

Draft Final Report

Ecological, Hydrological and Socio-economic impact studies for the Kalpasar Dam project, Gulf of Khambhat, Gujarat



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Ecological, Hydrological and Socio-economic Impact Studies for the Kalpasar Dam Project, Gulf of Khambhat, Gujarat

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Executive Summary

Gujarat, the western most state of India situated within the arid and semi-arid landscape with only 2.63% of the country's total freshwater resources. The ambitious Kalpasar Project envisaged to create a freshwater reservoir in part of the Gulf of Khambhat and designed to stock the runoffs of west flowing rivers like Sabarmati, Mahi, Dhadar, etc. This scenario will gradually change the existing marine system to brackish water and to the envisioned freshwater ecosystem, which subsequently will influence the existing biodiversity and socio-economics of the Gulf and its surrounding areas.

With the above view, the proposed study intended to look into the Biodiversity of the Gulf of Khambhat, spatially within the project influence area and also assess the probable shift of species as the ecosystem changes. The study also assessed the changes in the geohydrology of the area as well as the socio-economic effects due to the micro- and macro ecological changes in the landscape.

This report provides a comprehensive information on the existing biodiversity of the Kalpasar Project Influenced area with the compilation of both secondary information collected through literature review and the primary data collected from the field during the period between November, 2021 to June 2022.

The study area extends over 6348 km², of which 2856 km² represent the marine habitat and 3490 km² area in terrestrial habitat. To assess the biodiversity in the Terrestrial zone 5 X 5km (25 km²) grids were prepared using ArcGIS software. A land use land cover map also prepared to identify different land use classes within the study area. Standard methodology was adopted and followed during the study for various aspects. The checklist of the threatened species of the area was prepared and the species under IUCN Red List of Threatened species and various Schedules of Indian Wildlife (Protection) Act, 1972 were classified.

The primary data collected through the survey is analysed to estimate the species diversity in the project area using PAST software. For modelling purpose PAST and R software was used and SIMPER analysis was done to assess the change in species composition and identify species that will be affected as the ecosystem changes.

The study area is spread over five districts, viz. Ahmedabad, Vadodara, Anand, Bhavnagar, and Bharuch which encompasses a total of 480 villages under ten different talukas. Socio-economic impact survey was conducted using Stakeholder's Discussion, 12 separate Focus Group Discussions and Questionnaire Survey (355 Participants) in the 37 fishing villages and at 3 fish landing centres.

The secondary information through the review of all the existing literature generated a list of 777 faunal species (Chapter 2) with 222 recorded species of Ichthyofauna and 145 Arthropodes, followed by 95 avifauna and 47 mammal species from the study area.

The survey in the Project area recorded 188 aquatic and 156 terrestrial faunal species along with 191 floral species (Chapter 3). The phytoplankton diversity and density differed between marine, estuarine and fresh water habitats. Bacillariophyceae members dominated in the marine samples, whereas Cyanophyceae and Chlorophyceae members dominated in the riverine samples. The estuarine samples were characterised with the dominance of *Synedra* and *Coscinodiscus* spp. The zooplankton diversity was represented by five major groups viz., Protozoa, Calanoida, Harpacticoida, Cyclopoida and Decapoda.

Among the 51 fish species recorded in the study area, 32 species belong to marine, 10 species represent estuarine, and 19 species are freshwater. There were 15 species of Elasmobranchs which includes eight rays, six sharks and one saw fish. Among rays, two are critically endangered viz., *Maculabatis bineeshi* (short-tail whipray) and *Maculabatis arabica* (Arabic whip ray); three species are endangered and six are vulnerable as per the IUCN Red data list. Among the marine species, *Macrobrachium rosenbergii* (giant freshwater prawn), Crabs and marine shrimps, *Octopus*, *Ulva lactuca* are the commercially important species. Bombay duck (*Harpodon nehereus*), and mudskippers form the important fishery of the study area. *Sousa plumbea* (Humpback Dolphin) is the only marine mammals recorded from the study area and is categorised as endangered species. It moves in the deep waters of the Gulf area sometimes sighted near shore. *Ulva lactuca* is the only seaweed recorded in the intertidal region.

Mugger, *Crocodylus palustris*, recorded in the freshwater system is a vulnerable species and is listed in Schedule-I of Indian Wildlife (Protection) Act 1972 (IWPA 1972). There are about 27 high conservation priority species according to the IUCN red list of Threatened species and Indian Wildlife (Protection) Act 1972.

A total of 149 avifaunal species was recorded during the study period. Since the region falls within the Central Asian Flyway (Western Migratory Route), about 17% of the recorded species are long distance migrant species including Common Pochard, Demoiselle Crane, Eurasian Wigeon, Greylag Goose and Northern Shoveler. Based on IWPA, (1972), there are 11 avifauna species falls under the Schedule -I category with high degree of protection and conservation.

The Gulf of Khambhat supports about 12% of the mangrove cover of the Gujarat state. All the mangrove sites were dominated by *A. marina* species, with less representation of *Rhizophora* sp. and *Ceriops* sp. Associated halophytes species include *Suaeda maritima*, *Sesuvium portulacastrum*, *Salvadora persica*. In the present study, no tree class mangrove was observed and overall average density of *A. marina* is higher in the West Khambhat area (55,836 individuals/ ha) compared to other sites. The East Khambhat area showed comparatively low overall average density (31,433 individuals / ha) and the Sabarmati area showed the lowest density (8,542 individuals / ha).

A total of 191 plant species were recorded from the study area, spread in five different habitats viz., coastal area, riverine, coastal wetlands, scrubland and agriculture. None of the species recorded in the present study fall under IUCN Red list data.

The transition of the ecosystem from Marine to Brackish water and then to freshwater will take considerable time depending on the rainfall and subsequent rate of inflow of riverine water and associated factors. The probable shift of species and species which will be vulnerable or having risk of extinction is also assessed (Chapter 4).

In case of phytoplankton marine species likely to disappear include *Amphora*, *Bacillaria*, *Biddulphia*, *Ceratium*, *Cyclotella*, *Dictylum*, *Lauderia*, *Eucampia*, *Leptocylindricus*, *Odontella*, *Planktoniella*, *Pleurosigma*, *Triceratium*. The species like *Chlorella*, *Chlamydomonas*, *Ceratoceros*, *Coscinodiscus*, *Grammatophora*, *Navicula*, *Pediastrum*, *Peridinium*, *Rhizosolenia*, *Synedra*, *Ulothrix* are the opportunistic species and will proliferate in the enclosure system as part of the brackish water system. Fresh water species like *Anabaena*, *Aphanocapsa*, *Chlamydomonas*, *Eudorina* sp, *Spirogyra*, *Spirulina*, *Scenedesmus*, *Microcystis* will dominate the areas wherever there is presence of fresh water.

In case of zooplankton, *Paracalanus*, *Lucifer*, *Eucalanus*, *Euphausia*, *Labidocera*, *Tornaria* larvae will totally wiped out when the ecosystem shift from marine to fresh water

ecosystem. In the initial phase as the system turns brackish *Nauplius* larvae and *Calanopia* will proliferate and will continue to increase in fresh water system as well. They will form as important diet to fishes thus play a major role through the food chain.

In case of benthos, *Neries*, *Glaucanome angulata* and *Laternula anatine* will be dominating. The other species like Nematoda, Amphipod, *Dotilla* sp, *Donax* sp, *Tellina* sp, and *Indosphenia* sp (Bivalave) present purely in the estuarine water will also proliferate. In the freshwater system there are 15 species reported and these are exclusive for the habitat of fresh water with low salinity below 1 ppt and these species will remain restricted in the riverine stretch.

Lower invertebrates include the species representing sponges, worms, shelled animals and others. In the proposed Kalpasar dam the marine species belonging to arthropod (9) and molluscs (19) will gradually disappear from the area including the octopus. When the system is brackish in nature the species under Cnidaria (*Diadumene lineate*; *Stephenson actisornata*), Annelids- (*Neries* 3 spp), Ribbon worms (*Cerebratulus* sp.) Arthropod (9 species.), Molluscs (15 species) will be benefitted. *Macrobrachium rosenbergii* (Giant fresh water prawn) has high commercial value and will occupy the new areas with fresh water availability.

In case of fishes, 22 marine fishes recorded in the primary survey will disappear from the area. However, species like *Boleophthalmus dussumieri*, *Scylla olivacea*, *Scylla serrata* found dominantly in the estuarine system will get benefitted for some period of time till the brackish water environment is available. About 19 species are reported in the fresh water system and species like *Puntius sophor* and *Salmostoma bacaila* will dominate in due course of time.

In the reptiles, there is a possibility of increase in the population of mugger and terrestrial snake is expected due to change in land use pattern and increase in green cover in the newly exposed mudflats.

In case of avifauna species like Lesser Sand plover, Black Tailed Godwit, Gull billed Tern, Western Reef Heron, Pallas's Gull Dunlin are likely to disappear. The species in the fresh water wetland and the coastal water wetlands will be benefitted and include Gull billed Tern Western Reef Heron, Barn Swallow, Painted Stork, Lesser Sand plover, Eurasian Coot, Greater Flamingo, Gray lag Goose, Eurasian Wigeon, Barn Swallow and Bar Headed Goose and Northern Shoveler.

The only marine mammal present is *Sousa plumbea*, the Indian Ocean humpback dolphin which is sighted in both the estuarine and marine waters may sustain in the downstream areas.

In the coastal fringes with high salinity area will be covered by species such as *Calotropis procera*, *Tamarix aphylla*, *Capparis decidua*, etc. The reduction in salinity due to ecosystem changes along the coastal belt supports the establishment and invasion of *Prosopis juliflora* as well as the other vegetation including native grasses. This will have a positive effect on the population of certain faunal species (Jackal, Wild Boar, Lesser Cats and Wolf) by providing suitable habitats. On the negative side, the invasion of *Prosopis* will change the grassland biodiversity and will also impacts on other productive lands. Thus, necessitates an appropriate management plan for the *Prosopis* I the project area. Further, spreading of *Prosopis* is also possible along the riverine areas of Mahi, Dadhar and Sabarmati, etc.

The species of mangroves will probably disappear as the salinity regimes will change. It is estimated that approximately 36 km² area will be vulnerable and expected to be abolished in upstream of this project. Along with this, 10.68 km² mangrove area in the downstream will also be affected during the construction and operational phase. *A. marina* will be replaced by other less salt tolerant mangrove and its associated species. The ecological succession of wetland ecosystem will be taken place in the terrestrial ecosystem in which various terrestrial plants such as neem, babul and other native as well as water loving plant species will flourish gradually.

Fishery statistics show that there are 191 fish landing centres in the study area and Vadodara is the only district within the study area with no marine landing centres. The total fishermen population which includes the marine (24,617) as well as inland (57,823) population of these five districts sums up to 82,440. The total number of active fisher families is high in Bharuch district, followed by Ahmedabad district (Chapter 5).

The total number of *Pagadia* fishermen recorded was 1467, in the year 2019-20. Anand district was reported to have the highest number of *Pagadia* fishermen (484) followed by Bharuch (410), Bhavnagar (325), Ahmedabad (192) and Vadodara (55) districts.

The socio-economic survey was conducted in 37 villages of the four districts; Bharuch, Anand, Ahmadabad and Bhavnagar with a total population of around 2,17,796. There are a total of 2201 fishermen engaged in fishing from the marine and estuarine zones within

the Gulf of Khambhat of which the number of traditional fishermen (*Pagadia*) using non-mechanized fishing gear or hand picking are predominant (1551).

Based on the data generated, the average monthly income of the fishermen estimated was Rs. 9,064 (based on the involvement of approximately 20 days/month in fishing) in the surveyed villages. While, the average monthly per capita income of India is Rs. 10974/-. Thus, the fishermen earn less compared to the average monthly income of India and need to be considered as families under Below Poverty Level (BPL). The marine aquaculture farms earn around Rs. 25000/pond/month when the production is in full swing after seeding.

The salt pans in the area of Gandhar, Paniyadra, Jambusar and Khambat will be affected. However, the leases of these salt pans are not renewed after 2012 in these areas. The overall salt production has decreased for districts like Anand and Bhavnagar from 2014-15 to 2018-19.

Benefits to fisheries post dam construction will depend on the time taken between construction and operation. During the initial phase of the construction of the dike at the Gulf segment will be transforming to a brackish water status which is suitable for adoption of culture of euryhaline food fishes like seabass, milk fish, pearl spot and mullets etc. This less saline water can be beneficial for initiating the culture of shrimps, prawns and bivalve molluscs in the cages.

The geo-hydrological study envisaged that due to the impounding of the freshwater in the reservoir major changes will take place in the land use and there will be a possibility of three season agriculture (Chapter 6). The proposed reservoir will stop the supra tidal water ingress in many areas of Dhandhuka, Khambhat, Padra and Hansot blocks, and present saline soil will gradually turn into non saline soil.

The study also envisaged the long term monitoring of the biodiversity and mangrove ecosystem during the construction and operational phase of the project to assess the species change and its effect on the diversity of the project impact area (Chapter 7). Different studies on various aspects of the change detection assessment and regular monitoring of biodiversity and the socio-economy of the affected Talukas are also suggested.

1. INTRODUCTION

1.1. Conceptualization of the Project

Gujarat state is located in the western region of India with about 2.63% of the country's total freshwater resources and 4.86% of the country's population. The water crisis of the state has several important and critical dimensions; starting from wide gap between demand and supply of freshwater, competing claims over limited resources and inequitable access to freshwater resources (<https://www.gidb.org/>; Dinesh, 2003). The Gulf of Khambhat is embraced by the Gujarat mainland and Eastern coast of Saurashtra peninsula of the state. The runoff from Sabarmati, Mahi, Dhadar and Narmada flows to Gulf of Khambhat with a yearly volume of over 30,000 Mm³ of waters (GoG 1998). In Saurashtra region per capita water availability is only 540 M³/annum against the minimum annual requirement of 1700 m³/annual minimum requirement. Only 1.5 million ha of the total 4.2 million ha agricultural land is under irrigation facilities within the Saurashtra region. A reconnaissance report was prepared in the year 1988-1989, based on the available literature, and the technical viability of the construction of a multipurpose dam/dike with the closure of the Gulf of Khambhat. The dike will have the capacity to store about 10000 Mm³ of freshwater and will be used to mitigate the severe shortage of drinking and irrigation requirements in Gujarat, especially in the Saurashtra region.

The proposed project on the development of a coastal reservoir at the eastern part of the Gulf of Khambhat below the confluence of the rivers viz., Viswamitri-Dhadhar and Sabarmati, mainly intended to store fresh water. The coastal area of the Gulf of Khambhat shares its area with four districts of the state of Gujarat namely, Bhavnagar, Ahmedabad, Anand, and Bharuch (Figure 1).

The major benefits of the upcoming coastal reservoir are providing freshwater for agriculture, livestock and domestic consumption, industries and recharge the groundwater levels, which are under the immense pressure from over-exploitation. Previous studies have highlighted the fact that there is enough water available in the river channels considered for impoundment, however there is absence of storage structures resulting in loss of fresh water into the Gulf. The coastal reservoir would enable the storage of excess river flood waters (Sitharam, 2016).

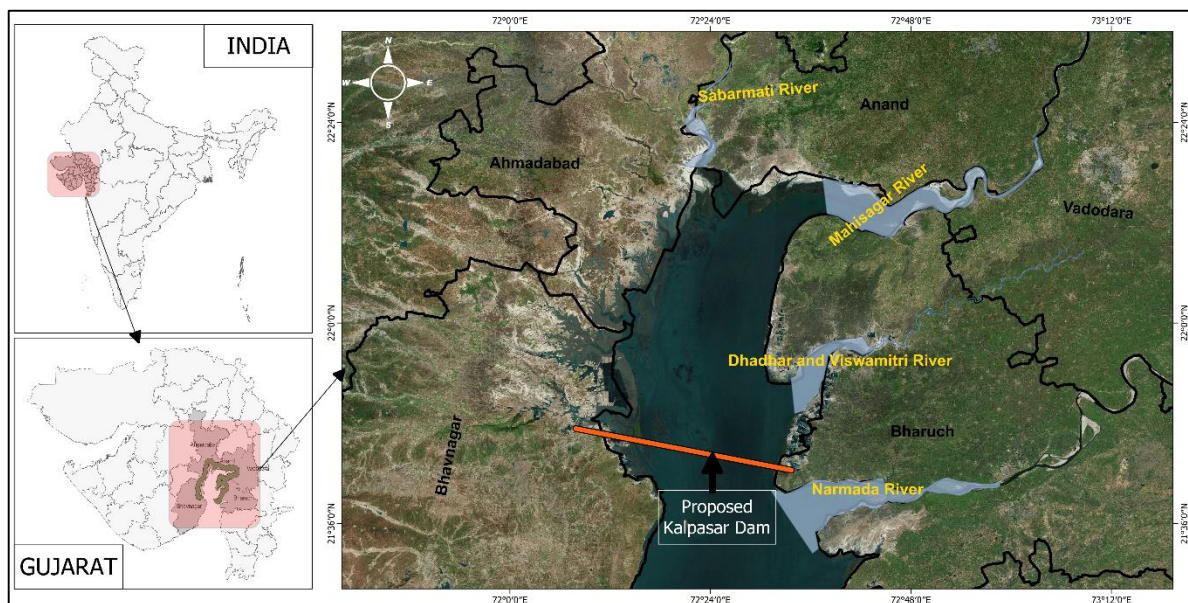


Figure 1; Kalpsar Project Area in the Gulf of Khambhat region of Gujarat, India

The benefits envisaged from the Kalpsar Project

- Irrigation and Drinking water for the Saurashtra and Central Gujarat Region.
- More than 1.054 million ha agricultural area within 39 Talukas of 6 districts of Saurashtra region will get irrigation benefits.
- More than 60 existing dams will get permanent water storage along with expected rejuvenation of water.
- Bhavnagar Port will get revived along with the other site-specific development.
- Travel distance will be reduced by 200 km between Bhavnagar to Surat-Mumbai.
- The saline groundwater of the coastal area of Saurashtra & Central Gujarat will get converted into freshwater with a reduction in soil salinity.
- Substantial improvement in groundwater quality as well as soil salinity of the coastal area regions of Saurashtra & Central Gujarat.
- About 0.2 million ha land along the periphery of the reservoir will be opened up for development towards value-based land utilization.
- The enhanced benefit of world-class industrial estates like Dahej and Dholera will be available to Bhavnagar/Saurashtra region.

2. Rationale of this Study

Development of any reservoirs, Ports and harbours, and dams involves an effective management plan towards environmental well-being that guarantees both sustainable growth and a healthy ecosystem functioning around its vicinity. There is a need for innovative solutions for any developmental activity in harmony with the ecosystem. The change in the ecosystem over the temporal scale, due to the influence of natural phenomena viz. climatic shift, change in landscape features, etc., and anthropogenic pressure, the change in biological community and species shift is commonly observed. Insights from the above concept, the ambitious project envisaged a marine water ecosystem to be converted into a freshwater ecosystem, projected over a period of few decades in the Gulf of Khambhat region. In the context of the inherent salinity of the aquatic system of Gulf of Khambhat, , there are three major ecosystems viz., marine, brackish water/estuarine and freshwater persisting in the Gulf.

Along with these major ecosystems, multiple macro and micro-ecosystem and habitats are also present in the areas which are classified under coastal ecosystem (intertidal mudflats, swamp forests, salt marsh, creeks, etc.) and terrestrial ecosystem (coastal sand dune, grassland, scrubland, small islands, sandy beaches, riverbank, etc.). These admixtures of ecosystems and habitats support thousands of species adapted and distributed with different diversity ranges and community compositions in spatial and temporal gradients. Hence, understanding the status of biodiversity in each of the ecosystems is a pre-requisite to generate baseline status of the ecology and biodiversity of the project area and its influence area. Thus, the study was proposed to generate baseline status of biodiversity in the project area, assessing the probable shift in species diversity due to ecosystem changes, socio-economic impact assessment with respect to change in biodiversity and fisheries, and assessment of the groundwater regime of the area in view of the change in the aquatic ecosystem of the project influence areas.

3. Objectives

Following are the objectives of the study:

- I. Species diversity in the Gulf of Khambhat especially around the project influence area (PIA).
- II. Probable Shift in species diversity as the environment changes from saline, brackish and freshwater.
- III. Socio-economic impacts due to change in Biodiversity especially with respect to Fisheries and dependent communities with special reference to *Pahadiyas*.
- IV. Ground water status and Technology for ground water quick recharge as the environment changes from saline, brackish and freshwater.

This report gives detailed comprehensive information on the biodiversity of the Kalpsar Project Influenced area. Web based search engines such as Google, Google scholar, Harzing's Publish and Perish were searched extensively to establish a preliminary reference database on both the floral and faunal biodiversity of the area. The first chapter of this report briefs about the conceptualization of the project, the rationale of the project, the study area description and the methodology adopted to generate information on biodiversity status.

The baseline primary data for the environmental conditions in the Project Influenced Area (PIA)/ (Kalpsar Dam project) are established based on reconnaissance survey and field survey investigation. And largely this is to understand the ecological setup, identification of various ecosystems and habitats, and fix sample size and location for sampling each taxonomic group. The scope of the present investigation includes analysis of different biological components of the proposed Kalpsar project environment, such as marine, estuarine, and freshwater environmental biodiversity monitoring strategies. The detailed survey for collection of primary and secondary information was conducted from November 2021 to June 2022.

4. Study Area

The study area falls within the Gulf of Khambhat extending from 21°61' and 22°51' N latitude and 72°03' and 73°07' E longitude. The area is well-known for its industrialization as many large industries are established, especially in the east coast part of the gulf *i.e.*, Dahej. The ancient port of Ghogha in Bhavnagar district is located on the west coast of the Gulf.

To study the impact of the proposed dam on the downstream, Bharuch district was considered. Therefore, the study area is situated in five districts, *viz.* Ahmedabad, Vadodara, Anand, Bhavnagar, and Bharuch with a total of 480 villages under ten different talukas. The study area is divided into a core zone, *i.e.*, marine (~2856 km²) and its 10 km buffer area (3490 km²) covers approximately 6436 km² in the Gulf of Khambhat (GoK hereafter) region, of Gujarat and spread about 75 km in width and 95 km in length. The Sabarmati, Mahi and Dhadhar-Vishwamitri are the major rivers flowing through the area. These rivers form large estuaries before the confluence to the Arabian Sea. Each river carries loads of suspended sediments into the sea. The area comprises of a variety of ecosystem habitats, like intertidal mudflats, creeks, estuaries, mangroves, etc., provide a home to a lot of faunal diversity, including marine species (crabs, shrimps, barnacles, lobsters, prawns, molluscs, sea snakes, green sea turtle humpback dolphin, etc.), as well as estuarine, freshwater and terrestrial species (vipers, crocodile, turtles, , pelican, flamingo, stork, curlew, godwit, smooth coated otter, wolf, jungle cat, blackbuck, etc.).

4.1. Physiography and Climate

The study area falls within the semi-arid landscape and receives rainfall through southwest monsoon between June to September. The area receives 700 mm of rain annually, with east Khambhat experiencing relatively more rainfall (800 mm) than the west Khambhat region (600 mm) (Ramanathan *et al.*, 2002). The relative humidity ranged between 65-86% and the area henceforth falls under the sub-humid climate zone. The temperature varies from 8°C (lowest) during the month of January to the 43°C (highest) during the month of May.

In marine areas, the water depth range varies from 18 m to 27 m. However, in most places, the depth is up to 20 m. The gulf is unique due to presence of funnel shaped which results in highest tidal amplitude in the Country (Sengupta & Deshmukhe 2000). Due to

its unique geographic location (near to tropic of cancer), this area experiences the highest tides than other areas along the Indian coast. The region shows variation in the mean tidal height across its span, with about 4.5 m at Mahuva port and 10 m at Bhavnagar port. During spring, the tidal elevation reaches its maximum (12.5 m), which is reported as the second highest in the world.

4.2. Demography and Socio-economic Structures

There are about 480 villages within the five districts of the study area. Khambhat and Borsad Taluka of Anand district is having 86 and 82 villages respectively followed by the Bharuch district (146 villages). The Jambusar, Vagra and Amod taluka of the Bharuch district having 98, 35 and 13 villages respectively, within the study area. Ahmedabad, Vadodara and Bhavnagar districts have 43, 64 and 59 villages. The Dhandhuka, and Dholka talukas of Ahmedabad district have 24 and 19 villages within the project area respectively. Most of the villages of the Bhavnagar district are situated within the Bhavnagar taluka, except the two villages that are situated within Valabhipur Taluka. The villages of Vadodara district were located within Padra Taluka.

Fishery is one of the main occupation for the livelihood of the local coastal community (Vishwanathan, 2016). Out of the total 146 villages within the study area, there are 50 fishing villages (GOI, 2012). Of these, the highest number of villages (26) in the Bhavnagar district, whereas 23 in Bharuch and the rest 1 in Anand.

The fisherman population is estimated to be about 22,316 under 4345 families. A total of 5,989 persons were involved in the fishing activities, with about 4636 persons pursuing this activity full-time, while for the rest (1353 persons), it forms a part-time activity. There are 15 fishing landing centres in the area with eight centres in Bhavnagar district, six in Bharuch and one in Anand district.

5. Methodology

To achieve the objectives of the project a road map for proper implementation of the deliverables was prepared. The schematic diagram shows the various activities carried out during the project (Figure 2). In the initial phase, an inception workshop was organized to plan out the activities and data collection. A reconnaissance survey was conducted in the study area based on the grids prepared and sample size and sample

locations were fixed based on approachability and characteristic features of the ecosystem.

Intensive survey was carried out from December 2021 to May 2022 to collect primary data from the study area. The socio-economic survey was also done in the 37 villages and fish collection data was collected from three fish landing centres. The collected data was collated and analysis was done to understand trends in species assemblage. Further the data was analysed to get different diversity indices and to assess the difference in species assemblage in marine, brackish water and freshwater habitats.

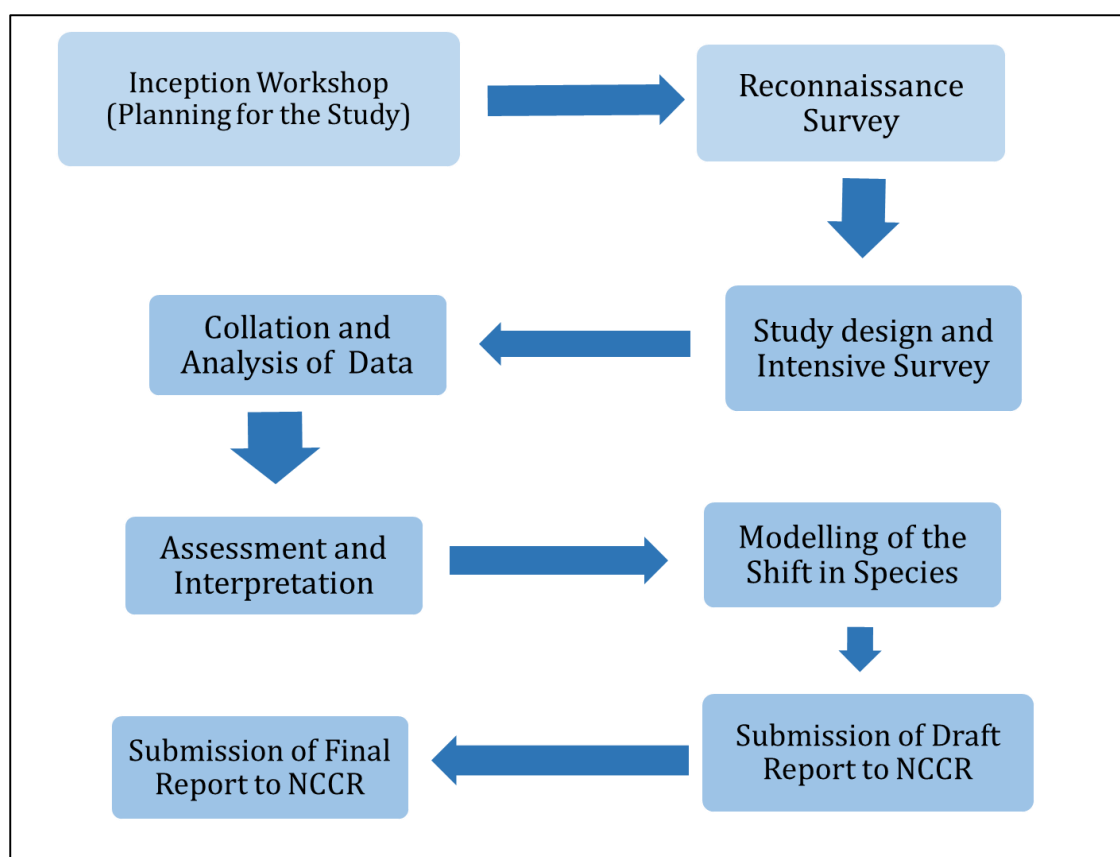


Figure 2: Flow Diagram of Methodology Applied to Achieve the Deliverables

5.1. Grid based survey and Identification of sampling locations

The study area extends over 6348 km², of which 2856 km² represent the marine habitat and 3490 km² area in terrestrial habitat. To assess the biodiversity in the Terrestrial zone 5km X 5km (25 km²) grids were prepared using ArcGIS software (Figure 3). Out of the 218 grids 88 grids (~40%) were selected for sampling (Figure 3). A land use land cover map also prepared to identify different land use classes within the study area (Figure 4).

