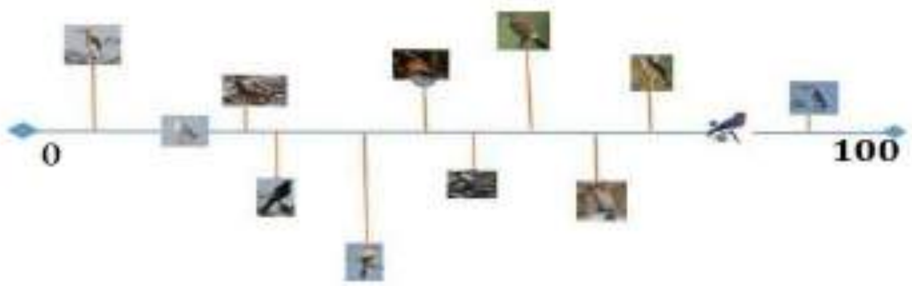


Figure 12. Line transect method for Avifauna survey

3.9. Data analysis

Data collected in situ and through laboratory analysis of the samples were subjected to descriptive statistical analysis (PAST and Primer 7.0) for the mean, range and distribution of different variables from the 15 selected study sites (Plate.7).

Plate 7. Statistical Data analysis methods

4. Results

4.1. Physico-Chemical Characteristics of water and Sediment

The data on the maximum and minimum of the three seaon mean values of the various water quality parameters measured at the time of sampling of the biological components from the 15 study sites are presented in Table11.

Table-11. Physico-chemical characteristics of the DPA Jurdictitioon 2022-2023

Parameter		Monsoon 2021	Post Monsoon 2021	Pre Monsoon 2022
Temperature	max	31	28	28
	min	23	9	20
pH	max	8.3	8.1	7.99
	min	7.1	7.1	7.29
Salinity	max	40	43	50
	min	28	38	38
Dissolved oxygen (mg/L)	max	6.9	8.0	8.6
	min	4.5	4.0	7.0
Total Suspended Solids (TSS) (mg/L	max	403	640	887
	min	127	140	270
Total Dissolved solids (TDS) (mg/L)	max	11288	45700	100923
	min	1967	32200	34615
Turbidity (NTU)	max	147.4	342	74.8
	min	43.7	46	30.2
Nitrate (NO3) (mg/L)	max	0.068	0.140	0.020
	min	0.008	0.003	0.003
Nitrite (NO2) (mg/L)	max	0.944	0.021	0.224
	min	0.050	0.007	0.014
Total Phosphorus (mg/L)	max	0.96	2.02	3.27
	min	0.02	0.67	0.77
PHs (µg/L)	max	9.85	8.75	18.46
	min	2.15	1.45	8.85
Chlorophyll a (mg/L)	max	0.22	1.14	2.59
	min	0.13	0.14	0.62

4.1.1. Water quality parameters

Water Temperature

The values of the surface temperature obtained from the 15 different sampling stations for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure-13. During monsoon, the value ranged from 23°C to 31°C while in post monsoon it ranged from 9°C to 28°C. However, in pre monsoon the values varied between 20°c and 28°c. During monsoon, the highest temperature was noticed at S-5 while the lowest temperature was observed at S-6. The maximum temperature recorded was 31°C in monsoon at S-5 while site S-9 exhibited the lowest temperature during the post monsoon.

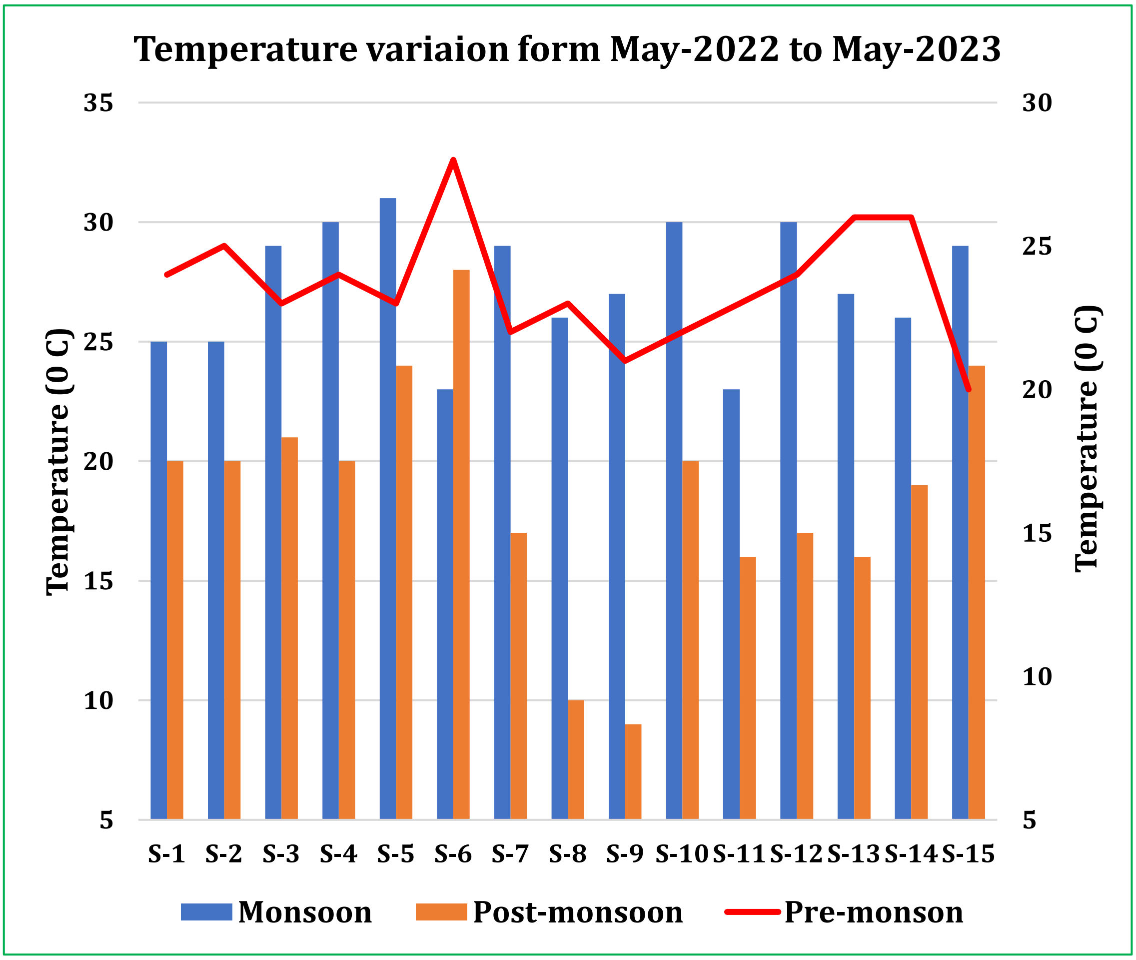


Figure 13. Temperature variation in the DPA study sites (May 2022-May 2023)

pH

The pH values obtained from 15 different sampling stations for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure-14. During monsoon, the value ranged from 7.1 to 8.3 while in post monsoon it varied from 7.1 to 8.1. However, in pre monsoon the values noted were in the range of 7.3 to 8.0. During monsoon, the highest pH was noticed at station S-15 and the lowest at S-14. During post monsoon the lowest pH was observed at S-11. For the total period of the study the maximum pH value was recorded in monsoon at S-15 and lowest was recorded at station S-11 and S-14 post monsoon and monsoon seasons respectively.

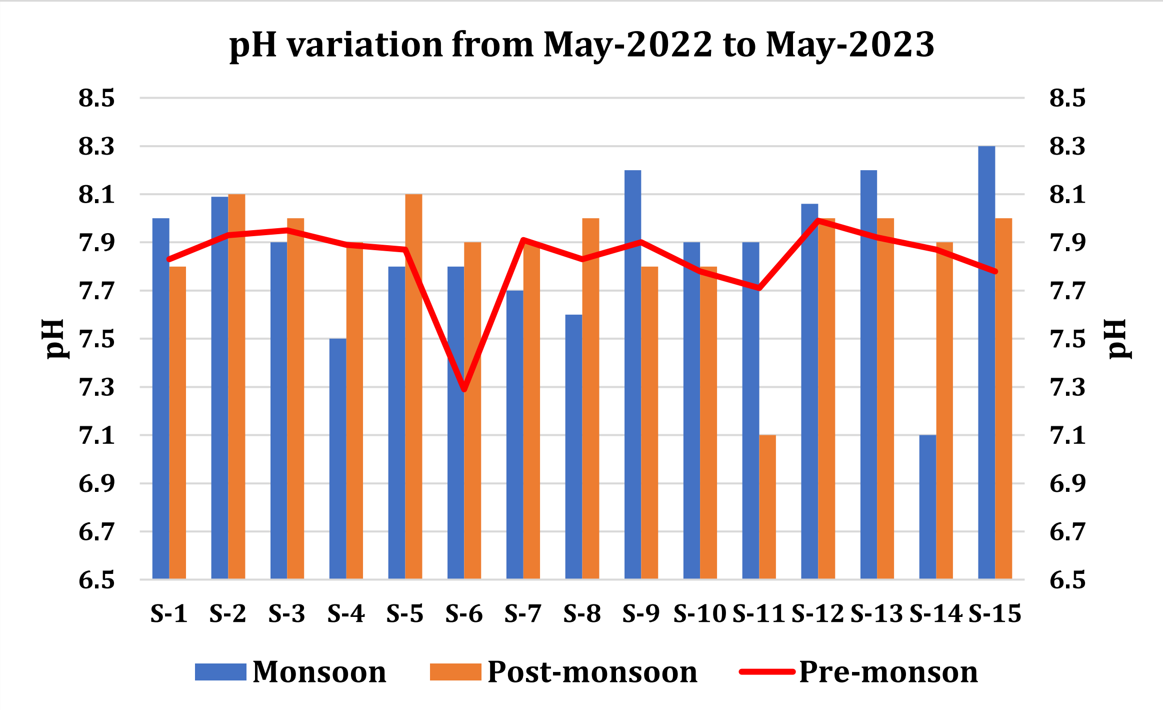


Figure 14. pH variation for the period May 2022 to May 2023

Salinity

The salinity values obtained from the 15 different sampling stations for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure-15. During monsoon, the salinity ranged from 28 ppt to 40 and in post monsoon from 38 ppt to 43 ppt . However, in pre monsoon the range was between 38 ppt and 50ppt. During premonsoon, the highest salinity was noted at station S-11 while the lowest at S-7 during monsoon season. The maximum salinity for the entire period of the study was recorded in pre-monsoon and lowest was recorded monsoon (S7) followed by Post-monsoon and pre-monsooon at S-2 & S-8.

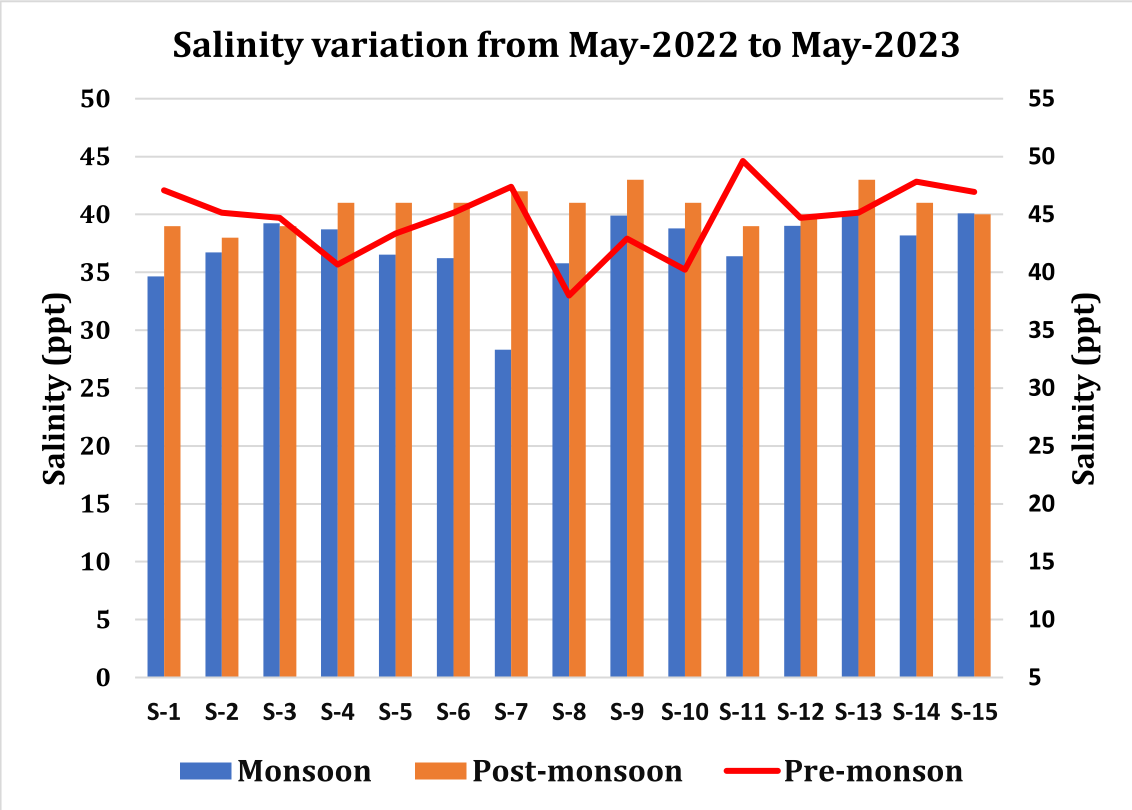


Figure 15. Seasonal variation of salinity during May 202 to May -2023

Dissolved oxygen (DO)

The maximum dissolved oxygen concentration of the sampling stations for the three seasons varied from 6.9 mg/L to 8.6 mg/L with average of 5.5 mg/L to 8.0 mg/L from May 2022 to May 2023. The minimum DO values varied from 4.0 mg/L to 7.0 mg/L . The seasonal variation of water dissolved oxygen among stations is presented in figure-16. During monsoon the highest dissolved oxygen concentration was observed at station S-7 (6.9 mg/L), and the lowest at S-15 (4.5 mg/L). In Post-monsoon, the highest dissolved oxygen was observed at S-6 & S-7 (8.0 mg/L) and the lowest value at S-5 (4.0 mg/L) During Pre-monsoon, the highest and lowest DO values were observed at stations S-9 (8.6 mg/L) and S-3 (7.20mg/L) respectively.

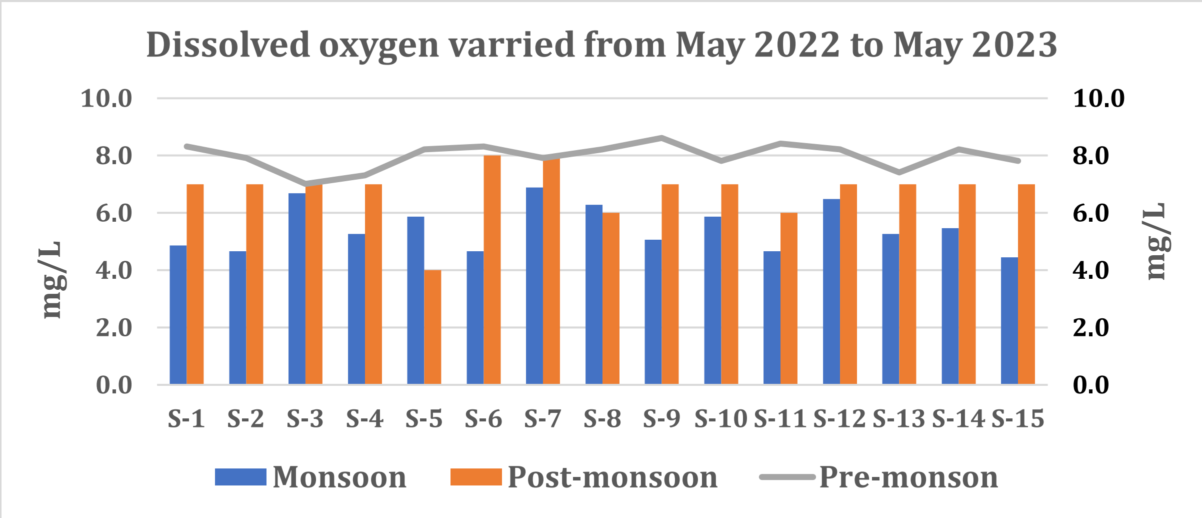


Figure 16. Seasonal variation Dissolved Oxygen during May-2022 to May-2023

Total Suspended Solids (TSS)

The values for the Total Suspended Solids (TSS) obtained from the 15 different sampling sites for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure-17. During monsoon, the value ranged from 127 mg/L to 403 mg/L, while in post monsoon it ranged from 140 mg/L to 640 mg/L. However, in pre monsoon the values varied between 270 mg/L and 887 mg/L. During monsoon, the highest TSS was noted at site S-15 while the lowest at S-7. The maximum TSS during post monsoon was observed at S-8 and lowest at S-12. In the pre monsoon S-6 exhibited the highest value and lowest value was observed at S-10(figure-15).

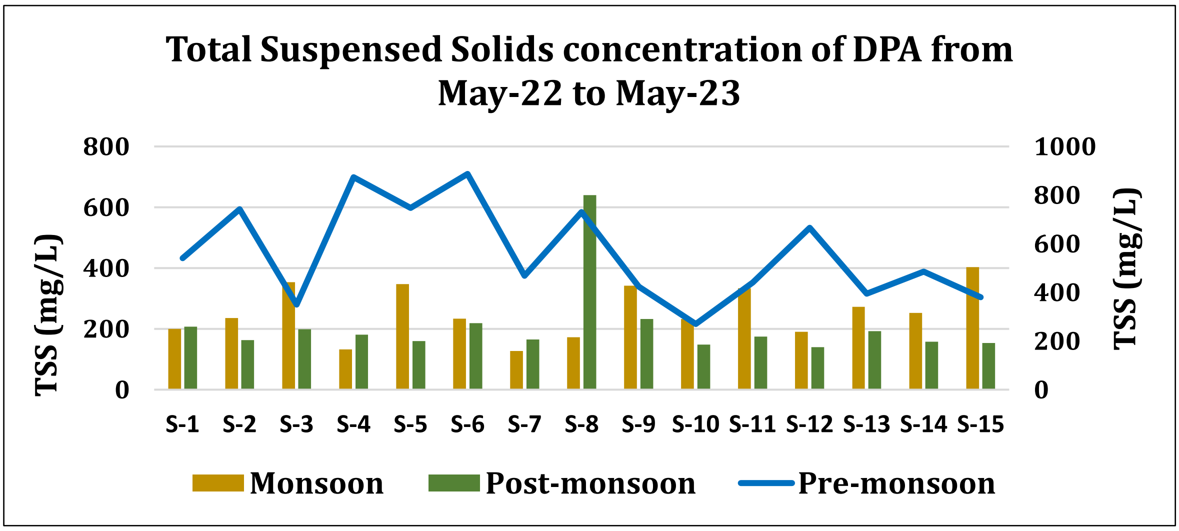


Figure 17. Seasonal variation of TSS during May 2022 to May 2023

Total Dissolved Solids (TDS)

The value for the Total Dissolved Solids (TDS) obtained from the 15 different sampling sites for all the three seasons (Monsoon, post monsoon and pre monsoon) are presented in Figure-18. During monsoon, the value ranged from 1967 mg/L to 11288 mg/L, while in post monsoon it varied between 32200 mg/L and 45700 mg/L. However, in pre monsoon the values were much higher and varied from 34615 mg/L to 100923 mg/L. During monsoon, the highest TDS was noted at site S-10 while the lowest at S-6. The maximum TDS value for both post monsoon and pre monsoon was observed at S-8 and similarly the minimum were recorded from site S-14 for the two above two seasons.

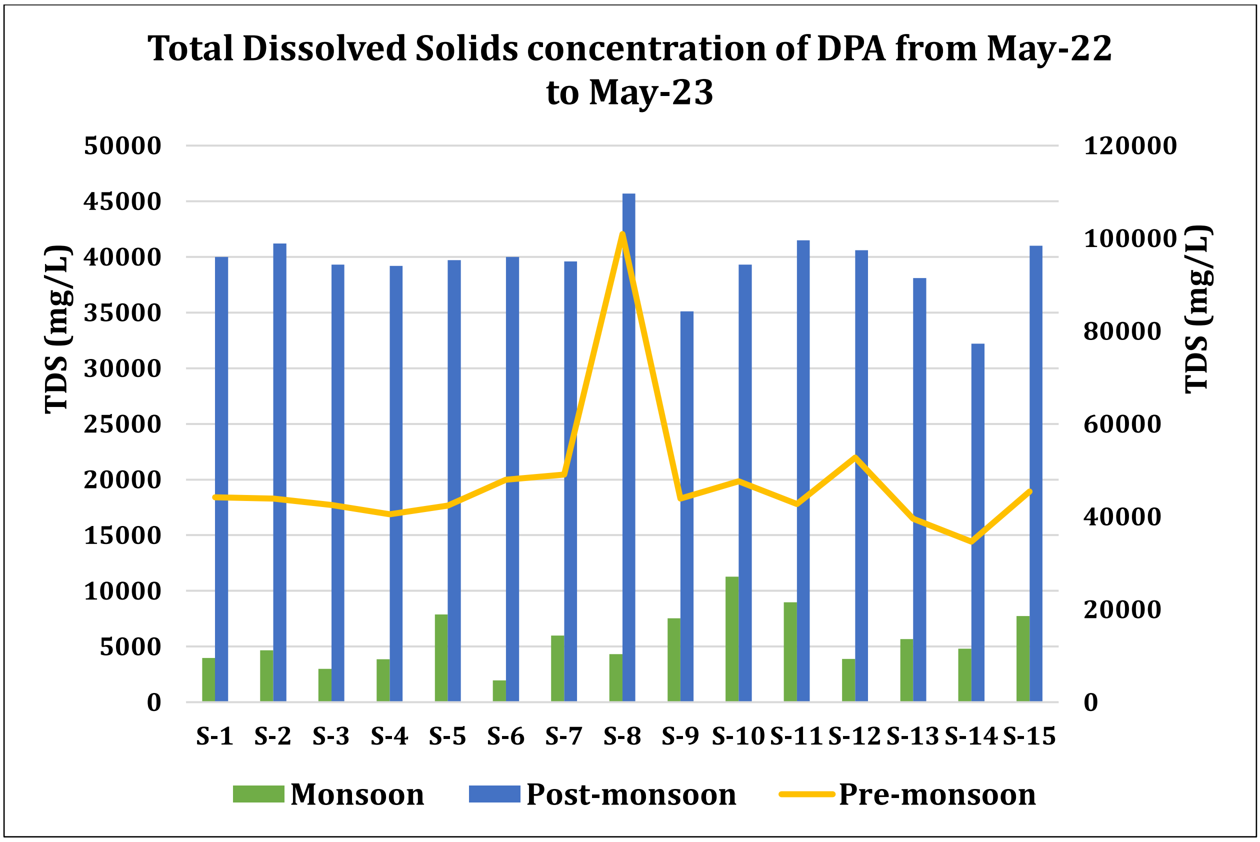


Figure 18. Total Dissolved Solids (TSS) during May-2022 to May-2023

Turbidity (NTU)

The Turbidity of the sampling stations varied from 30.2 NTU to 342 NTU for the period May 2022 to May 2023. The seasonal variation of water turbidity among the stations is presented in Figure-19. During Monsoon, the highest Turbidity was observed at S-3 (147.4 NTU) and the lowest was at S-6 (43.7 NTU). In Post-monsoon, the highest value was observed at S-9 (342 NTU) and the lowest was at station S-15 (46 NTU). Similarly in Pre-monsoon, the highest and lowest turbidity were observed at S-12 (74.8 NTU), at S-11 (30.2 NTU) respectively.

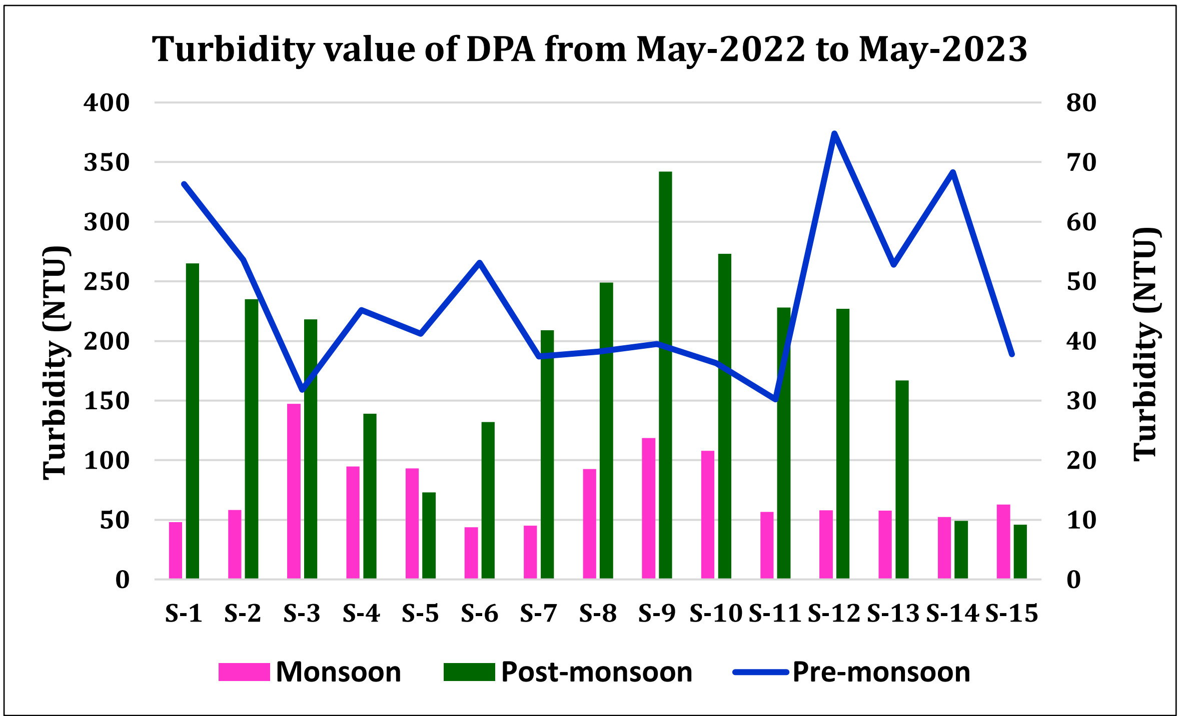


Figure 19. Seasonal variation of Turbidity during May-2022 to May-2023

Nitrate

The amount of Nitrate in the water sample was relatively low throughout the study period. The maximum Nitrate value for the three seasons was 0.140 mg/L from for the last one year. This value was noted at S-9 during post monsoon and the minimum 0.003mg/L was recorded at S-1. The nitrate at S-12 during pre-monsoon was the lowest but the highest value was reported from S-13(figure-20). During Monsoon, the highest Nitrate value observed (0.068 mg/L) at station S-13 and the lowest Nitrate value was

0.008 mg/L (station S-12). During Post-monsoon study, the values increased and highestvalue was observed at S-9 (0.140 mg/L) and lowest at S-1 (0.003 mg/L). Similarly in Pre-monsoon the highest (0.02 mg/L) and the lowest (0.003 mg/L) were reported S-13 & S-12 respectively.

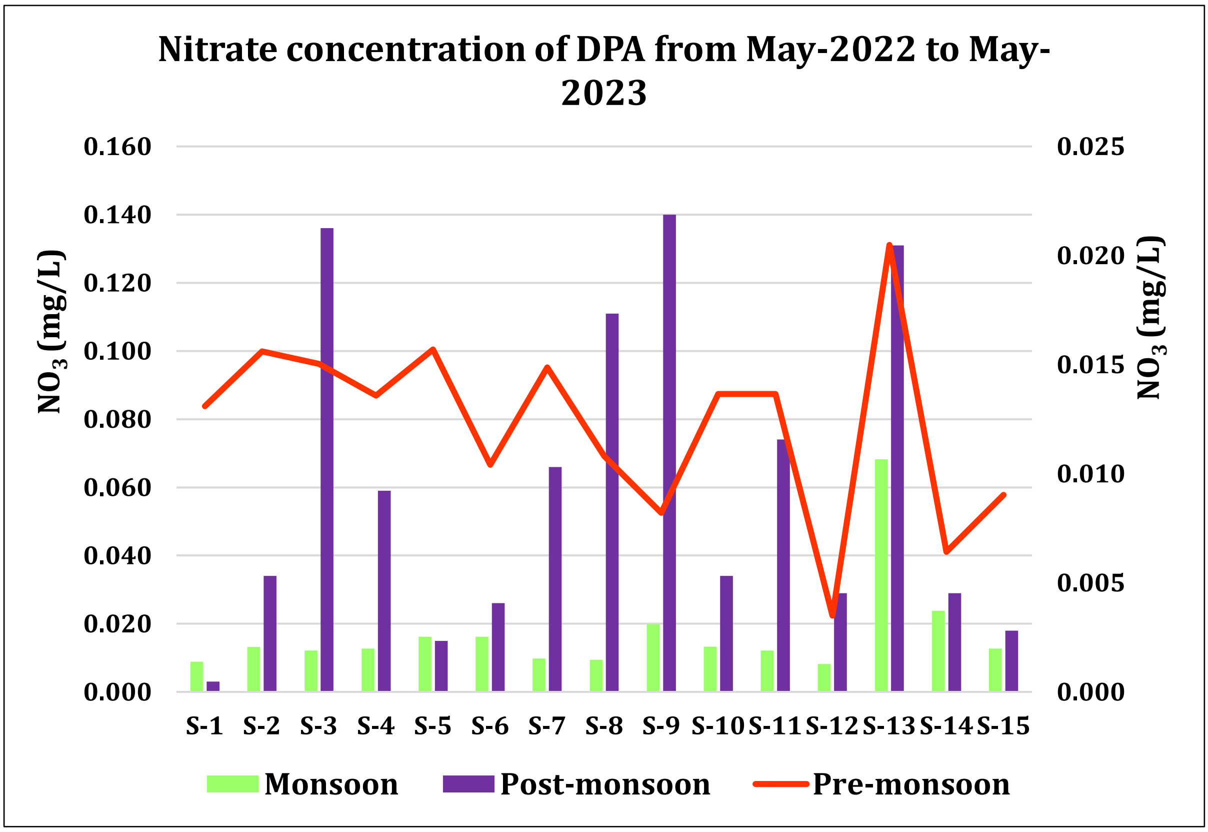


Figure 20. Seasonal variation of Nitrate concentration during May 2022 to May 2023

Nitrite

The amount of nitrite in the water sample is relatively high compared to the nitrate throughout the study period. The maximum value for the three seasons was 0.94 mg/L at S-13 from May 2022 to May 2023(Figure-21). During Monsoon, the highest nitrite concentration was noted at S-13 (0.94 mg/L) and the lowest at S-2 (0.05 mg/L). In Post-monsoon, the value in the majority of the stations did not vary considerably and the value 0.02 mg/L was observed at S-2, S-5, S-6, S-7, S-10, S-12 and S-13 and the lowest 0.01mg/L was observed at S-1, S-3, S-4, S-8, S-9, S-11, S-14 and S-15. Similarly in pre-monsoon the highest nitrite content was 0.22 mg/L and the lowestt (0.01 mg/L) was observed at S-2 and S-5 respectively.

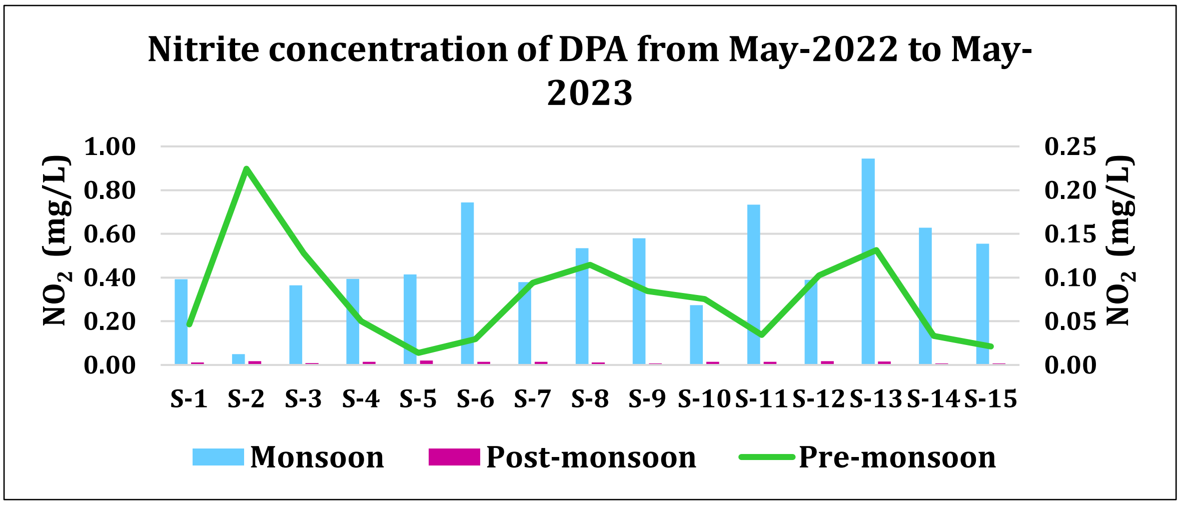


Figure 21. Nitrite concentration during May-2022 to May-2023

Total Phosphorous

The total phosphate content at S-6 was highest during the pre-monsoon season Through out the study period the phosphate values were in the range of 0.02 mg/L to 2.31 mg/L (Figure 22). During Monsoon, the maximum value noted was 0.96 mg/L at (S-13) and the lowest was 0.02 mg/L at (S-11). In Post-monsoon, the highest value was 2.02 mg/L at S-3 and 0.67 mg/L at S-12. In Pre-monsoon, the highest and the lowest values observed were 2.31 mg/L and 0.77 mg/L at S-6 and S-2 as well as S-9 respectively.

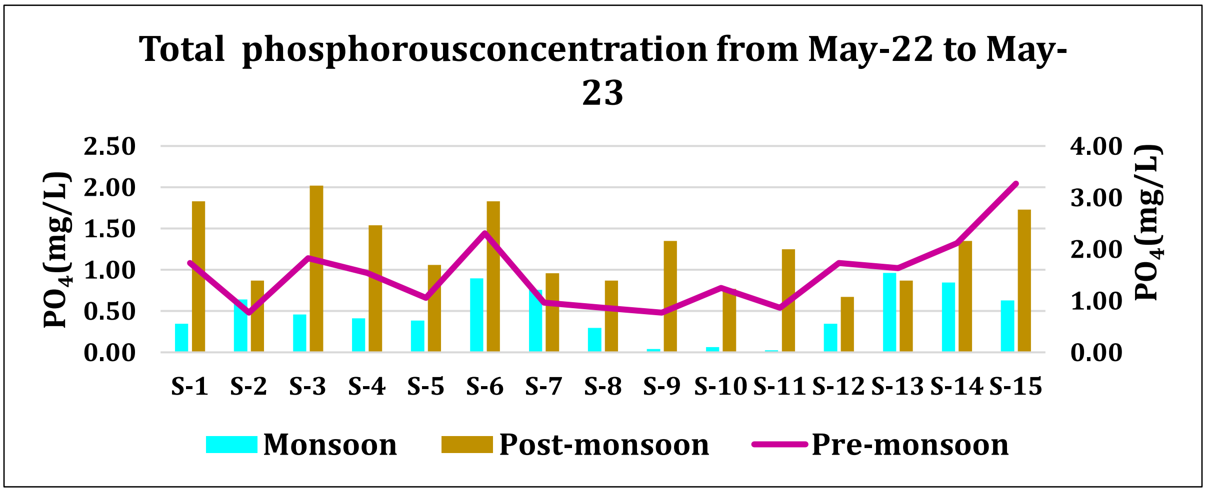


Figure 22. Seasonal variation Total Phosphorous from May-2022 to May-2023

4.1.2. Petroleum Hydrocarbon (PHs)

The PHs values were comparatively high at S-1 and S-4 during post-monsoon than the other seasons. The values for Petroleum Hydrocarbons (PHs) for the three-season varied from 1.5 µg/L to 18.5 µg/L (Fig.23). The PHs concentration in general, is at low level during monsoon. During Monsoon, the highest PH was observed at S-1 (9.9 µg/L) and lowest PHs was observed along S-13 (2.2 µg/L). In Post-monsoon, the highest PH value was observed at S-1 (8.8 µg/L) and the lowest PH was observed S-11 (1.5 µg/L). Similarly in Pre-monsoon, the maximum PH content was recorded (18.5 µg/L) at S-1 and the minimum was (8.8 µg/L) at S-10.

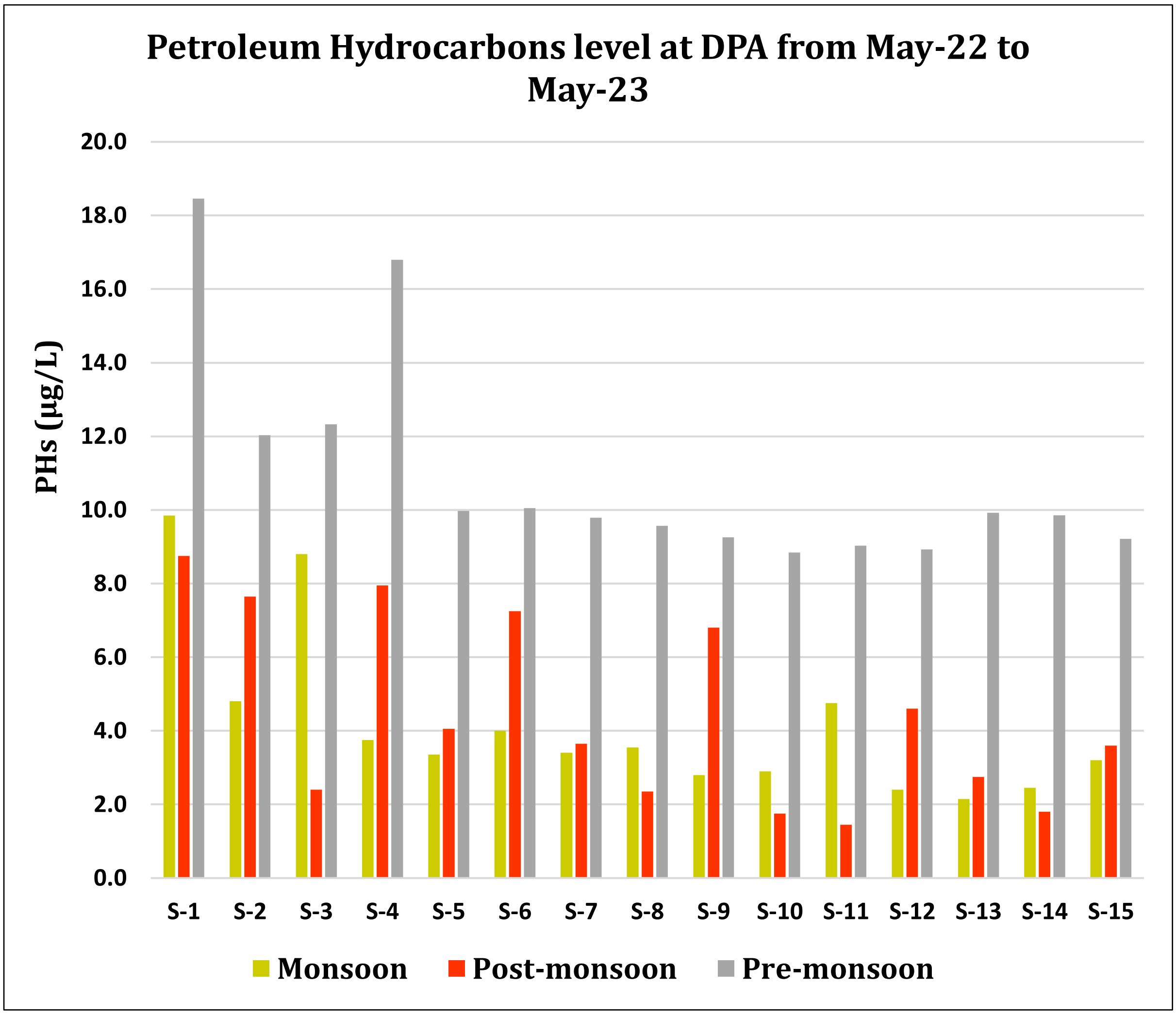


Figure 23. Seasonal variation of Petroleum Hydrocarbon during May-2022 to May-2023

4.1.3. Sediment

Texture

The soil texture was characterized by the proportion of clay, sand and silt fractions. Soil texture revealed dominance of silty-clay type in all the stations during post and pre-monsoon and in monsoon the sand fraction was high (figure 24). In monsoon the percentage of Sand, Silt and Clay varied from 48-53%, 20-24% and 24-30% respectively. In post-monsoon the percentage of the three fractions were 10-60%, (sand) 5-19% (silt) and 22-84% (clay). Similarly in premonsoon the percentage variation of sand was 20-50% , silt 11-33% and claybetween 19-68% respectively

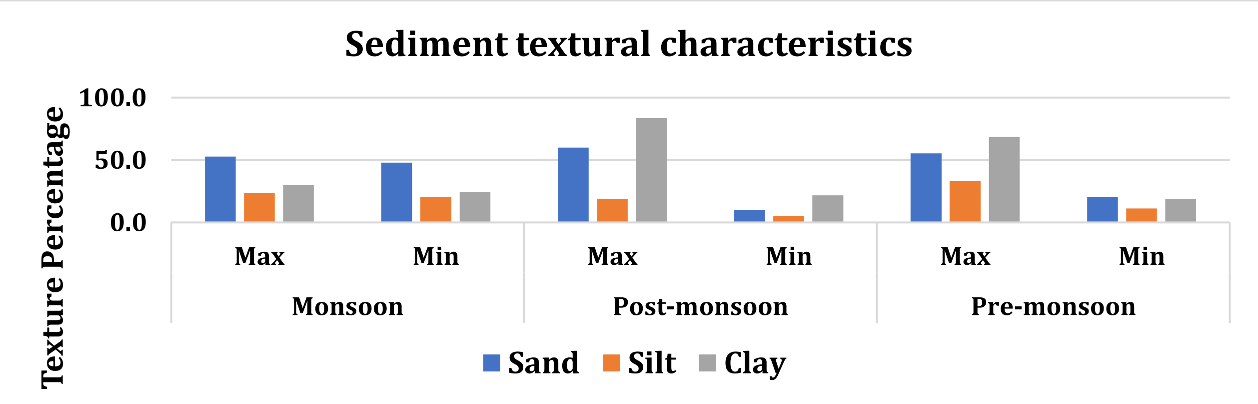


Figure 24. Sediment textural characteristics during May-2022 to May-2023

4.2. Biological Characteristics of water and Sediment

4.2.1. Primary productivity

Chlorophyll ‘a’ the photosynthetic pigment which can be used as a representation for phytoplankton productivity and thus is an essential water quality parameter. Generally, the primary production of the water column is assessed from Chlorophyll ‘a’ concentration. It is well known that half of the global primary production being mediated by the activity of microscopic phytoplankton. For the period May 2022 to May 2023 the highest concentration recorded varied from 0.22 mg/L to 2.59 mg/L among the sampling locations. The minimum Chlorophyll ‘a’ values ranged from 0.13 mg/L to 0.62 mg/L, The highest Chlorophyll ‘a’ concentration (2.59 mg/L) was observed at S-8 during pre monsoon. The seasonal variation of Chlorophyll ‘a’ among stations is presented in figure-25.

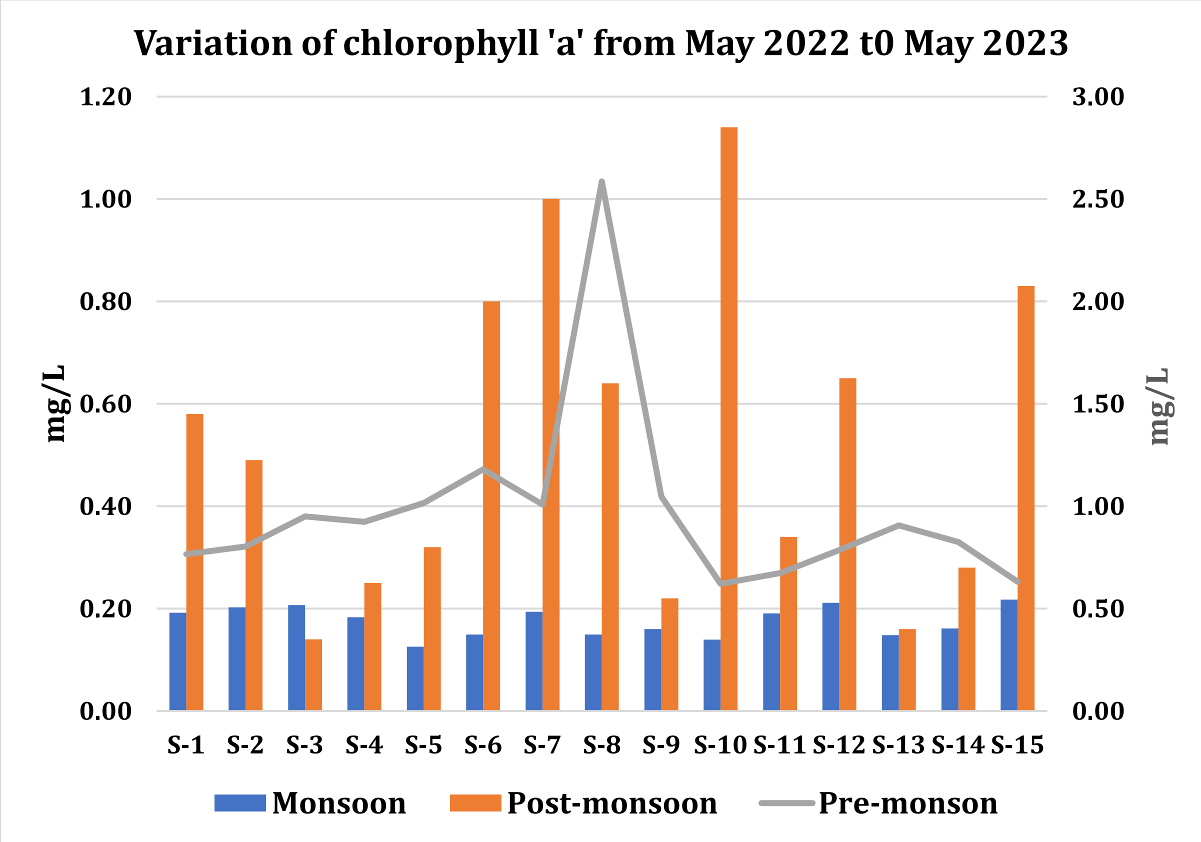


Figure 25. Concentration of Chlorophyll 'a' during May-2022 to May-2023

4.2.2. Phytoplankton

Phytoplankton are the main primary producers of marine and freshwater ecosystems. They play specific roles in the bio-geochemical cycling in the marine ecosystems. Their roles in calcification, silicification, dimethyl sulphide (DMS) production and nitrogen fixing have been well established. These tiny organisms initiate the marine food chain by the process of photosynthesis and serve as primary food in the marine pelagic zone. Phytoplankton, as the basis of the trophic chain, forms the biological community which regulates the food chain for which scientific attention is focused when a management plan is needed or an evaluation of the ecosystem health is required. The phytoplankton populations are mostly represented by members of Cyanobacteria, Chlorophyta, Dinophyta, Euglenophyta, Haptophyta, Chrysophyta, Cryptophyta, and Bacillariophyta. Planktonic representative taxa are absent in other algal divisions like Phaeophyta and Rhodophyta.

Generic Status

Season wise the number of phytoplankton genera varied from 26 to 37 in the fifteen stations sampled with an average 24-32 numbers. During the study the minimum number of genera reported was between 21 to 27 as represented in Figure 26.

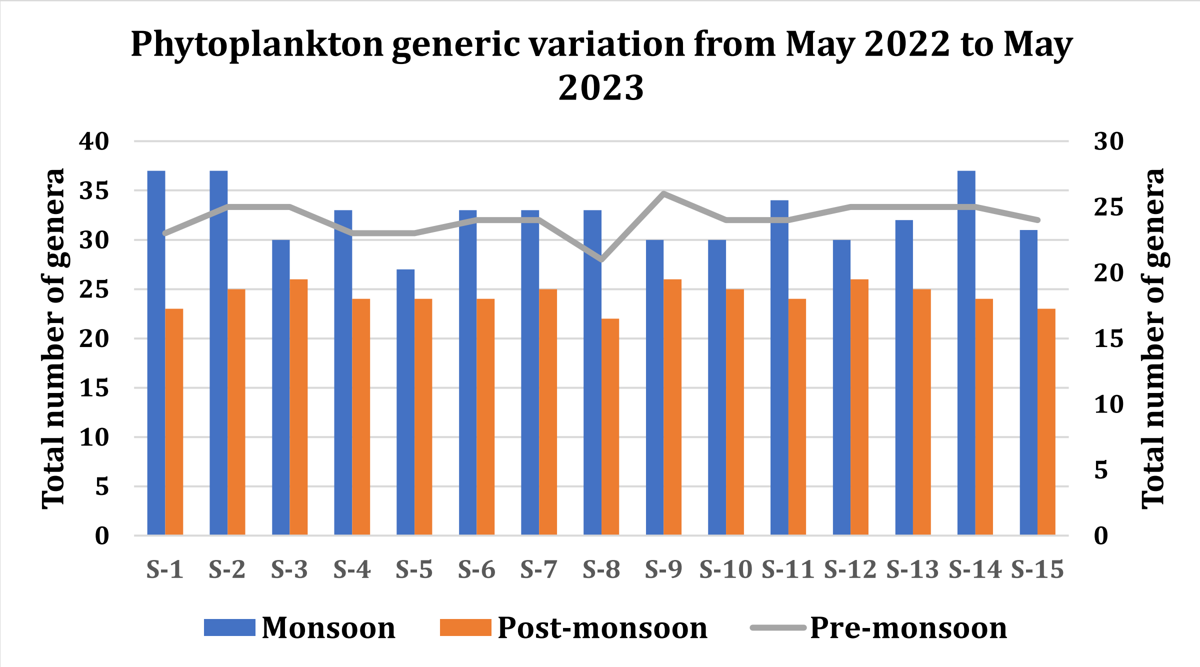


Figure 26. Seasonal variation of Phytoplankton genera from May-2022 to May2023

During monsoon the phytoplankton genera varied from 27 to 37 number and the maximum was observed at station S-14 (37 No) and lowest at station S-5 (27No).In post-monsoon it varied from 22 (S-8) to 26 (S9). Similarly during pre-monsoon the number of phytoplankton genera varied between 21 and 26 and the highest at S-9 at S-8 stations respectively.

Percentage composition

The phytoplankton recorded in the seasonal study are segregated into five groups such as Pennales, Centrales, Dinophyceae, Cyanophyceae and Chlorophyceae. The percentage composition of these groups in the samples during the seasonal study are presented in the figure 25. The diatoms, centrales and pennales were present at all seasons. At the different stations, the maximum percentage of the groups varied from 41 %to 64% and the minimum was 5%. The percentage of composition pennales varied from 28% (monsoon) to 38% (post monsoon). The centrales percentage fluctuated between 47% and 84%. The Dinophyceae group percentage was 10% and occurred during monsoon season only. The Cyanophyceae and clorophyceae genera alaso during nonsoon constituted 12% and 5% respectively (Figure.27).

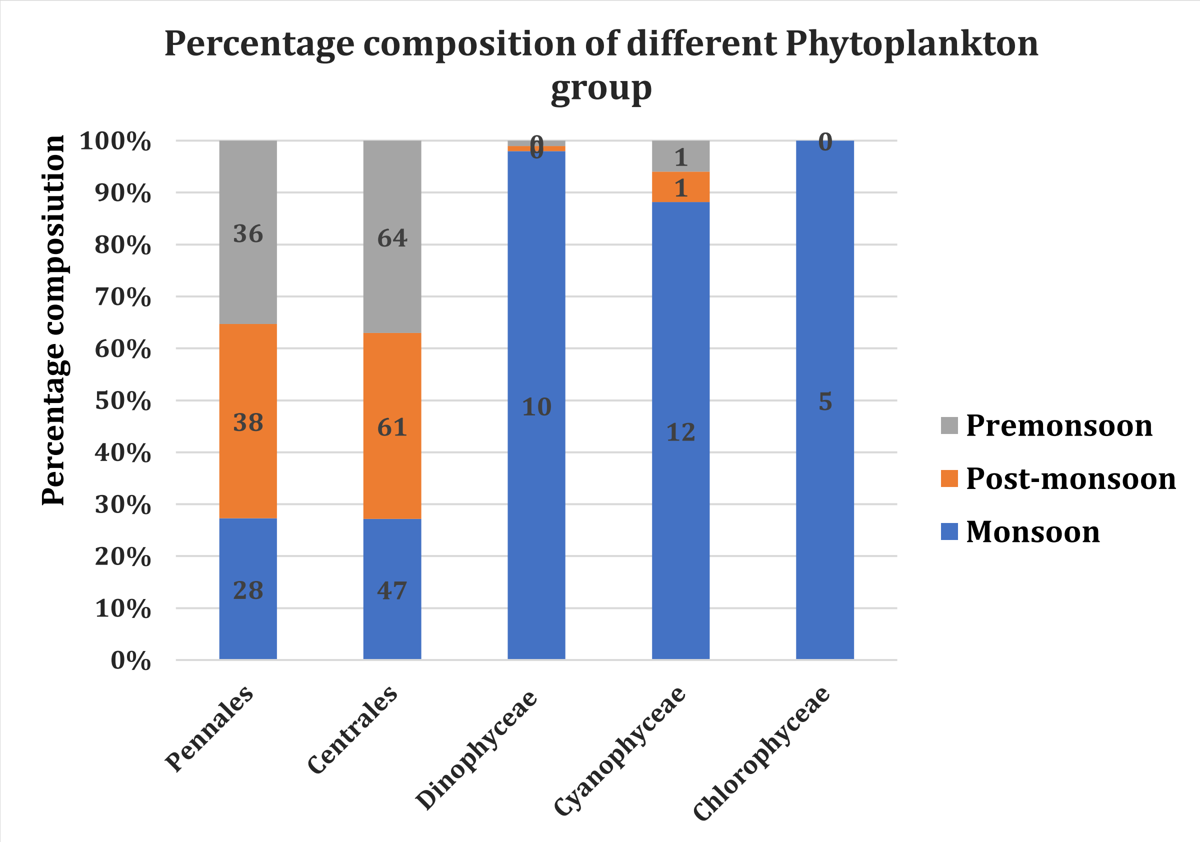


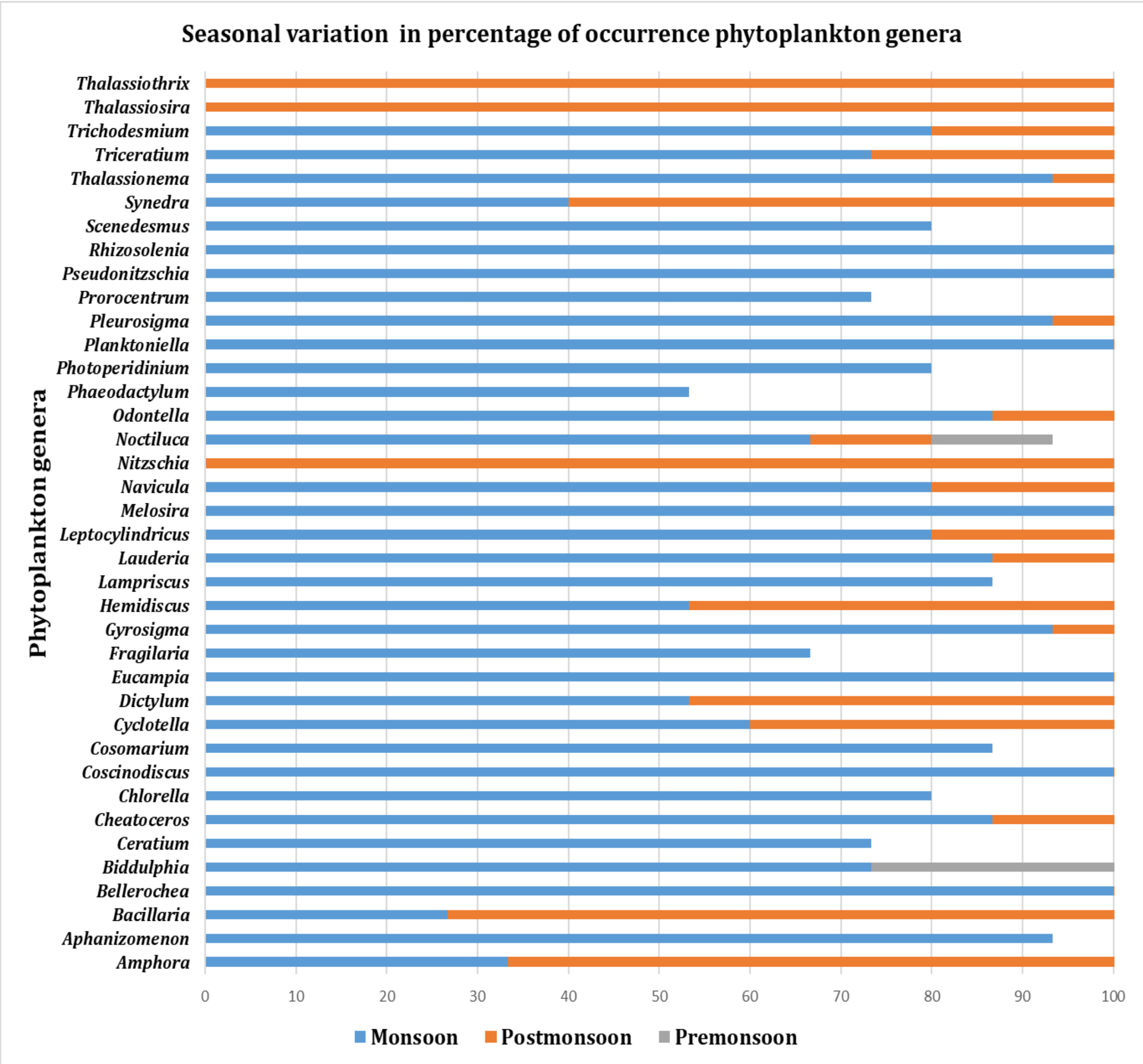
Figure 27. % composition of phytoplankton during May-2022 to May-2023

Percentage of Occurrence

Season wise the percentage occurrence of the different groups of phytoplankton varied from 13% to 100%. There were 17 phytoplankton genera showed 100% occurrence during the Post-monsoon and monsoon season and only three genera which were found only in post monsoon. The genera such as *Thalassiothrix,Thalassiosira and Nitzschia* are found only in postmonsoon. Similarly,*Biddulphia* and *Noctiluca* are observed only during the premonsoon sampling (Figure.28). The phytoplankton genera, *Bellerochea* , *Eucampia, Pseudonitzschia, Rhizosolenia* were found (100%) in monsoom (Plate 8).

Figure 28. percentage occurrence of phytoplankton genera

May-2022 to May-2023



Phytoplankton density

The density signifies the abundance of plankton which is measured as cell/ individual/L. The maximum phytoplankton density variation for the three seasons varied from 21,120 No/L to 35,040 No/L with average variation of 29,813 and the minimum phytoplankton density varied from 12,640 No/L to 16,320 No/L with the average variation of 14,880 (Figure.29).

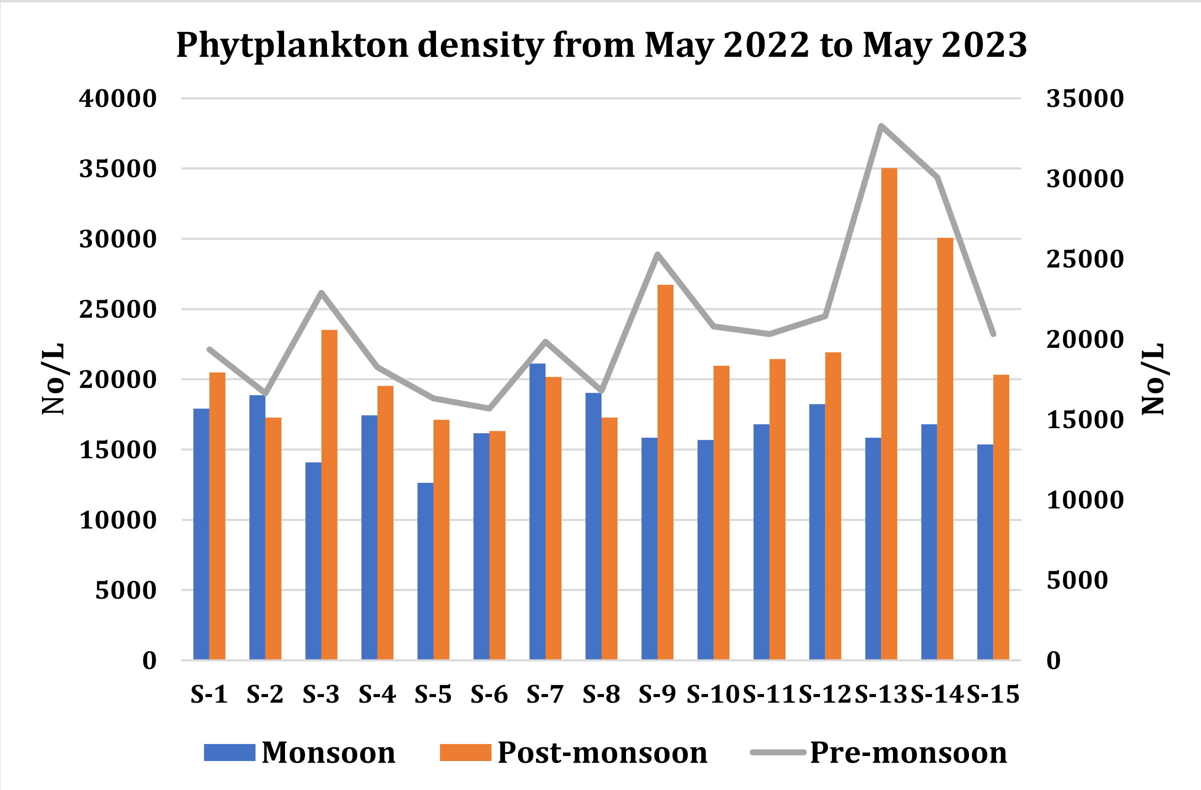


Figure 29. Seasonal variation Phytoplankton density during May 2022 to 2023

During monsoon the phytoplankton density varied from 12,649 No/L to 21,120 No/L where the highest density was observed at S-7. In post-monsoon the cell density varied from 16,320 No/L (S-6) to 35,040 No/L (S-13) .Similarly during pre-monsoon density fluctuated between 15,680 No/L at S-6 to 33,280 No/L at S-13.

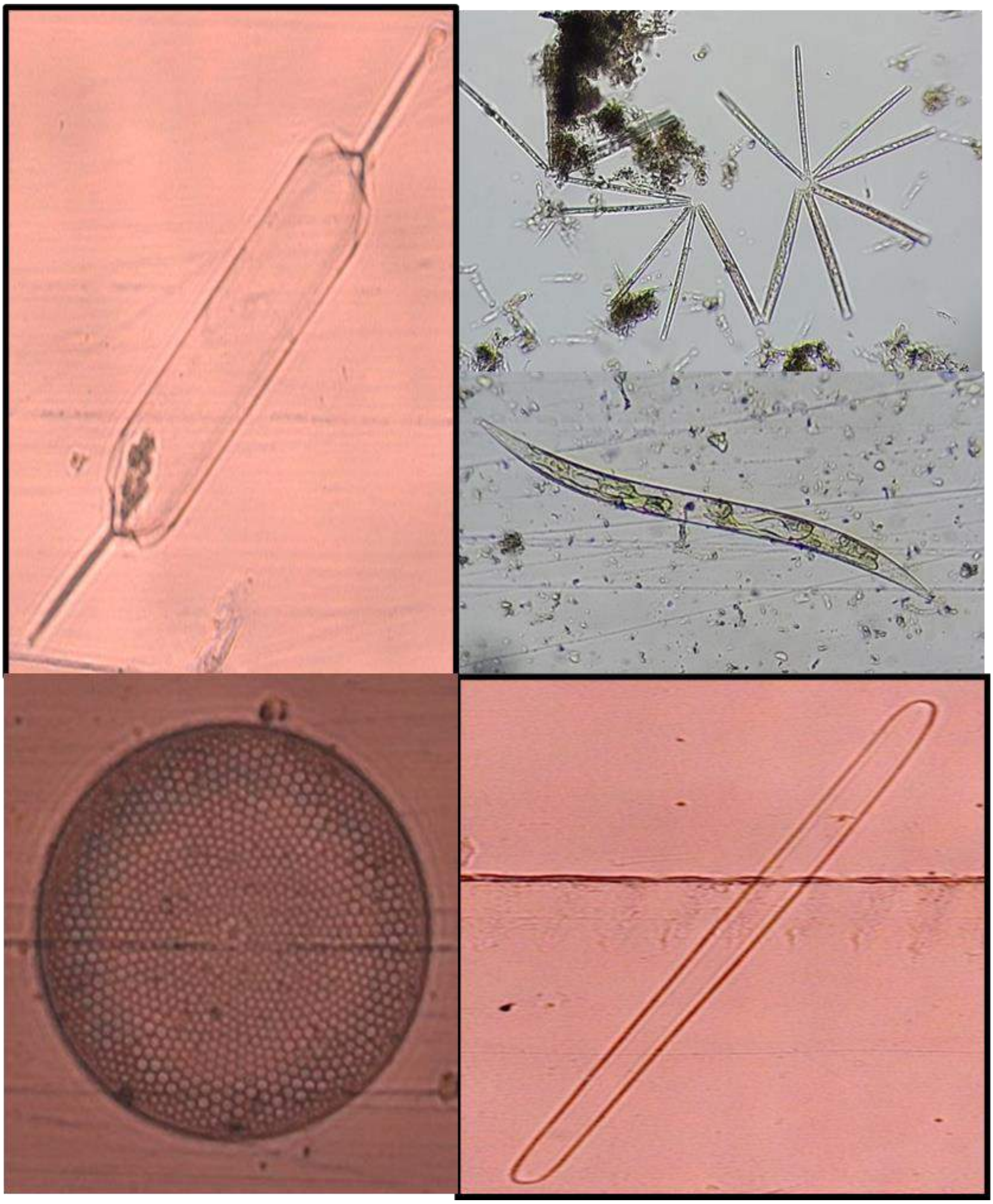


Plate 8: Phytoplankton of Deendayal Port Authority

4.2.3. Zooplankton

Zooplankton is a key player in the pelagic marine ecosystems particularly as prey for shellfish, fish, marine mammals and seabirds. In addition, zooplankton waste products are also of importance for the vertical flux of organic matter that settles in sediment supports the benthic community. Thus, zooplankton occupies a key position in shaping the pelagic system and coupling of pelagic and benthic food webs. The zooplankton species of Indian waters is very diverse, which could be due to a series of environmental factors, most significantly ocean currents (Jagadeesan *et al*., 2013), upwelling (Madhupratap *et a*l., 1990), high primary productivity (Smith and Madhupratap, 2005) and salinity. These studies also recorded species compositions of the plankton community with marked spatial, seasonal, and diurnal fluctuations in both the Bay of Bengal and the Arabian Sea. Zooplankton are strongly responsive to environmental variables, including light, temperature, salinity, pH, dissolved oxygen, turbulence, and food availability. In recognition of this multifaceted ecological and economic significance of zooplankton in the marine environments, there has been a long emphasis on studying their systematics, ecology, and other biological aspects at different spatio-temporal scales.

Zooplankton plays a major role in the functioning and productivity of aquatic ecosystems through its impact on the nutrient dynamics and its unique position in the food web. Many species of zooplankton can be used as biological indicators for water pollution, water quality, and eutrophication. Zooplankton communities are highly influenced by spatio-temporal variations in hydrochemical parameters and physical forces. The Spatio-temporal variations in zooplankton species composition and distribution in the Arabian Sea and Bay of Bengal have been extensively studied during the past 100 years and with more emphasis since the 1950s. Copepods are the most dominant zooplankton group and the most diverse in species composition in the pelagic realm of the marine environment. The preponderance of copepods among the various taxonomic groups has been reported as a common feature in coastal and oceanic environments. As the study area of DPA is under the influence of various port and cargo handling activities, regular monitoring is highly essential to know the environmental pressures at the Kandla coast and its nearby creek environment with respect to plankton which supports the fishery resources and several ecological services.

Phylum group and generic status

The zooplankton identified from the 15 stations falls under 8-11 phylum and 12-19 group for the period May-2022 to May 2023. In the monsoon season 11 phylum and 12 zooplankton groups were recorded. Ssimilarly, in post-monsoon season 8 phylum and 16 groups and during pre-monsoon season 10 phylum and 19 zooplankton groups were recorded (Figure.30).

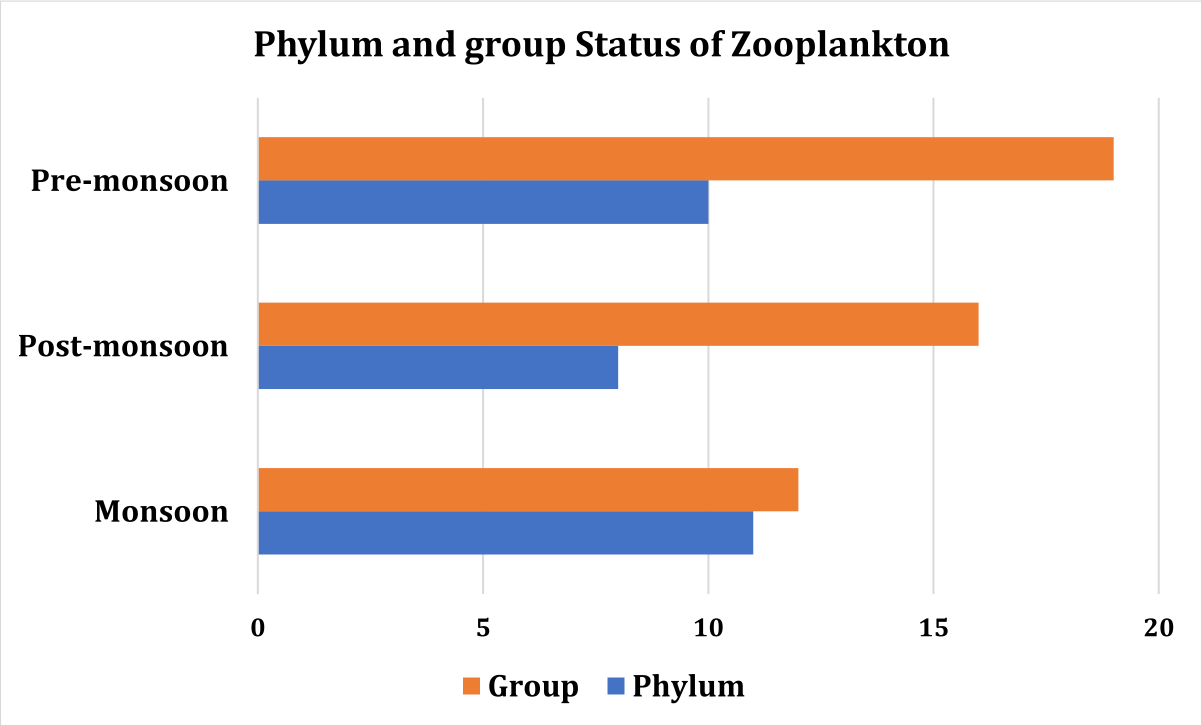


Figure 30 Zooplankton Phylum and group status fromMay 2022 to May 2023

The phylum Arthropoda was the predominant represented with 8 groups in monsoon and post-monsoon and 6 groups during pre monsoon. The groups are namely. Calonoida, arpacticoida, Cyclopoida, Decapoda, Crab larvae and Malacostraca. The maximum number zooplankton genera among the stations varied from 37 to 41 with an average variation of 39, and the minimum zooplankton genera varied from 27-31 with an average variation of 30. During monsoon season highest number (37) of genera was recorded at S-14 and lowest number (27) at S-5. During post-monsoon, the highest number of genera was observed at S-13 (41) and the minimum at S-8 (31). Likewise, in pre-monsoon, the highest and lowest genera were observed at stations S-13 (40) and S-8 (31) as depicted in figure 31.

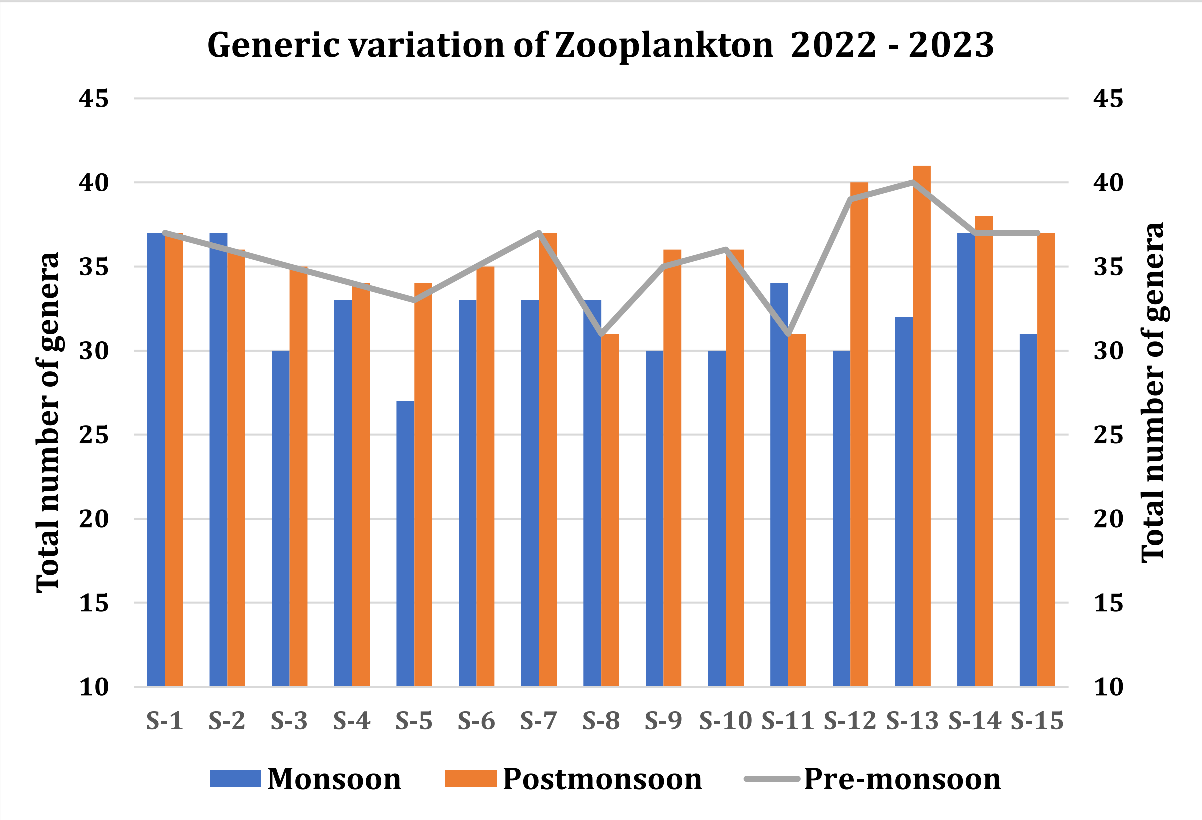


Figure 31. Generic status of Zooplankton during May 2022 to May 2023

Percentage of composition of zooplankton groups

The maximum percentage of zooplankton ranged from 36.9% to 40.4% and the minimum percentage varied between 1.6% and 2.8%. In monsoon, the highest percentage was contributed by the Copepoda (36.9%) followed by Decapoda (13.2%) and *Harpacticoida* (9.2%) During post-monsoon the Copepoda shared the highest numbers (40.4%) followed by the Decapoda (16.4%) and Gastropod (6.4%) while the other groups are very low. Similarly, in the pre-monsoon season, the Copepoda group predominated (38.2%), while the Decapoda (14.1%) became the second important group and was followed by Fish larvae (5.7%) (Figure 32. The other groups among the zooplankton community formed 16.1% (monsoon) to 25.8 % (post-monsoon).

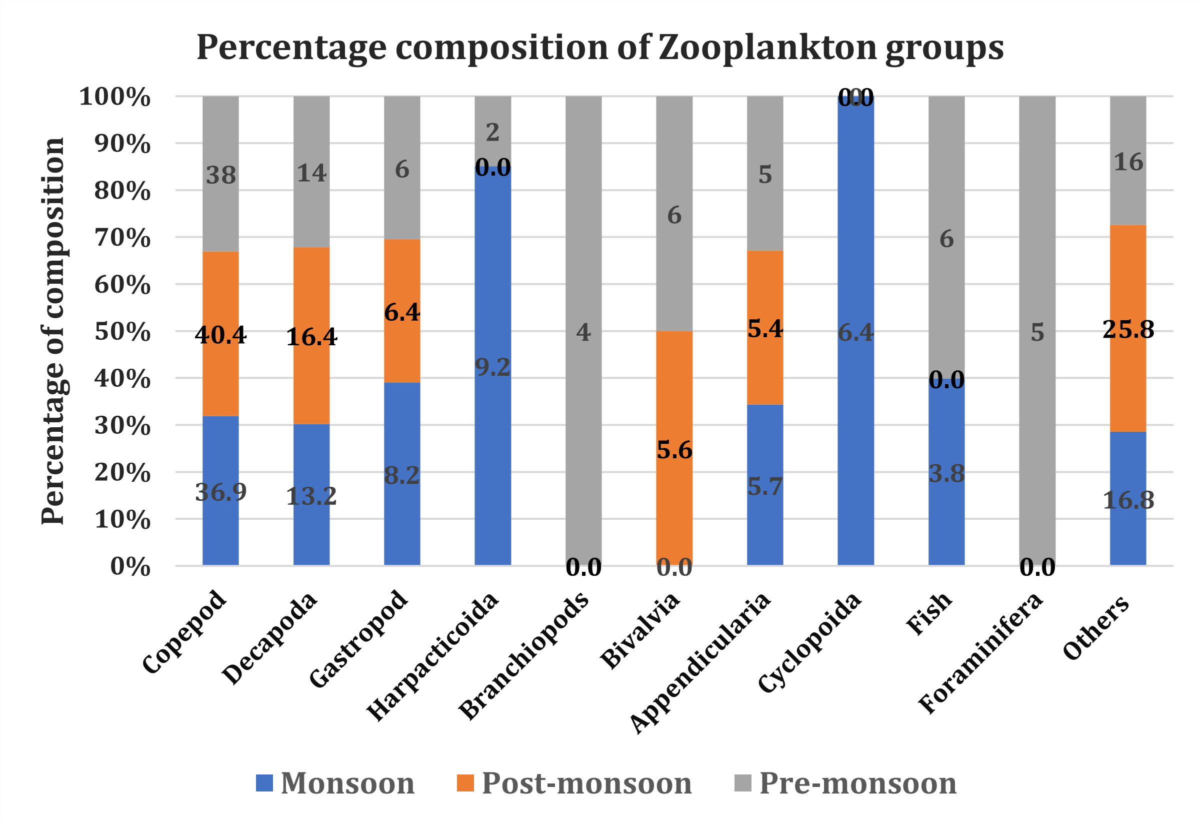


Figure 32. Percentage composition of Zooplankton during May 2022 to May2023

Percentage of occurrence of zooplankton genera

Percentage occurrence of zooplankton genera varied from 7-100%. In the monsoon season, the copepod, *Acartia sp* (100%) ranked first which was followed by *Microsetella sp* and sagittal (935). In post-monsoon the maximum occurrence was contributed by *Bivalve larvae* and *Brachyuran larvae, each formed* (100%) and the least percentage by the Onychopoda (53%). Similarly, during pre-monsoon *Acartia* sp, *Acrocalanus sp. ,Aetideus sp. Calanus sp. Caridean larvae, Eucalanus sp., Euphausia sp. ,Fish larvae , Gastropod larvae, Globigerina sp., Labidocera sp.,Paracalanus sp. Polychaete larvae, and Sagitta sp showed their presence* (100%) at all the sampling sites as presented figure 33,

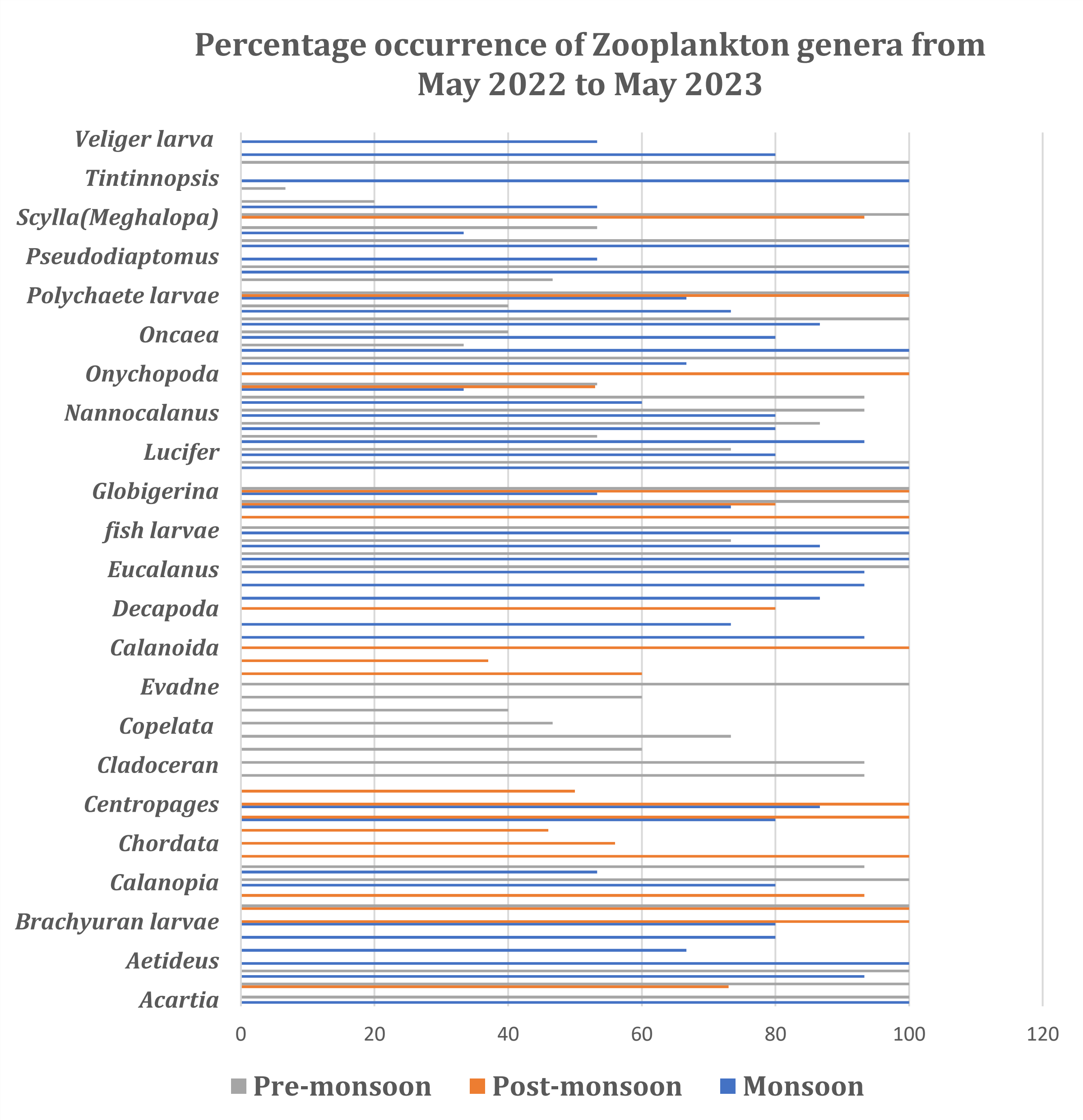


Figure 33. Percentage occurrence of Zooplankton from May-2022 to May-2023

Zooplankton density

During monsoon season the zooplankton density varied from 12,540 No/L at S-7 to 21,120 No/L at S-5. During the post monsoon and pre monsoon the density varied from 16,480 no/L at S-14 to 37,280 no/L at S-11 as shown in figure 34.

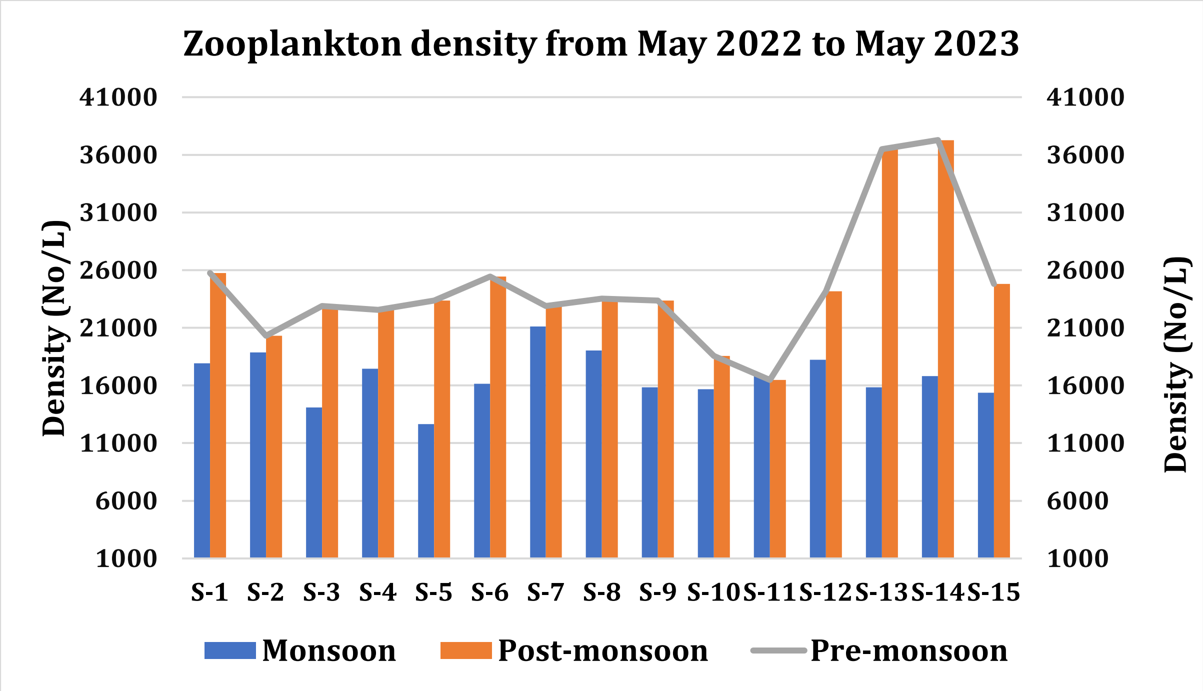


Figure 34. Density Zooplankton from May-2022 to May-2023

Plate 9: Zooplankton Deendayal Port Authority

4.2.4. Intertidal fauna

The intertidal habitats are found along the margins of the oceans, include estuaries, mudflats, salt marshes and rocky shores (Chakraborty, 2017). This intertidal zone is rich in biodiversity because of the availability of high concentrations of nutrients in the water that are discharged from the land. Although these habitats differ in many respects, they share the common feature that organisms living in them experience enormous changes in their abiotic environment caused by the tidal cycle. The tide rises roughly every 12.5 h, and during this time, intertidal organisms can be exposed to marine-like temperature and salinity conditions. The Gulf of Kachchh (GoK), occupying an area of 7300 km2, is biologically one of the most productive environments with diversified habitats along the west coast of India. The southern shore has numerous Islands and inlets which harbour vast areas of mangroves and coral reefs. The northern shore with numerous shoals and creeks also sustains large stretches of mangroves. A variety of marine wealth exists in the Gulf includes algae, mangroves, corals, sponges, molluscs, prawns, fishes, reptiles, birds and mammals.

The marine environment is a complex system influenced by various physical, chemical and biological processes and harbours broad assemblages of diversified fauna. Intertidal fauna represents species of invertebrates and chordates. They have an essential role in the pelagic and benthic food chain at different trophic levels in the coastal environment. Hence, periodic environmental monitoring to assess the abundance and diversity of macrofauna in this habitat is inevitable. The intertidal fauna show comparatively less mortality based on the condition of their habitat, and many environmental impacts can be identified by following the changes in the assemblages. Activities of organisms influence sedimentation and erosion and the physical and chemical nature. Tidal flats occur mainly in areas where saline and freshwater mix. Benthic organisms occur here usually in high densities because estuaries are among the most productive regions in the sea. Nutrient input by freshwater discharges sustains a relatively high primary production by phytoplankton and micro-and macro flora. The organisms living on the tidal flats utilize these intertidal flora and fauna as food. Moreover, there is a high input of organic matter (food) from the rivers. However, as the organisms must tolerate rapid tidal and seasonal changes in salinity, the number of benthic species is usually lower than in the open sea and freshwater. Therefore, the macrofauna of the intertidal area worldwide has received considerable attention in recent years. The Rapid coastal industrialization in the recent years has underlined the importance of complete understanding and continuous monitoring of marine environments, especially coastal stretches where human activity is intense, to evaluate their stability and functioning. In ports, activities like dredging, frequent vessel movement, and human interference in large numbers have a significant impact on the living organisms in the intertidal zone. Assessment of these effects has usually targeted bottom substrata and the associated benthic fauna. Hence, benthic communities are the logical targets whose density, diversity, community structure and seasonal shift will be a powerful tool for understanding any marine environment.

Phylum wise diversity

The survey of the intertidal fauna of DPA at Kandla area recorded the presence of 6 phyla (Nematoda, Nemertea, Annelida, Arthropoda, Mollusca and Chordata), including 26 species. The species diversity was the highest for phylum Mollusca (22), followed by Arthropoda (19), Annelida (4) and Nematoda,(1) Nemertea(1), Chordata (1) respectively (Figure.35).

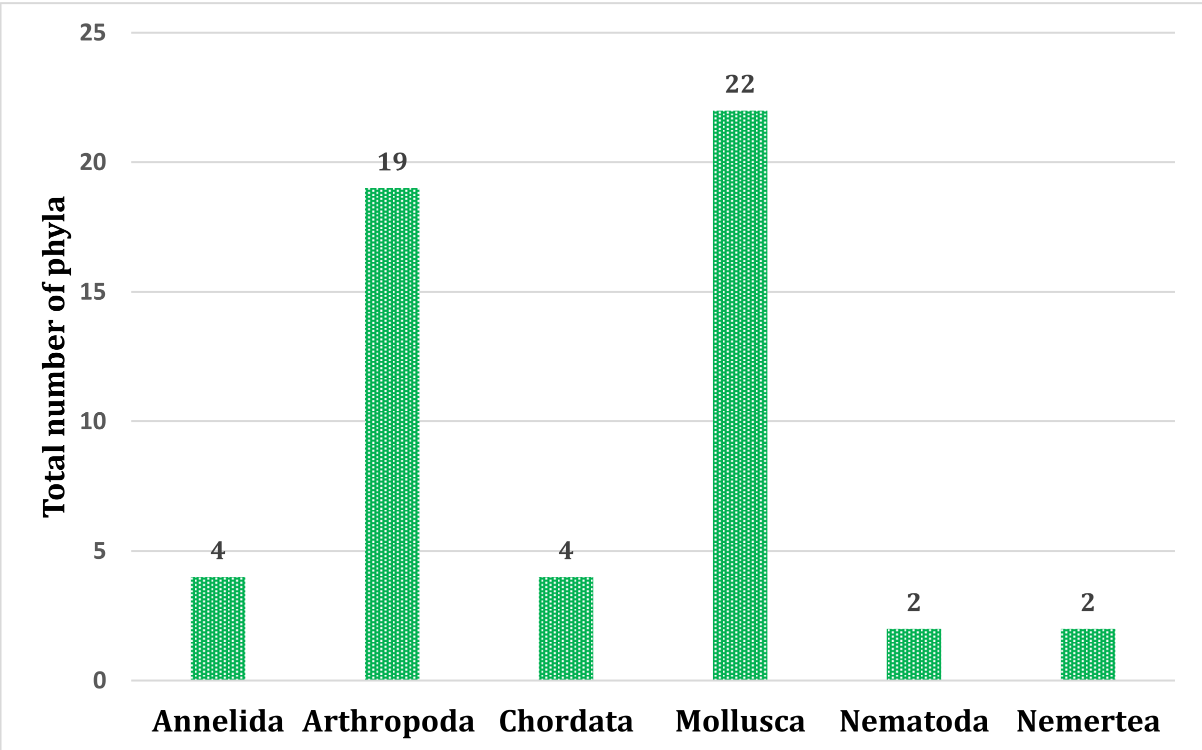


Figure 35. intertidal faunal diversity during May-2022 to May-2023

Density variation of intertidal fauna

The total density of intertidal organism varied from 1285 No/m2 to 2597 No/m^2 (Fig.34). The highest number of organisms was documented during monsoon (2597 No/m^2), followed by Post-monsoon (1329 No/m^2) and Monsoon (1285 No/m^2) respectively. During the intertidal fauna survey 26 species belonging to six phyla such as Nemertea, Nematoda, Annelida, Arthropoda, Mollusca and Chordata were recorded. The species diversity of molluscs was very high at all the seasons; pre-monsoon (6 species), Post-monsoon and Monsoon (each 8 species) occurred. The second most dominant phylum was Arthropoda represented with 8 Species in the monsoon period, Post-monsoon period (6 species) and Monsoon (5 species). The least diversity was documented by Chordata, Nemertea, and Nematoda (Figure 36)

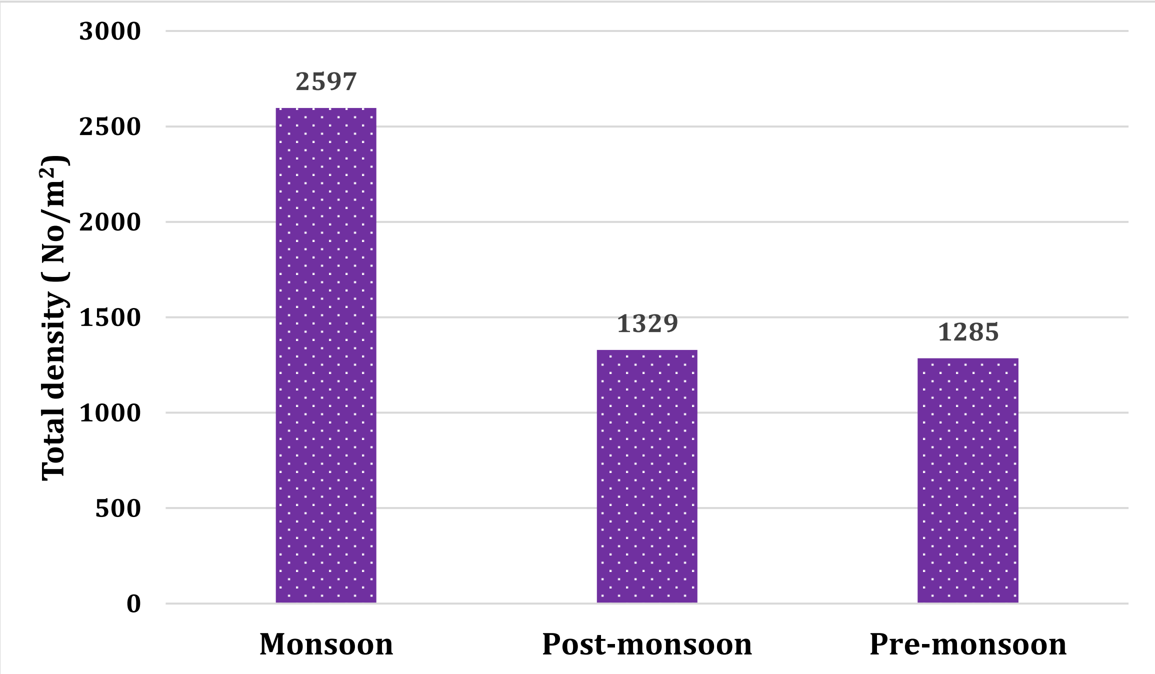


Figure 36. Intertidal population density during May 2022 – May 2023

Abundance of intertidal fauna

During monsoon period, the highest number of animals enumerated was *Parasesarma plicatum* the crab while in post-monsoon it was *Pirenella cingulata* (gastropod). During pre-monsoon *Austruca variegata* was the predominant species (Figure 37). In general the intertidal faunal diversity was high in monsoon and the lowest in pre-monsoon.

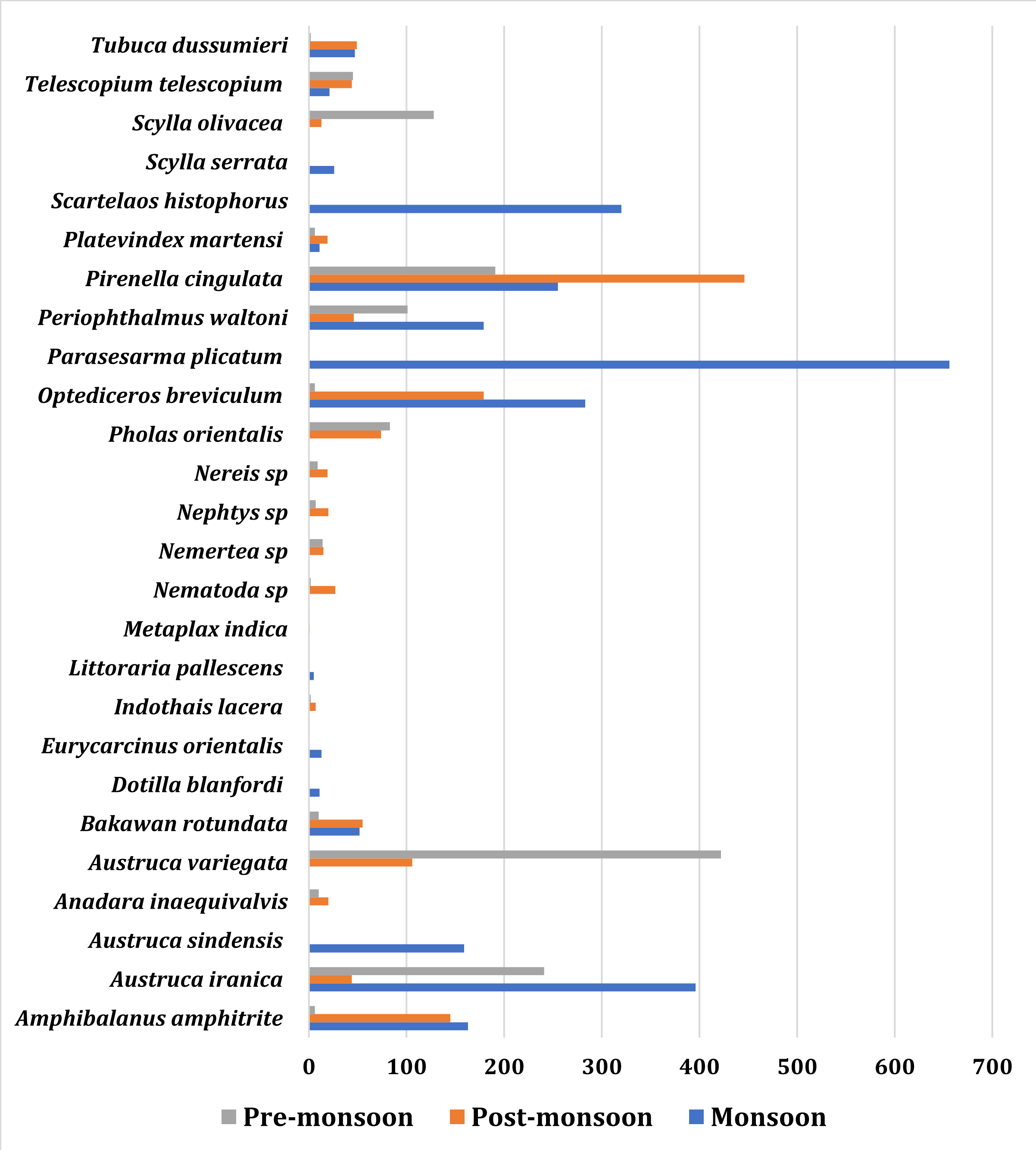


Figure 37. Seasonal variation of Intertidal fauna diversity during May-2022 to May-2023

Intertidal Fauna density (No/m^2)

The intertidal faunal density among different stations during the three seasonal survey are presented in figure 38. was documented, where the highest no of organisms was documented from the monsoon season (268 No/m^2), followed post-monsoon (262 No/m2) and pre-monsoon (152 No/m^2), respectively. The most common species were the molluscs such as *Pirenella cingulata*, *Austruca variegata*, and *Parasesarma plicatum*. The lowest density noticed was that of *Indothais lacera* and *Metaplax indica*.(plate 10).

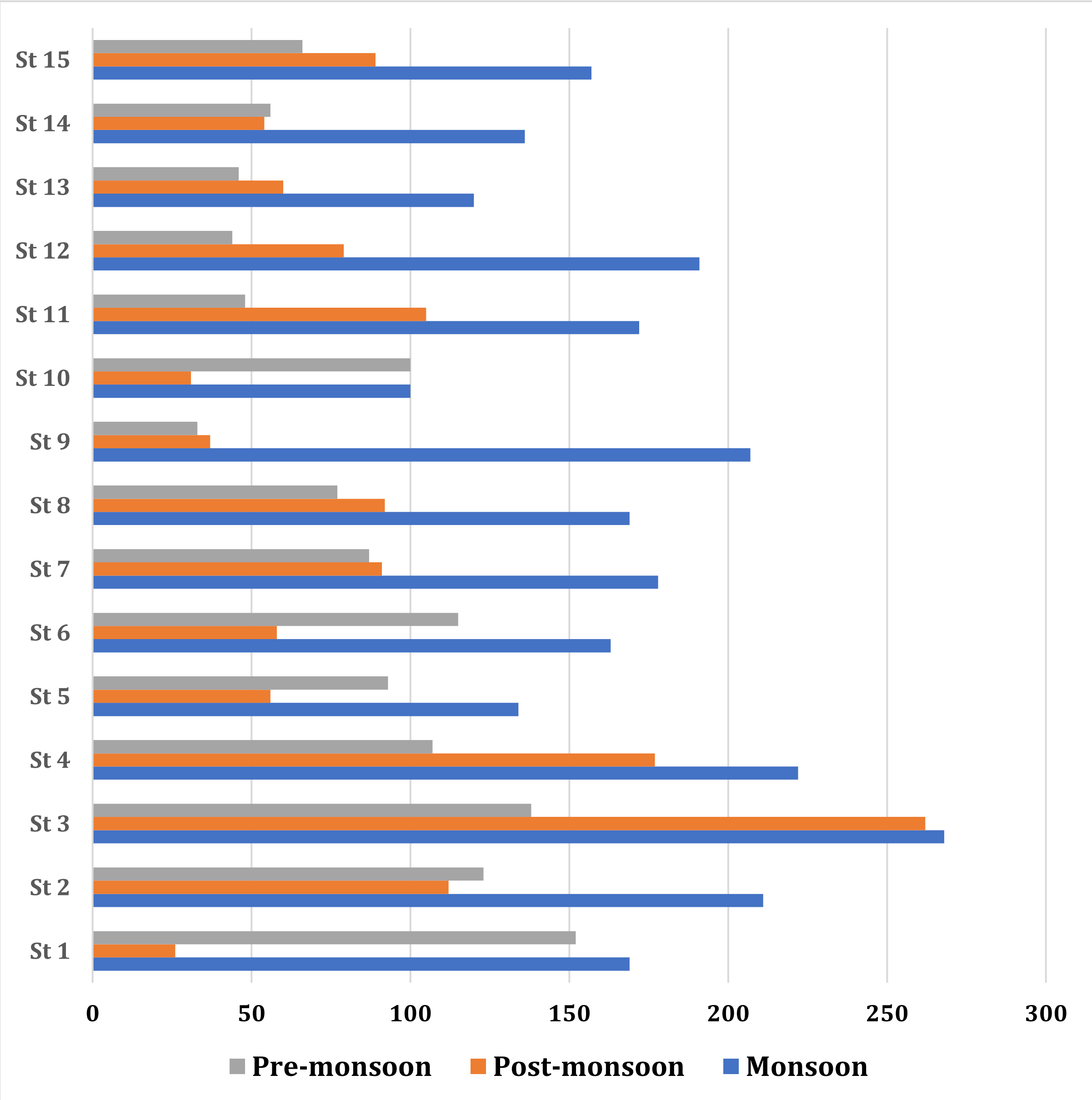


Figure 38. Season wise intertidal faunal density during May-2022 to May-2023

Plate10 Intertidal Arthropods fauna of Deendayal Port Authority

Percentage of composition

In Monsoon the highest percentage composition of intertidal macrofauna was shared by the crab *Parasesarma plicatum* (25.3%), followed by the fiddler crab *Austruca iranica* (15.2 %). The most negligible percentage of diversity was documented from the commercially important gastropod *Littoraria pallescens* (0.2%) and *Telescopium telescopium* (0.8%). Similarly in Post-monsoon the highest percentage composition of intertidal macrofauna was shared by the gastropod *Pirenella cingulata* (33.6%), followed by *Optediceros breviculum* (13.5) and *Amphibalanus amphitrite* (10.9%). The lowest percentage of density was recorded for the crab *Metaplax indica* (0.1%), During pre-monsoon the highest percentage composition of intertidal macrofauna was shared by the crab *Austruca variegata* (32.8%) which is followed by *Pirenella cingulata* (14.9%). The lowest percentage was documented for *Indothais lacera* *Anadara inaequivalvis* and *Tubuca dussumieri* .

Plate.11. Intertidal Molluscs fauna of Deendayal Port Authority

4.2.5. Subtidal Fauna

Intertidal and subtidal environments may be composed of parts of both estuarine and marine systems (Aquatic Ecosystems Task Group, 2012; Cowardin et al., 1979). Subtidal benthic habitats are essential for estuarine and marine life since marine species depend directly or indirectly on the seafloor for food, hide, rest or reproduction and nutrient recycling. The Seasonal difference in rainfall, salinity, nutrients and light intensity might be a remarkable to influence the subtidal diversity. Subtidal ecosystems are permanently submerged owing to tidal influence. However, intertidal ecosystems are found among the high tide and low tide, facing the regular fluctuations and influences from the land and sea (Karleskint, 1998; Levinton, 1995; Pitcher et al., 2007; Rees, 2009). The intertidal and subtidal mangrove forests are important nurseries for the breeding ground of many species of fishes and crustaceans. They provide food and shelter for the larval and juvenile stages. Most soft bottom subtidal animals are dominated by infaunal or burrowing invertebrates such as polychaetes, crustaceans, and molluscs. These organisms associated with soft bottom subtidal environments provide various environmental services, such as nutrient recycles and food for deposit feeders and microorganisms living within the sediments (Chaves and Bouchereau, 1999; Vendel *et al*., 2002).

Phylum wise and season wise density of subtidal fauna

The subtidal fauna during the seasonal survey recorded the presence of 4 phyla (Cnidaria, Annelida, Arthropoda and Mollusca) and totally 64 species. The species diversity was the highest for phylum Mollusca (42species), followed by Annelida (14 species), Arthropoda (5 species), and Cnidaria (3 species) respectively (Fig 39) The highest no of organisms was recorded in the post-monsoon (373), followed by pre-monsoon (305) and monsoon 231 respectively (Fig.40).

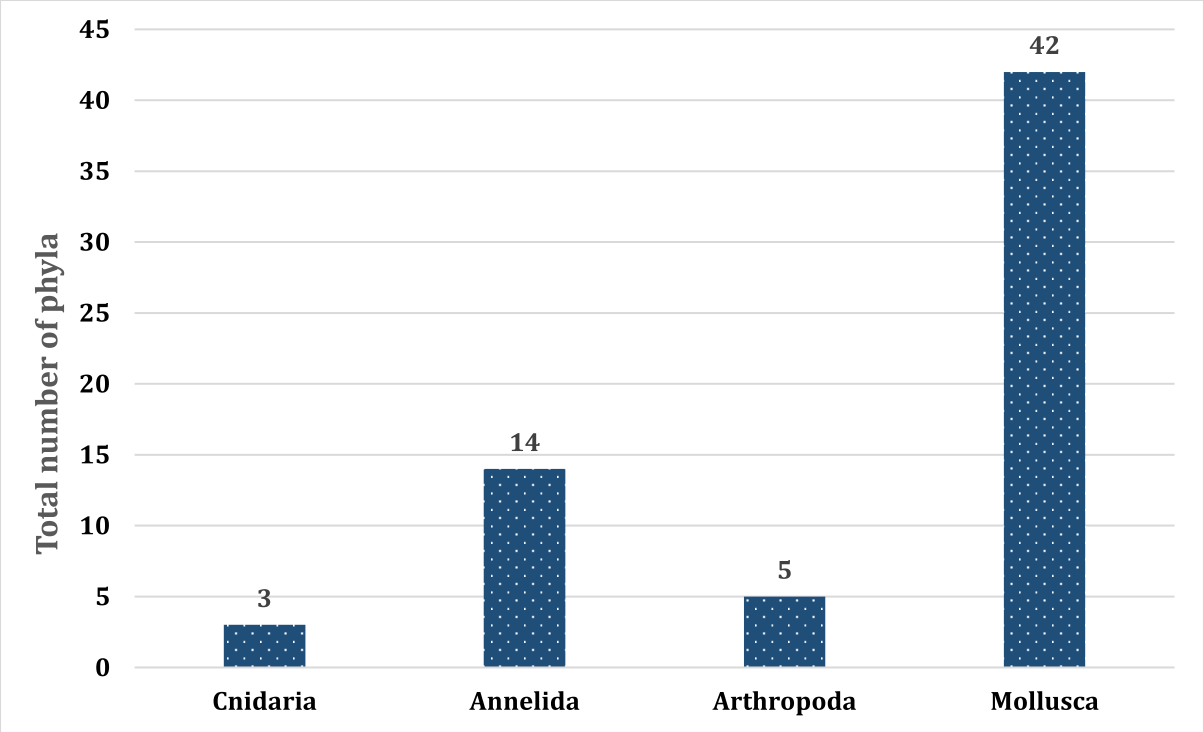


Figure 39. Phylum wise subtidal faunal diversity during May-2022 to May-2023

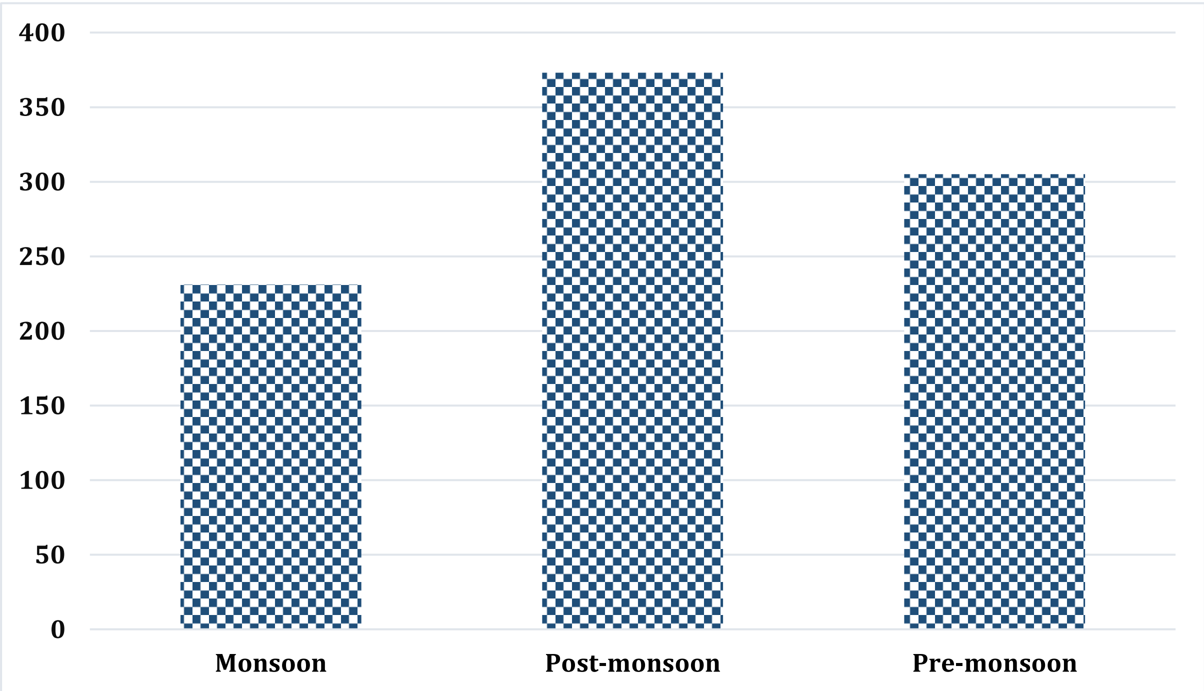


Figure 40. Seasonal variation of subtidal fauna density (No/m^2) during May-2022 to May-2023

Subtidal faunal diversity

Among the stations the highest number of animals was documented during the post-monsoon contributed by *Glauconome angulata* (51) followed by *Pirenella cingulata* (48) whereas in pre-monsoon the number of *Pirenella cingulata* (43) was veryhigh followed by *Glauconome angulate* (38). Similarly in the monsoon season the highest number was due to *Optediceros breviculum* (35) followed by *Pirenella cingulata* (27).It was noticed that the gastropod *Pirenella cingulata* was present at all the seasons (fig.41)

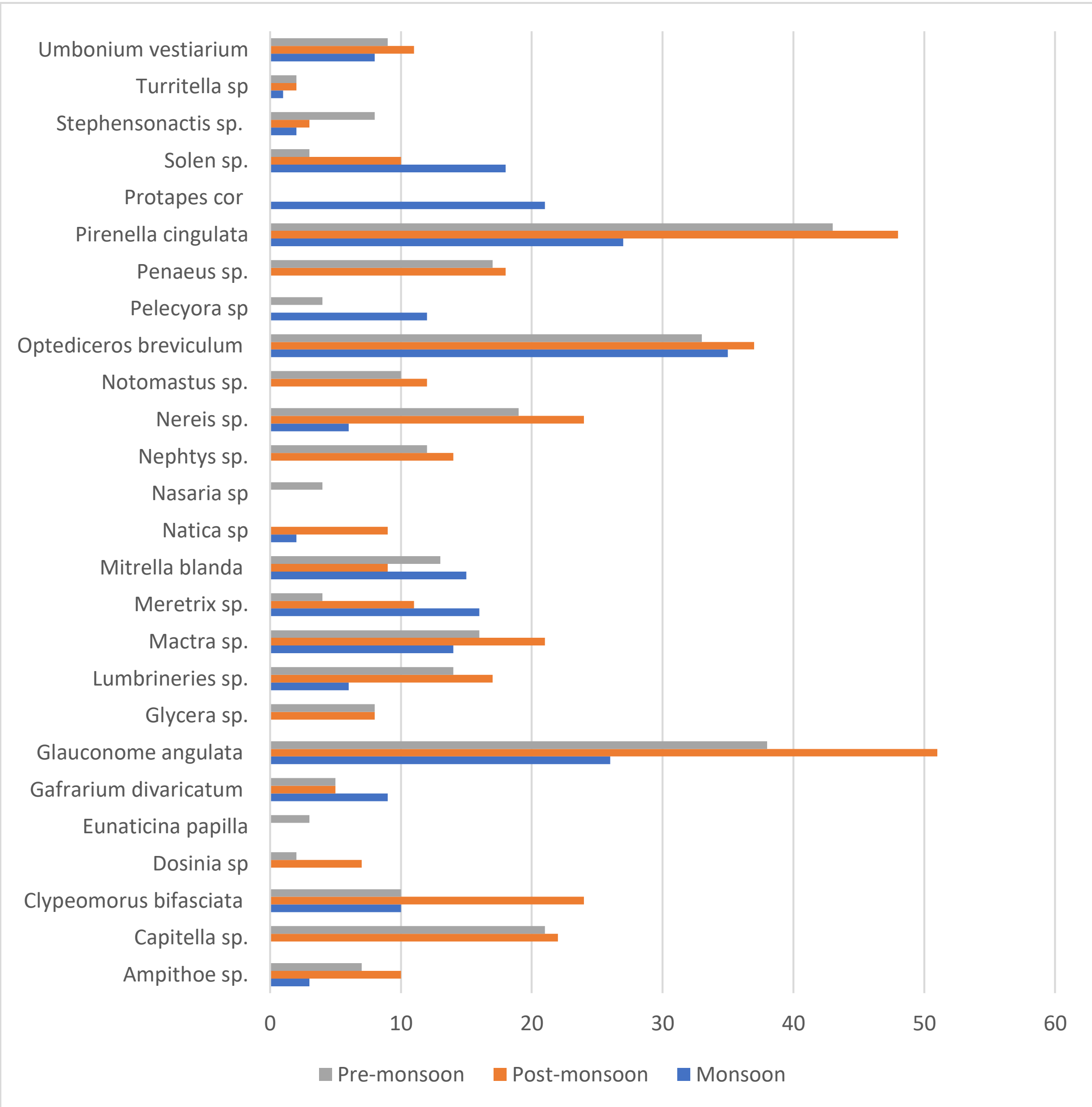


Figure 41. Subtidal Fauna diversity variation during May2022- May2023

Density of subtidal benthos

Total density of subtidal benthic organism varied from 5,775 No/m^2 to 9329 No/m^2 with the average density of 7576 No/m^2. Highest density was recorded in post-monsoon followed by pre-monsoon (Figure.42). Among the season highest density of organism was recorded at S-14(post-monsoon) followed by S-6 (pre-monsoon) and S-7 during monsoon (Figure 43).

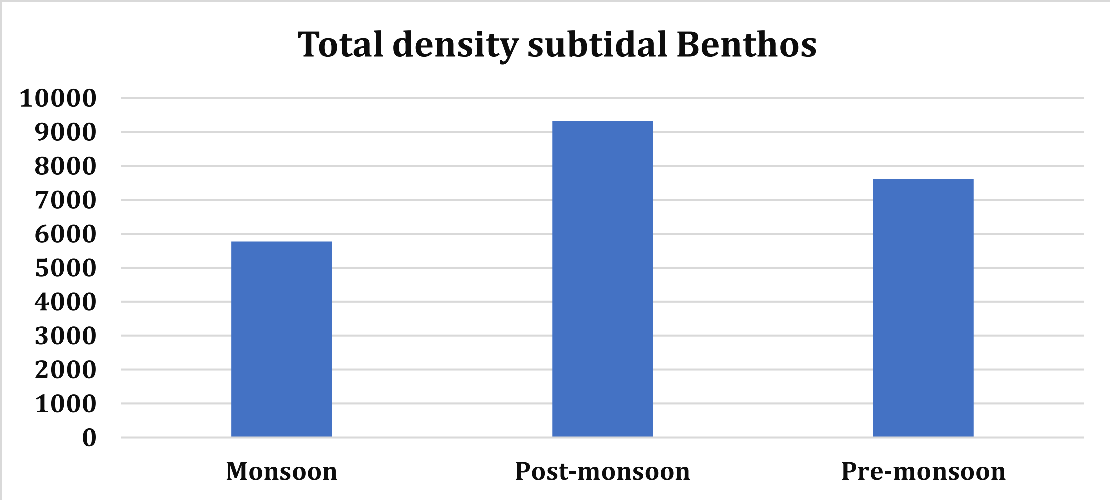


Figure 42. Subtidal benthic organism density (No/m^2) from May2022- May2023

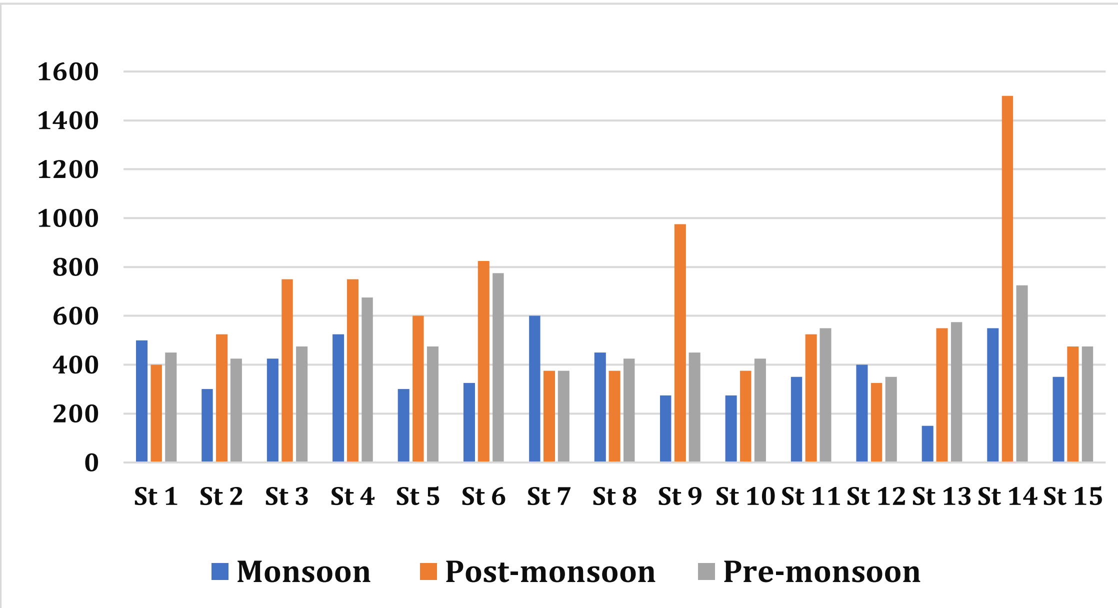


Figure 43. Station wise density of subtidal benthos(No/m2) in DPA from May-2022 to May-2023

Percentage of composition

During monsoon the highest percentage composition was shared by *Optediceros breviculum* (15.2%) and *Pirenella cingulata* (11.7%). A minuscule percentage of density was recorded for *Turritella* sp. (0.4%). In post-monsoon the highest percentage composition of subtidal macrofauna was shared by the muddy shore bivalve *Glauconome angulata* (13.7%), *Pirenella cingulata* (12.9%) and the gastropod, *Turritella* sp. (0.5%.). Likewise in Pre-monsoon the highest percentage of intertidal macrofauna was contributed by the gastropod *Pirenella cingulata* (14.1%) and the lowest due to *Turritella* sp. (o.7%) respectively. (Figure.44).

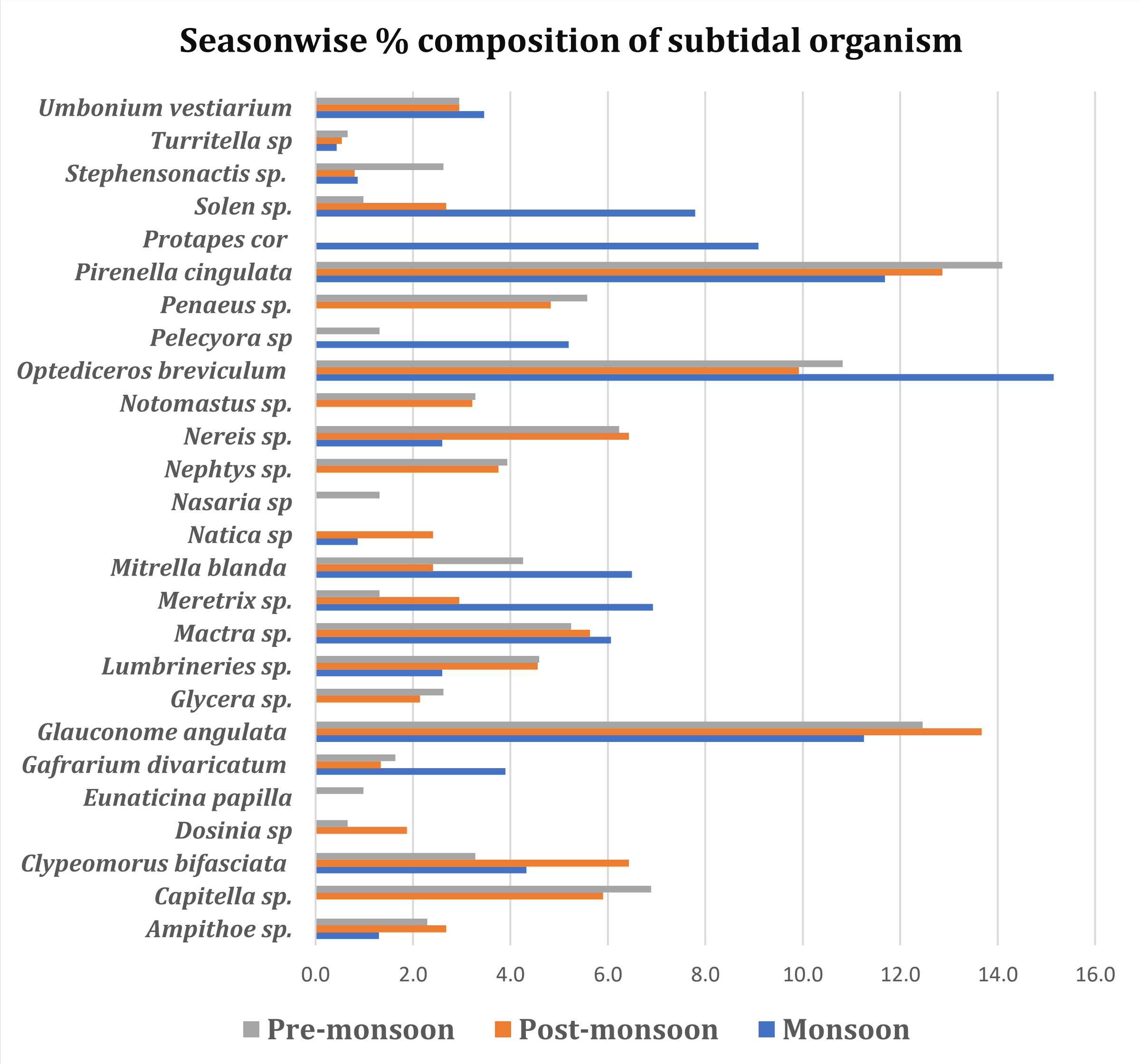


Figure 44 Percentage composition of subtidal organisms from May 2022 to May 2023

4.3. Mudflats

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 as 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 a direct indicator of mudflat productivity and blue carbon sequestration.

4.3.1. Bulk density of the sediment

The data on the bulk density of the sediment samples are presented (Figure.45). Among the stations sampled the maximum bulk density value ranges from 1.33 g/cm^3 to 1.52 g/cm^3 and the minimum bulk density ranges was 1.23 g/cm^3 to 1.26 g/cm^3. Station wise the highest bulk density was recorded at station S-13 in post-monsoon season (1.52 g/cm^3), whereas lowest values noted from S-11 and S-15 during pre-monsoon and post-monsoon(1.23 g/cm^3) seasons.

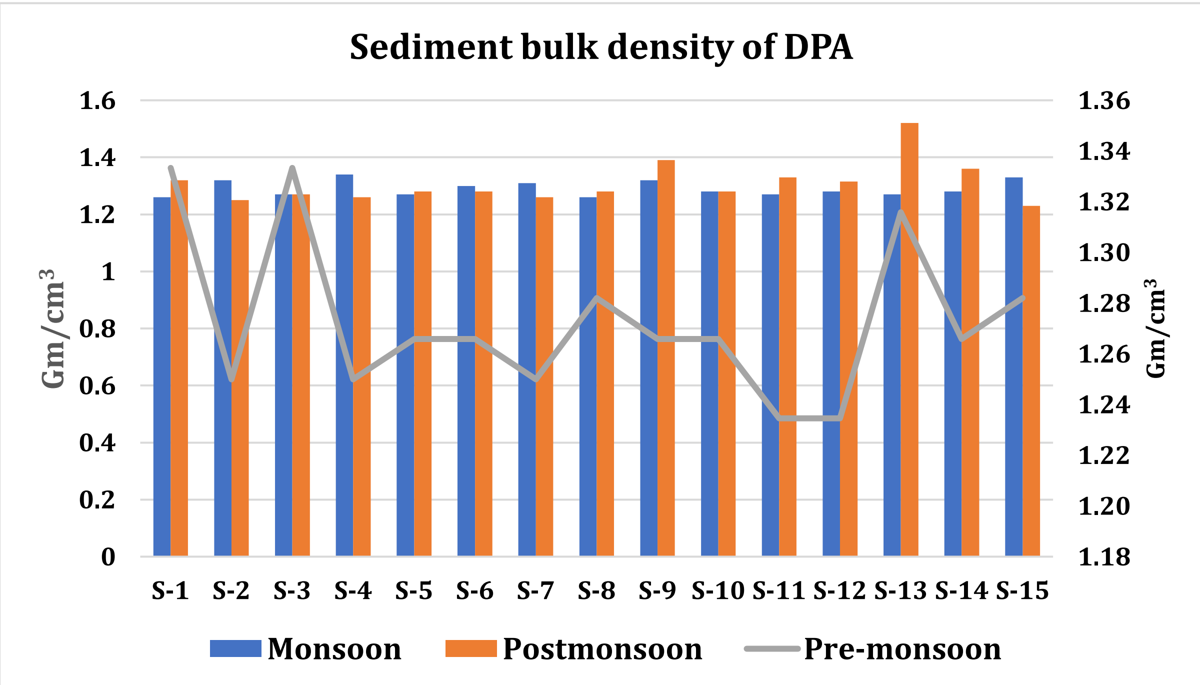


Figure 45 Bulk density of sediment from May 2022 to May 2023

4.3.2. Total Organic Carbon (TOC)

The data on the total organic carbon of the sediment samples are presented (Figure.46). Among the stations of DPA port area the maximum sediment carbon value ranged from 0.8% to 2.4% and the minimum sediment carbon ranges was 0.6% to 2.0%. Station wise the highest sediment carbon was recorded at station S-14 during pre-monsoon (2.4%), whereas lowest (0.6%.) at S-7 and S-15 during monsoon and pre-monsoon.

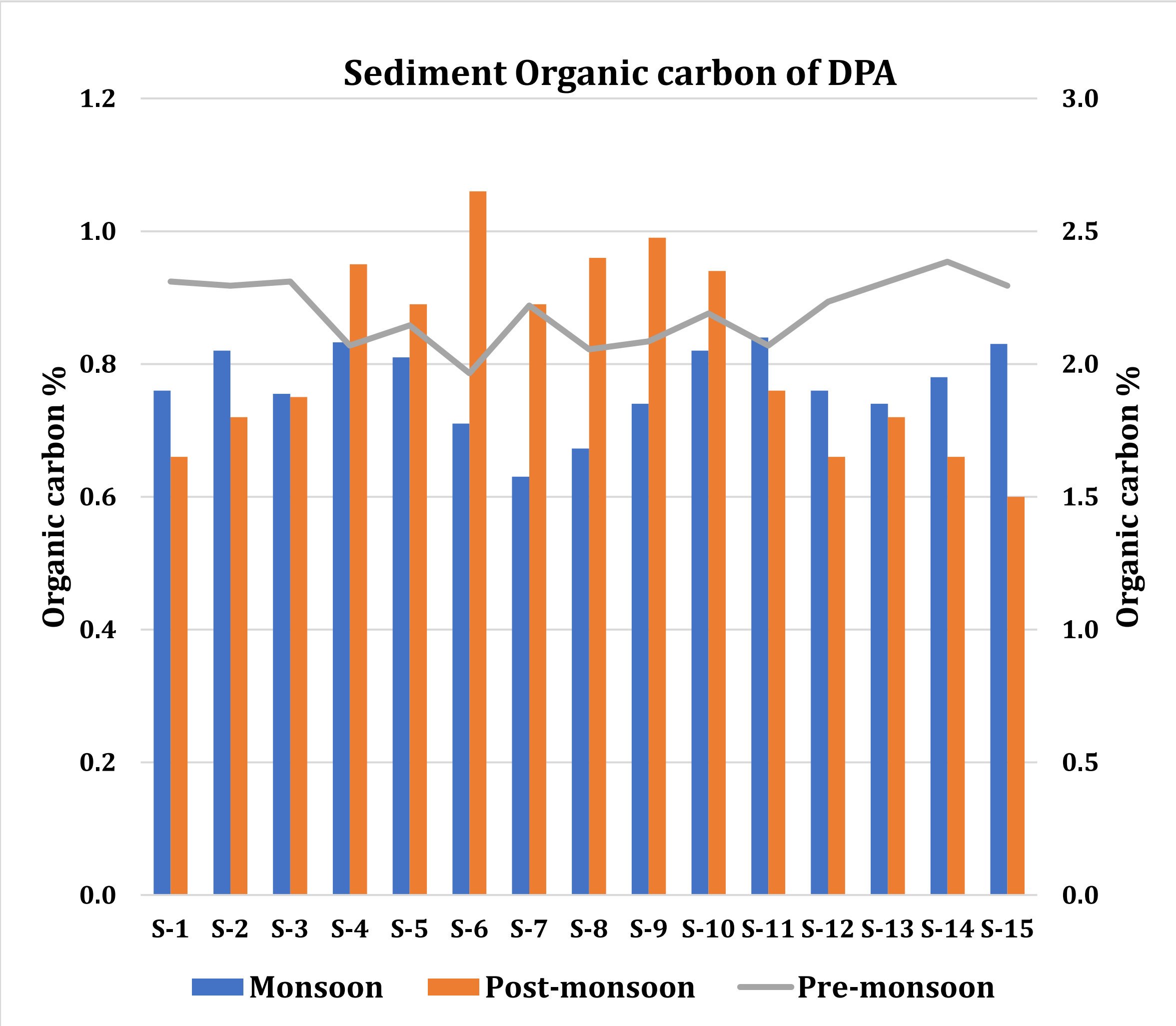


Figure 46. Percentage of organic carbon in sediment from May 2022 to May 2023

4.4. Mangroves

Mangroves are coastal plants primarily serve coastal community throughout the world for their regular requirements of fodder, firewood, medicines, timber and in a few cases as vegetables. They also provide various ecological services in protecting the coastal biodiversity. The mangrove ecosystem is one of the most productive ecosystems which covers 47% world's mangrove area. Almost 85% of the world's mangrove species from different habitats of 30 countries that border along the Indian Ocean show their essential role in the enhancement of coastal biodiversity. India although have a long coastline of about 7516.6 km, shows a total mangrove cover of only 4,992 km^2 (FSI, 2021). As per the India State of Forest Survey (2021), the state of West Bengal has the maximum cover (2114 Km2), followed by Gujarat (1175 Km2). Although, Gujarat reported to have 15 mangrove species viz., *Acanthus illicifolius, Aegiceras corniculatum, Avicennia alba, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, Bruguiera gymnorrhiza, Ceriops decandra, Ceriops tagal, Excoecaria agallocha, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata, Rhizophora mucronata* and *Sonneratia apetala* (Singh, 2020), total mangrove cover in Gujarat is totally dominated by only one species. The vegetation characteristics of mangroves of Gulf of Kachchh have been thoroughly studied and documented by GUIDE.