Based on the habitat type four land use classes were defined and the grids were selected from each habitat types (Table 1).

Table 1: Distribution of sampling grids within each habitat type

S. No	Habitat Type	No of Grids
1	Coastal Wetlands	21
2	Freshwater Wetlands	09
3	Thorn scrub forest	28
4	Agriculture land	29

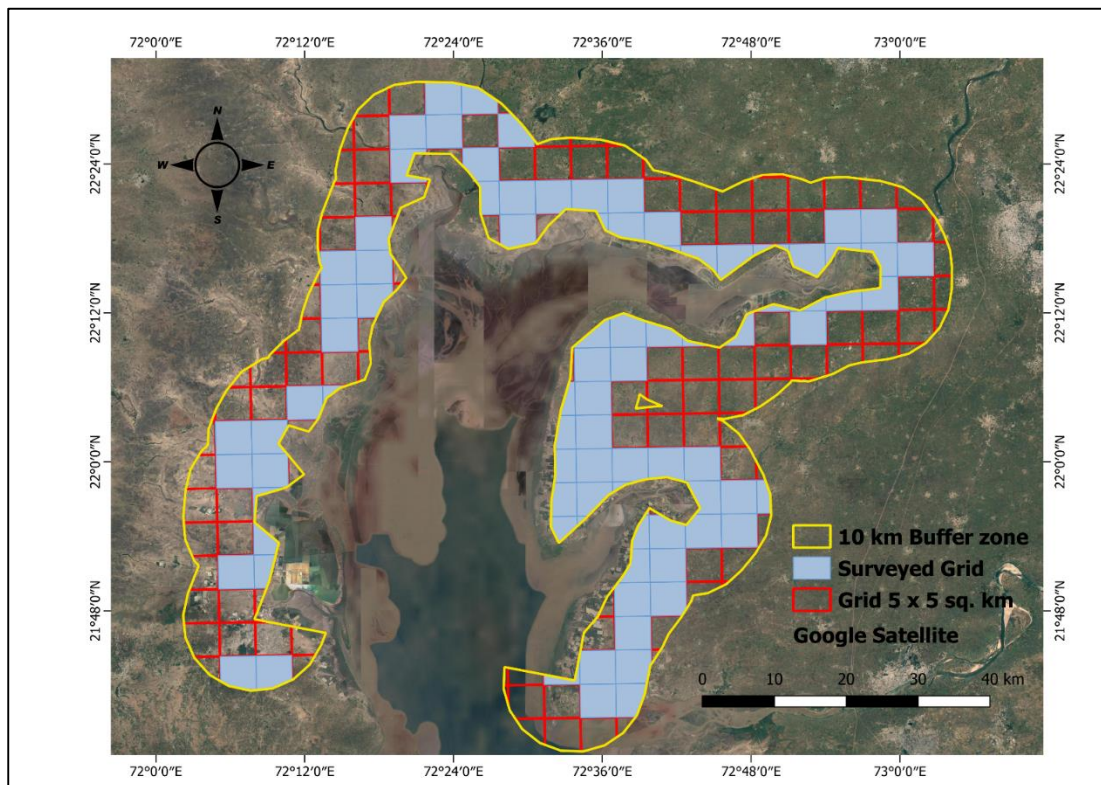


Figure 3: Sampling grids (25 km²) in the study area with the surveyed grids

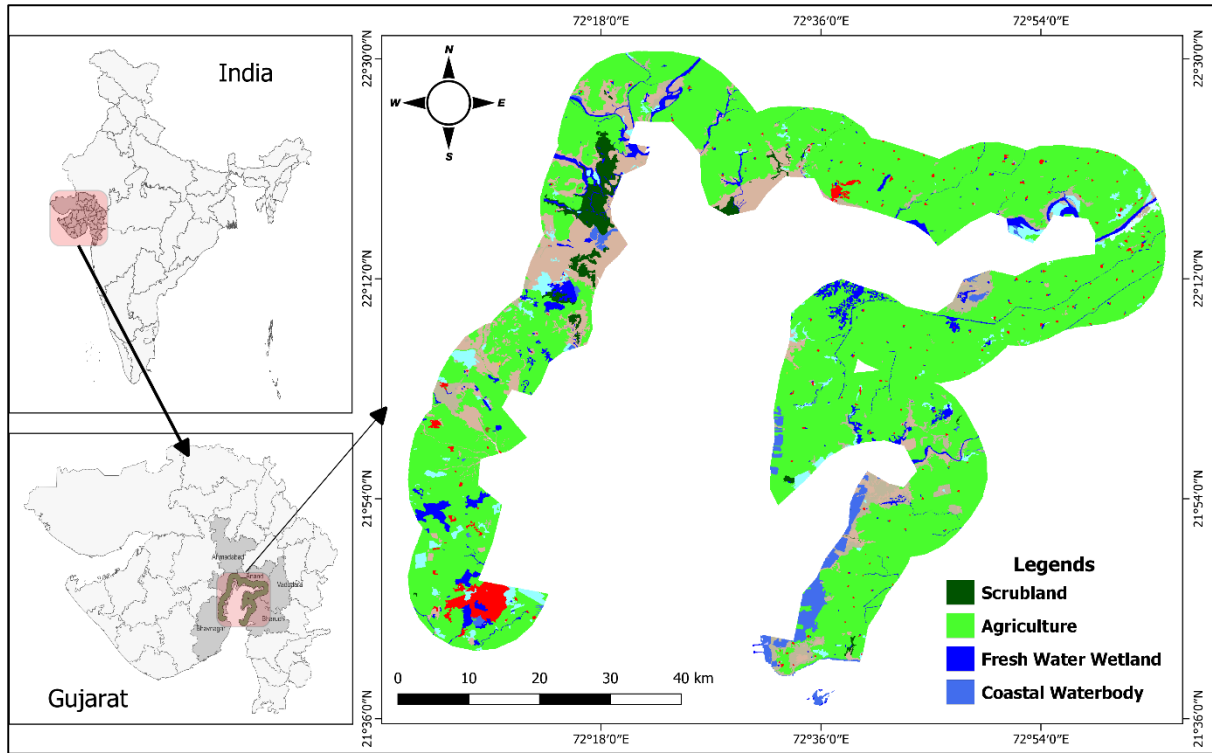


Figure 4: The major land use land cover class of the study area

The marine survey was done in 60 sampling location distributed in four gradients *viz.* freshwater (10), estuarine (17), intertidal and Gulf (33). The freshwater sampling locations were within the Sabarmati, Mahi and Dhadhar - Vishwamitri river along with nine tributaries (Figure 5a, 5b, 5c).

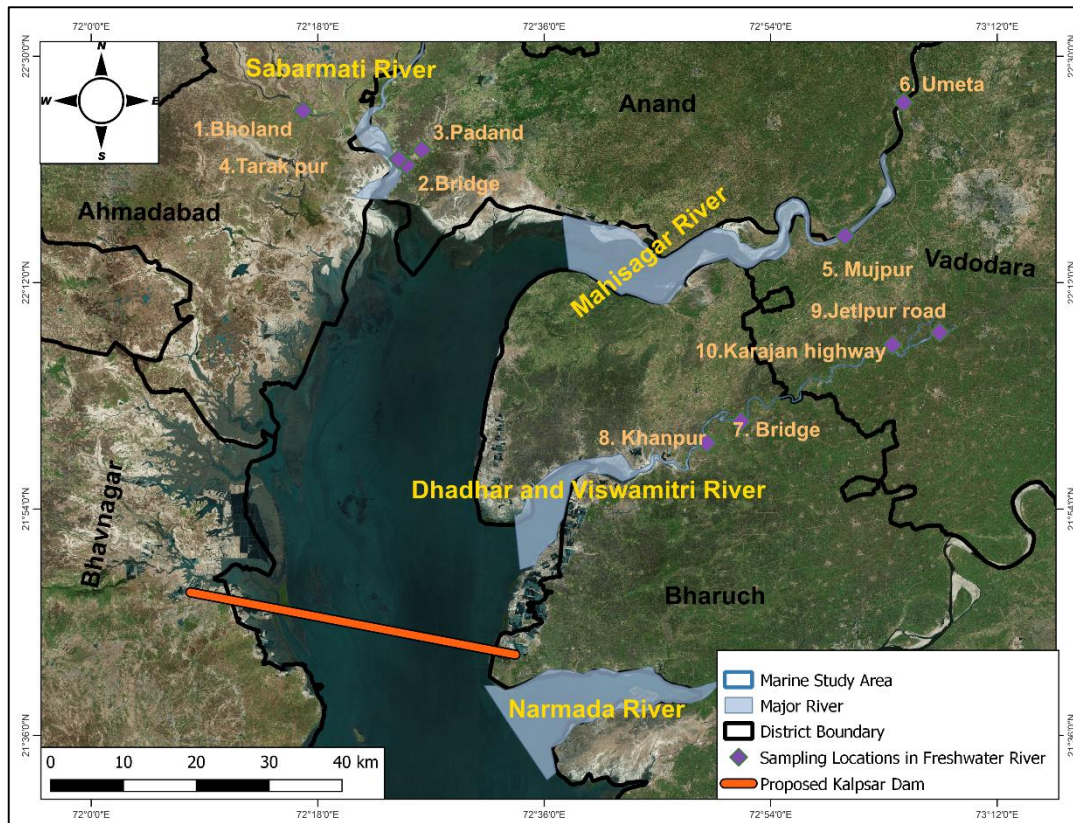


Figure 5a: Sampling locations for aquatic fauna in Freshwater habitat

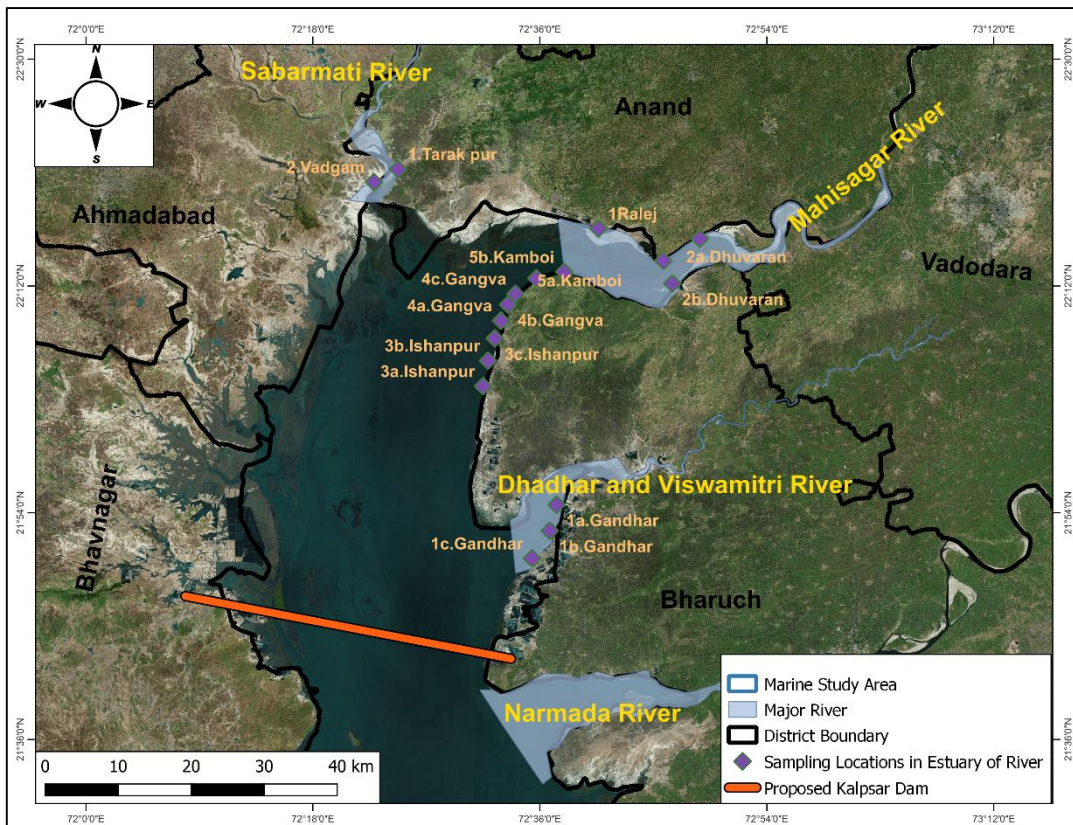


Figure 5b: Sampling locations for aquatic fauna in Estuarine habitat

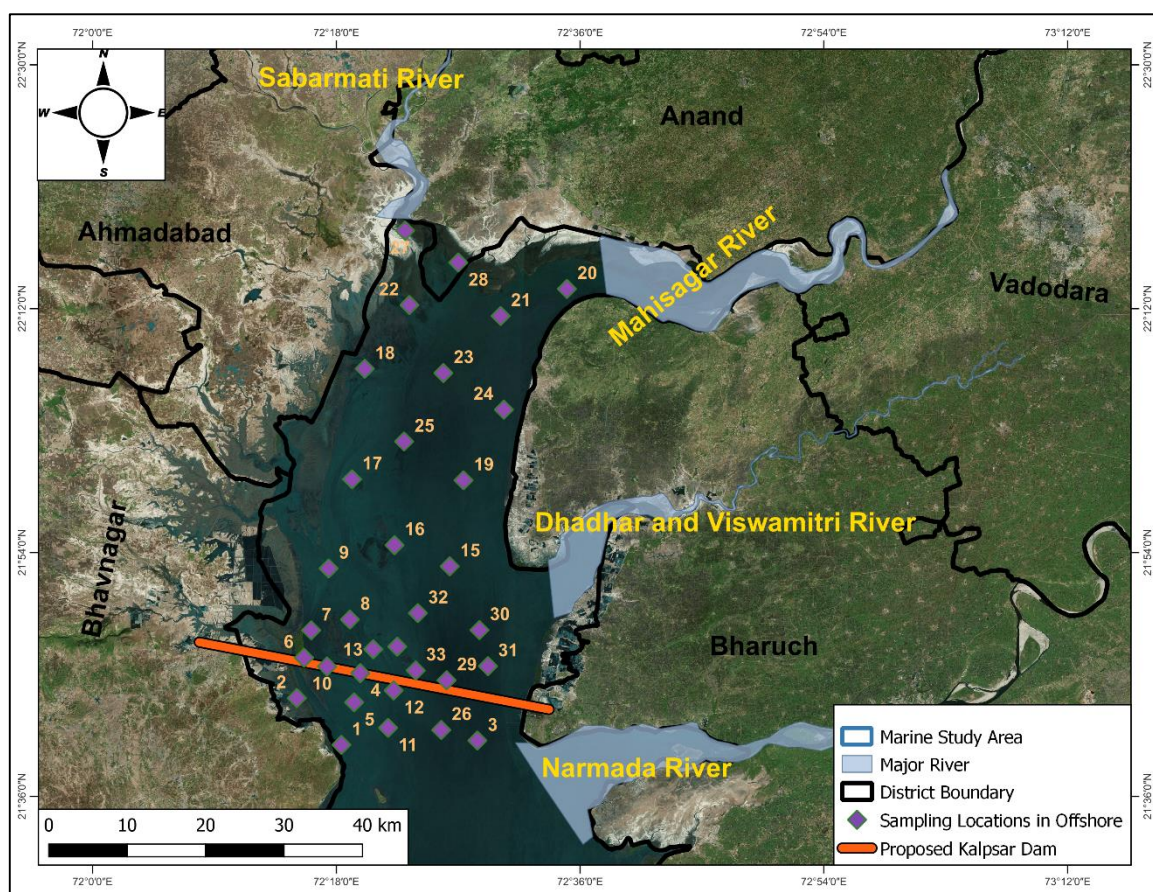


Figure 5c: Sampling locations for aquatic fauna in Offshore/Marine habitat

For the assessment of intertidal fauna in the marine and estuarine environment faunal sampling was done within a 1X1 m quadrat over different tidal levels. Three to six replicates were randomly assessed for the variability in macro-faunal population structure and the density was averaged for the entire intertidal belt. A detail description on the marine faunal sampling as well as mangrove sampling is depicted in table 2.

Table 2: Details of the sampling methods and laboratory analysis for marine fauna and mangrove vegetation

Floral and Faunal Group	Methodology (Survey and Sampling)	Laboratory Analysis
Benthos	Sediment grab samples collected and sieved through 0.5 mm mesh. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution.	Sorting, enumeration, and identification.

Intertidal macrofauna	Quadrates of 1 m x 1 m randomly laid. All visible macro faunal organisms encountered inside the quadrates were recorded.	Sorting, enumeration, and identification.
Plankton	Standard Plankton Net Mesh size:50 µm, Standard Zooplankton Net Mesh size:100 µm, 5% neutralized formaldehyde and Lugol's iodine solution	Sorting, enumeration, and identification. Sedgewick-Rafter counting chamber cells of the counting chambers phyto (1/1000) and Zoo (1/100).
Mangrove	Grids with a sample size of 5x5 km ² . For trees, quadrates of 10 x 10 m ² were laid. quadrates of 1m×1m and 2m×2m were laid randomly to enumerate regeneration and recruitment classes, respectively.	-
Fish	Online database for fishery statistics. Repositories of marine and freshwater fauna, landing Centres and fish collected from fishermen's gill nets. Interaction with fishermen, district fisheries officials, Central and state agencies.	Identification of fish using appropriate manuals

5.2. Detailed methodology for aquatic fauna

All benthic samples were collected through the Van Veen grab sampling (Ravinesh and Bijukumar 2022; Patterson *et al.* 2022), from the marine water and properly preserved from 5% formaldehyde and rose Bengal solutions. In Mangroves and Intertidal areas, macro-invertebrates and vertebrate samples were collected during the low tide. At each site along the transects three to six quadrates replicates of 1X1 m² were placed randomly, and all visible macro-faunal organisms encountered inside the quadrates were identified, counted and recorded (Davidson *et al.*, 2004; Ravinesh and Biju Kumar, 2013). The density of the different faunal groups was averaged for the entire intertidal belt. Organisms, which could not be identified in the field, were preserved in 5% formaldehyde, brought to the laboratory and identified using standard identification keys (Abott, 1954; Vine, 1986; Oliver, 1992; Rao, 2003; 2017; Psomadakis *et al.*, 2015; Apte, 2012; 2014; Naderloo 2017; Ravinesh *et al.* 2021; Edward *et al.*, 2022). Opportunistic sampling of different species such as fishes, crustaceans, sea snakes and octopods were

collected using stack net, fish nets used by Pagadiya, gill net operations and also from local landings. Identification of different invertebrate groups like Porifera (Hooper *et al.*, 2002); Scyphozoa (Jarms and Morandini, 2019), Mollusca (Apte, 2012; 2014; 2017; Subba Rao, 2003; 2017; Bosch *et al.*, 1996; Oliver, 1996), Crustacea (Naderloo, 2018), Echinoderms (James and Pears, 1971), and Polychaeta (Rouse and Pleijel, 2001) were carried out following the peer reviewed standard protocols.

List of fish fauna found in the coastal area, ponds and lakes was prepared by field survey, surveying local fish market (if fish market available nearby the study area), and conducting interviews with the local fisherman (if fishing activity takes place) and fish catch and landing centres around the project areas.

In mangroves, muddy areas and mudflats, the faunal diversity was calculated following the 1X1m² quadrature method and the number of animals encountered per quadrature. Numbered grid map was prepared for every 5 km interval, and a total of eight sampling sites were selected in the mangrove's intertidal areas/habitats. At each sampling site, ten quadrates are selected at every 10 m interval. All the identification were based on the manuals, research papers and field guides (Apte, 2012; 2014; Bosch *et al.*, 1996; Chhapgar, 2008; Jayaram, 2010; Naderloo, 2018; Oliver, 1996; Subba Rao, 2003, 2017).

5.3. Detailed methodology for Terrestrial Flora and Fauna

The entire terrestrial system of 10 km around the proposed Kalpasar project area was divided into 5X5 km grid and a total of 218 grids were marked (Figure 3). District wise grids was high in Bharuch district (75) followed by Anand (54). Out of the total grids seven grids were present in the estuarine area denoted as Marine (Figure 3). The number of grids in each district within the project area (including the buffer zone) is given in figure 6.

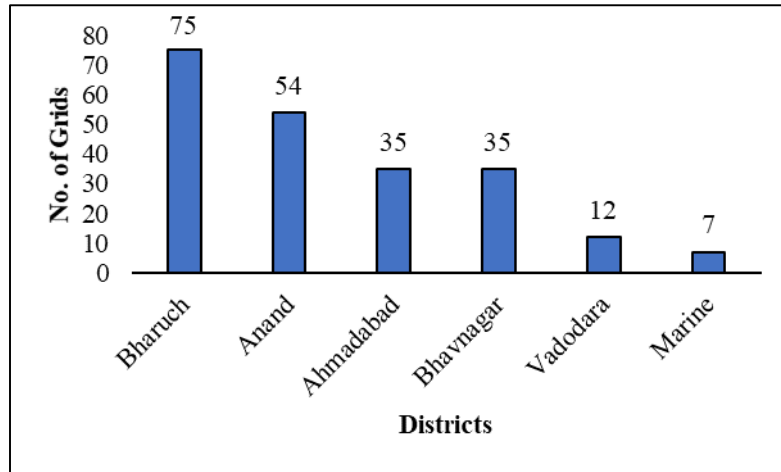


Figure 6: District wise grids (25 km²) distribution in the study area

A total of 10 talukas were present in the study area and Jambusar taluka (49) had the highest grid followed by Bhavnagar (35) and Khambhat (34) (Fig 7).

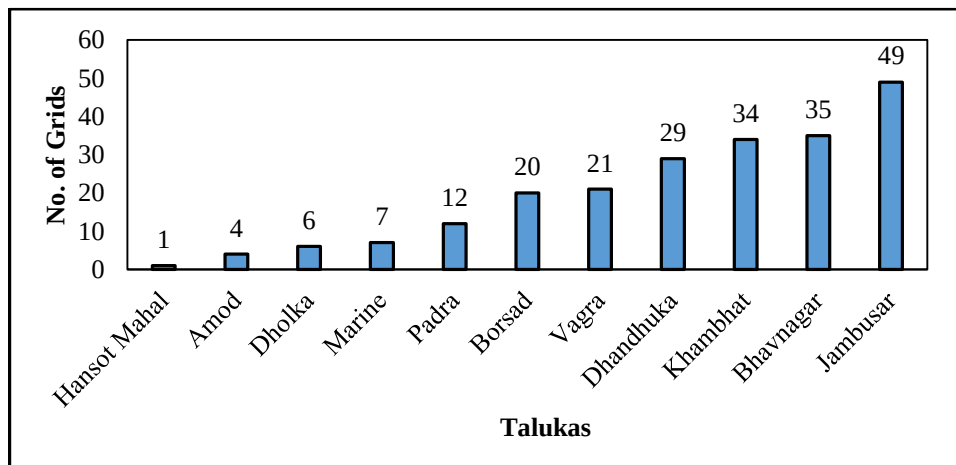


Figure 7: Taluka wise sampling grids distribution in the study area

Avifauna: For avifaunal studies a total of 87 samples grids were considered representing four distinct habitats viz., scrub forest, freshwater wetland, coastal wetland, and agricultural land (Figure 3). The district wise distribution of sampling grids in different landforms are presented in figure 8. The highest number of grids within the thorn shrub forest and agricultural area were surveyed in Bharuch district, whereas highest number of grids with coastal and freshwater wetlands were sampled in Bharuch, Anand, and Ahmedabad (Figure 8).

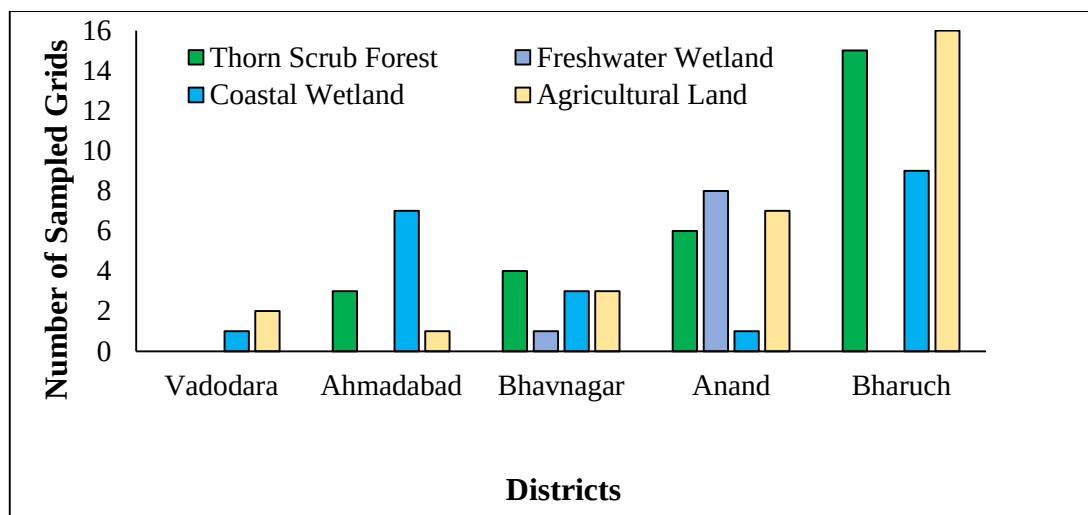


Figure 8: Habitat type-wise distribution of the sampled grids in each district

The maximum grids are in the agricultural land followed by Thorn scrub forest, coastal wetlands, and Freshwater wetlands. (Fig 9).

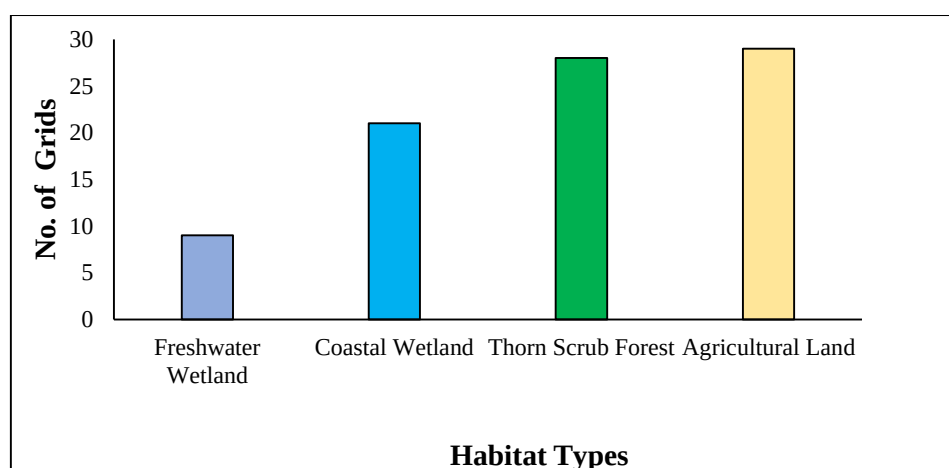


Figure 9: Number of grids surveyed in different habitat types

Avifaunal status was assessed both in terrestrial and aquatic habitats (freshwater bodies, brackish water, mangrove, marine, etc.). Total count or flock count method (Sridharan, 1989; Bhupathy, 1991; Thompson, 2002; Steinkamp *et al.*, 2003) was adopted to monitor and assess the aquatic birds in all wetlands and waterlogged areas. Point centre count method/perambulation techniques (Hutto *et al.*, 1986; Biby *et al.*, 1992; Rosenstock *et al.*, 2002) were applied to monitor and assess the status of terrestrial bird species. Additional efforts were made to locate/identify the presence of breeding/nesting sites of avifaunal species.