4.4.1. Tree Density

During the monsoon season of 2022, a of total 13 sites were surveyed for recording the mangrove growth parameters and the density of plants. However, in the further two studies (post-monsoon 2022 and pre-monsoon 2023), one site was eliminated and total 12 sites were surveyed. During monsoon, the overall average density of mangrove was reported as 4602 trees per hector. Among all the sampling stations, the average tree density was maximum at Tuna creek (6199/ha), followed by Kandla creek (5205/ha). Considering the sampling sites individually the highest tree density was reported at S-12 in the Tuna creek area (7359/ha). The lowest average tree density (2935/ha) was reported in Phang creek; however, the lowest density of individual site was recorded in S-5 at Phang creek (Table12 & Fig 47).

During the post-monsoon, the mean plant density was (4371/ ha) at Tuna creek, followed by Jangi creek (3210/ ha). Considering the sampling sites individually the highest tree density was reported at S-12 in the Tuna creek area (6515/ha). The average lowest tree density was (1491/ ha) reported from S-5 located at Phang creek. In terms of creeks, the lowest average density (2290.9/ha) was recorded at S-7 located in Kharo creek (Table13 & Fig.47).

During the pre-monsoon of 2023, the mean plant density was maximum (3277/ ha) at Phang creek, followed by Navlakhi creek (3070/ ha). In case of individual sampling sites, the highest tree density was reported at S-10 in the Phang creek area (3488/ha). The lowest average tree density of individual sites was reported in S-11 (1632 trees/ ha) sampling site located at Jangi creek (Table 14& Fig47). The inconsistency in mangrove status in various sites represents the variations in the local geo-morphology and seasonal climatic and environmental characteristics.

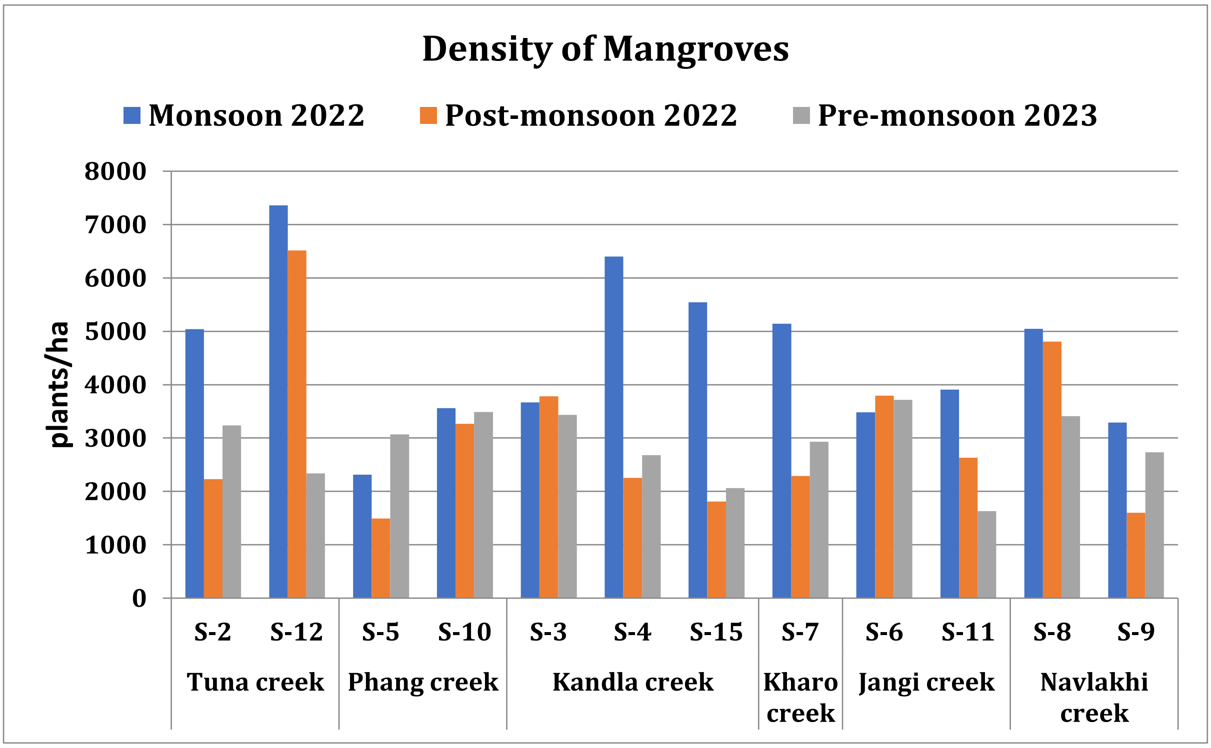


Figure 47. Density of mangrove in the Deendayal Port Authority area from May 2022- May 2023

4.4.2. Tree Height

The overall average height of mature trees in DPA port environment during the three seasons showed variations. During monsoon, the overall mean tree height was reported as 148.5 cm. The Phang creek area (167 cm) followed by Navlakhi creek (160 cm) recorded the highest tree height (Table12 & Figure.48). During post-monsoon, the overall average tree height was 179 cm. In the creek wise observation, the highest average tree height was recorded at Phang creek area (212 cm), followed by Tuna creek (192 cm). However, in terms of individual sites, the average highest tree height was recorded at S-2 located at Tuna creek, followed by S-10 located at Phang creek (Table 13 & Fig 48). During the pre-monsoon of 2023, the overall average tree height was recorded as 156 cm. The highest average tree height was recorded at Tuna creek area (175 m), followed by Navlakhi creek (172cm). In terms of individual sites, the average highest tree height was recorded at S-11 located at Janghi creek, followed by site S-8 located at Navlakhi creek (Table 14 ,Figure 48). The height of plant is an important parameter because it indicates the health status and the conditions prevailing at the specified site.

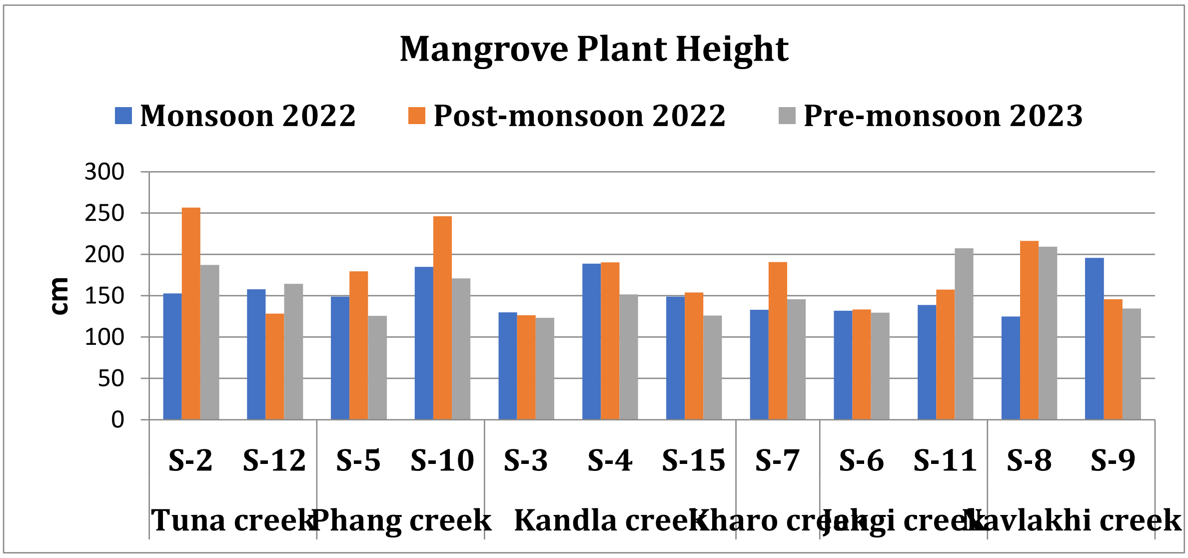


Figure 48. Mangrove plant height in the Deendayal Port Authority from May 2022- May 2023

4.4.3. Canopy Crown Cover

In DPA Kandla, the canopy cover of mangroves trees showed wide variations similar to other growth parameters such as height, basal girth etc. During the monsoon, the overall average was 2.54 m2, however, in station wise study, relatively larger canopy cover was recorded in S-5, S-9 and S-10, and the lowest canopy cover was reported at S-2 and S-7 (Table 12 Figure.49). During the post-monsoon, the overall average canopy cover reported was 4.8 m^2 while the highest average cwas noticed at S-2 (Tuna creek) which ranged from 0.48m^2 to 22.5m^2 (Table 13& figure 49). The second largest average canopy cover was reported at S-15 site of Kandla creek which ranged from 4m^2 to 8.4m^2. The sites S-12 at Tuna creek, S-3 at Kandla creek and S-6 at Jangi creek showed relatively lower average canopy cover compared to others. In the pre-monsoon season of 2023, the overall average canopy cover recorded was 3.8 m^2 during the survey. The sites S-11 at Jangi creek and S-2 at Tuna creek showed relatively higher canopy cover, and S-15 at Kandla creek and S-10 at Phang creek showed low average canopy cover among the study sites (Table 14 &Figure 49). The highest average canopy cover was reported at S-11, ranging from 0.28m^2 to 31.5m^2 during pre-monsoon. In Kandla sampling area, the canopy cover of mangroves showed wide variations.

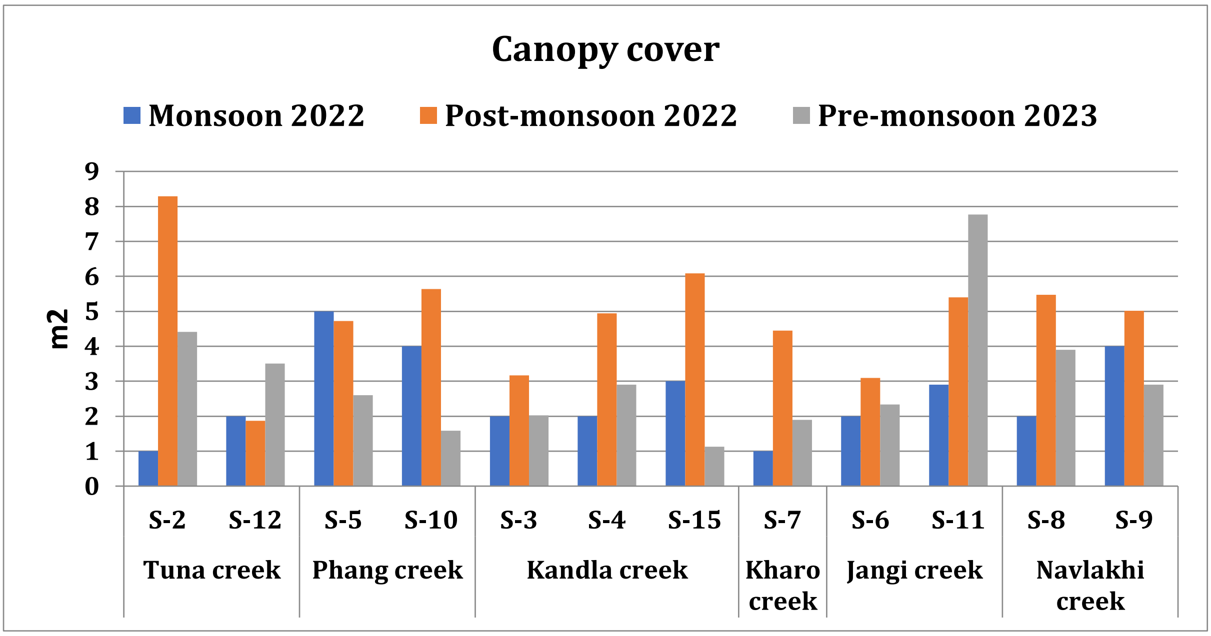


Figure 49. Average canopy cover of mangroves from May 2022 to May 2023

4.4.4. Basal Girth

The overall average basal girth value of the mangrove trees of the DPA environment showed variations during the entire study period (2022-2023). During the monsoon, the overall average of the tree basal girth was 14.64 cm. In station wise study, the mean basal girth was maximum (21 cm) at S-4 located in the Kandla creek followed by S-5 in Phang creek and S-11 in Jangi creek respectively (Table 12 & Figure 50). However, during post-monsoon, the overall average basal girth was 21.7 cm. In case of station wise study, the highest average basal girth was 40 cm at site S-5 followed by site S-10 (39.7 cm), located in the Phang creek(Table 13 & Figure 50).. The Pre-monsoon study showed the overall average basal girth as 10.2 cm and in case of individual sampling sites, the highest average basal girth (17 cm) was at site S-11 which is followed by site S-8 (13 cm), located in the Jangi and Navlakhi creek respectively(Table 14 & Fig 50.) The species Av*icennia marina* showed multiple stem pattern at most of the locations. .

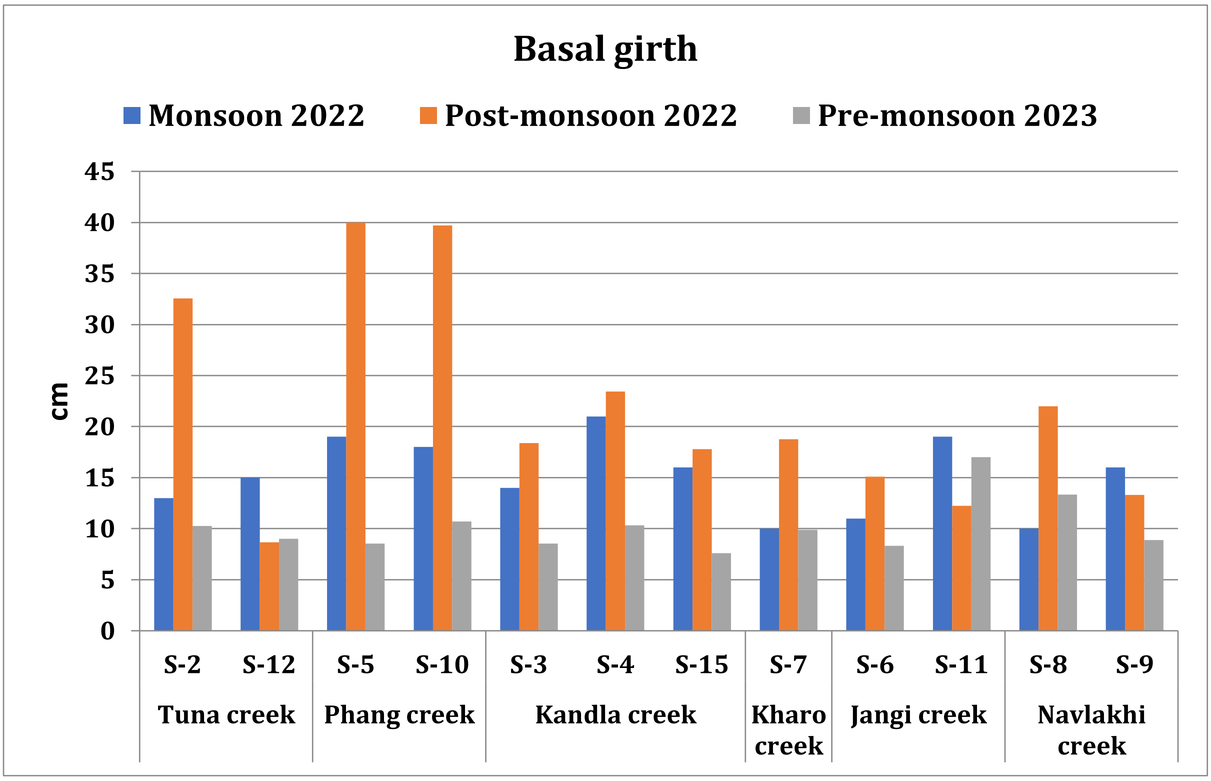


Figure 50. Average tree girth of mangroves in during May 2022 to May 2023

Table 12. Density of mangroves in the DPA vicinity during Monsoon (2022)

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

Table 13. Density of mangroves in the DPA vicinity during post-monsoon season 2022

Sampling stations	Density (Tree/Ha)	Tree height (cm)			Canopy cover (m^2)			Basal Girth(cm)		
		Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Tuna creek										
S2	2226.55	130.00	450.00	256.67	0.48	22.50	8.29	7.00	120.00	32.56
S12	6515.31	110.00	180.00	128.33	0.12	5.46	1.87	7.00	12.00	8.67
Mean	4370.93	120.00	315.00	192.50	0.30	13.98	5.08	7.00	66.00	20.62
Phang creek										
S5	1490.74	110.00	310.00	179.50	1.54	10.54	4.72	12.00	110.00	40.00
S10	3265.31	100.00	420.00	246.25	0.56	16.40	5.64	7.00	120.00	39.69
Mean	2378.03	105.00	365.00	212.88	1.05	13.47	5.18	9.50	115.00	39.85
Kandla creek										
S3	3780.86	105.00	210.00	126.32	0.42	15.58	3.17	7.00	80.00	18.37
S4	2256.25	110.00	380.00	190.53	0.40	12.24	4.94	7.00	80.00	23.42
S15	1810.77	110.00	230.00	154.00	3.99	8.40	6.08	10.00	40.00	17.80
Mean	2615.96	108.33	273.33	156.95	1.60	12.07	4.73	8.00	66.67	19.86
Kharo creek										
S7	2290.89	110.00	400.00	190.71	0.54	20.00	4.45	7.00	100.00	18.75
Jangi creek										
S6	3790.74	110.00	290.00	133.39	0.12	9.30	3.09	7.00	45.00	15.09
S11	2629.85	100.00	200.00	157.50	2.04	8.70	5.40	9.00	17.00	12.25
Mean	3210.30	105.00	245.00	145.45	1.08	9.00	4.25	8.00	31.00	13.67
Navlakhi creek										
S8	4805.21	110.00	400.00	216.29	0.72	21.60	5.47	7.00	80.00	22.00
S9	1600.00	105.00	200.00	146.00	2.21	9.60	5.01	9.00	18.00	13.30
Mean	3202.61	107.50	300.00	181.15	1.47	15.60	5.24	8.00	49.00	17.65
Overall average	3011.45	109.31	316.39	179.94	1.01	14.02	4.82	7.92	71.28	21.73

Table 14. Density of mangroves in the DPA vicinity during Pre-monsoon (2023)

Sampling stations	Density (Tree/Ha)	Tree height (cm)			Canopy cover (m)			Basal Area (cm)		
		Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Tuna creek										
S2	3237	100	420	187.42	0.24	27.5	4.41	7	30	10.27
S12	2339	100	310	164.41	0.63	13.32	3.51	7	18	9.00
Mean	2788.00	100.00	365.00	175.92	0.44	20.41	3.96	7.00	24.00	9.64
Phang creek										
S5	3066	105	210	125.59	0.24	8.37	2.60	7	20	8.53
S10	3488	110	300	171.00	0.00	18.00	1.59	7	40	10.70
Mean	3277.00	107.50	255.00	148.29	0.12	13.19	2.09	7.00	30.00	9.61
Kandla creek										
S3	3433	110	170	123.33	0.56	4.20	2.02	7	12	8.53
S4	2680	110	240	151.88	0.28	14.00	2.90	7	25	10.31
S15	2060	100	200	125.94	0.00	3.96	1.13	7	12	7.59
Mean	2724.33	106.67	203.33	133.72	0.28	7.39	2.02	7.00	16.33	8.81
Kharo creek										
S7	2930	110	270	146.05	0.24	6.48	1.89	7	26	9.89
Jangi creek										
S6	3716	105	220	129.76	0.00	14.00	2.34	7	20	8.33
S11	1632	110	320	207.50	0.28	31.50	7.77	7	40	17.00
Mean	2674.00	107.50	270.00	168.63	0.14	22.75	5.05	7.00	30.00	12.67
Navlakhi creek										
S8	3410	110	380	209.50	0.42	22.50	3.90	7	35	13.35
S9	2730	105	210	134.80	0.00	10.23	2.90	7	15	8.88
Mean	3070.00	107.50	295.00	172.15	0.21	16.37	3.40	7.00	25.00	11.12
Overall average	2893.42	106.25	270.83	156.43	0.24	14.51	3.08	7.00	24.42	10.20

4.4.5. Regeneration and Recruitment Class

During the monsoon, the overall average regeneration class density was 60167 plants/ha. The highest regeneration (140000 plants/ha) was recorded at S-9 of Navlakhi creek. The lowest number of regeneration class found at S-14 of Vira coast site (Table15). During monsoon, it was expected more regeneration class mangrove than the other seasons. In post-monsoon season, the overall average regeneration class density was 67829 plants/ha (Table 16). The highest average of the regeneration class plants was recorded (141000 plants/ha) at S-8 site located in the Navlakhi creek. During the pre-monsoon season the overall average regeneration class density was recorded as 67250 plants/ha. In the site wise observation, the highest average regeneration class plant density (132000 plants/ha) was recorded at S-8 site located in the Navlakhi creek (Table 17).

During the monsoon, the overall average recruitment class density was 15434 plants/ha. The highest recruitment class density (31500 plants/ha) was recorded at Kharo creek (S-7), followed by S-8 and S-9 sites of Navlakhi cree. The lowest recruitment plants density was found at S-14 station of Vira coast site. Similarly, during post-monsoon season the overall average recruitment class density was 13483 plants/ha. The highest average recruitment class density was recorded at site S-3 (28625 plants/ha) located in the Kandla creek. The highest ratio for tree density to recruitment class was observed at S-3 site while the lowest ratio value at S-11 site. In the pre-monsoon season, the overall average recruitment class density recorded was 13271 plants/ha. In the site wise observation, the highest average recruitment class density was recorded at S-3 (24750 plants/ha) located in the Kandla creek. The highest ratio for tree density to recruitment class was observed at Kharo creek, however, there was only one site (S-7) surveyed. The complex hydro-edaphic conditions in the DPA Kandla premises can influence the mangrove stature and are substantiated with infrequent tidal coverage and high evapo-transpiration rate . The availability of regeneration and recruitment class plants in the sampling sites can assure that there are plants to take the position of trees in case of any harm to the mature plants.

Table 15. Regeneration and Recruitment class plants during monsoon (2022)

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

Table 16. Regeneration and Recruitment of Mangrove along the DPA Kandla area during post-monsoon 2022

Station	Tree density- No/ha (1)	Regeneration density- No/ha (2)	Recruitment density- No/ha (3)	Ratio of 1:3	Ratio of 2:3
Tuna creek					
S-2	2226.55	140000	11775	1 : 5.29	11.89 : 1
S-12	6515.31	70000	11750	1 : 1.80	5.96 : 1
Mean	4370.93	105000	11763	1 : 2.69	8.93 : 1
Phang creek					
S-5	1490.74	80000	6562	1 : 4.40	12.19 : 1
S-10	3265.31	43000	11250	1 : 3.45	3.82 : 1
Mean	2378.03	61500	8906	1 : 3.75	6.91 : 1
Kandla creek					
S-3	3780.86	46500	28625	1 : 7.57	1.62 : 1
S-4	2256.25	84000	7000	1 : 3.10	12.00 : 1
S-15	1810.77	48000	8750	1 : 4.83	5.49 : 1
Mean	2615.96	59500	14792	1 : 5.65	4.02 : 1
Kharo creek					
S-7	2290.89	45000	22250	1 : 9.71	2.02 : 1
Jangi creek					
S-6	3790.74	54444	12500	1 : 3.30	4.36 : 1
S-11	2629.85	34500	4375	1 : 1.66	7.89 : 1
Mean	3210.30	44472	8438	1 : 2.63	5.27 : 1
Navlakhi creek					
S-8	4805.21	141000	16000	1 : 3.33	8.81 : 1
S-9	1600.00	42000	13500	1 : 8.44	3.11 : 1

Table 17. Regeneration and Recruitment class plants during Pre-monsoon (2023)

Station	Tree density- No/ha (1)	Regeneration density- No/ha (2)	Recruitment density- No/ha (3)	Ratio of 1:3	Ratio of 2:3
Tuna creek					
S-2	3237	111000	16000	1 : 4.94	6.94 : 1
S-12	2339	73000	14250	1 : 6.09	5.12 : 1
Mean	2788	92000	15125	1 : 5.43	6.08 : 1
Phang creek					
S-5	3066	126000	10250	1 : 3.34	12.29 : 1
S-10	3488	57000	8500	1 : 2.44	6.71 : 1
Mean	3277	91500	9375	1 : 2.86	9.76 : 1
Kandla creek					
S-3	3433	49000	24750	1 : 7.21	1.98 : 1
S-4	2680	49000	20250	1 : 7.56	2.42 : 1
S-15	2060	74000	9500	1 : 4.61	7.79 : 1
Mean	2724	57333	18167	1 : 6.67	3.16 : 1
Kharo creek					
S-7	2930	68000	24000	1 : 8.19	2.83 : 1
Jangi creek					
S-6	3716	33000	7000	1 : 1.88	4.71 : 1
S-11	1632	7000	1000	1 : 0.61	7.00 : 1
Mean	2674	20000	4000	1 : 1.50	5.00 : 1
Navlakhi creek					
S-8	3410	132000	18000	1 : 5.28	7.33 : 1
S-9	2730	28000	5750	1 : 2.11	4.87 : 1
Mean	3070	80000	11875	1 : 3.87	6.74 : 1
Overall average	2893	67250	13271	1 : 4.52	5.83 : 1

Plate 12 Mangrove species recorded along the Deendayal Port Authority

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

4.5. Halophytes

The holophytes are the plants that are adopted in coastal estuaries and salt marshes. It is common in arid and desert milieu which often have substantial salt accumulation in the tissues. Technically these plants which have tolerance to moderate to high salt concentration in their growth substrate. Halophytes are plants that survive to reproduce in environments where the salt concentrations around 200 mM NaCl or more, constitute about 1% of the world's flora. (Timothy *et.al.,* 2008). Halophytes are classified based on their growth conditions as obligate halophytes, facultative halophytes, and habitat-indifferent halophytes. During the period of May 2022 to May 2023 four major halophytes were recorded along the selected study stations of Deendayal Port Authority area. They are *Salicornia brachiata*, *Aeluropus lagopoides*, *Salvadora persica* and *Sesuvium portulacastrum*. Maximum percentage coverage was that of *Salicornia brachiata* both in post-monsoon and pre-monsoon period The percentage cover of different halophytes are depicted in figure 51.

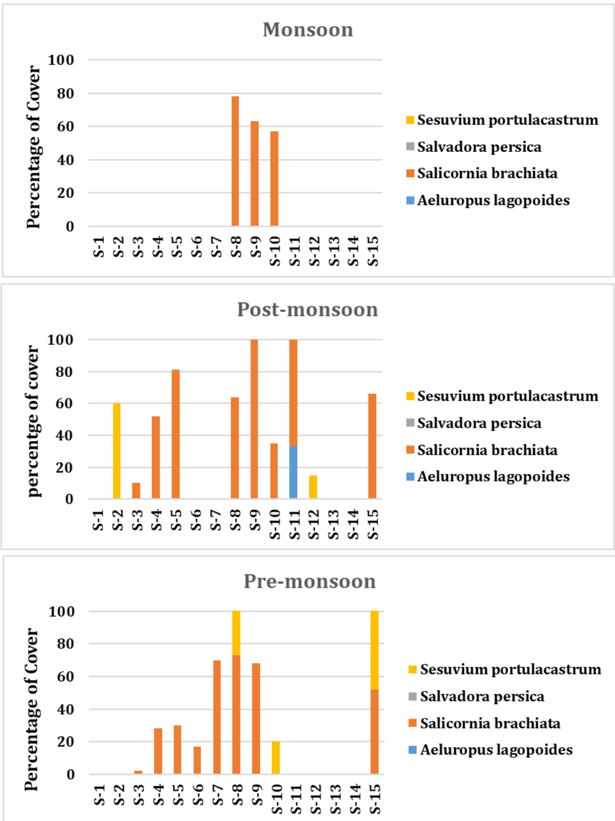
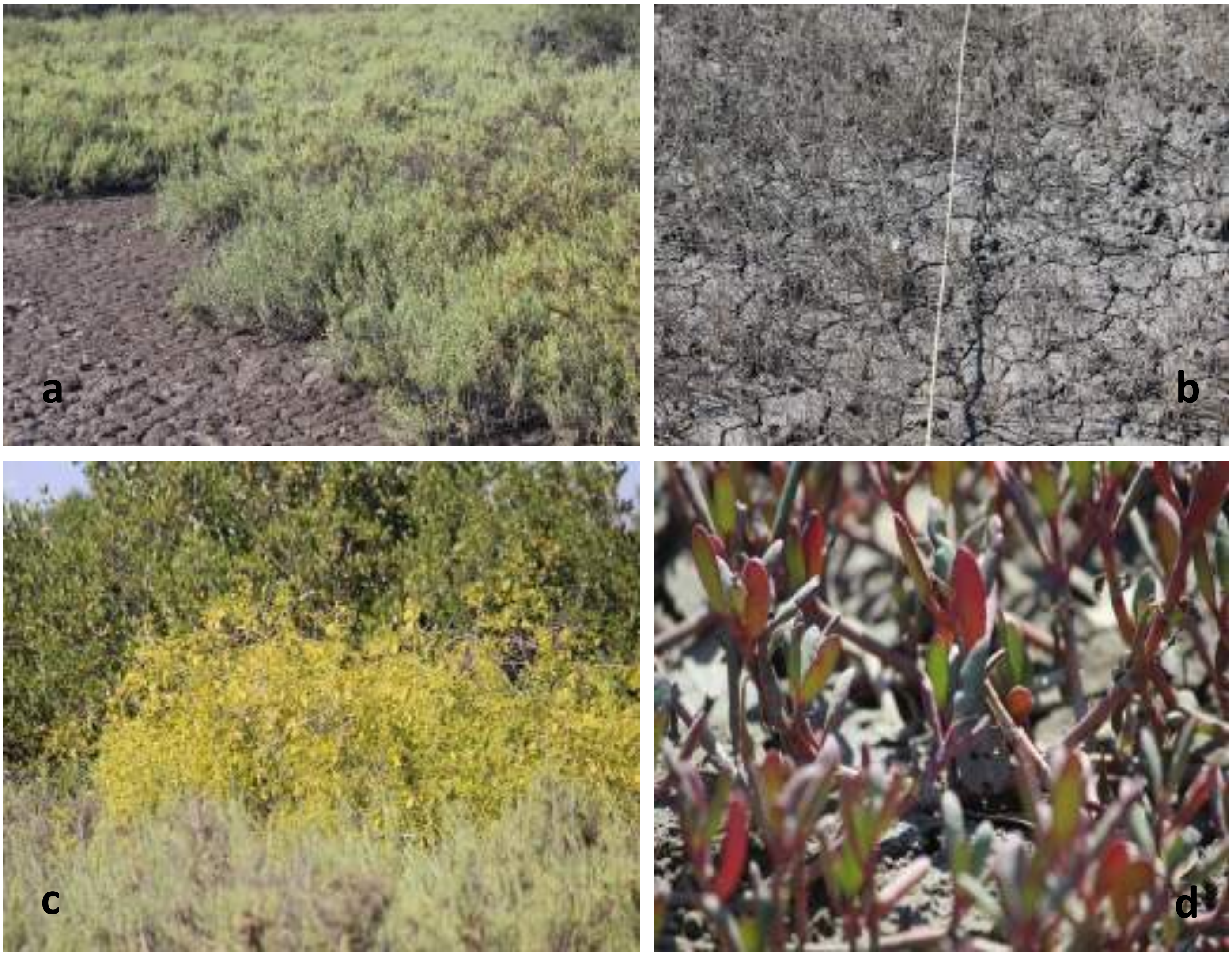


Figure 51. Percentage cover of halophytes reported during May 2022 to May 2023



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

Plate 13: Halophyte species on the intertidal zone of along the Deendayal Port Authority

4.6. Seaweed and Seagrass

Seaweeds are an integral part of coastal ecosystems and offer invaluable ecosystem services supporting the life of many marine forms. The economic value of seaweeds significantly contributes to the sustainable development of rural coastal regions. Seaweeds are consumed as food in some Asian countries, but their utilization for the production of phyco-colloids is widespread across the globe, with an estimated value of more than one billion US$. In India, seaweeds have been utilized exclusively for the production of phyco-colloids but recently they are used for the production of plant growth stimulants for agricultural applications. The recent inventory from the Indian region documented the presence of approximately 865 seaweed taxa so far (Mantri *et al*., 2020). Various studies have been conducted since last few decades with respect to the distribution and diversity of seaweeds from various parts of the Indian coast and few dotted pieces of literature available. Along the Gujarat coast which is represented by 1600 km coastline, harbours 198 species of which 109 species of the 62 genera belonging to Rhodophyta, 54 species from 23 genera of Chlorophyta, and 35 species from 16 genera to Ochrophyta (Jha *et.al*.,2009). According to Mantri *et.al*. (2020) there are 13 potential sites identified for the occurrence of seaweed density and diversity.

The survey conducted by CSIR-CSMCRI (Jha *et.al*., 2009) confirmed the presence of industrially important taxa, namely, *Gelidiella acerosa*, *Gelidium micropterum*, *G. pusillum*, *Ahnfeltia plicata*, *Gracilaria dura*, *G. debilis*, *Gracilariopsis longissima* (formerly *G. verrucosa), Hypnea musciformis*, *Meristotheca papulosa, Porphyra sp, Asparagopsis taxiformis* (Rhodophyta), *Sargassum tenerrimum*, *S. plagiophyllum*, *S. swartzii*, *Turbinaria ornate* (Ochrophyta), *Ulva prolifera* (formerly *Enteromorpha prolifera*), *Ulva compressa* (formerly *Enteromorpha compressa*), and *Ulva flexuosa* (formerly *Enteromorpha tubulosa*) (Chlorophyta) from the coastal waters of Gujarat. In the present study, an attempt was made to describe the occurrence, diversity and other ecological features of seaweeds within Deendayal Port jurisdiction but there is no observation of seaweed during the period from may 2022 to May 2023.

Seagrass

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

4.7. Marine fisheries

In the northern gulf of Kachchh, the total fish production estimated was 67674 metric tons of which 4,29,41 metric tons constitutes the share of 28 major commercial species and the rest 2,47,33 metric tons of miscellaneous species for the financial year020-2021 (Gujarat State fisheries report 2021) (Figure 52).

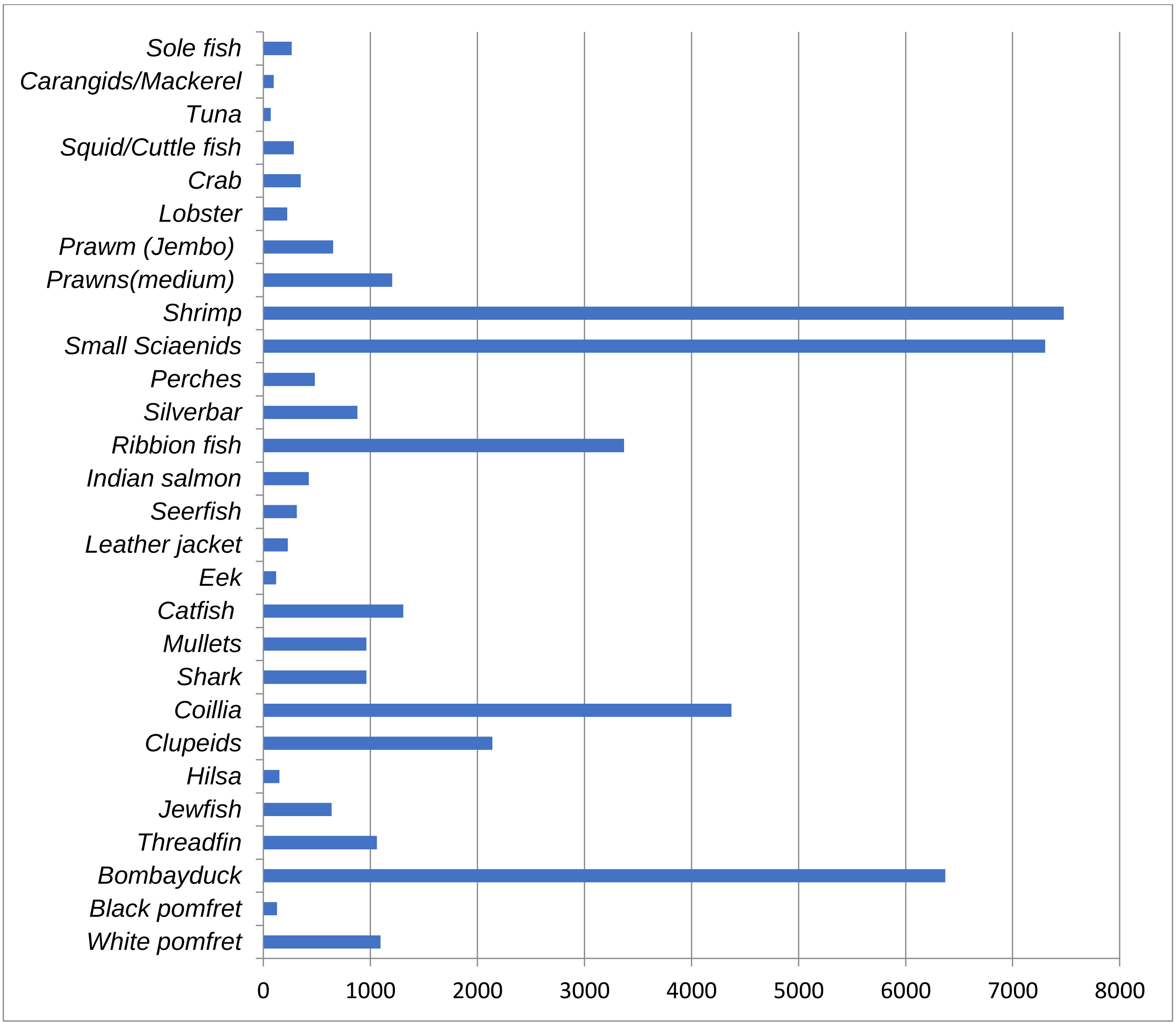


Figure 52. Major fisheries of Gulf of Kachchh

Major fisheries in Kandla and its peripheral environment

The Ichthyofauna diversity in and around the Kandla port and its peripheral environment was investigated through catch composition observation from the landing centers located near Sikka coast of Jamnagar. There were 112 species belonging to 50 families, 12 orders, and 84 genera have been reported (Katira & Kardani 2017). Similarly, around the Marine National Park, Gulf of Kachchh nearly 109 fishes belonging to 58 families, 19 orders, and 93 genera has been identified (Brahmane et al. 2014). Apart from this, a recent study conducted by Sidat *et,al.* (2021) and recorded 96 species which include 20 order and 47 families.

The fishing activity is carried out in the extensive creek systems such as Khari, Tuna, Navalakhi and Jhangi locations. The cast net is generally used for fishing in the creeks. During the period of period 2022-2023, the catch was mainly composed of the shrimp *Penaeus indicus; the fishes such as Chanos chanos, Mudskipper, mullets, catfishes* and *Therapon sp. The crabs Scylla serratus, Portunus sanguinolentus* and *Portunus pelagicus and Lobster were* also form a very good fishery from the creeks. *The* total quantity landed was was 295 kg (Figure 51). The fish catch observed in Tuna creek was comparatively higher which was followed by Navlaki and Jangi creek systems.

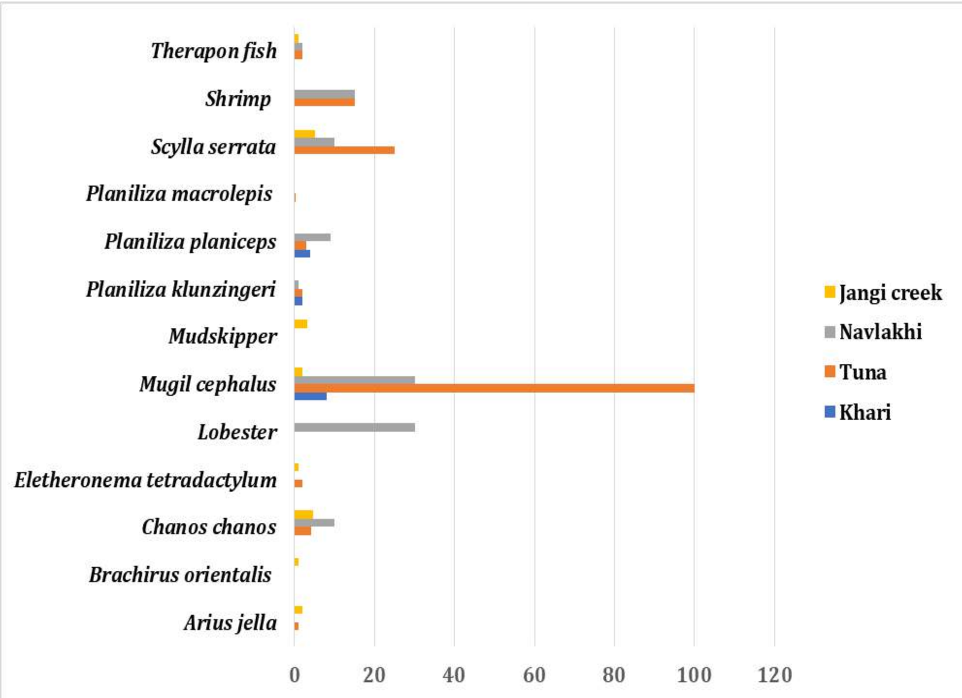


Figure 53.Fish catch in different creek system of DPA during 2022-2023

On the seasonal basis data on fishery resources was recorded from the different creeks (plate 13). Of the total 295 kg fish catch collected ,the maximum weight was reported in Post-monsoon followed by pre monsoon and the mullets (*Mugil cephalus, Planiliza macrolepis)* formed the major portion thought out year (Figure 52).

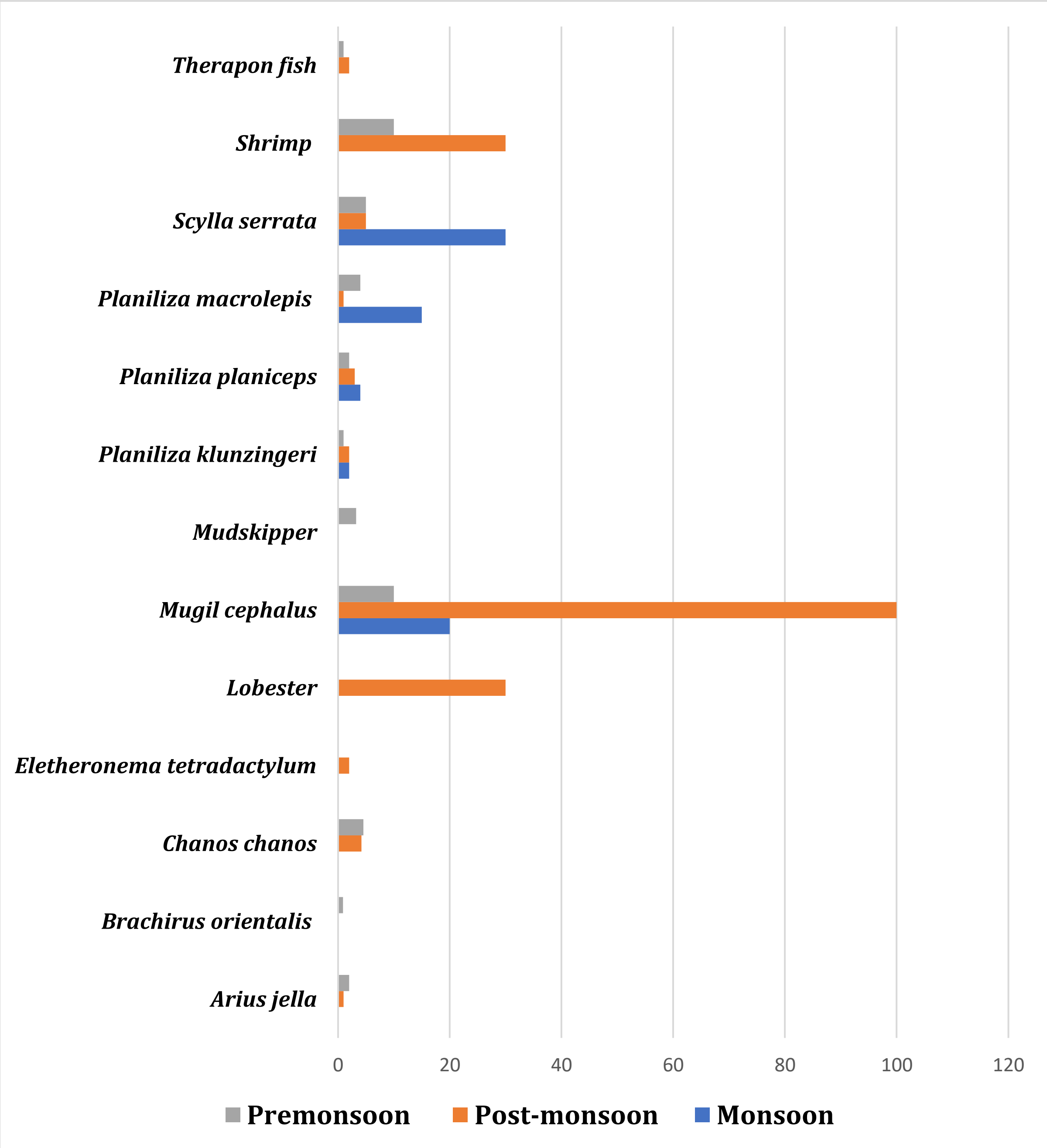


Figure 54. Season wise fish catch from the reek systems of DPA Jurisdiction

Plate 14: Fisheries of DPA Jurisdiction

4.8. Marine Mammals

Marine mammals play critical ecological roles as predators (mainly hunts fish) and prey, both for sharks and other, larger marine mammals (Roman and Estes, 2018).Dolphins are highly intelligent marine mammals and are part of the toothed whales, including orcas and pilot whales. They are distributed worldwide, mostly living on the continental shelves of shallow seas and are carnivores, mostly eating fish and squid (Thomas 2009).The *Sousa plumbea* (plate.14) commonly known as the Indian Ocean humpback dolphin, is listed as "Endangered" by the International Union for the Conservation of Nature (IUCN, 2022) and was documented from the Kandla waters during Premonsoon station between S-9 (Navalaki creek) and S-5 and S-6 in the Phang creek at S-14 near to AKBTL jetty 1 adult and 2 juvenile dolphins (total 3 numbers). These dolphins have a more uniform dark-grey (plumbeous or lead) colour with white mottling interspersed with slight pink pigmentation in specific individuals. The belly or the ventral surface of the body is lighter. This dolphin is found close to the shore and around larger creeks, the open sea and estuarine mouth. The Indian Ocean humpback dolphin mainly feed on fish like mullet, mackerel, sardines and pomfrets found along the estuarine areas (Thomas *et al*., 2012).

Plate 15: Marine Mammals of DPA Jurisdiction

4.9. Reptiles

India has the highest incidence of deaths due to snakebites in the world. *Echis carinatus* (EC) is known as a saw-scaled viper, and its bite causes one of the most mortality and morbidity in the Indian subcontinent (Daniels,2002, Rudresha *et al*., 2021). During the monsoon period of 2022 field surveys, the saw-scaled viper *E. carinatus* (plate 16), was recorded at site S-3 located in the northern part of Sat Saida bet opposite to oil jetty. Similar species also recorded during Post-monsoon at S-10 located in the western part of Sat Saida bet opposite to Phang creek. But during pre-monsoon this species was not sighted any one of the study station This species was spotted on the branches of mangrove trees, on top of the *Salvadora persica* and bottom of the mangrove trees and on the halophytes. The colour pattern consists of a pale buff, greyish, reddish, olive or pale brown ground colour. This snake is not active during the daytime and hides at the bottom of the trees, branches of mangrove trees, associated with halophytes and mangrove litter.

Plate 16: *Echis carinatus* (Saw-scaled viper)

4.10. Avifauna

Mangrove forest habitats serve as host to a number of bird species around the world. Detailed investigations of bird ecology in the mangrove forest habitats are sparse. The common birds found in the mangrove forest habitats are of the family Ardeidae, Charadriidae, Laridae, Ciconidae, Accipitridae and Alcedinidae. Migratory birds visiting the mangroves may fly long distances to find food and nesting places there (Parrish and Sherry, 1994). This may be particularly true in the neotropics (Confer and Holmes, 1995; Lefebvre and Poulin, 1996; Panitz, 1997).

Mangrove forests are extremely essential for the survival of many species of birds (Kathiresan, 2000), but information on birds associated with mangroves in India is scanty (Sampath, 1989; Sethuraman and Subramanian, 1997). A checklist of some birds associated with the mangroves of Ratnagiri has been prepared by Samant (1985) and Apate *et al*. (2005) reviewed the potential and prospects of estuarine ecotourism with special emphasis on mangrove birds from the same area. Deshmukh (1990) has recorded 147 bird species from the mangrove swamps of Vikhroli, near Mumbai. A study on the birds of Purathur and Kadalundy estuarine mangrove patches all along the Kerala coast was reported by Kurup (1991b). Nature Education Society, Thrissur (NEST, 1993) published a list of birds seen in Kumarakam mangrove. Similarly, birds(57 species) occurring in the Asramam mangroves at Kollam was recorded by Mohandas *et al*. (1994) and Jayson (1997) described the avifauna of different coastal protected areas in Kerala. Shreekumar (2001) studied the birds of Vembanad Lake, one of the declared Ramsar sites, is a coastal lagoon which has significant bird diversity in mangrove forest habitats (Nameer, 1993). There were 3,000 to 4,000 Black-crowned Night Herons *Nycticorax nycticorax* used to breed, along with Darter, Little Cormorant, Median Cormorant, Purple Heron, Large Egret and Pond Heron in the vembanad lake and the adjacent mangrove (Sreekumar 2002).

Sanyal (2002) identified 163 species of birds from Sunderban mangroves in India but recently, Sujan Chatterjee (2003) has listed 219 species. Mukherjee (1959) recorded 16 species in a breeding colony, including the near threatened Darter A*nhinga melanogaster* and Black-necked Stork *Ephippiorhynchus asiaticus* from the Sunderban mangrove forest. Ali (1945) published a book on the Birds of Kutch which includes species present in both India and Pakistan part of Kachchh. Abdul Ali (1962,) published ornithological check list based on his ornithological trip to the Gulf of Kachchh. Himmatsinhji (1968) reported some migratory birds in the Gulf of Kachchh. Parasharya (1984) studied the coastal birds association with marine habitats with special reference to Reef heron in the Saurashtra cost. Naik and Parasharya (1987) studied the impact of the food availability, nesting-habitat destruction and cultural variations of human settlements on the nesting distribution of the reef heron *Egretta gularis* in the Gujarat state including Gulf of Kachchh. Mundkur *et al*. (1988) studied the occurrence and distribution of the slender billed Gull *Larus genei* from various localities in the Gulf of Kachchh. Palmes and Briggs (1986) reported the Crab-Plover in the Gulf of Kachchh. Naik *et al*. (1991) studied the avifaunal assemblage of the Gulf coast covering different habitats namely intertidal mudflats, coral reefs, sand and rock beaches and mangrove forests. Overall, 170 species of birds which includes 76 terrestrial birds recorded from 17 heronries in the mangrove forests and six species breeding in the salt works. The GEER Foundation (2002) studied the avifaunal assemblage in the marine national Park at Jamnagar during 2000 and 2002. The study revealed the presence of a total of 123 species of waterfowls and 85 species of terrestrial birds, out of which 50 water birds were migratory, five globally threatened, 11 near threatened (Bird Life International 2008) and 23 species breeding migrants. The breeding was mainly confined to the mangroves and the salt pans. Urfi (2002) studied the costal warders in the Byet of Dwaraka Island and reported that the mangroves were used by the waders during the high tide. Immense numbers of migratory birds pass through the Gulf of Kachchh, in addition to considerable number of resident birds recorded in the mangroves (Naik et al. 1991).

The globally threatened Dalmatian Pelican, Pallahs fish eagle, Greater spotted Eagle, Indian Skimmer and the near threatened Spot billed Pelican, Oriental Darter, Painted Stork, Black necked stork, Black headed Ibis, Lesser Flamingo, Eurasian curlew, Black tailed Godwit were recorded in the Marine national park (Bird-Life International 2008). Among these, Black - headed Ibis, Oriental Darter, Painted Stork, Black-necked Stork were breed in the mangroves (GEER, 2002). Previous research suggests that although there are similar numbers of bird species found in the mangroves throughout the world, the highest numbers of mangrove-dependent birds are found in Southeast Asia and Australia (Sethuraman and Subramanian, 1997). Majority of the mangrove-restricted species (or species with at least one mangrove-restricted subspecies) are located in Asia (26) and northern Australia (23), but the data on habitat association and utilization is scanty (Panitz, 1997).

A large amount of research on bird diversity emphasizes the general negative effects of land conversion to human dominated habitats (Brooks *et al*. 1997; Castelletta *et al*. 2000). But human dominated and coastal habitats vary a lot and therefore the effect on birds can be very different. Birds depend on the habitats where they occurred, so the response of the species in particular habitat may always differ according to the habitat changes (Tworek, 2002, Beier *et al*. 2002; Kurosawa & Askins 2003).

Overall, a total of 87 species belonging to nine orders, 35 families and 64 genera were recorded from the coastal area of Kandla Port during this one-year study (Figure 55 , Annexure 1). Among these, 53 species were aquatic and 34 species were terrestrial, which included six species listed as Near Threatened in the IUCN 2023, Red List.

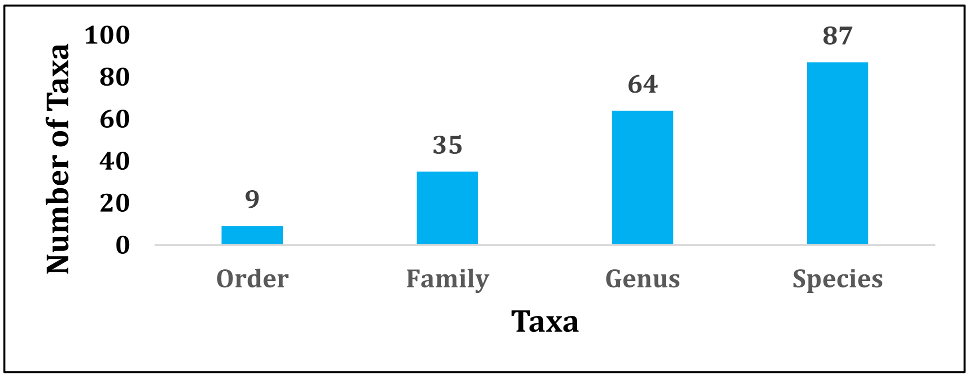


Figure55 : Taxonomic Diversity of Avifauna of the Study Area

Among the recorded species, nearly one-third belong to the order Charadriiformes (30 species), followed by Passeriformes (22 species), Pelecaniformes (17 species), Coraciiformes (6 species), Accipitriformes (4 species), Columbiformes (3 species) while two order represented by two species each and one order represented by one species in the study area (Figure 56).

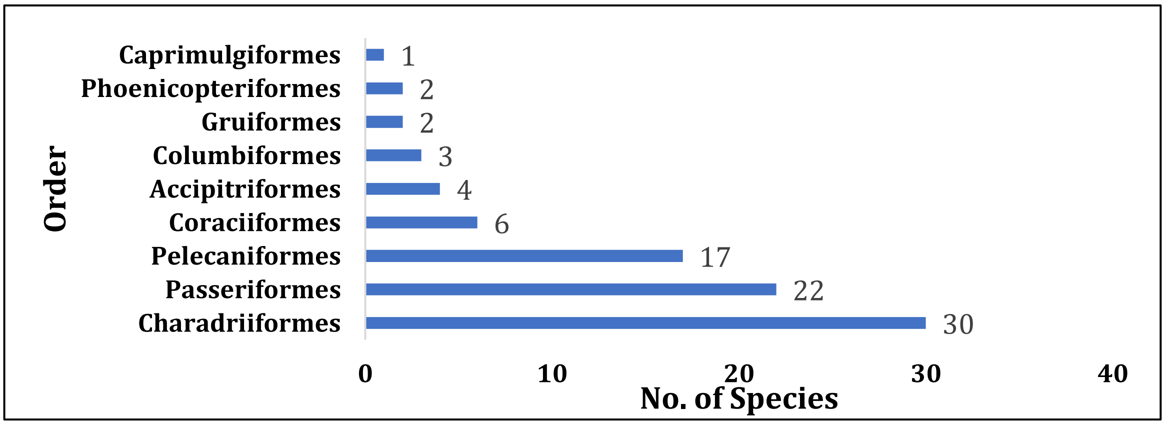


Figure 56 : Species Recorded from Various Orders of Birds from the Study Area

The families with a greater number of species were Scolopacidae (twelve spp.), Ardeidae (eight spp.), Laridae (seven spp.), Charadriidae (six Spp.), Hirundinidae (four spp.), Columbidae (three spp.), and Passeridae (one spp.). From the recorded species, 27 species were migrants, 15 species were local migrants or resident migrants, 45 species were breeding resident (Figure 57).

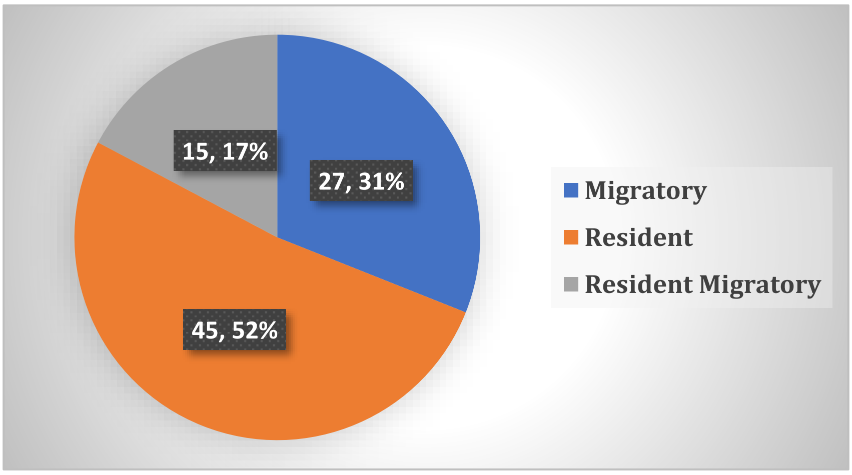


Figure 57 : Migratory Status of Avifauna Recorded from the Study Area

Thirteen (13) kinds of feeding guilds, viz., aquatic invertebrate-feeder, piscivore, insectivore, granivore, frugivore, reptile-feeder, amphibian feeder, nectarivore, weedivore, plankton-feeder, herbivore, carrion-feeder and predatory were identified; among the bird species observed (Ali and Ripley 1987). Here, the aquatic invertebrate guild is the most frequent one with thirty six percent incidence and 31 species occurring under this shared category. Whereas, omnivore, frugivore, granivore, and plankton-feeder guilds are the least frequent each having a single species. Data collected from point counts allows us to calculate species diversity, richness and species composition. The overall three season results shows that the maximum diversity across the seasons was found from the Site 1 (H' 4.0) followed by Site 2 (H' 3.9) and the minimum diversity recorded from site 5 (H' 3.3). The results of species richness shows that maximum species richness was recorded from Site 1 (11.43 spp.) and minimum species richness recorded from Site 12 (8.07 spp.). Other diversity indices details are given in the Table 18 . The overall mean number of species from the 15 sites was 87; Shannon diversity (H') was 4.23 with richness index 9.94. The overall species evenness index value for study area was 0.79 with Equitability 0.94 .

Table 18. Overall Avifaunal Species Diversity in Different sites in the Study Area

Sites	No. of Species	Individuals	Shannon_H	Evenness_e^H/S	Richness	Equitability_J
S-1	71	456	4.004	0.7724	11.43	0.9394
S- 2	68	596	3.929	0.7477	10.48	0.9311
S-3	45	313	3.509	0.7424	7.657	0.9218
S- 4	49	243	3.68	0.8094	8.738	0.9457
S- 5	46	237	3.394	0.6473	8.23	0.8864
S- 6	54	359	3.718	0.7623	9.009	0.932
S- 7	60	522	3.438	0.5188	9.428	0.8397
S- 8	60	360	3.856	0.7877	10.02	0.9417
S-9	65	468	3.72	0.6345	10.41	0.891
S-10	62	391	3.858	0.7643	10.22	0.9349
S-11	60	380	3.876	0.8041	9.932	0.9467
S- 12	47	299	3.548	0.7395	8.07	0.9216
S-13	64	331	3.904	0.7749	10.86	0.9387
S-14	58	334	3.828	0.7928	9.809	0.9428
S- 15	62	389	3.84	0.7504	10.23	0.9304
Total	87	5678	4.231	0.7904	9.949	0.9473

Comparative status of avifaunal species diversity over the three seasons

Totally fifteen sites were surveyed during the three seasonal study, in which the maximum number of species (79 spp.) was found in post monsoon season. Among the sites, S-1 recorded highest number of species (57 spp.) followed by S-2 (55 spp.), followed by S-9 (46 spp.) and S-7 (45 spp.). The Site 5 recorded the least richness (31 spp.) value (Table 19). During the monsoon survey the overall number of species (49 spp.) was less however, at S-1 recorded the highest number (33 spp.) which is followed by S-9 (27 spp.) and S-10 (26 spp.).The station S-5 recorded the least richness (16 spp.). During the premonsoon the mean number of bird species recorded was 53 and the number of species relatively high at S-1,S-13, S-7 and S-2.

Table 19 : Season wise Number of species recorded from the study area.

	No. of Species			
Sites	**Pre-Monsoon**	**Monsoon**	**Post-Monsoon**	**Overall**
S-1	34	33	57	71
S- 2	31	33	55	68
S-3	19	19	34	45
S- 4	18	20	35	49
S- 5	21	16	31	46
S- 6	25	23	38	54
S- 7	33	25	45	60
S- 8	17	22	43	60
S-9	17	27	46	65
S-10	22	26	45	62
S-11	15	25	39	60
S- 12	21	18	32	47
S-13	33	20	37	64
S-14	23	25	33	58
S-15	17	26	45	62
Total	**53**	**49**	**79**	**87**

The site wise migratory status of the birds enumerated showed that maximum number of species was found in Post monsoon season (26 spp.) particularly at S-1 and S-2 the highest number of migratory birds (19 spp.) which is followed by S-15 (18 spp.) S- 9 (17 spp.), while S-5 recorded the least number (9 spp.) (Table 20). The number of migratory species was very low during monsoon season.(4 spp.) and sites 2,9,13,15 showed each 3 species. spp.

The overall three season results showed that the maximum diversity from the S- 1 (H' 4.0) followed by S-2 (H' 3.9) and the minimum diversity from S- 5 (H' 3.3). The species richness was maximum from S-1 (11.43 spp.) and the minimum S- 12 (8.07 spp.). The diversity indices details are given in the table 21&22. The overall mean number of species was 87 from the 15 study sites and the Shannon diversity (H') was 4.23 with richness index 9.94 for the three seasons. The overall species evenness index value was 0.79 with Equitability value 0.94.

Table 20.: Sitewise Migratory status of Bird species recorded from the study area.

	Migratory			Resident			Resident Migratory		
Sites	Pre Monsoon	Monsoon	Post Monsoon	Pre Monsoon	Monsoon	Post Monsoon	Pre Monsoon	Monsoon	Post Monsoon
Site 1	5	2	19	23	25	28	6	6	10
Site 2	8	3	19	20	25	29	3	5	7
Site 3	3	1	12	13	15	16	3	3	6
Site 4	3	2	15	12	14	15	3	4	5
Site 5	4	2	9	15	11	16	2	3	6
Site 6	6	1	13	14	16	19	5	6	6
Site 7	5	1	12	22	19	24	6	5	9
Site 8	1	2	16	12	13	19	4	7	8
Site 9	4	3	17	9	17	20	4	7	9
Site 10	3	1	14	15	18	24	4	7	7
Site 11	2	2	14	10	19	17	3	4	8
Site 12	3	1	13	14	13	12	4	4	7
Site 13	7	3	12	21	13	20	5	4	5
Site 14	5	3	14	13	17	14	5	5	5
Site 15	3	3	18	11	18	18	3	5	9
Total	**11**	**4**	**26**	**34**	**35**	**40**	**8**	**10**	**13**

Black-headed Gull

Crab Plover

Black-headed Ibis

Citrin Wagtail

Plate 17. Avifauna status of Deendayal Port Area

Table 21. Comparative status of avifaunal species diversity over three Seasons in the study area during May 2022 to May 2023

Diversity Indices	No. of Species			Individuals			Shannon_H		
	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon
Site 1	34	33	57	111	125	220	3.273	3.308	3.834
Site 2	31	33	55	131	196	269	3.182	3.199	3.719
Site 3	19	19	34	67	89	157	2.656	2.725	3.177
Site 4	18	20	35	61	66	116	2.796	2.815	3.404
Site 5	21	16	31	63	39	135	2.7	2.555	2.906
Site 6	25	23	38	102	96	161	3.036	2.848	3.488
Site 7	33	25	45	114	103	305	3.267	3.023	2.776
Site 8	18	22	43	56	100	204	2.703	2.832	3.479
Site 9	19	27	46	74	133	261	2.645	2.927	3.284
Site 10	22	26	45	85	113	193	2.903	2.985	3.557
Site 11	19	25	39	87	119	174	2.787	3.02	3.403
Site 12	21	18	32	72	72	155	2.922	2.621	3.085
Site 13	33	20	37	128	66	137	3.32	2.815	3.47
Site 14	23	25	33	76	103	155	2.975	3.023	3.216
Site 15	17	26	45	64	113	212	2.547	2.985	3.531
Total	**53**	**49**	**79**	**1291**	**1533**	**2854**	**3.769**	**3.636**	**4.048**

Table 22. Comparative diversity index status of avifaunal species diversity over three Seasons during May 2022 to May 2023

Diversity Indices	Evenness_e^H/S			Species Richness			Equitability_J		
	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon
Site 1	0.7761	0.8281	0.8113	7.007	6.628	10.38	0.9281	0.9461	0.9483
Site 2	0.7775	0.7428	0.7496	6.154	6.063	9.652	0.9267	0.915	0.9281
Site 3	0.7491	0.8026	0.7049	4.281	4.01	6.527	0.9019	0.9253	0.9008
Site 4	0.9096	0.8346	0.8594	4.135	4.535	7.152	0.9672	0.9397	0.9574
Site 5	0.7085	0.8046	0.5898	4.827	4.094	6.116	0.8868	0.9216	0.8462
Site 6	0.833	0.7503	0.8607	5.189	4.82	7.281	0.9432	0.9084	0.9588
Site 7	0.7949	0.8219	0.3569	6.756	5.178	7.692	0.9344	0.9391	0.7294
Site 8	0.8294	0.7721	0.7542	4.223	4.56	7.898	0.9353	0.9163	0.925
Site 9	0.7412	0.6918	0.5802	4.182	5.317	8.087	0.8983	0.8882	0.8578
Site 10	0.8285	0.7612	0.779	4.727	5.288	8.361	0.9391	0.9162	0.9344
Site 11	0.8542	0.8197	0.7703	4.031	5.022	7.366	0.9465	0.9382	0.9287
Site 12	0.8848	0.7635	0.6836	4.677	3.975	6.147	0.9598	0.9067	0.8902
Site 13	0.8385	0.8346	0.8685	6.595	4.535	7.317	0.9496	0.9397	0.961
Site 14	0.8513	0.8219	0.7551	5.08	5.178	6.345	0.9487	0.9391	0.9197
Site 15	0.7508	0.7612	0.7589	3.847	5.288	8.214	0.8988	0.9162	0.9275
Total	0.8177	0.7746	0.7251	7.259	6.544	9.803	0.9493	0.9344	0.9264

These changes in individual species abundance, whether they occur independently of one another (Wiens, 1989) or are influenced by interactions with other bird species are governed by the degree of anthropogenic pressure including disturbance to habitat of species (Block and Brennan, 1993). The distribution and abundance of many bird species are mainly determined by the configuration and composition of the vegetation that comprises a major element of their habitat (Cody, 1985; Block & Brennan, 1993). As vegetation changes along complex geographical and environmental gradients, particular bird species may appear, increase in abundance, decrease, and disappear, when habitat becomes more or less suitable for its persistence. The results of the present study indicated that l 16% species were found rarely distributed in the study area while 36% species were very common. Aquatic and Insectivores form the major groups while each of the frugivores, omnivores and nectarivores constitute about 2% of all species. Although more than 67% of the birds in the study area were Aquatic and insectivores, food competition was reduced by the utilization of different habitat types and distinct feeding behaviour. Largely insectivorous birds like babblers (Sylviidae) and drongos (Corvidae) feed on fruits and seeds of plants particularly during winter season due to the shortage of insect food. Aquatic birds were dominated largely by the those depend on the food aquatics environment followed by insectivore and grainivore species (Annexure 1).

The present three season study shows 87 different types of birds belonging to nine orders and 32 families from the coastal area of Deendayal Port. The richness of avifauna is little low, indicative of decline in the ecological health status of the coastal area of Deendayal Port. Proper and in-depth study, awareness, regarding the importance of birds and their role in ecosystem, to the local peoples through different massive programs will ultimately help the protection of birds of this region.

5. Discussion

5.1. Physico-chemical status of Deendayal Port Authority Environment

Water quality of coastal water reveals the state of the overall environment. The quality of water determines the biological and other resources in the marine environment. However, water quality parameters in marine environment vary to a great extent, which becomes difficult to explain, especially in the absence of a holistic benchmark study. The geophysical and geo-chemical factors such as shape and size of the coastal areas, prevailing currents, temperature, salinity, tidal impacts, directions of prevailing winds and influx of fresh water influence the quality of water in a marine environment. The above factors affect the various inputs that are being added into the harbour water. Hence, it is impossible explain the overall impact of all these environmental factors that influence the water quality of the creeks and adjacent coastal water. The shifting nature of water column due to the tides makes the task more difficult for the assessment. Nonetheless, water quality indicators are fair enough to reveal the state of harbour environment. The pollution indicators in the water column can predict the possible impacts that are likely to occur both in the near future as well as in the long term at the present rate of occurrence.

Temperature and pH

Water temperature in DPA port area generally varies in the range 9°C 31.°C. However, the present study showed a reduced range of water temperature in Kandla DPA port in previous year of 2021. Water temperature of the port region varies during monsoon, ranging from 23°C to 31°c while in post monsoon it varied between 9°c to 28°c . However, in pre monsoon the values were noted in the range of 20°c to 28°C. The monsoon water temperature has been recorded as high (31°C). There is no vertical variation in temperature of marine water in Kandla Port area due to lack of thermal stratification in Creek (NIO,1998). This is because of the strong currents, high tidal impact and low depth of the harbour areas. The currents influence vertical mixing and restrict the stratification of water layer in the harbour area.

The high temperature during monsoon attributed to thermal stratification by fresh ingress of tidal water during monsoon season.

pH

The pH of seawater of DPA Port area varied in the range of 7.3 to 8.3. Generally, the pH of seawater is controlled by carbonate and biocarbonate system and falls in the narrow range of (0.2-0.3). The pH was alkaline during summer and showed downward pattern up to monsoon and remained alkaline during post monsoon, (Vajravelu *et.al.,* 2018). Changes in pH will depend on the factors like the removal of CO_2 by photosynthesis through bicarbonate degradation, fresh water influx, reduction in salinity and temperature and decomposition of organic matter (Rajasegar et al., 2002).

Salinity

As temperature influences the salinity of marine water in the tropics, water in DPA region has higher salinity in the range of 38ppt 50ppt. Highest salinity observed during pre-monsoon (50.7ppt) at station S-11. The higher salinity towards inner regions around S-11 indicates localized effects of seepage of high saline (brine) water from salt marshes and saltpans of salt industries (Zingde& Anand ,1996). Hundreds of salt industries in and around Kandla Port use seawater with salinity in the range of 35 to 50 ppt. They release 'bittern' remains of salt after manufacturing, which has salinity as high as 250 ppt in Kandla Creek, thereby increasing the salinity in isolated regions of port areas (Chhaya, & Chhaya, 1997). Lack of fresh water from catchments coupled with higher evaporation is the cause of higher salinity in Kandla Port area. In the Little Gulf of Kuchchh water salinity has been recorded as high as 50 ppt (NIO,1998).

Dissolved oxygen

Dissolved oxygen(DO) is consumed in marine ecosystem by the respiration and decaying organic matter in the water column. High loads of organic matter may deplete the dissolved oxygen to its minimum level, which can be detrimental for the aquatic life. A severe depletion of DO may lead to 'Eutrophication' in an aquatic system. However, no such event has been reported in Kandla port region so far. The dissolved oxygen in the water of Kandla Port region has been found in the range of 6.9 mg/l and 8.6 mg/l in the 3 seasons. The current range of dissolved oxygen in the Kandla Port region conforms to the designated best use for Salt pans, Shell fishing, Mariculture and Ecologically Sensitive Zone. For ecologically sensitive zone not less than 3.5mg/l at any time in a year (or 5.0 mg/l at 60 percent saturation level) of DO is essential for the protection of aquatic life.

Total Suspended Solids

Suspended solids in Deendayal port area varied in the range 127 mg/l to 887 mg/l. Generally, the suspended solids in the port region are relatively high and vary to a great extent from the inner port region to the out harbour region and further towards outer Gulf..The higher value of suspended solids and their variations across the stations in the inner Gulf including Kandla Port regions results from the dispersion of sediment loads due to strong currents and tidal influence Zingde& Anand (1996)

Turbidity

Since Kandla Port areas fall under inner Gulf of Kuchch, there is a high turbulence in the creeks, due to strong ocean currents and tidal influence. Therefore, the turbidity of tropical seas is higher than other tropical and subtropical seas. The marine water turbidity is expressed in Nephelo Turbidity Unit (NTU). Water turbidity in DPA Port region has been recorded in the range of 30.2 NTU to 342 NTU. Generally, water turbidity is high due to high organic load including mud and silt. (Omprakash, 1997) Higher turbidity of the water at the DPA Port region, may also be associated with the washed sediment from mangrove environment and partially from dredging activities, which is done on a regular basis along the Kandla Creek.

Nutrients

Nutrients in the water such as Nitrate and Nitrite and Phosphate are very crucial for the marine life. Their increase in concentration enhances the primary productivity in marine water. Nonetheless, excessive concentration sometimes can be detrimental to the aquatic life especially in creeks, estuaries and bays where there is a restricted water exchange. These increased nutrients lead to an excessive growth of algae resulting in eutrophication in some extreme cases (NIO,1998). During the period of May 2022 to May 2023 covering 3 season it was observed that the concentrations were within the permissible limit to the diverse marine life.

Petroleum Hydrocarbon (PHs)

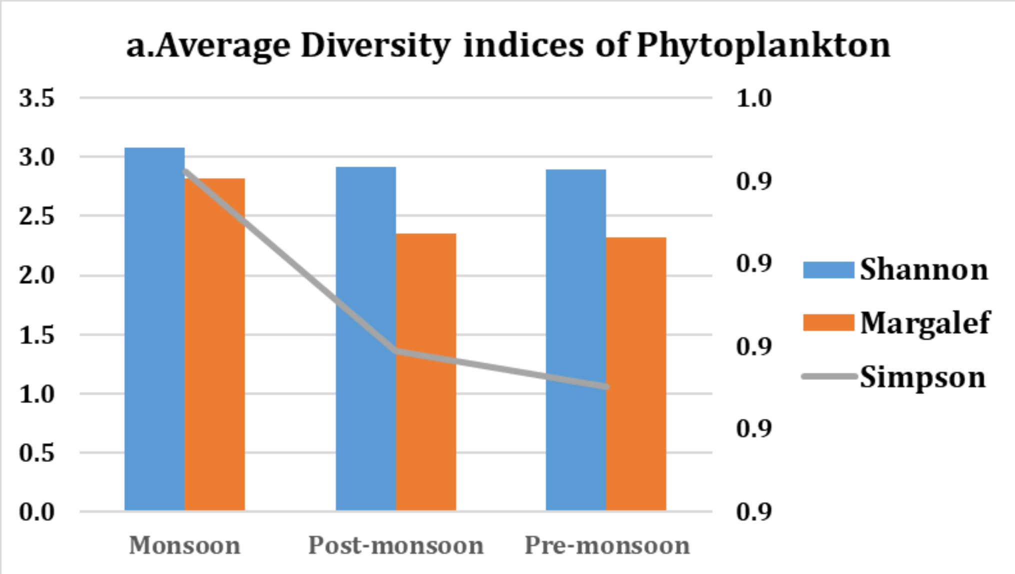
Petroleum hydrocarbons in the water column of Deendayal port area have been found in the range of 1.5 μg/l to 18.8 μg/l. The high range of petroleum hydrocarbon results from the spills and leakage during the handling of crude petroleum products at the Port especially at oil terminals (NIO2002).

5.2. Biological status of Deendayal Port Authority Environment

Biological resources of a marine area reflect the overall environmental health of the region in question. The coastal areas especially bays, creeks and estuaries are rich in biota and are habitat of many marine species. Usually, ports are also built in these areas for their geographical advantages. The port and harbour activities in these locations disturb the habitat of many marine biota. However, in the process many habitats are also created for marine biota. The Gulf of Kachchh is an example of such habitat and has been considered to be rich in biodiversity. Kandla port has been built right in the gulf and has been serving this region nearly seventy years.

Chlorophyll 'a' , Phytoplankton and Zooplankton

In general the basic parameters of marine biota like Chlorophyll 'a' and Phytoplankton are observed to be moderate in their values but similar to those prevailing along the coastal waters of India (NIO,2002). During the period May 2022 to May 2023 the Chlorophyll 'a' concentration is within the limit of 0.22 mg/l to 2.59mg/l which is quite satisfactory for port environment. The index value of both phytoplankton and Zooplankton of the 3 season shows the moderate rate of pollution of the environmental status (figure.58 a&b). As per Shannon Wiener's rules for the aquatic environment i.e both soil and water is classified as 'very good' when H' value is greater than four (>4), whereas " 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" when the H' value significantly less than one (<1). Presently the DPA port and its peripheral environment have been influenced by contaminants deposited from industries and the cargo movements. Accordingly, species diversity decreases at sites with poor water quality. Since the Shannon diversity index values that varied between 3-4 throughout the three seasons, it is inferred that the values represent the moderate quality of environmental status dominated by the few genera of phytoplankton such as *Coscinodiscus* sp. and *Synedra* sp, and zooplankton like copepods. A community dominated by relatively few species indicates environmental stress (Plafkin *et al*., 1989). According to Staub *et. al* (1970) species diversity index value between 3.0 to 4.5 represents slightly polluted and the lightly polluted environment, the index value characterizes 2.0-3.0, similarly, moderately polluted environment shows index value of 1.0-2.0 and finally, the heavily polluted environment index value is 0.0-1.0. While considering the overall index values it is inferred that the study sites can be included under the category of lightly polluted environment.



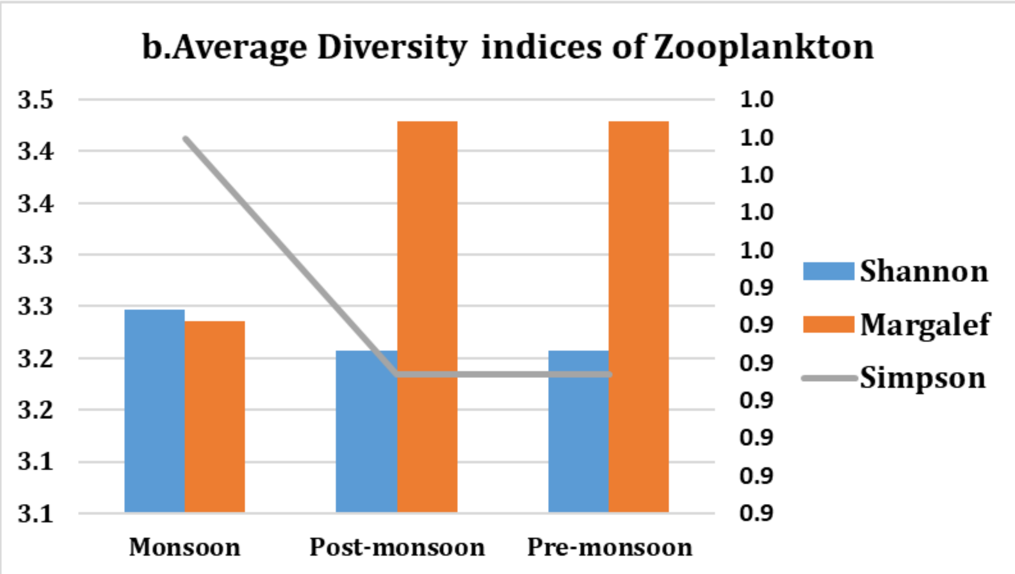


Figure 58. Diversity indices of Phytoplankton and Zooplankton

Natural geographical processes such as strong currents and higher tidal influence have been responsible for the high turbidity and suspended solids which in turn reduce the light penetration thereby reducing the growth of Plankton and primary productivity. The seasonal distribution of phytoplankton was 21,120 No./l to 35,040 No./l and Zooplankton density ranges from 12,540No./l to 21,12 No./l .

Intertidal Fauna

Macrofaunal communities did not show much spatial and temporal variation in their components at the 15 sampling locations. The distribution of intertidal fauna seems to be entirely governed by the environmental parameters like Physico-chemical and biological characteristics of the ambient milieu. Generally, intertidal fauna on the Kachchh coast scope a harsher environment with relatively high salinity, wide temperature fluctuations, seasonal fluctuation of different hydrological parameters and a high sedimentation rate. The suspended solids (SS) in the water were generally found due to the dispersion of fine sediment from the bed and the intertidal mudflats due to tidal movements at the mouth of the Kachchh coast (Kandla). An earlier study by Saravanakumar *et al*. (2007) revealed the presence of five intertidal Fauna in the mangrove environments along the Kachchh coast, with a diversity index ranging from 1.84 to 2.45. The species composition and diversity indices reported during 2018-2019, 2019-2020, 2020-21, and 2021-2022 did not vary significantly in the DPA port environment. It was understood that the intertidal fauna community in the Kachchh mangrove had not varied much in terms of its species diversity. An earlier study by Saravanakumar et al. (2007) revealed the presence of five intertidal Fauna in the mangrove environments along the Kachchh, with a diversity index ranging from 1.84 to 2.45. During the 2022 to 2023 average Shannon diversity indices varied from 1.56 to 1.88 similarly the Margalef and Simpson index ranged from 1.46 to 1.76 and 0.71 to 0.81 (Figure. 59). According to Magurran (1991), the Shannon diversity index >3.0 indicates a healthy coastal environment. However, diversity indices around the DPA coastal environment were <3.0, indicating that the moderate faunal diversity .

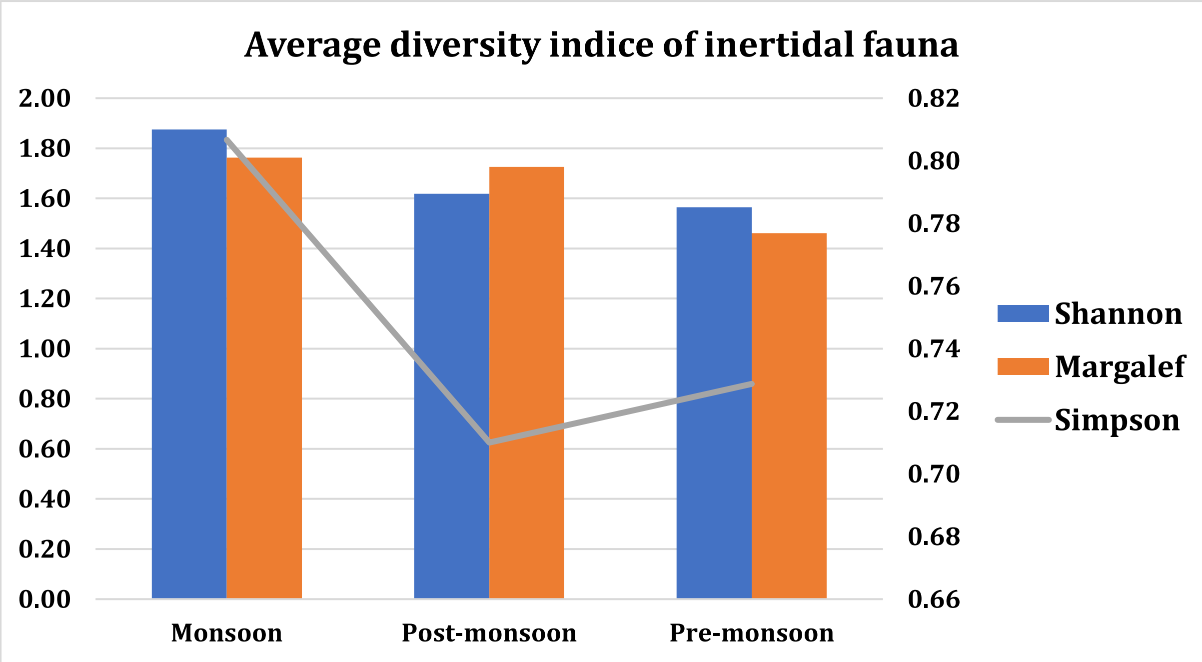


Figure 59 Average diversity indices of intertidal fauna from DPA

In the present observation, the species composition of the benthic macrofauna showed dominance of the Phyla such as Mollusca, Arthropoda, Annelida, Nematoda, Nemertea and Chordata. Previously, Ansari *et al*. (1986), Mohammed (1995) and Kumar (2001) recorded the presence of the Mollusca, Arthropoda, Annelida, and Chordata in various parts of Indian coastal waters.

Subtidal Fauna

The subtidal Fauna of the DPA Kandla survey recorded the presence of 4 phyla (Cnidaria, Annelida, Arthropoda and Mollusca,), including 26 species. Among the sampling stations, the highest number of animals was documented during the post-monsoon including *Glauconome angulata* (51 no) followed by *Pirenella cingulate* (48 no) in post-monsoon. In pre-monsoon highest number of animals contributed by the species *Pirenella cingulata* (43 no) followed by *Glauconome angulata* (38 no). Similarly in the monsoon the highest number of species contributed by *Optediceros breviculum* (35 no) followed by *Pirenella cingulata* (27 no). In general the gastropod, *Pirenella cingulata* dominated in all the seasons. Previously, Ansari *et al*. (1986), Mohammed (1995) and Kumar (2001) recorded the presence of the Mollusca, Arthropoda, Annelida, and Chordata in various parts of Indian coastal waters. The subtidal faunal diversity was low in the DPA port area with their lower population density during the seasonal study throughout the stations. Mahapatro *et al.* (2011) documented the macrofaunal diversity in Bhitarkanika (Odisha coast) mangroves, and the diversity ranged from 1870 No/m^2. Ramakrishna *et al.* (2011) studied the population structure and density of macrofaunal from the Andaman and Nicobar Islands and documented the diversity from 1015 No/m2 in the. In the Gulf of Kachchh, Saravanakumar *et al*. (2007) documented that from 1999 to 2000.

The Shannon diversity indices ranged from 1.93 to 2.74, similarly Margalef and Simpson indices ranged from 2.37 to 5.05, 0.84 to 0.92. The results obtained from this study represent similar moderate environmental status (Figure.60). However, they provide baseline information on which further studies on biodiversity and conservation strategies might be undertaken or recommended. There is a need for an in-depth study of benthic fauna and their interactions in mangrove ecosystems. Also, practices directed at managing mangrove resources should go hand in hand with conservation strategies.

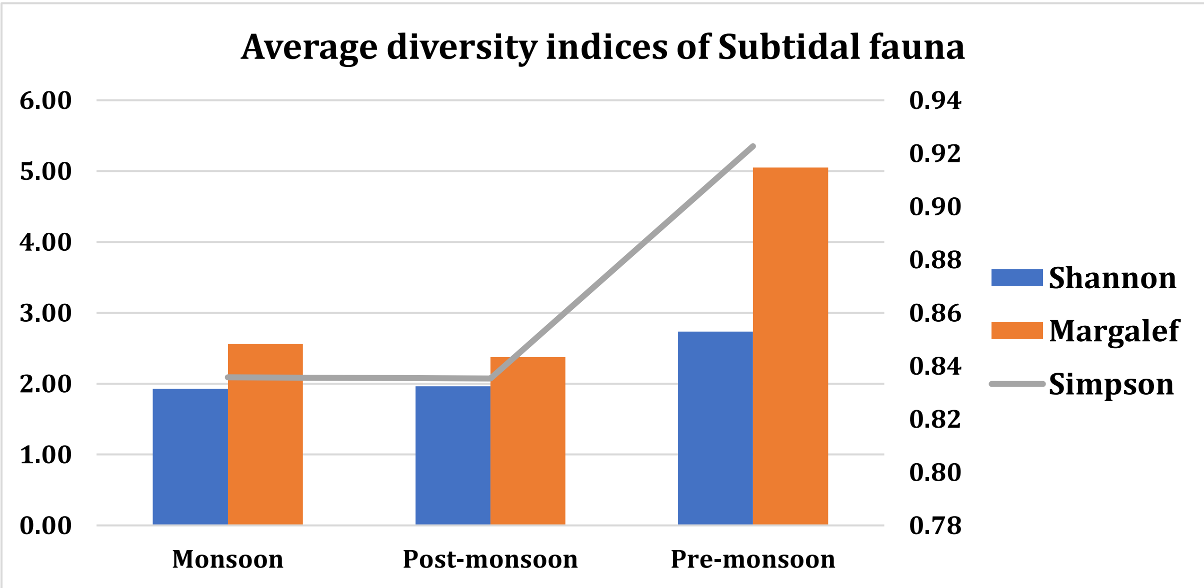


Figure 60. Average diversity indices of intertidal fauna from DP

Mangroves

In DPA Kandla sites, the overall plant characteristics were surveyed, in three classes of plants which are regeneration class, recruitment class and tree class. The parameters considered for tree class were density, height, girth, plant height, canopy cover. In this surveyed year, during the monsoon, the tree class density was observed higher than other two seasons in various creeks. This might because of the availability of fresh water during this season. It is also possible that, the recruitment class present in the sites were turned into the tree class and more tree class tensity was observed this season. As per year analysis, the average density was found higher in Navlakhi creek, followed by Kharo creek where only one station was surveyed (Figure61) . Probably, the anthropogenic pressure in Navlakhi creek is less comparatively sites in other creeks which result in good mangrove condition in that creek. However, the number of pneumatophores, carb holes and mudskippers were also found more in that creek site in Janghi creek has facing bigger anthropogenic pressure because of the development of saltpans in the nearby areas. With this, there may be less possibility of getting freshwater in that creek show less mangrove density even in monsoon season.

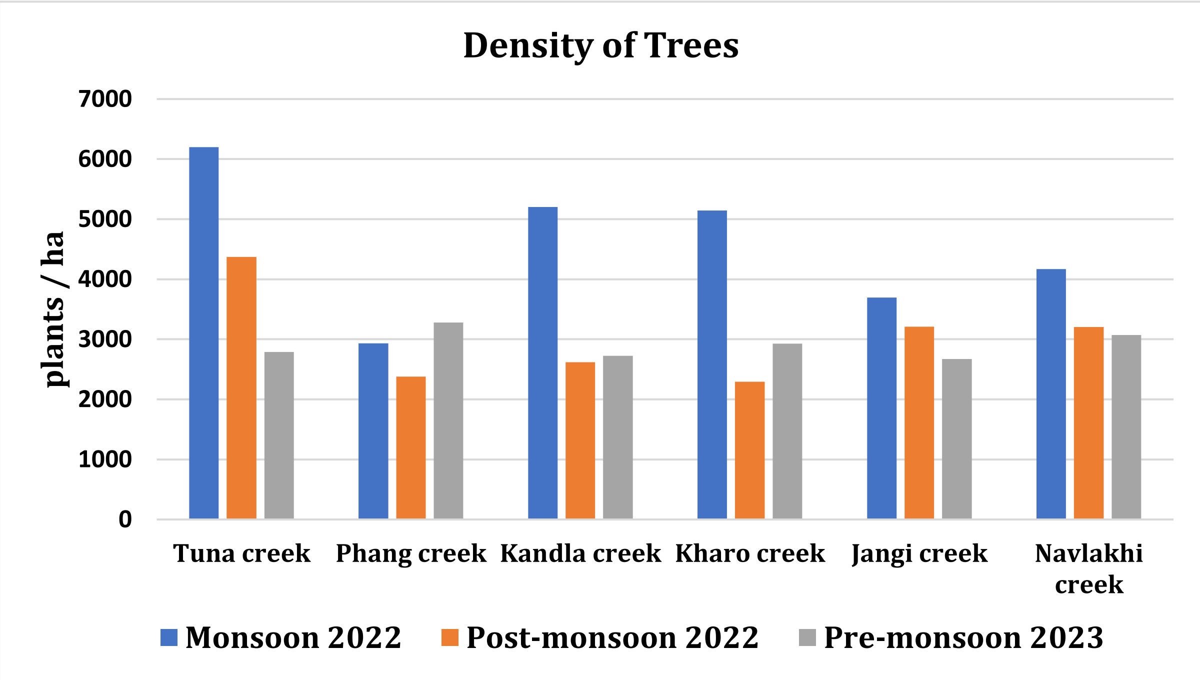


Figure 61. Mangrove density as per creeks in 2022-2023

6. Impact identification and Evaluation

The Deendayal Port, Kandla, in Kachchh district is surrounded by a large number of port associated industries and salt pans and salt processing industries. There are a number of minor and creeks that are connected to the Gulf of Kachchh. The DPA has been the prominent industrial and transport facility primarily associated with the inter connected creek environment which influences the open oceanic zone. The adjacent marine zone is well known for the multitude of the biological resources however, the very sensitive ecosystems like coral reefs, sea grass meadows and salt marshes are not found within the 10 km radius of the DPA port Jurisdiction, and the direct impacts are not experienced.

The general consequences of the port associated activities, particularly on the free-floating microscopic animals and plants, the macrofauna inhabiting the sub-tidal and Intertidal habitats and the birds have been well known, In this respect it is imperative to analyze the major impacts and put forth effective mitigation measures.

Routine dredging Impact

- Dredging and dredge spoil disposal activities for port development and maintenance can induce short- and long-term impacts on aquatic systems, namely degradation of marine resources such as fisheries and other aquatic biota.
- Dredging activities often disturb sediments reducing visibility and transparency of water.
- Dredging activities potentially affect not only the site itself, but also surrounding areas, through a large number of impact factors such as turbidity, sedimentation, resuspension and release of contaminants effects can be immediate to site specific.

Impact on Air quality of Port pemises

- Emissions from burning waste materials and escaping dust (due to handling of fine-particulate materials such as fertilizers and minerals causing air pollution in port areas.

7. Mitigation

Adopting mitigation techniques for reducing carbon concentration like green belt/plantation, conservation of water and energy etc. Various other considerations to control air and water quality in the port and the influencing environment are recommended. Depending on the physical and chemical characteristics of the dredged material, disposal may be confined, unconfined or treated prior to release in open water, along the shoreline, or on land. Ultimately, Environmental mitigation and management Plan (EMMP) acts as a comprehensive manual for environmental protection, reduction in carbon (GHG) emission and finally it helps in converting major ports into "Green Ports". The ultimate goal of a Green Port Plan program is to achieve long-term environmental, societal and economic benefits through resource conservation, waste reduction and pollution prevention. The Green Port Program unifies the Port's environmental sustainability goals (in many key areas) by way of setting measurable goals and evaluating progress in each area on an annual basis.

Pollution control

The major health impacts of pollution from ports are related to the gaseous and particulate emissions arising from the combustion of petroleum products and coal leading to various respiratory tract diseases, cardiovascular disease, lung cancer and also climate change related issues. Petroleum contamination is a very common problem these days arising from leaking tanks, oil spill, and gas into the surrounding water and soil and takes long time for reclamation by bio-agents or physical and chemical treatments. A process called thermal soil remediation helps in the remediation of contaminated soil which can be reclaimed and reused by this method.

The possible soil contamination due to spillage of oil residues, petroleum products, cement, paint, plastics, non -degradable solids etc. are to be handled effectively by scrupulous preventive management guidelines. The laborer and officials should be aware of the extend of damage they can bring on the ecosystem and in turn to human as well through the process of biomagnification through the marine food chain. In this regard any potentially contaminated soils from construction activities must be handled, transported and disposed off in accordance with the Environmental Management Act (EMA) and its Regulations of Government of India.

Afforestation

The port authority should take up plantation of various kinds according to the space, soil types and water availability. Also, it is utmost necessary to carry out compensatory mangrove and associated vegetation plantation along the shoreline at the suitable tidal level with the common species. The development of such green belts surrounding the whole project area will enhance the integrity of the ecosystem and provide ecological and economic services at large on a long and regular basis. The plantation needs to be carried out with higher density of seedlings to realize high survival rates and growth performance, considering the past experiences in the coast and the type of natural stands existing in the creek system as well.

Mangrove plantation

The Green Port Program is an umbrella program designed to achieve the Port's environmental sustainability goals by adopting appropriate afforestation programmes to develop large green belt areas at all prospective locations. The afforestation would not only contribute to the aesthetics but also would serve as a 'sink' for the pollutants released from the station and would thereby protect the quality and ecology and environment in and around the projects. Green belt will help in supporting the biological diversity, controls soil moisture, erosion and coastal protection, increase the rate of ground water recharge and act as carbon sink to reduce climate change. Green cover interventions capture the fugitive, attenuate the noise, subside the particulate matter in the air and reduce the temperature in the surroundings. The mangrove plantation is expected to support the avifauna diversity of the local environment. It is recommended that construction activities are to be restricted during the non-migratory season of the birds (November – February) to avoid disturbance to the migratory species as the Kachchh wetlands serve as major wintering grounds, located in the major central Asia fly way. Since the intertidal zone of the creeks comprising the mangroves and salt pan habitats support many benthic fauna including finfishes and shell fishes, aquatic and terrestrial migratory birds, the protection of these productive environments is very much essential for the restoration of the biodiversity and the livelihood of the fishermen. The above suggested mangrove plantation needs to be monitored for the next five years till it attains maturity and later on evaluation of the ecosystem and economic services rejoiced by the community in view of the evolving climate change related issues. The monitoring of the mangrove and coastal zone should include the study of species composition, population characteristics, growth rate of plants, abundance of the flora and fauna in order to estimate the diversity and health status at every season of the entire environment.

Soil erosion control

Shore line substratum erosion is a major threat to the intertidal habitats in DPA port jurisdiction. Often the rate of erosion is severe in the port environment due to the continuous vessel movement and the churning effect induced hydrological regime and other natural causes. During the present study it was noticed that few stretches in the Kandla creek are susceptible to erosion due to high water currents and tides. The dual purpose of controlling erosion and promoting intertidal biodiversity could be best achieved by installation of artificial reef structures, limestone rocks, laterite, cement and granite as well as bio reefs. Artificial coastal structures are cheap and installation is easy and adaptable and for better results it can be supplemented with the addition of a substrate that will support marine organisms as that of the natural intertidal and sub tidal environment. The structural diversity of the artificial reef will determine the diversity of marine organisms utilizing the created habitat. Artificial reefs once built will last for decades and would enrich marine biodiversity in a short period of time by providing ideal habitat for sessile and free-living benthic organisms and their larvae. Natural materials such as dead shells can be used for building artificial reefs and are environment-friendly. Reef balls are another form of artificial reef increasingly used in western countries to create sustainable marine reef habitat which may be easily attempted at Deendayal port Areas. Both reef balls and artificial reefs being inexpensive and locally available, can be built in different creek systems of the port jurisdiction. Application of coir mats are also suitable to control the shoreline erosion in the mangrove patches and open shore in conjunction with the rocky and cement structures.

8. Conservation and management Plan

Conservation of biodiversity is considered as the key component for administration of natural assets. Biodiversity is an all-encompassing concept that describes the magnitude of ecological diversity addressing the wide range of life associated with different types ecosystems. Biodiversity conservation is the protection and management of the biotic ad abiotic resources for sustainable development and existence and preservation of the diverse species, Sustainable utilization of species in the ecosystem along with the maintenance of the life-supporting systems are essential for the functioning of the various ecological processes. It is an integral part of any commercial activity and infrastructure development in the marine environment. Emphasis is given towards the reinstatement of the physical, chemical and biological characteristics of the coastal ecosystem which are much complex and vulnerable on which the human is highly dependent. Management of the marine biodiversity is the prime concern in the development of Ports and harbours which occupy the fragile continental shelf which is highly productive and supports numerous living resources. Hence Environmental Management Plan (EMP) is considered as an important component in any developmental activity with sustainable management goals which are to be fulfilled within a time frame. Thus, EMP aims to suggest concrete measures that would mitigate the impacts paving way for maintaining the integrity of the project environment.

Development of ports involves effective management plan towards environmental wellbeing that guarantees both sustainable port growth and a healthy ecosystem functioning in its vicinity. There is a need for innovative solutions for port development which are in harmony with the ecosystem and which are robust or adaptable under change. The recent trends like growth of global trade, increasing vessel movements and size, modernize port facilities, driving urgent investments in ports has been negatively impact water quality and marine flora and fauna. This simultaneously calls for sustainable and inclusive development which ensures productive nature of its marine environment.

The port authorities mandate to their activities environmentally sustainable and benign need to understand the marine ecological setting of their ports including water quality, biotic components and the factors that impact them. In spite of all the pressures, the ecosystem continues to deliver many services which are often intangible. In order to maintain these services intact, it is imperative that different biotic and abiotic components of the port environment are sustainably managed in the long run.

Accordingly Deendayal Port has initiated several environmental management measures as mandated by the MoEF &CC from time to time with the purpose of maintaining and preservation of its terrestrial and coastal environmental integrity. The following measures have been taken by the port authorities:

Ongoing Environment Management Measures by DPA

A holistic and comprehensive study on the marine ecology of the port including different marine faunal and floral components and preparation of management plan has been initiated like EC granted by MoEF&CC, GoI dated 18/2/2020, 19/2/2020 and 20/11/2020 as per the specific condition No. xviii of the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016. The results of the seasonal observations on the environmental characteristics and biodiversity of the intertidal zones have been compiled along with the conservation plan recommendation for three consecutive years (2017 to 2021).ii. Deendayal Port has already carried out 1600 ha of mangrove plantation since the year 2005-2006 in various location. The black mangrove *Avicennia marina* was used in these plantation activities as this species is more suitable to the existing environmental condition in this coast.

Based on the information gathered through the seasonal studies on the different biotopes and the biodiversity along with the mangrove, macrofauna, plankton density and diversity, productivity of mudflat and avifauna for the period 2018-2022 within the limits of the Deendayal port, it is evident that the impact is insignificant since management action plans are showing positive responses to a large extent in spite of the climate change induced impacts on the marine ecosystem. This project aims to draw a holistic management framework for conserving the Marine Biodiversity and Ecology of the DPA port marine environment which include many biotopes such as mangroves, intertidal and subtidal realms, mudflats and salt marshes, each serving as an abode for a variety of fauna and flora. Given the economic importance of DPA port and the increasing national and global demand for sustainability, it is planned to study the marine ecology of this port seasonally, with the long term objective of rendering the port existence and operations environmentally sustainable.The proceeding section outlines management initiatives to be undertaken by the port authorities for holistic management of marine biodiversity within the port limits envisaging several facilities will be built within port premises in the future.

Intertidal and Subtidal Biodiversity Management

The intertidal zone constitutes the coastal environment where land and sea meet, i.e., the area between extreme high-water springs (EHWSs) and extreme low water springs (ELWSs). The subtidal zone lies below the lowest water level beyond the intertidal zone. Both these zones provide habitats for various marine fauna and flora and needs to be managed effectively for the overall wellbeing of the ecosystem. In addition, intertidal zone biodiversity index did not vary very much in the recent years but the population density has not increased and remained stable. The intertidal zone may be susceptible to natural and anthropogenic pressures such as soil erosion, industrial pollution, continuous dredging and sedimentation. Hence, interventions are required to mitigate or support the natural recovery of the fauna in the bottom sediment. The sedentary benthic species produce a large number of their larva as an adaptation for their survival which get attached to the mangrove surfaces and metamorphose into adults and also serve as food for several fishes and shellfishes. Hence, soil erosion control interventions could help to improve the restoration of many benthos and plankton productivity. In the DPA vicinity, intertidal and subtidal zones are mostly dominated by clayey substratum admixed with silt and there are no rocky or sandy shores. The intertidal belts of the study area support many biological elements indicating the overall health of the ecosystem.

Study conducted from MAY 2022 to MAY-2023

The results on the quantitative and qualitative data of the intertidal organisms showed that the crustaceans (crabs) and mudskippers (Fish) are the predominant groups at all the sampling sites throughout the year. The other invertebrates which are generally inhabitants of the intertidal zone are very much restricted or even absent. It’s imperative to take measures to conserve and promote the intertidal biodiversity of DPA coastal / creek environments. Majority of the intertidal fauna were found particularly associated in the mangrove and halophyte habitats and many of them are true mangrove species. Mangroves provide natural habitats for a variety of intertidal macrofauna like crabs, gastropods, saw scale Viper and avifauna. Hence, promoting mangrove plantation or increasing mangrove cover would help to conserve the intertidal macrofauna. Mangroves, mudflats and intertidal creeks are the major ecological entities within the port boundary and they function in close synchrony with each other, thus their conservation and management call for a holistic approach.

Plankton and Productivity

Planktonic community and productivity were studied in the creek waters of Deendayal port jurisdiction fro the period 2022 to 2023. Diversity and density of phytoplankton community in DPA port creek environment was moderate as only 24 to 30 genera were reported during monsoon, post-monsoon and winter seasons. Similarly, a maximum of 35 genera of zooplankton have been reported during post-monsoon and winter. The productivity of the water column was low as indicated by the Chlorophyll 'a' pigment concentration, due to the prevalence of high rate of suspended solids which prevents the photosynthesis. However, the observed species diversity was moderate and support the biodiversity of the creek system.

Mangrove Management

DPA has around 26.52km^2 of mangroves cover in their jurisdiction which consists of many major and minor creek systems within its limit, port infrastructure occupies only ~1% of the total area. Establishment of facilities is a continuous process and the expansion of infrastructure over the coming years will bring remarkable changes in the landscape and seascape in and around the port area. Mangrove environment will continue to be stable and balanced if there are no external stressors such as change in hydrology, elevation and slope, soil and water salinity and pH, soil texture and wave energy are maintained in a natural condition without wide fluctuations. In addition, human centered stress factors such as resource collection, camel grazing, tree felling and other habitat modification activities are controlled. Generally, micro-topography controls the distribution and well-being of mangroves, and physical processes play a dominant role in the formation and functioning of the mangrove ecosystem through reproduction, seed germination and establishment of young plants. The mangrove forests undergo self-repair over a period of time, provided that the normal tidal hydrology is not disrupted and the availability of water borne seeds are not blocked. Regular monitoring of mangrove hydrology through simple scientific methods will go a long way in maintaining ecosystem balance. The natural regeneration capacity of the stand is to be assessed by quantifying the degree and extent of the entrance of younger classes such as saplings into the mature tree category. The ratio between these different size classes will indicate the dynamic state of the mangrove forest. Only if the natural seedling recruitment is not occurring does the system requires an assisted recovery by plantation and physical amendments. The present study displays that natural regeneration in the studied mangrove formations is expected, as indicated by the entry of younger classes into adult categories. In addition to *A. marina*, three species namely, *Rhizophora mucronata, Ceriops taga*l and *Aegiceras corniculatum*, have been recorded sporadically within DPA limits. It is strongly recommended that in all the future plantation efforts, these additional species also could be selected at appropriate locations and tidal levels.

Conservation of Island

Islands support a rich marine fauna, flora and avifauna diversity and deserve special conservation efforts. Land cover classification of Sat Saida Island using GIS tool revealed sparse and dense mangroves, mudflats and halophytic vegetation other than mangroves are other prominent land cover categories. Though equipped with all the features to support a dense mangrove formation, the mangroves of Sat Saida Island are rather sparse and scrubby and confined mostly to creek banks. Different elevation features of the Island render the tidal flooding and hydroperiod in the interior region poor resulting in sparse and open mangrove formations. This Island could be an ideal site for mangrove plantations while implementing ministry's mandated plantation activities, other mangrove restoration and rehabilitation activities with biophysical amendments such as de-silting existing creeks, joining existing minor creeks could be taken up which will increase the mangrove cover in this Island. These physical activities in the mangrove lined minor creeks will increase tidal flooding and hydro-period and convert sparse mangroves into dense mangroves in due course of time. Deendayal port has already carried out 1600 ha of mangrove plantation since 2005-2006 in various location.

Management plan to improve the water quality in the port area

- The drains and outfall should be cleaned regularly to avoid anaerobic decomposition and also for proper flow of water/wastewater. This will also enable the characterization of wastewater and calculation of waste load.
- Domestic and canteen wastewater should be discharged only after proper treatment.
- The solid waste generated from the canteen and other diffused sources should be collected and disposed properly for which modern purification system should be established.

- The discharge of oil waste into the sea from the following main sources should be controlled
  1. Discharge of oil waste from liquid chemical corridor area. This liquid waste is generated during tanker cleaning, and oil spills during filling operations,
  2. Oil spills at berth during unloading operations.
  3. Tanker ballast discharge from ships.
- Bulk material should not be disposed into the sea. All drains and roads should be cleaned before the rainy season to avoid runoff from land to sea carrying a myriad of pollutants, including chemicals that may be imposed for oily discharges in and around the port.

Management plan for marine fisheries

Regular dredging activities in the Port area can impact marine fauna and the flora particularly the phytoplankton and seaweeds. The fishes and other fishery resources such as shrimps and crabs are affected through noise and vibration levels, water quality and loss of habitat and food sources. Since fishes in the water column are free swimming in nature, they tend to avoid the turbid areas and move to safer zones. Once the turbidity increase becomes reversed due to sedimentation and dispersion by current and wave influences, the fishes are expected to occupy the area. Hence, there will be virtually no impact on fish due to dredging in the long term. As the area does not have any breeding ground for fisheries, no significant impact on marine ecology and particularly the fishes are anticipated during the dredging phase. The most important potential impact would be the rise in suspended solid load, which hinders the photosynthesis of the producer communities, especially the phytoplankton and affects the food chain. The high turbidity due to heavy suspended solids load during dredging and reclamation can result in the clogging of the gills of the filter feeding organisms, thereby causing asphyxiation.

Co-Management with the Community

Management program for mangroves is feasible in the case of Deendayal Port Authority since all the mangrove formations are under its legal control and hence any management program could be implemented without any sectoral conflicts with forest or any other government departments. It was proven in many instances that involving the stakeholder communities in the surrounding villages will yield better results in mangrove management. Though the population in the port surroundings has different livelihood activities, fishermen community could be targeted to involve in community-based mangrove management.

The fishermen in the villages such as Vera, Khari Rohar, and Tuna close to the port could be involved by forming "Samithies" for the conservation of mangroves with possible funding resources. The communities are expected to involve in the plantation and management activities for which awareness campaign and interactive sessions are to be conducted time to time and the feedback and experiences are to be recorded and duly acknowledged. The community's resource dependency, perception about the conservation of mangroves and associated flora and fauna and their level of involvement in such resource management activities are to be assessed before forming such a community-based organization. They could be assigned the specific task of conserving the mangroves by involving them in plantation/restoration activities, physical protection and other conservation measures. This could be taken up as part of the port's CSR activity.

Mannagement plan for Avifauna

1. Direct and indirect impact on ecologically sensitive ecosystems

The Deendayal SEZ project site located in the mid of the Deendayal Port area surrounded by port associated industrial sectors and salt industries. Since no Protected Areas located within 10 km radius of the SEZ site, impacts on sensitive ecosystem was not visualized.

2. Loss of Inter-tidal habitats - Coastal

- The project proponent (Deendayal Port Authority) should take up compensatory mangrove plantation in and around the project area
- The plantation needs to be carried out with fourfold density of seedlings compare to the natural mangrove density of the Kandla creek area and to maintain the density at the requirement stage
- This mangrove plantation expected to support mangrove associated bird species and thereby enhance the avifauna diversity of the local environment
- Since the intertidal (mangrove and creeks) and salt pan habitats supports few thousands of aquatic birds' species and migratory species, the project proponent should plan the establishment /construction activities (if any) outside the migratory season (November – February) to avoid the disturbance to the migratory species.

- The above suggested mangrove plantation needs to be monitored at least for the next five years till it attains maturity with the expert team to understand the growth rate and enhancement and assemblage of associated faunal species.
- Since the area located in the Intertidal habitat and adjacent areas supports thousands of aquatic avifauna, the project proponent (Deendayal Port authority) should take up long-term (five years) Ecological Monitoring Program of the adjacent creek, mangrove and salt pan habitats to assess the change in avifaunal diversity due the any developmental activities take place in the future project

9. Summary and Conclusion

Intertidal Fauna

The survey of the intertidal fauna of DPA Kandla area recorded the presence of 6 phyla (Nematoda, Nemertea, Annelida, Arthropoda, Mollusca and Chordata), including 26 species. The species diversity was the highest for phylum Mollusca (22), followed by Arthropoda (19), Annelida (4) and Nematoda, Nemertea, Chordata (1) respectively. The diversity indices around the DPA coastal environment were <3.0, indicating that the moderate impact of the environmental disturbances on the fauna. In the present observation, the species composition of the benthic macrofauna showed dominance of the following Phyla; Molluscs, Arthropoda, Annelida, Nematoda, Nemertea and Chordata only.

Subtidal Fauna

The subtidal fauna of the DPA Kandla survey recorded the presence of 4 phyla (Cnidaria, Annelida, Arthropoda and Mollusca,), including 26 species. The highest number of animals was documented during the post-monsoon particularly *Glauconome angulata* (51 no) followed by *Pirenella cingulata* (48 no). During pre-monsoon highest number of individuals was contributed by *Pirenella cingulata* (43 no) followed by *Glauconome angulata* (38 no). Similarly, in monsoon *Optediceros breviculum* (35 no) followed by *Pirenella cingulata* (27 no) were abundant , however, *Pirenella cingulata* was dominated in all the seasons.

Mangrove Environment

The overall average tree density of mangrove ranged from 3011/ha to 4602/ha during the period 2022 to 2023.

Halophytes

Halophytes are predominantly present in the premises of Deendayal Port since habitat conditions are suitable for halophytes at the inner part of Gulf of Kachchh. Halophytes are mostly found beyond the highest high tidal levels where spring tides reach occasionally and pore-water salinity often reaches >90 ppt. Their presence is widely noticed intermingled with mangrove formations in all the mudflats. During period of May 2022 to May 2023 4 halophyte species, respectively were recorded within the quadrates from 14sampling locations.

Conclusion

It is imperative to create strong baseline data on the marine environment in the port vicinity in tune with the spatial extent of developmental activities. Continuous marine ecological monitoring study since May 2017 focused on the biological and productivity of mudflats. Based on the detailed investigations of marine ecological components and the possible impacts of the DPA port environment, it could be concluded that the effects on the various biotic components are minimal and confined to high activity areas only with limited impacts on the surroundings. From 2017-2018, 2018-2019, 2019-2020, 2020-2021 and 2022 -2023 studies conducted by GUIDE, it was inferred that there was no significant variation with respect to taxa/genera/species composition as well as faunal density in all the sampling locations in the Deendayal port Authority and its surroundings.

In addition to biological parameters, the port authorities also cover essential physico-chemical parameters like water turbidity, suspended load, sediment texture, soil organic carbon, water nutrients like nitrate, nitrite, silicate and phosphate and petroleum hydrocarbons in the port environment are assessed from the selected sites during the period May 2022 to May 2023. Both biological and physico-chemical data on every season would be helpful in providing more insight into the ecological status of the Deendayal Port Authority. Hence it is recommended to continue the regular monitoring of the ecological status of the coastal and the adjoining land, inclusive of the Port adjoining peripheral land cover areas, to have an integrated management plan to fulfil the green port mission successfully.

Annexure 1: Overall Checklist of Avifauna recorded from the Study area

Sl No	Order	Family	Species	MS	Habitat	FG	IUCN-2023
1	Accipitriformes	Accipitridae	Black-winged Kite *Elanus caeruleus*	R	T	C	LC
2	Accipitriformes	Accipitridae	Western Marsh Harrier *Circus aeruginosus*	M	T	P,A,C,PD	LC
3	Accipitriformes	Accipitridae	Shikra *Accipiter badius*	R	T	C	LC
4	Accipitriformes	Pandionidae	Osprey *Pandion haliaetus*	RM	T	P	LC
5	Caprimulgiformes	Apodidae	Indian House Swift *Apus affinis*	M	T	I	LC
6	Charadriiformes	Scolopacidae	Black-tailed Godwit *Limosa limosa*	M	A	IN	NT
7	Charadriiformes	Scolopacidae	Common Sandpiper *Actitis hypoleucos*	R	A	IN	LC
8	Charadriiformes	Scolopacidae	Whimbrel *Numenius phaeopus*	M	A	IN	LC
9	Charadriiformes	Scolopacidae	Marsh Sandpiper *Tringa stagnatilis*	M	A	IN	LC
10	Charadriiformes	Burhinidae	Eurasian Thick-knee *Burhinus oedicnemus*	R	A	IN	LC
11	Charadriiformes	Charadriidae	Common Ringed Plover *Charadrius hiaticula*	RM	A	IN	LC
12	Charadriiformes	Scolopacidae	Dunlin *Calidris alpina*	M	A	IN	LC
13	Charadriiformes	Recurvirostridae	Black-winged Stilt *Himantopus himantopus*	R	A	IN	LC
14	Charadriiformes	Charadriidae	Red-wattled Lapwing *Vanellus indicus*	R	T	I,IN	LC
15	Charadriiformes	Scolopacidae	Little Stint *Calidris minuta*	M	A	IN	LC
16	Charadriiformes	Scolopacidae	Sanderling *Calidris alba*	RM	A	P	LC
17	Charadriiformes	Laridae	River Tern *Sterna aurantia*	R	A	P	LC
18	Charadriiformes	Laridae	Lesser Black-backed Gull *Larus fuscus*	M	A	P	LC
19	Charadriiformes	Recurvirostridae	Pied Avocet *Recurvirostra avosetta*	M	A	IN	LC
20	Charadriiformes	Burhinidae	Great Thick-knee *Esacus recurvirostris*	R	A	AP/I	LC
21	Charadriiformes	Charadriidae	Yellow-wattled Lapwing *Vanellus malabaricus*	R	T	I	LC

Sl No	Order	Family	Species	M S	Habitat	FG	IUCN-2023
22	Charadriiformes	Charadriidae	Little Ringed Plover *Charadrius dubius*	M	A	IN	LC
23	Charadriiformes	Charadriidae	Lesser Sand Plover *Charadrius mongolus*	M	A	IN	LC
24	Charadriiformes	Charadriidae	Greater Sand Plover *Charadrius leschenaultii*	M	A	IN	LC
25	Charadriiformes	Scolopacidae	Eurasian Curlew *Numenius arquata*	R M	A	IN	NT
26	Charadriiformes	Scolopacidae	Spotted Redshank *Tringa erythropus*	M	A	IN	LC
27	Charadriiformes	Scolopacidae	Common Greenshank *Tringa nebularia*	M	A	IN	LC
28	Charadriiformes	Scolopacidae	Common Redshank *Tringa totanus*	M	A	IN	LC
29	Charadriiformes	Scolopacidae	Wood Sandpiper *Tringa glareola*	M	A	IN	LC
30	Charadriiformes	Dromadidae	Crab-plover *Dromas ardeola*	M	A	IN	LC
31	Charadriiformes	Laridae	Black-headed Gull *Chroicocephalus ridibundus*	M	A	IN	LC
32	Charadriiformes	Laridae	Brown headed Gull *Chroicocephalus bunnicephalus*	M	A	IN	LC
33	Charadriiformes	Laridae	Little Gull *Hydrocoloeus minutus*	M	A	IN	LC
34	Charadriiformes	Laridae	Little Tern *Sternula albifrons*	M	A	IN	LC
35	Charadriiformes	Laridae	Caspian Tern *Hydroprogne caspia*	M	A	IN	LC
36	Columbiformes	Columbidae	Rock Pigeon *Columba livia*	R	T	G	LC
37	Columbiformes	Columbidae	Laughing Dove *Streptopelia senegalensis*	R	T	G	LC
38	Columbiformes	Columbidae	Eurasian Collared Dove *Streptopelia decaocto*	R	T	G	LC
39	Coraciiformes	Alcedinidae	Common Kingfisher *Alcedo atthis*	R	A	P,A,IN	LC
40	Coraciiformes	Alcedinidae	White-throated Kingfisher *Halcyon smyrnensis*	R	A	P,A,IN	LC
41	Coraciiformes	Alcedinidae	Pied Kingfisher *Ceryle rudis*	R	A	P,A,IN	LC
42	Coraciiformes	Meropidae	Green Bee-eater *Merops orientalis*	R	T	I	LC
43	Coraciiformes	Coraciidae	Indian Roller *Coracias benghalensis*	M	T	I,RP	LC
44	Coraciiformes	Coraciidae	European Roller *Coracias garrulus*	M	T	I,RP	LC

Sl No	Order	Family	Species	M S	Habitat	FG	IUCN-2023
45	Gruiformes	Rallidae	Common Moorhen *Gallinula chloropus*	R	A	H,I,IN	LC
46	Gruiformes	Rallidae	Watercock *Gallicrex cinerea*	R	A	IN	LC
47	Passeriformes	Cisticolidae	Ashy Prinia *Prinia socialis*	R	T	I	LC
48	Passeriformes	Leiothrichidae	Common babblar *Argya caudata*	R	T	G	LC
49	Passeriformes	Corvidae	House Crow *Corvus splendens*	R	T	O	LC
50	Passeriformes	Dicruridae	Black Drongo *Dicrurus macrocercus*	R	T	I	LC
51	Passeriformes	Estrildidae	Indian Silverbill *Euodice malabarica*	R	T	G	LC
52	Passeriformes	Passeridae	House Sparrow *Passer domesticus*	R	T	G	LC
53	Passeriformes	Ploceidae	Baya Weaver *Ploceus philippinus*	R	T	G	LC
54	Passeriformes	Muscicapidae	Indian Robin *Saxicoloides fulicatus*	R	T	I	LC
55	Passeriformes	Sturnidae	Rosy Starling *Pastor roseus*	M	T	O	LC
56	Passeriformes	Sturnidae	Common Myna *Acridotheres tristis*	R	T	O	LC
57	Passeriformes	Hirundinidae	Wire-tailed Swallow *Hirundo smithii*	R	T	I	LC
58	Passeriformes	Hirundinidae	Red-rumped Swallow *Cecropis daurica*	R	T	I	LC
59	Passeriformes	Hirundinidae	Dusky Crag Martin *Ptyonoprogne concolor*	R	T	I	LC
60	Passeriformes	Pycnonotidae	Red-vented Bulbul *Pycnonotus cafer*	R	T	FU,I,H	LC
61	Passeriformes	Pycnonotidae	White-eared Bulbul *Pycnonotus leucotis*	R	T	FU,I	LC
62	Passeriformes	Cisticolidae	Plain Prinia *Prinia inornata*	R	T	I	LC
63	Passeriformes	Alaudidae	Crested Lark *Galerida cristata*	R	T	G,I	LC
64	Passeriformes	Nectariniidae	Purple Sunbird *Cinnyris asiaticus*	R	T	N	LC
65	Passeriformes	Motacillidae	Western Yellow Wagtail *Motacilla flava*	R M	A	I	LC
66	Passeriformes	Motacillidae	Citrine Wagtail *Motacilla citreola*	R M	A	I	LC
67	Passeriformes	Motacillidae	White-browed Wagtail *Motacilla maderaspatensis*	M	A	I	LC

Sl No	Order	Family	Species	MS	Habitat	FG	IUCN-2023
68	Passeriformes	Hirundinidae	Streak-throated Swallow *Petrochelidon fluvicola*	M	T	I	LC
69	Pelecaniformes	Phalacrocoracidae	Little Cormorant *Microcarbo niger*	R	A	P	LC
70	Pelecaniformes	Phalacrocoracidae	Indian Cormorant *Phalacrocorax fuscicollis*	R	A	P	LC
71	Pelecaniformes	Ardeidae	Grey Heron *Ardea cinerea*	RM	A	P,A	LC
72	Pelecaniformes	Ardeidae	Great Egret *Ardea alba*	RM	A	P,A	LC
73	Pelecaniformes	Ardeidae	Little Egret *Egretta garzetta*	R	A	I,P,A	LC
74	Pelecaniformes	Ardeidae	Cattle Egret *Bubulcus ibis*	R	T	I,P,A	LC
75	Pelecaniformes	Ardeidae	Indian Pond Heron *Ardeola grayii*	R	A	I,P,A	LC
76	Pelecaniformes	Ardeidae	Purple Heron *Ardea purpurea*	RM	A	P,A,OP	LC
77	Pelecaniformes	Ardeidae	Intermediate Egret *Ardea intermedia*	R	A	I,P,A	LC
78	Pelecaniformes	Ardeidae	Western Reef Egret *Egretta gularis*	R	A	I,P,A	LC
79	Pelecaniformes	Pelecanidae	Great White Pelican *Pelecanus onocrotalus*	RM	A	P	LC
80	Pelecaniformes	Threskiornithidae	Black-headed Ibis *Threskiornis melanocephalus*	RM	A	A,IN,I,W	NT
81	Pelecaniformes	Threskiornithidae	Indian Black Ibis *Pseudibis papillosa*	R	T	I,G,RP	LC
82	Pelecaniformes	Threskiornithidae	Eurasian Spoonbill *Platalea leucorodia*	RM	A	A,IN,I,W	LC
83	Pelecaniformes	Ciconiidae	Painted Stork *Mycteria leucocephala*	RM	A	P,IN	NT

Sl No	Order	Family	Species	MS	Habitat	FG	IUCN-2023
84	Pelecaniformes	Phalacrocoracidae	Great Cormorant *Phalacrocorax carbo*	R	A	P	LC
85	Pelecaniformes	Anhingidae	Oriental Darter *Anhinga melanogaster*	R	A	P.A,OP	NT
86	Phoenicopteriformes	Phoenicopteridae	Lesser Flamingo *Phoeniconaias minor*	RM	A	PL	NT
87	Phoenicopteriformes	Phoenicopteridae	Greater Flamingo *Phoenicopterus roseus*	RM	A	PL,IN	LC
RM= Resident Migrant; R=Resident; M=Migratory; T=Terrestrial; A= Aquatic; FU=Frugivore; N=Nectarivore; P=Piscivore; G=Granivore; C=Carnivore; I=Insect and other terrestrial invertebrate feeder; PL=Plankton Feeder; IN=Aquatic Invertebrate feeder; A=Amphibian feeder; OP=Ophidiovore; RP=Reptile feeder; W= weedivore; H=Herbivore; PD=Predatory; NT= Near Threatened; LC= Least Concern							

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Kandla

Annexure -D

INCEPTION REPORT

Third year May 2023 to May 2024

For the project entitled

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

DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/11

Submitted to

DEENDAYL PORT AUTHORITY

Administrative office Building

Post Box No. 50, Gandhidham (Kachchh)

Gujarat-370201

Submitted by

GUJARAT INSTITUTE OF DESERT ECOLOGY

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1. INTRODUCTION

1.1. Deendayal Port is located at Kandla in the Kachchh district of Gujarat state, operated by Deendayal Port Authority (DPA) 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 includes edible oil, crude oil and other petroleum products. Cargo handling has increased from 127 MMT to135 MMT during 2022-2023. 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 at Vadinar for handling oil. Regular expansion or developmental activities such as the addition of jetties, allied SIPC and ship bunkering facilities are underway inorder 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.

1.2. 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 19/12/16 Development of 7 integrated facilities – specific condition no. xviii.

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

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

1.3. Study Area

The coastal belt in and around DPA port jurisdiction is characterized by a network of creek systems and mudflats which are covered by sparse halophytic vegetation like scrubby to dense mangroves, creek water and salt-encrusted landmass which forms the major land component. The surrounding environment in a radius of 10 km from the port includes built-up areas, salt pans, human habitations and port related structures on the west and north and creek system, mangrove formations and mudflats in the east and south (**Error! Reference source not found.**). The nearest major habitation is Gandhidham town about 12 km west with a population of 2, 48,705 (as per 2011 census).

1.4. Background of the Present Study

As part of its ongoing developmental activities, Deendayal Port Authorities intend to develop seven (7) integrated facilities which include development of oil jetty and ship bunkering terminal at old Kandla, a multi-purpose oil terminal near Tuna, up-gradation of barge handling facility at Kandla, construction of one rail over bridge and strengthening of existing oil jetties. While according environmental clearance to these developmental initiatives, MoEF & CC, among other conditions, stipulated the following: ***"Marine Ecology shall be monitored Regularly also in terms of Seaweeds, Sea grasses, Mudflats, Fisheries, Echinoderms, Shrimps, Turtles, Corals, Coastal vegetation, Mangroves and other Biodiversity components as a part of the management plan. Marine ecology shall be monitored regularly also in terms of all Micro, Macro and Mega floral and faunal components of marine biodiversity".***

In accordance with this directive, DPA assigned the task of carrying out a holistic marine ecological monitoring study to Gujarat Institute of Desert Ecology (GUIDE), Bhuj during May 2018-21. Since marine ecological components are to be studied regularly as stipulated by the Ministry, DPA authorities approached GUIDE to continue the study for another three years, i.e. 2021 – 2024.

The inception report is prepared considering the 4 months of work activity in the Project (May 2023to August 2023). The present project is designed considering the scope of work given in the EC conditions with the specific objectives as follows

2. Scope of the Work

The scope of the present investigation includes different physcio chemical and marine biological component as mentioned in the above stipulations of MoEF & CC EC & CRZ clearance dated 18th and 19th February 2020 with specific conditions xxiii, xv, iv, xix and xiv respectively. A detailed holistic approach to different components of marine Physico-chemical and marine biodiversity within the Deendayal Port area has been carried out. Based on the results obtained during the project period, a detailed management plan has been drawn at the end of the project. The biological and physicochemical variables have been investigated during the present study on seasonal basis i.e. monsoon, post monsoon and pre-monsoon for the period May 2023 to May 2024 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.

3. Sampling locations (2023-2024)

Locations	GPS coordination	
	Latitude	Longitude
S1	22.9410	70.1358
S2	22.9616	70.1244
S3	22.9876	70.2345
S4	23.0285	70.2331
S5	23.0804	70.2245
S6	23.1622	70.3951
S7	22.9771	70.2125
S8	23.0378	70.4070
S9	22.9960	70.3932
S10	23.1007	70.2961
S11	23.1608	70.4948
S12	22.9446	70.1062
S13	22.9067	70.0002
S14	22.8959	70.0745
S15	23.0654	70.2172

Fig.1. Maps showing the sampling location of the year 2023-2024

4. Sampling Parameters

Sampling will be carried out in surface and bottom water for physical and chemical characteristics of coastal water in the proposed developmental site. Similarly, physical and chemical characteristics of sediment in the proposed site will be analyzed. Biological parameters (benthic and pelagic fauna & flora, productivity) will also be included. The following table shows the parameters planned to be gathered.

Table 1: Parameters to be study

<table>
<tr><th colspan="3">Parameters</th></tr>
<tr><th>Water Quality</th><th>Mangrove</th><th>Intertidal fauna</th></tr>
<tr><td>pH
Temperature
Salinity (ppt)
Petroleum Hydrocarbon-PHc
DO
Total Suspended Solids (TSS)
Total Dissolved solids (TDS)</td>
<td rowspan="8">Mangrove- vegetation structure including density, diversity, height, canopy and other vegetation characteristics.

Halophytes: occurrence, distribution, and diversity

Sea grasses, seaweeds: occurrence, distribution, and diversity.</td>
<td rowspan="8">Intertidal faun: composition, distribution, diversity, density and other characteristics, other mega faunal components such as mammals, reptiles and amphibians.

Avifauna: Density, diversity, composition, habitat, threatened and endangered species and characters</td></tr>
<tr><td>Nutrients</td></tr>
<tr><td>Nitrate (NO_3)
Nitrite (NO_2)
Total phosphate
Silicate
Ammonia (NH_4)
Total Nitrogen</td></tr>
<tr><td>Sediment Quality</td></tr>
<tr><td>Texture
Total organic carbons (TOC)
Total Nitrogen
Total Phosphorus
Petroleum Hydrocarbon-PHc</td></tr>
<tr><td>Biological Parameters</td></tr>
<tr><td>Phytoplankton – Species, abundance, diversity and biomass
Productivity-Chlorophyll a
Zooplankton – Species, abundance, diversity and biomass
Macrobenthos - Species, abundance, diversity
Fishery Resources - Common fishes available, composition, diversity, Catch Per Unit Effort (CPUE)</td></tr>
</table>

5. Working Methodology

5.1. Water Quality

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

5.2. **Temperature:** Temperature will be recorded using a mercury thermometer with an accuracy of 0.1°C.

5.3. **pH:** pH will be measured on a microprocessor controlled pH analyzer. The instrument has been calibrated with standard buffers before use.

5.4 Suspended Solids (SS): A known volume of water will be filtered through a pre-weighed0.45 micron membrane filter paper (Millipore), dried and weighed again.