Herpeto-fauna (Amphibian and Reptile): Intensive search were made along the hedges of waterbodies including pond, lake, river, and streams to assess the biodiversity status of herpetofauna (Campbell and Christman, 1982; Welsh, 1987; Corn and Bury, 1990 and Heyer, *et al.*, 1994).

Mammals: Status and distribution of different mammal species were monitored and quantified by direct count while walking along the transects in various type of habitats (Burnham *et al.*, 1980; Sale and Berkmuller, 1988; Rodger, 1991).

In addition, indirect evidence for the presence of mammalian species were also collected through opportunistic survey for estimation of the relative density and abundance of mammalian fauna in the project area. The indirect survey of the mammalian fauna was conducted using standard methods (Thompson *et al.*, 1989; Daniel, 1992; Henke and Knowlton, 1995; Allen *et al.*, 1996).

Floral Biodiversity Status: Status of floral species was assessed in the four major habitats around the project site. Quantitative data were collected using Standard Quadrat Sampling Methods following Mueller-Dombois and Ellenberg, 1967, and Kershaw and Wright, 1980. Status of tree, shrub, grass, creepers, and herbs were quantified using nested quadrat plot size of 10X10 m, 5X5 m and 1X1 m respectively.

Mangroves

Intensive survey of the mangrove vegetation was carried out to assess the species composition, density, and distribution pattern at some prefixed sites in the intertidal belts of the Gulf of Khambhat and the adjacent estuarine environment. The assessment was done during low tide at each 25km² grid within the buffer area of the Project Sites. Of the total study area (3284.23 km²), 10% of the area was surveyed, which comes to approximately 328 km². Similarly, the inner core area is approximately 2063.4 km² in which the total area covered for sampling was 206 km². The plants were categorized in two classes,

1. Sapling or Regeneration class: These are the plants geminated from seeds and with height less than 50 cm.
2. Mature saplings: These are matured sapling with height more than 50 cm.

For regeneration class plants we used 1 m × 1 m quadrats plots which were laid randomly for enumeration. In each quadrat, the total number of plants less than 50 cm and girth

less than 7 cm were recorded. The measurements of mature sapling were done by using 2 m x 2 m quadrates for the plants with height more than 50 cm but less than 100 cm. The plants with height more than 100 cm but girth less than 7 cm were recorded by following Point Centered Quarter Method (PCQM). The method for measurement of density, height variations and basal area was adopted as described by Cintron and Novelli, 1984.

For measuring the plants in plantation sites, quadrates of 10 m x 10 m were considered and for trees, their height, girth, and canopy cover (length and width) were measured using ranging rods and measuring tapes. The girth at breast height (GBH) of all individuals above >1 m was also measured. In the case of a branching stem at a specific height, all the branches were added together.

5.4. Preparation of Checklist for Endemic and Threatened Species

Based on the primary survey on different components of biodiversity and collation of secondary information on biodiversity of the project coverage area, an intensive checklist of various floral and faunal biodiversity under major ecosystem types viz. terrestrial, marine, coastal/brackish, freshwater ecosystem, etc. have been prepared. As per the intensive checklist, the endemic species of the Gulf of Khambhat, Endemic to Gujarat coast and Endemic to India was identified based on available species distribution map and from various literatures. Further, the checklist of the threatened species of the area was prepared based on the Red List of Threatened species of IUCN and various Schedules of Indian Wildlife (Protection) Act, 1972.

5.5. Data Documentation, Analysis, and Interpretation

Data collected through the intensive survey and available secondary information, the comprehensive checklist of species in each ecosystem was prepared. Further, the primary data collected through the survey is analysed to estimate the species diversity in the project area using PAST software. For modelling purpose PAST and R software was used and SIMPER analysis was done to assess the change in species composition and identify species that will be affected as the ecosystem changes.

5.6. Socio-economic assessment

Intensive field surveys were conducted in the study area during December 2021 and January 2022 within the study area along with the influence areas of Kalpsar project around the Gulf of Khambhat Coast and in the rivers meeting with the Gulf of Khambhat.

Socio-economic impact survey was conducted using Stakeholder's Discussion, Focus Group Discussion (12) and Questionnaire Survey (355 participants) in the fishing villages (37) and at the fish landing centres (3). A reconnaissance survey of the study area, specific to the fisherman villages, fish market, fish landing centre and fisheries culture sites was conducted. Through the survey, livelihood patterns and parameters and indicators for the socio-economic study was identified, on which the final survey was conducted. This survey is made for planning of study location, sample size estimation for further intensive field survey and collection of baseline information about demographic structure and socio-economic condition of the communities' dependent on fish resources for livelihood and fishery business. The survey has been helpful in identifying parameters and indicators for the socio-economic study.

Finally, survey and sampling was conducted in the entire coastal stretch of the project influence area using questionnaire survey; Focus Group Discussion (FGD), stakeholder's discussion and consultation was carried out with the fisheries department and organization working on different aspects of fisheries.

The baseline information is collected to define the socio-economic profile/status of the fishing community and people residing in the coastal villages, includes:

- i. Demographic structure: Population, Caste and Community, Agriculture & Livestock
- ii. Economic attributes: Employment, Income, etc.
- iii. Awareness and opinion of the people about the project: Collection of data on probable Positive and Negative impacts.

6. Brief outline of the report

The following two sections (Chapter Two and Three) of the report gives the detailed information on the historic and present account of floral and faunal distribution within the study area. Chapter two gives a detailed literature review on different aquatic and terrestrial taxa with annotation of conservation important species followed by the Chapter three which gives a detailed account of species richness of different taxa resulting from the present study.

The change in the hydrology and physiography of the area after the dike formation is expected to affect the community structure of different aquatic and terrestrial taxa. Along with the decrease in salinity and other hydrological features in future, the community, obligatory to brackish water will eventually disappear and estuarine and freshwater communities will dominate and thrive along with some facultative species, that can sustain in low salinity. Chapter Four deals with the expected change in the community structure and gave insight into the community change of different taxonomic groups studied.

The socio-economy of the Talukas adjacent to the Gulf of Khambhat depends on the fisheries and saltpan industries. The details of the socio-economic dependency on the marine resources and alternative livelihood options that can be generated after the operational phase of the project were discussed in Chapter Five of the report followed by a detailed account of the geo-hydrology of the area in Chapter Six.

The implementation of the projects involves both structural and functional change within the landscape and it will have impacts on the biodiversity of the area as well. So, both conservation and management of different species with high conservation values and management of their habitat will be an essential task in future. Some new conservation and management initiatives need to be in place along with the continuous monitoring of biodiversity and associated habitat. Suggestive measures and conservation and management plan for some endangered and threatened species was given in Chapter Seven.

CHAPTER 2 LITERATURE REVIEW

Literature survey was undertaken for presence of similar structures as proposed around the world. The literature review indicated presence of similar types of embankment projects undertaken in other parts of the world where the main purpose was to trap the fresh water and create reservoir that would cater for irrigation. Recent past example is the “The Shihwa Coastal Reservoir (SCR)” in South Korea which was created to supply agricultural water by the construction of dikes in the mouth of the river in 1994. In the process land reclamation of the coastal tidal flats were undertaken. However, within two years the water quality inside the reservoir drastically deteriorated due to leaching of pollutants from the bottom of the reservoir leading to anoxic conditions and stratifications was observed in the summer. As a result, in 1996, the sluice gates were opened to dilute water pollution levels through the physical mixing of seawater from outside and freshwater from inside. Over, the last 20 years, the Korean government has invested more than US \$ 1.5 billion to recover SCR water. Yet, within the reservoir, water quality has minimally improved, sediment pollution continues to be detected. In parallel, the pelagic and benthic communities have also been affected by the deterioration of multiple water and sediment quality indices. The SCR project presents a clear example that how incorrect policy leads to the mishandling of both coastal ecosystems and substantial governmental budgets (Lee *et al.*, 2014).

Construction of Coastal reservoirs cause adverse effects on aquatic life with space and time. Particularly the migratory fishes that move between sea and rivers, such as *Hilsa*, *Anguilla* and *salmonids* are affected as dams are blocking up their routes to reproduce or as part of their life cycle. By providing fish ways at appropriate segments and providing passages would serve them from such disasters. The shrimps and crabs and many marine fishes move towards the estuarine and mangrove environments during their breeding season. With the closure of the reservoir on the Gulf below the estuarine complex the recruitment of the larvae of these fishery resources will be declined and subsequently the catch of the adults will be lost. Dams and barrages act as barriers and block migration and spawning routes of fishes. Discharges led to nutrient impoverishment, decrease in primary production and deterioration of coastal mangrove forests (Snedaker 1984; Quraishie 1988). Seismic studies in the Gulf revealed a seismically active zone with an 80 km radius (Mukhopadhyay 2002).

With the completion of dams and barrages on the Indus River, the shrimp industry in Pakistan decreased by tenfold and a significant reduction in the catch rate for all fish species.

According to Subbarao (2011) ecosystem mega-engineering facilitates invasions by exotic biota. Disturbances to the resident communities are common and often cause partial removal of dominant species (Badano and Marquet, 2008). Zhou et al, (2014), studied the impact of severn barrage on the hydro-environment of the Bristol Channel and Severn Estuary using the Environmental Fluid Dynamics Code (EFDC) model. The predicted results suggested that the minimum water level will change in the region of seven estuaries to the extent that about 80.5 sq km of intertidal habitats will be lost.

The Rance barrage was constructed and commissioned in 1966 and environmental and ecological study was conducted in 2006. After 40 years of the operational phase of the dam, the assessment revealed that the estuary bed changed from predominantly sandy to muddy sand inducing prolific benthic community to occupy the enclosure. The diversity of fish community was similar to the surrounding (Kirby and Retiere, 2009) environment.

A study on the Marina basin, Singapore prior to the construction of barrage recorded 139 fish species, including four endangered. The study predicted that only 25 of the species will survive in fresh water, and 17 others will survive, however, the survived species were not able to breed with-out access to the sea.

Yoon *et al.*, (2016) studied the impact of estuary barrage in the Nakdong River, South Korea on the fish diversity. A long term (20-years) monitoring data revealed that after the construction of the barrage, 36 fish species disappeared and another 18 species appeared at this site, including eight freshwater species, seven of which were exotic or translocated species. Barrage construction affected freshwater fish more severely than it did estuarine and marine species because of the existence of an estuarine environment below the barrage.

The review of literature indicated that availability of fresh water is a challenge for the coming years and the best way to suffice the same is through construction of the coastal reservoirs. However, the change in the bathymetry and environmental variables is a challenge which affects the biota especially the sensitive species may get affected and in due course do not survive. Careful study and monitoring of the existing case studies has to be

undertaken to be incorporated in the reservoir design with the context of the safeguarding the biodiversity and loss of species.

Extensive literature survey was conducted for the records of secondary information on the species reported in the area representing various ecosystems. The present section deals with a glimpse of the already published information on the Gulf of Khambhat regarding the freshwater, marine as well as terrestrial biodiversity. A thorough review of literature was undertaken for each of the taxa to assess the existing information of the species present within the study area. The secondary resources were collated by consulting the published papers, monographs, conference papers and posters, websites, reports from the department of fisheries and other associated departments of the Gujarat state with reference to the Gulf of Khambhat area. The web search engines like Publish and Perish and Google search were used with key words like biodiversity, species richness and taxon specific keywords. For each reported freshwater and marine species, the scientific name was confirmed based on the World Register of Marine Species (WoRMS) 2022 and FishBase (version 6/2022). The identifications were not checked for correctness, as in most cases, publications contain no photographs of the recorded species. The taxa specific literature review is given herewith in the following sections.

2.1 Foraminifera

Foraminifera, in short “forams,” are single-celled organisms generally live in the oceans. They are included under the Phylum Foraminifera, are known as hole-bearing organisms. Foraminifera floats in the water column (planktonic) or lives on the seafloor (benthic). Approximately 6,000 living species are benthic, and more than 50 species are planktonic. Members of the Foraminifera are distributed worldwide, mostly living in marine, and few species live in freshwater environments (Sen Gupta *et al.*, 2009, Pawlowski *et al.*, 2013, Rigaud *et al.*, 2015).

Studies on the Foraminifera of Gujarat coast were carried out earlier (Sastry and Pant, 1960; Rao, 1970 a, b; 1971; Rao *et al.*, 1971; Jain and Bhatia, 1978; Gajbhiye *et al.*, 1981; Varshney *et al.*, 1981; Desai and Pandya, 1982; Nigam 1984; Srivastava *et al.* 1984; Bhalla and Lal, 1985; Pandya, 1985; Talib and Farooqui, 1994; Nigam and Khare, 1995; Raj and Chamyal,

1997, 1998; Ghosh *et al.*, 2009; Ghosh, 2012; Mondal *et al.*, 2020) and also from Gulf of Khambhat very few reports are available (Rao, 1970 a, b; 1971; Rao *et al.*, 1971; Gajbhiye *et al.*, 1981, Ghosh *et al.*, 2009; Nigam, 1984; Nigam and Khare 1995; Varshney *et al.*, 1981; Ghosh 2012; Mondal *et al.*, 2020).

In the present study 96 species belonging to the phylum Foraminifera classified under 8 Orders, 25 Super families, 42 families and 52 genera have been reported from the estuarine and marine environments of the Gulf of Khambhat. Of the total, twenty-six species are from brackish water environment, seventy-six species are exclusively marine, and six shares both estuarine and marine environments. The identification of the species was done following the classification of Foraminifera by Pawlowski *et al.* (2013) and Rigaud *et al.* (2015) and the earlier literature. All the names are verified through the world Foraminifera database by Hayward *et al.* (2022) and WoRMS (2022). There were no published records of foraminiferan species from the freshwater environments in the project site. A checklist of species is given in table 2.1.

Table 2.1: Checklist of species representing phylum Foraminifera based on secondary literature

Phylum: Foraminifera

Class: Globothalamea

S.no.	Order	Superfamily	Family	Scientific name	Habitat			IUCN status	References
					FW	BW	MW		
1.	Rotaliida	Rotalioidea	Ammoniidae	<i>Ammonia beccarii</i> (Linnaeus, 1758)	-	+	+	Not Evaluated	Rao 1971 and Ghosh 2012.
2.	Rotaliida	Rotalioidea	Ammoniidae	<i>Ammonia tepida</i> (Cushman, 1926)	-	+	-	Not Evaluated	Ghosh 2012.
3.	Rotaliida	Rotalioidea	Ammoniidae	<i>Rotalidium annectens</i> (Parker & Jones, 1865)	-	+	-	Not Evaluated	Ghosh 2012.
4.	Rotaliida	Rotalioidea	Murrayinellidae	<i>Murrayinella minuta</i> (Takayanagi, 1955)	-	+	-	Not Evaluated	Ghosh 2012.
5.	Rotaliida	Rotalioidea	Calcarinidae	<i>Pararotalia venusta</i> (Brady, 1884)	-	-	+	Not Evaluated	Rao 1971.
6.	Rotaliida	Rotalioidea	Calcarinidae	<i>Pararotalia nipponica</i> (Asano, 1936)	-	+	-	Not Evaluated	Ghosh 2012.
7.	Rotaliida	Rotalioidea	Calcarinidae	<i>Neorotalia calcar</i> (d'Orbigny in Deshayes, 1830)	-	-	+	Not Evaluated	Rao 1970a.
8.	Rotaliida	Discorboidea	Eponididae	<i>Eponides concameratus</i> (Montagu, 1808)	-	-	+	Not Evaluated	Rao 1971.
9.	Rotaliida	Discorboidea	Eponididae	<i>Pulvinulina punctulata</i> (d'Orbigny in Parker, Jones & Brady, 1865)	-	-	+	Not Evaluated	Rao 1971.
10.	Rotaliida	Discorboidea	Eponididae	<i>Poroeponides lateralis</i> (Terquem, 1878)	-	+	-	Not Evaluated	Ghosh 2012.

11.	Rotaliida	Discorboidea	Cancrisidae	<i>Cancris oblongus</i> (Williamson, 1858)	-	-	+	Not Evaluated	Rao 1971.
12.	Rotaliida	Discorboidea	Cancrisidae	<i>Cancris oblongus</i> (Williamson, 1858)	-	+	-	Not Evaluated	Ghosh2012.
13.	Rotaliida	Globigerinoidea	Globigerinidae	<i>Globigerina bulloides</i> (d'Orbigny, 1826)	-	-	+	Not Evaluated	Rao 1971.
14.	Rotaliida	Globigerinoidea	Globigerinidae	<i>Globigerina dubia</i> (Egger, 1857)	-	-	+	Not Evaluated	Rao 1971.
15.	Rotaliida	Globigerinoidea	Globigerinidae	<i>Globigerinella siphonifera</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1971.
16.	Rotaliida	Globigerinoidea	Globigerinidae	<i>Globorotalia menardii</i> (d'Orbigny in Parker, Jones & Brady, 1865)	-	-	+	Not Evaluated	Rao 1971.
17.	Rotaliida	Chilostomelloidea	Gavelinellidae	<i>Gavelinella ammonoides</i> (Reuss, 1844)	-	-	+	Not Evaluated	Rao 1971.
18.	Rotaliida	Chilostomelloidea	Gavelinellidae	<i>Gyroidina turgida</i> (Hagenow, 1842)	-	+	-	Not Evaluated	Ghosh2012.
19.	Rotaliida	Discorbinelloidea	Discorbinellidae	<i>Discorbinella bertheloti</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970a.
20.	Rotaliida	Discorboidea	Discorbidae	<i>Discorbis vilardeboanus</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970a.
21.	Rotaliida	Discorboidea	Rosalinidae	<i>Discanomalina coronata</i> (Parker & Jones, 1865)	-	-	+	Not Evaluated	Rao 1971.
22.	Rotaliida	Discorboidea	Rosalinidae	<i>Rosalina globularis</i> (d'Orbigny, 1826)	-	+	+	Not Evaluated	Rao 1970a and Ghosh2012.
23.	Rotaliida	Discorboidea	Rosalinidae	<i>Rosalina williamsoni</i> (Chapman & Parr, 1932)	-	-	+	Not Evaluated	Rao 1970a.
24.	Rotaliida	Discorboidea	Rosalinidae	<i>Cymbaloporetta squamosa</i> (d'Orbigny, 1839)	-	+	-	Not Evaluated	Ghosh2012.

25.	Rotaliida	Asterigerinoidea	Asterigerinidae	<i>Biasterigerina planorbis</i> (d'Orbigny, 1846)	-	-	+	Not Evaluated	Rao 1970a.
26.	Rotaliida	Asterigerinoidea	Epistomariidae	<i>Palmerinella palmerae</i> (Bermúdez, 1934)	-	-	+	Not Evaluated	Rao 1971.
27.	Rotaliida	Planorbuloidea	Cibicidinae	<i>Cibicides refulgens</i> Montfort, 1808	-	-	+	Not Evaluated	Rao 1971.
28.	Rotaliida	Planorbuloidea	Cibicidinae	<i>Lobatula lobatula</i> (Walker & Jacob, 1798)	-	-	+	Not Evaluated	Rao 1971.
29.	Rotaliida	Planorbuloidea	Cibicidinae	<i>Cibicoides pseudoungerianus</i> (Cushman, 1922)	-	-	+	Not Evaluated	Rao 1971.
30.	Rotaliida	Planorbuloidea	Cibicidinae	<i>Cibicoides wuellerstorfi</i> (Schwager, 1866)	-	-	+	Not Evaluated	Rao 1971.
31.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Sagrinella convallaria</i> (Millett, 1900)	-	+	-	Not Evaluated	Ghosh2012.
32.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Sagrinella pacifica</i> (Asano, 1938)	-	+	-	Not Evaluated	Ghosh2012.
33.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Bolivina variabilis</i> (Williamson, 1858)	-	+	-	Not Evaluated	Ghosh2012.
34.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Bolivina punctata</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970a.
35.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Bolivina nitida</i> (Brady, 1884)	-	-	+	Not Evaluated	Rao 1970a.
36.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Bolivina nobilis</i> (Hantken, 1875)	-	-	+	Not Evaluated	Rao 1970a.
37.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Bolivina aenariensis</i> (Costa, 1856)	-	-	+	Not Evaluated	Rao 1970a.
38.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Bolivina vadesens</i> (Cushman, 1933)	-	-	+	Not Evaluated	Rao 1970a.
39.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Fursenkoina squamosa</i> (d'Orbigny in Deshayes, 1832)	-	-	+	Not Evaluated	Rao 1970a.

40.	Rotaliida	Cassidulinoidea	Bolivinitidae	<i>Loxostomina limbata</i> (Brady, 1881)	-	-	+	Not Evaluated	Rao 1970a.
41.	Rotaliida	Cassidulinoidea	Tortoplectellidae	<i>Tortoplectella rhomboidalis</i> (Millett, 1899)	-	-	+	Not Evaluated	Rao 1970a.
42.	Rotaliida	Cassidulinoidea	Uvigerinidae	<i>Uvigerina tenuistriata</i> (Reuss, 1870)	-	-	+	Not Evaluated	Rao 1970a.
43.	Rotaliida	Rotalioidea	Elphidiidae	<i>Elphidium craticulatum</i> (Fichtel & Moll, 1798)	-	+	-	Not Evaluated	Ghosh2012.
44.	Rotaliida	Rotalioidea	Elphidiidae	<i>Elphidium crispum</i> (Linnaeus, 1758)	-	+	+	Not Evaluated	Rao 1970a and Ghosh2012.
45.	Rotaliida	Rotalioidea	Elphidiidae	<i>Elphidium fichtelianum</i> (d'Orbigny, 1846)	-	-	+	Not Evaluated	Rao 1970a.
46.	Rotaliida	Rotalioidea	Haynesinidae	<i>Haynesina germanica</i> (Ehrenberg, 1840)	-	+	-	Not Evaluated	Ghosh2012.
47.	Rotaliida	Rotalioidea	Haynesinidae	<i>Haynesina depressula</i> (Walker & Jacob, 1798)	-	+	+	Not Evaluated	Rao 1970a and Ghosh2012.
48.	Rotaliida	Nonionoidea	Nonionidae	<i>Nonionoides grateloupii</i> (d'Orbigny, 1839)	-	+	-	Not Evaluated	Ghosh2012 and Mondal et al., 2020.
49.	Rotaliida	Nonionoidea	Nonionidae	<i>Nonion boueanum</i> (d'Orbigny, 1846)	-	-	+	Not Evaluated	Rao 1970a.
50.	Rotaliida	Nonionoidea	Nonionidae	<i>Nonion pacificum</i> (Cushman, 1924)	-	-	+	Not Evaluated	Rao 1970a.
51.	Rotaliida	Nonionoidea	Nonionidae	<i>Melonis pompilioides</i> (Fichtel & Moll, 1798)	-	-	+	Not Evaluated	Rao 1970a.
52.	Rotaliida	Guembelitrionidea	Guembelitriidae	<i>Neogallitellia vivans</i> (Cushman, 1934)	-	+	-	Not Evaluated	Ghosh2012.
53.	Rotaliida	Nummulitoidea	Nummulitidae	<i>Operculina subgranulosa</i> (d'Orbigny, 1850)	-	-	+	Not Evaluated	Rao 1970a.

54.	Rotaliida	Nummulitoidea	Nummulitidae	<i>Operculina gaimardi</i> (d'Orbigny in Deshayes, 1832)	-	-	+	Not Evaluated	Rao 1970a.
55.	Rotaliida	Buliminoidea	Buliminidae	<i>Bulimina marginata</i> (d'Orbigny, 1826)	-	-	+	Not Evaluated	Rao 1970a.
56.	Rotaliida	Astrorhizoidea	Rhabdamminidae	<i>Rhabdammina abyssorum</i> (Sars in Carpenter, 1869)	-	-	+	Not Evaluated	Rao 1970b.
57.	Rotaliida	Eggerelloidea	Valvulinidae	<i>Goesella cylindrica</i> (Cushman, 1922)	-	-	+	Not Evaluated	Rao 1970b.
58.	Rotaliida	Textularioidea	Textulariidae	<i>Textularia cuneiformis</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970b.
59.	Rotaliida	Textularioidea	Textulariidae	<i>Textularia agglutinans</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970b.
60.	Rotaliida	Textularioidea	Textulariidae	<i>Textularia sagittula</i> (Defrance, 1824)	-	-	+	Not Evaluated	Rao 1970b.
61.	Rotaliida	Textularioidea	Textulariidae	<i>Textularia stricta</i> (Cushman, 1911)	-	-	+	Not Evaluated	Rao 1970b.
62.	Rotaliida	Textularioidea	Textulariidae	<i>Textularia semialata</i> (Cushman, 1913)	-	-	+	Not Evaluated	Rao 1970b.
63.	Rotaliida	Textularioidea	Textulariidae	<i>Textularia candeiana</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970b.
64.	Rotaliida	Eggerelloidea	Eggerellidae	<i>Eggerella bradyi</i> (Cushman, 1911)	-	-	+	Not Evaluated	Rao 1970b.
65.	Rotaliida	Milioloidea	Hauerinidae	<i>Quinqueloculina lamarckiana</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970b.
66.	Rotaliida	Milioloidea	Hauerinidae	<i>Quinqueloculina akneriana</i> (d'Orbigny, 1846)	-	+	-	Not Evaluated	Ghosh 2012.
67.	Rotaliida	Milioloidea	Hauerinidae	<i>Quinqueloculina vulgaris</i> (d'Orbigny, 1826)	-	-	+	Not Evaluated	Rao 1970b.
68.	Rotaliida	Milioloidea	Hauerinidae	<i>Quinqueloculina seminulum</i> (Linnaeus, 1758)	-	+	+	Not Evaluated	Rao 1970b & Ghosh 2012.

69.	Rotaliida	Milioloidea	Hauerinidae	<i>Quinqueloculina boueana</i> (d'Orbigny, 1846)	-	-	+	Not Evaluated	Rao 1970b.
70.	Rotaliida	Milioloidea	Hauerinidae	<i>Quinqueloculina reticulata</i> (d'Orbigny, 1826)	-	-	+	Not Evaluated	Rao 1970b.
71.	Rotaliida	Milioloidea	Hauerinidae	<i>Quinqueloculina candeiana</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970b and Rao et al., 1971.
72.	Rotaliida	Milioloidea	Spiroloculinidae	<i>Spiroloculina depressa</i> (d'Orbigny, 1826)	-	-	+	Not Evaluated	Rao 1970b.
73.	Rotaliida	Milioloidea	Spiroloculinidae	<i>Spiroloculina rotunda</i> (d'Orbigny, 1826)	-	-	+	Not Evaluated	Rao 1970b.
74.	Rotaliida	Milioloidea	Spiroloculinidae	<i>Spiroloculina planulata</i> (Lamarck, 1804)	-	+	+	Not Evaluated	Rao 1970b & Ghosh2012.
75.	Rotaliida	Milioloidea	Spiroloculinidae	<i>Spiroloculina grateloupi</i> (d'Orbigny, 1852)	-	-	+	Not Evaluated	Rao 1970b.
76.	Rotaliida	Milioloidea	Spiroloculinidae	<i>Spiroloculina antillarum</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970b.
77.	Rotaliida	Milioloidea	Spiroloculinidae	<i>Spiroloculina aequa</i> (Cushman, 1932)	-	-	+	Not Evaluated	Rao 1970b.
78.	Rotaliida	Milioloidea	Hauerinidae	<i>Triloculina trigonula</i> (Lamarck, 1804)	-	-	+	Not Evaluated	Rao 1970b.
79.	Rotaliida	Milioloidea	Hauerinidae	<i>Triloculina tricarinata</i> (d'Orbigny in Deshayes, 1832)	-	-	+	Not Evaluated	Rao 1970b.
80.	Rotaliida	Milioloidea	Hauerinidae	<i>Miliolinella oceanica</i> (Cushman, 1932)	-	+	-	Not Evaluated	Ghosh2012.
81.	Rotaliida	Miliamminoidea	Miliamminidae	<i>Miliammina fusca</i> (Brady, 1870)	-	-	+	Not Evaluated	Rao 1970a.
82.	Rotaliida	Soritoidea	Soritidae	<i>Sorites marginalis</i> (Lamarck, 1816)	-	+	-	Not Evaluated	Ghosh2012.
83.	Rotaliida	Trochamminoides	Trochamminidae	<i>Trochammina inflata</i> (Montagu, 1808)	-	+	-	Not Evaluated	Ghosh2012.