5.5. Turbidity: Turbidity will be measured in a calibrated Nephelometer (Hanna make) and the results will be expressed in Nephelometer Turbidity Unit (NTU).

5.6 Salinity: A suitable volume of the sample will be titrated against silver nitrate (25g/l) with potassium chromate as an indicator. Standardization of silver nitrate was done using standard seawater (IAPSO, OSIL, UK).

5.7. Dissolved oxygen (DO): DO will be determined by Winkler's method.

5.8. Phosphate: Acidified molybdate reagent will be added to the sample to yield a phosphomolybdate complex that will be reduced with ascorbic acid to a highly coloured blue compound, which was measured at the wavelength of 690 nm in spectrophotometer (Shimadzu UV 5040).

5.9. Total phosphorus: Phosphorus compounds in the sample will be oxidized to phosphate with alkaline potassium per sulphate at high temperature and pressure. The resulting phosphate will be analyzed and described as total phosphate.

5.10. Nitrite: Nitrite in water sample will be allowed to react with sulphanilamide in acid solution. The resulting diazo compound has reacted with N-1-

Naphthylethylenediaminedihydrochloride to form a highly coloured azo-dye. The light absorbance will be measured at the wavelength of 543 nm in spectrophotometer (Shimatzu UV 5040).

5.11. Nitrate: Nitrate will be determined as nitrite (as mentioned above) after its reduction bypassing the sample through a column packed with amalgamated cadmium.

5.12. Ammonia: Ammonium compounds (NH_3^+ NH_4^+) in water will be reacted with phenol in presence of hypochlorite to give a blue colour of indophenol. The absorbance will be measured at the wavelength of 630 nm.

5.13. Total nitrogen: Nitrogen compounds in the sample will be oxidized to nitrate by autoclaving with alkaline per sulphate. The solution will be neutralized and nitrate will be estimated and described as total nitrate.

5.14. Silicate: The method is based on the reaction between silicate ions and excess ammonium molybdate reagent to give a yellow silico-molybdic complex. This complex is then reduced to the heteropoly blue compound by means of ascorbic acid. Absorbance values are measured at 830 nm, and are stable for more than 2 h

5.15. Petroleum Hydrocarbons (PHs): Water sample (2.5 l) will be extracted with hexane and the organic layer will be separated, dried over anhydrous sodium sulphate and reduced to 10 ml at 30^{o}C under low pressure. Fluorescence of the extract will be measured at 360 nm (excitation at 310 nm) with Saudi Arabian crude residue as a standard. The residue will be obtained by evaporating lighter fractions of the crude oil at 100°C.

6. Sediment Quality

Sediment analyses will be carried out using standard methodologies. Sediment samples will be collected in prefixed stations in using a Van Veen grab or by a non-metallic plastic spatula. In each location (grid), sediment samples will be collected from the three different locations and will be pooled together to make it composite sample, representative of a particular site. Collected samples will be stored in a sterile, black polythene bag at 4^{o}C in an icebox to avoid possible bio leaching of metals by microbes. The collected samples will be in air dried and used for further analysis.

6.1. Sediment Texture

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

6.2. Total Phosphorus

The phosphate in sediment solution reacts with ammonium molybdate and form molybdophosphoric acid, which gets reduced to a complex of blue colour in the presence of stannous chloride. The absorption of light by this solution was measured at 690 nm to calculate the phosphate concentration.

6.3. Total Nitrogen

Total Nitrogen present in the sediment samples will be measured following the Kjeldah Method.

6.4. Organic carbon

Percentage of organic carbon in the dry sediment was determined by oxidizing organic matter in the sample by chromic acid and estimating excess chromic acid by titrating against ferrous ammonium sulphate with ferroin as an indicator.

6.5. Petroleum Hydrocarbon-PHc

For estimating Petroleum hydrocarbon (PHc) in sediment, the sample will be reflexed with KOH-Methanol mixture and extracted with hexane. After removal of excess hexane, the residue will be subjected to silica gel chromatography and PHC and the florescence will be estimated at 360 nm.

7. Mangrove assessment

Total fifteen (15) sites will be primarily considered which will be widely distributed and covered the entire DPT jurisdiction. The mangrove sites will be named Tuna, Jangi, Kandla, Phang creek, Vira coast and Navlakhi based on the nearest location to their respective creek system. The vegetation structural attributes of all the mangrove stands will be based on Point Centered Quadrate Method (PCQM). The methodology and measurement accuracy of Cintron & Novelli (1984) will be adopted to study both measurements of density, height variations and basal area at each stand. A transect of a maximum of 200 m will be laid out either perpendicular or parallel to the creek and sampling points at an interval of 10 m will be fixed to record the vegetation structure of the stand. Along the transects, sub-plots of 1×1 m^2 and 2×2 m^2 will be laid randomly to enumerate regeneration and recruitment class, respectively. Seedlings with a height of <50 cm will be considered as regeneration class, while recruitment class will be well-established saplings >50cm in height.

8. Intertidal Fauna, Marine Mammals and Reptiles: Sample collection and assessment of intertidal communities will be done in the intertidal zone during the low tide period. At each site, 1 m^2 quadrates will be placed randomly and all visible macro-faunal organisms encountered inside the quadrate will be identified, counted and recorded. At each site along the transects which ran perpendicular to the waterfront, three to six replicate quadrate samples will be assessed for the variability in macro-faunal population structure and the density will be averaged for the entire intertidal belt. Organisms, which could not be identified in the field, will preserved in 5% formaldehyde, bring to the laboratory and identified using standard identification keys (Abott, 1954; Chapgar, 1957; Apte, 1998). Average data at each site will be used to calculate the mean density (No/m^2).

9. Subtidal Macro Benthic Fauna: For studying the benthic organisms, triplicate samples will be collected at each station using Van Veen grab which covered an area of 0.04m^2. The wet sediment will be passed through a sieve of mesh size 0.5 mm for segregating the organisms. The organisms retained in the sieve will be fixed in 5-7% formalin and stained further with Rose Bengal solution for the ease of spotting at the time of sorting. The number of organisms in each grab sample will be expressed as No. /m^2. All the species will be sorted, enumerated and identified by following available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; SubbaRao *et al.* (1991) and Ramakrishna (2003) for molluscs.

Further, the data will be treated with following univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clark & Warwick, 2001).

10. Phyto and Zooplankton: Plankton samples will be collected from prefixed 15 sampling sites from DPT location. Plankton samples will be collected using standard plankton net with a mesh size of 51µm and 200µm and a mouth area of 0.1256 m^2 (20 cm radius). The net fitted with a flow meter (Hydrobios) will be towed from a motorized boat at 2 nautical miles/hr. Plankton adhering to the net will be concentrated in the net bucket by splashing seawater. The plankton retained will be transferred to a pre-cleaned and rinsed container and preserved with 5% neutralized formaldehyde and appropriately labelled indicating the details of the collection and transferred to the laboratory for further analysis.

The Quantitative analysis of phytoplankton (cell count) will be carried out using a Sedge wick-Rafter counting chamber. Exactly 1 ml of the well mixed sample added to a Sedgwick counting chamber will be observed under an inverted compound microscope. The number of cells present in individual cells of the counting chamber (1/1000) will be noted and identified up to species level. Several observations were made to represent the entire quantity of the soup (generally >30 times) and the recorded data will be used for further calculations with which density and diversity of the plankton in l liter of the seawater will be calculated.

The density (No/l) wil be calculated using the formula: $N=n\times v/V$

(Where, N is the total no/liter, n is average no of cells in 1 ml, v is the volume of concentrate; V is the total volume of water filtered.

11. Marine Fishery: Fishery resources and diversity will be assessed in the sampling sites. Samples of finfish and shell fish will be collected using a gill net with 10 mm mesh size. The net will operated onto the water from the canoe or by a person standing in waist during the high tide start. For effective sampling, sampling points were fixed at regular distance in 15 sites close to areas where parameters such as plankton and subtidal fauna will be investigated. In each sampling point, the gill net will be deployed 5 times and the CPUE (Catch Per Unit Effort) was estimated per hour. The collected specimens will be segregated into groups, weighed and preserved in 10% neutralized formalin solution. Finfishes will be identified following Fischer & Bianchi (1984), Masuda *et al*. (1984), de Bruin *et al*. (1995) and Mohsin & Ambiak (1996). Relevant secondary information pertaining to fishery resources of Deendayal Port creek systems has been gathered through technical reports, district fisheries department, Government gazette and other research publications

12. Halophytes: To quantify and document the halophytes at Deendayal Port region, quadrate method will be followed. At each sampling location quadrates of various sizes will be laid in each season. For trees, the quadrates of 10 x 10 m will be laid. Quadrates of 5 x 5 m and 1 x 1 m will be laid within each tree quadrate to record shrubs and herbs, respectively (Misra, 1968; Kershaw, 1973; Bonham, 1989). Four quadrates each for shrubs and herbs will be laid in each tree quadrate to assess the halophytes in the study area. To enrich the species inventory, areas falling outside the quadrates will be also explored and the observed species will be recorded and photographed. Specimens of species will be collected to know more information on habitat and for preparation of herbarium specimens. The species will be identified using standard keys.

13. Avifauna: The mangrove habitat along the Gulf of Kachchh will be delineated into 15 major sites based on the subjective magnitude of anthropogenic pressure. In each project site creeks will be of varying length from 2 to 5 km. These creeks will be surveyed by using boat and adopting "line transect" method. A total of 12 transect (one at each site) will be placed to count the birds. Survey will be done in both terrestrial habitats like natural mangrove and plantation adjoining the mudflats and wasteland, and aquatic habitats like creek area, rivers and wetland.

14. Data Analysis

Data collected *in situ* and through laboratory analysis of samples were subjected to descriptive statistical analysis (PAST) for mean, range and distribution of different variable.

Table 2: Timeline – Organization of work (Yearly) for the period May 2023 to May 2024

Project Activities	1st Quarter (June-September)	2nd Quarter (October-January)	3rd Quarter (February-May)
Review of literature related to study Permission related to field work Planning and orientation of project objectives Initiation of inception study Submission of inception report **Monsoon sample collection**			
Sample analysis First season report Submission			
Post-monsoon season sample collection Sample analysis Second season report Submission			
Pre-monsoon season sample collection Sample analysis Third season report Submission			
Final Draft Report Submission			
Final Report Submission			

Details of work activity to be conducted for the First Quarter (June 2023-September 2023) :

In this first quarter of the study, The GUIDE team has visited the coastal stretches of DPA port jurisdiction for reconnaissance survey. After reconnaissance survey and permission from the above authorities, first season (monsoon : June to September) field wok will be conducted and the sampling will be undertaken as per the standard protocols and first season (Monsoon) report will be submit .

Details of work activity to be conducted for the Second Quarter (October 2023-January 2024)

During the second quarter, the field work will be conducted during the post monsoon season between October 2023 and January 2024. The samples will be collected as per standard protocols. The samples analyzed and validate the data based on the standard references. All the data will incorporated and submitted the second seasonal report (Post-monsoon) to the DPA office.

Details of work activity to be conducted for the third quarter during February 2024 to May 2024

During the third quarter, the analysis of samples collected during the season 3 pre-monsoon as per standard protocols. The data will be analyzed and validated based on the standard references.

Final Report

All three seasonal data (monsoon, post-monsoon and pre-monsoon) will be pooled together and incorporated to prepare the annual report will be submitted to the DPT by the end of the year as Final report.

Annexure -E

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: October-November, 2023)

Document Ref No.: GEMI/DPA/782(2)(2)/2023-24/54

Submitted to:
Deendayal Port Authority (DPA), Kandla

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"

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 (October-November, 2023)"* is prepared.

- **Name of the Report:** *Environment Monitoring Report (October-November, 2023)*
- **Date of Issue:** 19/12/2023
- **Version:** 1.0
- **Report Ref.:** GEMI/DPA/782(2)(2)/2023-24/54

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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.

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 monitoring period of 17th October-16th November, 2023.

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.

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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 **Figure 1** as follows:

Figure 1: Locations Map of Kandla and Vadinar

Figure 2: Map of Kandla Port

Figure 3: Map 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 4** as given below:

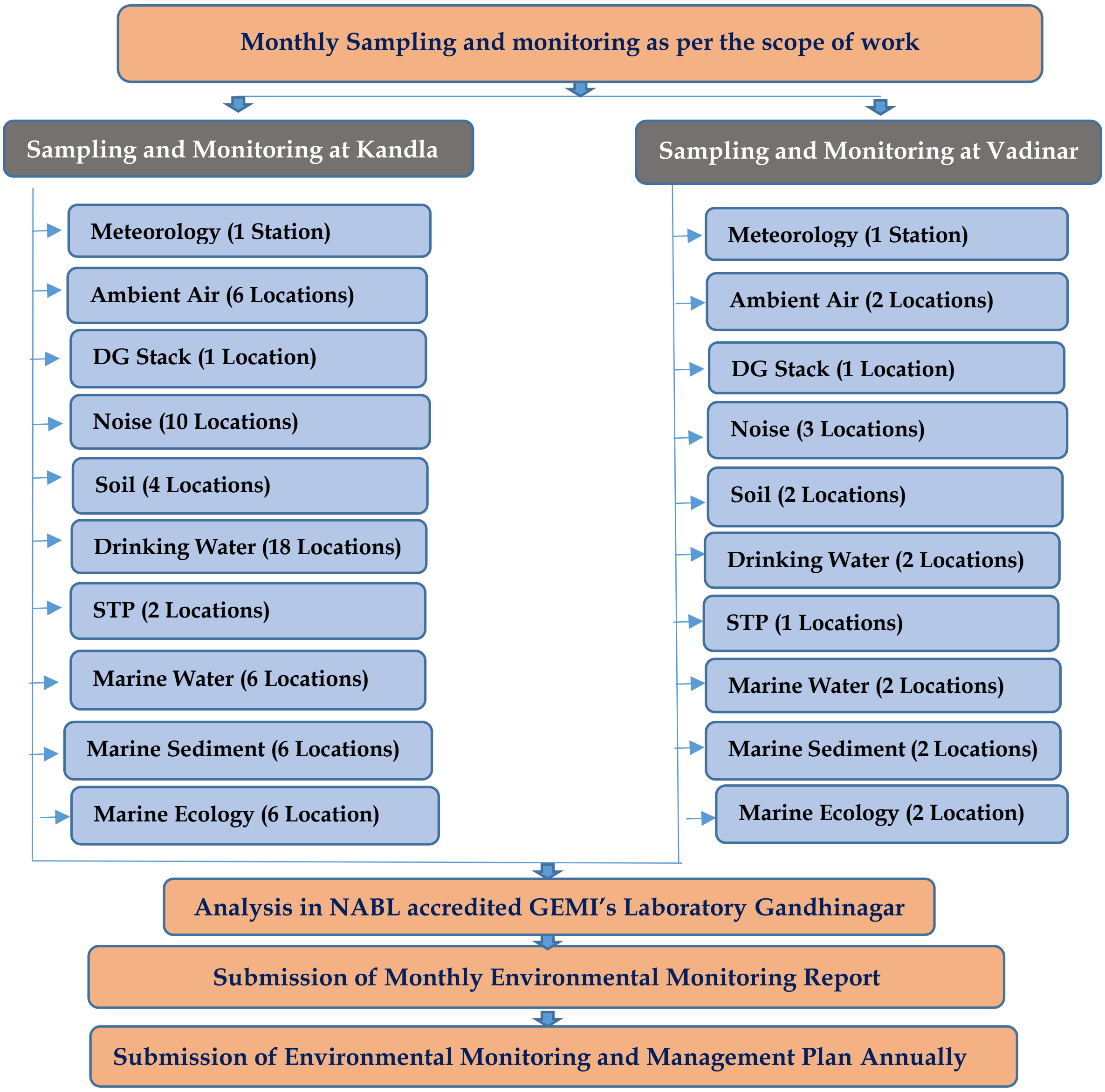

Figure 4: Methodology flow chart

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

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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

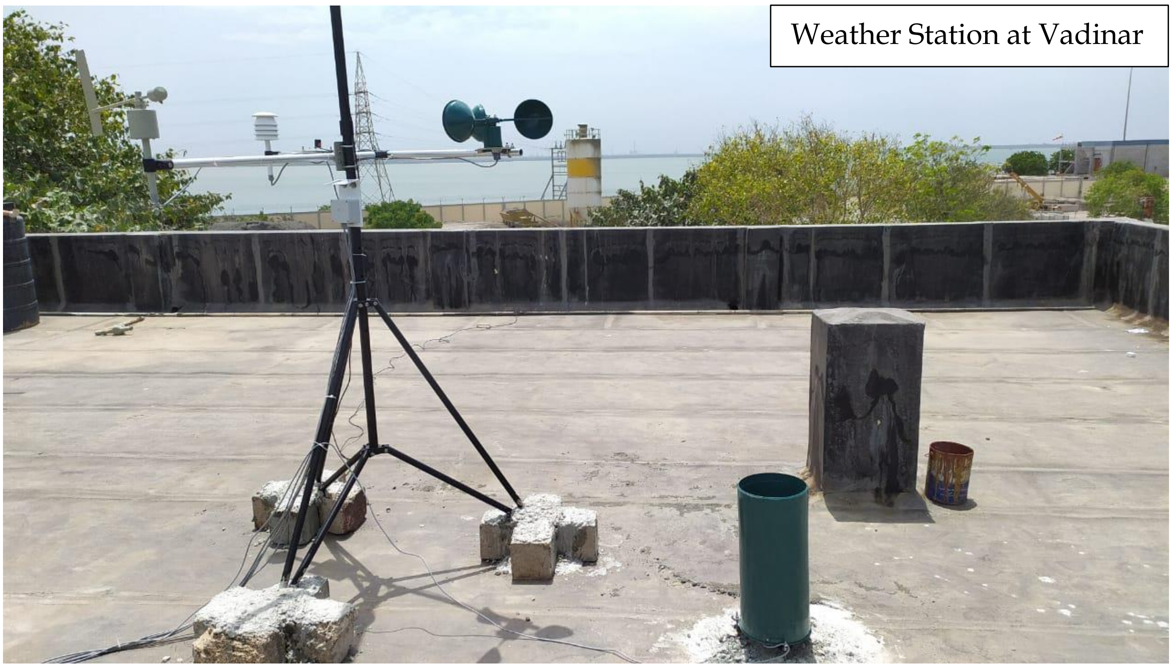
During the study, a continuous automatic weather monitoring station was installed at both the sites to record climatological parameters such as Wind speed, Wind Direction, Relative Humidity, Solar Radiation, Rainfall and Temperature to establish general meteorological regime of the study area. The methodology 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	^oC		
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.

Weather Station at Kandla



Weather Station at Vadinar

Figure 5: 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			
September-October 2023	1.15	9.85	0.025	30.41	31.24	29.63	52.18	55.40	49.02	65.11	North	0.012
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**			
September-October 2023	4.17	13.80	1.77	27.28	27.89	27.10	61.15	63.61	59.58	81.61	North-east	0.18

3.3 Data Interpretation and Conclusion

- **Temperature**

a. **Kandla:** The ambient temperature for the monitoring period varies between the range of 29.63-31.24°C for Kandla, with average temperature of 30.41°C.
b. **Vadinar:** The ambient temperature for the monitoring period varies between the range of 27.1-27.89°C for Vadinar, with average temperature of 27.28°C.

- **Relative Humidity**

a. **Kandla**: The Relative Humidity recorded between the range of 49.02-55.40%, with average Humidity of 52.18%.
b. **Vadinar:** During the study period, the Relative Humidity varies between 59.58-63.61%, with average Humidity of 61.15%.

- **Rainfall**

a. **Kandla:** The average rainfall during the monitoring period was found to be 0.012 mm.
b. **Vadinar:** The average rainfall was found to be 0.18 mm.

- **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 0.025-9.85 Km/hr.
b. **Vadinar:** During the monitoring period, the Wind speed recorded ranges between 1.77-13.80 Km/hr.

- **Solar Radiation:**

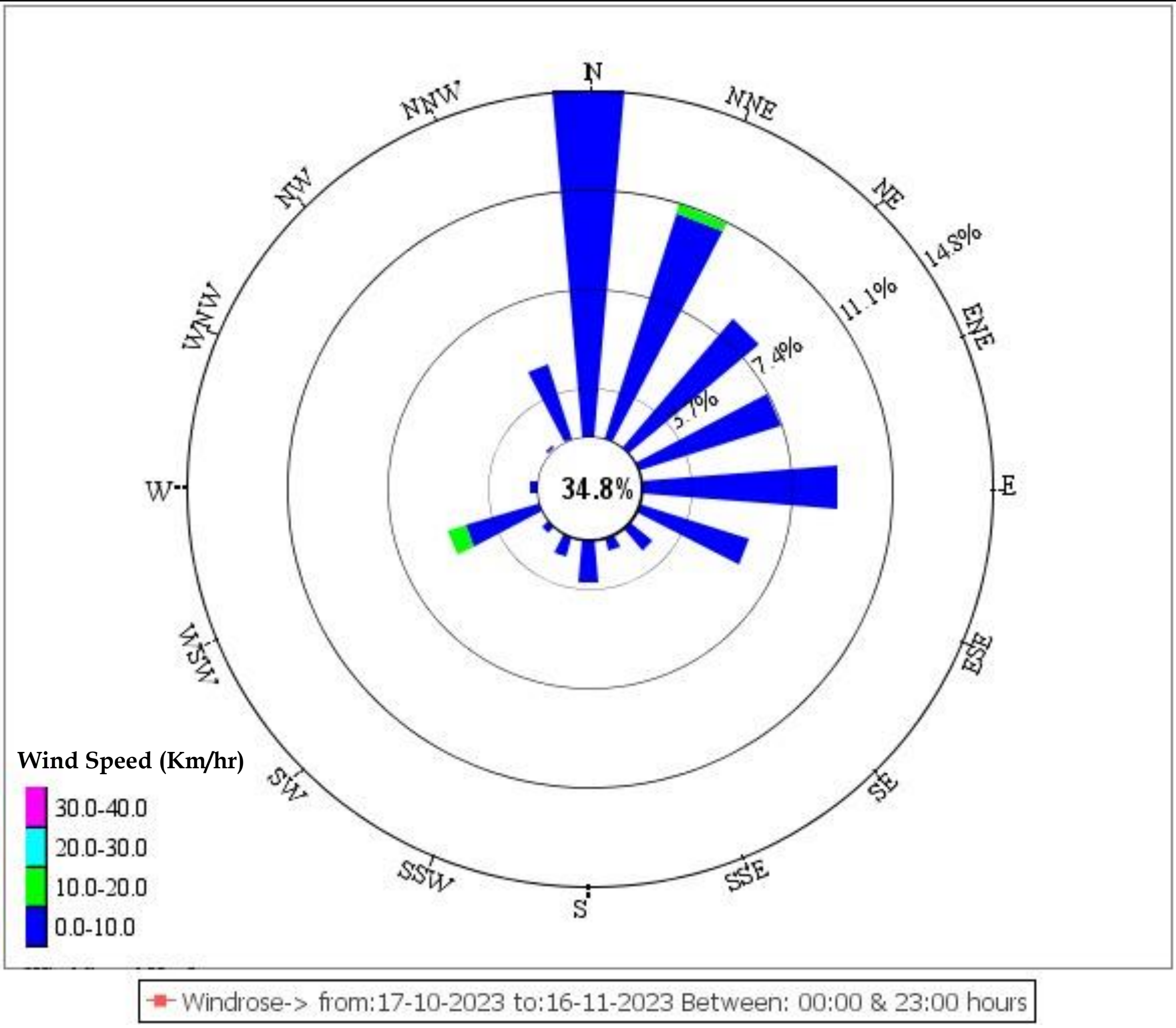
a. **Kandla:** The average Solar Radiation for the monitoring period was recorded as 65.11 W/m^2.
b. **Vadinar:** The average Solar Radiation was recorded as 81.61 W/m^2.

- **Wind rose diagram -**

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

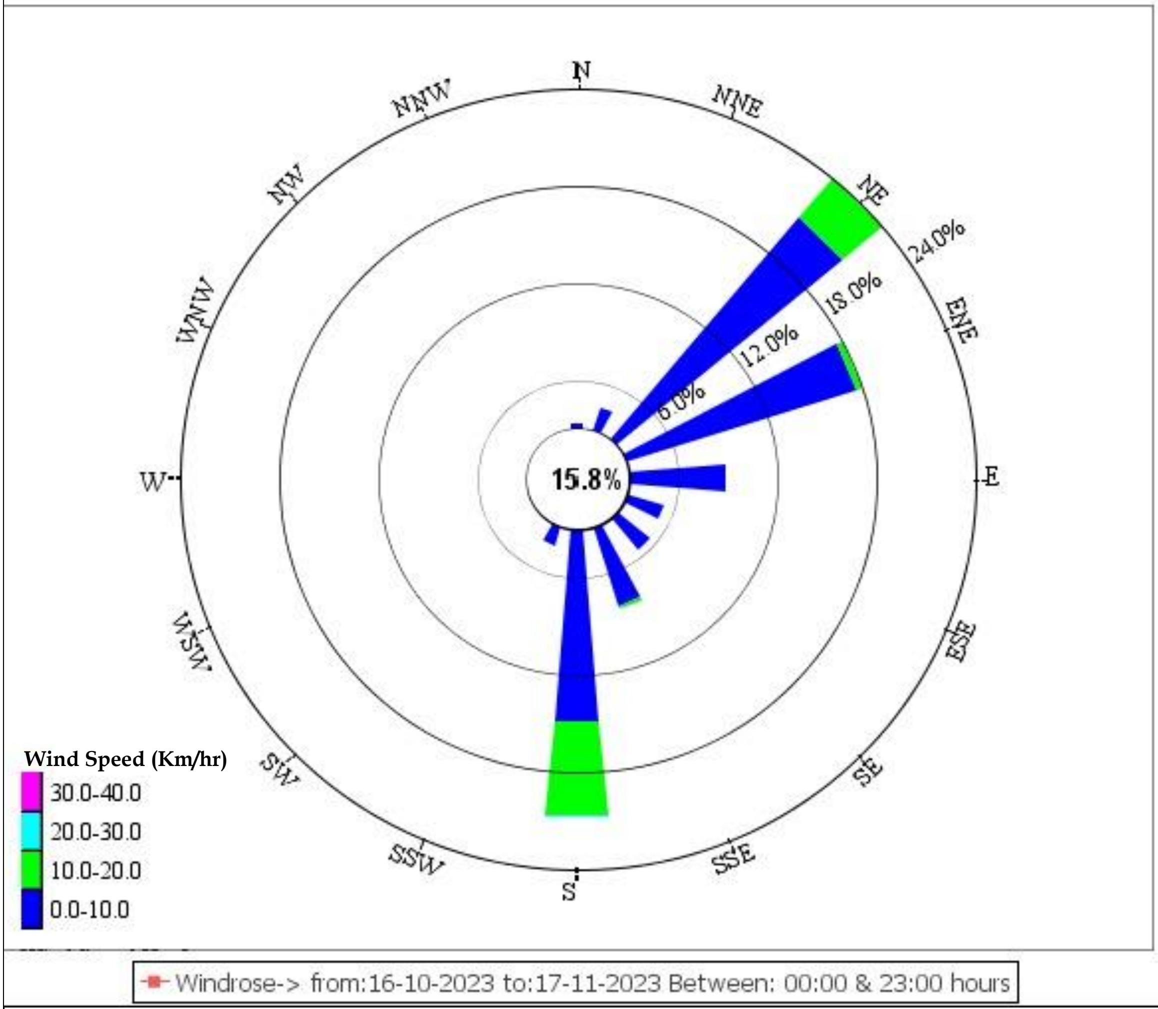
This Wind Rose Diagram reveals that at Kandla, during the period the prevailing winds predominantly blow from the North direction. Whereas the winds at Vadinar were observed to blow mainly from North-east and South directions.

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 17th October to 16th November, 2023.

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 stations monitored at Kandla and Vadinar have been specified in **Table 4**.

Table 4: Details of Ambient Air monitoring locations

Sr. No.	Location Code		Location Name	Latitude Longitude	Significance
1.	Kandla	A-1	Oil Jetty No. 1	23.029361N 70.22003E	Liquid containers and emission from ship
2.		A-2	Oil Jetty No. 7	23.043538N 70.218617E	
3.		A-3	Kandla Port Colony	23.019797N 70.213536E	Vehicular activity and dust emission
4.		A-4	Marine Bhavan	23.007653N 70.222197E	Construction and vehicular activity, road dust emission,
5.		A-5	Coal Storage Area	23.000190N 70.219757E	Coal Dust, Vehicular activity
6.		A-6	Gopalpuri Hospital	23.081506N 70.135258E	Residential area, dust emission, vehicular activity
7.	Vadinar	A-7	Admin Building	22.441806N 69.677056E	Vehicular activity
8.		A-8	Vadinar Colony	22.401939N 69.716306E	Residential Area, burning waste, vehicular activity

The monitoring locations at Kandla and Vadinar have been depicted in map in **Figure 6 and 7** respectively.

Ambient Air monitoring and sampling photographs

Kandla		
		
A-1: Oil Jetty No. 1	A-2: Oil Jetty No. 7	A-3: Kandla Port Colony
		
A-4: Marine Bhavan	A-5: Coal Storage Area	A-6: Gopalpuri Hospital

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

Figure 6: Location Map for Ambient Air Monitoring at Kandla

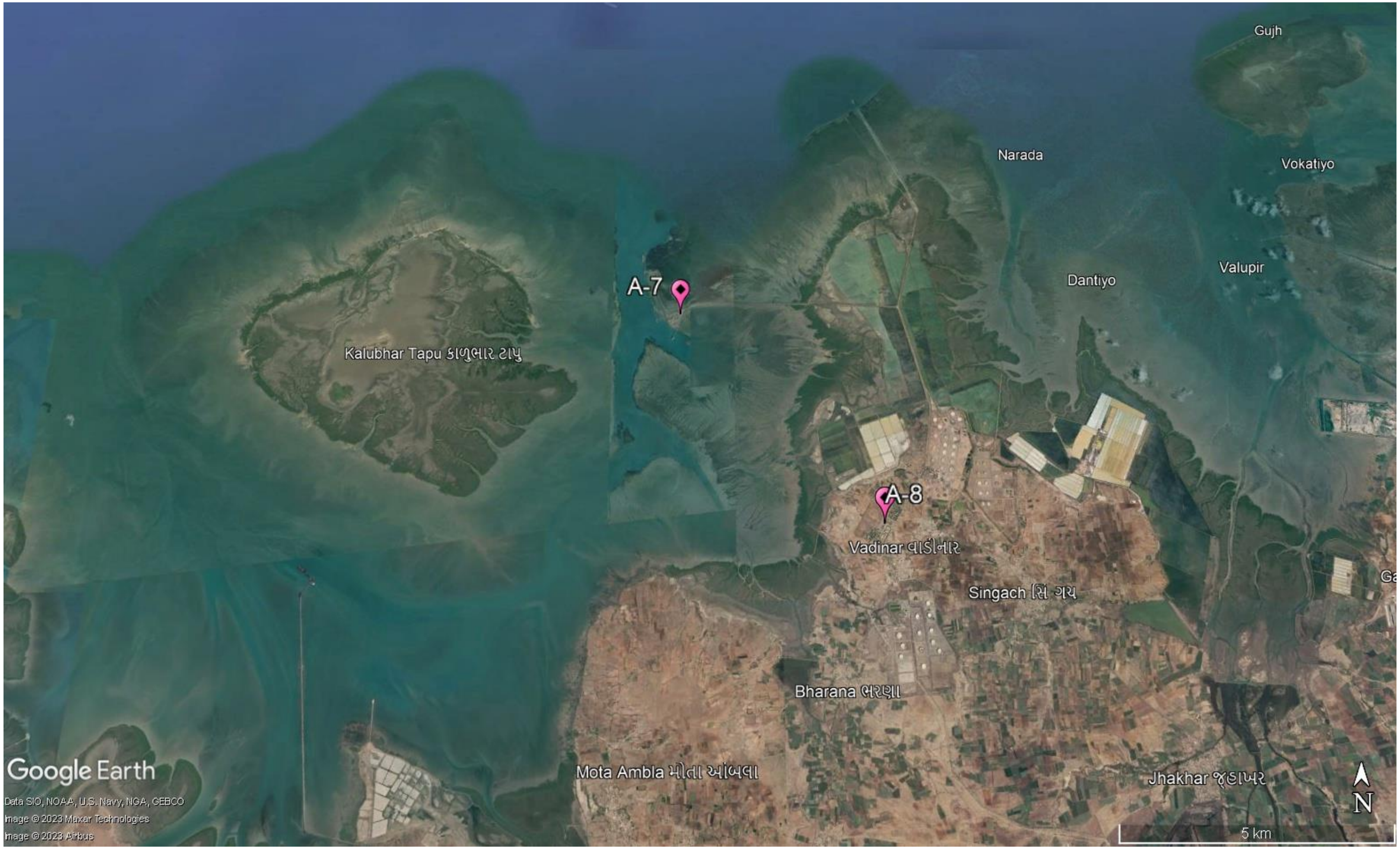


Figure 7: Location Map for Ambient Air Monitoring at Vadinar

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"x10" 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	mg/m³	GEMI/SOP/AAQM /11; Issue no 01, Issue date 17.01.2019: 2019	Sensor based Instrument (Make: Vaibhav Instruments)	
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**.**

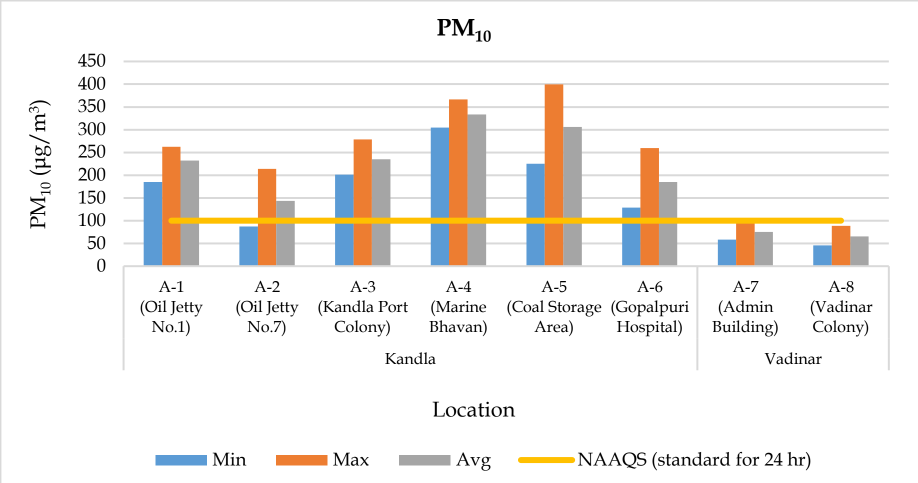
Table 6: Summarized results of PM_{10}, $PM_{2.5}$, SO_2, NO_x, VOC and CO for Ambient Air quality monitoring at Kandla and Vadinar

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration µg/m³ except for CO in mg/m³					
	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		**100**	**60**	**80**	**80**	**-**	**2**
A-1: Oil Jetty No.1, Kandla	20-Oct-23	232.58	40.91	4.7	7.76	2.14	0.88
	21-Oct-23	213.22	35.08	3.25	13.53	2.69	0.81
	25-Oct-23	185.15	36.29	2.23	4.72	3.14	0.89
	27-Oct-23	227.56	37.27	3.78	3.22	2.58	0.87
	30-Oct-23	245.15	53.43	1.26	4.12	1.67	0.86
	06-Nov-23	262.34	89.64	2.29	3.25	2.69	0.77
	07-Nov-23	231.86	77.44	3.47	5.71	2.47	0.80
	13-Nov-23	261.03	42.61	4.12	4.12	1.54	0.78
	Minimum	**185.15**	**35.08**	**1.26**	**3.22**	**1.54**	**0.77**
	Maximum	**262.34**	**89.64**	**4.70**	**13.53**	**3.14**	**0.89**
	Average	**232.36**	**51.58**	**3.14**	**5.80**	**2.37**	**0.83**
	Std. Deviation	**25.36**	**20.79**	**1.13**	**3.46**	**0.55**	**0.05**
A-2: Oil Jetty No.7, Kandla	20-Oct-23	127.03	36.73	3.32	4.21	3.17	0.76
	21-Oct-23	87.15	32.02	3.68	14.2	2.17	0.75
	25-Oct-23	104.01	38.91	2.65	4.35	1.07	0.79
	27-Oct-23	141.01	32.25	4.12	2.14	1.06	0.77
	30-Oct-23	180.20	61.97	2.88	3.46	2.17	0.80
	06-Nov-23	213.56	91.63	2.32	3.41	4.21	0.80
	07-Nov-23	150.32	61.32	1.79	5.34	2.59	0.69
	13-Nov-23	143.77	33.12	2.49	5.21	1.94	0.74
	Minimum	**87.15**	**32.02**	**1.79**	**2.14**	**1.06**	**0.69**
	Maximum	**213.56**	**91.63**	**4.12**	**14.20**	**4.21**	**0.80**
	Average	**143.38**	**48.49**	**2.91**	**5.29**	**2.30**	**0.76**
	Std. Deviation	**40.20**	**21.41**	**0.76**	**3.75**	**1.05**	**0.04**
A-3: Kandla Port Colony, Kandla	20-Oct-23	238.95	39.23	2.43	19.46	2.14	0.89
	21-Oct-23	265.34	53.14	2.92	26.17	1.16	0.71
	25-Oct-23	210.38	39.27	3.37	33.6	1.52	0.72
	27-Oct-23	228.56	52.00	4.12	30.06	1.90	0.85
	30-Oct-23	278.39	68.57	3.82	<6	2.67	0.82
	06-Nov-23	242.11	41.16	16.50	80.67	2.17	0.94
	07-Nov-23	214.63	77.18	51.15	63.63	2.91	0.82
	13-Nov-23	201.36	54.11	4.19	2.36	2.31	0.85
	Minimum	**201.36**	**39.23**	**2.43**	**2.36**	**1.16**	**0.71**
	Maximum	**278.39**	**77.18**	**51.15**	**80.67**	**2.91**	**0.94**
	Average	**234.97**	**53.08**	**11.06**	**36.56**	**2.10**	**0.83**
	Std. Deviation	**26.90**	**13.87**	**16.84**	**26.77**	**0.57**	**0.08**
A-4: Marine Bhavan, Kandla	20-Oct-23	366.89	38.55	2.86	10.37	1.69	0.85
	21-Oct-23	353.17	37.76	1.53	12.77	1.75	0.85
	25-Oct-23	304.36	43.36	3.09	5.12	3.16	0.73
	27-Oct-23	312.04	36.10	3.94	10.14	2.71	0.87
	30-Oct-23	342.55	62.65	4.15	13.57	1.84	0.88
	06-Nov-23	349.61	62.15	7.93	41.39	1.69	1.04

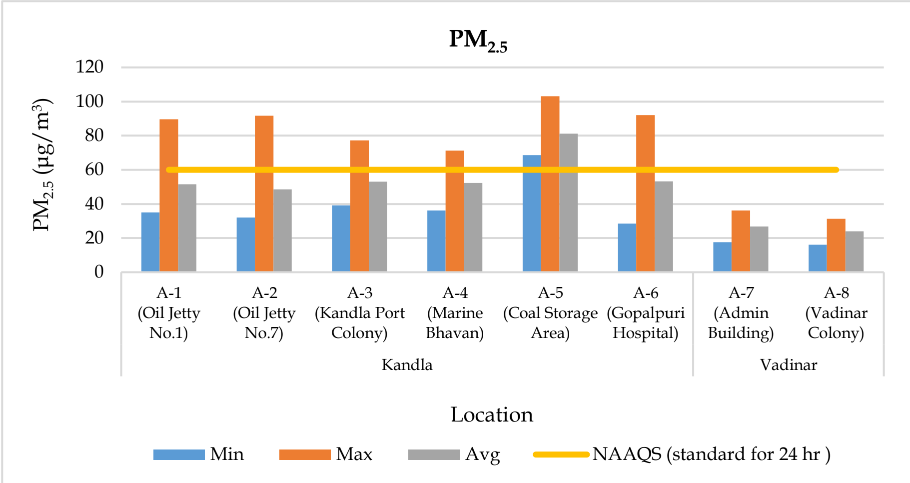
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration µg/m³ except for CO in mg/m³					
	Pollutants	PM_{10} µg/m³	$PM_{2.5}$ µg/m³	SO_2 µg/m³	NO_X µg/m³	VOC µg/m³	CO mg/m³
	Duration	(24 hr)				(2 hr)	(1 hr)
NAAQS by CPCB		100	60	80	80	-	2
	07-Nov-23	320.23	71.27	5.30	45.28	2.17	0.96
	13-Nov-23	321.20	66.74	4.89	23.54	1.74	0.86
	Minimum	**304.36**	**36.10**	**1.53**	**5.12**	**1.69**	**0.73**
	Maximum	**366.89**	**71.27**	**7.93**	**45.28**	**3.16**	**1.04**
	Average	**333.76**	**52.32**	**4.21**	**20.27**	**2.09**	**0.88**
	Std. Deviation	**22.30**	**14.71**	**1.92**	**15.18**	**0.56**	**0.09**
A-5: Coal Storage Area, Kandla	20-Oct-23	302.65	88.49	3.34	13.78	1.47	0.96
	21-Oct-23	225.34	70.72	2.86	4.98	1.52	0.94
	25-Oct-23	229.36	103.06	2.19	14.22	2.90	0.89
	27-Oct-23	399.32	76.10	1.91	25.48	2.14	0.98
	30-Oct-23	383.09	86.11	2.58	18.12	3.21	1.03
	06-Nov-23	265.80	73.95	3.31	6.06	2.67	1.17
	07-Nov-23	303.82	68.67	4.02	8.49	2.84	1.13
	13-Nov-23	341.86	82.13	4.48	15.88	1.76	0.96
	Minimum	**225.34**	**68.67**	**1.91**	**4.98**	**1.47**	**0.89**
	Maximum	**399.32**	**103.06**	**4.48**	**25.48**	**3.21**	**1.17**
	Average	**306.41**	**81.15**	**3.09**	**13.38**	**2.31**	**1.01**
	Std. Deviation	**65.41**	**11.35**	**0.88**	**6.80**	**0.68**	**0.10**
A-6: Gopalpuri Hospital, Kandla	20-Oct-23	165.34	35.6	5.05	3.54	1.26	0.68
	21-Oct-23	161.65	32.84	4.62	5.13	1.47	0.86
	25-Oct-23	128.59	28.57	4.01	4.25	2.10	0.59
	27-Oct-23	157.05	36.63	3.81	4.33	1.69	0.68
	30-Oct-23	209.53	75.71	2.84	5.78	2.18	0.66
	06-Nov-23	259.88	88.11	2.38	6.24	1.11	0.71
	07-Nov-23	250.67	91.97	3.58	4.87	1.69	0.78
	13-Nov-23	146.34	36.14	4.19	12.91	2.07	0.74
	Minimum	**128.59**	**28.57**	**2.38**	**3.54**	**1.11**	**0.59**
	Maximum	**259.88**	**91.97**	**5.05**	**12.91**	**2.18**	**0.86**
	Average	**184.88**	**53.20**	**3.81**	**5.88**	**1.70**	**0.71**
	Std. Deviation	**49.15**	**27.06**	**0.88**	**2.97**	**0.40**	**0.08**
A-7: Admin Building, Vadinar	20-Oct-23	67.21	30.27	16.32	12.03	2.14	0.21
	21-Oct-23	79.45	27.45	18.53	8.12	3.14	0.67
	25-Oct-23	72.18	24.12	12.11	16.28	2.74	0.44
	27-Oct-23	58.39	25.69	9.18	32.17	2.01	0.54
	30-Oct-23	95.17	21.85	10.78	14.82	1.47	0.43
	06-Nov-23	88.21	36.15	15.14	12.67	2.03	0.74
	07-Nov-23	71.64	31.52	19.42	13.74	1.49	0.65
	13-Nov-23	69.17	17.55	14.72	13.11	1.71	0.62
	Minimum	**58.39**	**17.55**	**9.18**	**8.12**	**1.47**	**0.21**
	Maximum	**95.17**	**36.15**	**19.42**	**32.17**	**3.14**	**0.74**
	Average	**75.18**	**26.83**	**14.53**	**15.37**	**2.09**	**0.54**
	Std. Deviation	**11.90**	**5.86**	**3.63**	**7.19**	**0.59**	**0.17**
	20-Oct-23	53.17	24.52	22.47	9.34	2.74	0.25

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration μg/m³ except for CO in mg/m³					
	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		100	60	80	80	-	2
A-8: Vadinar Colony, Vadinar	21-Oct-23	78.29	19.67	18.6	14.28	2.16	0.74
	25-Oct-23	88.34	26.34	12.70	6.45	2.30	0.69
	27-Oct-23	64.21	28.41	15.90	15.14	2.10	0.54
	30-Oct-23	47.13	31.25	11.36	12.07	1.47	0.64
	06-Nov-23	86.42	16.12	16.12	11.94	1.08	0.52
	07-Nov-23	57.95	21.66	17.82	14.75	1.75	0.42
	13-Nov-23	45.87	23.71	21.13	13.95	2.10	0.47
	Minimum	**45.87**	**16.12**	**11.36**	**6.45**	**1.08**	**0.25**
	Maximum	**88.34**	**31.25**	**22.47**	**15.14**	**2.74**	**0.74**
	Average	**65.17**	**23.96**	**17.01**	**12.24**	**1.96**	**0.53**
	Std. Deviation	**17.14**	**4.84**	**3.83**	**3.02**	**0.52**	**0.16**

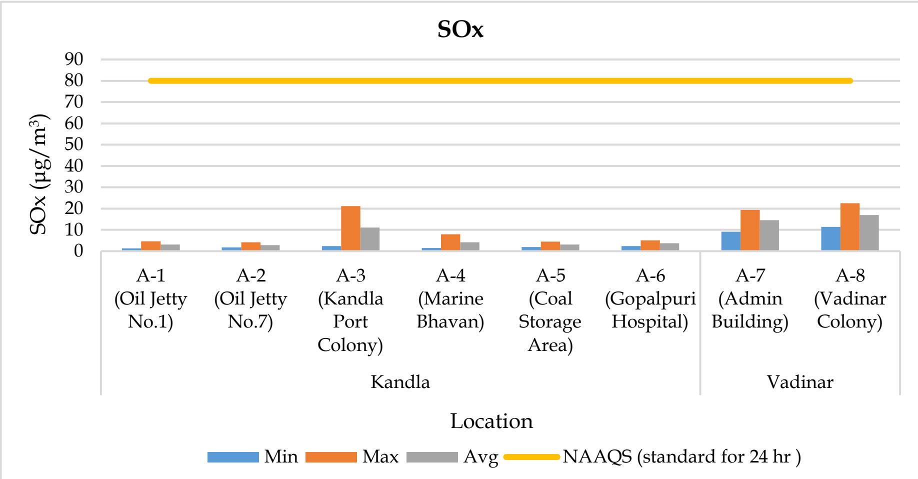
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar)



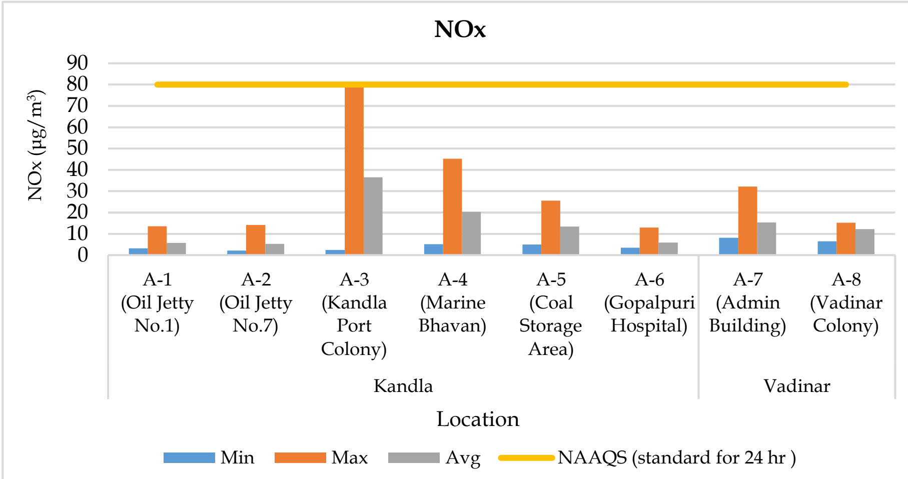
Graph 1: Spatial trend in Ambient PM_{10} Concentration



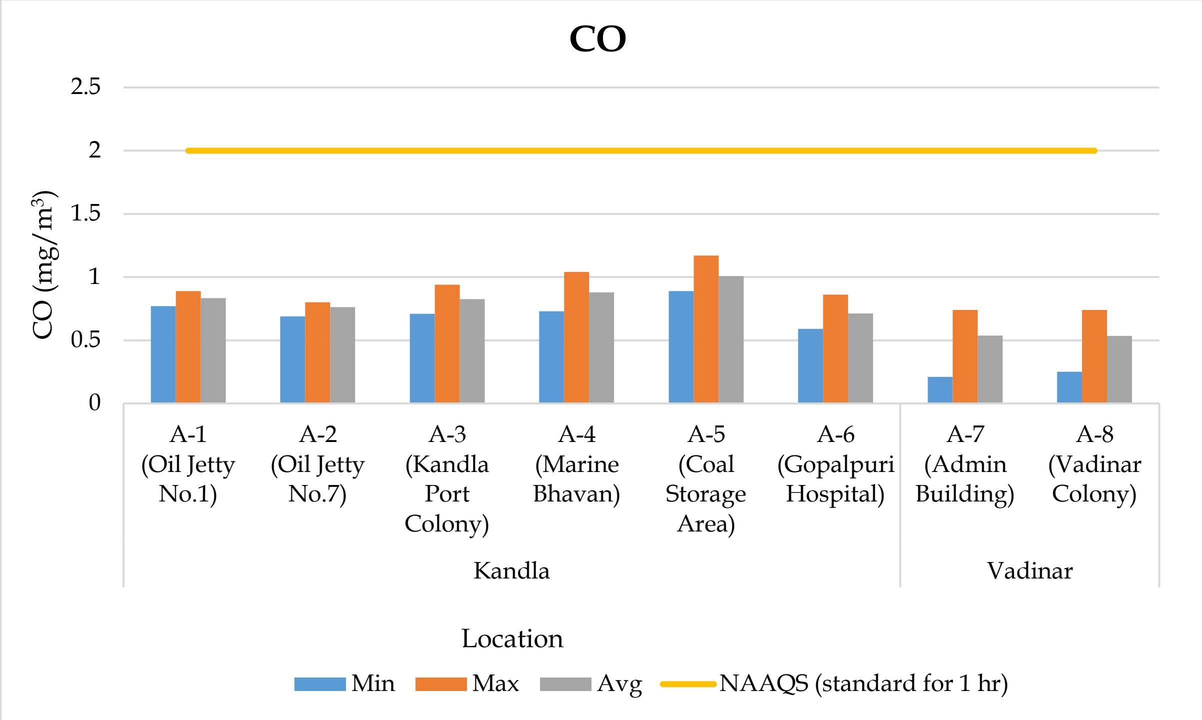
Graph 2: Spatial trend in Ambient $PM_{2.5}$ Concentration



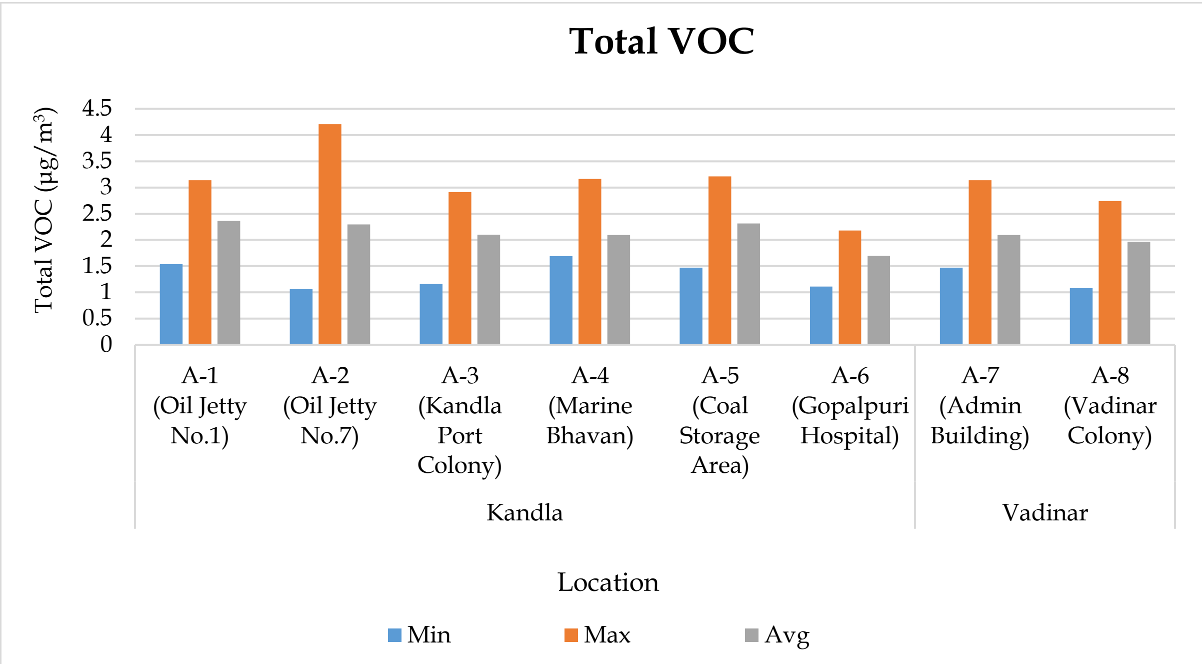
Graph 3: Spatial trend in Ambient SO_x Concentration



Graph 4: Spatial trend in Ambient NO_x 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	0.12	0.14	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	1.02	0.9	0.12	0.14	0.37	0.77	0.65	0.28
2	Acenaphthylene	0.49	0.37	0.54	0.95	0.14	0.46	0.28	0.44
3	Acenaphthene	0.12	0.09	0.13	0.66	0.41	0.12	0.41	0.61
4	Fluorene	0.39	0.34	0.46	0.37	0.57	0.45	0.39	0.14
5	Anthracene	0.13	0.42	0.97	0.28	0.62	0.91	0.41	0.43
6	Phenanthrene	0.00	0.00	0.00	0.03	0.17	0.00	0.82	0.28
7	Fluoranthene	0.24	0.19	0.97	0.63	0.14	0.28	0.03	0.64
8	Pyrene	0.36	0.14	0.67	0.55	0.28	0.34	0.07	0.11
9	Chrycene	0.16	0.22	0.96	0.42	0.19	0.54	0.14	0.06
10	Banz(a)anthracene	0.47	0.94	0.45	0.14	0.52	0.63	1.01	0.74
11	Benzo[k]fluoranthene	0.54	0.61	0.74	0.93	0.56	0.41	0.7	0.39
12	Benzo[b]fluoranthene	0.12	0.46	0.62	1.08	0.41	0.67	0.25	0.45
13	Benzopyrene	0.9	0.33	0.49	0.75	0.27	0.41	0.96	0.63
14	Indeno [1,2,3-cd] fluoranthene	0.13	0.77	0.42	0.48	0.73	0.67	0.52	0.46
15	Dibenz(ah)anthracene	0.11	0.14	0.69	0.13	0.51	0.28	0.17	0.71
16	Benzo[ghi]perylene	0.31	0.24	0.21	0.46	0.61	0.76	0.22	0.63

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	2.11	2.67	3.54	1.07	1.19	2.01	2.15	1.67

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 87.15 to 399.89 µg/m³**.** PM_{10} exceeded NAAQS at all the monitoring locations of Kandla. Whereas, at Vadinar, the concentration varies 45.87 to 95.17 µg/m³ where majority of the monitoring days complies with the stipulated norm (100 µg/m³) for both monitoring locations.

- The highest concentration of PM_{10} at locations A-3 i.es Kandla Port Colony could be attributed to the presence of heavy vehicular traffic in upwind areas which bring higher impact causing the dispersion of emitted particulate matter in the ambient air. The unloading of coal directly in the truck, using grabs causes the coal to disperse in the air as well as coal dust to fall and settle on the ground. This settled coal dust again mixes with the air while trucks travel through it. Also, the coal-loaded trucks are generally not always covered with tarpaulin sheets and this might result in increased suspension of coal from trucks/dumpers during its transit from vessel to yard or storage site. This might increase the PM_{10} in and around the Coal storage area and Marine bhavan.
- The **$PM_{2.5}$** concentrations at Kandla monitoring location varies from 28.57 to 103.06 µg/m^3. $PM_{2.5}$ exceeded NAAQS limit at location A-1 (Oil Jetty No.1), A-5 (Coal Storage Area) and A-6 (Gopalpuri Hospital). Whereas, at Vadinar its concentration varies at Vadinar from 16.12 to 36.15 µg/m^3 which falls within the limit of NAAQS i.e. 60 µg/m^3.
- The concentration of **SO_x** varies from 1.26 to 21.15 µg/m^3 at Kandla and 9.18 to 22.47 µg/m^3 at Vadinar. The range falls within the prescribed limit of NAAQS of 80 µg/m^3 for both the monitoring site.
- The concentration of **NO_x** varies from 2.14 to 80.67 µg/m^3 at Kandla and 6.45 to 32.17 µg/m^3 at Vadinar. The range falls within the prescribed limit of NAAQS i.e. 80 µg/m^3 at both the monitoring site of Kandla and Vadinar.
- The concentration of **CO** varies from 0.59 to 1.17 mg/m^3 at Kandla and 0.21 to 0.74 mg/m^3 at Vadinar. The range falls within the norm of 2 mg/m^3 specified by NAAQS.
- The concentration of **Total VOCs** levels was recorded in range of 1.06 to 4.21 µg/m^3 at Kandla and 1.08 to 3.14 µg/m^3 at Vadinar. The main source of VOCs in the ambient air may be attribute to the burning of Gasoline and Natural gas in Vehicle exhaust and burning fossil fuels, wood, and garbage all release VOCs into the atmosphere. During the monitoring period, the wind flows towards West-south-west 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.
- The concentration of **Benzene** was not detected for the Ambient Air Monitoring locations of Kandla, whereas at Vadinar the Benzene concentration falls within the range of 0.12-1.04 µg/m^3. The said concentration complies with the specified limit of 5 µg/m^3 for both the study areas.
- **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. Comparative higher concentration of PAH was detected at location A-4 i.e Marine Bhavan and A-5 i.e. Coal Storage area, which is a commercial area. PAHs are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They the higher concentration which result from burning coal, oil, gas, road dust, etc might be attributed to higher traffic density in the area. 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 in the range of 1.07 to 3.54 µg/m^3. While at Vadinar, the NM VOC concentration falls in the range of 1.67 to 2.15 µg/m^3.

With reference to the Ambient Air Quality monitoring conducted under the study, it may be concluded that the particulate matter PM_{10} and $PM_{2.5}$, were reported in higher concentration and apparently exceeds the NAAQS particularly at locations of Kandla. The gaseous pollutants (NO_x, SO_x, CO, VOCs etc.) falls within the permissible limit. The probable reason 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.

4.4 Remedial Measures:

Efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits. 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.
- Ensuring maintenance of engines and machinery to comply with emission standards.
- 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.

- Retrofitting ships with exhaust gas cleaning systems can help reduce sulfur emissions. Engine upgrades, such as optimizing fuel combustion and improving engine efficiency, can reduce overall emissions.
- 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.

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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 8 and 9** as follows:

Figure 8: Location Map for DG Stack monitoring at Kandla

Figure 9: Location Map 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: Parameters to be monitored under the study

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: The results of DG Sets for Kandla and Vadinar

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	98.47	41.96
2.	Sulphur Dioxide (SO_2) (PPM)	100	6.45	N.D.
3.	Oxides of Nitrogen (NO_x) (PPM)	50	52.19	22.75
4.	Carbon Monoxide (CO) (%)	1	0.18	0.016
5.	Carbon Dioxide (CO_2) (%)	-	2.57	1.24

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 SPM, SO_2, NOx and CO.

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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 **Figure 10 and 11** 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

Figure 10: Location Map for Noise Monitoring at Kandla

Figure 11: Location Map 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 that carried out at Kandla and Vadinar

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	55.2	38.9	49.6	70	42.6	33.0	40.0
2	N-2	West Gate No.1	A	75	66.1	48.0	60.5	70	50.1	41.1	46.3
3	N-3	Canteen Area	B	65	60.2	44.2	55.5	55	49.2	37.2	43.2
4	N-4	Main Gate	A	75	58.4	46.9	54.9	70	45.4	37.9	42.1
5	N-5	Main Road	A	75	61.5	39.4	55.7	70	47.6	35.6	43.2
6	N-6	Marin Bhavan	B	65	62.3	39.5	56.9	55	42.0	34.6	38.9
7	N-7	Port & Custom Building	B	65	54.6	39.4	49.5	55	46.6	36.4	42.4
8	N-8	Nirman Building	B	65	54.5	42.6	50.7	55	44.3	38.6	41.4
9	N-9	ATM Building	B	65	58.1	41.6	53.9	55	45.9	37.2	41.9
10	N-10	Wharf Area/ Jetty	A	75	61.5	42.6	56.3	70	47.2	40.6	44.6
11	N-11	Near Main Gate	A	75	71.1	57.5	59.0	70	68.9	57.0	57.8
12	N-12	Near Vadinar Jetty	A	75	72.8	59.0	62.1	70	62.1	53.0	55.4
13	N-13	Port Colony Vadinar	C	55	60.1	49.0	50.1	45	62.8	48.0	49.4

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. The Day Time the average noise level at all 10 locations at Kandla ranged from 49.5 dB(A) to 60.5 dB(A), while at Vadinar, the noise levels for the three-location ranged from 50.1 dB(A) to 62.1 dB(A). Whereas, during Night Time the average Noise Level ranged from 38.9 dB(A) to 46.3 dB(A) at Kandla and 49.4 dB(A) to 57.8 dB(A) at Vadinar which was within the permissible limits for the industrial, residential and commercial area except for location N-13 which exceeds the stipulated norms for night time.

6.4 Remedial Measures

As per the noise level found within the norms thus no need to bring it down from the existing level however, the noise could 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 locations

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: List of parameters to be monitored for Soil Quality

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 12 and 13** as follows:

Figure 12: Location Map for Soil Quality Monitoring at Kandla

Figure 13: Location Map 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		9.39	8.8	7.54	8.64	8.32	8.4
2	Conductivity	µS/cm	1847	4380	75700	704	94	127
3	Inorganic Phosphate	Kg/ha	1.92	1.7	1.24	3.15	0.95	0.77
4	Organic Carbon	%	0.06	0.14	0.98	0.49	0.25	0.65
5	Organic Matter	%	0.10	0.24	1.69	0.84	0.431	1.12
6	SAR	meq/L	5.29	6.14	29.26	0.67	0.11	0.09
7	Aluminium	mg/Kg	812.75	830.95	840.71	916.40	735.77	754.58
8	Chromium	mg/Kg	60.76	57.44	42.48	46.75	76.06	60.93
9	Nickel	mg/Kg	14.92	14.38	11.91	16.54	29.15	26.73
10	Copper	mg/Kg	78.66	74.40	62.62	16.84	102.62	70.50
11	Zinc	mg/Kg	101.93	76.19	44.26	23.57	46.12	29.32
12	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	4.67	3.27	1.29	3.46	BQL	BQL
14	Arsenic	mg/Kg	BQL	BQL	BQL	2.377	0.099	BQL
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	36	38	50.8	46	42	62
17	Sand	%	73.52	73.52	51.52	73.52	54.24	64.24
18	Silt	%	23.28	21.28	33.28	11.28	33.44	25.44
19	Clay	%	3.2	5.2	15.2	15.2	12.32	10.32
20	Texture	-	Loamy Sand	Loamy Sand	Loam	Sandy 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 following parameters has been given an interpretation based on the observations.

- The value of **pH** ranges from 7.54 to 9.39, highest at location S-1 (Oil Jetty 7) and lowest at S-3 (Khori Creek); while the average pH for Kandla was observed to be 8.59.

Whereas, at Vadinar the pH value observed at S-5 i.e., Near SPM (8.32) and at S-6 i.e., Near Jetty Area (8.4). 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 704 to 75700 µs/cm, highest at location S-3 (Khori Creek) with the average as 20657.75 µs/cm. Whereas, at Vadinar the range of conductivity was between the range of 94 to 127 µs/cm with an average value of 110.5 µs/cm.

- At Kandla, the concentration of **Inorganic Phosphate** varied from 1.24 to 3.15 Kg/ha, with average 2 Kg/ha. Whereas, at the locations of Vadinar, the Inorganic Phosphate was observed at S-5 i.e., Near SPM (0.95 Kg/ha) and detected at S-6 i.e., near Jetty Area (0.77 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 0.06 to 0.98% while the average TOC at Kandla was detected as 0.42%. Whereas, at Vadinar the average TOC was found to be 0.45% where the observed TOC value found at S-5 and S-6 to be 0.25 and 0.65 respectively.

- The concentration of **Water Holding Capacity** in the soil samples of Kandla and Vadinar varies from 36 to 50.8% and 42 to 62% respectively.

- The concentration of **Sodium Adsorption Ratio** ranges from 0.67 to 29.26 meq/L with an average value 10.34 meq/L at Kandla. Whereas, at Vadinar, the average SAR was found to be 0.1 meq/L where the observed SAR value found at S-5 (0.11 meq/L) and S-6 (0.09 meq/L).

- Loam to Sandy Loam **Soil Texture** was observed at all the monitoring locations of Kandla and Vadinar.

Heavy Metals

- For the sampling period, the concentration of **Aluminium** varied from 812.75 to 916.40 mg/kg at Kandla and 735.77 to 754.58 mg/kg at Vadinar and the average value was observed to be 850.20 and 745.18 mg/kg at Kandla and Vadinar monitoring station, respectively.
- The concentration of **Chromium** varied from 42.48 to 60.76 mg/kg at Kandla and 60.93 to 76.06 mg/kg at Vadinar and the average value was observed to be 51.86 and 68.496 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Nickel** varied from 11.91 to 16.54 mg/kg at Kandla and 26.73 to 29.15 mg/kg at Vadinar and the average value was observed to be 14.43 and 27.94 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Zinc** varied from 23.57 to 101.93 mg/kg at Kandla and 29.32 to 46.12 mg/kg at Vadinar and the average value was observed to be 61.48 and 37.72 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Copper** varied from 16.84 to 78.66 mg/kg at Kandla and 70.50 and 102.62 mg/kg at Vadinar and the average value was observed to be 58.13 and 86.56 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Lead** varied from 1.29 to 4.67 mg/kg at Kandla with average value 3.17 mg/Kg, whereas for Vadinar, the value recorded below the detection limit.

- The concentration of **Arsenic** found to be BQL at Kandla except for location S-4 i.e. 2.38 mg/kg. Whereas for Vadinar the value recorded for location S-5 to be 0.09 mg/kg and BQL at S-6.

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

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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 details of the drinking water sampling stations have been mentioned in **Table 20** and the locations have been depicted through Google map in **Figure 14 and 15.**

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	Port & Custom Building	23.009033N 70.222047E
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

Figure 14: Location Map for Drinking Water Monitoring at Kandla

Figure 15: Location Map for Drinking Water Monitoring at Vadinar

Methodology

The water samples were collected from the finalized sampling locations and analyzed 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	-	7.38	6.77	6.75	7.37	7.83	7.94	7.42	7.82	6.62	6.82	8.12	6.62	7.81	8.03	7.45	7.08	7.42	7.19	7.27	7.87
2.	Colour	Hazen	5	15	1	1	1	1	5	5	1	5	1	1	5	1	1	1	1	1	1	1	1	1
3.	EC	µS/cm	-	-	260	165.2	205	42.7	1257	1181	55.7	1156	117.7	194.5	1183	194.9	81.5	818	147.3	63.2	246	63.4	178.3	132.5
4.	Salinity	mg/L	-	-	0.13	0.08	0.10	0.03	0.62	0.59	0.03	0.57	0.06	0.10	0.59	0.10	0.11	0.58	0.7	0.05	0.31	0.04	0.09	0.34
5.	Turbidity	NTU	1	5	1.20	1.48	0.93	0.90	1.6	1.1	1.13	1.14	0.97	1.23	3.4	1.02	BQL	7.01	BQL	BQL	BQL	BQL	1.5	0.7
6.	Chloride	mg/L	250	1000	57.98	42.49	37.99	12.50	262.42	259.92	16	244.92	28.99	48.98	244.92	45.99	35.47	285.40	45.4	22.1	65.2	16.3	27.49	19.1
7.	Total Hardness	mg/L	200	600	8	10	12	4	230	230	4	210	8	3	210	20	12	170	8	5	12	4	38	30
8.	Ca Hardness	mg/L	-	-	4	7	8	3	110	120	2	110	4	2	90	12	6	90	5	3	7	3	18	18
9.	Mg Hardness	mg/L	-	-	4	3	4	1	120	110	2	100	4	1	120	8	6	80	3	2	5	1	20	12
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	84	104	22	630	598	28	580	60	98	600	98	BQL	512	73	33	185	34	90	81
12	TSS	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	2	BQL	BQL	8	BQL	BQL	BQL	BQL	BQL	BQL
13	Fluoride	mg/L	1.0	1.5	BQL	BQL	0.36	BQL	0.89	0.91	0.42	BQL	BQL	BQL	1.06	BQL	BQL	0.15	BQL	BQL	BQL	BQL	BQL	BQL
14	Sulphate	mg/L	200	400	BQL	BQL	BQL	BQL	93.16	93.24	BQL	BQL	BQL	BQL	93.38	BQL	BQL	88.2	10.3	BQL	11.48	BQL	BQL	25.4
15	Nitrate	mg/L	45	-	12.04	BQL	4.08	BQL	6.68	5.69	BQL	4.53	BQL	4.23	6.47	BQL	BQL	1.78	BQL	BQL	2.51	BQL	BQL	3.44
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	-	-	46.24	28.73	32.72	11.54	135.8	117.01	10.47	109.5	18.28	34.08	115.72	24.85	21.25	88.2	15.3	BQL	46.4	9.05	20.56	35.7

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
18	Potassium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
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	0.08	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	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
24	Iron	mg/L	0.3	-	BQL	BQL	0.16	BQL	0.14	0.16	BQL	BQL	BQL	BQL	0.17	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	0.002	BQL	BQL	BQL	BQL	BQL
26	Manganese	mg/L	0.1	0.3	BQL	BQL	BQL	BQL	BQL	0.04	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		150	5	10	5	160	120	5	145	190	81	39	140	52	102	11	48	40	120	BQL	10

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)

*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 6.62 to 8.12, with an average pH of 7.35. In Vadinar, its values ranged from 7.27 to 7.87, with an average pH of 7.57. Notably, the pH levels at both project sites fall within the acceptable range of 6.5 to 8.5, as specified under IS:10500:2012.
- **Turbidity:** At the drinking water locations of Kandla, the turbidity was found in range from 0.9 to 7.01 NTU with average value 1.77 NTU. Whereas, at Vadinar the value of turbidity was reported 1.5 NTU at DW-19 and 0.7 NTU at DW-20 with average at 1.10 NTU.
- **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 22 to 630 mg/L, with an average concentration of 227.71 mg/L. while in Vadinar, it ranged from 81 to 90 mg/L, with average at 85.50 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 except for location DW-5, DW-11, DW-14.
- **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 42.7 to 1257 µS/cm, with an average value of 412.89 µS/cm. In Vadinar, the EC values showed variation from 132.5 to 178.3 µS/cm, with an average value of 155.40 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 12.5 to 285.4 mg/L, with an average value of 98.49 mg/L. In Vadinar, it ranged from 19.1 to 27.49 mg/L, with an average value of 23.30 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 except for location DW-5, DW-11, DW-14.
- **Total Hardness (TH):** Total Hardness varied from 3 to 230 mg/L, with the average value as 64.44 mg/L. While at Vadinar, the variation was observed from 30 to 38 mg/L; with the average conc. at 34 mg/L. which was found to be within the acceptable norm of 200 mg/L as specified by IS:10500:2012 and is not harmful for local inhabitants.
- **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 varied from 10.3 to 93.38

mg/L, with an average value of 64.96 mg/L. In Vadinar, the sulphate concentration was observed BQL at location DW-19 and 25.4 mg/L at DW-20.

- **Sodium:** During the monitoring period, at Kandla variation in the concentration of sulphate was observed to be in the range of 9.05 to 135.8 mg/L, with the average concentration of 50.89 mg/L. While at Vadinar, the concentration recorded 20.56 mg/L at DW-19 and 35.7 mg/L at DW-20.
- **Nitrate:** During the monitoring period, at Kandla & Vadinar variation in the concentration of Nitrate was observed to be in the range of 1.78 to 12.03 mg/L, with the average concentration of 5.34 mg/L also majority of the location recorded as "BQL". While at Vadinar, the concentration recorded BQL at DW-19 and 3.44 mg/L at DW-20, with average concentration of 3.44 mg/L.
- **Fluoride:** The concentration was found to be BQL in majority of the monitoring location except for location DW-3 (North Gate) i.e. 0.36 mg/L, DW-5 (Canteen Area) i.e. 0.89 mg/L, DW-6 (West Gate 1) i.e. 0.91 mg/L, DW-7 (Sewa Sadan-3) i.e. 0.42, DW-11 (Wharf area/Jetty) i.e. 1.06 mg/L, DW-14 (School Gopalpuri) i.e. 0.15 mg/L at Kandla. While at Vadinar its value also reported to be BQL for both the monitoring location.
- The parameters such as **Potassium, Free Residual Chlorine, Total Suspended Solids, Nitrite, Hexavalent Chromium**, and **the metals Arsenic, Cadmium, Copper, Iron, Lead, Manganese, Mercury, Total Chromium and Zinc** were all observed to have concentrations "Below the Quantification Limit (BQL)" at majority of the locations during the monitoring period.
- Bacteriological Analysis of the drinking water reveals that Total Coliforms were detected in small concentration at majority of the monitoring locations of Kandla and Vadinar. Reporting such concentration of Coliforms indicates certain external influx may contaminate the source. Hence, it should be checked at every distribution point.

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.

Furthermore, a regular monitoring 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.

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: Norms of treated effluent 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 16 and 17** as follows:

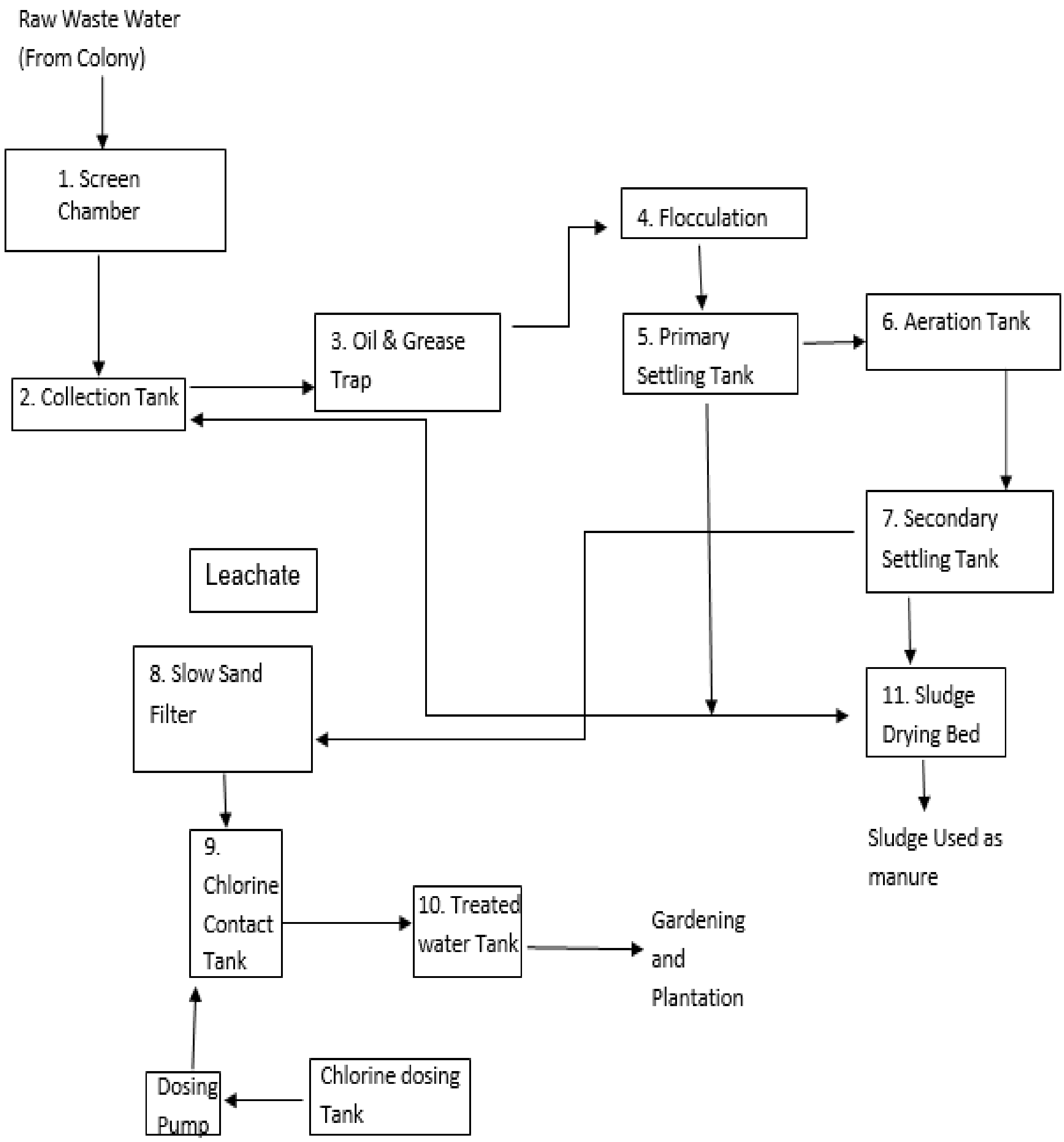

Figure 16: Process flow diagram of Kandla STP

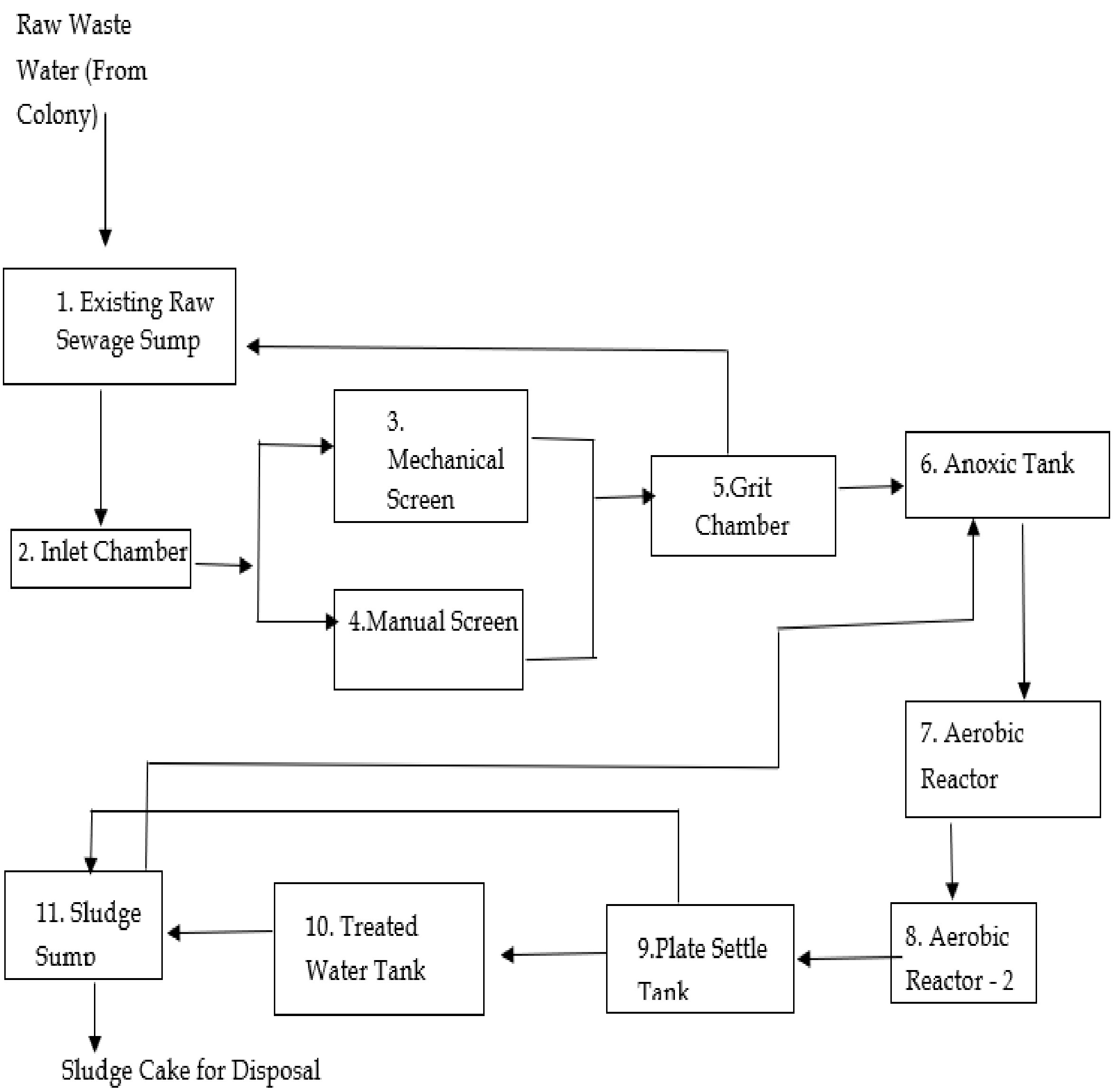

Figure 17: Process flow diagram of Gopalpuri STP

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 18** as follows:

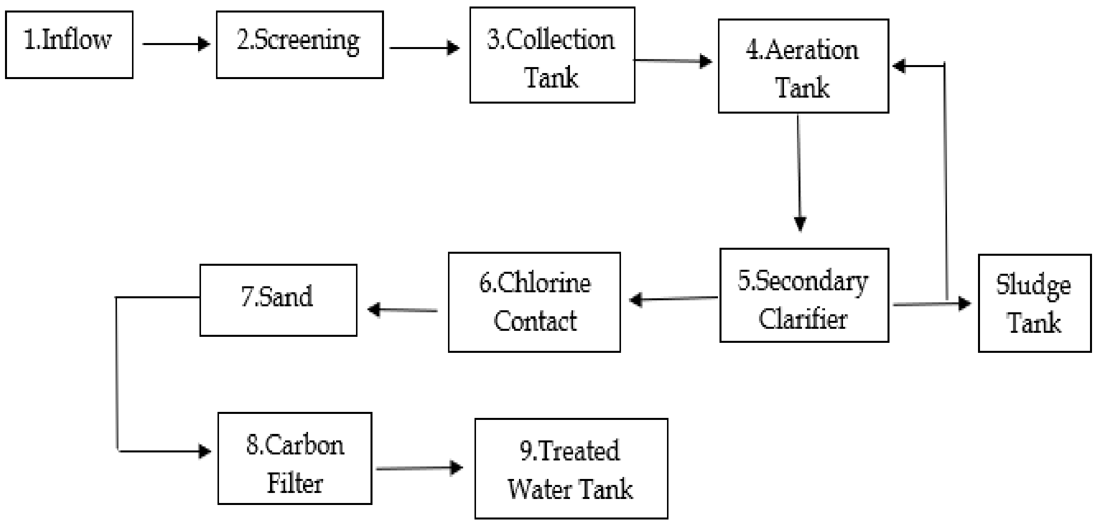

Figure 18: Process flowchart for the Vadinar STP

The map depicting the locations of STP to be monitored in Kandla and Vadinar have been shown in **Figure 19 and 20** as follows:

Figure 19: Location Map for STP Monitoring at Kandla

Figure 20: Location Map 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

The quality of the water samples collected from the inlet and the outlet of the STP's of Kandla and Vadinar has been summarized in **Table 27 & 28**. The said water quality has been represented in comparison with the standard values 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 October				Week 4 of October				Week 1 of November				Week 2 of November			
				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	7.09	7.42	7.45	7.11	7.43	7.12	7.12	7.55	7.70	7.34	7.13	7.59	7.40	7.52	7.16	7.45
2.	TDS	mg/L	-	1652	1128	1563	1074	1376	954	1554	1468	8702	4208	1232	1046	8668	1954	1138	1084
3.	TSS	mg/L	100	59	21	59	21	83	33	106	16	58	26	46	28	344	82	58	22
4.	DO	mg/L	-	0.65	6.25	BQL	7.41	0.94	5.36	BQL	2.8	BQL	2.8	BQL	3.8	BQL	6.9	BQL	4.1
5.	COD	mg/L	-	175	43.1	82.37	44.92	76.11	36.48	192	36	130.95	83.33	170.63	43.82	436.51	79.37	162.70	47.62
6.	BOD	mg/L	30	76.21	6.52	53.14	2.01	69.16	3.44	57.6	5.4	40.92	15.62	53.32	8.22	136.41	14.88	40.67	8.93
7.	SAR	meq/L	-	6.32	5.17	7.56	7.12	6.84	5.11	7.51	7.21	21.56	15.52	6.97	6.20	21.27	8.88	5.73	5.64
8.	Total Coliforms	MPN/ 100ml	<1000	1600	1600	1600	1600	1600	1600	1600	1600	1600	130	1600	1600	1600	1600	1600	1600

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

Sr No.	Parameter	Units	GPCB Norms (Vadinar)	Vadinar							
				Week 3 of October		Week 4 of October		Week 1 of November		Week 2 of November	
				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	7.12	7.24	7.15	7.20	7.26	7.00	7.26	7.17
2.	TDS	mg/L	-	424	352	420	354	428	354	486	372
3.	TSS	mg/L	20	26	16	46	4	18	10	18	12
4.	DO	mg/L	-	BQL	6.2	BQL	5.9	BQL	5.3	BQL	2.8
5.	COD	mg/L	50	171.31	35.86	157.48	19.69	115.08	27.78	158.73	27.78
6.	BOD	mg/L	10	53.53	4.48	47.24	4.92	35.96	3.47	49.60	5.21
7.	SAR	meq/L	-	2.19	2.22	2.23	2.15	2.72	2.53	2.54	2.24
8.	Total Coliforms	MPN/100ml	100-230	1600	1600	1600	1600	1600	1600	1600	1600

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 conform to the standard of 6.5-8.5. Whereas, pH for STP-3 at Vadinar conforms the norm of 5.5-9 as specified in the CCA.
- The **TSS** for the STP-1 and STP-2 of Kandla and STP-3 of Vadinar falls within the stipulated norms of 100 and 20 mg/L for outlet of Kandla and Vadinar, respectively and hence conforms to the norms specified.
- As per the norms, the **Chemical Oxygen Demand** falls within the CCA norms (50 mg/L) for the STP-3 of Vadinar.
- The **BOD** of the outlet for the STPs of Kandla and Vadinar falls within the stipulated norms.
- The **Total Coliforms** were exceeding the norms at the locations of the STP-1 & STP-2 outlets of Kandla and STP-3 outlet of Vadinar.

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 of 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 treatment parameters such as retention time, Mixed Liquor Suspended Solids (MLSS), Mixed liquor volatile suspended solids (MLVSS), Recirculation rate, sludge generation, etc should be monitored timely.
- During the treatment, the required retention time and rate of aeration should be maintained, so that the efficiency of the treatment plant is maintained.
- The dosage of chemicals administered during the treatment should be reviewed and alterations in the dosage should be done.
- 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.
- Enhanced biological treatment processes, such as Moving Bed Biofilm Reactors (MBBR), Integrated Fixed-film Activated Sludge (IFAS) systems, and Membrane Bio-Reactors (MBRs) are utilised to improve the efficiency of organic matter and nutrient removal from wastewater.

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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 21 and 22** as follows:

Figure 21: Location Map for Marine Water Monitoring at Kandla

Figure 22: Location Map 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	

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

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	-	1.021	1.022	1.022	1.021	1.022	1.022	1.022	1.022
2.	pH	-	6.5-9.0	8.05	8.17	8.14	8.13	8.16	8.21	8.07	8.18
3.	Color	Hazen	No Noticeable	5	5	10	5	5	5	10	10
4.	EC	µS/cm	-	51,600	52,000	51,300	51,900	52,000	51,900	54,400	55,200
5.	Turbidity	NTU	-	56.4	33.9	61.8	69.0	94.5	70.1	7.8	7.12
6.	TDS	mg/L	-	33,960	34,146	33,724	34,038	33,882	34,368	31,490	33,540
7.	TSS	mg/L	-	44	26	52	58	80	58	307	309
8.	COD	mg/L	-	45.58	40.47	40.0	40.0	38.14	37.67	43.7	33.5
9.	DO	mg/L	3.0 mg/L	6.2	6.4	4.5	6.2	6.3	6.7	5.2	6.3
10.	BOD	mg/L	5.0 mg/L	BQL	BQL	5.00	5.00	BQL	BQL	6.2	4.2
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	2860.6	2897.7	2925.2	3029.2	2916.8	2862.6	2547.1	3016.4
13.	Nitrate	mg/L	-	4.93	4.36	5.13	5.24	6.92	6.84	4.14	4.21
14.	Nitrite	mg/L	-	0.12	BQL	BQL	BQL	0.11	0.13	BQL	BQL
15.	Phosphate	mg/L		0.54	BQL	0.69	0.61	0.70	0.65	BQL	BQL
16.	Silica	mg/L	-	2.13	2.47	2.47	2.58	4.00	2.48	0.47	0.62
17.	Sodium	mg/L	-	10,625	10,341	10,308	10,323	10,278	10,722	5376.25	8472
18.	Potassium	mg/L	-	311.40	310.40	311.10	306	313.50	289.70	298.3	342.2
19.	Hexavalent Chromium	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	-	-	1	1	1	1	1	1	1	1
21.	Arsenic	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	0.11	0.085
22.	Cadmium	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

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
24.	Iron	mg/L	-	0.88	0.77	0.90	1.05	1.57	1.19	BQL	BQL
25.	Lead	µg/L	-	BQL	BQL	BQL	BQL	3.85	BQL	BQL	BQL
26.	Manganese	µg/L	-	BQL	BQL	BQL	BQL	47.74	BQL	BQL	BQL
27.	Total Chromium	µg/L	-	BQL	BQL	BQL	BQL	5.82	BQL	BQL	BQL
28.	Zinc	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Mercury	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Particulate Organic Carbon	mg/L	-	1.17	0.61	0.59	1.88	1.51	1.43	BQL	BQL
31.	Total Coliforms	MPN/ 100ml	500/100 ml	23	50	52	2	14	22	20	17
32.	Floating Material (Oil grease scum, petroleum products)	mg/L	10 mg/L	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit; Turbidity (DL=50 NTU), Biochemical Oxygen Demand (QL=3 mg/L), Oil & Grease (QL=1 mg/L), Nitrate as NO_3 (QL=1 mg/L), Nitrite as No_2 (QL=0.1 mg/L), Phosphorous (QL=0.5 mg/L), Silica (QL=0.05 mg/L), Sodium as Na (QL=10,000 mg/L), Hexavalent Chromium (QL=0.01 µg/L), Arsenic (QL=5 µg/L), Cadmium (QL=2 µg/L), Copper (QL=5 µg/L), Iron (QL=0.1 mg/L), Lead (QL=2 µg/L), Manganese (QL=40 µg/L), Total Chromium (QL=5 µg/L), Zinc (QL=0.5 mg/L), Mercury (QL=0.5 µg/L)

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 2023 at high tide. The detailed interpretation of the parameters in comparison to the Class SW-IV for Harbour Waters is as follows:

- **pH** at Kandla was observed in the range of 8.05 to 8.21, with the average pH as 8.14. Whereas for the locations of Vadinar, it was observed in the range of be 8.07 to 8.18, with the average pH as 8.13. For the monitoring location of both the study areas, pH was found to comply with the norms of 6.5-8.5.
- **Color** was observed to be 5 Hazen at all the six-monitoring location of Kandla, whereas the value observed 10 Hazen at both the monitoring locations of Vadinar.
- For all monitoring locations of Kandla the value of **Turbidity** was observed in range of 33.9 to 94.5 NTU and for Vadinar it ranges from 7.12 to 7.8 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.
- **Electrical conductivity (EC)** was observed in the range of 51,300 to 52,000 µS/cm, with the average EC as 51,783.33 µS/cm for the locations of Kandla, whereas for the locations of Vadinar, it was observed in the range of 54,400 to 55,200 µS/cm, with the average EC as 54,800 µS/cm.
- For the monitoring locations at Kandla the value of **Total Dissolved Solids (TDS)** ranged from 33,724 to 34,368 mg/L, with an average value of 34019.67 mg/L. Similarly, at Vadinar, the TDS values ranged from 31,490 to 33,540 mg/L, with an average value of 32,515 mg/L.
- **TSS** values in the studied area during high Tide varied between 26 to 80 mg/L at Kandla and 168 to 307 mg/L at Vadinar, with the average value of 53 mg/L and 237.5 mg/L respectively for Kandla and Vadinar.
- **COD** varied between 37.67 to 45.58 mg/L at Kandla and 33.5 to 43.7 mg/L at Vadinar, with the average value as 40.31 mg/L and 38.6 mg/L respectively for Kandla and Vadinar.
- **DO** level in the studied area varied between 4.5 to 6.7 mg/L at Kandla and 5.2 to 6.3 mg/L at Vadinar, which represents that the marine water is suitable for marine life.
- **BOD** observed "below the detection limit" in the studied area of Kandla except for location MW-4 (Khori Creek) i.e. 5 mg/L, whereas at Vadinar the value observed 6.2 mg/L at MW-7 and at MW-8 recorded as 4.2 mg/L.
- **Sulphate** concentration in the studied area during high Tide varied between 2860.6 to 3029.2 mg/L at Kandla and 2547.1 to 3016.4 mg/L at Vadinar. A high variation in the sulphate concentration is observed at Kandla. Sulphate is naturally formed in inland waters by mineral weathering or the decomposition and combustion of organic matter.
- **Phosphate** in the studied area varied between 0.54 to 0.7 mg/L at Kandla, while at Vadinar, the concentration of Phosphate was recorded BQL.

- In the study area of Kandla the value **Potassium** during high Tide varied between 289.7 to 313.5 mg/L and 298.3 to 342.2 mg/L at Vadinar, with the average value as 307.01 mg/L and 320.25 mg/L respectively for Kandla and Vadinar.
- **Sodium** in the study area varied between 10,278 to 10,722 mg/L at Kandla whereas at Vadinar its value recorded 5376.25 mg/L at MW-7 and 8472 mg/L at MW-8.
- **Silica** in the studied area varied between 2.13 to 4 mg/L at Kandla and 0.47 to 0.62 mg/L for Vadinar.
- **Arsenic** in the study area of Kandla recorded below the quantification while at Vadinar the value observed to be 0.11 µg/L at MW-7 and 0.08 µg/L at MW-8.
- **Iron** in the study area varied between 0.77 to 1.57 mg/L at Kandla whereas at Vadinar its value recorded BQL at both the monitoring locations (MW-7 and MW-8).
- **Manganese** recorded BQL at all the monitoring location of Kandla and Vadinar excepts MW-5 i.e. 47.74 µg/L.
- **Oil & Grease, Copper, Nitrite, Hexavalent and Total Chromium, Cadmium, Zinc, and Mercury, Floating Material (Oil grease scum, petroleum products)** were observed to have concentrations **"Below the Quantification Limits (BQL)"** for all the locations of Kandla and Vadinar.
- **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 **Figure 23 and 24** as follows:

Figure 23: Location Map of Marine Sediment Monitoring at Kandla

Figure 24: Locations Map 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	4.02	9.47	19.32	7.82	18.36	16.81	5.39	4.48
2.	Phosphate	mg/Kg	994.23	1246.4	813.7	581.3	763.24	886.36	402.3	519.3
3.	Organic Matter	mg/Kg	0.42	BQL	BQL	0.77	0.93	0.53	0.15	0.17
4.	Sulphate as SO^{4-}	mg/Kg	183.25	113.50	246.90	165.50	113.65	108.30	86.36	143.40
5.	Calcium as Ca	mg/Kg	1963.62	2251.40	1463.80	2343	2347	2164	2896	2637.90
6.	Magnesium as Mg	mg/Kg	1383.23	1843.60	1573.20	1521.60	1568	1402.63	926.80	1623.80
7.	Silica	g/Kg	481.3	347.8	336.1	255.12	375.6	305.8	346.7	373.9
8.	Nitrite	mg/Kg	0.51	0.31	0.36	0.75	0.29	0.53	0.15	0.2
9.	Nitrate	mg/Kg	19.84	12.79	14.86	14.31	15.93	16.24	14.84	8.04
10.	Sodium	mg/Kg	3813	2707	3645	2643	3571	4123.95	5231.7	9291.4
11.	Potassium	mg/Kg	1823.3	1247.6	2943.5	2943.62	1546.4	3025.68	1236.7	3271.6
12.	Aluminium	mg/Kg	2442.3	2324.56	2168.9	2261.3	1316.2	1533.65	1584.3	1826.7
13.	Chromium	mg/Kg	62.13	43.9	48.32	43.5	50.23	53.65	27.9	56.72
14.	Copper	mg/Kg	2.73	3.83	3.12	4.02	5.12	3.63	3.12	5.12
15.	Nickel	mg/Kg	39.42	20.49	28.45	29.34	23.83	25.38	16.84	27.95
16.	Zinc	mg/Kg	60.76	63.26	46.3	55.53	57.36	56.64	25.89	88.74
17.	Cadmium	mg/Kg	BQL	0.60	0.87	BQL	BQL	0.15	BQL	BQL
18.	Lead	mg/Kg	5.86	5.92	4.56	5.37	4.32	3.67	5.49	8.21
19.	Arsenic	mg/Kg	3.22	2.58	3.81	3.13	2.86	2.35	2.04	3.20
20.	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21.	Texture	-	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy 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 2023. The detailed interpretation of the parameters is given below:

- **Inorganic Phosphate** for the sampling period was observed in range of 4.02 to 19.32 Kg/ha for Kandla. Whereas for Vadinar the value observed at location MS-7 i.e., Nakti creek (5.39 Kg/ha) and MS-8, i.e., Near Vadinar Jetty (4.48 Kg/ha). For Kandla and Vadinar the average value of Inorganic Phosphate was observed 12.63 and 4.94 Kg/ha respectively.
- The value of **Phosphate** was observed in range of 581.3 to 1246.4 mg/Kg for Kandla and for Vadinar the value observed at location MS-7 i.e., Nakti creek (402.3 mg/Kg)

and MS-8, i.e., Near Vadinar Jetty (519.3 mg/Kg). For Kandla and Vadinar the average value of Phosphate was observed 880.87 and 460.8 mg/Kg respectively.

- The value of **Organic Matter** for the sampling period was observed in the range of 0.42 to 0.93 % for Kandla with the average value of 0.66% and for Vadinar the value recorded at location MS-7 and MS-8 was observed 0.15% & 0.17% respectively.
- The value of **Sulphate** was observed in the range of 108.3 to 246.9 mg/Kg for Kandla and for Vadinar the value observed at MS-7 is 86.36 mg/Kg and at MS-8, is 143.40 mg/Kg. For Kandla and Vadinar the average value of Sulphate was observed 155.18 and 114.88 mg/Kg respectively.
- The value of **Calcium** was observed in the range of 1463.8 to 2347 mg/Kg for Kandla and for Vadinar the value observed at MS-7 is 2896 mg/Kg and at MS-8, is 2637.90 mg/Kg. The average value of Calcium for the monitoring period was observed 2088.80 mg/Kg and 2766.95 mg/Kg at Kandla and Vadinar, respectively.
- The value of **Magnesium** for the sampling period was observed in the range of 1383.23 to 1843.6 mg/Kg for Kandla and for Vadinar the value observed at MS-7 is 926.80 mg/Kg and at MS-8, is 1623.80 mg/Kg. For Kandla and Vadinar the average value of Magnesium was observed 1548.71 mg/Kg and 1275.3 mg/Kg respectively.
- The value of **Nitrate** was observed in the range of 12.79 to 19.84 mg/Kg for Kandla with average value 15.66 mg/Kg and for Vadinar the value observed to be 14.84 and 8.04 mg/Kg at MS-7 and MS-8, respectively with average 11.44 mg/Kg.
- The value of **Nitrite** was observed in the range of 0.29 to 0.75 mg/Kg for Kandla with average value 0.45 mg/Kg and for Vadinar the value observed to be 0.15 and 0.2 mg/Kg at MS-7 and MS-8, respectively with average 0.18 mg/Kg.
- The value of **Sodium** was observed in the range of 2643 to 4123.95 mg/Kg for Kandla with average value 3417.16 mg/Kg and for Vadinar the value observed to be 5231.7 and 9291.4 mg/Kg at MS-7 and MS-8, respectively with average 7261.55 mg/Kg.
- For the sampling period **Silica** was observed in the range of 255.12 to 481.3 mg/Kg for Kandla with average value 350.28 mg/Kg and for Vadinar the value observed to be 346.7 and 373.9 mg/Kg at MS-7 and MS-8, respectively with average 360.3 mg/Kg
- The value of **Potassium** was observed in the range of 1247.6 to 3025.68 mg/Kg for Kandla with average value 2255.01 mg/Kg and for Vadinar the value observed to be 1236.7 and 3271.6 mg/Kg at MS-7 and MS-8, respectively with average 2254.15 mg/Kg.
- The value of **Aluminium**, was observed in the range of 1316.2 to 2442.3 mg/Kg for Kandla with average value 2007.82 mg/Kg and for Vadinar the value observed to be 1584.3 and 1826.7 mg/Kg at MS-7 and MS-8, respectively with average 1705.5 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 Loamy**" in both Kandla and Vadinar the sampling period, except location MS-8 which is Loamy soil.

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	3.22	2.58	3.81	3.13	2.86	2.35	2.04	3.20
2.	Copper	mg/Kg	2.73	3.83	3.12	4.02	5.12	3.63	3.12	5.12
3.	Chromium	mg/Kg	62.13	43.9	48.32	43.5	50.23	53.65	27.9	56.72
4.	Nickel	mg/Kg	39.42	20.49	28.45	29.34	23.83	25.38	16.84	27.95
5.	Lead	mg/Kg	5.86	5.92	4.56	5.37	4.32	3.67	5.49	8.21
6.	Zinc	mg/Kg	60.76	63.26	46.3	55.53	57.36	56.64	25.89	88.74
7.	Cadmium	mg/Kg	BQL	0.60	0.87	BQL	BQL	0.15	BQL	BQL

- **Arsenic** was observed in the range of 2.35 to 3.81 mg/Kg for Kandla with average value 2.9 mg/Kg and for Vadinar the value observed to be 2.04 and 3.20 mg/Kg at MS-7 and MS-8, respectively with average 2.62 mg/Kg.
- **Copper** was observed in the range of 2.73 to 5.12 mg/Kg for Kandla with average value 3.74 mg/Kg and for Vadinar the value observed to be 3.12 and 5.12 mg/Kg at MS-7 and MS-8, respectively with average 4.12 mg/Kg.
- **Chromium** was observed in the range of 43.5 to 62.13 mg/Kg for Kandla with average value 50.28 mg/Kg and for Vadinar the value observed to be 27.9 and 56.72 mg/Kg at MS-7 and MS-8, respectively with average 42.31 mg/Kg.
- **Nickel** was observed in the range of 20.49 to 39.42 mg/Kg for Kandla with average value 27.82 mg/Kg and for Vadinar the value observed to be 16.84 and 27.95 mg/Kg at MS-7 and MS-8, respectively with average 22.39 mg/Kg.

- **Lead** was observed in the range of 3.67 to 5.92 mg/Kg for Kandla with average value 4.95 mg/Kg and for Vadinar the value observed to be 5.49 and 8.21 mg/Kg at MS-7 and MS-8, respectively with average 6.85 mg/Kg.
- **Zinc** was observed in the range of 46.3 to 63.26 mg/Kg for Kandla with average value 56.64 mg/Kg and for Vadinar the value observed to be 25.89 and 88.74 mg/Kg at MS-7 and MS-8, respectively with average 57.32 mg/Kg.
- **Cadmium** was observed BQL for majority of locations at Kandla and Vadinar during sampling period except for location except MS-2 (0.6), MS-3 (0.87 mg/L) and MS-6 (0.15 mg/L).

Analysis of the sediments does not indicate any 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.

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 **Figure 25 and 26** as follows:

Figure 25: Locations Map of Marine Ecological Monitoring at Kandla

Figure 26: Locations Map 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.

- **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:

$$d = \frac{N_{max}}{\mathrm{N}_i}$$

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	135	184	122	211	149	124	102	94
2.	Net Primary Productivity (NPP)	mg/L/hr	0.19	BQL	0.84	1.29	BQL	BQL	BQL	1.05
3.	Gross Primary Productivity (GPP)	mg/L/hr	1.57	BQL	1.2	2.31	BQL	0.22	1.52	2.61
4.	Pheophytin	mg/m^3	0.22	BQL	0.25	BQL	0.51	BQL	1.02	1.11
5.	Chlorophyll-a	mg/m^3	1.34	0.235	1.02	0.87	1.41	0.99	2.14	1.74
6.	Particulate Oxidisable Organic Carbon	mg/L	1.17	0.61	0.59	1.88	1.51	1.43	BQL	BQL
7.	Secchi Depth	ft	0.85	1.18	0.8	0.75	0.61	0.74	3.01	3.19

- **Biomass:**

  With reference to the **Table 39**, the value of **Biomass** reported from location ME-1 to ME-6 in range between 122-211 mg/L where lowest biomass presents in ME-3 (Near Coal Berth) and highest biomass present in ME-4 (Khori Creek) during sampling period. In Vadinar, the value of biomass was observed 102 mg/L at ME-7 (Near SPM) and 94 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 0.22 to 2.31 mg/L/48 Hr where the highest value recorded for Khori Creek (ME-4) and lowest recorded at Nakti creek, near to NH-8A i.e. ME-6. In Vadinar, the value of **GPP** was observed was observed 1.52 mg/L/48 Hr at ME-7 (Near SPM) and 2.61 mg/L/48 Hr in 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 estimated to be between 0.19 to 1.29 mg/L/48 Hr. While in Vadinar, the value of **NPP** was observed BQL at ME-7 and 1.05 mg/L/48 Hr at ME-8 monitoring station.

- **Pheophytin**

  The level of Pheophytin was detected in the range from 0.22 to 0.51 mg/m^3 where the highest value observed at ME-5 (Nakti creek) and the lowest or below quantification limit observed at ME-2, ME-4 and ME-6. While in Vadinar, the value of Pheophytin was observed 1.12 at ME-7 and 1.01 mg/L/48 Hr at ME-8 monitoring station.

- **Chlorophyll-a**

  In the sub surface water, the value of Chlorophyll-a reported in range from 0.24 to 1.41 mg/m^3. The highest value observed at ME-5 (Nakti creek) while the lowest value observed at ME-2 (Kandla Creek, near to KPT Colony). In Vadinar, the value of chlorophyll-a was observed 2.14 mg/m^3 at ME-7 (Near SPM), monitoring station and 1.74mg/m^3 in ME-8 (Near Vadinar Jetty).

- **Particulate Oxidisable Organic Carbon**

  During the sampling period, the particulate oxidisable organic carbon falls within the range of 0.61 to 1.18 mg/L from monitoring location ME-1 to ME-6 at Kandla, whereas for Vadinar it recorded BQL at both the monitoring station (ME-7 and ME-8).

- **Secchi Depth**

  In monitoring station of Kandla (ME-1 to ME-6) the level of Secchi Depth was observed between 0.61 to 1.18 ft whereas at Vadinar, the value recorded at ME-7 i.e. Near SPM is 3.01 ft and in Near Vadinar Jetty is 3.19 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 is 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.	300	40	150	184	250	-	-	-
Chaetoceros sp.	-	-	110	75	210	-	130	-
Chlamydomonas sp.	-	113	-	130	-	120	-	-
Cyclotella sp.	140		250	-	-	350	98	260
Ditylum sp	-	-	-	140	-	160	110	255
Coscinodiscus sp.	423	354		64	120	-	-	-
Fragilaria sp.	-	-	320	-	-	-	250	
Bacteriastrum sp.	-	-	-	260	-	310	220	210
Pleurosigma sp.	230	140	45	-	60	-	-	-
Navicula sp.	-	-	-	-	-	145	350	4167
Nitzschia sp.	245	120	260	-	120	42	-	-
Synedra sp.	-	-	-	75	-	-	150	100
Planktothrix sp.	170	40	130	-	-	180	-	-
Oscillatoria sp.	174	-	340	280	-	-	70	156
Thallassiosira	-	250	-	-	120	70	-	-
Density-Units/L	**1682**	**1057**	**1495**	**1133**	**670**	**1377**	**1378**	**5148**
No. of genera	**7**	**7**	**7**	**7**	**5**	**8**	**8**	**6**

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 12 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 670 to 1682 units/L, while for Vadinar its density of phytoplankton observed 1378 units/L at ME-7 and 5148 units/L at ME-8. During the sampling, phytoplankton communities were dominated by *Coscinodiscus sp*. and *Bacillaria sp*. in Kandla, while *Navicula sp*. in Vadinar.

The details of Species richness Index and Diversity Index in Phytoplankton is 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	12	12	14	13	16	13	12	14
Individuals	7450	8745	9155	9100	10310	7990	8025	9650
Shannon diversity	1.88	1.37	1.90	1.64	1.23	1.73	1.77	1.02
Simpson 1-D	0.84	0.79	0.84	0.84	0.80	0.83	0.84	0.34
Species Evenness	0.97	0.70	0.91	0.79	0.69	0.83	0.85	0.57
Margalef richness	0.81	0.86	0.95	0.99	0.74	0.97	0.97	0.59
Berger-Parker	0.25	0.33	0.21	0.23	0.28	0.25	0.25	0.81
Relative abundance	0.42	0.66	0.50	0.66	0.68	0.58	0.58	0.12

- **Shannon- Wiener's Index (H)** of phytoplankton communities was in the range of 1.23 to 1.90 between selected sampling stations from ME-1 to ME-6 with an average value of 1.63 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of phytoplankton communities recorded to be 1.77 at ME-7 and 1.02 at ME-8 with an average value of 0.38. 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 0.79 to 0.84 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.82. Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was 0.84 at ME-7 and 0.34 at ME-8 with an average of 0.59.

- **Margalef's diversity index** (Species Richness) of phytoplankton communities in Kandla and nearby creeks sampling stations was varying from 0.74 to 0.99 with an average of 0.89 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of phytoplankton communities observed 0.97 at ME-7 and 0.59 at ME-8 with an average value of 0.78.

- **Berger-Parker Index (d)** of phytoplankton communities was in the range of 0.21 to 0.33 between selected sampling stations from ME-1 to ME-6 with an average value of 0.26 at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of 0.25 to 0.81 with an average value of 0.53. 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 0.69 to 0.97 for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of 0.57 to 0.85, during the monitoring month. This indicates varying degrees of evenness or unevenness in the distribution of individuals among the studied species.

- During the sampling period, **Relative Abundance** of phytoplankton communities was in range of 0.42 to 0.68 between selected sampling stations from ME-1 to ME-6 with an average value of 0.58 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 0.58 at ME-7 and 0.12 at ME-8 with an average value 0.35, 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 is 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	2	1	-	2	-	-	1
Acrocalanus	-	-	-	-	-	2	-	-
Amoeba	2	-	3	4	2	-	4	1
Brachionus sp.	-	1	-	-	-	2	-	-
Calanus sp.	-	-	6	-	-	-	-	-
Cladocera sp.	6	1	-	1	-	2	1	2
Cyclopoid sp.	-	-	2		-	6	-	-
Copepod larvae	-	-	2	2	-	1	-	2
Diaptomus sp.	5	1	-	-	2	-	5	-
Eucalanus sp.	-	-	8	-	-	9	-	1
Mysis sp.	2	-	-	1	-	-	1	-
Paracalanus sp.		2	5	-	-	2	-	2
Density Unit/L	**16**	**7**	**27**	**8**	**6**	**24**	**11**	**9**
No. of genera	**5**	**5**	**7**	**4**	**3**	**7**	**4**	**6**

A total of 12 groups/taxa of zooplankton were recorded in Kandla and Vadinar during the study period which mainly constituted by copepods, branchiopoda, monogononata, fish and shrimp larval forms. *Eucalanus sp.* had the largest representation at all stations from (ME-1 to ME-8). The density of Zooplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from 6 to 27 units/L, while for Vadinar its density of zooplankton observed 11 units/L at ME-7 and 9 units/L at ME-8. During the sampling, zooplankton communities were dominated by *Eucalanus sp.* and *Cladocera sp.* in Kandla, while *Amoeba* in both the monitoring location of Kandla and Vadinar.

The details of Species richness Index and Diversity Index in Zooplankton communities is 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	5	5	7	4	3	7	4	6
Individuals	16	7	27	8	6	24	11	9
Shannon diversity	1.42	1.55	1.76	1.21	1.1	1.33	1.16	1.74
Simpson (1-D)	0.78	0.9	0.83	0.75	0.8	0.86	0.71	0.92
Species Evenness	0.88	0.96	0.9	0.87	1	0.68	0.84	0.97
Margalef	1.44	2.06	1.82	1.44	1.12	1.89	1.25	2.28
Berger-Parker	0.38	0.29	0.3	0.5	0.33	0.38	0.45	0.22
Relative abundance	31.25	71.43	25.93	50	50	29.17	36.36	66.67

- **Shannon- Wiener's Index (H)** of zooplankton communities was in the range of 1.1 to 1.76 between selected sampling stations from ME-1 to ME-6 with an average value of 1.39 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of zooplankton communities recorded to be 1.16 at ME-7 and 1.74 at ME-8 with an average value of 1.45. 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 0.75 to 0.9 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.82. Similarly, for Vadinar Simpson diversity index (1-D) of zooplankton communities was 0.71 at ME-7 and 0.92 at ME-8 with an average of 0.88.

- **Margalef's diversity index** (Species Richness) of zooplankton communities in Kandla and nearby creeks sampling stations was varying from 1.12 to 2.06 with an average of 1.63 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of zooplankton communities observed 1.25 at ME-7 and 2.28 at ME-8 with an average value of 1.76.

- **Berger-Parker Index (d)** of zooplankton communities was in the range of 0.29 to 0.5 between selected sampling stations from ME-1 to ME-6 with an average value of 0.36 at Kandla creek and nearby creeks. Berger-Parker Index (d) of zooplankton communities in the sampling stations of Vadinar, was in the range of 0.22 to 0.45 with an average value of 0.34. 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 0.68 to 1 for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of 0.84 to 0.97, during monitoring month, indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of 29.17 to 71.43 between selected sampling stations from ME-1 to ME-6 with an average value of 42.96 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 36.36 at ME-7 and 66.67 at ME-8 with an average value 51.52, 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** is mentioned in **Table 44.**

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

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Thiaridae	2	1	-	5	-	4	1	2
Mollusca sp.	2	2	2	1	-	1	2	-
Odonata sp.	5	1	-	2	1	1	-	-
Lymnidae	1	4	5	3	2	-	5	-
Planorbidae	-	-	2	-	-	3	-	1
Atydae	1	2	-	1	-	2	-	1
Gammaridae	-	1	1	-	-	-	2	4
Turbinidae	1	-	3	-	1	1	-	2
Palaemonidae	-	-	-	2	-	-	-	-
Density-m³	**12**	**11**	**13**	**14**	**4**	**12**	**10**	**10**
No of genera	**6**	**6**	**5**	**6**	**3**	**6**	**4**	**5**

Few Benthic organisms were observed in the collected sample by using the Van-Veen grabs during the sampling conducted for DPA Kandla and Vadinar. Majority of the species were found under the Macro-benthic organisms during the sampling period were represented by *Lymnidae sp, Thiaridae, Mollusca sp.* etc. The density of benthic fauna was varying from 4 to 14 m². The dominating benthic communities at Kandla Creek and nearby creek (Nakti and Khori creek) were represented *Lymnidae sp.* While lowest number of benthic species was represented by *Palaemonidae.*

The details of Species richness Index and Diversity Index in Benthic Organisms is 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	6	6	5	6	3	6	4	5
Individuals	12	11	13	14	4	12	10	10
Shannon diversity	1.58	1.64	1.48	1.63	1.04	1.63	1.17	1.42
Simpson 1-D	0.82	0.85	0.81	0.84	0.83	0.85	0.73	0.82
Species Evenness	0.88	0.92	0.92	0.91	0.95	0.91	0.84	0.88
Margalef	2.01	2.09	1.56	1.89	1.44	2.01	1.3	1.74
Berger-Parker	0.42	0.36	0.38	0.36	0.5	0.33	0.5	0.4
Relative abundance	50	54.55	38.46	42.86	75	50	40	50

- **Shannon- Wiener's Index (H)** of benthic organism was in the range of 1.04 to 1.64 between selected sampling stations from ME-1 to ME-6 with an average value of 1.5 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of benthic organism recorded to be 1.17 at ME-7 and 1.42 at ME-8 with an average value of 1.29. 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 0.81 to 0.85 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.83.

Similarly, for Vadinar Simpson diversity index (1-D) of benthic organism was 0.73 at ME-7 and 0.82 at ME-8 with an average of 0.78.

- **Margalef's diversity index** (Species Richness) of benthic organism in Kandla and nearby creeks sampling stations was varying from 1.44 to 2.09 with an average of 1.83 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of benthic organism observed to be 1.3 at ME-7 and 1.74 at ME-8.

- **Berger-Parker Index (d)** of benthic organism was in the range of 0.33 to 0.5 between selected sampling stations from ME-1 to ME-6 with an average value of 0.39 at Kandla creek and nearby creeks. Berger-Parker Index (d) of benthic organism in the sampling stations of Vadinar, was in the range of 0.4 to 0.5 with an average value of 0.45. 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 0.88 to 0.95 for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of 0.84 to 0.88, during monitoring month, indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of 38.46 to 75 between selected sampling stations from ME-1 to ME-6 with an average value of 51.81 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 40 at ME-7 and 50 at ME-8 with an average value 45.29, 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

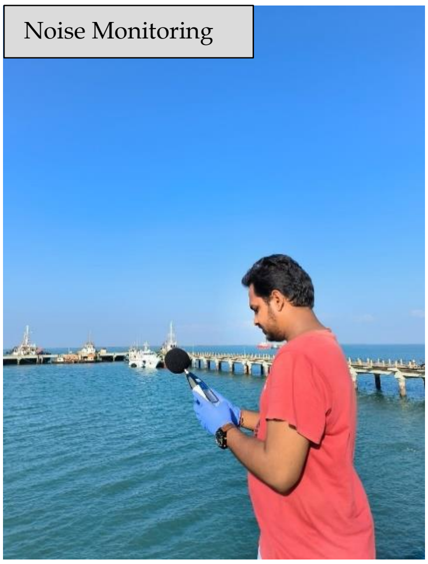
Marine Monitoring

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 -F

Final Report

On

Greenbelt Development for the Deendayal Port Authority at Kandla Port

Submitted to

Deendayal Port Authority

Administrative Office Building

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Final Report

on

Greenbelt Development for the Deendayal Port Authority at Kandla Port, Kandla

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Introduction

Green vegetation cover surrounding human environment is a vital entity for supply of oxygen, food, fodder and medicine for the survival of all living being, and also it has played an important role in maintaining ecological balance, climate regulation, biodiversity conservation, retention of soil moisture, control of soil erosion, increasing soil fertility, maintaining pleasant micro climate of the region, etc. In addition, vegetation cover also absorbs various pollutants from the environment and thus helps in effective pollution control. However, due to the various types and extent of economic development like industrialization, mining, infrastructural development, etc. has reducing and fragmenting natural vegetation cover day-by day all over the world. The infrastructural and industrial development leads to influence the life of all the living organisms in two directions: either upwards or downwards. In the upward mode, human being gets opportunities for luxuriant life with easy accessibility to the resources while in downward, the quality of ecosystem services gets affected. Most of the industrial and infra-structural developmental activities generate pollution of one or other types with varying magnitudes, which makes susceptible to all the organisms, nevertheless, the power of resistance of each organism helps themselves to overcome the hazards caused by such pollutants.

Therefore, development of green belts alongside of industries, mines, thermal power station, roadsides, and other development unit is an effective mechanism to rejuvenate vital vegetation cover for safeguarding health of human and other living being. Green belts in and around urban and industrial areas are important to the ecological health of any given region. Greenbelt is the raw of trees planted along the industrial units, mines, roadside for reducing the pollution originating from these operations (Flemming, 1967; Hanson and Throne, 1970; Warren, 1973; Ganguly, 1976). Greenbelt has developed considering following factors; (i) physical characteristics of the green belt eg. Distance from the source, width, and height and leaf surface area density (ii) aerodynamic properties eg. Wind speed through greenbelt and effective height of the incident air stream (iii) deposition velocity of the pollutant and (iv) atmospheric stability conditions (CPCB, 2000).

As per the National Forest Policy (NFP-1988), it is necessary to encourage the planting of trees alongside of roads, railway lines, rivers and streams and canals, and on other unutilized lands under state/corporate, institutional or private ownership. NFP give emphasis on the green belt developments. It says – Green belts should be raised in urban/industrial areas as well as in arid tracts. Such a programme will help to check erosion and desertification as well as improve the microclimate.

Green infrastructure serves to provide on ecological framework for social, economic and environmental health of the surroundings. The main components of this approach include storm water management, climate adaptation, less heat stress, more biodiversity, food production, better air quality, sustainable energy production, clean water and healthy soils, as well as the more anthropocentric functions such as increased quality of life through recreation and providing shade and shelter in and around infrastructure and industrial areas. Green infrastructure is thought to be effective in such scenarios, where green plants from a surface capable of absorbing air pollutants and act as a sink for pollutants. Leaves with their vast leaf area in the tree canopy, absorbs pollutants on their surface. Thus, effectively reduce their concentrations in the ambient air. Often the absorbed pollutants are incorporated in metallic streams and thus the air is purified. Plants grown in such a way as to function as pollutant sinks are collectively referred to as green infrastructure or green belts. Apart from functioning as a pollutant sink, green belts would also provide other benefits like aesthetic improvement and providing possible habitats for birds and animals along with maintain the soil moisture regime with the soil microorganisms and improve the Soil quality and ground water recharge. The greenbelts has helps in improving the ecology, maintenance of biodiversity, mitigation of dust pollution and fugitive emission, control of noise pollution, provide fresh air, mitigates soil erosion, increasing aesthetic values of an area and overall improvement of the landscape.

Rationale

Deendayal Port in Kachchh District of Gujarat State (formerly Kandla Port Trust), operated by Deendayal Port Authority (DPA), is a gateway Port to the hinterland in the western and northern states of India. It is one of the 11 major Ports of India situated at 22°59'39.77'' N latitude and; 70°13'20.14'' E longitude on Kandla creek at Gulf of Kachchh. The inclusion of Karachi Port in Pakistan after India's partition and heavy traffic congestion at the then Bombay Port gave impetus for promoting Deendayal Port during the year 1950s. In 1955, Deendayal Port acquired the status of a major Port in India. Because of its proximity to the Gulf countries, large quantities of crude petroleum and other assorted cargo are imported through Deendayal Port. The Port presently has 14 jetties, six oil terminals, and several allied facilities for handling dry and liquid cargo. Regular expansion/developmental activities such as the addition of jetties, allied Special Economic Zones (SEZ hereafter), industrial parks and ship bunkering facilities are underway to cope with the increasing cargo handling demands. Shri Mansukh Mandaviya, Minister of State for Ports, Shipping and Waterways (I/C) appreciated the efforts taken by Deendayal Port and added that it is indeed the major achievements in the challenging (COVID) times and it is significant indication that economy is bouncing back to achieve pre-COVID times.

Major commodities handled by the Deendayal Port are Crude Oil, Petroleum product, Coal, Salt, Edible Oil, Fertilizer, Sugar, Timber, Soya bean, Wheat. This major achievement can be attributed to the user-friendly approach of port with the Shipping fraternity / stakeholders and constant consultations with them to improve ease of doing business. An assortment of liquid and dry cargo is being handled at Deendayal Port. The dry cargo includes fertilizers, iron crap, steel, food grain, metal products, ores, cement, coal, machinery, sugar, wooden logs, salt extractions, etc. The liquid cargo includes edible oil, crude oil and other petroleum products. DPA created a new record by handling 127.10 million metric tonnes of cargo during FY 2021-22 compared to 117.566 MMT in FY 2020-21, with a growth of 8.11%. Incidentally, DPA is the only major Indian Port to handle more than 127 MMT cargo throughput, and it has also registered as the highest cargo throughput in its history. The Port has handled 3151 vessels during FY 2021-22 compared to 3095 vessels in FY 2019-20. While the Port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of Liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in September 2021. Deendayal Port is a natural harbour located on the eastern bank of North-South trending Kandla creek at an aerial distance of 145 km from the Gulf's mouth.

Being located at the inner end of the Gulf of Kachchh (GoK), Deendayal Port has a fragile marine ecosystem with a vast expanse of mangroves, mudflats, creek systems and allied biota. The Port location is marked by a network of major and minor mangrove-lined creek systems with a vast extent of mudflats. The coastal belt in and around the Port has an irregular and dissected configuration.

There are no perennial or seasonal rivers in Gandhidham taluka where the part is located. Total rainy days during the monsoon season is limited to only 15-20 days and used to be erratic. Freshwater input into the near coastal waters is relatively meagre and appears to have less influence on the ambient coastal water quality except during monsoon months, during which freshwater through flash floods get discharged in the near coastal waters. The annual average humidity is 60%, which increases to 80% during the southwest monsoon (June to September) and decreases to 50% during the months of November and December. The drought phenomenon is common with two drought years in a cycle of 5 years.

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

DPA is committed towards environment protection since its establishment and has taken many initiatives towards increasing green cover and greenbelt development in various areas under DPA through intensive plantation activities and developing greenbelt around its established port and jetty areas and human habitations.

In order to enhance and strengthen Greenbelt Development, the DPA has approached GUIDE to develop the greenbelt area within the port area in phase wise manner. It was finalised to raise 5000 plants at a suitable site during the first phase.

Project Site

Based on observation made by the GUIDE Team and Officials from Deendayal Port Authority, a site at adjacent to Berth 11-12 (Wood log site) have been selected on the peripheral boundary of two sides.

The area proposed for green development of Deendayal Port is barren land without any vegetation. The soil of the area is black muddy highly saline soil and with saline ground water. The area is very dry and hot during the summer. The highest temperature used to be recorded in this area.

Scope of Works

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

1. To make an inventory of suitable sites for greenbelt development in and around the Deendayal Port at Kandla.
2. To carryout Soil and Moisture Conservation (SMC) of the selected sites.
3. Identification of suitable native species of plants for the greenbelt plantation.
4. Adopting plantation technique of plant saplings.
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:

- Removal of exotic/unwanted plants plant species from the entire area demarcated for green belt development: The entire selected site have been cleared by removing unwanted weeds and material such as stones, plastics etc.by JCB and also with labours.

- Landscaping of the area and land preparation Trench line of 2.5x 2.5 ft. have been dig out through JCB along the boundary adjacent to birth 11 & 12 wood log area up to approximately 5000 ft.
- Soil and moisture conservation work since the port area is highly saline, SMC work was very much essential for better survival of the plants. Eight dumper of fertile soil from the field have been added.

- Identification of native species of plants for plantation in greenbelt as per the site suitability the site was very challenging for greenbelt development since the water and soil is highly saline with the extreme climatic condition, the selection of plant species for plantation has been made very carefully. 40 % of plants have been selected as native species for plantation where as 60% species of *Conocarpus*.
- Procurement of sapling of identified species or Nursery management or seeding of tree/shrub species all the saplings were procured where of 3-4 ft. in height from reliable nursery. All saplings were of tree species.

- Installation of irrigation facilities was not feasible therefore activity was planned preferably through tankers. The watering of the plantation have been schedule as per the seasons which is given in table. Regular watering as per the scheduled have been provided by the water tanker under the supervision of team expert
- Use of Manure, preferably organic fertilizer for enhancing soil fertility best quality organic manure of 12,500 kg have been provided to the saplings for better growth and survival. Weed management and trench repairing have been carried out periodically also as and when it required.

- Regular monitoring and management of the saplings by a qualified team from GUIDE the selected site is wood log site hence, the wood log used to roll down on a path for water tanker while uploading and downloading the wood log. The regular visit to the site has been made for monitoring and clearing the road for water tanker for irrigation. Gap filling were also made during the period.

Plantation Techniques:

- Site development for a plantation includes clearance for weeds and it involves, bush cutting, soil and moisture conservation works in 'nalas', construction of bunds or check dams, marking of pits for planting of saplings etc.

- After clearing the land sites for digging of 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 6 dumper have been added for better survival of plants

- Organic manure around 12,500 kg. Have been given for better growth and survival.

- The pit have been filled a little above the ground level so that after the earth settles the upper surface of the pit is level to the ground thus avoiding any water logging.

- The plantation has been out in two phase since the some areas were blocked by wood logs.

- Around 4100 saplings have been planted during the month of September 2022 at available plantation area.

- The remaining and gap filling of 1500 saplings have been planted after the clearance of the area during the month of Feb.2023. A total number of 5000 plantations, were completed in the area.

Selection of Plant Species for Plantation:

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

Number of Sapling:

Approximate numbers of saplings to be required for the greenbelt are as follows:

- Peripheral plantation adjacent to birth 11-12 (along the boundary of the wood log area both sides): 5000 saplings

Management and Monitoring of Greenbelt:

The plantation within the identified site have been managed and monitored for a period of one year from June 2022 to June 2023 The management of plantation includes appropriate irrigation of the plantation in regular intervals, during summer and winter periods and if required even during monsoon with dry spells.

Watering have been made through tanker service at given schedule during the different seasons. (Table 1)

The all plants are growing very well and reached more 4-6 ft. height. The survival of plants have been noted very high as 98% during June 2023.

Table: 1 Time Schedule for Watering

Sr. No.	Month & Year	Number of Time
1	September 2022	4 times/month
2	October 2022	5 times/ month
3	November 2022	8 times/ month
4	December 2022	8 times/ month
5	January 2023	8 times/ month
6	February 2023	8 times/ month
7	March 2023	12 times/ month
8	April 2023	12 times/ month
9	May 2023	12 times/ month
10	June 2023	2 times/ month (end of the project 4th June 2023

Table: 2 List of Plants for Plantation at Site for Greenbelt Development

SI. No.	Scientific Name	Local Name	No. of Plant
1	*Conocarpus lancifolius*	Conocarpus	3500
2	*Ficus religiosa*	Piplo	100
3	*Azadirachta indica*	Limblo	200
4	*Peltophorum pterocarpum*	Pletoforam	300
5	*Millettia pinnata*	Karanj	300
6	*Cassia fistula*	Garmalo	100
7	*Delonix regia*	Gulmahor	300
8	*Mimusops elengi*	Borssalii	200

Fig. 1 Before Plantation

Fig. 2 Map of Plantation Area

Fig. 3 Digging Out Trench for Plantation

Fig. 4 Transportation of Plants to Site

Fig. 5 Fertile Soil for Better Survival of Plants

Fig. 6 Plantation Pits of Soil Filling

Fig. 7 Organic Manure for Better Growth and Survival

Fig. 8 Regular Watering of the plants by tanker

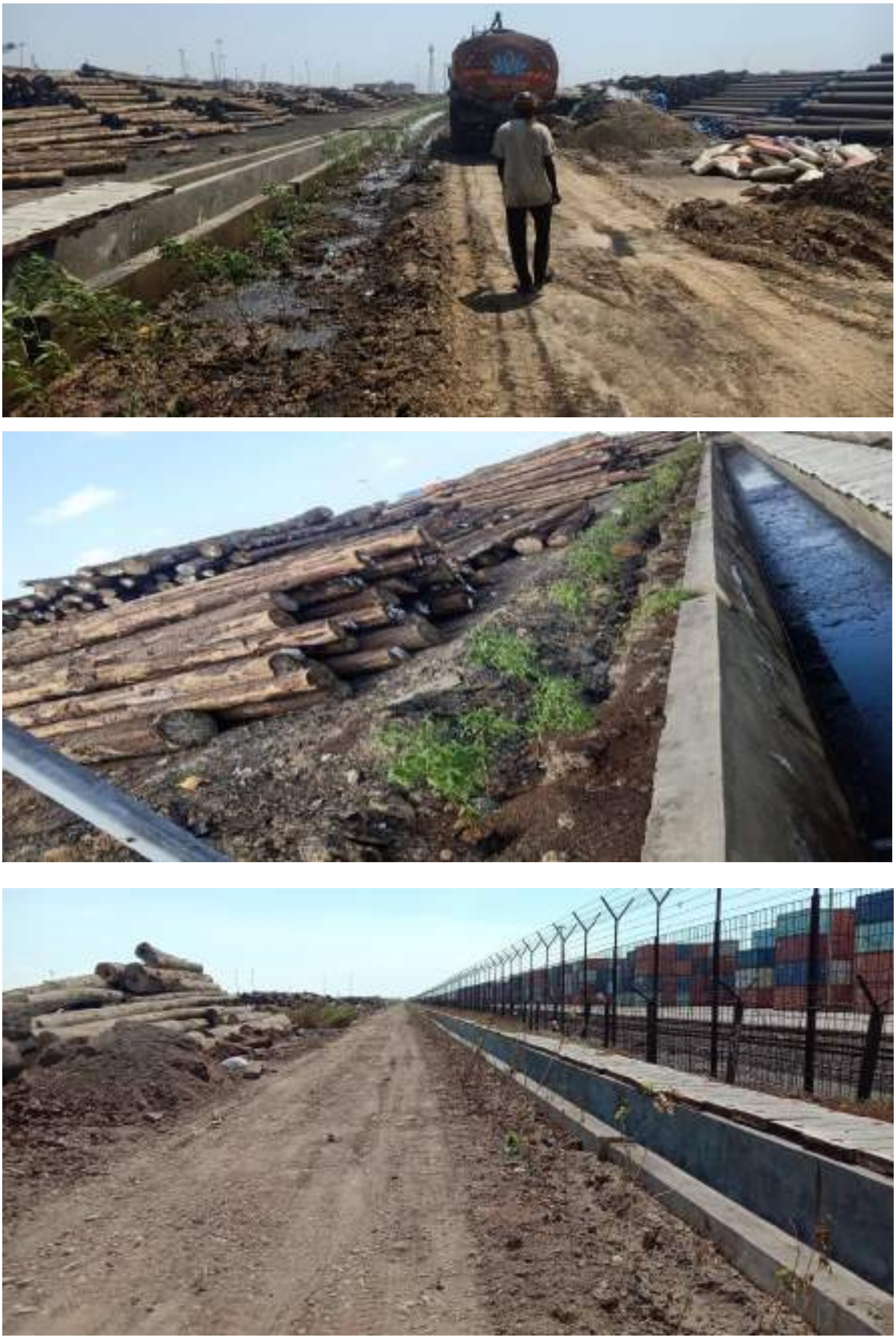

Fig. 9 Plantation in October 2022

Fig. 10 Plantation in December 2022

Fig. 11 Plantation in February 2023

Fig. 12 Plantation in May 2023

Annexure -G

Second Season Report

Studies on Dredged Materials for the presence of Contaminants and suggesting suitable disposal options

(As per EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific Condition No. vii)

DPA Work order No. EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021.