84.	Rotaliida	Nodosarioidea	Lagenidae	<i>Lagena striata</i> (d'Orbigny, 1839)	-	+	-	Not Evaluated	Ghosh2012.
85.	Rotaliida	Nodosarioidea	Chrysalogoniidae	<i>Lotostomoides calomorpha</i> (Reuss, 1866)	-	-	+	Not Evaluated	Rao 1970a.
86.	Rotaliida	Nodosarioidea	Nodosariidae	<i>Nodosaria radícula</i> (Linnaeus, 1758)	-	-	+	Not Evaluated	Rao 1970a.
87.	Rotaliida	Nodosarioidea	Nodosariidae	<i>Laevidentalina haueri</i> (Neugeboren, 1856)	-	-	+	Not Evaluated	Rao 1970a.
88.	Rotaliida	Nodosarioidea	Glandulonodosariidae	<i>Orthomorphina perversa</i> (Schwager, 1866)	-	-	+	Not Evaluated	Rao 1970a.
89.	Rotaliida	Nodosarioidea	Glandulonodosariidae	<i>Orthomorphina perversa</i> (Schwager, 1866)	-	-	+	Not Evaluated	Rao 1970a.
90.	Polymorphinida	Polymorphinoidea	Ellipsolagenidae	<i>Oolina globosa</i> (Montagu, 1803)	-	-	+	Not Evaluated	Rao 1970a.
91.	Polymorphinida	Polymorphinoidea	Ellipsolagenidae	<i>Fissurina marginata</i> (Montagu, 1803)	-	-	+	Not Evaluated	Rao 1970a.
92.	Polymorphinida	Polymorphinoidea	Ellipsolagenidae	<i>Fissurina orbignyana</i> (Seguenza, 1862)	-	-	+	Not Evaluated	Rao 1970a.
93.	Polymorphinida	Polymorphinoidea	Ellipsolagenidae	<i>Fissurina quadrata</i> (Williamson, 1858)	-	-	+	Not Evaluated	Rao 1970a.
94.	Polymorphinida	Polymorphinoidea	Lagenidae	<i>Lagena striata</i> (d'Orbigny, 1839)	-	-	+	Not Evaluated	Rao 1970a.
95.	Polymorphinida	Spirillinoidea	Spirillinidae	<i>Spirillina vivipara</i> (Ehrenberg, 1843)	-	-	+	Not Evaluated	Rao 1970a.
96.	Polymorphinida	Spirillinoidea	Spirillinidae	<i>Spirillina limbata</i> (Brady, 1879)	-	-	+	Not Evaluated	Rao 1970a.

2.2 Phylum Annelida

The members of the phylum Annelida typically have complex segmented body; with many internal organs repeated in each segment. The class Polychaeta of this phylum represents worms that mostly lives in marine and brackish water habitats; very few species live in freshwater environments. More than 15,000 known species of annelid worms live in the sea crawling under rocks on the shore and sea bottom, freely swimming or seeking protection from predators in burrows or tubes. The length of the Annelids varies from 1 mm (between sand grains) to 3 meters (Moore, 2006; Greg and Gonzalo, 2016; Philipp *et al.*, 2018).

Studies on the Annelida of Gujarat coast were carried out by (Southern, 1921; Fauvel, 1953; Menon and Datta Gupta, 1962; Menon *et al.*, 1964; Menon and Sareen, 1966; Datta Gupta and Menon, 1970; Day, 1973; Dalal and Dubalb, 1975, 1976; Haldar, 1981, 1991, 2004. Soota *et al.*, 1981; Nageswara-Rao and Soota, 1981; Raghunathan *et al.*, 2003; Misra and Chakraborty, 2004; Rao and Sastry, 2005; Hughes and Crisp, 2009; Veeramuthu *et al.*, 2012; Sanagoudra and Bhat, 2013; Chaudhari *et al.*, 2016; Gohil, 2018; Balakrishnan, 2020; Sanitha and Carvalho, 2020 and Sukumaran *et al.*, 2021) but studies within Gulf of Khambhat are very few (Fauvel 1953; Menon and Datta Gupta, 1962; Menon *et al.*, 1964; Menon and Sareen, 1966; Datta Gupta and Menon, 1970; Nageswara-Rao and Soota, 1981; Soota *et al.*, 1981; Haldar, 1981, 1991; Raghunathan *et al.*, 2003; Misra and Chakraborty 2004; Veeramuthu *et al.* 2012; Chaudhari *et al.*, 2016; Gohil, 2018; Sanitha and Carvalho, 2020 and Sukumaran *et al.*, 2021).

The literature survey indicated the presence of 47 species of the phylum Annelida falling under 5 Orders, 18 families and 35 genera from the freshwater, estuarine and marine regions of the Gulf of Khambhat (Table. 2.2). There were three species recorded from the freshwater environment, six are documented from brackish water habitat, and forty-three are exclusively marine.

Table 2.2: Checklist of species representing phylum Annelida based on secondary literature

Phylum – Annelida

Class – Polychaeta

Subclass: Echiura

S.no.	Order	Superfamily	Family	Scientific name	Habitat			IUCN status	References
					FW	BW	MW		
1.	Echiuroidea	Bonellioidae	Ikedidae	<i>Ikeda pirotansis</i> (Menon & DattaGupta, 1962)	-	+	-	Not Evaluated	Menon and DattaGupta, 1962; Menon et al., 1964; Datta Guptaand Menon1970; Haldar 1981 and Sanitha and Carvalho2020.
2.	Echiuroidea	Bonellioidae	Thalassematidae	<i>Anelassorhynchus sabinus</i> (Lanchester, 1905)	-	-	+	Not Evaluated	Haldar 1991 and Sanitha and Carvalho 2020.
3.	Echiuroidea	Bonellioidae	Thalassematidae	<i>Ochetostoma palense</i> (Ikeda, 1924)	-	-	+	Not Evaluated	Haldar 1991 and Sanitha and Carvalho 2020.
Subclass: Errantia									
4.	Phyllodocea	-	Aphroditidae	<i>Pontogenia indica</i> (Grube, 1875)	-	-	+	Not Evaluated	Sanitha and Carvalho2020.
5.	Phyllodocea	-	Aphroditidae	<i>Aphrodita aculeata</i> (Linnaeus, 1758)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.

6.	Phyllodo- cida	-	Glyceridae	<i>Glycera alba</i> (O.F. Müller, 1776)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981 and Misra and Chakraborty 2004.
7.	Phyllodo- cida	-	Glyceridae	<i>Glycera tridactyla</i> (Schmarda, 1861)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
8.	Phyllodo- cida	-	Glyceridae	<i>Glycera tessellata</i> (Grube, 1863)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
9.	Phyllodo- cida	-	Aphroditidae	<i>Pontogenia indica</i> (Grube, 1875)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
10.	Phyllodo- cida	-	Phyllodocidae	<i>Phyllodoce madeirensis</i> (Langerhans, 1880)	-	-	+	Not Evaluated	Fauvel1953;Misra and Chakraborty 2004; Sanitha and Carvalho2020.
11.	Phyllodo- cida	-	Phyllodocidae	<i>Eulalia viridis</i> (Linnaeus, 1767)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
12.	Phyllodo- cida	-	Hesionidae	<i>Hesione splendida</i> (Lamarck, 1818)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
13.	Phyllodo- cida	-	Syllidae	<i>Syllis variegata</i> (Grube, 1860)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
14.	Phyllodo- cida	-	Nereididae	<i>Neanthes glandicincta</i> (Southern, 1921)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.

15.	Phyllodo- cida	-	Nereididae	<i>Ceratonereis costae</i> (Grube, 1840)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
16.	Phyllodo- cida	-	Nereididae	<i>Namalycastis indica</i> (Southern, 1921)	+	+	-	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
17.	Phyllodo- cida	-	Nereididae	<i>Nereis persica</i> (Fauvel, 1911)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
18.	Phyllodo- cida	-	Nereididae	<i>Neanthes indica</i> (Kinberg, 1865)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
19.	Phyllodo- cida	-	Nereididae	<i>Neanthes willeyi</i> (Day, 1934)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
20.	Phyllodo- cida	-	Nereididae	<i>Pseudonereis anomala</i> (Gravier, 1899)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
21.	Phyllodo- cida	-	Nereididae	<i>Hediste diversicolor</i> (O.F. Müller, 1776)	-	-	+	Not Evaluated	Raghunathan et al., 2003.
22.	Phyllodo- cida	-	Nephtyidae	<i>Nephtys polybranchia</i> (Southern, 1921)	+	+	-	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
23.	Phyllodo- cida	-		<i>Tylonereis bogoyawlenskyi</i> (Fauvel, 1911)	-	-	+	Not Evaluated	Fauvel1953; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
24.	Amphino- mida	-	Amphinomida e	<i>Eurythoe complanata</i> (Pallas, 1766)	-	-	+	Not Evaluated	Fauvel1953; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.

25.	Eunicida	-	Eunicidae	<i>Palola siciliensis</i> (Grube, 1840)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
26.	Eunicida	-	Eunicidae	<i>Eunice paupera</i> (Grube, 1878)	-	-	+	Not Evaluated	Sanitha and Carvalho2020.
27.	Eunicida	-	Eunicidae	<i>Eunice petersi</i> (Fauchald, 1992)	-	-	+	Not Evaluated	Sanitha and Carvalho2020.
28.	Eunicida	-	Eunicidae	<i>Laetmonice hystrix</i> (Savigny in Lamarck, 1818)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
29.	Eunicida	-	Eunicidae	<i>Leodice australis</i> (Quatrefages, 1866)	-	-	+	Not Evaluated	Sanitha and Carvalho2020.
30.	Eunicida	-	Eunicidae	<i>Leodice laticeps</i> (Ehlers, 1868)	-	-	+	Not Evaluated	Sanitha and Carvalho2020.
31.	Eunicida	-	Eunicidae	<i>Lysidice natalensis</i> (Kinberg, 1865)	-	-	+	Not Evaluated	Sanitha and Carvalho2020.
32.	Eunicida	-	Eunicidae	<i>Marphysa corallina</i> (Kinberg, 1865)	-	-	+	Not Evaluated	Veeramuthu et al. 2012 and Sanitha and Carvalho2020.
33.	Eunicida	-	Eunicidae	<i>Marphysa sanguinea</i> (Montagu, 1813)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
34.	Eunicida	-	Eunicidae	<i>Lysidice collaris</i> (Grube, 1870)	-	-	+	Not Evaluated	Veeramuthu et al. 2012 and Sanitha and Carvalho2020.

35.	Eunicida	-	Polynoidae	<i>Lepidonotus cristatus</i> (Grube, 1876)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
36.	Eunicida	-	Polynoidae	<i>Lepidonotus carinulatus</i> (Grube, 1869)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
37.	Eunicida	-	Polynoidae	<i>Lepidonotus tenuisetosus</i> (Gravier, 1902)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
38.	Eunicida	-	Polynoidae	<i>Thormora jukesii</i> Baird, 1865)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
39.	Eunicida	-	Polynoidae	<i>Paralepidonotus ampulliferus</i> (Grube, 1878)	-	-	+	Not Evaluated	Nageswara-Rao and Soota 1981; Soota et al., 1981; Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
40.	Eunicida	-	Lumbrineridae	<i>Lumbrineris polydesma</i> (Southern, 1921)	+	+	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
41.	Eunicida	-	Lumbrineridae	<i>Lumbrineris pseudobifilaris</i> (Fauvel, 1932)	+	+	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.

42.	Eunicida	-	Lumbrineridae	<i>Lumbrineris simplex</i> (Southern, 1921)	+	+		Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
43.	Eunicida	-	Lumbrineridae	<i>Ninoides notocirrata</i> (Fauvel, 1932)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
44.	Eunicida	-	Onuphidae	<i>Diopatra cuprea</i> (Bosc, 1802)	-	-	+	Not Evaluated	Gohil2018.
45.	Terebellida	-	Terebellidae	<i>Loimia medusa</i> (Savigny, 1822)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
46.	Terebellida	-	Terebellidae	<i>Streblosoma persica</i> (Fauvel, 1908)	-	-	+	Not Evaluated	Misra and Chakraborty 2004 and Sanitha and Carvalho2020.
47.	Terebellida	-	Sabellariidae	<i>Neosabellaria clandestinus</i> (Menon & Sareen, 1966)	-	-	+	Not Evaluated	Menonand Sareen1966; Chaudhari et al., 2016; Sanitha and Carvalho2020 and Sukumaran et al., 2021.

2.3 Arthropoda

The phylum Arthropoda represents the largest group with high species diversity in the animal kingdom. Crustaceans are diverse invertebrate animals, including crabs, lobsters, shrimp, krill, isopods, copepods, amphipods, and barnacles (Hayward and Ryland, 1990). Along the Indian coasts, Arthropod diversity is very high with more than 2023 species recorded (Chandra *et al.*, 2020) and many are yet to be identified. One of the first studies on crustaceans of Gujarat was carried out in the Gulf of Kachchh on anomuran crabs by (Southwell, 1909 and Hornell and Southwell, 1909). After that, Chhapgar (1955, 1957a, b, 1958a, b). Chhapgar and Mundkar (1955), Chandy (1969, 1973), Chhapgar *et al.* (2004), Ghosh (2004) and Subba Rao and Sastry (2005) had published crustacean fauna of Gujarat. Recently crustacean fauna of Gujarat was studied by the following authors (Trivedi *et al.*, 2015b; Trivedi *et al.*, 2016a, b; Gosavi *et al.*, 2017a, b, c; Trivedi and Vachhrajani, 2017a,b; Trivedi *et al.*, 2017a,b; Trivedi and Vachhrajani, 2018a; Trivedi *et al.*, 2018; Purohit and Vachhrajani, 2019 a,b; Bhat and Trivedi, 2021; Patelet *et al.*, 2021; Trivedi *et al.*, 2020; Trivedi *et al.*, 2021a,b).

Extensive studies have been carried out on the crustacean fauna of the Gulf of Khambhat (Alcock, 1898, 1900, Hornell and Southwell, 1909, Tesch, 1918, Chhapgar, 1957a,b, c, Chhapgar, 1958, Silas and Algarswami, 1967, Thomas, 1969, Shanbhogue, 1969, Gopalakrishnan, 1970, Daniel, 1972, Chandy, 1973, Schmitt *et al.* 1973, Patel and Balapatel, 1983, Devi and Rao, 1986, Deb 1989, Frazier and Margaritoulis, 1990, Chhapgar, 1995, Chhapgar and Mundkur, 1995, Yeragi and Yeragi, 1997, Chhapgar *et al.* 2004, Ghosh 2004, Chanda and Roy, 2004, Subba Rao and Sastry 2005, Fernando, 2006, Saravanakumar *et al.* 2007, Burton and Davie, 2007, Dev Roy, 2008, 2013, Trivedi and Vachhrajani, 2012, Trivedi *et al.* 2012, 2015a,b, 2016a,b, 2018, 2020, 2021a,b, Shukla *et al.* 2013, Pandya and Vachhrajani, 2013, Pati and Sharma, 2014, Beleem *et al.* 2014, 2016, 2017, Kachhiya *et al.*, 2016, 2017, Solanki *et al.*, 2016, Gosavi *et al.*, 2017, 2021, Parmar *et al.*, 2018, Purohit and Vachhrajani, 2019, Vaidya and Vachhrajani, 2021).

The literature survey indicated presence of 145 species of the phylum Arthropoda classified under 4 Orders, 25 superfamilies, 38 families and 84 genera from the freshwater, estuarine

and marine regions of the Gulf of Khambhat (Table 2.3). From the freshwater environment, three species and forty-eight species from brackish water were recorded. There were 109 species which are exclusively marine and fifteen species which occur in both the estuarine and marine environments.

The mangrove-associated crab *Lyphira georgei* (Trivedi *et al.*, 2016) was initially described from the Mahi Sagar River and the lower estuarine regions. This species is one of the possible endemics of the Gulf of Khambhat.

Table 2.3: Checklist of species representing the phylum Arthropoda based on secondary literature

Phylum – Arthropoda

Class - Malacostraca

S No .	order	Super family	Family	Scientific name	Common Name	Habitat			IUCN status	Re marks	References
						FW	BW	MW			
1.	Decapoda	Dromioid ea	Dromiidae	<i>Ascidiphilus caphyraeformis</i> (Richters, 1880)		-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Dev Roy 2008; Dev Roy 2013; Trivedi et al., 2018.
2.	Decapoda	Dromioid ea	Dromiidae	<i>Conchoecetes artificiosus</i> (Fabricius, 1798)		-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
3.	Decapoda	Calappoid ea	Calappidae	<i>Calappa exanthematosa</i> (Alcock & Anderson, 1894)	Box Crab	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
4.	Decapoda	Calappoid ea	Calappidae	<i>Calappa guerini</i> Brito-(Capello, 1871)	Box Crab	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
5.	Decapoda	Calappoid ea	Matutidae	<i>Ashtoret lunaris</i> (Forskål, 1775)	Yellow mooncrab , spotted moon crab or box crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Chhapgar et al. 2004; Dev Roy 2013; Trivedi et al., 2018.
6.	Decapoda	Calappoid ea	Matutidae	<i>Ashtoret miersii</i> (Henderson, 1887)	Moon Crab	-	-	+	Not Evaluated	NA	Dev Roy 2013; Trivedi et al., 2018.

7.	Decapoda	Calappoid ea	Matutidae	<i>Matuta planipes</i> (Fabricius, 1798)	Flower moon crab	-	-	+	Not Evaluated	NA	Chhapgar et al. 2004; Trivedi & Vachhrajani 2012; Dev Roy 2013; Trivedi et al., 2018.
8.	Decapoda	Calappoid ea	Matutidae	<i>Matuta victor</i> (Fabricius, 1781)	Common moon crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Shukla et al. 2013; Dev Roy 2013; Pandya and Vachhrajani 2013; Trivedi et al., 2018.
9.	Decapoda	Dorippoid ea	Dorippidae	<i>Dorippoides nudipes</i> (Manning & Holthuis, 1986)		-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
10.	Decapoda	Dorippoid ea	Menippida e	<i>Myomenippe hardwickii</i> (Gray, 1831)	Mangrove stone crab	-	+	-	Not Evaluated	NA	Dev Roy 2008; Trivedi & Vachhrajani 2012; Trivedi et al., 2018.
11.	Decapoda	Dorippoid ea	Menippida e	<i>Epixanthus frontalis</i> (H. Milne Edwards, 1834)		-	-	+	Not Evaluated	NA	Trivedi & Vachhrajani 2012; Trivedi et al., 2018.
12.	Decapoda	Dorippoid ea	Menippida e	<i>Eriphia sebana</i> Shaw & (Nodder, 1803)	Smoothre deye crab	-	-	+	Not Evaluated	NA	Gopalakrishnan 1970; Trivedi et al., 2018.
13.	Decapoda	Dorippoid ea	Menippida e	<i>Eriphia smithii</i> (MacLeay, 1838)	Roughred eyecrab	-	-	+	Not Evaluated	NA	Thomas 1969; Gopalakrishnan

											1970; Trivedi & Vachhrajani 2012; Trivedi et al., 2018.
14.	Decapoda	Goneplac oidea	Euryplacid ae	<i>Eucrater crenata</i> (De Haan, 1835)	Bluntspined euryplacid crab	-	-	+	Not Evaluated	NA	Chandy 1973; Trivedi et al., 2018.
15.	Decapoda	Goneplac oidea	Euryplacid ae	<i>Eucrater indica</i> (Castro & Ng, 2010)	Indian euryplacid crab	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
16.	Decapoda	Goneplac oidea	Euryplacid ae	<i>Dentoxanthus iranicus</i> (Stephensen, 1946)		-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
17.	Decapoda	Goneplac oidea	Euryplacid ae	<i>Barusa guerini</i> (H. Milne Edwards, 1853)		+	-	+	Least Concern	NA	Pati and Sharma 2014.
18.	Decapoda	Leucosioidea	Iphiculiidae	<i>Pariphiculus mariannae</i> (Herklots, 1852)		-	-	+	Not Evaluated	NA	Chandy 1973; Dev Roy 2013; Trivedi et al., 2018.
19.	Decapoda	Leucosioidea	Leucosiidae	<i>Arcania heptacantha</i> (De Haan, 1861)		-	-	+	Not Evaluated	NA	Beleem et al. 2016; Trivedi et al., 2018.
20.	Decapoda	Leucosioidea	Leucosiidae	<i>Arcania septemspinosa</i> (Fabricius, 1787)	Seven Spined Box Crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Subba Rao & Sastry 2005; Dev Roy 2013; Trivedi et al., 2018.

21.	Decapoda	Leucosioidea	Leucosiidae	<i>Leucosia sima</i> (Alcock, 1896)		-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Subba Rao & Sastry 2005; Dev Roy 2013; Trivedi et al., 2018.
22.	Decapoda	Leucosioidea	Leucosiidae	<i>Lyphira georgei</i> (Trivedi, Soni & Vachhrajani, 2016)		-	-	+	Not Evaluated	NA	Trivedi et al. 2016a; 2018.
23.	Decapoda	Majoidea	Epialtidae	<i>Doclea muricata</i> (Fabricius, 1788)		-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
24.	Decapoda	Majoidea	Epialtidae	<i>Doclea rissoni</i> (Leach, 1815)		-	-	+	Not Evaluated	NA	Chandy 1973; Dev Roy 2013; Trivedi et al., 2018.
25.	Decapoda	Majoidea	Inachidae	<i>Camposcia retusa</i> (Latreille, 1829)	Decorator crab or Harlequin crab	-	-	+	Not Evaluated	NA	Beleem et al. 2017; Trivedi et al., 2018.
26.	Decapoda	Hymenosomatoida	Hymenosomatidae	<i>Elamena cristatipes</i> (Gravely, 1927)		-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Subba Rao & Sastry 2005; Trivedi et al., 2018.
27.	Decapoda	Hymenosomatoida	Hymenosomatidae	<i>Elamena sindensis</i> (Alcock, 1900)		-	-	+	Not Evaluated	NA	Chhapgar 1958; Dev Roy 2013; Trivedi et al., 2018.

28.	Decapoda	Partheno poidea	Parthenopi dae	<i>Enoplolambrus pransor</i> (Herbst, 1796 [in Herbst, 1791-1796])		-	-	+	Not Evaluated	NA	Chhapgar 1957a, Gosavi et al., 2021.
29.	Decapoda	Pilumnoi dea	Pilumnidae	<i>Eurycarcinus orientalis</i> (A. Milne-Edwards, 1867)		-	+	-	Not Evaluated	NA	Chhapgar 1957a, c; Trivedi et al. 2012; Pandya & Vachhrajani 2013; Trivedi et al., 2018 and Gosavi et al., 2021.
30.	Decapoda	Pilumnoi dea	Pilumnidae	<i>Glabropilumnus laevis</i> (Dana, 1852)		-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Subba Rao & Sastry 2005; Dev Roy 2013; Trivedi et al., 2018.
31.	Decapoda	Pilumnoi dea	Pilumnidae	<i>Heteropanope glabra</i> (Stimpson, 1858)		-	-	+	Not Evaluated	NA	Trivedi et al. 2015b; Trivedi et al., 2018.
32.	Decapoda	Pilumnoi dea	Pilumnidae	<i>Heteropilumnus angustifrons</i> (Alcock, 1900)		-	-	+	Not Evaluated	NA	Chandy 1973; Dev Roy 2013; Trivedi et al., 2018.
33.	Decapoda	Pilumnoi dea	Pilumnidae	<i>Benthopanope indica</i> (de Man, 1887 [in de Man, 1887-1888])		-	-	+	Not Evaluated	NA	Gosavi et al., 2021. Trivedi et al., 2021b.

34.	Decapoda	Pilumnoidea	Pilumnidae	<i>Pilumnopeus convexus</i> (Maccagno, 1936)		-	-	+	Not Evaluated	NA	Gosavi et al., 2017, 2021; Trivedi et al., 2018.
35.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis affinis</i> (Dana, 1852)	Smooth shelled swimming crab	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
36.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis annulata</i> (Fabricius, 1798)	Banded le gged swimming crab	-	-	+	Not Evaluated	NA	Dev Roy & Nandi 2005a; Dev Roy 2013; Trivedi & Vachharajani 2012; Trivedi et al., 2018.
37.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis callianassa</i> (Herbst, 1798)		-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Dev Roy 2013; Trivedi et al., 2018 and Gosavi et al ., 2021.
38.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis feriata</i> (Linnaeus, 1758)	Crucifix crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Trivedi et al. 2012; Dev Roy 2013; Trivedi et al., 2018; Gosavi et al., 2021.
39.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis lucifera</i> (Fabricius, 1798)	Yellowish -brown crab	-	-	+	Not Evaluated	NA	Trivedi & Vachhrajani

											2012; Trivedi et al., 2018.
40.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis miles</i> (De Haan, 1835)	Soldier swimming crab	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
41.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis natator</i> (Herbst, 1794)	Ridged swimming crab	-	-	+	Not Evaluated	NA	Chandy 1973; Dev Roy & Nandi 2005a; Dev Roy 2013; Trivedi et al., 2018.
42.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis orientalis</i> (Dana, 1852)		-	-	+	Not Evaluated	NA	Chandy 1973; Dev Roy & Nandi 2005a; Dev Roy 2013; Trivedi et al., 2018.
43.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis hoplites</i> (Wood-Mason, 1877)		-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
44.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis smithii</i> (MacLeay, 1838)	Swimming crab	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
45.	Decapoda	Pilumnoidea	Pilumnidae	<i>Charybdis vadorum</i> (Alcock, 1899)		-	-	+	Not Evaluated	NA	Trivedi et al., 2018a, b; Gosavi et al., 2021.
46.	Decapoda	Pilumnoidea	Pilumnidae	<i>Monomia petrea</i> (Alcock, 1899)		-	-	+	Not Evaluated	NA	Dev Roy & Nandi 2005a; Trivedi et al., 2018.

47.	Decapoda	Pilumnoidea	Pilumnidae	<i>Podophthalmus vigil</i> (Fabricius, 1798)	Periscope crab	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.
48.	Decapoda	Pilumnoidea	Pilumnidae	<i>Portunus sanguinolentus</i> (Herbst, 1783)	Three-spot swimming crab, blood-spotted swimming crab or red-spotted swimming crab	-	+	+	Not Evaluated	NA	Dev Roy 2013; Trivedi et al., 2018; Gosavi et al., 2021.
49.	Decapoda	Pilumnoidea	Pilumnidae	<i>Portunus segnis</i> (Forskål, 1775)	Swimming blue crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Trivedi et al. 2012; Dev Roy 2013; Beleem et al. 2014; Trivedi et al., 2018.
50.	Decapoda	Pilumnoidea	Pilumnidae	<i>Scylla olivacea</i> (Herbst, 1796)	Orange mud crab	-	+	-	Not Evaluated	NA	Trivedi & Vachhrajani 2013b; Trivedi et al., 2018.
51.	Decapoda	Pilumnoidea	Pilumnidae	<i>Scylla serrata</i> (Forskål, 1775)	Mud crab or mangrove crab	-	+	-	Not Evaluated	NA	Chhapgar 1957a, c; Trivedi & Vachhrajani 2013b; Dev Roy 2013; Trivedi

											et al., 2018; Gosavi et al., 2021.
52.	Decapoda	Pilumnoidea	Pilumnidae	<i>Scylla tranquebarica</i> (Fabricius, 1798)	Purple mud crab	-	+	-	Not Evaluated	NA	Trivedi & Vachhrajani 2013b; Trivedi et al., 2018; Gosavi et al., 2021.
53.	Decapoda	Pilumnoidea	Pilumnidae	<i>Thalamita crenata</i> (Latreille, 1829)	Powder blue-clawed swimming crab or crenate swimming crab or spiny rock crab	-	+	-	Not Evaluated	NA	Trivedi et al., 2018.
54.	Decapoda	Pilumnoidea	Pilumnidae	<i>Thalamita prymna</i> (Herbst, 1803)	Bluespined swimming crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Dev Roy 2013; Trivedi et al., 2018.
55.	Decapoda	Pilumnoidea	Pilumnidae	<i>Xiphonectes tenuipes</i> (De Haan, 1835)		-	-	+	Not Evaluated	NA	Dev Roy 2013; Trivedi et al., 2018.
56.	Decapoda	Xanthoidea	Xanthidae	<i>Actaea calculosa</i> (H. Milne Edwards, 1834)		-	-	+	Not Evaluated	NA	Deb 1989a; Dev Roy 2013; Trivedi et al., 2018.