Submitted by

Gujarat Institute of Desert Ecology
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Submitted to

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2023

Project Team

Project Co-Ordinator **:** Dr. V. Vijay Kumar, Director

S. No	Name and Designation	Role	Background
1.	Dr. K. Karthikeyan Assistant Director	Principal Investigator	M.Sc., Ph.D. in Environmental Science; 15 years of experience in Marine Environmental Monitoring and Pollution Assessment studies.
2.	Dr. G. Jayanthi Scientist	Co- Investigator	MSc., MPhil., PhD in Botany; 13 years of Research and teaching experience inclusive of Post-Doctoral experience for 5 years.
3.	Dr. Krushnakant. D. Baxi Scientific Officer	Co- Investigator	Ph.D in Zoology (Marine Biology) with 5 years of experience
4.	Dr. T. Dhananjayan Sr. Scientific Assistant	Team Member	M.Sc. in Environmental Sciences; 8 years of experience in sediment, water analysis and instrumentation.
5.	Ms. Dipti Parmar Scientific Assistant	Team member	M.Sc. in Environmental Sciences; 4 years of experience in sediment and water analysis.

Dr. V. Vijay Kumar
Director

Gujarat Institute of Desert Ecology

Certificate

This is to state that the **Second Season Report** of the work entitled, **"Studies on Dredged Material for the presence of contaminants"** has been prepared in line with the Work order issued by DPT vide No. EG/WK/4751/Part (EC & CRZ-1) / 84. Dt.18.09.2021 as per the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016, Specific Condition No. vii. This work order is for a period of Three years from 2021 –2024 for the above-mentioned study.

This Second Season report is for the project period from May 2023 – July 2023.

Authorized Signatory **Institute Seal**

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CONTENTS

Deendayal Port, formerly known as Kandla Port, holds a prominent position as a significant maritime gateway in India, situated within Gujarat's Kutch district. Among the twelve major ports across the nation, Deendayal Port Authority stands out as the largest Creek-based port, positioned at the southwestern tip of the Gulf of Kachchh, on India's north-western coastline within the state of Gujarat. Deendayal Port Authority (DPA) serves as a pivotal hub for maritime trade, facilitating the transportation needs of several hinterland states. It boasts excellent connectivity through an extensive rail and road network, functioning as a crucial gateway for the export and import activities of northern and western Indian states, including Jammu & Kashmir, Delhi, Punjab, Himachal Pradesh, Haryana, Rajasthan, Gujarat, as well as parts of Madhya Pradesh, Uttaranchal, and Uttar Pradesh.

This port ranks among the largest and most essential ports in the country, playing a vital role in India's international trade and maritime infrastructure. The administration and operations of the port are overseen by the Deendayal Port Trust (DPT), an autonomous entity established under the Major Port Trusts Act of 1963. The Deendayal Port Trust is entrusted with the comprehensive management, development, and administration of the port. The authority is comprised of a dedicated team of professionals and experts who work diligently to ensure the efficient operation of the port and all related activities.

About 35% of the country's total export takes place through the ports of Gujarat in which the contribution by Deendayal port is considerable. The port handled a total cargo of 105 MMTPA during 2016-17, 110 MMTPA during 2017-18, 115 MMTPA during 2018-19, 122.5 MMTPA during 2019-2020, 117.5 MMTPA during 2020-21 and 137 MMTPA during 2022-23. DPA is the only major Indian port to handle more than 127 MMT cargo throughput, and it has also registered the highest cargo throughput in its history. The port has handled a total of 3151 vessels during FY 2021-22. Over the years, the port has witnessed significant growth and development, becoming a crucial gateway for India's international trade. Deendayal Port has a strategic location on the west coast of India, offering direct access to the Arabian Sea.

It serves as a vital link for India's trade with countries in the Middle East, Africa, Europe, and Asia. The port handles a wide range of cargoes, including petroleum products, chemicals, coal, iron ore, fertilizers, salt, and general cargo.

Further, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. With such capacity, the Port ranks No. 1 among all the major ports in India for 12th Consecutive year. Further, a regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. The port has high commercial importance in the Indian maritime trade as it handled 36.1 million tons (17%) of Cargo out of total Cargo of 213.1 million tons of the maritime Cargo of India during 2015. In addition, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements.

Deendayal Port Authority (DPA) has taken up Development of 7 Integrated facilities, and the Ministry of Environment, Forest and Climate Change (MoEF & CC), has put up some conditions while according Environmental and CRZ clearance. One of the conditions is to carry out the *"Study on Dredged Material for presence of contaminants"* as accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific condition no. vii)" which states that ***"Dredged materials should be analyzed for presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted and the findings should be shared with the Gujarat SPCB and Regional Office of the Ministry"***.

1.1 Need of the study

Considering the aforementioned condition, DPA has assigned the task of carrying out the study to Gujarat Institute of Desert Ecology (GUIDE), Bhuj. This study will be attempted three times in a year at two specified locations. Further, the study will envisage the evaluation of physico-chemical constituents in the dredged materials in the dumped locations in the study area. GUIDE has been entrusted with the project, which has duration of three years (01.11.2021 – 31.10.2024) as specified in the work order. Accordingly, the study was initiated to evaluate the dredged materials for potential contamination, employing a systematic investigation that encompasses the analysis of physical, chemical, and biological characteristics with special reference to pollutants including heavy metal, Petroleum hydrocarbon etc.

1.2. Scope of the study

a. To monitor the locations where dredged materials are dumped will be conducted.
b. Dredged materials in the area will be analyzed for the presence of contaminants in two different locations.
c. Detailed assessment of the dredged materials for physical, chemical and biological characteristics will be studied.
d. Suggesting suitable disposal options for the dredged material will be made.

1.3. Sampling locations for 2022 – 23

The study focused on investigating the presence of contaminants in the dredged materials during the year 2022-2023. The specific locations for sampling can be found in Table 1 and Plate 1. The selection of these sampling sites was based on information supplied by the Hydraulic and Dredging Division to the Department of Port Administration (DPA), concerning the locations of dumping grounds. These location details were subsequently shared with the Gujarat Institute of Desert Ecology (GUIDE) via an email dated October 24, 2018. Three seasonal studies covering Location 1, Location 2 and Location 3 with the second season of the study was conducted during 08.05.2023 – 10.05.2023.

Table 1: GPS Co-ordinates of sampling locations

Station	Latitude (N)	Longitude (E)
Location 1 (Offshore)	22° 51' 00" N	70° 10’ 00" E
Location 2 (Cargo jetty)	22°56' 31" N	70 13' 00" E
Location 3 (Phang Creek)	23° 04' 28" N	70°13’ 28" E

1.4. Details of work done during 3rd Quarter (May – July 2023)

During the Third quarter of 2022-2023, the Second season sampling was conducted in the month of May 2023, in which the surface and bottom water samples and bottom sediment samples were collected from the three locations such as Offshore, Cargo Jetty and Creek systems which was pre-designated locations as earmarked by CPWRS was conducted.

After the collection, the samples were preserved using standard protocols and stored in an Ice box and brought to the laboratory within 2-3 hrs of collection Comprehensive analysis was performed on all the samples, both water (36 samples) and sediment (18 samples), to determine various physical, chemical, and biological characteristics. The analysis followed the standard methods prescribed by the Integrated Coastal and Marine Area Management (ICMAM) in 2012. All samples were analysed in triplicates, and the obtained data was compared against the marine water limits specified by the Central Pollution Control Board (CPCB) and other relevant standards.

Plate 1: Map showing locations of proposed sampling (2022-2023)

The sediment samples from the study area were collected for the purpose of characterization employing standard methodology and the analysis of the samples were also performed as per standard protocol and the data of sediment analysis is presented in this Chapter 1. The sediment samples were collected in pre-fixed stations using a Van-Veen type of grab sampler. After collection, the sediment samples were preserved with Rose Bengal and formalin to avoid decomposition of samples and processed for analysis and the samples after collection were brought to the laboratory on the same day of collection and air dried and used for further analysis for the test parameters (Table 2).

Table 2: Physico-chemical and biological characteristics of sediment samples

S. No.	Physico-chemical and Biological parameters
1	pH (1: 10 suspension)
2	Salinity (ppt)
3	Sand (%)
4	Silt (%)
5	Clay (%)
6	Total organic carbon (%)
7	Phosphorus (mg/kg)
8	Sulphur (mg/kg)
9	Petroleum Hydrocarbon (µg/kg)
10	Cadmium (mg/kg)
11	Lead (mg/kg)
12	Chromium (mg/kg)
13	Copper (mg/kg)
14	Cobalt (mg/kg)
15	Nickel (mg/kg)
16	Zinc (mg/kg)
17	Magnesium (mg/kg)
18	Macrobenthos

2.1. pH and Salinity (1: 10 suspension)

The pH of the sediment suspension is a measure of the activity of H+ ions within the sediment-water system. It indicates whether the sediment is acidic, neutral or alkaline in nature. Since ions are the carrier of electricity, the electrical conductivity (EC) of the sediment-water system rises according to the content of soluble salts. The EC measurement directly corresponds to the concentration of soluble salts in the sediment at any particular temperature. To conduct the analysis, ten grams of the finely sieved sediment was dissolved in 100ml of distilled water to prepare leachate. This leachate was taken for shaking using a rotator shaker for one hour to ensure proper homogenization of the suspension. Following this, the suspension was allowed to settle for two hours, and the supernatant was collected after filtration for the subsequent analysis of pH and salinity using the pH and EC meter (Make: Systronics 361) and Refractometer (Make: Atago) respectively. Each sample was analyzed in triplicates to ensure accuracy, and the mean values were considered for further evaluation.

2.2. Textural analysis (Sand/Silt/Clay)

Sediment samples were collected using Van Veen grab whereas intertidal sediments will be collected using a handheld shovel. After collection, the scooped samples are transferred to polythene bags, labelled and stored under refrigerated conditions. The sediment samples are thawed, oven dried at 40ºC and ground to a fine powder before analyses.

For texture analysis, specified unit of sediment samples were sieved using sieves of different mesh size as per Unified Sediment Classification System (USCS). Cumulative weight retained in each sieve will be calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves. The percent retained will be calculated from the weight retained and the total weight of the sample. The cumulative percent will be calculated by sequentially subtracting percent retained from 100%.

2.3. Total organic carbon

Total organic carbon refers to the carbon content stored within sediment organic matter. It is derived from various sources such as the decomposition of plant and animal residues, root exudates, living and deceased microorganisms, sediment biota etc. To measure total organic carbon in sediment, a process of oxidation is employed using potassium dichromate in the presence of concentrated sulfuric acid. During the analysis, potassium dichromate generates nascent oxygen, which reacts with the carbon present in organic matter, resulting in the production of carbon dioxide (CO2). The excess volume of potassium dichromate is then titrated against a standardized solution of ferrous ammonium sulfate in the presence of phosphoric acid, using Ferroin indicator to detect the initial appearance of unoxidized ferrous iron. This titration allows the determination of the volume of potassium dichromate required to oxidize the organic carbon present in the sample.

Procedure

The determination of the percentage of total organic carbon in sediment involves oxidizing the organic matter within the sediment samples using chromic acid. The excess chromic acid is then estimated by titrating it against ferrous ammonium sulfate, with ferroin serving as an indicator. The step-by-step procedure is outlined as follows:

To begin, 1 gram of sediment sieved to a particle size of 0.5 mm is weighed and transferred into a 500 ml conical flask. Then, 10 ml of 1N $K_2Cr_2O_7$ is added to the flask with pipette followed by gentle swirling to ensure thorough mixing. Next, 20 ml of concentrated H2SO4 is added, and the sediment and reagents are mixed gently. This mixture is allowed to react for 30 minutes on a marble stone to avoid any damage caused by the release of intense heat from the sulfuric acid reaction. Afterward, 200 ml of distilled water is slowly added to the flask, along with 10 ml of concentrated orthophosphoric acid and approximately 0.2 grams of NaF. The sample and reagent mixture is left to stand for 1.5 hours, as the titration endpoint is better observed in a cooled solution. Just before the titration, 1 ml of ferroin indicator is added to the conical flask. The excess $K_2Cr_2O_7$ is then titrated with 0.5 N ferrous ammonium sulfate until the color changes from yellowish green to greenish, and finally to a brownish-red color indicating the endpoint. A blank test without the sediment sample is also performed simultaneously for reference. Through this procedure, the percentage of total organic carbon in the sediment can be accurately determined.

2.4. Total Phosphorus

The determination of total phosphorus in sediment is commonly conducted using Bray's extraction method. This method involves the formation of specific-colored compounds by adding appropriate reagents to the solution, with the intensity of the color being directly proportional to the concentration of phosphorus being estimated. The color intensity is measured spectrophotometrically. In the spectrophotometric analysis, a light source emitting light of a specific wavelength (usually within a band width of 0.1 to 1.0 nm) in the ultraviolet region of the spectrum is used. The photoelectric cells in spectrophotometer measure the light transmitted by the solution allowing for quantitative analysis.

Procedure

To perform the analysis, 50 ml of the Bray's extractant is added to a 100 ml conical flask containing 5 grams of sediment sample. The flask is shaken for 5 minutes and then filtered. Exactly 5 ml of the filtered sediment extract is transferred to a 25 ml measuring flask using a bulb pipette. Subsequently, 5 ml of the molybdate reagent is added using an automatic pipette, followed by dilution to 20 ml with distilled water and shaken well. Furthermore, 1 ml of dilute Stannous Chloride solution is added, and the volume is made up to the 25 ml mark. Thorough shaking is performed to ensure proper mixing. The mixture is then allowed to develop color, and after 10 minutes, readings are taken in the spectrophotometer at a wavelength of 660 nm. Prior to the readings, the instrument is zeroed using a blank prepared similarly but without the sediment.

2.5. Total Sulphur

Total sulphur in the sediment extract was determined using a turbidimetric method with a spectrophotometer. A series of standards containing sulphur at concentrations of 2, 4, 6, 8, and 10 ppm were prepared from a stock solution. Each flask in the series received 25 ml of the respective standard solution, and 2.5 ml of conditioning reagent solution was added. Additionally, 5 ml of extraction solution was added to the mixture. To facilitate the reaction, 0.2-0.3 grams of barium chloride were included and thoroughly mixed. The volume was adjusted to 25 ml with distilled water, and readings were taken at 340 nm using a spectrophotometer.

For the sample analysis, 5 grams of marine sediment were placed in a 100 ml conical flask. To this, 25 ml of a 0.15% $CaCl_2$ solution was added and shaken for 30 minutes. The mixture was then filtered through Whatman No. 42 filter paper. Subsequently, 5 ml of the sample aliquot was transferred into a 25 ml volumetric flask. Conditioning reagent (2.5 ml) and 0.2 to 0.3 grams of barium chloride powder were added, followed by making up the volume to 25 ml with distilled water. The flask contents were shaken for 2 minutes, and the absorbance was measured using the same procedure as the standard solutions.

2.6. Petroleum Hydrocarbons

To analyze petroleum hydrocarbons in sediment, the following procedure will be conducted. First, the sediment will undergo reflux with a mixture of KOH and methanol, allowing for the extraction of petroleum hydrocarbons. This reflux process helps release the hydrocarbons from the sediment matrix. Next, the sediment will be subjected to extraction using hexane, which selectively dissolves the hydrocarbons present in the sediment. The excess hexane will be carefully removed, leaving behind a residue containing the concentrated hydrocarbons of interest. To further purify the sample and remove any impurities, a clean-up procedure will be performed using silica gel column chromatography. This column chromatography process helps separate the hydrocarbons from other compounds present in the residue, resulting in a cleaner sample for analysis. Finally, the hydrocarbon content in the sediment will be estimated by measuring fluorescence, following the standard method for petroleum hydrocarbon analysis. This fluorescence measurement allows for quantification and determination of the hydrocarbon levels present in the sediment sample. By following this procedure, accurate analysis of petroleum hydrocarbons in sediment can be achieved.

2.7. Heavy metals

Heavy metals, such as Cadmium (Cd), Lead (Pb), Chromium (Cr), Nickel (Ni), Cobalt (Co), Copper (Cu), Zinc (Zn), Manganese (Mn), and others, are of particular concern in relation to the environment. To release mineral elements from sediment samples, wet oxidation is commonly employed, utilizing oxidizing acids, such as tri/di-acid mixtures.

In the analysis procedure, a sediment sample weighing 1.0 gram is taken in a 100 ml beaker, which is covered with a watch glass. A mixture of Aqua regia (1:3 HNO_3:HCl) in the amount of 12 ml is added to the beaker. The beaker is then subjected to digestion for 3 hours at 100°C on a hot plate using a sand bath. Afterward, the samples are evaporated to near dryness, allowed to cool for 5 minutes, and then 20 ml of 2% nitric acid is added. The beaker is placed on a hot plate for digestion for 15 minutes, after which it is removed from the hot plate and allowed to cool. The mixture is then filtered using Whatman No. 42 mm filter paper. Finally, the volume is adjusted to 50 ml with 2% nitric acid to make up the final solution. The extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis. By following this procedure, the heavy metal content in the sediment can be accurately analyzed using wet oxidation, filtration, and AAS techniques.

2.8. Results

2.8.1. pH (Hydrogen Ion)

pH values play a significant role in marine sediments, influencing various biogeochemical processes and ecosystem dynamics. These values are influenced by various factors, including the carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron, and manganese cycles. They are closely associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and the dissolution of calcium carbonate in marine water and sediments. In our investigation, we conducted measurements of average pH values at different locations. The offshore area exhibited an average pH of 7.56±0.26, the cargo jetty had an average pH of 8.02±0.12, and the Phang Creek showed an average pH of 7.71±0.01. Among all the stations, the highest pH concentration of 8.15 was observed at 2A

Cargo jetty, while the lowest pH concentration of 7.33 was recorded in 1A Offshore (refer to Tables 3-5).

2.8.2. Salinity

Salinity levels in marine water and sediment exhibit a wide range, typically spanning from 0 to 36 in most estuaries. Semi-enclosed bays can experience hyper-salinity conditions. The salinity of water is subject to fluctuations influenced by temperature changes, following diurnal and seasonal cycles that correspond to variations in atmospheric temperature. In our study, we observed various salinity concentrations at different stations. The highest salinity concentration of 31.41 ppt was recorded at station 2D in the cargo jetty area, while the lowest salinity concentration of 10.26 ppt was found at station 3C in the Phang creek area. The mean ± standard deviation (SD) salinity values were determined to be 20.23±3.05 ppt, 24.94±3.35 ppt, and 13.80±3.70 ppt in the offshore, cargo jetty, and Phang creek, respectively. These findings are summarized in Tables 3-5, where all the data is presented.

2.8.3. Sediment Texture

The sediment texture plays a significant role in determining the physical and chemical properties of the marine sediment, influencing the distribution and abundance of benthic organisms. Understanding the sediment texture at different stations provides valuable insights into the habitat characteristics and ecological dynamics of the marine environment. At the offshore station, the average percentage composition of sand, silt, and clay was found to be 17.72%, 8.47%, and 73.82%, respectively. The cargo jetty station exhibited average percentages of 77.68% for sand, 19.53% for silt, and 2.78% for clay. Similarly, at the Phang creek station, the average percentages were 17.12% for sand, 6.42% for silt, and 76.47% for clay. These findings are summarized in Tables 3-5, which presents the data from all the stations.

2.8.4. Total organic Carbon

Organic carbon in marine sediments primarily originates from the decomposition of animals, plants, and anthropogenic sources such as chemical waste, fertilizers, and organic-rich waste. These sources contribute to the enrichment of the marine environment with organic material, which subsequently settles to the bottom sediments from the water column. This pathway leads to an increase in Total Organic Carbon (TOC) values and can have implications for the faunal communities inhabiting the sediments. In our study, during season three, we investigated the TOC concentrations at different stations. The mean ± standard deviation (SD) TOC percentages were determined to be 0.45±0.06% at the offshore station, 0.19±0.04% at the cargo jetty station, and 0.44±0.12% at the Phang creek station. The TOC concentrations at all stations are presented in Tables 3-5. Understanding the dynamics of organic carbon in marine sediments is vital for assessing the health and ecological integrity of marine environments. It helps in monitoring anthropogenic influences and their potential impacts on the marine ecosystem.

2.8.5. Organic matter

Organic matter serves as the primary reservoir of organic carbon in marine sediments, encompassing the chemical, physical, and biological degradation processes that contribute to the formation of organic material in the marine environment. It consists of a mixture of materials derived from various planktonic and benthic species, forming the ecological foundation for primary producers and consumers in the overlying surface sediment.

In our study conducted during the third season, we investigated the levels of organic matter in different locations. The organic matter percentages ranged from 0.62% to 0.82% in the offshore location, 0.25% to 0.41% at the cargo jetty, and 0.56% to 1.08% in the Phang creek area. These findings are summarized in the below tables (3-5), which illustrates the variation in organic matter content across the studied locations. Understanding the presence and dynamics of organic matter in marine sediments is crucial for assessing the overall health and ecological functioning of marine ecosystems. It provides insights into the cycling of carbon and nutrients, as well as the interactions between different species and trophic levels within the sediment community. Monitoring and studying organic matter in marine sediments helps to comprehend the intricate processes that shape marine environments and their associated biota.

2.8.6. Phosphorus and Sulphur

Phosphorus (P) is an essential nutrient for life and plays a crucial role in regulating primary productivity within marine systems. It serves as a key element in various biological processes. In marine sediments, phosphorus availability influences primary productivity, affecting the growth and development of marine organisms. Sulphur (S), on the other hand, is involved in dissimilatory sulfate reduction by microbial activity, which is a primary pathway for organic matter mineralization in anoxic sea beds. This process leads to the production of sulfide. Subsequently, chemical or microbial oxidation of the produced sulfide forms a complex network of pathways in the sulfur cycle, resulting in intermediate sulfur species and partial conversion back to sulfate.

In our study, we examined the concentrations of phosphorus and sulphur in marine sediments. The highest phosphorus concentration was found to be 61.64 mg/kg at station 1B in the offshore location, while the lowest concentration of 15.56 mg/kg was observed at station 3B in the Phang creek station. Regarding sulphur, the highest concentration of 23.80 mg/kg was recorded at station 1A in the offshore location area, while the lowest concentration of 10.07 mg/kg was observed at station 2C in cargo jetty. The concentrations of phosphorus and sulphur at all stations are presented in Tables 3,4 and 5.

Understanding the levels of phosphorus and sulphur in marine sediments is crucial for comprehending nutrient dynamics and biogeochemical processes in marine ecosystems. These elements influence the availability of essential nutrients and can have implications for primary productivity and the overall functioning of marine ecosystems.

2.8.7. Petroleum hydrocarbon

Petroleum hydrocarbons (PHCs) are a major source of contamination in marine environments, primarily comprising compounds from three classes: alkanes, olefins, and aromatics. These hydrocarbons have low solubility in marine water and tend to adsorb onto particulate matter, leading to their long-term persistence in sediment bottoms. This persistence can have significant negative impacts on benthic aquatic communities within the marine ecosystem.

In our study, we measured the levels of PHCs in different locations. The range of PHC concentrations was found to be 29.12 to 37.42 µg/kg in the offshore area, 27.68 to 48.93 µg/kg at the cargo jetty, and 11.78 to 30.91 µg/kg in the Phang Creek. The highest concentration of PHCs with 48.93 µg/kg was observed at station 2C in the Cargo Jetty, while the lowest concentration with 11.78 µg/kg was found at station 3B in the Phang Creek.

The presence of petroleum hydrocarbons in marine environments is of great concern due to their potential harmful effects on marine organisms and ecosystems. These contaminants can bioaccumulate in organisms and disrupt their physiological processes, as well as cause long-lasting damage to the benthic communities. Continuous monitoring and mitigation efforts are necessary to prevent and minimize the negative impacts of petroleum hydrocarbon contamination in marine ecosystems.

2.8.8. Magnesium

The flux of dissolved magnesium from the overlying ocean into marine sediments is primarily driven by molecular diffusion. This process occurs as pore water magnesium is depleted during the formation of authigenic minerals within the sediment column. Additionally, direct burial of seawater occurs as sediment accumulates on the seafloor, contributing to the input of magnesium into the sediment. Its concentration in sediments can have implications for nutrient availability, sediment mineralogy, and the diverse organisms inhabiting the sediment environment.

In our study conducted during the third season at Deendayal Port, we determined the concentrations of magnesium at different stations. The average ± standard deviation (SD) magnesium concentrations were found to be 2986.17±355.74 mg/kg at the offshore station, 2250.67±268.30 mg/kg at the cargo jetty, and 3167.50±391.29 mg/kg at the Phang Creek station. The highest concentration of magnesium 3724.50 mg/kg was observed at station 3B in the Phang Creek, while the lowest concentration with 1901.00 mg/kg was found at station 2B in the Cargo jetty.

Understanding the distribution and dynamics of magnesium in marine sediments provides valuable insights into the geochemical processes occurring within the sediment column and their impact on the marine ecosystem. Continuous monitoring of magnesium levels is crucial for assessing the health and ecological integrity of marine environments.

2.8.9. Heavy metals

The study examined the presence of heavy metals in sediment samples collected from various stations at different locations at Deendayal Port. The concentrations of heavy metals including nickel (Ni), lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), manganese (Mn), and cobalt (Co) were determined. Lead, chromium, copper and cobalt were not detected (Below Detection Limit) at all three stations. Among three stations, Nickel was not detected in the Cargo jetty station. The highest concentration of nickel was found to be 19.00 mg/kg at station 1B in Offshore station, while the lowest concentration was observed at station 3E in Phang creek, measuring 2.20 mg/kg. Among the three stations, 1D station in offshore region recorded the highest concentration of zinc, with 46.50 mg/kg at, while the lowest concentration was found at station 2A of Cargo jetty, measuring 7.50 mg/kg. For manganese, the 1B in offshore station had the highest average concentration of 667.30 mg/kg, while Control 2 in Cargo jetty recorded the lowest mean concentration of 56.20 mg/kg. The highest concentration of cadmium,0.13 mg/kg, was observed in Control 1 at the offshore station, whereas the lowest concentration of 0.05 mg/kg was found at station 3E in Phang creek. The data is presented in Tables 3-5.

Table 3: Physico-chemical characteristics of sediment samples collected from Offshore location

S. No	Parameters	1A	1B	1C	1D	1E	Control 1
1	pH (1: 10 suspension)	7.33	7.55	7.48	7.47	8.08	7.47
2	Salinity	17.89	18.86	20.96	16.84	21.58	25.26
3	Petroleum Hydrocarbon	29.12	29.12	29.41	35.89	33.86	37.42
4	Magnesium	3211.0	2956.0	3211.5	2291.5	3195.0	3052.0
5	Sand (%)	12.8	16.5	16.7	23.9	19.7	16.7
	Silt (%)	7.1	9.4	8.7	7.3	9.1	9.2
	Clay (%)	80.1	74.1	74.6	68.8	71.2	74.1
6	Organic matter (%)	0.72	0.81	0.72	0.82	0.82	0.62
7	Total organic carbon	0.42	0.51	0.42	0.48	0.48	0.36
8	Phosphorus	35.36	61.64	38.39	37.79	39.20	31.12
9	Sulphur	23.80	21.05	22.83	21.90	20.94	21.28
10	Nickel	11.40	19.00	10.35	8.00	12.70	4.05
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	BDL	0.25	0.20	0.25	BDL	0.30
13	Chromium	BDL	BDL	BDL	BDL	BDL	BDL
14	Zinc	41.00	45.95	41.35	46.50	45.15	36.10
15	Copper	BDL	BDL	BDL	BDL	BDL	BDL
16	Manganese	335.90	667.30	508.30	345.60	372.15	545.30
17	Cobalt	BDL	BDL	BDL	BDL	BDL	BDL

Table 4: Physico-chemical characteristics of sediment samples collected from Cargo jetty

S. No	Parameters	2A	2B	2C	2D	2E	Control 2
1	pH (1: 10 suspension)	8.15	8.01	7.8	8.03	8.08	8.03
2	Salinity	23.07	25.09	24.82	31.41	22.37	22.89
3	Petroleum Hydrocarbon	37.29	44.70	48.93	36.74	27.96	27.68
4	Magnesium	2312.5	1901.0	2512.5	2500.5	1941.5	2336.0
5	Sand (%)	81.6	74.8	64.6	76.5	86.5	82.1
	Silt (%)	15.2	19.6	32.0	21.6	12.1	16.7
	Clay (%)	3.2	5.6	3.4	1.9	1.4	1.2
6	Organic matter (%)	0.31	0.25	0.31	0.41	0.36	0.25
7	Total organic carbon	0.18	0.15	0.18	0.24	0.21	0.15
8	Phosphorus	27.48	29.70	22.43	24.85	35.56	20.21
9	Sulphur	12.16	11.71	10.07	12.84	14.34	11.40
10	Nickel	BDL	BDL	BDL	BDL	BDL	BDL
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	0.20	BDL	BDL	0.20	BDL	0.15
13	Chromium	BDL	BDL	BDL	BDL	BDL	BDL
14	Zinc	7.50	BDL	BDL	BDL	BDL	BDL
15	Copper	BDL	BDL	BDL	BDL	BDL	BDL
16	Manganese	102.70	96.80	144.60	64.50	113.60	56.20
17	Cobalt	BDL	BDL	BDL	BDL	BDL	BDL

Table 5: Physico-chemical characteristics of sediment samples collected from Phang creek

S. No	Parameters	3A	3B	3C	3D	3E	Control 3
1	pH (1: 10 suspension)	7.71	7.72	7.71	7.72	7.71	7.69
2	Salinity	13.33	20.79	10.26	12.37	11.66	14.38
3	Petroleum Hydrocarbon	30.91	11.78	21.17	19.59	27.62	17.73
4	Magnesium	3350.5	3724.5	3395.0	2950.0	2648.5	2936.5
5	Sand (%)	12.4	7.1	13.8	12.0	27.8	29.6
	Silt (%)	5.6	3.7	5.5	4.0	10.2	9.5
	Clay (%)	82.0	89.2	80.7	84.0	62.0	60.9
6	Organic matter (%)	0.77	0.56	0.56	0.67	0.87	1.08
7	Total organic carbon	0.45	0.33	0.33	0.39	0.51	0.63
8	Phosphorus	23.84	15.56	16.37	18.18	24.65	19.80
9	Sulphur	17.38	17.41	19.67	20.24	20.38	20.66
10	Nickel	BDL	BDL	BDL	BDL	2.20	BDL
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	0.20	BDL	0.10	BDL	0.05	0.20
13	Chromium	BDL	BDL	BDL	BDL	BDL	BDL
14	Zinc	29.60	31.90	22.70	21.15	37.60	30.70
15	Copper	BDL	BDL	BDL	BDL	BDL	BDL
16	Manganese	310.95	296.50	287.40	167.95	232.25	223.95
17	Cobalt	BDL	BDL	BDL	BDL	BDL	BDL

3.1. Introduction

Earth surface contains more than 97% of water in which the oceans show biggest part of the life. The five oceans together constitute approximately 71% of the world's water bodies. Indian Ocean is the third largest ocean in the world with average depth of 3,890 meters (12,760 ft). As having at long coastline of almost 8000 km, India has vast marine resources. The Indian Ocean's connection is a very large scale, including the Red Sea, East Africa, the Persian Gulf, Southern Arabia, India and Other Indian sub continental countries Gujarat state of India shows longest coastline in India which is famous for various coastal ecosystems. Gujarat coasts having different coastal ecosystems like mangrove, sandy shores, muddy shores, rocky shores, mixed shores, wet sand shore, coral reefs and intertidal mudflats (Brink, 1993; Parasharya and Patel, 2014). Gujarat state is the only state in India bestowed with two gulfs, Gulf of Kachchh and Gulf of Khambhat. The Kachchh, largest district of the country with an area of 45,652 sq. km. Deendayal Port Authority is (DPT) one among the 12 major ports of the country and it is located in India's western coastal region

Benthos

Benthos is nothing but water bottom communities or the organisms (floral and faunal) live in a benthic region regarding the sediment, rock and other substratum. They include mollusca (gastropods and bivalves), coral, sponges, worms (mostly polychaetes and nematode), crustacean crabs, other crustaceans, echinoderms, oysters etc. The faunal benthic organisms are called as zoo-benthos, while floral benthic organisms are called as phyto-benthos. They play an important role in conversion of organic detritus from the sedimentary storage into the dissolved nutrients. Their distribution in water bodies can be varies and, on that basis, they can be classified into three types which are Endo-benthos, Epi-benthos (Pearson and Rosenberg, 1978) and Hyper-benthos (Mees and Jones,1997). They are the food source of diverse groups of various organisms including the bottom feeding animals. They are one of the best indicators to assess the health and productivity of aquatic ecosystems. They are sensitive to wide range of environmental challenges including water movements, pollutants and living spaces (Martin et al., 2011). Their variations to tolerate changes in various environmental factors make them to be considered as an important bio-indicator for monitoring and research of marine environment.

3.2. Methodology

To study the benthic organisms, triplicate samples were collected at each station using Van-Veen grab which covered an area of $0.1m^2$. The wet sediment was sieved with varying mesh sizes (0.5 mm-macrofauna) for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution for easy spotting at the time of sorting. The number of organisms in each grab sample was expressed as number/ meter square (No/m^2). All the species were sorted, enumerated and identified to the advanced taxonomic level possible with the consultation of available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; Subba Rao *et al.* (1991) and Ramakrishna (2003) for molluscs.

Further, the data were treated with univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clarke and Warwick, 1994)

a) Shannon – Wiener index

In the present study, the data were analyzed for diversity index (H') by following Shannon – Wiener's formula (1949):

$$H' = -\sum^{S} Pi \log 2\, Pi \ldots\ldots \quad i = 1$$

which can be rewritten as

$$H' = \frac{3.3219\,(N \log N - \sum ni - \log ni}{N}$$

where, H'= species diversity in bits of information per individual

ni = proportion of the samples belonging to the ith species

(number of individuals of the ith species)

N = total number of individuals in the collection and

$\sum$ = sum

b) Species richness(S) was calculated using the following formula given by Margalef (1958)

c) Margalef index (d)

$$d = (S-1) / \log N$$

d) Pielou's evenness index

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\text{In}S}$$

Where, J' = evenness; H' = species diversity in bits of information per individual and S = total number of species.

3.3. Results on Species Composition, Population density and Biomass of Macrofauna of selected sites

Species Composition, Population density and Biomass of Macrofauna at selected sites

1.Offshore

In Offshore region of port, selected six sites were (1A, 1B, 1C, 1D, 1E and 1- control). A total of 4 groups (of benthic community) of animals were recorded in all stations at Offshore sites and they are Razor clam (Mollusca), Other Bivalves, Crustaceans animals, Gastropods (Mollusca). Data on Density and Biomass expressed in (Nos./m^2), (gm/m^2) respectively (Table 6). Dentalium-tusk shell (Mollusca), Polychaeta worms (Annelida) were totally absent in Offshore.

Highest population density of benthic organisms was recorded in station 1 control at Offshore (1600 nos/m^2), whereas lowest in station 1A-Offshore (300nos/m^2). The density range of all stations varied from 300 to 1600 nos./m^2. Bivalves and Gastropoda were more abundant among all the benthic organisms. Rarely recorded benthos was Razor clams. The highest biomass value (expressed wet weight) of benthic fauna was observed in station 1control-Offshore (5.58 gm/m^2) and lowest value was 1C-Offshore (1.3 gm/m^2) (Table 6). High Biomass values and also density values suggested suitable substratum for benthos and less predator pressure of higher animals. Intermediate association was also one responsible factor for the same. Offshore region of sea is always more influences by the Water Currents, Upwelling - Downwelling (Churning process of water) movements of water and that for also same for Nutrients.

2. Cargo Jetty

In Cargo Jetty, frequently observed benthic groups were Bivalves-Gastropods than Crustacean animal and Razor clam (Bivalve). The population density range of 675 to 1225 nos/m^2 was recorded between all the stations (Cargo Jetty-2A, 2B, 2C, 2D, 2E &2-Control) during the study period. Highest and Lowest density were recorded in station 2B- Cargo Jetty (1225 nos./m^2) and 2control-Cargo Jetty (675 nos./m^2) respectively. Polychaete worms and Razor clams (Bivalve) were absent in all stations. The Biomass value indicated a highest value in station 2A- Cargo Jetty (5.57 gm/m^2) and lowest in 2C- Cargo Jetty (2.51 gm/m^2) (Table 6). Average Biomass and Population density value of all station were 3.69 gm/m^2, 971 nos./m^2 respectively which indicated the moderate favourable environment condition of biota, water quality as well as substratum (mostly rocky). The population density and biomass of benthic community largely affected by the symbiotic and intermediate relation between them or with other invertebrates and suitable rocky substratum or coral reef in bottom of sea. Availability of Plankton, as a food source, also affected the benthic animals (Table 6 and Fig. 1 & 2).

3. Phang creek

Six Stations of Phang creek were selected for the study namely 3A, 3B, 3C, 3D, 3E and 3-control-Phang Creek. In this Phang Creek benthic organisms were mostly represented by Bivalves and Gastropoda. Other benthic groups were recorded very less numbers (Dentalium sp) and some other are totally absent. The population density was highest in station 3B-Phang Creek (1175 nos./m^2) and on the other side, lowest density was recorded in 3A-Phang Creek (800 nos./m^2). Station 3control-Phang Creek comprises highest wet. wt (4.52 gm/m^2), whereas low at was recorded in3E-Phang Creek (1.98 gm/m^2).

Overall result of macrofaunal community showed highest population density in 1control-Offshore (1600 nos/m^2) and high biomass was observed (5.58gm/m^2) at 1control-Offshore. Table 6 showed highest population values of Bivalves in 3E-Phang creek (675 nos/m^2) and same highest value of Gastropoda showed in 3control and 3B-Phang creek (550 nos/m^2). The lowest value comprised by other groups at various sites including some is totally absent. Less frequently recorded Dentalium-tusk shell, Razor clam *and* Polychaete worms which indicated extreme weather condition (may be high temperature of summer season) or unfavourable environment condition. Bivalves and Gastropods, dominant groups, were preferred rocky substratum and any other hard substrata**.** Table 6 showed that average population density and biomass higher in Cargo jetty and Phang Creek area where mostly rocky or covered with muddy area providing a unique habitat against high temperature of summer for gastropods, bivalves. Low density and biomass were observed at Offshore (Table 6 and Figure 1) which indicated stressful environment, seasonal effect, more anthropogenic activities and also might be some chemical and biological changes in water.

In benthic communities, recorded species at all sites were*, Umbonium vestiarium Tellina sp., Clypeomorus bifasciata, Trochus sp, Radix sp, Donax sp Pholas orientalis, Turris sp,Marcia sp, Dentalium sp Dosinia sp, Donax sp, Anadara sp, Turris sp, Solen, Nereis sp* etc. The percentage of occurrence (Table 6) was revealed highest group present by *Bivalves and Gastropods (100%) then follow Crustacean animals (17 %), Dentalium tusk shell (11%), Polychaete worms (6%) and Razor clams (6%).* Detail status of Population density, Group composition and biomass of the benthic community of all selected sites were depicted in (Table 6) and (Figure 1).

In all the stations, highest percentage composition recorded by Bivalves (52%) followed by Gastropods (40%), Crustaceans (3%), Dentalium- tusk shell and Razor clams (2%) *and 1%* comprised by Polychaete marine worms. Phytoplankton abundance and their size, zooplankton Body composition, patchy distribution of zooplankton, water currents, ebb and flow tides, and water churning process, changing in structure of muddy, rocky and sandy habitats are the main reasons for biomass and density fluctuation in Benthic communities. In Crustacean most commonly observed species are Crabs and attached Barnacles. Main Mollucsa families recorded Trochidae, Cerithidea, Turritellidae, Tellinidae, Mitridae, Veneridae, Donacidae and Bucciniae etc. *Nereis sp*, *Capitella sp, Nephtys sp*., like polychaetes (annelids worms) were observed in samples. More number of the broken bivalves, debris, plant items and broken gastropods and small rocks are frequently observed during benthic organism's study.

Diversity Indices of Benthic Community

Table 7 shows various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.64-1.04) indicated very low diversity. Highest diversity indices were recorded in Station 2A-Cargojetty (1.04) where high value of density and biomass of benthos and other side in 3E-Phang creek diversity indices value was 0.64 where biomass was comparatively very low. The evenness values ranged between (0.80 to 1). The highest evenness value (1) is observed in station 1D &1E of Offshore and 3B &3C of Phang creek where only Gastropods and Bivalves are present and the lowest evenness index value 0.80was at station 2E-Cargojetty. Evenness value "1" indicated all organisms occurred in same area or same group. Simpson's Index value ranged between 0.45 to 0.63 indicated to lower to very less moderate diversity. The Margalef value showed a slightly variation of 0.14 to 0.32 indicated normal variation in species/group numbers. (Table 7).

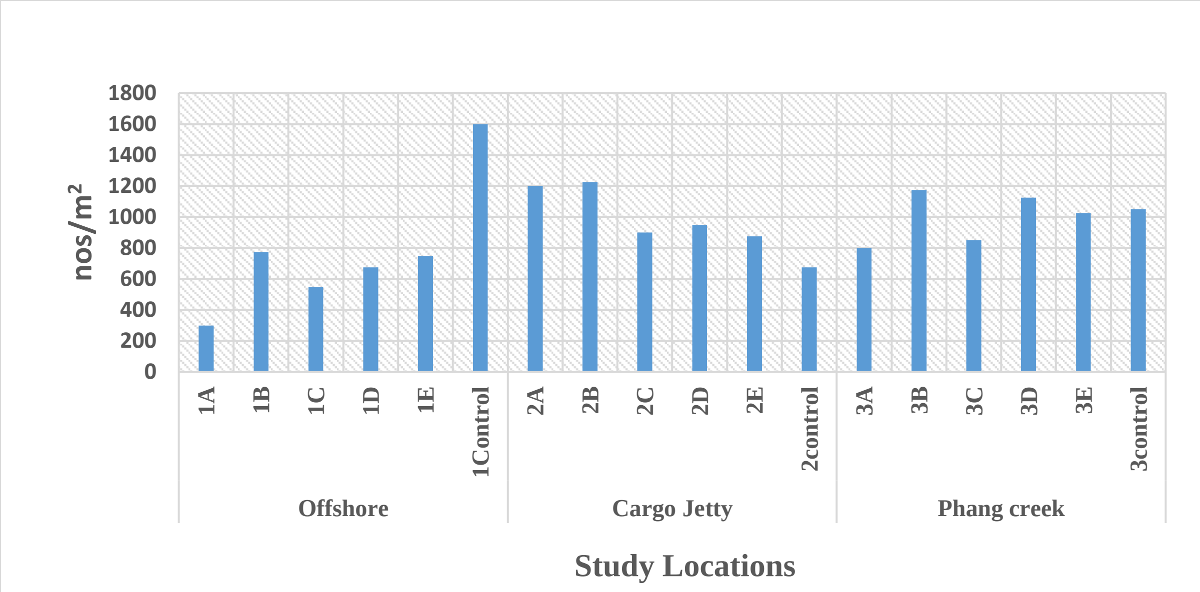

Figure 1. Population density of benthic organisms (nos/m^2) in various sites

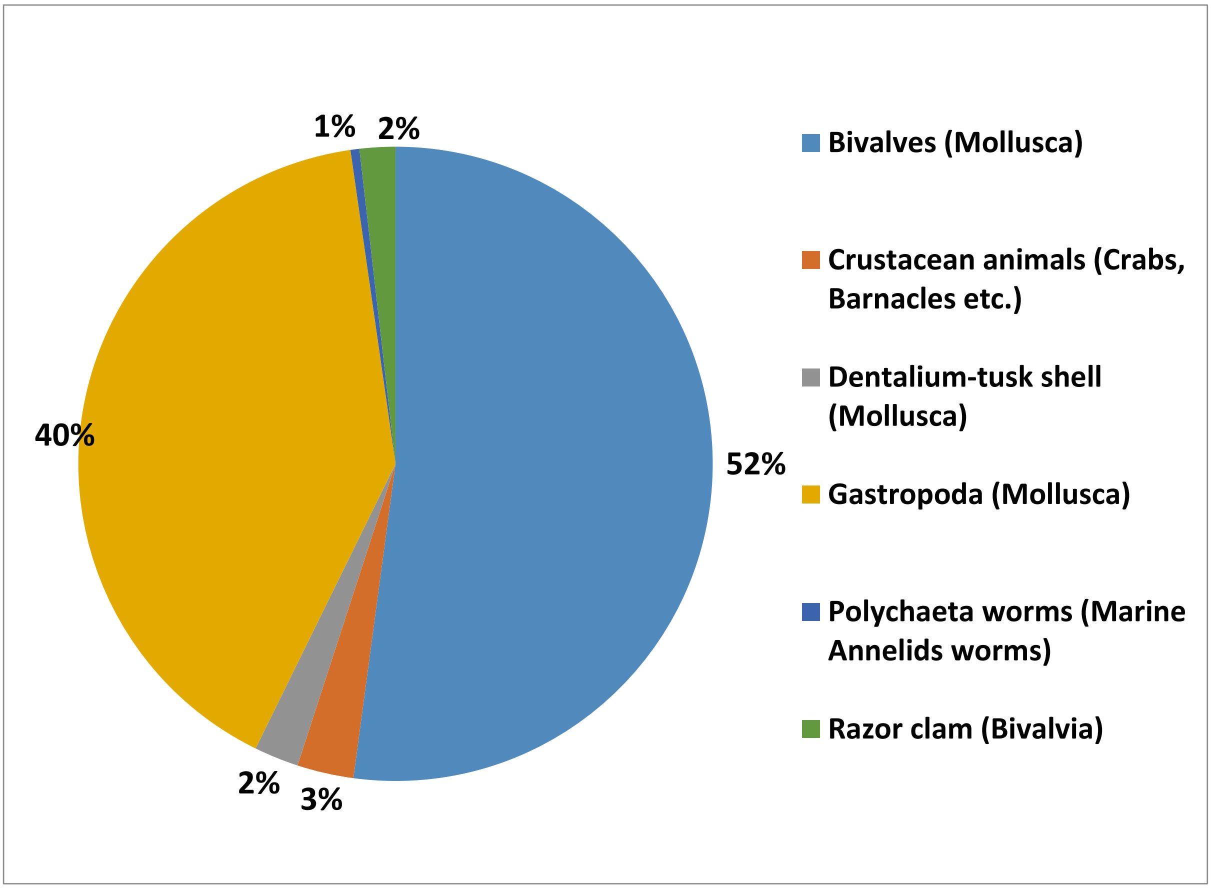

Figure 2. Percentage composition of benthic organisms in various sites

Table 6. Macrobenthos distribution in different sites of Deendayal Port

Name of Station	**Offshore**						**Cargo Jetty**						**Phang creek**						**% of Occurrence**
	1A	**1B**	**1C**	**1D**	**1E**	**1-Control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Control**	
Name of the Benthic Group																			
Bivalves (Mollusca)	175	125	275	350	400	875	575	600	500	550	525	375	500	625	400	700	675	375	100
Crustacean animals (Crabs, Mysis etc.)	0	150	100	0	0	0	0	225	0	0	0	0	0	0	0	0	0	0	17
Dentalium-tusk shell (Mollusca)	0	0	0	0	0	0	250	0	0	0	0	0	0	0	0	0	0	125	11
Gastropoda (Mollusca)	125	500	175	325	350	425	375	400	400	400	275	300	300	550	450	425	350	550	100
Polychaeta worms (Marine Annelids worms)	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	6
Razor clam (Bivalvia)	0	0	0	0	0	300	0	0	0	0	0	0	0	0	0	0	0	0	6
Total Population Density Nos/m^2	300	775	550	675	750	1600	1200	1225	900	950	875	675	800	1175	850	1125	1025	1050	
Biomass wet wt gm/m^2	2.08	3.27	1.3	1.86	3.32	5.58	5.57	4.01	2.51	3.22	4.31	2.57	3.37	3.21	2.22	2.9	1.98	4.52	

Table 7. Diversity indices of benthic faunal groups at various station of Deendayal Port

Variables	Offshore						Cargo Jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-cont**
Taxa_S	2	3	3	2	2	3	3	3	2	2	3	2	2	2	2	2	2	3
Individuals (Nos./m^2)	300	775	550	675	750	1600	1200	1225	900	950	875	675	800	1175	850	1125	1025	1050
Dominance_D	0.51	0.48	0.38	0.50	0.50	0.40	0.37	0.38	0.51	0.51	0.47	0.51	0.53	0.50	0.50	0.53	0.55	0.42
Shannon Diversity Index (H)	0.68	0.89	1.02	0.69	0.69	1.00	1.04	1.03	0.69	0.68	0.88	0.69	0.66	0.69	0.69	0.66	0.64	0.96
Simpson_1-D	0.49	0.52	0.62	0.50	0.50	0.60	0.63	0.62	0.49	0.49	0.53	0.49	0.47	0.50	0.50	0.47	0.45	0.58
Evenness_e^H/S	0.99	0.82	0.93	1.00	1.00	0.90	0.95	0.93	0.99	0.99	0.80	0.99	0.97	1.00	1.00	0.97	0.95	0.87
Menhinick	0.12	0.11	0.13	0.08	0.07	0.08	0.09	0.09	0.07	0.06	0.10	0.08	0.07	0.06	0.07	0.06	0.06	0.09
Margalef	0.18	0.30	0.32	0.15	0.15	0.27	0.28	0.28	0.15	0.15	0.30	0.15	0.15	0.14	0.15	0.14	0.14	0.29

4.1. Introduction

In recent decades, there has been a notable deterioration in aquatic ecosystems primarily caused by the presence of a diverse array of organic and inorganic contaminants. Among these pollutants, heavy metals (HMs) and microplastics (MPs) have emerged as significant contributors to this environmental degradation (Frew et al., 2020; Saha et al., 2016). These substances are recognized for their capability to infiltrate and accumulate within the aquatic food chain, making them hazardous pollutants in aquatic environments (Olojo et al., 2005). Of particular concern are heavy metals due to their toxic nature, long-lasting presence, resistance to degradation, the potential for bioaccumulation, and the ability to magnify up the food chain, all of which have raised global alarms (Begum et al., 2013; Cai et al., 2017).

Heavy metal pollution in aquatic ecosystems can be attributed to a variety of sources, including natural factors such as atmospheric deposition and weathering (Ebrahimpour and Mushrifah, 2010; Hamidian et al., 2016) as well as human activities like mining, agricultural runoff, sewage discharge, industrial effluent release, gasoline leaks from fishing vessels, and accidental chemical waste spills (Arulkumar et al., 2017). It is essential to recognize that certain heavy metals, such as copper (Cu), iron (Fe), nickel (Ni), cobalt (Co), zinc (Zn), manganese (Mn), and chromium (Cr), play vital roles in physiological processes and are necessary for the proper biological functioning of organisms in trace amounts. However, exposure to nonessential heavy metals can lead to various health concerns, including renal, cardiovascular, nervous, and bone diseases, as well as immune-related issues (Abadi et al., 2018; Madreseh et al., 2018). It is crucial to acknowledge that all heavy metals become toxic when their concentration exceeds a certain threshold level (Makedonski et al., 2017). In light of these concerns, it is imperative to assess the various characteristics of water in order to determine the extent of pollutant presence in aquatic environments.

4.2. Materials and Methods

In this study, marine water and sediment samples were collected following standard protocols, and their analysis was conducted using established methods for marine water and sediment analysis as prescribed by APHA (2012), NIO manual (1982), and ICMAM Manual (2012). For general analysis, surface water samples were collected using a clean polyethylene bucket, while water samples from the bottom were collected using a weighted Niskin sampler. Water samples at a depth of 1 meter below the surface were collected using a 1-liter glass bottle sampler. Parameters such as pH, temperature, and salinity were measured on-site using handheld meters and verified in the laboratory.

The collected water samples were stored under refrigerated conditions until further analysis of other parameters. According to the standard protocol, fixatives and preservatives were added to the samples for specific parameters. For example, Winkler A&B solution was immediately added to measure dissolved oxygen, concentrated H2SO4 was used to bring the pH below 2 for chemical oxygen demand analysis, and nitric acid was used for the preservation of heavy metals. Formalin was added to marine water samples for planktonic analysis. In general, all water and sediment samples were stored in sterile polythene bottles and Ziplock bags and kept in an icebox to maintain suitable conditions until they were transported to the laboratory. The parameters to be analyzed (Table 8) and the methods used for the sample analysis are described below.

Table 8: Physico-chemical and biological characteristics of marine water samples

S. No	Physico-chemical and Biological parameters
1	pH
2	Salinity (ppt)
3	Total Dissolved Solids (mg/L)
4	Turbidity (NTU)
5	Dissolved Oxygen (mg/L)
6	Bio-Chemical Oxygen Demand (mg/L)
7	Chemical Oxygen Demand (mg/L)
8	Phenolic compound (µg/L)
9	Petroleum Hydrocarbons (µg/L)
10	Oil and grease (mg/L)
11	Cadmium (mg/L)
12	Lead (mg/L)
13	Chromium (mg/L)
14	Copper (mg/L)
15	Cobalt (mg/L)

16	Nickel (mg/L)
17	Zinc (mg/L)
18	Magnesium (mg/L)
19	Chlorophyll (mg/m^3)
20	Phaeophytin (mg/m^3)
21	Phytoplankton Phytoplankton cell counts (no/L) Total Genera (no.) Major Genera
22	Zooplankton Biomass (ml/100m^3) Population (no/100m^3) Total Group (no.) and Major Groups

4.2.1. pH, Temperature and Salinity

pH and temperature measurements were conducted using a Thermo Fisher pH/EC/Temperature meter. Prior to use, the instrument was calibrated with standard buffers. For pH determination, an appropriate volume of the sample was titrated against silver nitrate (20 g/l), with potassium chromate serving as an indicator. The chlorinity of the sample was estimated, and salinity values were derived using a specific formula.

Total Dissolved Solids (TDS)

To confirm the readings obtained from the handheld meter, the samples underwent a gravimetric procedure. Approximately 100 ml of the water sample was taken in a beaker and filtered. The filtered sample was then completely dried in a hot air oven at 105°C. The TDS values were calculated by measuring the difference between the initial and final weight of the dried sample.

Turbidity

For turbidity measurement, a sample tube (Nephelometric cuvette) was filled with distilled water and inserted into the sample holder. The lid of the sample compartment was closed, and the meter reading was adjusted to zero by manipulating the 'SET ZERO' knob. The sample tube containing the 40 NTU standard solution was then placed in the tube, and the meter reading was set to 100. Similar measurements were carried out for other standard solutions. To determine the turbidity of the marine water sample, the sample tube was filled with the water sample, and the corresponding reading was recorded.

Dissolved Oxygen (DO)

To determine the Dissolved Oxygen (DO) levels in a water sample obtained from a marine environment, the following procedure was employed. Collect sea water sample, ensuring that the sampling container is clean and free from any potential contaminants that may affect the accuracy of the results. Subsequently, transfer the water sample into a Winkler's bottle or a suitable container, taking care to eliminate any trapped air bubbles. It is crucial to completely fill the bottle to minimize any headspace that could potentially alter the DO readings. Next, add the appropriate volumes of Winkler's reagents, such as manganese sulfate and alkali-iodide-azide, to the water sample as per the specific instructions of the Winkler's method. Gently and thoroughly mix the contents of the bottle to ensure uniform distribution of the reagents without introducing any air bubbles. Allow the bottle to stand undisturbed for a designated incubation period, typically around 30 minutes, to enable the necessary reactions to occur. After the incubation period, perform a titration using a standardized sodium thiosulfate (Na2S2O3) solution until a faint yellow color appears, indicating the complete consumption of dissolved oxygen in the sample. Record the volume of sodium thiosulfate solution used for titration, which represents the amount of dissolved oxygen present in the water sample. To account for any dissolved oxygen in the reagents, it is essential to conduct the same procedure with blank samples that do not contain the water sample. This allows for an accurate calculation of the DO levels in the original water sample. Finally, employ the appropriate formula provided by Winkler's method to calculate the DO concentration in the water sample.

Biochemical Oxygen Demand (BOD)

To determine the Biochemical Oxygen Demand (BOD), the following procedure was employed using the direct unseeded method. Collect representative sea water sample from the desired location, ensuring the sampling container is clean and uncontaminated. Fill a BOD bottle with the water sample, leaving minimal headspace to prevent air contact that could affect BOD measurements. It's important to completely fill the bottle to minimize air bubbles. Record the initial Dissolved Oxygen (DO) level in the water sample using a dissolved oxygen meter or appropriate measurement method. Seal the BOD bottle tightly with the stopper to prevent air exchange. Incubate the sealed BOD bottle in a controlled environment, such as a BOD incubator, at a specified temperature (typically 20°C), for a designated incubation period, usually around 5 days. Throughout the incubation period, keep the BOD bottle in darkness to minimize the impact of photosynthetic activity. After the incubation period, measure the final DO level in the water sample using the same method or instrument as the initial measurement. Calculate the BOD by subtracting the final DO level from the initial DO level, accounting for any necessary dilution or blank corrections. This difference represents the amount of oxygen consumed by the organic matter in the water sample during the incubation period.

Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) test is a widely used method for quantifying the levels of organic and inorganic pollutants in water samples. The first step involves collecting representative water samples from the target site, ensuring proper labeling and record-keeping. Subsequently, these samples are placed into digestion vials or tubes, to which digestion reagents, typically potassium dichromate and sulfuric acid, are added. This step initiates the oxidation of organic matter in the sample. The sealed vials or tubes are then subjected to high-temperature heating, typically around 150-160°C, for a predetermined period, usually around 2 hours. This heating process breaks down complex organic compounds into simpler forms. After digestion, the samples are allowed to cool to room temperature. To determine the COD concentration, a colorimetric measurement is taken. A suitable reagent is added to the digested samples, reacting with any residual potassium dichromate, and generating a color change proportional to the COD concentration. This color intensity is measured using a colorimeter or spectrophotometer, and the results are calibrated using known COD standards. The final calculations yield the COD value, typically expressed in milligrams of oxygen per liter (mg/L) of the sample.

Phenolic compounds

To analyze phenolic compounds in water, the following procedure was followed. A 500 ml water sample containing phenols was treated with 4-aminoantipyrine, which converted the phenols into an orange-colored antipyrine complex. This complex was then extracted using 25 ml of chloroform. The absorbance of the extracted complex was measured at 460 nm using phenol as a standard for comparison. This measurement allowed for the quantification of phenolic compounds present in the water sample.

Petroleum Hydrocarbons (PHc)

The analysis of Petroleum Hydrocarbons (PHc) in a water sample involved the following protocol. One liter seawater sample was extracted using organic solvent, hexane. The mixture was then separated into an organic layer and an aqueous layer. The organic layer, containing the petroleum hydrocarbons, was isolated. To remove any remaining water, the organic layer was dried using anhydrous sulphate. The volume of the organic layer was subsequently reduced to 10 ml at a temperature of 30°C under low pressure. The fluorescence of the extracted organic compound was measured at 360 nm (with excitation at 310 nm) using Saudi Arabian crude residue as a standard. This residue was obtained by evaporating the lighter fractions of crude oil at 120°C. By comparing the fluorescence intensity of the extract with that of the standard, the concentration of petroleum hydrocarbons in the water sample could be determined.

Oil and Grease

To determine the content of Oil and Grease in a sample, the following procedure was followed. Approximately 500 ml of the sample was transferred to a separating funnel, and the sample bottle was rinsed with 30 ml of trichlorotrifluoroethane. The rinsing solvent was then added to the separating funnel. Next, 5 ml of 1:1 hydrochloric acid (HCl) was added to the mixture, and the contents were vigorously shaken for about 2 minutes. If a soluble emulsion was formed, the sample container was shaken for an additional 5 to 10 minutes. After shaking, the layers in the separating funnel were allowed to separate, and the lower layer (organic layer) was discarded.

The solvent layer was drained through a funnel containing a filter paper moistened with solvent, and it was collected in a clean distillation flask that had been pre-weighed. The solvent was then distilled from the flask using a water bath set at 70°C. The resulting residue was carefully transferred into a clean, pre-weighed, and dried beaker, using the minimum amount of solvent necessary. The beaker was placed on a water bath at 70°C for 15 minutes to evaporate off all the solvent. After the evaporation process, the beaker was cooled in a desiccator for 30 minutes to reach a consistent temperature, and its weight was then measured.

Heavy metals

Heavy metals are a significant concern, especially in coastal environments, since it is biomagnifying from lower organisms to higher organisms through water and sediment. Common heavy metals of concern include Cadmium (Cd), Lead (Pb), Chromium (Cr), Copper (Cu), Cobalt (Co), Nickel (Ni), Zinc (Zn), Magnesium (Mg) and Manganese (Mn). To release mineral elements from sediment and analyze them, a wet oxidation process is typically employed using oxidizing acids, such as a mixture of Tri / Di-acids.

The procedure begins by weighing 0.5 grams of the sediment sample and placing it in a 100 ml beaker, which is covered with a watch glass. Then, 12 ml of Aqua regia (a mixture of 1 part HNO3 and 3 parts HCl) is added to the beaker. The beaker is placed in a digestion apparatus and heated at 100°C for 3 hours on a hot plate using a sand bath. The sample is evaporated until it is nearly dry, and then allowed to cool for 5 minutes. Next, 20 ml of 2% nitric acid is added to the cooled sample in the beaker, and the mixture is further digested on the hot plate for 15 minutes. After digestion, the beaker is removed from the hot plate and allowed to cool. The sample is then filtered using a Whatman No. 42 mm filter paper to remove any solid particles. To make up the final volume, the filtrate is diluted with 2% nitric acid to a total volume of 50 ml. The resulting extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis of the heavy metal concentrations.

Results

Throughout the study conducted in the present year, we closely monitored three distinct locations: Offshore, Cargo Jetty, and Phang Creek. A comprehensive analysis of physico-chemical characteristics in marine water samples was conducted at each of these sites. The collected data is thoughtfully presented in Tables 9-11. These findings serve as a significant source of information regarding the precise physico-chemical conditions prevailing at each of these locations. Consequently, they play a pivotal role in enhancing the comprehension of the environmental factors that exert influence on the quality of marine water in these specific areas.

Location 1 - Offshore location

In the offshore location (Location 1), the recorded data shows that the mean value of temperature was recorded as 25.23±0.28°C. The pH values ranged between 7.80 and 7.93, with an average pH value of 7.85±0.04. The salinity of the seawater recorded the mean value as 37.65±2.23 ppt, while the TDS which indicates the presence of various anions and cations, had an average value of 45809.17±672.54 mg/L. Turbidity values ranged from 18.60 to 49.20 NTU. The maximum Dissolved Oxygen and Biochemical Oxygen Demand were in the order of 7.00 mg/L and 3.60 mg/L respectively. The average COD value was determined to be 34.17±3.56mg/L. The concentrations of Phenolic compounds and Petroleum hydrocarbons varied between 11.02 to 46.91 µg/L, and 49.20 to 139.29 µg/L, respectively. It is observed that the concentration of Petroleum hydrocarbons (PHC) was higher than the prescribed limit of 100 µg/L set by CPCB. The concentration of oil and grease ranged from 0.40 mg/L to 2.0 mg/L, which is within the acceptable limit of 10 mg/L according to GPCB norms whereas some samples ex. Additionally, the maximum concentrations of heavy metals were observed for Magnesium (372.20 mg/L), Nickel (4.36 mg/L), Lead (BDL), Cadmium (1.67 mg/L), Chromium (BDL), Zinc (2.18 mg/L), Copper (BDL), Manganese (0.21 mg/L), and Cobalt (1.17 mg/L), as shown in Table 9.

Location 2 – Cargo Jetty

At the Cargo Jetty location, the recorded data shows that the mean value of temperature was recorded as 27.07±0.585°C, and the mean value of pH was observed as 7.873±0.038. The average salinity of the seawater was 37.324±1.686 ppt reflecting the salt content, while the TDS which indicates the presence of various anions and cations, had an average value of 43881.00±2851.613 mg/L. Turbidity values ranged from 23.2 to 57.1 NTU. The maximum values recorded for Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were 6.9 mg/L and 2.9 mg/L respectively (as shown in Table 10). The average COD value was determined to be 38.167±2.623 mg/L. The concentrations of Phenolic compounds and Petroleum hydrocarbons were within permissible limits set by CPCB in most of the samples except a few in case of PHc where some samples recorded a higher value with the maximum values ranging from 56.02 µg/L and 129.5 µg/L respectively for Phenolic compounds and PHc. The mean concentration of oil and grease in the marine water samples was 3.367±2.468 mg/L, which falls below the acceptable limit of 10 mg/L according to GPCB norms. Regarding heavy metal concentrations, the mean values for Magnesium, Nickel, Lead, Cadmium, Chromium, Zinc, Copper, Manganese, and Cobalt were 211.375±40.007 mg/L, 0.692±0.332 mg/L, BDL, 0.687±0.604 mg/L, BDL, 0.732±0.144 mg/L, BDL, 0.155 mg/L and BDL respectively as presented in Table 10.

Location 3 - Phang Creek

In case of Phang creek near the port, the mean value of temperature was recorded as 27.033±0.429°C and the pH value was recorded between 7.86 to 7.96. The average salinity of the seawater in the vicinity was found to be 36.467±1.305 ppt, while the TDS which indicates the presence of various anions and cations, had an average value of 44746.833±1486.111 mg/L. Turbidity values ranged from 7.2 to 10.8 NTU. Pollution indices such as Dissolved Oxygen and Biochemical Oxygen Demand, Phenolic compounds, and Oil and grease concentrations had maximum values of 6.5 mg/L, 3.2 mg/L, 11.32 µg/L, and 5.2 mg/L, respectively. The average value of PHc was 35.609±6.064 µg/L. In case of heavy metals, the mean values for Magnesium, Cadmium and Zinc were 264.142±42.132 mg/L, 0.150±0.268 mg/L, 0.425 mg/L, respectively. These values are presented in Table 11.

Table 9: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore)

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	25.40	25.10	25.30	25.10	25.60	25.30	25.70	25.50	24.90	25.10	24.90	24.90
2	pH	7.83	7.82	7.81	7.83	7.91	7.93	7.80	7.86	7.84	7.80	7.83	7.90
3	Salinity (ppt)	36.90	36.90	38.61	36.04	36.04	36.04	40.76	41.19	33.46	39.47	37.33	39.04
4	Total Dissolved Solids (mg/L)	46377	45034	45920	45906	45442	44921	46816	46608	46511	44914	45851	45410
5	Turbidity (NTU)	49.2	47.3	33.9	48.2	35.4	33.6	44.5	41.9	18.8	43.4	18.6	19.3
6	Dissolved Oxygen(mg/L)	7.00	7.00	6.80	6.50	6.80	6.70	6.90	6.80	6.60	6.60	6.30	6.30
7	Bio-Chemical Oxygen Demand (mg/L)	3.10	3.00	2.70	2.40	3.10	2.40	3.60	2.90	2.60	2.70	2.60	2.50
8	Chemical Oxygen Demand (mg/L)	38.00	32.00	36.00	34.00	40.00	32.00	38.00	32.00	36.00	34.00	30.00	28.00
9	Phenolic Compounds (µg/L)	41.02	45.44	26.17	46.91	35.58	24.11	39.65	35.00	14.26	33.67	11.02	11.4.7
10	Petroleum Hydrocarbons (µg/L)	67.25	65.25	139.29	137.55	81.80	79.45	50.85	49.20	61.24	62.95	97.25	98.30
11	Oil and grease (mg/L)	1.2	2.0	0.8	1.2	1.2	0.8	0.4	1.2	1.2	1.2	0.8	0.4
12	Magnesium (mg/L)	292.5	372.2	325	276.3	134.95	252.1	245.75	229	294.2	268.9	227.5	170.4
13	Nickel (mg/L)	BDL	0.85	BDL	BDL	4.36	BDL	BDL	BDL	BDL	BDL	BDL	BDL
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	0.09	0.09	0.31	0.07	0.88	0.83	0.16	1.67	1.58	0.95	0.10	0.97
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Zinc (mg/L)	0.33	0.70	0.12	0.83	1.32	BDL	BDL	BDL	BDL	2.18	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	BDL	0.21	BDL	BDL	0.02	BDL	BDL	0.02	BDL	BDL	BDL	BDL
20	Cobalt (mg/L)	0.80	0.13	0.40	0.20	1.17	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit.

Table 10: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty)

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	26.1	26	27.8	27.5	27.3	27.4	27.5	27.3	27.4	27.3	26.8	26.5
2	pH	7.8	7.88	7.88	7.85	7.88	7.9	7.87	7.87	7.82	7.93	7.87	7.93
3	Salinity (ppt)	34.75	38.18	36.47	38.61	37.75	37.75	38.61	36.9	34.75	35.61	38.18	40.33
4	Total Dissolved Solids (mg/L)	445/82	46691	46982	43087	44081	46523	44976	40707	40508	38675	46405	44056
5	Turbidity (NTU)	57.1	55.7	54.3	54.7	55.1	55.7	36.6	36.1	34.2	24.8	28.8	23.2
6	Dissolved Oxygen(mg/L)	6.9	6.8	6.2	6.1	6.8	6.5	6.7	6.4	6.9	6.5	6.2	5.9
7	Bio-Chemical Oxygen Demand (mg/L)	2.7	2.7	2.6	2.6	2.7	2.6	2.6	2.7	2.9	2.7	2.7	2.3
8	Chemical Oxygen Demand (mg/L)	42	38	40	36	40	40	38	36	42	34	36	36
9	Phenolic Compounds (µg/L)	56.02	55.44	38.38	50.73	47.94	45.58	26.91	26.91	26.17	25.58	22.2	19.7
10	Petroleum Hydrocarbons (µg/L)	66.45	65.00	49.20	52.67	129.50	128.35	127.05	128.45	97.85	96.42	81.80	80.00
11	Oil and grease (mg/L)	1.6	5.6	5.2	4	0.8	0.8	7.6	0.8	3.6	1.2	6.8	2.4
12	Magnesium (mg/L)	147.45	208.85	154.2	210.1	219.85	239.35	252.75	263.9	255.3	196.15	161.35	227.3
13	Nickel (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.32	0.94	BDL	BDL	0.82
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	1.155	0.305	0.875	0.93	1.115	0.055	0.185	1.595	0.12	1.65	0.02	0.24
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Zinc (mg/L)	0.81	0.82	BDL	0.565	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	BDL	BDL	BDL	0.16	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Cobalt (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit

Table 11. Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek)

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	26.5	26.3	27.5	27.4	27.5	27.5	27.1	27	26.8	26.5	27.3	27
2	pH	7.93	7.96	7.87	7.88	7.88	7.87	7.91	7.89	7.94	7.9	7.94	7.86
3	Salinity (ppt)	37.33	35.18	34.32	36.47	36.47	36.47	38.61	38.17	35.18	36.04	35.61	37.75
4	Total Dissolved Solids (mg/L)	43740	41597	43001	45381	46581	45271	44318	44001	46296	46231	45705	44840
5	Turbidity (NTU)	8.5	8.7	8	7.9	7.2	7.2	10.2	8.9	9.7	10.7	10.8	10.7
6	Dissolved Oxygen(mg/L)	6	5.9	5.9	5.6	5.9	5.5	6.1	5.9	6.5	6.2	6.2	5.9
7	Bio-Chemical Oxygen Demand (mg/L)	3.2	2.9	3.2	2.8	2.7	2.2	2.7	2.5	2.4	2.4	2.5	2.4
8	Chemical Oxygen Demand (mg/L)	42	36	36	34	40	38	28	24	32	28	30	30
9	Phenolic Compounds (µg/L)	6.61	6.02	4.11	2.64	3.67	3.67	8.82	11.32	8.23	6.32	11.02	9.55
10	Petroleum Hydrocarbons (µg/L)	35.70	32.00	45.50	45.25	32.95	31.30	28.05	29.95	41.80	40.45	31.61	32.75
11	Oil and grease (mg/L)	4.8	3.6	3.6	1.2	4.0	5.2	2.2	0.8	4.0	2.4	1.6	2.4
12	Magnesium (mg/L)	232.7	292.15	190.65	259.1	243.55	252.55	327.15	209.85	279.15	326.25	264.75	291.85
13	Nickel (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	0.055	0.89	0.12	0.005	0.225	0.045	0.01	0.065	0.025	BDL	0.055	BDL
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Zinc (mg/L)	BDL	BDL	BDL	0.425	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Cobalt (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit

5.1. Introduction for Plankton

Plankton is defined as all those living organisms which are suspended and drifting in water. The planktonic communities encompass of aquatic organisms which drift passively and also have limited mobility to move contrary of the water mass. Plankton are divided in two parts which are phytoplankton and zooplankton (Brink. 1993). The tiny flora or plants are called as Phytoplankton, and weak swimming tiny fauna or animals are called as Zooplankton. Phytoplankton are the primary producers in marine ecosystems and form the basis of the food web. Zooplankton are pelagic animals play a role in the food chain in aquatic ecosystem to provide a food resource to various organisms. Major phytoplankton in sea water is Diatoms (Tiwari and Nair, 1998; Thakur et al, 2015), Cocolithophores, Sillicoflagellates, Blue green algae (Cyanobacteria) and Dinoflagellates. Zooplankton comprises the second level in the food chain and includes Tintinnids, Foraminiferans, Radiolarians, Amphipoda, Copepoda, Calanoida, Chaetognaths, larvae of benthic invertebrates and fish larvae etc. (Gajbhiye and Abidi, 1993; Thirunavukkarasu, 2013; Chakrabarty et al. 2017). Size is very important to understanding about the classification of both zooplankton and phytoplankton. Based on size, various categories of plankton are smallest one Picoplankton (0.2-2 µm), Nanoplankton (2-20 µm), Microplankton (20-200 µm), Mesoplankton (200 µm-2 mm), Macroplankton (2-20 mm) and Megaplankton (> 20 mm) . The population of plankton diversity is largely related to seasonal and monthly variability in Physical, Chemical and Biological parameters; Interspecific competition among the Zooplankton; Inter-relationship for prey and predator between zooplankton and their mostly predator animals; Grazing ratio of primary-secondary consumers; Suspension of sediment; Fluctuation in Phytoplankton abundance; Waves, Currents and Tidal turbulence effect; Fluctuation in Chlorophyll a and Nutrients; Input of Organic and other Pollution creating sources; Fish potential ratio; Monsoon effect; Suddenly changes in atmosphere; Peak time of every seasons and its effect; Vertical migration of Zooplankton; Food selection pattern of predator; Collection time and number of collected samples, mixing of water column, high surface action, Seasonal up welling and down welling process in water column

Phytoplankton

Phytoplankton are single celled marine algae with great difference in shape, size and form, either use flagella for movement in water or just drift with currents (Zohari et al, 2014). These photosynthetic organisms need sunlight for photosynthesis. With trapping carbon in the process of photosynthesis, they can control the atmospheric carbon dioxide and help in combating the global climate change. With this, they have significant role in the management of nutrients cycles in the ocean systems. Their role as primary producers in aquatic ecosystem, in the process of nutrients cycling in the ocean systems, also in calcification, silicification, nitrogen-fixing, etc. made them important marine component for marine life study. Their sensitiveness for various anthropogenic activities in the marine environment such as Eutrophication, introduction of invasive species, overfishing etc, make them one of the best indicators to analyse these activities.

Zooplankton

The faunal species particularly microscopic fauna, living inside the water bodies are known as zooplankton. Zooplankton is tiny-small animals found in all water bodies particularly the pelagic and littoral zone in the ocean. They are classified by size and or by development stages. Zooplankton community is composed of both primary consumers (which eat phytoplankton) and secondary (which feed on the other zooplankton). Nearly all fish depend on zooplankton for food in both larval stages and entire life period (Madin et al., 2001). They are attractive, various and plentiful group of faunal species which can swim or generally drift with water currents but have no potential to swim against water currents (Alcaraz and Calbet, 2003). The important role of them is to be a major link in the marine life in between marine microalgae or phytoplankton and fish. Although they can be classified according to their habitat and depth, distribution, size and duration of planktonic life period (Omori and lkeda, 1984), generally, it is considered as there are two types of zooplanktons. Holoplanktons are those which live permanently in the planktonic form, while meroplanktons are the temporary members in this form. The potential of zooplankton to respond quickly to environment changes and short generation life span, make them important bioindicator of water pollution and all variation occurred in their living environment. Their study is the important part for getting knowledge of the functioning of marine ecosystems (Mees and Jones, 1997).

5.2. Methodology

5.2.1 Estimation of Chlorophyll and Phaeophytin

Estimating Chlorophyll and Phaeophytin was done using known volume of water (500 ml) was filtered through a 0.45µm Millipore membrane filter paper and the pigments retained on the filter paper were extracted in 90% acetone overnight at 50°C. The extinction of the acetone extract was measured using fluorimeter before and after treatment with dilute acid (0.1N HCI).

5.2.2. Phytoplankton sampling and analysis

Phytoplankton samples were collected in the ten prefixed sampling sites using a standard plankton net with a mesh size of 51 µm. Plankton nets are with a square mouth covering an area of 0.900 cm^2 (30cm square mouth) fitted with a flow meter (Hydrobios). Nets were towed from a moving boat for 10 minutes and the plankton adhering to the net was concentrated in the net bucket. Plankton soup from the net bucket was transferred to a pre-cleaned and rinsed container and preserved with 5% neutralized formaldehyde. The containers were appropriately labelled. The initial and final flow meter reading was noted down for calculating the amount of water filtered to estimate plankton density. As per flow meter reading, a total amount of $165m^3$ of water was filtered by the net. One liter of water was separately collected for density estimation to counter check density estimation obtained by the flow meter reading. Quantitative analysis of phytoplankton (cell count) was carried out using a sedge wick-Rafter counting chamber. One ml of soup added to a Sedgwick counting chamber was observed under an inverted compound microscope. The number of cells present in individual cells of the counting chambers (1/1000) was noted and identified up to a generic level. Several observations were fixed to represent the entire quantity of the soup (generally more than30 times) and the recorded data were used to calculate the density (No/l) using the formula, N = n×v/V (where N is the total no/l; n is an average number of cells in 1 ml; v is the volume of concentrate; V is the total volume of water filtered). The phytoplankton diversity richness and evenness were past software.

5.3. Phytopigments

The concentration of phytopigments is inversely proportional to the turbidity of the waters and in general, waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.32-0.72 mg/m^3 with a mean ± SD being 0.52±0.15 mg/m^3 in the Offshore (Table 12), 0.229 to 0.845 mg/m^3 with mean ± SD of 0.466±0.205 mg/m^3 in the Cargo Jetty (Table 13) and 0.296 to 0.721 mg/m^3 with mean ± SD being 0.47±0.137 mg/m^3 in the Phang creek location (Table 14).

Another phytopigment estimated was Phaeophytin, which is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.12-0.76 mg/m^3 with a Mean±SD of 0.37±0.21 mg/m^3 in the Offshore location (Table 12). In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.101 - 0.4 mg/m^3 with a Mean±SD of 0.235±0.089 mg/m^3 (Table 13) and in case of the creek location, the concentration of phaeophytin was almost similar when compared to the other two locations and was ranging between 0.202 – 0.487 mg/m^3 with a Mean±SD of 0.336±0.092 mg/m^3 (Table 14). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 12: Chlorophyll and Phaeophytin concentration observed in the Offshore site

Parameters	1A		1B		1C		1D		1E		1 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.602	0.332	0.323	0.700	0.401	0.441	0.721	0.338	0.652	0.679	0.515	0.52
Phaeophytin	0.486	0.328	0.221	0.120	0.190	0.385	0.173	0.160	0.592	0.762	0.602	0.424

Table 13: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site

Parameters	2A		2B		2C		2D		2E		2 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.544	0.229	0.641	0.807	0.321	0.481	0.280	0.845	0.442	0.332	0.340	0.324
Phaeophytin	0.282	0.120	0.288	0.400	0.189	0.272	0.101	0.205	0.325	0.218	0.180	0..27

Table 14: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site

Parameters	3A		3B		3C		3D		3E		3 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.452	0.430	0.721	0.721	0.339	0.390	0.401	0.512	0.296	0.352	0.496	0.526
Phaeophytin	0.389	0.380	0.339	0.383	0.287	0.289	0.391	0.487	0.214	0.202	0.229	0.442

Phytoplankton

The study was conducted at 3 sites (or regions) at Deendayal Port and near area where dredging activities is going on Creek and the stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

In this site, frequently observed species were *Coscindiscus radiatus, Coscinodiscus granii, Coscinodiscus sp, Planktoniella blanda, Synedra ulna, Thalassiosira ferelineata, Thalassiosira sp.,* whereas less observed species were *Biddulphia sp, Coscinodiscus centralis, Diploneis sp, Entomoneis sp, Gyrosigma sp, Nitzschia sigmoidea, Nitzschia sp, Rhizosolenia sp, Thalassiosira ecentrica, etc.* Total 34 Phytoplankton were recorded in this Offshore area. Highest population density was recorded at site 1C-Offshore (16640 nos./m^3) and low density recorded at site 1B-Offshore(8160 nos./m^3).The maximum number of species observed in site 1C-Offshore (18 nos.) followed by 1D and 1control-Offshore (17 nos.), 1A-Offshore (14 nos.),1E-Offshore (13 nos.)and1B-Offshore (12nos).The population density greatly varied between (8160 nos./m^3 to 16640 nos./m^3).*Biddulphia sp, Navicula sp. Oscillatoria sp, Synedra ulna, Fragilaria sp colonies* were recorded which are sometimes considering for pollution indicator species in water. Oscillatoria sp was also recorded in location 1A-1C-Offshorewhich is generally found in freshwater or polluted water indicated mixing of water in some level.

Cargo jetty

Total 32 Phytoplankton were recorded in this Cargo Jetty area. The population density greatly varied between 6880 Nos/m^3 to 11200 Nos/m^3. Highest density value recorded at 2E-Cargo Jetty (11200 nos./ m^3) and lowest value was at 2B-Cargo Jetty (6880 nos./m^3). The lowest number of species noticed in the site 2A and 2B- Cargo Jetty (09 nos.) whereas highest in 2E-CargoJetty (15 nos.) The density and species number, both highest in 2E-Cargo Jetty. In this Cargo Jetty station commonly or frequently observed species were *Coscindiscus radiatus, Coscinodiscus centralis, Coscinodiscus sp, Planktoniella blanda, Thalassionema frauenfeldii colonies, etc.* The rarely found species were *Bacillaria paxillifera colonies, Biddulphia sp, Climacosphaenia sp, Cyclotella sp, Green algae, Navicula sp, Noctiluca sp, Thalassiosira punctigera, Protoperidinium sp,* *etc. The Dinoflagellated cysts like Noctiluca sp*(mostly consider deep sea species) and *Protoperidinium sp* were recorded only in this site of station 2C-Cargo Jetty and 2D-Cargo Jetty respectively. Unidentified Green algae was also recorded in site 2A-Cargo Jetty.

Phang Creek

The population density of phytoplankton ranged from 11680 nos./m^3 to 26080 nos./m^3 same way species availability ranged from 16 to 28 nos. Maximum and Minimum value of population density were recorded in site 3A-Phang Creek (26080 nos./m^3) and 3D-Phang Creek (11680 nos./m^3) respectively. Highest number of species recorded in site 3E-Phang Creek (28 nos.) and lowest in site 3D-Phang Creek (16 nos.). Total recorded phytoplankton was 43 in this creek area. *Actinocyclus sp, Coscindiscus radiatus, Coscinodiscus centralis, Coscinodiscus wailesii, Gyrosigma sp, Odontella mobiliensis, Planktoniella blanda, Synedra ulna, Thalassiosira aculeate, Triceratium sp, etc.* were frequently noticed in samples whereas less observed species were *Bacillaria paxillifera colonies, Bacillaria paradoxa colonies, Ceratium furca, Coscinodiscus oculus-iridis, Diploneis elliptica, Nitzschia sigmoidea, Paralia sulcata colony, Triceratium broeckii etc in* this site. *Ceratium furca, Dinoflagellated cysts*, are sometimes responsible for algal blooms of water recorded which recorded in 3C-Phang Creek

Overall view of Phytoplankton showed that a total 55s pecies of Marine phytoplankton were identified during summer season of the year 2023. Among them,32-Centric diatoms, 17-Pennate diatoms, 3-Dinoflagellates, 2-Blue green algae and some phytoplankton were Unidentified. Plankton identification, both zooplankton and phytoplankton, were done by using relevant identification and taxonomic keys and with standard literatures, monographs and research articles (Kasturirangan, 1963; APHA, 1992; Mitra et al., 2003;Goswami, 2005; Carling et al., 2004; Mandal, 2004; Hussain and Kalaiyarasi, 2013; Guglielmo et al., 2015; Hussain et al., 2016; Sreenivasulu et al., 2017; NIO,1998; NIO,2002) ,etc. Some species like *Bacillaria paxillifera colonies, Bacillaria paradoxa colonies, Campylodiscus sp, Coscinodiscus asteromphalus, Coscinodiscus oculus-iridis, Ditylum brightwelli, Entomoneis sp, Nitzschia sigmoidea, Triceratium favus, Trieres mobiliensis, Protoperidinium sp, etc.,* were rarely recorded during sample analysis. Input of the fresh water indicated by the presence of some common fresh water species like *Green algae*, *Oscillatoria sp*. Presence of *Dinoflagellated (Noctiluca sp* and *Protoperidinium sp)* indication of bottom water circulation up to surface water layer in some level. Noctiluca genus is also considering bioluminescent organisms. Highest phytoplankton density was observed at the site 3A-Phang Creek (26080 nos./m^3) and lowest was observed at site 2B-Cargo Jetty (6880 nos./m^3) (Table 15). Total number of highest species observed at site 3A-Offshore (24 nos.) and lowest in site 2A and 2B-Cargo Jetty (09 nos.).

The high population density composed by species like *Coscindiscus radiates, Coscinodiscus sp, Coscinodiscus centralis, Planktoniella blanda, Synedra ulna, Thalassionema frauenfeldii colonies, Thalassiosira sp, etc.* (Table 15). This result indicated that genus *Coscinodiscus sp*. *Thalassionema sp and Synedra sp.* were very common with good numbers in all sites. In some sites, least number of species and low density of phytoplankton might be responsible due to some factors like extreme hot weather because of summer season, high pre-predation ratio, marine pollution (anthropogenic pressure), high turbidity, total suspended solids, water current and suddenly changes in environment conditions etc. Diatoms, type of phytoplankton, constitute major part in total phytoplankton composition The individual density of species of sites viz. has been depicted in Table 15. All values of phytoplankton density, list of phytoplankton and others shown in Table 15.

Diversity Indices of Phytoplankton

According to Table 16, diversity indices calculation for phytoplankton showed that the Shannon Index ranged from (2.01 to 3.20) indicated moderate level to slightly high level of diversity status. High Shannon Index was recorded at 3E-Phang Creek (3.20) and low at 2A-Cargo Jetty (2.01). Lowest evenness recorded at site 3control-Phang Creek (0.69) whereas highest was in at 1A-Offshore (0.95). Dominance_D index ranged from 0.06 to 0.15 where higher value in 2A-Cargo Jetty (0.15) and lowest was at in 3B-Phang creek (0.06). Value of Margalef D (0.89 to 2.70) showed more variation in species numbers. (Table 16.).

Table 15. Density of Phytoplankton at different sites of Deendayal Port

Name of Sites	Offshore						Cargo Jetty						Phang Creek					
	1A	1B	1C	1D	1E	1 control	2A	2B	2C	2D	2E	2 control	3A	3B	3C	3D	3E	3 control
Genus of Phytoplankton																		
Actinocyclus sp.	0	0	0	960	640	640	1920	0	0	0	480	0	480	1440	800	1280	1760	640
Bacillaria paxillifera colonies	0	0	0	0	0	0	0	0	0	640	0	0	0	320	0	0	320	0
Bacillaria paradoxa colonies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	480
Biddulphia sp	0	0	0	0	640	0	0	0	0	480	0	0	480	0	0	0	320	0
Campylodiscus sp	0	0	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratium furca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0	0	0
Climacosphaenia sp	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0
Coscinodiscus asteromphalus	0	0	0	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0
Coscindiscus radiatus	800	960	0	640	800	800	320	640	320	800	800	1440	1280	1120	1440	1280	960	640
Coscinodiscus centralis	0	0	0	1280	0	0	480	0	480	320	1440	0	960	1120	640	480	480	800
Coscinodiscus granii	1120	0	640	0	1600	960	0	0	0	0	0	0	0	0	0	0	0	0
Coscinodiscus oculus-iridis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	960	0
Coscinodiscus sp	1120	0	1280	640	0	1600	1600	1440	1600	0	1120	0	5280	1280	0	0	800	1440
Coscinodiscus sp (Grazing)	0	0	0	0	0	0	0	0	0	0	0	0	1920	0	0	0	0	0
Coscinodiscus wailesii	0	0	0	0	0	0	0	0	3200	1440	1120	1600	4000	1280	0	960	800	5120
Cyclotella sp	0	0	0	0	0	0	0	0	1120	0	0	0	0	960	640	0	0	0
Diploneis elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0	0	0	0
Diploneis sp	0	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ditylum brightwelli	0	0	0	0	0	0	0	0	0	0	320	0	0	0	0	0	0	0
Entomoneis sp.	0	0	0	0	0	640	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria sp colonies	1120	0	640	0	0	0	0	0	0	0	0	0	800	320	640	0	0	160
Green algae	0	0	0	0	0	0	960	0	0	0	0	0	0	0	480	480	0	
Gyrosigma sp.	0	0	800	0	0	800	0	0	0	0	0	0	480	0	0	320	480	480
Hemidiscus sp	0	320	0	320	0	0	0	0	640	0	0	0	640	0	0	0	0	640
Navicula sp.	0	640	0	0	0	640	0	0	0	0	0	320	800	0	0	0	0	640
Nitzschia sigmoidea	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0	640	0	0
Nitzschia sp	0	0	960	0	0	0	0	800	0	0	320	640	0	960	640	0	640	0
Noctiluca sp	0	0	0	0	0	0	0	0	320	0	0	0	0	0	0	0	0	0
Odontella sinensis	800	480	320	480	0	0	0	320	640	0	320	320	0	0	0	0	800	0

Odontella mobiliensis	0	0	0	0	480	0	0	0	0	800	0	0	640	640	480	0	640	960
Oscillatoria sp	640	0	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paralia sulcata chain	0	0	0	0	0	0	0	0	0	0	0	0	640	0	0	0	0	0
Pinnularia sp.	320	0	0	960	0	1120	0	0	0	0	0	0	320	0	0	0	640	0
Planktoniella blanda	800	800	800	480	320	960	480	480	0	0	480	480	480	0	480	960	480	320
Planktoniella sol.	0	0	0	0	0	0	0	0	160	800	0	160	0	0	0	0	0	0
Pleurosigma sp.	0	0	0	960	640	640	0	0	0	0	1120	800	0	640	0	0	320	320
Protoperidinium sp.	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0
Rhizosolenia setigera	640	0	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhizosolenia sp	0	0	0	320	0	0	0	0	0	320	0	0	0	0	0	0	800	480
Surirella sp.	480	0	960	0	480	640	320	0	0	0	320	320	0	640	1120	320	480	320
Synedra crystallina	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640	0
Synedra sp	0	0	0	0	1440	0	0	960	0	0	0	0	320	0	0	640	640	480
Synedra ulna	1120	1280	1120	1440	800	640	1120	0	0	640	480	960	960	640	1280	480	960	1120
Thalassionema frauenfeldii colonies	0	640	1600	1280	0	800	0	1280	1440	800	1120	1120	640	0	640	960	960	1440
Thalassionema nitzschioides colonies	0	480	0	0	1120	0	0	0	0	0	0	0	640	0	0	0	0	0
Thalassiosira aculeata	0	0	0	960	640	0	640	0	0	0	0	0	1120	640	320	640	960	0
Thalassiosira ecentrica	0	0	0	0	0	960	0	0	0	0	0	0	0	1280	960	0	960	1440
Thalassiosira ferelineata	640	800	640	1120	0	800	0	0	0	0	0	480	640	0	1920	640	480	0
Thalassiosira punctigera	0	0	800	640	480	0	0	0	0	320	0	0	1120	800	0	0	2400	960
Thalassiosira sp.	800	960	1920	640	0	2560	0	0	**1120**	1120	800	960	0	0	1440	1120	1440	0
Triceratium broeckii	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0	0	0	0
Triceratium favus	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0	640	0
Triceratium sp	0	0	0	0	0	0	0	0	0	0	0	0	800	0	800	480	480	0
Trieres mobiliensis	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0	0	0
Unidentified	0	320	1440	160	0	1280	0	0	0	0	960	0	640	1120	640	0	0	0
Density of Phytoplankton (diff. sites wise.)(no/m^3)	**11040**	**8160**	**16640**	**13280**	**10080**	**16480**	**7840**	**6880**	**11040**	**9440**	**11200**	**9600**	**26080**	**16640**	**15680**	**11680**	**22240**	**18880**
Total= 1180640 no/m^3																		
Total No Of Genus/Species=**55**																		

Table 16. Diversity Indices of Phytoplankton at different sites at Deendayal Port

Variables	Offshore						Cargo jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-control	2A	2B	2C	2D	2E	2-contrl	3A	3B	3C	3D	3E	3-control
Taxa_S	14	12	18	17	13	17	9	9	11	14	15	13	24	20	19	16	28	20
Individuals (Nos/m^2)	11040	8160	16640	13280	10080	16480	7840	6880	11040	9440	11200	9600	26080	16640	15680	11680	22240	18880
Dominance_D	0.08	0.10	0.07	0.07	0.09	0.07	0.15	0.14	0.15	0.09	0.08	0.10	0.09	0.06	0.07	0.07	0.05	0.11
Shannon Diversity Index (H)	2.59	2.40	2.81	2.72	2.46	2.74	2.01	2.09	2.10	2.54	2.58	2.39	2.82	2.90	2.83	2.68	3.20	2.63
Simpson_1-D	0.92	0.90	0.93	0.93	0.91	0.93	0.85	0.86	0.85	0.91	0.92	0.90	0.91	0.94	0.93	0.93	0.95	0.89
Evenness_e^H/S	0.95	0.92	0.92	0.89	0.90	0.91	0.83	0.89	0.74	0.91	0.88	0.84	0.70	0.91	0.89	0.92	0.88	0.69
Menhinick	0.13	0.13	0.14	0.15	0.13	0.13	0.10	0.11	0.10	0.14	0.14	0.13	0.15	0.16	0.15	0.15	0.19	0.15
Margalef	1.40	1.22	1.75	1.69	1.30	1.65	0.89	0.91	1.07	1.42	1.50	1.31	2.26	1.96	1.86	1.60	2.70	1.93

Zooplankton

The study was conducted at 3 sites in Deendayal Port and nearby areas where dredging activities are going on. The three selected study stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

Bolivina sp (Foraminifera), Foraminifera (unidentified), Globigerina sp (Foraminifera), Mysida shrimp (Mysids), Sponge Spicules, Tintinnopsis tubulosa (Tintinnida), Zoea larva of Crab etc.were the mostly common zooplankton and throughout observed in all sites of Offshore area. Highest population density was recorded at site 1D-Offshore (44800 nos./100m^3)and lowest density in 1A-Offshore (21600 nos./100m^3) where number of species recorded lowest numbers (13 nos.). High biomass was observed in the site 1E-Offshore (46.51 ml/100m^3) and low biomass was in site 1A-Offshore (20ml/100m^3).The range of the population density, biomass and number of species were (21600 to 44800 nos./100m^3), (20 to 46.51 ml/100m^3) and (13 to 27 nos.) respectively in all sites. Less observed species are *Acartia sp (Calanoida), Bolivinita quadrilateral, Calcarina sp (Foraminifera), Copepoda eggs sac(egg pouch), Cyphonautes larva (Bryozoa) Globigerinita sp (Foraminifera), Rosalina sp (Foraminifera), Tintinnopsis radix (Tintinnida), Triloculina sp (Foraminifera),*

etc. rarely recorded in this station. Total 60 zooplankton was recorded in Offshore area adding that more composition of zooplankton by the Phylum Crustacea (Arthropoda), Tintinnids and Foraminifera (Protozoa) and Sponge Spicules (Porifera)

Cargo Jetty

The population density of zooplankton varied from 21920 nos./100m^3 to 46880 nos./100m^3. Maximum density was noticed in site 2control-Cargo Jetty (46880 nos./100m^3) and minimum was at site 2C-Cargo Jetty (21920 nos./100m^3). The Sites,2control and 2B -Cargo Jetty comprises highest number of species (24 nos.) and minimum number of species was observed in site 2A-Cargo Jetty (14 nos.). Biomass ranged between 11.22 to 46.51 ml/100m^3 where highest biomass noted in site2E-

Cargo Jetty and lowest in 2cont-Cargo Jetty. Frequently observed species were *Ammonia beccarii (Foraminifera), Calanoida (unidentified), Foraminifera (unidentified, Globigerina sp (Foraminifera), Ostracoda, Sponge Spicules, Veliger larvae of Bivalve, Zoea larva of Crab* etc. whereas less observed species were *Acartia ohtsukai, Bolivina sp (Foraminifera), Clausocalanus sp (Calanoida), Elphidium sp (Foraminifera), Jelly fish (Hydrozoa : Cnidaria), Polychaete larvae (Annelids), Spirillina sp (Foraminifera), Tintinnopsis tubulosa (Tintinnida).* etc. Total recorded zooplanktons were 49 in Cargo Jetty.

Phang Creek

This Creek area was represented by the zooplankton fauna majority of them were *Globigerina sp (Foraminifera), Leprotintinnus simplex (Tintinnida), Loxostomum sp (Foraminifera), Ostracoda, Sponge Spicules, Tintinnopsis sp (Tintinnida), Veliger larvae of Bivalve, Zoea larva of Crab, Mysida shrimp (Mysids) etc.*Very less time or rarely recorded species were *Acrocalanus sp (Calanoida), Ammonia beccarii (Foraminifera), Bulimina sp (Foraminifera), Cibicides sp (Foraminifera), Copepoda eggs sac(egg pouch), Discorbis sp (Foraminifera), Narcomedusae (Hydrozoa:Cnidaria), Rosalina bradyi, Tintinnopsis kofoidi (Tintinnida), Tintinnopsis parvula (Tintinnida), Tortanus sp (Calanoida)* etc. The range of zooplankton Biomass was between 23.33 to 86.42 ml/100m^3. Highest Biomass was recorded in site 3E-Phang creek (86.42 ml/100m^3) and lowest in site 3B-Phang creek (23.33 ml/100m^3). Maximum and Minimum species count was at in site 3C-Phang creek (31 nos.) and 3control (23 nos.) respectively. Population density was maximum recorded in site 3A-Phang creek (32960 nos./100m^3) and minimum in site 3control (19520 nos./100m^3).

Overall assessment of zooplankton showed that the total number of 96 Zooplankton recorded during summer season. Out of these (96) zooplankton, 60 zooplankton recorded in Offshore region, 49 zooplankton at Cargo Jetty and 69 zooplankton in Phang Creek region. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea), , Protozoa (mainly foraminifera and tintinnids), Porifera (sponge spicules). Crustacean zooplankton was the dominant due to the dominance of different larval stages which mainly feed on phytoplankton. Generally zooplankton population dynamics and studies emphasize is given up to group level rather than to species level because of microscopic size of zooplankton so owing to the difficulty in identifying the zooplankton as some species are considered as a group or genus level. The most dominant or frequently observed species(all 3 station) were *Calanoida (unidentified), Egg capsules of Littorinids, Foraminifera (unidentified), Globigerina sp (Foraminifera), Mysida shrimp (Mysids), Ostracoda, Sponge Spicules, Tintinnopsis sp (Tintinnida), Veliger larvae of Bivalve. Zoea larva of Crab,* etc. Foraminiferans belonging to the meroplankton were present at all three station Overall range of Population density, Biomass and Number of Species were (19520 to 46480 no/100 m^3), (11.22 to 86.42 ml/100m^3) and (13 to 31nos) respectively. Average high biomass noted at Phang Creek (53.78) followed by Offshore (32.71) than Cargo Jetty (25.10) (Table 17-19). Highest population density was recorded in site 2control-Offshore (46480No/100m^3) and lowest was recorded in site 1control-Offshore (19520 No/100m3). Among all recorded zooplankton, majority dominance occurrence was by the Copepoda, Crustacean larvae, Spong Spicules, Foraminifera (Protozoa), Tintinnids (Protozoa), Zoea larva of Crab, Mysida shrimp (Mysids).Egg capsules of Littorinids (Mollusca).Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda, Mollusca, Protozoa, Poriffera. The Chaetognatha, Tunicata and Cnidaria groups or phylum were only represented by the one species namely *Sagitta sp (arrow worm), Salpa sp, Small Jellyfish* respectively. Small fish and Fish larva, as small plankton, represented the Fish. Veliger larva of Bivalve and Gastropoda shells include in Phylum Mollusca. In Offshore**,** maximum Occurrence (%) was by the Zoea larva of the Crab (21.75%) and minimum by the Ammonia beccarii, *Eutintinnus apertus* and *Elphidium sp* (0.15%). In Cargo Jetty, maximum Percentage of Occurrence (%) by the Zoea larva of the Crab (47.50%) and minimum by *Spirillina sp* (foraminifera) and *Tintinnopsis beroidea* (0.08%).In Phang Creek maximum Occurrence (%) was by the Foraminifera (9.98%) and minimum (0.10%) by the *Corycaeus sp.*.

During microscopic sample analysis more number of species varieties of Foraminifera, Sponge spicules, Crustacean larva and Tintinnids were observed. These all three are very important for paleontological study aspects and also for evolutionary, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Some deep sea species also recorded that is indication of water circulation pattern. Data on zooplankton density, list of zooplankton is shown in Table (17-19).

Diversity Indices of Zooplankton

Table 20 shows diversity indices of zooplankton. The Shannon-wiener diversity index (H') fluctuated between 1.65 to 3.37 indicated moderate to quite high range of diversity added indication of healthy body of water with a maximum value in site 3C-Phang Creek (3.37) where highest species number count (31) and minimum value in site 2D-Cargo Jetty (1.65) where species number was 19 (nos.). Range of the evenness was 0.27 to 0.94 where lowest and highest recorded in site 2D-Cargo Jetty (0.27) and 3C-Phang Creek (0.94) respectively. Range of Simpson index was 0.58 to 0.96. The range value of Margalef indices was 1.20 to 3.02 that means high species number variations. (Table 20).

Table 17. Density of Zooplankton at Offshore site of Deendayal Port

Name of Genera/Group	1A	1B	1C	1D	1E	1 Control	Individual total density (no/100m^3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	0	0	0	640	0	0	640	0.30
Ammonia beccarii (Foraminifera)	0	0	0	0	320	0	320	0.15
Arcella sp (Amoebozoa)	640	0	0	480	0	0	1120	0.53
Bolivina sp (Foraminifera)	640	480	640	1600	0	0	3360	1.58
Bolivinita quadrilatera	0	0	0	0	0	960	960	0.45
Bolivinita sp (Foraminifera)	0	0	480	0	0	0	480	0.23
Calanoida (unidentified)	0	1120	800	320	800	1440	4480	2.11
Calcarina sp (Foraminifera)	0	0	0	480	0	0	480	0.23
Centropages sp (Calanoida)	0	480	0	0	0	0	480	0.23
Cibicides sp (Foraminifera)	0	0	0	0	0	640	640	0.30
Copepoda (Unidentified)	800	0	0	0	0	0	800	0.38
Copepoda eggs sac(egg pouch)	0	0	0	0	0	960	960	0.45
Corycaeus sp (Calanoida)	0	480	960	0	0	0	1440	0.68
Crustacea (unidentified)	0	960	0	0	0	0	960	0.45
Cyclopoida (unidentified)	0	0	800	640	0	0	1440	0.68
Cyphonautes larva (Bryozoa)	0	640	0	0	0	0	640	0.30
Cypris larva (Barnacle larva)	0	0	0	480	0	0	480	0.23
Egg capsules of Littorinids	0	0	800	320	0	0	1120	0.53
Elphidium sp Foraminifera)	0	0	0	320	0	0	320	0.15
Eponides sp (Foraminifera)	0	0	800	0	0	0	800	0.38
Eutintinnus apertus (Tintinnida)	0	0	0	0	0	320	320	0.15
Foraminifera (unidentified)	1600	2560	3520	10880	6080	5120	29760	14.00
Gastropoda shells	0	480	0	0	0	0	480	0.23
Gastrula larva of Sea star	0	640	0	1120	0	0	1760	0.83
Globigerina sp (Foraminifera)	1120	1920	800	2880	1120	0	7840	3.69
Globigerinita sp (Foraminifera)	0	0	1120	0	0	0	1120	0.53
Globigerinoides sp (Foraminifera)	0	640	0	0	0	1120	1760	0.83
Harpacticoida (unidentified)	0	0	0	320	0	480	800	0.38
Lagena sp (Foraminifera)	0	480	0	0	0	0	480	0.23
Larva (Unidentified)	0	0	0	1280	0	0	1280	0.60
Mysida shrimp (Mysids)	7200	10720	4320	5280	8320	2080	37920	17.83
Nauplius larvae of Barnacles	0	0	0	0	0	480	480	0.23
Nauplius larvae of Calanoida	0	0	0	0	0	480	480	0.23
Nauplius larvae of Copepoda	0	0	0	0	480	0	480	0.23
Nauplius larvae of	0	0	960	640	800	0	2400	1.13

Crustacea								
Oithona sp (Cyclopoida)	0	0	640	0	0	0	640	0.30
Ostracoda	0	0	0	1440	0	640	2080	0.98
Tintinnids (Unidentified)	0	1120	0	0	0	0	1120	0.53
Paracalanus sp (Calanoida)	640	0	640	0	0	0	1280	0.60
Parvocalanus sp (Calanoida)	0	0	640	0	0	0	640	0.30
Radiolarian skeletons	0	0	0	2400	800	0	3200	1.50
Rosalina sp (Foraminifera)	0	0	0	480	0	0	480	0.23
Sagitta sp (arrow worm)	960	0	0	0	0	640	1600	0.75
Spirillina sp (Foraminifera)	0	0	0	0	0	640	640	0.30
Spiroloculina sp. (Foraminifera)	0	0	480	0	0	0	480	0.23
Sponge Spicules	800	7520	2880	3680	1760	1600	18240	8.58
Subeucalanus (Calanoida)	640	0	0	0	0	0	640	0.30
Tintinnids (Unidentified)	0	0	2080	0	0	0	2080	0.98
Tintinnopsis beroidea (Tintinnida)	0	0	0	480	800	640	1920	0.90
Tintinnopsis cylindrica (Tintinnida)	640	1120	0	800	0	960	3520	1.66
Tintinnopsis karajacensis (Tintinnida)	0	0	0	0	480	0	480	0.23
Tintinnopsis parvula (Tintinnida)	0	0	0	480	320	0	800	0.38
Tintinnopsis radix (Tintinnida)	640	0	0	0	0	0	640	0.30
Tintinnopsis sp (Tintinnida)	0	0	0	2240	320	3040	5600	2.63
Tintinnopsis tubulosa (Tintinnida)	0	1120	0	1280	320	2400	5120	2.41
Tintinnopsis corniger (Tintinnida)	0	0	0	0	0	640	640	0.30
Triloculina sp (Foraminifera)	0	960	0	0	0	640	1600	0.75
Veliger larvae of Bivalve	0	800	0	1280	320	480	2880	1.35
Zoea larva of Crab	5280	9920	4320	2560	9920	14240	46240	21.75
Unidentified	0	0	0	0	0	800	800	0.38
Total No. Of Genera/Groups =60								
Site-wise Total Density (no/100m^3)	21600	44160	27680	44800	32960	41440	**Total Density =212640**	**100%**
Biomass (ml/100m^3)	**20**	**41.67**	**33.13**	**29.09**	**46.51**	**25.86**		

Table 18. Density of Zooplankton at Cargo Jetty site of Deendayal Port

Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Individual total density (no/100m^3))	% of Occurrence (Site-wise)
Acartia ohtsukai	0	480	0	0	0	0	480	0.23
Acartia sp (Calanoida)	0	640	0	960	320	1120	3040	1.44
Acrocalanus sp (Calanoida)	0	0	0	480	640	800	1920	0.91
Ammonia beccarii (Foraminifera)	0	480	0	640	320	480	1920	0.91
Bolivina sp (Foraminifera)	0	0	480	0	0	480	960	0.46
Calanoida (unidentified)	640	2720	960	1600	2080	800	8800	4.17
Calcarina sp (Foraminifera)	0	0	0	0	0	0	0	0.00
Canthocalanus sp (Calanoida)	960	800	0	0	0	0	1760	0.83
Centropages sp (Calanoida)	0	640	0	800	0	0	1440	0.68
Cibicides sp (Foraminifera)	0	1120	0	0	0	0	1120	0.53
Clausocalanus sp (Calanoida)	0	0	960	0	0	0	960	0.46
DiCyclops sp (Cyclopoida)	0	0	0	480	0	0	480	0.23
Egg capsules of Littorinids	2400	960	1600	1280	1440	1920	9600	4.55
Elphidium sp (Foraminifera)	0	320	0	0	0	0	320	0.15
Eutintinnus sp (Tintinnida)	0	0	0	640	0	0	640	0.30
Fish larva	0	640	800	0	960	1120	3520	1.67
Foraminifera (unidentified)	1920	4320	1120	1760	1120	3680	13920	6.60
Gastrula larva of Sea star	1120	1280	0	0	0	0	2400	1.14
Globigerina sp (Foraminifera)	800	800	1120	800	320	800	4640	2.20
Globigerinoides sp (Foraminifera)	0	0	0	0	480	160	640	0.30
Harpacticoida (unidentified)	0	0	0	0	0	160	160	0.08
Jelly fish (Hydrozoa : Cnidaria)	0	0	320	0	0	0	320	0.15
Larva (Unidentified)	0	640	0	0	0	0	640	0.30
Leprotintinnus pellucidus (Tintinnida)	0	0	1600	0	0	0	1600	0.76
Loxostomum sp (Foraminifera)	640	0	0	0	160	0	800	0.38
Microsetella sp (Harpacticoida)	0	0	0	0	640	0	640	0.30
Mysida shrimp (Mysids)	0	0	0	0	960	1760	2720	1.29
Nauplius larvae of Barnacles	0	0	0	0	480	320	800	0.38
Nauplius larvae of Crustacea	0	960	0	480	1120	1120	3680	1.75
Oithona sp (Cyclopoida)	0	0	0	640	0	0	640	0.30
Ostracoda	320	800	320	0	320	640	2400	1.14
Paracalanus sp (Calanoida)	0	0	0	480	0	960	1440	0.68
Parvocalanus sp	0	0	0	0	1280	640	1920	0.91

(Calanoida)								
Polychaete larvae (Annelids)	640	0	0	0	0	0	640	0.30
Radiolarian skeletons	320	1440	0	0	0	0	1760	0.83
Rosalina sp (Foraminifera)	0	480	160	0	0	320	960	0.46
Sagitta sp (arrow worm)	800	0	0	1120	0	0	1920	0.91
Salpa sp (Tunicata)	0	640	0	0	0	0	640	0.30
Spirillina sp (Foraminifera)	0	0	0	0	0	160	160	0.08
Sponge Spicules	4160	4160	1600	1280	2240	2400	15840	7.51
Subeucalanus (Calanoida)	0	0	0	0	800	0	800	0.38
Tintinnids (Unidentified)	0	0	0	0	0	960	960	0.46
Tintinnopsis beroidea (Tintinnida)	0	0	0	160	0	0	160	0.08
Tintinnopsis cylindrica (Tintinnida)	0	640	0	0	0	0	640	0.30
Tintinnopsis karajacensis (Tintinnida)	0	0	0	0	0	320	320	0.15
Tintinnopsis sp (Tintinnida)	0	1280	1760	1760	960	0	5760	2.73
Tintinnopsis tubulosa (Tintinnida)	0	320	0	0	0	0	320	0.15
Veliger larvae of Bivalve	1280	0	480	800	160	800	3520	1.67
Zoea larva of Crab	9920	640	8640	28800	27200	24960	100160	47.50
Total No. Of Genera/Groups =49								
Site-wise Total Density (no/100m^3)	**25920**	**27200**	**21920**	**44960**	**44000**	**46880**	**Total Density =210880**	**100%**
Biomass (ml/100m^3)	**28.74**	**30.61**	**17.86**	**15.63**	**46.51**	**11.22**		

Table 19. Density of Zooplankton at Phang Creek site of Deendayal Port

Name of Genera/Group	3A	3B	3C	3D	3E	3 Control	Total density (no/100m3)	% of Occurrence (Site-wise)
Acartia amboinensis	480	0	0	0	0	1120	1600	1.01
Acrocalanus sp (Calanoida)	0	320	0	0	0	0	320	0.20
Ammonia beccarii (Foraminifera)	0	0	0	320	0	0	320	0.20
Arcella sp (Amoebozoa)	0	0	0	0	320	0	320	0.20
Bolivina sp (Foraminifera)	480	0	0	320	0	480	1280	0.81
Bolivinita sp (Foraminifera)	640	0	0	0	0	0	640	0.40
Bulimina marginata	0	640	0	0	0	0	640	0.40
Bulimina sp (Foraminifera)	0	0	320	0	0	0	320	0.20
Calanoida (unidentified)	800	0	640	0	640	320	2400	1.51
Centropages sp (Calanoida)	0	0	640	0	640	640	1920	1.21
Cibicides sp (Foraminifera)	0	0	0	960	0	0	960	0.60
Clausocalanus sp (Calanoida)	480	640	800	0	0	0	1920	1.21
Copepoda (Unidentified)	0	800	640	0	0	0	1440	0.91
Copepoda eggs sac(egg pouch)	0	960	0	0	0	320	1280	0.81
Corycaeus sp (Calanoida)	0	0	0	160	0	0	160	0.10
Cyclops sp (Cyclopoida)	640	0	0	0	0	0	640	0.40
Discorbis sp (Foraminifera)	0	0	0	320	0	0	320	0.20
Egg capsules of Littorinids	320	0	800	1280	0	800	3200	2.02
Elphidium sp (Foraminifera)	320	0	0	0	0	0	320	0.20
Fish	0	0	480	640	320	0	1440	0.91
Foraminifera (unidentified)	3360	3360	1120	2240	4640	1120	15840	9.98
Gastrula larva of Sea star	0	0	0	0	320	0	320	0.20
Globigerina sp (Foraminifera)	960	800	320	1280	960	960	5280	3.33
Globigerinita sp (Foraminifera)	1120	0	800	0	1120	0	3040	1.92
Globigerinoides sp (Foraminifera)	0	800	0	0	0	0	800	0.50
Harpacticoida (unidentified)	0	0	0	0	160	320	480	0.30
Lagena sp (Foraminifera)	0	480	0	0	0	0	480	0.30
Larva (Unidentified)	0	0	640	0	0	0	640	0.40
Leprotintinnus pellucidus (Tintinnida)	0	960	640	0	640	960	3200	2.02
Leprotintinnus simplex (Tintinnida)	800	640	480	640	800	800	4160	2.62
Leprotintinnus sp (Tintinnida)	640	0	800	2880	0	0	4320	2.72
Loxostomum sp (Foraminifera)	0	0	640	800	960	960	3360	2.12
Mysida shrimp (Mysids)	0	0	0	1920	5920	2720	10560	6.65
Narcomedusae (Hydrozoa:Cnidaria)	0	0	0	320	480	0	800	0.50
Nauplius larva of Cyclopoida	0	0	0	0	320	0	320	0.20
Nauplius larvae of Barnacles	0	800	960	0	640	0	2400	1.51

Nauplius larvae of Calanoida	0	0	0	960	0	0	960	0.60
Nauplius larvae of Copepoda	1120	0	640	0	0	0	1760	1.11
Nauplius larvae of Crustacea	0	640	0	640	0	480	1760	1.11
Nonion sp (Foraminifera)	480	320	640	0	0	0	1440	0.91
Oithona sp (Cyclopoida)	0	480	480	480	0	0	1440	0.91
Ophthalmidium sp (Foramonifera)	0	0	0	0	320	0	320	0.20
Ostracoda	1920	800	800	640	800	320	5280	3.33
Crustacea (Unidentified)	0	0	640	0	0	0	640	0.40
Parvocalanus sp (Calanoida)	0	480	0	640	320	0	1440	0.91
Radiolarian skeletons	0	0	0	640	800	0	1440	0.91
Rosalina bradyi	0	0	0	480	0	0	480	0.30
Rosalina sp (Foraminifera)	0	0	480	0	0	800	1280	0.81
Rotaliida (Foraminifera)	0	0	0	0	320	0	320	0.20
Rotifera	0	0	640	0	0	0	640	0.40
Sagitta sp (arrow worm)	0	0	0	0	480	0	480	0.30
Spirillina sp (Foraminifera)	640	320	0	0	0	0	960	0.60
Spiroloculina sp. (Foraminifera)	960	640	320	0	640	0	2560	1.61
Sponge Spicules	2400	2720	1120	1440	3040	1760	12480	7.86
Subeucalanus sp (Calanoida)	0	320	0	0	0	0	320	0.20
Textularia sp (Foraminifera)	0	800	0	0	0	0	800	0.50
Tintinnids (Unidentified)	800	0	0	0	0	0	800	0.50
Tintinnids radix (Tintinnida)	0	0	0	0	0	640	640	0.40
Tintinnopsis beroidea (Tintinnida)	960	640	0	0	0	0	1600	1.01
Tintinnopsis cylindrica (Tintinnida)	0	1120	0	800	0	0	1920	1.21
Tintinnopsis estuariensis (Tintinnida)	800	960	640	640	0	1120	4160	2.62
Tintinnopsis kofoidi (Tintinnida)	0	0	640	0	0	0	640	0.40
Tintinnopsis parvula (Tintinnida)	800	0	0	0	0	640	1440	0.91
Tintinnopsis sp (Tintinnida)	1920	1600	480	1120	0	0	5120	3.23
Tintinnopsis tubulosa (Tintinnida)	1920	1440	800	1120	2080	480	7840	4.94
Tintinnopsis minuta (Tintinnida)	0	0	320	0	0	0	320	0.20
Tortanus sp (Calanoida)	800	0	0	0	0	0	800	0.50
Veliger larvae of Bivalve	640	800	0	1120	480	960	4000	2.52
Zoea larva of Crab	5760	1760	1440	1120	4320	800	15200	9.58
Total No. Of Genera/Groups =69								
Site-wise Total Density (no/100m^3)	**32960**	**27040**	**20800**	**25920**	**32480**	**19520**	**Total density =158720**	**100%**
Biomass (ml/100m^3)	**55**	**23.33**	**51.28**	**47.14**	**86.42**	**59.52**		

Table 20. Diversity indices of Zooplankton at different sites of Deendayal Port

	Offshore						Cargo jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	13	20	19	27	16	24	14	24	15	19	21	24	28	29	31	28	27	23
Individuals (nos. /m^2)	21600	44160	27680	44800	32960	41440	25920	27200	21920	44960	44000	46880	32960	27040	20800	25920	32480	19520
Dominance_D	0.19	0.15	0.09	0.10	0.20	0.15	0.20	0.08	0.19	0.42	0.39	0.30	0.07	0.05	0.04	0.05	0.09	0.06
Shannon Diversity Index(H)	2.07	2.32	2.64	2.76	2.00	2.51	2.08	2.87	2.17	1.65	1.72	2.02	3.03	3.16	3.37	3.14	2.77	2.98
Simpson_1-D	0.81	0.85	0.91	0.90	0.80	0.85	0.80	0.92	0.81	0.58	0.61	0.70	0.93	0.95	0.96	0.95	0.91	0.94
Evenness	0.61	0.51	0.73	0.59	0.46	0.51	0.57	0.73	0.58	0.27	0.27	0.31	0.74	0.82	0.94	0.83	0.59	0.86
Menhinick	0.09	0.10	0.11	0.13	0.09	0.12	0.09	0.15	0.10	0.09	0.10	0.11	0.15	0.18	0.21	0.17	0.15	0.16
Margalef	1.20	1.78	1.76	2.43	1.44	2.16	1.28	2.25	1.40	1.68	1.87	2.14	2.60	2.74	3.02	2.66	2.50	2.23

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Annexure -H

YEAR WISE ACTUAL WORK COSTING OF CSR WORKS APPROVED BY BOARD

1) CSR Works executed during the year 2011 – 2012 and year 2012 – 2014. (Upto Dec'21)

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	(a).Road from Dr. Baba Saheb Ambedkar Circle to N.H. 8-A (Via Ganesh Nagar).	Rs.482.65 Lakhs
	(b)Road from S.T. Bus Stand (N.H. 8 – A) to Sunderpuri Cross Road Via Collector Road.	
	(C)Road from N.H. 8 –A Railway Crossing to Maninagar (Along Rly Track).	
	(d)Road from Khanna Market Road (Collector Road) to Green Palace Hotel.	
2.	Construction of Internal Roads at "Shri Ram" Harijan Co-op. Housing Society Ltd. (Nr. Kidana).	
3.	(a)Construction of Cremation Ground and kabrastan with other facilities at Vadinar.	Rs 19.44 (Lakhs)
4.	(b)Providing Cement Concrete internal roads in village Vadinar Stage –I.	Rs 16.16 (Lakhs)
	(a)Approach Road provided for developing the Tourism at village Veera near Harsidhi Mata Temple where lot of tourists & Pilgrims visit.	Rs. 4.65 (Lakhs)
	(b)Water Tank along with R.O. provided near by developing Tourism area.	Rs. 30,000 (Thousand)
	(c)Creating facility of flooring and steps surrounding the lake to stop the soil erosion and attract the tourists, at Village Veera.	Rs. 4.80 (Lakhs)
	Total Rs	**528 Lakhs**

2)CSR Works for the year 2014-2015.

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	Construction of Community Hall-cum school at Maheshwari Nagar, G'dham	Rs 51.90 Lacs
2.	Renovation of "Muktidham" at Kandla	Rs 10.65 Lacs
3.	Sunderpuri-1 valmiki community hall	Rs 5.00 Lacs
	Sunderpuri-2 valmiki community hall	Rs 5.00 Lacs
	Ganeshnagar Community Hall	Rs 10.00 Lacs
	JagjivanMaheshwari community hall	Rs 10.00 Lacs
	Various works of Road of Sapanagar	Rs 99.19 Lac
4.	Construction of compound wall in the Dam of Jogninar village	Rs 14.48 lacs
5.	In addition above 30 Lakhs as committed in Public Hearing meeting held on 18/12/2013 an amount Rs 30 Lakhs shall also be contributed for the CSR works to be carry out at villages Tuna, Vandi , Rampar, Veera etc.	Rs 30.00 Lacs
	Total Rs.	**Rs 236.22 Lacs**

3)CSR Works for the year 2015-2016.

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	Construction of toilets for Girls / Ladies at Khari Rohar village	**Rs. 3.00 Lakhs**
2.	Construction of Toilets for Girls manatMathak Primary School, Mathak Village	**Rs. 3.00 Lakhs**
	Total	**Rs.6.00 Lakhs**

4)CSR Works for the year 2016-2017.

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	RCC Community Hall at Harshidhi Mata Temple, Veera village, AnjarTaluka	Rs.19.00 Lakhs
2.	Fabricated Community Hall at Sanghad village, AnjarTaluka	Rs.21.00 Lakhs
3.	CSR Works for Shri MaheshwariMeghvadSamaj, Gandhidham at Grave Yard , Behind Redison Hotel.	Rs.8.00 Lakhs
4.	CSR works for ShirDhanrajMatiyadevMuktiDham, Sector-14 , Rotary Nagar, Gandhidham	Rs. 30.50 Lakhs
5.	CSR works for NirvasitHarijan Co-operative Housing Society, Gandhidham.(Health Cum Education Centre)	Rs. 41.00 Lakhs
6.	CSR works for Shri Rotary Nagar Primary school, Gandhidham.	Rs. 2.80 Lakhs
7.	CSR works at NU -4 , NU-10(B) Sapnanagar& Saktinagar, Golden Jublee Park, at Gandhidham	Rs. 18.00 Lakhs
	Total	**Rs 140.30 Lakhs**

5)CSR Works for the year 2017-2018.

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR works at Shri Ganesh Nagar Govt High School, Gandhidham	38.30
2.	Grant Financial contribution for facility of Army cantonment for 50 air coolers at Kutch Border Area.	15.00
3.	CSR works at Tuna & Vandi villages (providing drainage lines under Swachh Bharat Abhiyan)	39.80
4.	CSR works for S.H.N Academy English School (Managed by Indian Institute of Sindhology –Bharati Sindhu Vidyapeeth), Adipur	40.00
5.	Construction of Internal Road at Bhaktinagar Society, Kidana	
	Total	**148.10**

6) CSR Works for the year 2018-19

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	CSR work to Donate 100 Nos of Computers to Daughters of Martyred Soldiers in the country under the "BETI BACHAO BETI PADHAO" program by Atharva Foundation, Mumbai	Rs 24.00 Lakhs
2.	CSR work to Donate ONE (40 Seater) School Bus for Deaf Children Students for the Institute of Mata Lachmi Rotary Society, Adipur	Rs 18.00 Lakhs
3.	CSR work to Providing One R.O Plant with Cooler at Panchyat Prathmik Sala, Galpadar Village for the ANARDE Foundation, Kandla & Gandhidham Center.	Rs 1.50 Lakhs
4.	CSR work for Providing Drainage Line at Meghpar Borichi village, Anjar Taluka	Rs 25.00 Lakhs
5.	CSR work for Construction of Health Centre at Kidana Village	Rs 13.00 Lakhs
6.	CSR work to provide 4 Nos. of Big Dust Bin for Mithi Rohar Juth Gram Panchayat	Rs 3.40 Lakhs
7.	CSR work for Renovation & construction of shed at Charan Samaj, Gandhidham –Adipur.	Rs 10.00 Lakhs
8.	CSR Work for Renovation/Repairing of Ceiling of School Building at A. P Vidhyalay, Kandla	Rs 10.00 Lakhs
9.	CSR work for Construction of Over Head Tank & Providing 10 Nos of Computers (for students) of Navjivan Viklang Sevashray, Bhachau, Kutch	Rs 9.50 Lakhs
10.	CSR work to Provide Books & Tuition fees for Educational facilities to weaker section children of ValmikiSamaj, Kutch	Rs 2.00 lakhs
11.	CSR work to provide Water Purifier & Cooler for the ST. Joseph's Hospital, Gandhidham	Rs 1.50 Lakhs
12.	CSR work for Construction of Second Floor (Phase – I) for Training Centre of "GarbhSanskran Kendra" "Samarth Bharat Abhiyan" of Kutch KalyanSangh, Gandhidham	Rs 37.00 Lakhs
	Total cost	**Rs 154.90 Lakhs**

7) CSR Works for the year 2019-20

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR activities for Providing Drainage line at Nani Nagalpar village.	3.00
2.	CSR activities for Development of ANGANWADI Building at School no- 12 at Ward no 3 & 6 at Anjar.	7.00
3.	CSR activities for Improving the facilities of Garden at Sapna Nagar(NU-4) & (NU-10 B),Gandhidham.	18.00
4.	CSR activities for development of School premises of Shri Guru Nanak Edu. Society, Gim.	30.00
5.	CSR activities for the improvement of the facilities at St JOSEPH Hospital &Shantisadan at Gandhidham	20.00
6.	Consideration of Expenditure for running of St Ann's High School at Vadinar of last five years 2014 to 2019 under CSR.	825.00
7.	CSR activities for development of school premises of Shri Adipur Group Kanya Sala no-1 at Adipur	6.50
8.	CSR activities for development of school premises of ShriJagjivan Nagar PanchyatPrathmiksala, Gandhidham	16.50
9.	CSR activities for development of school premises of Ganeshnagar Government high school, Gandhidham	9.00
10.	CSR activities for improving greenery, increase carbon sequestration and beat Pollution at Kandla, DPA reg.	352.32
11.	CSR activities for providing infrastructures facilities at "Bhiratna Sarmas Kanya Chhatralaya" under the Trust of SamajNav- Nirman at Mirjapur highway, Ta Bhuj.	46.50
	Total cost	**1333.82**

8) CSR Works for the year 2020-21

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR Proposal for earmarking of 15% Funds for National Marintime Heritage Complex, Lothal, Gujarat (NMHC) from allocated CSR Fund of Rs 3.46 Cr	51.90
	Total	**51.90**

9) CSR Works for the year 2021-22

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR Activities for providing Water supply pipe line for drinking water facilities for poor people & Fishermen at VANDI Village.	20
2.	CSR activities for providing facilities in Girls Hostel of Kasturba Gandhi Balika Vidhyalay, Gandhidham. Cost for Construction of compound wall, entrance gate, girls toilets)	30
3.	CSR works for Construction of Auditorium Hall at RSETI (Rural Self Employment Training Institute) at Bhujodi-Bhuj.	16
4.	CSR works for the providing of SOLAR POWER SYSTEM and other facilities for 0the JEEV SEVA SAMITI at Gandhidham.	9.3
5.	CSR Activities for providing HD projector for KANYA MAHA VIDYALAYA, Adipur	1.5
6.	CSR works for Construction of New Building for Setting up of skill development centre at Rajkot (Sewa Gujarat).	250
7.	CSR Works for Ladies Environment Action Foundation (LEAF) Trust for providing infrastructure to the primary school at Gandhinagar District	46.5
8.	CSR works lor Providing of Furniture for the School "Shri Galpadar Panchayat Prathmic Kumar group Sala" at Galpadar village,Taluka:Gim	5
	Total Cost	**378.3**

10) CSR Works for the year 2022-23

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR work for providing One Bore hole with construction one room along with Motor pump at Village MOTI NAGALPAR, Anjar.	18
2.	CSR work for Construction of Shamashan bhoomi (Crematorium) at Gandhidham.	49.5
3.	CSR work for providing metallic sheet DOME in Community Hall at Old Sunderpuri for Shri Juni Sundarpuri Maheshwari Samaj at Gandhidham.	15
4.	CSR Activities for construction of Samajwadi at village: Rampar,Taluka:Anjar.	15
5.	Financial assistance under CSR for providing basic facilities at Gandhidham GSRTC bus station.	25
6.	CSR Activities for construction of School Building for physically disabled, deaf & mute children, Shri & Shrimati Chhaganlal Shyamjibhai Virani Behera Munga Shala Trust, Virani Deaf School at Rajkot.	5
7.	CSR work for construction of new Administrative staff block for the Maitri Maha Vidhyalaya, Adipur.	64.65
8.	Financial support under CSR for providing 60 seater school bus for "Aadhaar Sankul", Manav Seva Trust,Gandhidham.	25
9.	CSR work for extension of Night shelter cum old age home for “DADA BHAGWANDAS ADVANI TRUST” Adipur.	78
10.	Financial assistance under CSR for Rooftop Solar System & Afforestation under clean energy & sustainable development in 10 villages around DPA	63.72
	Total Cost	**358.87**

11) CSR Works for the year 2023-24

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	CSR works for Shree Kachchh Mahila Kalyan Kendra, Bhuj-Kutch	55
2.	CSR Activities for Installation of 125 no. Sanitary Pad Vending Machines at Women Hostels,NGOs etc, in Kutch District	15
3.	CSR Fund for Vadinar Village & surrounding	128.54
4.	CSR Activities for Girls Hostel at Kasturba Gandhi Balika Vidhyalaya At Shinay, Taluka:Gim.	33.25
5.	CSR request for Allotment of fund for construction of Community hall at Adipur for Maheshwari Meghval Samaj.	25
6.	CSR Request for requirement of funds for renovation work in Sector-7, Gandhidham (Aryasamaj Gandhidham)	30
7.	CSR Request for providing"Antim Yatra Bus" & Mortuary Cabinet Morgue" for Adipur-Gandhidham from CSR Funds,	25
8.	CSR Request for creation of a Children park at Gandhidham Military Station, Gandhidham	15
9.	CSR Request for construction of Toilet block units for Girls & Boys NAV JIVAN VIKLANG SEVA SHREY Bhachau	3.04
10.	CSR Request for laying Synthetic Athletic track in Galpadar and to Provide One E-Kart facility for Conveyance of youths at BSF Campus, Gandhidham	75
11.	CSR request for submitted by AAS, Indore for solid waste Management at Gandhidham & Kandla.	49.93
12.	CSR request from Trikamsaheb Manav Seva Trust at Madhapar Near Bhuj for grant for Construction of Community Hall, Compound Wall etc.	40
13.	CSR Request for construction of Dome shaped shed at Rampar Village Prathmik Shala,Rampar	24
14.	CSR Fund for development of School premises of Shri Guru Nanak Education	4.5
15.	CSR Request for conducting Awareness campaigns on T.B. Prevention & treatment, Mumbai	60
16.	CSR Request for fund under CSR for Railway Institute, Gandhidham, Western	5
17.	CSR Proposal project for Sanitary Pad Making Machine for School Girls, Anjar	12.39
	Total Cost	**600.65**