57.	Decapoda	Xanthoidea	Xanthidae	<i>Actaea savignii</i> (H. Milne Edwards, 1834)	Spinylegged rock crab	-	-	+	Not Evaluated	NA	Alcock 1898; Dev Roy 2013; Trivedi et al., 2018.
58.	Decapoda	Xanthoidea	Xanthidae	<i>Atergatis integerrimus</i> (Lamarck, 1818)	Red egg crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Dev Roy & Nandi 2005a; Trivedi et al. 2012; Beleem et al. 2014; Trivedi et al., 2018.
59.	Decapoda	Xanthoidea	Xanthidae	<i>Etisus laevimanus</i> (Randall, 1840)	Smooth spooner crab	-	-	+	Not Evaluated	NA	Chhapgar 1957a, c; Trivedi & Vachhrajani 2012; Dev Roy 2013; Trivedi et al., 2018.
60.	Decapoda	Xanthoidea	Xanthidae	<i>Euxanthus exsculptus</i> (Herbst, 1790)		-	-	+	Not Evaluated	NA	Chhapgar 1995; Chhapgar & Mundkur 1995; Trivedi et al., 2018.
61.	Decapoda	Xanthoidea	Xanthidae	<i>Leptodius exaratus</i> (H. Milne Edwards, 1834)	Fan round crab	-	-	+	Not Evaluated	NA	Chandy 1973; Dev Roy & Nandi 2005a; Dev Roy 2013; Trivedi et al., 2018.
62.	Decapoda	Grapsoidea	Grapsidae	<i>Grapsus albolineatus</i>	Mottled Crab,	-	-	+	Not Evaluated	NA	Trivedi et al., 2018.

				(Latreille, in Milbert, 1812)	Shore Crab						
63.	Decapoda	Grapsoidea	Sesarmidae	<i>Episesarma mederi</i> (H. Milne Edwards, 1854)		-	+	-	Not Evaluated	NA	Saravanakumar et al. 2007; Dev Roy 2008; Trivedi et al. 2012; Trivedi et al., 2018.
64.	Decapoda	Grapsoidea	Sesarmidae	<i>Labuanium vitatum</i> (Ng & Davie, 2011)		-	+	-	Not Evaluated	NA	Trivedi et al., 2018.
65.	Decapoda	Grapsoidea	Sesarmidae	<i>Nanosesarma jousseaumei</i> (Nobili, 1996)		-	+	-	Not Evaluated	NA	Ghosh 2004; Dev Roy 2013; Trivedi et al., 2018.
66.	Decapoda	Grapsoidea	Sesarmidae	<i>Nanosesarma minutum</i> (De Man, 1887)		-	+	-	Not Evaluated	NA	Saravanakumar et al. 2007; Dev Roy 2013; Trivedi et al., 2018; Gosavi et al., 2021.
67.	Decapoda	Grapsoidea	Sesarmidae	<i>Neosarmatium smithi</i> (H. Milne Edwards, 1853)		-	+	-	Not Evaluated	NA	Chhapgar 1957b, c; Chandy 1973; Trivedi et al., 2018.
68.	Decapoda	Grapsoidea	Sesarmidae	<i>Parasesarma persicum</i> (Naderloo & Schubart, 2010)		-	+	-	Not Evaluated	NA	Trivedi and Vachhrajani 2017; Trivedi & Vachhrajani, 2018a; Trivedi et al., 2018;

											Gosavi et al., 2021.
69.	Decapoda	Grapsoidea	Sesarmidae	<i>Parasesarma plicatum</i> (Latreille, 1803)		-	+	-	Not Evaluated	NA	Chhapgar 1957b, c; Dev Roy & Nandi 2005a; Saravanakumar et al. 2007; Trivedi et al., 2018; Gosavi et al., 2021.
70.	Decapoda	Grapsoidea	Sesarmidae	<i>Pseudosesarma glabrum</i> (Ng, Rani & Nandan, 2017)		-	+	-	Not Evaluated	NA	Gosavi et al., 2021.
71.	Decapoda	Grapsoidea	Sesarmidae	<i>Selatium brockii</i> (De Man, 1887)		-	+	-	Not Evaluated	NA	Saravanakumar et al. 2007; Trivedi et al., 2018.
72.	Decapoda	Grapsoidea	Sesarmidae	<i>Selatium brockii</i> (De Man, 1887)		-	+	-	Not Evaluated	NA	Saravanakumar et al. 2007; Trivedi et al., 2018.
73.	Decapoda	Grapsoidea	Sesarmidae	<i>Metopograpsus latifrons</i> (White, 1847)		-	+	-	Not Evaluated	NA	Chhapgar 1957b, c; Trivedi et al., 2018; Gosavi et al., 2021.
74.	Decapoda	Grapsoidea	Sesarmidae	<i>Metopograpsus messor</i> (Forskål, 1775)		-	+	-	Not Evaluated	NA	Trivedi et al., 2018; Gosavi et al., 2021.

75.	Decapoda	Grapsoidea	Sesarmidae	<i>Metopograpsus thukuhar</i> (Owen, 1839)	Alamihicrab	-	+	-	Not Evaluated	NA	Trivedi et al., 2018.
76.	Decapoda	Grapsoidea	Varunidae	<i>Metaplex indica</i> (H. Milne Edwards, 1852)		-	-	+	Not Evaluated	NA	Chhapgar 1957b, c; Trivedi et al. 2012; Shukla et al. 2013; Trivedi et al., 2018; Gosavi et al., 2021.
77.	Decapoda	Grapsoidea	Varunidae	<i>Ptychognathus barbatus</i> (A. Milne-Edwards, 1873)		+	+	-	Not Evaluated	NA	Ghosh 2004; Dev Roy 2013; Trivedi et al., 2018.
78.	Decapoda	Grapsoidea	Varunidae	<i>Varuna litterata</i> (Fabricius, 1798)		+	+	-	Not Evaluated	NA	Chhapgar 1957b, c; Trivedi et al., 2018; Gosavi et al., 2021.
79.	Decapoda	Grapsoidea	Varunidae	<i>Circulium vitatum</i> (P.K.L. Ng & Davie, 2011)		-	-	-	Not Evaluated	Terr estri al crab	Chhapgar, 1957b; Gosavi et al., 2021.
80.	Decapoda	Ocypodoidea	Camptandriidae	<i>Leptochryseus kuwaitense</i> (Jones & Clayton, 1983)		-	-	+	Not Evaluated	NA	Trivedi et al., 2018.

81.	Decapoda	Ocypodoidea	Camptandriidae	<i>Nasima dotilliformis</i> (Alcock, 1900)		-	+	-	Not Evaluated	NA	Trivedi et al., 2018.
82.	Decapoda	Ocypodoidea	Camptandriidae	<i>Opusia indica</i> (Alcock, 1900)		-	+	-	Not Evaluated	NA	Trivedi et al., 2018.
83.	Decapoda	Ocypodoidea	Dotillidae	<i>Dotilla blanfordi</i> (Alcock 1900)		-	+	+	Not Evaluated	NA	Saravanakumar et al. 2007; Dev Roy 2013; Trivedi et al., 2018; Gosavi et al., 2021.
84.	Decapoda	Ocypodoidea	Dotillidae	<i>Dotilla myctiroides</i> (H. Milne Edwards, 1852)		-	+	+	Not Evaluated	NA	Saravanakumar et al. 2007; Dev Roy 2013
85.	Decapoda	Ocypodoidea	Dotillidae	<i>Ilyoplax frater</i> (Kemp, 1919)		-	+	+	Not Evaluated	NA	Trivedi et al., 2018.
86.	Decapoda	Ocypodoidea	Dotillidae	<i>Ilyoplax sayajiraoi</i> (Trivedi, Soni, Trivedi & Vachhrajani, 2015)		-	+	+	Not Evaluated	NA	Trivedi et al., 2015; 2018; Gosavi et al., 2021; Vaidya&Vachhrajani (2021).
87.	Decapoda	Ocypodoidea	Dotillidae	<i>Ilyoplax stevensi</i> (Kemp, 1919)		-	+	+	Not Evaluated	NA	Trivedi et al., 2018.
88.	Decapoda	Ocypodoidea	Dotillidae	<i>Scopimera crabricauda</i> (Alcock, 1900)		-	+	+	Not Evaluated	NA	Trivedi et al., 2018.

89.	Decapoda	Ocypodoidea	Dotillidae	<i>Scopimera proxima</i> (Kemp, 1919)		-	+	+	Not Evaluated	NA	Trivedi et al., 2018; Gosavi et al., 2021.
90.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Chaenostoma sinuspersici</i> (Naderloo & Türkay, 2011)		-	-	+	Not Evaluated	NA	Trivedi & Vachhrajani 2017; Trivedi et al., 2018.
91.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Macrophthalmus sulcatus</i> (H. Milne Edwards, 1852)	Sulcated Crab	-	+	+	Not Evaluated	NA	Chhapgar 1957b, c; Shukla et al. 2013; Pandya & Vachhrajani 2013; Trivedi et al., 2018; Gosavi et al., 2021.
92.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Macrophthalmus brevis</i> (Herbst, 1804 [in Herbst, 1799-1804])		-	+	+	Not Evaluated	NA	Pandya & Vachhrajani 2013; Gosavi et al., 2021.
93.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Macrophthalmus crinitus</i> (Rathbun, 1913)	Little sentinel crab	-	+	+	Not Evaluated	NA	Chhapgar 1957b, c; Dev Roy 2013; Trivedi et al., 2018.
94.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Macrophthalmus depressus</i> (Rüppell, 1830)	Depressed mud crab.	-	+	+	Not Evaluated	NA	Chhapgar 1957b, c; Saravanakumar et al. 2007; Trivedi et al., 2018; Gosavi et al., 2021.

95.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Macrophthalmus laevis</i> (A. Milne-Edwards, 1867)		-	+	+	Not Evaluated	NA	Trivedi et al. 2014, 2018; Gosavi et al., 2021.
96.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Macrophthalmus pacificus</i> (Dana, 1851)		-	+	+	Not Evaluated	NA	Chhapgar 1957b, c; Dev Roy 2013; Trivedi et al., 2018.
97.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Macrophthalmus japonicus</i> (De Haan, 1835)		-	+	+	Not Evaluated	NA	Trivedi et al., 2018.
98.	Decapoda	Ocypodoidea	Macrophthalmidae	<i>Venitus dentipes</i> (Lucas, in Guérin-Méneville, 1838)		-	+	-	Not Evaluated	NA	Chhapgar 1957b, c; Dev Roy 2008; Trivedi et al. 2012; Trivedi et al., 2018; Gosavi et al., 2021.
99.	Decapoda	Ocypodoidea	Ocypodidae	<i>Austruca annulipes</i> (H. Milne Edwards, 1837)	Fiddler Crab	-	+	-	Not Evaluated	NA	Chhapgar 1957b; Trivedi et al., 2018; Gosavi et al., 2021.
100.	Decapoda	Ocypodoidea	Ocypodidae	<i>Austruca iranica</i> (Pretzmann, 1971)	Fiddler Crab	-	+	-	Not Evaluated	NA	Trivedi and Vachhrajani 2017; Trivedi et al., 2018.
101.	Decapoda	Ocypodoidea	Ocypodidae	<i>Austruca sindensis</i> (Alcock, 1900)	Fiddler Crab	-	+	-	Not Evaluated	NA	Chhapgar 1958; Dev Roy 2013; Trivedi

											et al., 2018; Gosavi et al., 2021.
102.	Decapoda	Ocypodoidea	Ocypodidae	<i>Gelasimus vocans</i> (Linnaeus, 1758)	Fiddler Crab	-	+	-	Not Evaluated	NA	Shukla et al. 2013; Trivedi et al., 2018; Gosavi et al., 2021.
103.	Decapoda	Ocypodoidea	Ocypodidae	<i>Ocypode brevicornis</i> (H. Milne Edwards, 1837)	Ghost crab	-	-	+	Not Evaluated	NA	Chhapgar et al. 2004; Dev Roy 2013; Trivedi et al., 2018.
104.	Decapoda	Ocypodoidea	Ocypodidae	<i>Ocypode ceratophthalmus</i> (Pallas, 1772)	Horned ghost crab or horn-eyed ghost crab	-	-	+	Not Evaluated	NA	Chhapgar 1957b, c; Trivedi et al. 2012; Dev Roy 2013; Trivedi et al., 2018; Gosavi et al., 2021.
105.	Decapoda	Ocypodoidea	Ocypodidae	<i>Ocypode cordimana</i> (Latreille, 1818)	Smooth-handed ghost crab	-	-	+	Not Evaluated	NA	Chhapgar 1957b, c; Trivedi et al., 2018; Gosavi et al., 2021.
106.	Decapoda	Ocypodoidea	Ocypodidae	<i>Ocypode macrocera</i> (H. Milne Edwards, 1852)	Red ghost crab	-	-	+	Not Evaluated	NA	Saravanakumar et al. 2007; Trivedi et al., 2018.
107.	Decapoda	Ocypodoidea	Ocypodidae	<i>Ocypode rotundata</i> (Miers, 1882)	Rounded ghost crab	-	-	+	Not Evaluated	NA	Alcock 1900b; Chhapgar 1957b, c; Dev

											Roy 2013; Trivedi et al., 2018.
108.	Decapoda	Ocypodoidea	Ocypodidae	<i>Tubuca acuta</i> (Stimpson, 1858)	Acute fiddler crab	-	+	-	Not Evaluated	NA	Saravanakumar et al. 2007; Trivedi et al., 2018.
109.	Decapoda	Ocypodoidea	Ocypodidae	<i>Tubuca alcocki</i> (Shih, Chan & Ng, 2018)	Fiddler crab	-	+	-	Not Evaluated	NA	Chandy 1973; Trivedi et al. 2015c; Trivedi et al., 2018.
110.	Decapoda	Ocypodoidea	Ocypodidae	<i>Tubuca dussumieri</i> (H. Milne Edwards, 1852)	Dussumier's Fiddler Crab	-	+	-	Not Evaluated	NA	Chhapgar 1957b, c; Trivedi et al. 2012; Pandya & Vachhrajani 2013; Dev Roy 2013; Trivedi et al., 2018; Gosavi et al., 2021.
111.	Decapoda	Pinnothereoidea	Pinnotheridae	<i>Arcotheres placunae</i> (Hornell & Southwell, 1909)	Pea crab	-	-	+	Not Evaluated	NA	Hornell & Southwell 1909; Tesch 1918; Silas & Algarswami 1967; Schmitt et al. 1973; Devi & Rao 1986; Yeragi & Yeragi 1997; Subba Rao & Sastry 2005;

											Trivedi et al., 2018.
112.	Decapoda	Pinnotheroidea	Plagusiidae	<i>Plagusia squamosa</i> (Herbst, 1790)	Tidal Spray Crab	-	-	+	Not Evaluated	NA	Chhapgar 1957b, c; Trivedi & Vachhrajani 2012; Dev Roy 2013; Trivedi et al., 2018.
113.	Decapoda	Penaeoid ea	Penaeidae	<i>Metapenaeus dobsoni</i> (Miers, 1878)	Kadal shrimp	-	-	+	Least Concern	NA	Patel and Balapatel 1983; Solanki et al., 2016; Gosavi et al., 2021.
114.	Decapoda	Penaeoid ea	Penaeidae	<i>Metapenaeus kutchensis</i> (P.C. George, M.J. George & Rao, 1963)	Ginger shrimp	-	-	+	Least Concern	NA	Jebakumar et al., 2015.
115.	Decapoda	Penaeoid ea	Penaeidae	<i>Metapenaeus monoceros</i> (Fabricius, 1798)	Pink shrimp or brown shrimp or speckled shrimp	-	-	+	Least Concern	NA	Chanda and Roy, 2004; Gosavi et al., 2021.
116.	Decapoda	Penaeoid ea	Penaeidae	<i>Mierspenaeopsis sculptilis</i> (Heller, 1862)	Rainbow shrimp	-	-	+	Least Concern	NA	Chanda and Roy, 2004; Solanki et al., 2016; Gosavi et al., 2021.

117.	Decapoda	Penaeoid ea	Penaeidae	<i>Penaeus monodon</i> (Fabricius, 1798)		-	-	+	Least Concern	NA	Solanki et al., 2016; Gosavi et al., 2021.
118.	Decapoda	Alpheoide a	Alpheidae	<i>Alpheus lobidens</i> (De Haan, 1849)		-	-	+	Least Concern	NA	Purohit and Vachhrajani, 2019a; Gosavi et al., 2021.
119.	Decapoda	Paguroide a	Diogenidae	<i>Clibanarius infraspinatus</i> (Hilgendorf, 1869)		-	-	+	Least Concern	NA	Kachhiya et al., 2016, 2017; Gosavi et al., 2021.
120.	Decapoda	Paguroide a	Diogenidae	<i>Clibanarius longitarsus</i> (De Haan, 1849 [in De Haan, 1833- 1850])		-	-	+	Least Concern	NA	Kachhiya et al., 2016, 2017; Gosavi et al., 2021.
121.	Decapoda	Paguroide a	Diogenidae	<i>Clibanarius rhabdodactylus</i> (Forest, 1953)		-	-	+	Least Concern	NA	Kachhiya et al., 2016, 2017; Gosavi et al., 2021.
122.	Decapoda	Paguroide a	Diogenidae	<i>Clibanarius rutilus</i> (Rahayu, 1999)		-	-	+	Least Concern	NA	Kachhiya et al., 2016; Gosavi et al., 2021.
123.	Decapoda	Paguroide a	Diogenidae	<i>Clibanarius signatus</i> (Heller, 1961)		-	-	+	Least Concern	NA	Kachhiya et al., 2016; Gosavi et al., 2021.
124.	Decapoda	Paguroide a	Diogenidae	<i>Clibanarius virescens</i> (Krauss, 1843)		-	-	+	Least Concern	NA	Kachhiya et al., 2017; Gosavi et al., 2021.
125.	Decapoda	Paguroide a	Diogenidae	<i>Dardanus setifer</i> (H. Milne Edwards, 1836)		-	-	+	Least Concern	NA	Kachhiya et al., 2016; Gosavi et al., 2021.

126.	Decapoda	Paguroidea	Diogenidae	<i>Diogenes avarus</i> (Heller, 1865)		-	+	-	Least Concern	NA	Kachhiya et al., 2016; Gosavi et al., 2021.
127.	Decapoda	Paguroidea	Diogenidae	<i>Diogenes chhappari</i> (Trivedi, Osawa & Vachhrajani, 2016)		-	+	-	Least Concern	NA	Trivedi et al., 2016b; Gosavi et al., 2021.
128.	Stomatopoda	Gonodactyloidea	Gonodactylidae	<i>Gonodactylellus demanii</i> (Henderson, 1893)		-	-	+	Not Evaluated	NA	Shanbhogue 1969; Trivedi et al., 2020.
129.	Stomatopoda	Gonodactyloidea	Gonodactylidae	<i>Gonodactylus chiragra</i> (Fabricius, 1781)		-	-	+	Not Evaluated	NA	Shanbhogue 1969; Trivedi et al., 2020.
130.	Stomatopoda	Gonodactyloidea	Gonodactylidae	<i>Gonodactylus smithii</i> (Pocock, 1893)		-	-	+	Not Evaluated	NA	Trivedi et al., 2020.
131.	Stomatopoda	Squilloidea	Squillidae	<i>Clorida bombayensis</i> (Chhapgar & Sane, 1967)		-	-	+	Not Evaluated	NA	Trivedi et al., 2020.
132.	Stomatopoda	Squilloidea	Squillidae	<i>Erugosquilla hesperia</i> (Manning, 1968)		-	-	+	Not Evaluated	NA	Trivedi et al., 2020.
133.	Stomatopoda	Squilloidea	Squillidae	<i>Harpisquilla harpax</i> (de Haan, 1844)		-	-	+	Not Evaluated	NA	Trivedi et al., 2020.
134.	Stomatopoda	Squilloidea	Squillidae	<i>Miyakella nepa</i> (Latreille in Latreille, Le		-	-	+	Not Evaluated	NA	Trivedi et al., 2020.

				Peletier, Serville & Guérin, 1828)							
Class – Thecostraca											
135.	Balanomorph	Coronuloid	Tetracitida	<i>Tetracitella ehsani</i> (Chan, Shahdadi & Sari, 2010)		-	-	+	Not Evaluated	NA	Trivedi et al., 2021a, b.
136.	Balanomorph	Coronuloid	Tetracitida	<i>Tetracitella karandei</i> (Ross, 1971)		-	-	+	Not Evaluated	NA	Trivedi et al., 2021b
137.	Balanomorph	Coronuloid	Tetracitida	<i>Tetracitella rufotincta</i> (Pilsbry, 1916)		-	-	+	Not Evaluated	NA	Daniel, 1972; Fernando, 2006; Parmar et al., 2018, Trivedi et al., 2021b
138.	Balanomorph	Coronuloid	Tetracitida	<i>Tetracitella karandei</i> (Ross, 1971)		-	-	+	Not Evaluated	NA	Trivedi et al., 2021b.
139.	Balanomorph	Chthamaloidea	Chthamalidae	<i>Microeuraphia withersi</i> (Pilsbry, 1916)		-	-	+	Not Evaluated	NA	Trivedi et al., 2021b
140.	Balanomorph	Chthamaloidea	Chthamalidae	<i>Chthamalus barnesi</i> (Achituv and Safriel, 1980)		-	-	+	Not Evaluated	NA	Trivedi et al., 2021a, b
141.	Balanomorph	Balanoidea	Balanidae	<i>Amphibalanus amphitrite</i> (Darwin, 1854)		-	-	+	Not Evaluated	NA	Trivedi et al., 2021a,
142.	Balanomorph	Balanoidea	Chelonibiidae	<i>Chelonibia testudinaria</i> (Linnaeus, 1758)		-	-	+	Not Evaluated	NA	Frazier and Margaritoulis (1990)
143.	Balanomorph	Balanoidea	Scyllaridae	<i>Thenus indicus</i> (Leach, 1816)		-	-	+	Not Evaluated	NA	Burton and Davie(2007).

144.	Balanomorphs	Balanoidea	Palinuridae	<i>Panulirus polyphagus</i> (Herbst, 1793)	Mud spiny lobster	-	-	+	Not Evaluated	NA	Jebakumar et al., 2015.
145.	Isopoda	Cymothoidea	Cymothoidae	<i>Nerocila depressa</i> (Milne Edwards, 1840)		-	-	+	Not Evaluated	NA	Sahoo et al., 2022.

2.4 Mollusca

The molluscs constitute the second largest phylum of invertebrates after the arthropods, comprising 23% of all marine organisms (Margulis and Schwartz, 1998) representing over 85,000 extant species comprising about 23% of all the named marine organisms. Molluscs are essential in the marine food chains and species are of direct or indirect commercial and even medical importance to humans. Many gastropods, bivalves, and cephalopods are a source of food for people and therefore play an essential role in the fishing industry of many countries (Ponder and Lindberg, 2008). The classes Aplousophora, Polyplousophora, Scaphopoda and Cephalopoda are exclusively marine forms about 2%, whereas two large classes such as Gastropoda and Bivalvia have extended into freshwater as well as land, constitute 98% of the total living molluscs (Ponder and Lindberg, 2008).

Initially, Hornell (1909, 1916) extensively surveyed the molluscan fauna of the Okhamandal coast. After that, Gideon *et al.* (1957) published a report on mollusks in the Gulf of Kachchh following a preliminary survey of the area. Simultaneously, Kundu (1965), and Menon *et al.* (1961) gave a detailed account of the Gulf of Kachchh's marine gastropods. Apte (1998, 2014), Surya Rao *et al.* (2004), Subba Rao and Sastry, (2005), Apte *et al.* (2010), Trivedi and Vachhrajani (2013), Vadher *et al.* (2014), Carmona *et al.* (2014), Soni and Thakur (2015), Venkataraman *et al.* (2015), Apte and Desai (2017) Solanki *et al.*, (2016, 2017), and Yadav *et al.* (2019) studied the molluscs of Gujarat coast. The study on the molluscan fauna of the Gulf of Khambhat was restricted to Pandya and Vachhrajani, (2012), Solanki *et al.*, (2016, 2017), and Yadav, *et al.* (2019).

Based on the published literature, a total of 48 species belongs to the phylum Mollusca were reported and classified under 2 Classes, 4 Orders, 25 superfamilies, 38 families and 48 genera from the freshwater, estuarine and marine regions of the Gulf of Khambhat (Table 2.4). There are 17 species inhabiting exclusively in freshwater habitats, 20 species from the brackish water environment, 22 species from the marine, and 11 species share both estuarine and marine environments.

Table 2.4: Checklist of species representing phylum Mollusca based on secondary literature

Phylum – Mollusca

Class - Gastropoda

Sr. no.	Order	Superfamily	Family	Scientific name	Common Name	Habitat			IUCN status	References
						FW	BW	MW		
1.	Trochida	Trochoidea	Tegulidae	<i>Rochia nilotica</i> (Linnaeus, 1767)	Banded Trochus Snail	-	-	+	Not evaluated. This species comes under the Sch IV Wildlife protection Act.	Solanki et al., 2016, Yadav et al 2019
2.	Trochida	Trochoidea	Tegulidae	<i>Trochus radiatus</i> (Gmelin, 1791)	Radiate top shell	-	-	+	Not evaluated	Solanki et al., 2016,
3.	Trochida	Trochoidea	Tegulidae	<i>Trochus cariniferus</i> (Reeve, 1842)	Top Shell	-	-	+	Not evaluated	Yadav et al 2019
4.	Cycloneritida	Neritoidea	Neritidae	<i>Neripteron violaceum</i> (Gmelin, 1791)	Violet Nerite	-	+	-	Not evaluated	Solanki et al., 2016, Yadav et al 2019
5.	Cycloneritida	Neritoidea	Neritidae	<i>Nerita balteata</i> (Reeve, 1855)		-	-	+	Not evaluated	Yadav et al 2019
6.	Caenogastrópoda	Cerithioidea	Cerithiidae	<i>Clypeomorus batillariaeformis</i> (Habe & Kosug, 1966)	Necklace or channeled cerith	-	+	+	Not evaluated	Solanki et al., 2016, Yadav et al 2019
7.	Caenogastrópoda	Cerithioidea	Cerithiidae	<i>Clypeomorus bifasciata</i> (G.B. Sowerby II, 1855)	Morus cerith	-	+	+	Not evaluated	Solanki et al., 2016, Yadav et al 2019

8.	Caenogastr opoda	Cerithioidea	Thiaridae	<i>Melanoides tuberculata</i> (O. F. Müller, 1774)	Red rimmed Melania	+	-	-	Least Concern	Pandya and Vachhrajani 2012,
9.	Caenogastr opoda	Cerithioidea	Thiaridae	<i>Tarebia granifera</i> (Lamarck, 1816)	Quilted Melania	+	-	-	Least Concern	Pandya and Vachhrajani 2012,
10.	Caenogastr opoda	Cerithioidea	Thiaridae	<i>Mieniplotia scabra</i> (O. F. Müller, 1774)		+	-	-	Least Concern	Pandya and Vachhrajani 2012,
11.	Caenogastr opoda	Cerithioidea	Thiaridae	<i>Sermyla riquetii</i> (Grateloup, 1840)		+	-	-	Least Concern	Pandya and Vachhrajani 2012,
12.	Caenogastr opoda	Cerithioidea	Potamidida e	<i>Pirenella cingulata</i> (Gmelin, 1791)	Horn snail	-	+	+	Least Concern	Solanki et al., 2016, 2017, Yadav et al 2019,
13.	Caenogastr opoda	Cerithioidea	Potamidida e	<i>Telescopium telescopium</i> (Linnaeus, 1758)	Telescope snail	-	+	-	Least Concern	Yadav et al 2019
14.	Caenogastr opoda	Cerithioidea	Potamidida e	<i>Cerithidea obtusa</i> (Lamarck, 1822)	Mud Creeper	-	+	-	Least Concern	Yadav et al 2019
15.	Caenogastr opoda	Cerithioidea	Turritellida e	<i>Turritella acutangula</i> (Linnaeus, 1758)		-	-	+	Not evaluated	Yadav et al 2019
16.	Architaenio glossa	Viviparoidea	Viviparidae	<i>Filopaludina bengalensis</i> (Lamarck, 1822)		+	-	-	Least Concern	Pandya and Vachhrajani 2012,
17.	Architaenio glossa	Viviparoidea	Viviparidae	<i>Mekongia crassa</i> (Benson, 1836)		+	-	-	Least Concern	Pandya and Vachhrajani 2012,
18.	Littorinimo rpha	Truncatelloi dea	Bithyniidae	<i>Bithynia textum</i> (Annandale, 1921)		+	-	-	Least Concern	Pandya and Vachhrajani 2012,
19.	Littorinimo rpha	Truncatelloi dea	Bithyniidae	<i>Gabbia alticola</i> (Annandale, 1918)		+	-	-	Least Concern	Pandya and Vachhrajani 2012,
20.	Littorinimo rpha	Truncatelloi dea	Pomatiopsi dae	<i>Tricula montana</i> (Benson, 1843)		+	-	-	Least Concern	Pandya and Vachhrajani 2012,

21.	Littorinimorpha	Truncatelloidea	Assimineidae	<i>Optediceros breviculum</i> (L. Pfeiffer, 1855)	Red mangrove snail	-	+	-	Least Concern	Solanki et al., 2016, Yadav et al 2019
22.	Littorinimorpha	Truncatelloidea	Assimineidae	<i>Angustassiminea nitida</i> (Pease, 1865)	Red mangrove snail	-	+	-	Least Concern	Yadav et al 2019
23.	Littorinimorpha	Truncatelloidea	Naticidae	<i>Paratectonatica tigrina</i> (Röding, 1798)	Moon snail	-	+	+	Not evaluated	Yadav et al 2019
24.	Neogastropoda	Muricoidea	Muricidae	<i>Purpura bufo</i> (Lamarck, 1822)	Toad shell	-	-	+	Not evaluated	Yadav et al 2019
25.	Neogastropoda	Buccinoidea	Nassariidae	<i>Nassarius stolatus</i> (Gmelin, 1791)		-	-	+	Not evaluated	Solanki et al., 2016, Yadav et al 2019
26.	Neogastropoda	Buccinoidea	Nassariidae	<i>Nassarius olivaceus</i> (Bruguière, 1789)	Olivaceous nassa	-	-	+	Not evaluated	Yadav et al 2019
27.	Neogastropoda	Buccinoidea	Nassariidae	<i>Nassarius pupinoides</i> (Reeve, 1853)	Mud snail	-	-	+	Not evaluated	Yadav et al 2019
28.	Ellobiida	Ellobioidea	Ellobiidae	<i>Melampus sincaporensis</i> (L. Pfeiffer, 1855)	Air breathing salt marsh snail	-	+	-	Least Concern	Yadav et al 2019
29.	Ellobiida	Ellobioidea	Ellobiidae	<i>Pythia plicata</i> (Férussac, 1821)	Coastal snail	-	+	-	Least Concern	Yadav et al 2019
30.	Ellobiida	Onchidioidea	Onchidiidae	<i>Peronia verruculata</i> (Cuvier, 1830)	Air breathing sea slug	-	+	+	Not evaluated	Solanki et al., 2016, Yadav et al 2019
31.	Ellobiida	Lymnaeoidea	Bulinidae	<i>Indoplanorbis exustus</i> (Deshayes, 1833)	Air breathing freshwater snail.	+	-	-	Not evaluated	Pandya and Vachhrajani 2012,

32.	Arcida	Arcoidea	Arcidae	<i>Tegillarca granosa</i> (Linnaeus, 1758)	Ark clam or Blood clam	-	+	+	Not evaluated	Yadav et al 2019
33.	Ostreida	Osteroidea	Ostereidae	<i>Saccostrea cucullata</i> (Born, 1778)	Hooded oyster or Natal rock oyster	-	-	+	Not evaluated	Yadav et al 2019
34.	Cardiida	Tellinoidea	Donacidae	<i>Donax incarnatus</i> (Gmelin, 1791)	Bean clams or wedge shells	-	+	+	Not evaluated	Pandya and Vachhrajani 2012,
35.	Venerida	Cyrenoidea	Cyrenidae	<i>Corbicula krishnaea</i> (Ray, 1967)		+	-	-	Not evaluated	Pandya and Vachhrajani 2012,
36.	Venerida	Cyrenoidea	Cyrenidae	<i>Corbicula peninsularis</i> (Prashad, 1928)		+	-	-	Not evaluated	Pandya and Vachhrajani 2012,
37.	Venerida	Cyrenoidea	Cyrenidae	<i>Corbicula sylhetica</i> (Preston, 1908)		+	-	-	Not evaluated	Pandya and Vachhrajani 2012,
38.	Venerida	Mactroidea	Mactridae	<i>Mactra grandis</i> (Gmelin, 1791)	Big brown mactra clam	-	+	+	Not evaluated	Yadav et al 2019
39.	Venerida	Mactroidea	Mactridae	<i>Mactra luzonica</i> (Reeve, 1854)	Luzon trough clam	-	+	+	Not evaluated	Yadav et al 2019
40.	Venerida	Veneroidea	Veneridae	<i>Meretrix meretrix</i> (Linnaeus, 1758)	Asiatic hard clam	-	+	-	Not evaluated	Yadav et al 2019
41.	Venerida	Veneroidea	Veneridae	<i>Pelecypora trigona</i> (Reeve, 1850)	Venus clam	-	+	-	Not evaluated	Yadav et al 2019
42.	Adapedont a	Solenoidea	Solenidae	<i>Solen guinensis</i> (Hanley, 1842)	Guinea razor clam	-	+	+	Not evaluated	Yadav et al 2019
43.	Adapedont a	Solenoidea	Solenidae	<i>Solen lamarckii</i> (Chenu, 1843)	Lamarck razor clam	-	+	+	Not evaluated	Yadav et al 2019
44.	Unionida	Unionoidea	Unionidae	<i>Parreysia corrugata</i> (O. F. Müller, 1774)		+	-	-	Not evaluated	Pandya and Vachhrajani 2012,

45.	Unionida	Unionoidea	Unionidae	<i>Radiatula chaudhurii</i> (Preston, 1912)		+	-	-	Not evaluated	Pandya and Vachhrajani 2012,
46.	Unionida	Unionoidea	Unionidae	<i>Indonaia rugosa</i> (Gmelin, 1791)		+	-	-	Not evaluated	Pandya and Vachhrajani 2012,
47.	Unionida	Unionoidea	Unionidae	<i>Indonaia caerulea</i> (I. Lea, 1831)		+	-	-	Not evaluated	Pandya and Vachhrajani 2012,
48.	Myida	Pholadoidea	Pholadidae	<i>Pholas orientalis</i> (Gmelin, 1791)	Orient Angel's Wing	-	-	+	Not evaluated	Yadav et al 2019

2.5 Phytoplankton

Phytoplankton are microscopic algae primarily found in the upper sunlit layer of aquatic ecosystems and occupying about 1% of the global biomass. Phytoplankton are extremely diverse and grouped into Bacillariophyta, Dinophyta, Cyanophyta, Chlorophyta, Euglenophyta, Chrysophyta, Cryptophyta, and Xanthophyta. They constitute the base of all aquatic food webs, play an essential role as primary producers, in nutrient cycling, and contribute to the climatic processes by regulating the carbon cycle. They are indicators of the health and productivity of the aquatic environment (Brutemark *et al.*, 2006; Goebel *et al.*, 2013). Generally, phytoplankton are dependent on the accessibility of nutrients, light, and other predominant conditions such as regional and seasonal variations of both physiological (salinity, temperature, currents, precipitation and mixing of water layers) as well as biological conditions (e.g. parasitic planktons, grazing, of potential predators, etc.) (Mackas *et al.* 1985; Fenchel 1988; Reid *et al.* 1990; Falkowski and Oliver 2007; Racault *et al.* 2012).

All the Phytoplankton act as primary producers and share the biological carbon pump. Subsequently, they take up carbon dioxide (CO₂) from the air and bind the carbon in their cells, which are then occupied by sophisticated trophic levels or convert part of sinking particles and remineralisation. Time balances for the carbon to re-enter the cycle and to be second hand can vary from days, over work weeks and years up to several times, particularly for carbon reaching the outward sediment area (Emerson and Hedges, 1988; Shen and Benner, 2018). Sinking particles that initiate from fragmentation, after ingesting by higher trophic levels, such as zooplankton, can either be expended again or be decomposed by microbial processes. At the same time, active vertical relocation by the organisms allocates the carbon further within different water layers and therefore has a noteworthy impact on the oceanic carbon cycle and productivity (Azam 1998; Buesseler *et al.* 2007).

Phytoplankton are subject to high fluctuations and show seasonality as well as spatial heterogeneity. To produce biomass, phytoplankton needs certain nutrients, the most important being carbon (C), nitrogen (N) and phosphorous (P). Redfield (1958) calculated the relationship between the important nutrients required for marine primary production as C: N: P = 106:16:1.

Phytoplankton can serve as an indicator of the climate or ecological change-induced swings in the plankton community. Earlier studies have exhibited that climate change does have a noticeable effect on the ocean (Madden and Ramanathan, 1980; Cess and Goldenberg, 1981; Hansen *et al.* 1981; Ramanathan, 1981; Etkins and Epstein, 1982). Enhanced carbon dioxide levels result in climate change worldwide, influencing precipitation and temperature. The global temperatures eventually lead to higher ocean temperatures and, therefore, a reduction of sea ice in both attenuation and thickness (Manabe and Stouffer 1980; Rhein *et al.* 2013). This results in local ocean desalination, to which phytoplankton cells must respond. Higher CO₂ saturation in the atmosphere will lead to a shift in equilibrium between air and water and result in the elevation of CO₂ concentration in the ocean. Thus, the ocean environment will become more acidic, potentially influencing sensitive molecular interactions (Kuma *et al.* 1996).

Considering the ecological importance of phytoplankton, numerous studies have been conducted from the freshwater systems, particularly in Sabarmati river (Kumar *et al.* 2012); Narmada river (Sharma, & Mankodi 2011); Hukal river (Chavada *et al.*, 2017); Tapti river (Sarang & Manoj, 2017), Mahi River (Sharma & Bhardwaj, 2011). Similarly, a number of investigations have been undertaken on the plankton communities of the coastal and estuarine ecosystems, Auranga, Ambika, Purna and Mindola estuaries (Desai *et al.* 1984), Tapti estuary (George *et al.* 2012), Narara and Poshitra Island (Joshi *et al.*, 2019); Gulf of Khambhat (Kauresh & Mankodi, 2007; Bhavsar & Pandya, 2018).

2.6 Zooplankton

The zooplankton comprises of organisms that float or drift on the surface and deeper layers of any aquatic surroundings and move passively along with water currents. Zooplankton are divided into three trophic groups such as herbivores, carnivores, and omnivores created on the morphology of their feeding apparatus, mode of feeding and nature of food (Morgado *et al.*, 2007). The gesture and biomass of zooplankton are mostly controlled by phytoplankton dispersal and community structure. It is strongly responsive to ecological variables which include physico-chemical parameters like light intensity, temperature, salinity, pH, dissolved oxygen, turbulence and availability of food source. The abundance of zooplankton in marine environment has a direct impact on fishery resources and it is

influenced by environmental parameters such as circulatory movements and vertical turbulent mixing. It plays a significant role in energy transfer in trophic level and the cycling of nutrients in marine environment.

The phytoplankton and zooplankton and the predator-prey relationship determine the organic export and transfer of energy to the higher order food chain. The density of zooplankton will serve as a vital factor for forecasting potential fisheries grounds (Mansor *et al.*, 2001), as it acts as an important foodstuff for a wide range of fish larvae and fishes.

The species composition of zooplankton in Indian water is very diverse and influenced by oceanic currents (Jagadeesan *et al.*, 2013), upwelling (Madhupratap *et al.*, 1990), high primary productivity (Smith and Madhupratap, 2005) and salinity (Jagadeesan *et al.*, 2013). In Indian context most of the studies in zooplankton ecology are confined to areas like cochin backwaters (Madhu *et al.*, 2007), Mandovi and Zuari estuary and their nearby area (Dalal, 2001) Vellar estuary and its adjacent coastal area (Santhanan *et al.*, 2003) and Hoogly estuary (Sarkar *et al.*, 2006).

Zooplankton studies in Gujarat coast in general, remained scanty and were limited to certain group and area specific, Foraminifera from Kharo creek, Gulf of Kachchh (Nigam & Chaturvedi, 2000; Kardani, 2011), Gulf of Khambhat (Nigam, 1984; Gosh, 2012), Sabarmati river and Central Gujarat (Soni, 1980, 2013) and Narmada River (Sharma, 2011).

The studies carried out by CSMCRI (2011) along the Gulf of Khambhat revealed high zooplankton density at Dahej ($3963.96 \times 10^3/\text{m}^3$) compared to the west coast of the Gulf of Khambhat ($284.2 \times 10^3/\text{m}^3$). Species such as Cyclops, Calanoids, and Nauplius dominated the zooplankton diversity in the studied region. The dominance of Cyclops indicated the presence of the hyper-nutritive condition in terms of pollution (Gavali *et al.*, 2021).

2.7 Chordata

Phylum Chordata is the most advanced faunal group consists of fishes, reptiles, birds and mammals. Chordates are distributed in all the available habitat types in the earth. In the following section the results of the literature survey on Chordates recorded in the study area of Kalpasar project in and around Gulf of Khambhat are described.

2.7.1 Ichthyofauna

Fishes occupy nearly all major aquatic habitats, from lakes, swamps, ponds, intertidal pools, ocean depths, and other benign environments within the various extremes. Fishes have been ecological dominants in aquatic habitats throughout the history of complex life. To colonize and thrive in various environments, fishes have evolved obvious and striking anatomical, physiological, behavioural, and ecological adaptations. Scientific descriptions exist for approximately 27,977 living species of fishes represented by 515 families and 62 orders (Nelson 2006). Fishes are typically divided into three groups: superclass Agnatha (jawlessfishes), class Chondrichthyes (cartilaginous fishes), and superclass Osteichthyes (bony fishes). The latter two groups are included within the infraphylum Gnathostomata, a category containing all jawed vertebrates (Nelson, 2006).

Ichthyofaunal investigation of the Gujarat state was started by the workers like Hora and Nair, (1941), Kulkarni (1950, 1951), Karamchandani, *et al.* (1967), and Karamchandani and Pandit, (1971). After that, Jayaram, (1981), Doria, (1990), Rao, *et al.* (1991), Talwar and Jhingran, (1991), Tuli and Pande, (1992), Menon (1999), Nath and Shrivastava (1999), Sen and Banerjee (2000), Burman *et al.*, (2000) and Chakraborty and Agrawal (2000), Arya *et al.* (2001), Jayaram (2006), Vyas *et al.* (2009), Singh (2009), Das *et al.* (2013), Bakawale and Kanhere, (2013), Bose *et al.* (2013), Mahendrasinh and Pradeep, (2013), Vyas and Vishwakarma (2013), Khedkar *et al.* (2014), Pathak, *et al.* (2014), Sharma *et al.* (2014), Vishwakarma, *et al.* (2014), Vishwakarma *et al.* (2014), Solanki *et al.* (2016), Saini and Dube (2017), Bhakta *et al.* (2018, 2019, 2020), CIFRI (2018), Shah *et al.* (2018), Kakodiya and Mehra (2018), Thakkar *et al.* (2018), Sarma and Mankodi (2019) and Bhatt and Mankodi (2020) had done significant contributions on the ichthyofaunal study throughout the state.

The major studies focused on the riverine fish fauna adjoining the Gulf of Khambhat are by Hora and Nair, (1941); Kulkarni, (1950, 1951); Karamchandani *et al.* (1967); Karamchandani and Pandit, (1971); Jayaram, (1981); Doria, (1990); Rao, *et al.* (1991); Tuli and Pande, (1992); Menon, (1999); Sen and Banerjee, (2000); Burman *et al.*, (2000); Chakraborty and Agrawal (2000); Singh, (2009); Vyas *et al.* (2009); Das, *et al.*, (2013);

Bakawale and Kanhere, (2013); Bose *et al.*, (2013); Mahendrasinh and Pradeep, (2013); Vyas and Vishwakarma, (2013); Khedkar *et al.*, (2014); Pathak, *et al.*, (2014); Sharma *et al.*, (2014); Vishwakarma *et al.*, (2014); Solanki *et al.*, (2016); Saini and Dube, (2017); Bhakta *et al.* (2018, 2019, 2020); CIFRI (2018); Shah *et al.* (2018); Kakodiya and Mehra, (2018); Thakkar *et al.* (2018); Sarma and Mankodi, (2019) and Bhatt and Mankodi, (2020).

Based on the above literatures, a total of 222 species of fishes under 3 Classes 15 Orders, 18 superfamilies, 54 families and 139 genera were enlisted from the freshwater, brackish water and marine regions of the Gulf of Khambhat. Totally 159 species which are from freshwater and 63 species are from the brackish water and marine environment. There were 72 species, which are exclusively marine and eight species share freshwater and brackish water, 45 species share brackish water and marine environments. Eight species share freshwater, brackish water, and marine environments and two species survive all the environments and there were six migratory fishes enlisted in the checklist (Table 2.5).

Table 2.5: Check list of Fish species in the Gulf of Khabhat and adjacent estuaries and rivers

Phylum – Chordata

Class - Elasmobranchii

S. no.	Order	Family	Scientific name	Common Name	Habitat			IUCN status	Remarks	References
					FW	BW	MW			
1.	Orectolobiformes	Hemiscyllidae	<i>Chiloscyllium griseum</i> (Müller & Henle, 1838)	Grey bambooshark	-	-	+	Vulnerable	Commercially Important	Khedkar <i>et al.</i> , 2014,
2.	Anguilliformes	Anguillidae	<i>Anguilla bengalensis</i> (Gray, 1831)	Indian mottled eel	+	+	+	Near Threatened	Commercially Important and Catadromous Migratory species.	Karamchandani <i>et al.</i> , 1967, Anon 1971, CIFRI 2018, Bhakta <i>et al.</i> , 2020.
3.	Aulopiformes	Harpadontidae	<i>Harpadon nehereus</i> (Hamilton, 1822)	Bombay-duck	-	+	+	Near Threatened		Singh 2009, Das <i>et al.</i> , 2013, Khedkar <i>et al.</i> , 2014, CIFRI 2018, Bhakta <i>et al.</i> 2018, 2019, 2020.
4.	Aulopiformes	Belonidae	<i>Strongylura strongylura</i> (van Hasselt, 1823)	Spottail needlefish	-	+	+	Not Evaluated		Das <i>et al.</i> , 2013, Khedkar <i>et al.</i> , 2014, Bhakta <i>et al.</i> 2018, Bhakta <i>et al.</i> , 2020.
5.	Aulopiformes	Adrianichthyidae	<i>Oryzias setnai</i> (Kulkarni, 1940)	Malabar ricefish	+	+	-	Least Concern		Karamchandani and Pandit 1971;

										Jayaram1981; Menon1999.
6.	Aulopiformes	Adrianichthyidae	<i>Xenentodon cancila</i> (Hamilton, 1822)	Freshwater garfish	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
7.	Aulopiformes	Hemiramphidae	<i>Hyporhamphus limbatus</i> (Valenciennes, 1847)	Congaturi halfbeak	-	+	+	Least Concern		Bhakta et al. 2018, Bhakta et al., 2020.
8.	Aulopiformes	Hemiramphidae	<i>Hyporhamphus dussumieri</i> (Valenciennes, 1847)	Dussumier's halfbeak	-	-	+	Not Evaluated		Khedkar et al., 2014, Bhakta et al., 2020.

9.	Aulopiformes	Hemiramphidae	<i>Hyporhamphus quoyi</i> (Valenciennes, 1847)	Quoy's garfish	-	-	+	Not Evaluated		Khedkar et al., 2014, Bhakta et al., 2020.
10.	Clupeiformes	Clupeidae	<i>Anodontostoma chacunda</i> (Hamilton, 1822)	Chacunda gizzard shad	-	-	+	Least Concern		Das et al., 2013, Bhakta et al., 2020.
11.	Clupeiformes	Clupeidae	<i>Corica soborna</i> (Hamilton, 1822)	Ganges river sprat	-	+	+	Not Evaluated		Das et al., 2013, Bhakta et al., 2020.
12.	Clupeiformes	Clupeidae	<i>Escualosa thoracata</i> (Valenciennes, 1847)	White sardine	-	-	+	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
13.	Clupeiformes	Clupeidae	<i>Gonialosa manmina</i> (Hamilton, 1822)	Ganges river gizzard shad	+	-	-	Least Concern		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Vyas et al. 2009, Bhakta et al., 2020.
14.	Clupeiformes	Clupeidae	<i>Gudusia chapra</i> (Hamilton, 1822)	Indian river shad	+	+	+	Least Concern		Sen and Banerjee 2000; Bakawale and Kanhere 2013, Bhakta et al., 2020.
15.	Clupeiformes	Clupeidae	<i>Hilsa kelee</i> (Cuvier, 1829)	Kelee shad	+	+	+	Least Concern	Commercially important and Anadromous migration.	Kulkarni 1950, 1951; Bhakta et al. 2018, Bhakta et al., 2020.

16.	Clupeiformes	Clupeidae	<i>Tenualosa ilisha</i> (Hamilton, 1822)	Hilsa shad	+	+	+	Least Concern	Commercially important and Anadromous migration.	Kulkarni 1950, 1951; Karamchandani et al., 1967, Jayaram1981; Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Das et al., 2013, CIFRI 2018, Bhakta et al. 2018, 2020; Sarma and Mankodi 2019.
17.	Clupeiformes	Clupeidae	<i>Tenualosa toli</i> (Valenciennes, 1847)	Toli shad	+	+	+	Vulnerable	Commercially important anadromous migration.	Kulkarni 1950, 1951; Khedkar et al., 2014, Bhakta et al. 2018, Bhakta et al., 2020.
18.	Clupeiformes	Engraulidae	<i>Coilia dussumieri</i> (Valenciennes, 1848)	Goldspotted grenadier anchovy	-	+	+	Least Concern		Das et al., 2013, Bhakta et al., 2020.
19.	Clupeiformes	Engraulidae	<i>Setipinna breviceps</i> (Cantor, 1849)	Shorthead hairfin anchovy	-	-	+	Least Concern		Bhakta et al. 2018, Bhakta et al., 2020.
20.	Clupeiformes	Engraulidae	<i>Setipinna phasa</i> (Hamilton, 1822)	Gangetic hairfin anchovy	-	-	+	Least Concern		CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
21.	Clupeiformes	Engraulidae	<i>Setipinna taty</i> (Valenciennes, 1848)	Scaly hairfin anchovy	-	-	+	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.

22.	Clupeiformes	Engraulidae	<i>Thryssa malabarica</i> (Bloch, 1795)	Malabar thryssa	-	-	+	Least Concern		Khedkar et al., 2014, Bhakta et al., 2020.
23.	Clupeiformes	Engraulidae	<i>Thryssa mystax</i> (Bloch & Schneider, 1801)	Moustached thryssa	-	-	+	Least Concern		Mahendrasinh and Pradeep 2013;
24.	Clupeiformes	Pristigasteridae	<i>Pellona ditchela</i> (Valenciennes, 1847)	Indian pellona	-	+	+	Least Concern		Khedkar et al., 2014, Bhakta et al. 2018, Bhakta et al., 2020.
25.	Clupeiformes	Pristigasteridae	<i>Raconda russeliana</i> (Gray, 1831)	Raconda	-	-	+	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
26.	Cypriniformes	Botiidae	<i>Botia dario</i> (Hamilton, 1822)	Bengal loach	+	-	-	Least Concern		Pathak et al., 2014, Bhakta et al., 2020.
27.	Cypriniformes	Cyprinidae	<i>Amblypharyngodon mola</i> (Hamilton, 1822)	Mola carplet	+	-	-	Least Concern		Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.

28.	Cypriniformes	Cyprinidae	<i>Amblypharyngodon microlepis</i> (Bleeker, 1853)	Indian carplet	+	-	-	Least Concern		Vyas and Vishwakarma 2013, Bhakta et al., 2020.
29.	Cypriniformes	Cyprinidae	<i>Aspidoparia jaya</i> (Hamilton, 1822)	Jaya	+	-	-	Least Concern		Bakawale and Kanhere 2013, Vyas and Vishwakarma 2013, Bhakta et al., 2020.
30.	Cypriniformes	Cyprinidae	<i>Bangana dero</i> (Hamilton, 1822)	Kalabans	+	-	-	Least Concern		Pathak et al., 2014, Bhakta et al., 2020.
31.	Cypriniformes	Cyprinidae	<i>Barilius bendelisis</i> (Hamilton, 1807)	Barilius	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Rao et al. 1991, Sen and Banerjee 2000; Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Sharma et al., 2014, Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
32.	Cypriniformes	Cyprinidae	<i>Barilius barila</i> (Hamilton, 1822)		+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Vyas et al. 2009, Bose et al., 2013, Das et al., 2013, Sharma et al.,

										2014, Kakodiya and Mehra 2018, Bhakta et al., 2020.
33.	Cypriniformes	Cyprinidae	<i>Barilius evezardi</i> (Day, 1872)		+	-	-	Data Deficient		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bhakta et al., 2020.
34.	Cypriniformes	Cyprinidae	<i>Barilius radiolatus</i> (Gunther, 1868)	Gunther's baril	+	-	-	Data Deficient		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bhakta et al., 2020.
35.	Cypriniformes	Cyprinidae	<i>Barilius vagra</i> (Hamilton, 1822)	Barila	+	-	-	Data Deficient		Anon 1971, Rao et al. 1991, Bose et al., 2013, Bhakta et al., 2020.
36.	Cypriniformes	Cyprinidae	<i>Cabdio morar</i> (Hamilton, 1822)	Morari	+	-	-	Least Concern		Singh 2009, Das et al., 2013, Vishwakarma et al., 2014, Bhakta et al., 2020.
37.	Cypriniformes	Cyprinidae	<i>Gibelion catla</i> (Hamilton, 1822)	Catla	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al.,

										2014, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
38.	Cypriniformes	Cyprinidae	<i>Chagunius chagunio</i> (Hamilton, 1822)	Chaguni	+	-	-	Least Concern		Das et al., 2013, Bhakta et al., 2020.
39.	Cypriniformes	Cyprinidae	<i>Chela laubuca</i> (Hamilton, 1822)	Indian glass barb	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Singh 2009, Vyas et al. 2009, Das et al., 2013, Vyas and Vishwakarma 2013, Pathak et al., 2014, Sharma et al., 2014, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
40.	Cypriniformes	Cyprinidae	<i>Chela cachius</i> (Hamilton, 1822)		+	-	-	Least Concern		Sen and Banerjee 2000;

41.	Cypriniformes	Cyprinidae	<i>Cirrhinus cirrhosus</i> (Bloch, 1795)		+	-	-	Vulnerable		Bakawale and Kanhere 2013, Sharma et al., 2014, Saini and Dube 2017, Bhakta et al., 2020.
42.	Cypriniformes	Cyprinidae	<i>Cirrhinus mrigala</i> (Hamilton, 1822)	Mrigal carp	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Rao et al. 1991, Tuli and Pande 1992, Sen and Banerjee 2000; Singh 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
43.	Cypriniformes	Cyprinidae	<i>Cirrhinus reba</i> (Hamilton, 1822)	Reba carp	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Bakawale

										and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Mahendrasinh and Pradeep 2013; Khedkar et al., 2014, Pathak et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
44.	Cypriniformes	Cyprinidae	<i>Cirrhinus fulungee</i> (Sykes, 1839)		+	-	-	Least Concern		Mahendrasinh and Pradeep 2013;
45.	Cypriniformes	Cyprinidae	<i>Crossocheilus latius</i> (Hamilton, 1822)	Stone roller	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Rao et al. 1991, Tuli and Pande 1992, Sen and Banerjee 2000; Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Vishwakarma et al.,

										2014,Kakodiya and Mehra 2018, Bhakta et al., 2020.
46.	Cypriniformes	Cyprinidae	<i>Ctenopharyngodon idella</i> (Valenciennes, 1844)	Grass carp	+	-	-	Not Evaluated		Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Kakodiya and Mehra 2018, Bhakta et al., 2020.
47.	Cypriniformes	Cyprinidae	<i>Cyprinus carpio</i> (Linnaeus, 1758)	Common carp	+	-	-	Vulnerable		Se and Banerjee 2000; Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017,Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
48.	Cypriniformes	Cyprinidae	<i>Dawkinsia filamentosa</i> (Valenciennes, 1844)	Blackspot barb	+	-	-	Least Concern		Vyas and Vishwakarma 2013, Bhakta et al., 2020.

49.	Cypriniformes	Cyprinidae	<i>Devario aequipinnatus</i> (McClelland, 1839)	Giant danio	+	-	-	Data Deficient		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Bhakta et al., 2020.
50.	Cypriniformes	Cyprinidae	<i>Devario malabaricus</i> (Jerdon, 1849)	Malabar danio	+	-	-	Least Concern		Sen and Banerjee 2000; Khedkar et al., 2014, Bhakta et al., 2020.
51.	Cypriniformes	Cyprinidae	<i>Danio devario</i> (Hamilton, 1822)	Sind danio	+	-	-	Least Concern		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Pathak et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
52.	Cypriniformes	Cyprinidae	<i>Devario fraseri</i> (Hora, 1935)		+	-	-	Least Concern		Sen and Banerjee 2000.
53.	Cypriniformes	Cyprinidae	<i>Danio rerio</i> (Hamilton, 1822)	Zebra danio	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bhakta et al., 2020.

54.	Cypriniformes	Cyprinidae	<i>Danio dangila</i> (Hamilton, 1822)		+	-	-	Least Concern		Sen and Banerjee 2000.
55.	Cypriniformes	Cyprinidae	<i>Esomus danrica</i> (Hamilton, 1822)	Flying barb	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Khedkar et al., 2014, Bhakta et al., 2020.
56.	Cypriniformes	Cyprinidae	<i>Garra gotyla</i> (Gray, 1830)	Sucker head	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Singh 2009, Bose et al., 2013, Vyas and Vishwakarma 2013, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
57.	Cypriniformes	Cyprinidae	<i>Garra lamta</i> (Hamilton, 1822)		+	-	-	Least Concern		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Vyas et al. 2009,

										Bakawale and Kanhere 2013, Pathak et al., 2014, Bhakta et al., 2020.
58.	Cypriniformes	Cyprinidae	<i>Garra mullya</i> (Sykes, 1839)	Sucker fish	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Vyas et al. 2009, Bose et al., 2013, Khedkar et al., 2014, Bhakta et al., 2020.
59.	Cypriniformes	Cyprinidae	<i>Hypophthalmichthys molitrix</i> (Valenciennes, 1844)	Silver carp	+	-	-	Least Concern		Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Sharma et al., 2014, Bhakta et al., 2020.
60.	Cypriniformes	Cyprinidae	<i>Hypophthalmichthys nobilis</i> (Richardson, 1845)	Bighead carp	+	-	-	Data Deficient		Das et al., 2013, Khedkar et al., 2014, Bhakta et al., 2020.
61.	Cypriniformes	Cyprinidae	<i>Labeo angra</i> (Hamilton, 1822)		+	-	-	Least Concern		Kakodiya and Mehra 2018, Bhakta et al., 2020.
62.	Cypriniformes	Cyprinidae	<i>Labeo bata</i> (Hamilton, 1822)	Bata	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al.

										1991, Singh 2009, Bakawale and Kanhere 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
63.	Cypriniformes	Cyprinidae	<i>Labeo boga</i> (Hamilton, 1822)	Boga	+	-	-	Least Concern		Vyas et al. 2009, Das et al., 2013, Vyas and Vishwakarma 2013, Bhakta et al., 2020.
64.	Cypriniformes	Cyprinidae	<i>Labeo boggut</i> (Sykes, 1839)	Boggut labeo	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bose et al., 2013, Mahendrasinh and

										Pradeep 2013;Khedkar et al., 2014, Vishwakarma et al., 2014,CIFRI 2018,Bhakta et al. 2018, Bhakta et al., 2020.
65.	Cypriniformes	Cyprinidae	<i>Labeo calbasu</i> (Hamilton, 1822)	Orange fin labeo	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971,Doria 1990, Rao et al. 1991,Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017,Shah et al. 2018, CIFRI 2018,Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
66.	Cypriniformes	Cyprinidae	<i>Labeo dussumieri</i> (Valenciennes, 1842)		+	-	-	Least Concern		Khedkar et al., 2014, Bhakta et al., 2020.
67.	Cypriniformes	Cyprinidae	<i>Labeo dyocheilus</i> (McClelland, 1839)		+	-	-	Least Concern		Karamchandani et al., 1967, Doria

										1990, Rao et al. 1991, Sen and Banerjee 2000; Singh 2009, Khedkar et al., 2014, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
68.	Cypriniformes	Cyprinidae	<i>Labeo fimbriatus</i> (Bloch, 1795)	Fringed-lipped peninsula carp	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Sen and Banerjee 2000; Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Pathak et al., 2014, Sharma et al., 2014, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
69.	Cypriniformes	Cyprinidae	<i>Labeo gonius</i> (Hamilton, 1822)	Kuria labeo	+	-	-	Least Concern		Hora and Nair 1941, Bose et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
70.	Cypriniformes	Cyprinidae	<i>Labeo pangusia</i> (Hamilton, 1822)		+	-	-	Least Concern		Hora and Nair 1941,

										Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bakawale and Kanhere 2013, Pathak et al., 2014, Bhakta et al., 2020.
71.	Cypriniformes	Cyprinidae	<i>Labeo rohita</i> (Hamilton, 1822)	Roho labeo	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bose et al., 2013, Das et al., 2013, Mahendrasinh and Pradeep 2013; Khedkar et al., 2014, Pathak et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
72.	Cypriniformes	Cyprinidae	<i>Laubuka laubuca</i> (Hamilton, 1822)	Indian glass barb	+	-	-	Least Concern		Singh 2009, Vyas et al. 2009, Vishwakarma et al., 2014, CIFRI 2018, Bhakta et al., 2020.

73.	Cypriniformes	Cyprinidae	<i>Oreichthys cosuatis</i> (Hamilton, 1822)		+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
74.	Cypriniformes	Cyprinidae	<i>Osteobrama cotio</i> (Hamilton, 1822)		+	-	-	Least Concern		Vyas et al. 2009, Mahendrasinh and Pradeep 2013; Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
75.	Cypriniformes	Cyprinidae	<i>Osteobrama vigorsii</i> (Sykes, 1839)		+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Vyas et al. 2009, Bhakta et al., 2020.
76.	Cypriniformes	Cyprinidae	<i>Oxygaster gora</i> (Hamilton, 1822)		+	-	-	Least Concern		Bose et al., 2013, Bhakta et al., 2020.
77.	Cypriniformes	Cyprinidae	<i>Parapsilorhynchus tentaculatus</i> (Annandale, 1919)	Khandalla minnow	+	-	-	Least Concern		Hora and Nair 1941, Doria 1990, Rao et al.

										1991, Singh 2009, Bhakta et al., 2020.
78.	Cypriniformes	Cyprinidae	<i>Pethia conchonius</i> (Hamilton, 1822)	Rosy barb	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Kakodiya and Mehra 2018, Bhakta et al., 2020.
79.	Cypriniformes	Cyprinidae	<i>Pethia gelius</i> (Hamilton, 1822)	Golden barb	+	-	-	Least Concern		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Vyas et al. 2009, Bhakta et al., 2020.
80.	Cypriniformes	Cyprinidae	<i>Pethia guganio</i> (Hamilton, 1822)	Glass-barb	+	-	-	Least Concern		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Vyas et al.

										2009, Bose et al., 2013, Shah et al. 2018, Bhakta et al., 2020.
81.	Cypriniformes	Cyprinidae	<i>Pethia ticto</i> (Hamilton, 1822)	Ticto barb	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Mahendrasinh and Pradeep 2013; Bhakta et al., 2020.
82.	Cypriniformes	Cyprinidae	<i>Puntius ambasis</i> (Day, 1869)		+	-	-	Data Deficient		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Vyas and Vishwakarma 2013, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, Bhakta et al., 2020.

83.	Cypriniformes	Cyprinidae	<i>Puntius amphibious</i> (Valenciennes, 1842)	Scarlet-banded barb	+	-	-	Data Deficient		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Thakkar et al. 2018, Bhakta et al., 2020.
84.	Cypriniformes	Cyprinidae	<i>Puntius pinnauratus</i> (Day, 1865)		+	-	-	Not Evaluated		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.

85.	Cypriniformes	Cyprinidae	<i>Puntius chola</i> (Hamilton, 1822)	Swamp barb	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
86.	Cypriniformes	Cyprinidae	<i>Puntius dorsalis</i> (Jerdon, 1849)	Long snouted barb	+	-	-	Least Concern		Karamchandani et al., 1967, Bhakta et al. 2018, Thakkar et al. 2018, Bhakta et al., 2020.
87.	Cypriniformes	Cyprinidae	<i>Puntius sophore</i> (Hamilton, 1822)	Pool barb	+	-	-	Least Concern		Sen and Banerjee 2000; Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et

										al., 2014, Bhakta et al., 2020.
88.	Cypriniformes	Cyprinidae	<i>Puntius neilli</i> (Day, 1865)		+	-	-	Least Concern		Khedkar et al., 2014, Bhakta et al., 2020.
89.	Cypriniformes	Cyprinidae	<i>Rasbora daniconius</i> (Hamilton, 1822)	Slender rasbora	+	-	-	Least Concern		Anon 1971, Rao et al. 1991, Sen and Banerjee 2000, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
90.	Cypriniformes	Cyprinidae	<i>Rasbora rasbora</i> (Hamilton, 1822)	Gangetic scissortail rasbora	+	-	-	Least Concern		Bose et al., 2013, Bhakta et al., 2020.
91.	Cypriniformes	Cyprinidae	<i>Salmophasia bacaila</i> (Hamilton, 1822)	Large razorbelly minnow	+	-	-	Least Concern		Sen and Banerjee 2000; Singh 2009, Mahendrasinh and Pradeep 2013; CIFRI 2018, Bhakta et al., 2020.
92.	Cypriniformes	Cyprinidae	<i>Salmophasia boopis</i> (Day, 1874)	Boopis razorbelly minnow	+	-	-	Least Concern		Das et al., 2013, Bhakta et al., 2020.

93.	Cypriniformes	Cyprinidae	<i>Salmostoma orissaensis</i> (Bănărescu, 1968)	Orissa razorbelly minnow	+	-	-	Not Evaluated		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
94.	Cypriniformes	Cyprinidae	<i>Salmostoma balookee</i> (Sykes, 1839)	Bloch razorbelly minnow	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Menon 1999; Vyas et al. 2009, Bose et al., 2013, Das et al., 2013,

										Vyas and Vishwakarma 2013, Vishwakarma et al., 2014, Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
95.	Cypriniformes	Cyprinidae	<i>Salmostoma phulo</i> (Hamilton, 1822)	Finescale razorbelly minnow	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Vyas et al. 2009, Shah et al. 2018, Bhakta et al., 2020.
96.	Cypriniformes	Cyprinidae	<i>Securicula gora</i> (Hamilton, 1822)		+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Khedkar et al., 2014, Bhakta et al., 2020.
97.	Cypriniformes	Cyprinidae	<i>Systomus sarana</i> (Hamilton, 1822)	Olive barb	+	-	-	Least Concern		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Sen and Banerjee 2000; Singh 2009, Bakawale and Kanhere 2013,

										Mahendrasinh and Pradeep 2013;Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017, Bhakta et al., 2020.
98.	Cypriniformes	Cyprinidae	<i>Systomus chrysopoma</i> (Valenciennes, 1842)		+	-	-	Not Evaluated		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991,Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018,Bhakta et al. 2018, Kakodiya and Mehra 2018, 2Anon 1971, Bhakta et al., 2020.
99.	Cypriniformes	Cyprinidae	<i>Systomus pleurotaenia</i> (Bleeker, 1863)	Black lined barb	+	-	-	Vulnerable		Sen and Banerjee 2000.
100.	Cypriniformes	Cyprinidae	<i>Tor khudree</i> (Sykes, 1839)	Deccan mahseer	+	-	-	Least Concern		Hora and Nair 1941,

										Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bose et al., 2013, Das et al., 2013, Pathak et al., 2014, Vishwakarma et al., 2014, Kakodiya and Mehra 2018, 2Anon 1971, Bhakta et al., 2020.
101.	Cypriniformes	Cyprinidae	<i>Tor putitora</i> (Hamilton, 1822)	Putitor mahseer	+	-	-	Least Concern		Hora and Nair 1941, Anon 1971, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.

102.	Cypriniformes	Cyprinidae	<i>Tor tor</i> (Hamilton, 1822)	Tor barb	+	-	-	Data Deficient		Anon 1971, Sen and Banerjee 2000; Bhakta et al., 2020.
103.	Cypriniformes	Cobitidae	<i>Lepidocephalichthys guntea</i> (Hamilton, 1822)	Guntea loach	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Menon 1999; Bhakta et al., 2020.
104.	Cypriniformes	Nemacheilidae	<i>Acanthocobitis botia</i> (Hamilton, 1822)	Mottled loach	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Kakodiya and Mehra 2018, Bhakta et al., 2020.
105.	Cypriniformes	Nemacheilidae	<i>Schistura beavani</i> (Günther 1868)	Creek loach	+	-	-	Least Concern		hedkar et al., 2014, Bhakta et al., 2020.
106.	Cypriniformes	Nemacheilidae	<i>Schistura dayi</i> (Hora, 1935)		+	-	-	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
107.	Cypriniformes	Nemacheilidae	<i>Schistura denisoni</i> (Day, 1867)		+	-	-	Least Concern		Menon 1999
108.	Cypriniformes	Nemacheilidae	<i>Indoreonectes evezardi</i> (Day, 1872)		+	-	-	Least Concern		Rao et al. 1991, Bhakta et al., 2020.
109.	Cypriniformes	Nemacheilidae	<i>Paraschistura montana</i> (McClelland, 1838)		+	-	-	Not Evaluated		

										Khedkar et al., 2014, Bhakta et al., 2020.
110.	Cyprinodontiformes	Aplocheilidae	<i>Aplocheilus panchax</i> (Hamilton, 1822)	Blue panchax	+	-	-	Least Concern		Singh 2009, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
111.	Cyprinodontiformes	Poeciliidae	<i>Poecilia reticulata</i> (Peters, 1859)	Guppy	+	-	-	Least Concern	Invasive species	Singh 2009, Das et al., 2013, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
112.	Cyprinodontiformes	Cyprinodontidae	<i>Aphanius dispar</i> (Rüppell, 1829)	Arabian pupfish	+	+	+	Least Concern		Jayaram 1981; Menon 1999.
113.	Elopiformes	Megalopidae	<i>Megalops cyprinoides</i> (Broussonet, 1782)	Indo-Pacific tarpon	+	+	+	Data Deficient	Migratory species	Singh 2009, Das et al., 2013, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
114.	Gonorynchiformes	Chanidae	<i>Chanos chanos</i> (Forsskal, 1775)	Milkfish	-	+	+	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
115.	Mugiliformes	Mugilidae	<i>Crenimugil seheli</i> (Forsskal, 1775)	Bluespot mullet	-	+	+			Burman et al., 2000.
116.	Mugiliformes	Mugilidae	<i>Ellochelon vaigiensis</i> (Quoy & Gaimard, 1825)	Squaretail mullet	-	+	+			Burman et al., 2000.
117.	Mugiliformes	Mugilidae	<i>Osteomugil cunnesius</i>	Longarm mullet	-	+	+	Least Concern		Burman et al., 2000.

			(Valenciennes, 1836)							
118.	Mugiliformes	Mugilidae	<i>Osteomugil speigleri</i> (Bleeker, 1858)	Speigler's mullet	-	+	+			Burman et al., 2000.
119.	Mugiliformes	Mugilidae	<i>Planiliza macrolepis</i> (Smith, 1846)	Largescale mullet	-	+	+	Least Concern		Burman et al., 2000; Khedkar et al., 2014, Bhakta et al., 2020.
120.	Mugiliformes	Mugilidae	<i>Planiliza carinata</i> (Valenciennes, 1836)	Keeled mullet	-	+	+	Not Evaluated		Burman et al., 2000.
121.	Mugiliformes	Mugilidae	<i>Planiliza planiceps</i> (Valenciennes, 1836)	Tade gray mullet	-	+	+	Least Concern		Mahendrasinh and Pradeep 2013; Bhatt and Mankodi 2020.
122.	Mugiliformes	Mugilidae	<i>Planiliza melinoptera</i> (Valenciennes, 1836)	Otomebora mullet	-	+	+	Least Concern		Burman et al., 2000.
123.	Mugiliformes	Mugilidae	<i>Planiliza parsia</i> (Hamilton, 1822)	Goldspot mullet	-	+	+	Least Concern		Singh 2009, Das et al., 2013, Khedkar et al., 2014, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
124.	Mugiliformes	Mugilidae	<i>Planiliza tade</i> (Fabricius, 1775)		-	+	+	Least Concern		Burman et al., 2000.
125.	Mugiliformes	Mugilidae	<i>Chelon planiceps</i> (Valenciennes, 1836)	Tade gray mullet	-	+	+	Least Concern		Rao et al. 1991, Singh 2009, Das et al., 2013, Khedkar et al., 2014, CIFRI

										2018, Bhakta et al. 2018, Bhakta et al., 2020.
126.	Mugiliformes	Mugilidae	<i>Liza klunzingeri</i> (Day, 1888)	Klunzinger's mullet	-	+	+	Least Concern		Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Bakawale and Kanhere 2013, Bhakta et al., 2020.
127.	Mugiliformes	Mugilidae	<i>Mugil cephalus</i> (Linnaeus, 1758)	Flathead grey mullet	+	+	+	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Burman et al., 2000; Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020;

										Bhatt and Mankodi 2020.
128.	Mugiliformes	Mugilidae	<i>Rhinomugil corsula</i> (Hamilton, 1822)	Corsula	+	+	-	Least Concern		Anon 1971, Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Mahendrasinh and Pradeep 2013; Khedkar et al., 2014, Pathak et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020; Bhatt and Mankodi 2020.
129.	Osteoglossiformes	Notopteridae	<i>Chitala chitala</i> (Hamilton, 1822)	Clown knifefish	+	-	-	Nearly Threatened		Sen and Banerjee 2000; Vyas et al. 2009, Bhakta et al., 2020.
130.	Osteoglossiformes	Notopteridae	<i>Notopterus notopterus</i> (Pallas, 1769)	Bronze featherback	+	+	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990,

										Rao et al. 1991, Sen and Banerjee 2000; Singh 2009, Vyas et al. 2009, Pathak et al., 2014, Bose et al., 2013, Das et al., 2013, Mahendrasinh and Pradeep 2013; Khedkar et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, CIFRI 2018, Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
131.	Osteoglossi formes	Notopterid ae	<i>Parambassis baculis</i> (Hamilton, 1822)	Himalayan glassy perchlet	+	-	-	Least Concern		Rao et al. 1991, Bakawale and Kanhere 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Shah et al. 2018, Bhakta et al., 2020.
132.	Osteoglossi formes	Notopterid ae	<i>Parambassis ranga</i> (Hamilton, 1822)	Indian glassy fish	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et

										al., 1967, Doria 1990, Rao et al. 1991, Bose et al., 2013, Das et al., 2013, Mahendrasinh and Pradeep 2013; Pathak et al., 2014, Bhakta et al., 2020.
133.	Osteoglossi formes	Anabantidae	<i>Anabas testudineus</i> (Bloch, 1792)	Climbing perch	+	-	-	Least Concern		Khedkar et al., 2014, Bhakta et al., 2020.
134.	Osteoglossi formes	Badidae	<i>Badis badis</i> (Hamilton, 1822)	Badis	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Sen and Banerjee 2000; Singh 2009, Bose et al., 2013, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Kakodiya and Mehra 2018, Bhakta et al., 2020.

135.	Osteoglossi formes	Carangidae	<i>Scomberoides lysan</i> (Forsskal, 1775)	Doublespotted queenfish	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
136.	Osteoglossi formes	Channidae	<i>Channa gachua</i> (Hamilton, 1822)		+	-	-	Least Concern		Das et al., 2013, Khedkar et al., 2014, Bhakta et al., 2020.
137.	Osteoglossi formes	Channidae	<i>Channa marulius</i> (Hamilton, 1822)	Great snakehead	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Singh 2009, Bakawale and

										Kanhere 2013, Bose et al., 2013, Das et al., 2013, Mahendrasinh and Pradeep 2013; Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
138.	Osteoglossi formes	Channidae	<i>Channa orientalis</i> (Bloch & Schneider, 1801)	Walking snakehead	+	-	-	Vulnerable		Anon 1971, Sen and Banerjee 2000; Singh 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.

139.	Osteoglossi formes	Channidae	<i>Channa punctata</i> (Bloch, 1793)	Spotted snakehead	+	-	-	Least Concern		Singh 2009, Mahendrasinh and Pradeep 2013; CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
140.	Osteoglossi formes	Channidae	<i>Channa striata</i> (Bloch, 1793)	Striped snakehead	+	-	-	Least Concern		Singh 2009, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
141.	Osteoglossi formes	Cichlidae	<i>Pseudetroplus maculatus</i> (Bloch, 1795)	Orange chromide	+	-	-	Least Concern		Khedkar et al., 2014, Bhakta et al., 2020.
142.	Osteoglossi formes	Cichlidae	<i>Etroplus suratensis</i> (Bloch, 1790)	Pearlspot	+	+	-	Least Concern		Menon 1999; Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
143.	Osteoglossi formes	Cichlidae	<i>Oreochromis mossambicus</i> (Peters, 1852)	Mozambique tilapia	+	+	-	Vulnerable		Das et al., 2013, Mahendrasinh and Pradeep 2013; Bhakta et al. 2018, Bhakta et al., 2020.
144.	Osteoglossi formes	Eleotridae	<i>Eleotris fusca</i> (Forster, 1801)	Dusky sleeper	+	-	-	Least Concern		Khedkar et al., 2014, Bhakta et al., 2020.
145.	Osteoglossi formes	Gerreidae	<i>Gerres filamentosus</i> (Cuvier 1829)	Whipfin silver-bi	+	-	-	Least Concern		Khedkar et al., 2014, Bhakta et al. 2018, Bhakta et al., 2020.

146.	Osteoglossi formes	Gobiidae	<i>Awaous ocellaris</i> (Broussonet, 1782)		+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
147.	Osteoglossi formes	Gobiidae	<i>Boleophthalmus dussumieri</i> (Valenciennes, 1837)	Mudskipper	-	+	+	Least Concern		Das et al., 2013, Solanki et al., 2016; Bhakta et al. 2018, Bhakta et al., 2020.
148.	Osteoglossi formes	Gobiidae	<i>Periophthalmus waltoni</i> (Koumans, 1941)		-	+	+			Solanki et al., 2016.
149.	Osteoglossi formes	Gobiidae	<i>Scartelaos histophorus</i> (Valenciennes, 1837)		-	+	+			Solanki et al., 2016.
150.	Osteoglossi formes	Gobiidae	<i>Scartelaos cantoris</i> (Day, 1871)		-	+	+			Mahendrasinh and Pradeep 2013;

151.	Osteoglossi formes	Gobiidae	<i>Glossogobius giuris</i> (Hamilton, 1822)	Tank goby	+	-	-	Least Concern		Singh 2009, Mahendrasinh and Pradeep 2013; CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
152.	Osteoglossi formes	Gobiidae	<i>Odontamblyopus rubicundus</i> (Hamilton, 1822)		+	+	+	Least Concern		Singh 2009, CIFRI 2018, Bhakta et al., 2020.
153.	Osteoglossi formes	Gobiidae	<i>Periophthalmodon schlosseri</i> (Pallas, 1770)	Giant mudskipper	-	+	+	Least Concern		Bhakta et al. 2018, Bhakta et al., 2020.
154.	Osteoglossi formes	Gobiidae	<i>Periophthalmus variabilis</i> (Eggert, 1935)		-	+	+	Least Concern		Bhakta et al. 2018, Bhakta et al., 2020.
155.	Osteoglossi formes	Gobiidae	<i>Pseudapocryptes elongatus</i> (Cuvier, 1816)		+	+	-	Least Concern		Thakkar et al. 2018, Bhakta et al., 2020.
156.	Osteoglossi formes	Gobiidae	<i>Taenioides anguillaris</i> (Linnaeus, 1758)	Eel worm goby	+	+	-	Least Concern		Singh 2009, Das et al., 2013, Khedkar et al., 2014, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
157.	Osteoglossi formes	Gobiidae	<i>Trypauchen vagina</i> (Bloch & Schneider, 1801)		-	-	+	Least Concern		Hora and Nair 1941, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Bhakta et al., 2020.

158.	Osteoglossi formes	Gobiidae	<i>Bathygobius fuscus</i> (Rüppell, 1830)		-	+	+	Least Concern		Jayaram1981;
159.	Osteoglossi formes	Latidae	<i>Lates calcarifer</i> (Bloch, 1790)	Barramundi	-	+	+	Least Concern		Burman et al., 200; Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
160.	Osteoglossi formes	Lutjanidae	<i>Lutjanus argentimaculatus</i> (Forsskål, 1775)	Mangrove red snapper	-	+	+	Least Concern		Khedkar et al., 2014, Bhakta et al., 2020.
161.	Osteoglossi formes	Lutjanidae	<i>Lutjanus johnii</i> (Bloch, 1792)	John's snapper	-	+	+	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971,Doria 1990, Rao et al. 1991,Singh 2009, Vyas et al. 2009, Bakawale and Kanhare 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017,Shah et al. 2018, Bhakta et al., 2020.
162.	Osteoglossi formes	Mullidae	<i>Upeneus vittatus</i> (Forsskål, 1775)	Yellowstripe d goatfish	-	+	+	Least Concern		Sharma et al., 2014, Bhakta et al., 2020.

163.	Osteoglossi formes	Nandidae	<i>Nandus nandus</i> (Hamilton, 1822)	Gangetic leaf fish	+	-	-	Least Concern		Sharma et al., 2014, Bhakta et al., 2020.
164.	Osteoglossi formes	Osphronemidae	<i>Ctenopoma nobilis</i> (McClelland, 1845)	Frail gourami	+	-	-	Near Threatened		Bakawale and Kanhere 2013, Das et al., 2013, Pathak et al., 2014, Sharma et al., 2014, Shah et al. 2018, Bhakta et al. 2018, Bhakta et al., 2020.
165.	Osteoglossi formes	Osphronemidae	<i>Trichogaster chuna</i> (Hamilton, 1822)	Honey gourami	+	-	-	Least Concern		Das et al., 2013, Bhakta et al., 2020.
166.	Osteoglossi formes	Osphronemidae	<i>Trichogaster fasciata</i> (Bloch & Schneider, 1801)	Banded gourami	+	-	-	Least Concern		Singh 2009, Das et al., 2013, Khedkar et al., 2014, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
167.	Osteoglossi formes	Osphronemidae	<i>Trichogaster lalius</i> (Hamilton, 1822)	Dwarf gourami	+	-	-	Least Concern		Singh 2009, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
168.	Osteoglossi formes	Polynemidae	<i>Eleutheronema tetradactylum</i> (Shaw, 1804)	Forefinger threadfin	-	+	+	Least Concern		Das et al., 2013, Khedkar et al., 2014, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.

169.	Osteoglossi formes	Polynemid ae	<i>Leptomelanosoma indicum</i> (Shaw, 1804)	Indian threadfin	+	+	-	Least Concern		Bhakta et al. 2018, Bhakta et al., 2020.
170.	Osteoglossi formes	Scatophagi dae	<i>Scatophagus argus</i> (Linnaeus, 1766)	Spotted scat	-	-	+	Least Concern		Bhakta et al. 2018, Bhakta et al., 2020.
171.	Osteoglossi formes	Sciaenidae	<i>Daysciaena albida</i> (Cuvier, 1830)	Bengal corvina	-	+	+	Least Concern		Singh 2009, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
172.	Osteoglossi formes	Sciaenidae	<i>Johnius belangerii</i> (Cuvier, 1830)	Belanger's croaker	-	+	+	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
173.	Osteoglossi formes	Sciaenidae	<i>Otolithoides biauritus</i> (Cantor, 1849)	Bronze croaker	-	+	+	Data Deficien t		Khedkar et al., 2014, Bhakta et al., 2020.
174.	Osteoglossi formes	Sciaenidae	<i>Otolithoides pama</i> (Hamilton, 1822)	Pama croaker	-	+	+	Data Deficien t		Khedkar et al., 2014, Bhakta et al., 2020.
175.	Osteoglossi formes	Sciaenidae	<i>Panna microdon</i> (Bleeker, 1849)	Panna croaker	-	+	+	Data Deficien t		Bhakta et al. 2018, Bhakta et al., 2020.
176.	Osteoglossi formes	Sciaenidae	<i>Protonibea diacanthus</i> (Lacepède, 1802)	Blackspotted croaker	-	+	+	Near threaten ed		Khedkar et al., 2014, Bhakta et al., 2020.
177.	Osteoglossi formes	Scombrida e	<i>Scomberomorus guttatus</i> (Bloch & Schneider, 1801)	Indo-Pacific king mackerel	-	-	+	Data Deficien t		Bhakta et al. 2018, Bhakta et al., 2020.
178.	Osteoglossi formes	Sparidae	<i>Acanthopagrus latus</i> (Houttuyn, 1782)	Yellowfin seabream	-	-	+	Data Deficien t		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.

179.	Osteoglossi formes	Sillaginidae	<i>Sillago sihama</i> (Forsskål, 1775)	Silver sillago	-	+	+	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bhakta et al., 2020.
180.	Osteoglossi formes	Teraponida e	<i>Therapon jarbua</i> (Forsskål, 1775)	Jarbua terapon	-	+	+	Least Concern		Singh 2009, Mahendrasinh and Pradeep 2013; Khedkar et al., 2014, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
181.	Siluriforme s	Amblycepi dae	<i>Amblyceps mangois</i> (Hamilton, 1822)	Indian torrent catfish	+	-	-	Least Concern		Das et al., 2013, Bhakta et al., 2020.
182.	Siluriforme s	Plotosidae	<i>Plotosus lineatus</i> (Thunberg, 1787)	Striped eel catfish	+	-	-	Least Concern		Bhakta et al., 2020
183.	Siluriforme s	Ariidae	<i>Arius arius</i> (Hamilton, 1822)	Threadfin sea catfish	-	+	+	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
184.	Siluriforme s	Ariidae	<i>Arius gagora</i> (Hamilton, 1822)	Gagora catfish	-	+	+	Least Concern		Singh 2009, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
185.	Siluriforme s	Ariidae	<i>Osteogeneiosus militaris</i> (Linnaeus, 1758)	Soldier catfish	-	+	+	Not Evaluate d		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al.

										1991, Singh 2009, Vyas et al. 2009, Vishwakarma et al., 2014, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
186.	Siluriformes	Ariidae	<i>Ailia coila</i> (Hamilton, 1822)	<i>Ailia coila</i>	+	-	-	Near Threatened		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, CIFRI 2018, Bhakta et al.

										2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
187.	Siluriformes	Ariidae	<i>Nemapteryx nenga</i> (Hamilton, 1822)		+	-	-	Not Evaluated		Mahendrasinh and Pradeep 2013;
188.	Siluriformes	Bagridae	<i>Mystus bleekeri</i> (Day, 1877)	Day's mystus	+	-	-	Least Concern		Das et al., 2013, Khedkar et al., 2014, Bhakta et al. 2018, Bhakta et al., 2020.
189.	Siluriformes	Bagridae	<i>Mystus cavasius</i> (Hamilton, 1822)	Gangetic mystus	+	-	-	Least Concern		Vyas et al. 2009, Das et al., 2013, Bhakta et al., 2020.
190.	Siluriformes	Bagridae	<i>Mystus gulio</i> (Hamilton, 1822)	Long whiskers catfish	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Singh 2009, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
191.	Siluriformes	Bagridae	<i>Mystus tengara</i> (Hamilton, 1822)	Tengara catfish	+	-	-	Least Concern		Rao et al. 1991, Singh 2009, Vyas et al. 2009,

										Bakawale and Kanhere 2013, Das et al., 2013, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
192.	Siluriformes	Bagridae	<i>Mystus vittatus</i> (Bloch, 1794)	Striped dwarf catfish	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Singh 2009, Bakawale and Kanhere 2013, Das et al., 2013, Pathak et al., 2014, Sharma et al., 2014, CIFRI 2018, Bhakta et al. 2018, Thakkar et al. 2018, Bhakta et al., 2020.
193.	Siluriformes	Bagridae	<i>Rita rita</i> (Hamilton, 1822)	Rita	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Senand Banerjee

										2000; Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
194.	Siluriformes	Bagridae	<i>Rita gogra</i> (Sykes, 1839)		+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and

										Mehra 2018, Bhakta et al., 2020.
195.	Siluriformes	Bagridae	<i>Sperata aor</i> (Hamilton, 1822)	Long-whiskered catfish	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Sen and Banerjee 2000; Singh 2009, Bakawale and Kanhere 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Shah et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
196.	Siluriformes	Bagridae	<i>Sperata seenghala</i> (Sykes, 1839)	Giant river-catfish	+	-	-	Least Concern		Mahendrasinh and Pradeep 2013; Sharma et al., 2014, Bhakta et al., 2020.
197.	Siluriformes	Claridae	<i>Clarias magur</i> (Linnaeus, 1758)		+	-	-	Endangered		Hora and Nair 1941, Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bhakta et al., 2020.

198.	Siluriformes	Claridae	<i>Clarias gariepinus</i> (Burchell, 1822)	North African catfish	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Singh 2009, Bakawale and Kanhere 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Sharma et al., 2014, Saini and Dube 2017, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
199.	Siluriformes	Erethistidae	<i>Pseudolaguvia ribeiroi</i> (Hora, 1921)	Painted catfish	+	-	-	Least Concern		Bakawale and Kanhere 2013, Saini and Dube 2017, Bhakta et al. 2018, Bhakta et al., 2020.
200.	Siluriformes	Heteropneustidae	<i>Heteropneustes fossilis</i> (Bloch, 1794)	Stinging catfish	+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013,

										Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Saini and Dube 2017, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
201.	Siluriformes	Pangasiidae	<i>Pangasius pangasius</i> (Hamilton, 1822)	Pangas catfish	+	-	-	Least Concern		Rao et al. 1991, Singh 2009, Bose et al., 2013, Das et al., 2013, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
202.	Siluriformes	Schilbeidae	<i>Clupisoma garua</i> (Hamilton, 1822)	Garua bachcha	+	-	-	Least Concern		Das et al., 2013, Khedkar et al., 2014, Bhakta et al. 2018, Bhakta et al., 2020.
203.	Siluriformes	Schilbeidae	<i>Eutropiichthys vacha</i> (Hamilton, 1822)	Batchwa vacha	+	-	-	Least Concern		Singh 2009, Khedkar et al., 2014, Bhakta et al., 2020.
204.	Siluriformes	Schilbeidae	<i>Eutropiichthys murius</i> (Hamilton, 1822)		+	-	-	Least Concern		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013,

										Bose et al., 2013, Das et al., 2013, Vyas and Vishwakarma 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
205.	Siluriformes	Siluridae	<i>Silonia silondia</i> (Hamilton, 1822)	Silond catfish	+	-	-	Least Concern		Singh 2009, Saini and Dube 2017, Bhakta et al., 2020.
206.	Siluriformes	Siluridae	<i>Ompok bimaculatus</i> (Bloch, 1794)	Butter catfish	+	-	-	Near Threatened		Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Pathak et al., 2014, Bhakta et al., 2020.
207.	Siluriformes	Siluridae	<i>Ompok pabo</i> (Hamilton, 1822)	Pabo catfish	+	-	-	Near Threatened		Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013,

										Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Saini and Dube 2017, Shah et al. 2018, CIFRI 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
208.	Siluriformes	Siluridae	<i>Ompok pabda</i> (Hamilton, 1822)	Pabdah catfish	+	-	-	Near Threatened		Singh 2009, Sharma et al., 2014, Bhakta et al., 2020.
209.	Siluriformes	Siluridae	<i>Wallago attu</i> (Bloch & Schneider, 1801)	Wallago	+	-	-	Near Threatened		Sen and Banerjee 2000; Khedkar et al., 2014, Bhakta et al., 2020.
210.	Siluriformes	Sisoridae	<i>Bagarius bagarius</i> (Hamilton, 1822)	Goonch	+	-	-	Near Threatened		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Bhakta et al., 2020.
211.	Siluriformes	Sisoridae	<i>Gagata cenia</i> (Hamilton, 1822)	Indian gagata	+	-	-	Least Concern		Karamchandani et al., 1967, Doria 1990, Rao et al. 1991, Khedkar et al., 2014, Bhakta et al., 2020.
212.	Siluriformes	Sisoridae	<i>Gagata itchkeea</i> (Sykes, 1839)		+	-	-	Vulnerable		Pathak et al., 2014, Bhakta et al., 2020.

213.	Siluriformes	Sisoridae	<i>Glyptothorax lonah</i> (Sykes, 1839)		+	-	-	Least Concern		Das et al., 2013, Khedkar et al., 2014, CIFRI 2018, Bhakta et al. 2018, Bhakta et al., 2020.
214.	Siluriformes	Sisoridae	<i>Glyptothorax telchitta</i> (Hamilton, 1822)		+	-	-	Least Concern		Singh 2009, Bhakta et al., 2020.
215.	Pleuronectiformes	Cynoglossidae	<i>Cynoglossus cynoglossus</i> (Hamilton, 1822)	Bengal tongue sole	-	+	+	Least Concern		Das et al., 2013, Bhakta et al. 2018, Bhakta et al., 2020.
216.	Pleuronectiformes	Cynoglossidae	<i>Cynoglossus arel</i> (Bloch & Schneider, 1801)	Largescale tongue sole	-	+	+	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, Bhakta et al. 2018, Kakodiya and

										Mehra 2018, Bhakta et al., 2020.
217.	Pleuronecti formes	Cynoglossidae	<i>Cynoglossus macrolepidotus</i> (Bleeker, 1851)		-	+	+	Data Deficient		Burman et al., 2000.
218.	Pleuronecti formes	Soleidae	<i>Brachirus orientalis</i> (Bloch & Schneider, 1801)	Oriental sole	-	+	+	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
219.	Synbranchi formes	Mastacembelidae	<i>Macroglythys pancalus</i> (Hamilton, 1822)	Barred spiny eel	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli

										and Pande 1992, Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Daset al., 2013, Mahendrasinh and Pradeep 2013; Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
220.	Synbranchi formes	Mastacemb elidae	<i>Mastacembelus armatus</i> (Lacépède 1800)	Zig-zag eel	+	-	-	Least Concern		Hora and Nair 1941, Karamchandani et al., 1967, Anon 1971, Doria 1990, Rao et al. 1991, Tuli and Pande 1992, Sen and Banerjee 2000; Singh 2009, Vyas et al. 2009, Bakawale and Kanhere 2013, Bose et al., 2013, Das et al., 2013, Mahendrasinh and

										Pradeep 2013; Khedkar et al., 2014, Pathak et al., 2014, Sharma et al., 2014, Vishwakarma et al., 2014, Shah et al. 2018, Bhakta et al. 2018, Kakodiya and Mehra 2018, Bhakta et al., 2020.
221.	Eupercaria	Monodactylidae	<i>Monodactylus argenteus</i> (Linnaeus, 1758)	Silver moony	-	-	+	Least Concern		Burman et al., 2000.
222.	Eupercaria	Monodactylidae	<i>Monodactylus faLeast Concerniformis</i> (Lacepède, 1801)	Full moony	-	-	+	Least Concern		Burman et al., 2000.

2.7.2 Herpetofauna

So far, various studies have been conducted focusing on different aspects of herpetofauna in the state of Gujarat, especially within the Kalpasar study area. For instance, Jethava and Jhala (2003) in a study documented the presence of three snake species, *i.e.* Indian spectacled cobra, Saw-scaled viper and Russell's viper at Kalatalav and Dholera areas in the Bhal region of Saurashtra. Vyas (2015) recorded two species of turtles, namely the Ganges soft-shell turtle (*Nilssonina gangetica*) and Indian flapshell turtle (*Lessymus punctata*) in the area. Both the species were widespread in river systems of Sabarmati, Mahi and Vishwamitri-Dhadar. There are also records of Mugger or Indian crocodile inhabiting in the Vishwamitri and Narmada rivers and estuaries (Upadhyay and Sahu, 2013; Vyas, 2013). A study carried out by Solanki *et al.* (2017) has pointed out that the species are affected due to vehicular movements in the Bhavnagar district. The studies have reported the occurrence of fourteen different herpetofaunal species, including two amphibians (Asian common toad and green pond frog) and 12 reptiles (Oriental Garden Lizard, Indian Monitor lizard, Skink, Indian softshell turtle, Spectacle Cobra, Bronze back Tree Snake, etc.) and were prone to conflict incidences. There are also common reptiles (snake and lizards), including the garden lizard, common rat snake, fan-throated lizard, monitor lizard, are found inhabiting in the scrublands, agricultural area and barren lands (ZSI, 2000) (Table 2.6).

Table 2.6 Check list of species of Herpetofauna reported from the study area

Sl.no.	Order	Family	Zoological name	Common name	IUCN	WPA 1972	Reference
Class: Reptilia							
1	Testudines	Trionychidae	<i>Nilssonia gangetica</i>	Indian Softshell Turtle	EN	I	https://www.zoosprint.zooreach.org/ZoosPrintNewsLetter/ReptileRap_No17_Jul2015.pdf
2			<i>Lissemys punctata</i>	Indian Flapshell Turtle	VU	I	https://www.zoosprint.zooreach.org/ZoosPrintNewsLetter/ReptileRap_No17_Jul2015.pdf
3		Geoemydidae	<i>Pangshura tecta</i>	Indian Roofed Turtle	LC		
4		Testudinidae	<i>Geochelone elegans</i>	Indian Star Tortoise	VU		
5	Squamata	Typhlopidae	<i>Indotyphlops braminus</i>	Common Blind Snake	LC	IV	ZSI
6			<i>Grypotyphlops acutus</i>	Beaked Blind Snake	LC	IV	ZSI
7			<i>Indotyphlops porrectus</i>	Stoliczka's Slender Blind Snake	LC	IV	ZSI
8		Boidae	<i>Eryx conicus</i>	Russel's Sand Boa	NT	IV	ZSI
9			<i>Eryx johnii</i>	Indian Sand Boa	NT	IV	ZSI
10		Acrochoridae	<i>Acrochordus granulatus</i>	Marine File Snake	LC	IV	ZSI
11		Colubridae	<i>Coelognathus helenae</i>	Trinket Snake	LC	IV	ZSI
12			<i>Ptyas mucosa</i>	Indian Rat Snake	LC	IV	ZSI
13			<i>Argyrogena fasciolatus</i>	Banded racer	LC	IV	ZSI
14			<i>Oligodon arnensis</i>	Russet Kukri	LC	IV	ZSI
15			<i>Oligodon taeniolatus</i>	Streaked Kukri	LC	IV	ZSI
16			<i>Dendralphis tristis</i>	Ornate Flying Snake	LC	IV	ZSI
17			<i>Chrysopelea ornata</i>	Golden Tree Sanke	LC	IV	ZSI
18			<i>Lycodon striatus</i>	Barred Wolf Snake	LC	IV	ZSI

19			<i>Lycodon aulicus</i>	Common Wolf Snake	LC	IV	ZSI
20			<i>Sibynophis subpunctatus</i>	Dumeril's Black-headed Snake	LC	IV	ZSI
21			<i>Fowlea piscator</i>	Checkered Keelback	LC	II	ZSI
22			<i>Amphiesma stolatum</i>	Buff striped Keelback	LC	IV	ZSI
23			<i>Macropisthodon plumbicolor</i>	Green Keelback	LC	IV	ZSI
24			<i>Boiga trigonata</i>	Indian Cat Snake	LC	IV	ZSI
25			<i>Psammophis leithi</i>	Leith's Sand Snake	LC	IV	ZSI
26			<i>Ahaetulla nasuta</i>	Long-nosed Tree Snake	LC	IV	ZSI
27			<i>Gerardia prevostiana</i>	Glossy Marsh	LC	IV	ZSI
28			<i>Bungarus caeruleus</i>	Common Indian Krait	LC	IV	ZSI
29			<i>Calliophis melanurus</i>	Slender Coral Snake	LC	IV	ZSI
30			<i>Naja naja</i>	Indian Cobra	LC	II	ZSI
31			<i>Enhydrina schistosa</i>	Beaked Sea Snake	LC	IV	ZSI
32			<i>Hydrophis spiralis</i>	Yellow Sea Snake	LC	IV	ZSI
33			<i>Hydrophis cyanocinctus</i>	Annulated Sea Snake	LC	IV	ZSI
34			<i>Hydrophis gracilis</i>	Graceful small-headed Sea Snake	LC	IV	ZSI
35			<i>Microcephalophis cantoris</i>	Cantor's small-headed Sea Snake	DD	IV	ZSI
36			<i>Pelamis platurus</i>	Yellow-bellied Sea Snake	LC	IV	ZSI
37		Viperidae	<i>Daboia russelli</i>	Russel's Viper	LC	II	ZSI
38			<i>Echis carinatus</i>	Saw-scaled Viper	LC	IV	ZSI
39		Agamidae	<i>Calotes minor</i>	Hardwicke's Bloodsucker	DD		
40			<i>Calotes versicolor</i>	oriental garden lizard	LC		
41			<i>Psammophis blanfordanus</i>	Blanford's rock agama	LC		
42			<i>Sitana spinaecephalus</i>	spiny-headed fan-throated lizard	LC		
43			<i>Trapelus agilis</i>	Brilliant ground agama	NE		

44		Chamaeleonidae	<i>Chamaeleo zeylanicus</i>	Indian chameleon	LC		
45		Gekkonidae	<i>Hemidactylus flaviviridis</i>	Northern house gecko	LC		
46			<i>Hemidactylus frenatus</i>	common house gecko	LC		
47			<i>Hemidactylus gleadowi</i>	Gleadow's house gecko	NE		
48			<i>Hemidactylus leschenaultii</i>	Leschenault's leaf-toed gecko	LC		
49			<i>Hemidactylus murrayi</i>	Murray's house gecko	NE		
50			<i>Hemidactylus robustus</i>	Heyden's gecko	NE		
51			<i>Hemidactylus sahgalii</i>	Sahgal's termite hill gecko	LC		
52			<i>Eublepharis fuscus</i>	West Indian leopard gecko	LC		
53			<i>Acanthodactylus cantoris</i>	Indian fringe-fingered lizard	NE		
54		Lacertidae	<i>Ophisops beddomei</i>	Beddome's snake-eye	LC		
55			<i>Ophisops jerdonii</i>	Jerdon's snake-eye	LC		
56		Scincidae	<i>Eutropis allapallensis</i>	Allapalli grass skink	LC		
57			<i>Eutropis carinata</i>	keeled Indian mabuya	LC		
58			<i>Eutropis dissimilis</i>	striped grass mabuya	NE		
59			<i>Eutropis macularia</i>	speckled forest skink	LC		
60			<i>Riopa albopunctata</i>	white-spotted supple skink	LC		
61			<i>Riopa guentheri</i>	Günther's supple skink	LC		
62			<i>Riopa lineata</i>	lined supple skink	LC		
63			<i>Riopa punctata</i>	punctate supple skink	LC		
64		Varanidae	<i>Varanus bengalensis</i>	Bengal monitor	LC		
65	Crocodylia	Crocodylidae	<i>Crocodylus palustris</i>	Marsh crocodile	VU		
Class: Amphibia							
66	Anura	Bufonidae	<i>Duttaphrynus melanostictus</i>	Common Indian Toad	LC		ZSI
67			<i>Duttaphrynus stomatictus</i>	Marbled Toad	LC		ZSI

68		Microhylidae	<i>Uperodon systoma</i>	Marbled globular Frog	LC		ZSI
69			<i>Microhyla ornata</i>	Ornate Microhylid	LC		ZSI
70			<i>Microhyla rubra</i>	Red Microhylid	LC		ZSI
71			<i>Kaloula pulchra</i>	Painted Frog	LC		ZSI
72		Dicroglossidae	<i>Phrynoderma hexadactyla</i>	Indian Five-fingered Frog	LC		ZSI
73			<i>Hoplobatrachus tigerinus</i>	Indian Bull Frog	LC		ZSI
74			<i>Minervarya keralensis</i>	Kerala Warty Frog	LC		ZSI
75			<i>Fejervarya limnocharis</i>	Paddyfield Frog	LC		ZSI
76			<i>Sphaerotheca breviceps</i>	Indian Burrowing Frog	LC		ZSI
77			<i>Polypedates maculatus</i>	Chunam Tree Frog	LC		ZSI

2.7.3 Avifauna

Along the coastal zone within the 10 km buffer area of Kalpasar Dam project in the Gulf of Khambhat (hereafter GoKh) region, there exists a variety of coastal habitats, *i.e.* marshes, intertidal mudflats and Mangroves. These habitats provide foraging areas to a large number of local and migratory avifauna, including the egrets, herons, ibises, storks and flamingoes which breed in the area. There are several studies on the avifauna in the GoKh and its associated landscapes. Rao and Venkata (2010) carried out a study in the New Port area of Bhavnagar and reported that it harbours one of the largest colonies of Western Reef Heron (*Egretta gularis*) in the world. Parekh and Gadhavi (2013) from Kumbharvada marshy land area (IBA site) of Gujarat indicated the presence of 71 birds in the area. Another article published by Andharia (2018) had noticed a group of five individuals of black-bellied tern, an endangered bird, along the Narmada River stretch. The study by Makwana and Doodia (2022) on the avifaunal diversity at the Gaurishankar Lake (Bortalav) area of Bhavnagar city recorded about 235 species of birds grouped under 21 different orders, 65 families and 155 genera. A study carried out by Parashariya and Gadhvi (2019) for the first time identified successful breeding sites for Greater Flamingo in Gulf of Khambhat which is outside their known nesting and breeding range in India. Pandya and Vachhrajani (2010) assessed avifaunal diversity and distribution in the Mahi estuary area extending up to 50 km from Kamboi to Fajalpur in Gujarat. The study has documented a total of 118 bird species, belonging to 42 families. According to waterfowl census 2012, a total of 187 birds have been recorded in the wetlands in the Sabarmati basin area in Anand district (Wetland International 2012) (Table 2.7).

Further, the Gulf of Khambhat region exhibits high diversity of birds which are adapted to live in a wide range of terrestrial habitats, *i.e.* scrub and forest lands, agricultural land and wetlands. These include the species like House crow, Red-collared dove, House sparrow, Rose-ringed parakeet, Red-vented bulbul, Peacock, Asian Koel, Purple sunbird, Black drongo, Common myna, White-throated Kingfisher, Cattle egret, etc. (ZSI 2000).

Table 2.7: Checklist of species for Avifauna

Class: Aves

Sl. no.	Order	Family	Zoological name	Common name	IUCN	WPA 1972	Area	Reference
1	Psittaciformes	Psittaculidae	<i>Psittacula eupatria</i>	Alexandrine Parakeet	NT	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
2	Falconiformes	Falconidae	<i>Falco amurensis</i>	Amur Falcon	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
3	Apodiformes	Apodidae	<i>Cypsiurus balasiensis</i>	Asian Palm Swift	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
4	Gruiformes	Rallidae	<i>Zapornia pusilla</i>	Baillon's Crake	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
5	Charadriiformes	Turnicidae	<i>Turnix suscitator</i>	Barred Buttonquail	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
6	Podicipediformes	Podicipedidae	<i>Podiceps nigricollis</i>	Eared Grebe	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
7	Passeriformes	Muscicapidae	<i>Monticola solitarius</i>	Blue Rock Thrush	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
8	Coraciiformes	Meropidae	<i>Merops persicus</i>	Blue-cheeked Bee-eater	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
9	Coraciiformes	Meropidae	<i>Merops philippinus</i>	Blue-tailed Bee-eater	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

10	Passeriformes	Acrocephali dae	<i>Acrocephalus dumetorum</i>	Blyth's Reed Warbler	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
11	Accipitriforme s	Accipitridae	<i>Hieraaetus pennatus</i>	Booted Eagle	LC	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
12	Passeriformes	Laniidae	<i>Lanius cristatus</i>	Brown Shrike	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
13	Passeriformes	Muscicapida e	<i>Musicapa muttui</i>	Brown-breasted Flycatcher	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
14	Charadriiforme s	Laridae	<i>Chroicocephalus brunnicephalus</i>	Brown-headed Gull	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
15	Passeriformes	Passeridae	<i>Gymnoris xanthocollis</i>	Yellow-throated Sparrow	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
16	Charadriiforme s	Glareolidae	<i>Glareola pratincta</i>	Collared Pratincole	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
17	Passeriformes	Phylloscopid ae	<i>Phylloscopus collybita</i>	Common Chiffchaff	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
18	Cuculiformes	Cuculidae	<i>Hierococcyx varius</i>	Common Hawk Cuckoo	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
19	Passeriformes	Fringillidae	<i>Carpodacus erythrinus</i>	Common Rosefinch	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

20	Charadriiformes	Scolopacidae	<i>Gallinago gallinago</i>	Common Snipe	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
21	Anseriformes	Anatidae	<i>Nettapus coromandelianus</i>	Cotton Pygmy Goose	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
22	Accipitriformes	Accipitridae	<i>Aquila heliaca</i>	Eastern Imperial Eagle	VU	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
23	Passeriformes	Sylviidae	<i>Curruca crassirostris</i>	Eastern Orphee Warbler	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
24	Falconiformes	Falconidae	<i>Falco subbuteo</i>	Eurasian Hobby	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
25	Accipitriformes	Accipitridae	<i>Accipiter nisus</i>	Eurasian Sparrowhawk	LC	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
26	Piciformes	Picidae	<i>Jynx torquilla</i>	Eurasian Wryneck	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
27	Coraciiformes	Coraciidae	<i>Coracias garrulus</i>	European Roller	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
28	Anseriformes	Anatidae	<i>Mareca strepera</i>	Gadwall	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
29	Charadriiformes	Charadriidae	<i>Pluvialis squatarola</i>	Gray Plover	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

30	Passeriformes	Emberizidae	<i>Emberiza buchanani</i>	Gray-necked Bunting	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
31	Podicipediformes	Podicipedidae	<i>Podiceps cristatus</i>	Great Crested Grebe	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
32	Charadriiformes	Rostratulidae	<i>Rostratula benghalensis</i>	Greater Painted-snipe	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
33	Charadriiformes	Scolopacidae	<i>Tringa ochropus</i>	Green Sandpiper	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
34	Cuculiformes	Cuculidae	<i>Cacomantis passerinus</i>	Gray-bellied Cuckoo	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
35	Passeriformes	Alaudidae	<i>Mirafra erythroptera</i>	Indian Bushlark	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
36	Charadriiformes	Glareolidae	<i>Cursorius coromandelicus</i>	Indian Courser	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
37	Passeriformes	Oriolidae	<i>Oriolus kundoo</i>	Indian Golden Oriole	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
38	Passeriformes	Pittidae	<i>Pitta brachyura</i>	Indian Pitta	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
39	Charadriiformes	Burhinidae	<i>Burhinus indicus</i>	Indian Thick-knee	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

40	Galliformes	Phasianidae	<i>Perdica asiatica</i>	Jungle Bush Quail	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
41	Passeriformes	Cisticolidae	<i>Prinia sylvatica</i>	Jungle Prinia	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
42	Charadriiformes	Charadriidae	<i>Charadrius alexandrinus</i>	Kentish Plover	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
43	Anseriformes	Anatidae	<i>Sarkidiornis melanotos</i>	Knob-billed Duck	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
44	Phoenicopteriformes	Phoenicopteridae	<i>Phoeniconaias minor</i>	Lesser Flamingo	NT	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
45	Anseriformes	Anatidae	<i>Dendrocygna javanica</i>	Lesser Whistling Duck	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
46	Charadriiformes	Charadriidae	<i>Charadrius dubius</i>	Little ringed Plover	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
47	Charadriiformes	Scolopacidae	<i>Calidris minuta</i>	Little Stint	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
48	Charadriiformes	Laridae	<i>Sternula albifrons</i>	Little Tern	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
49	Passeriformes	Motacillidae	<i>Anthus similis</i>	Long-billed Pipit	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

50	Anseriformes	Anatidae	<i>Anas platyrhynchos</i>	Mallard	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
51	Passeriformes	Aegithinidae	<i>Aegithina nigrolutea</i>	Marshall's Iora	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
52	Anseriformes	Anatidae	<i>Anas acuta</i>	Northern Pintail	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
53	Suliformes	Anhingidae	<i>Anhinga melanogaster</i>	Oriental Darter	NT	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
54	Charadriiformes	Glareolidae	<i>Glareola maldivarum</i>	Oriental Pratincole	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
55	Charadriiformes	Charadriidae	<i>Pluvialis fulva</i>	Pacific Golden Plover	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
56	Galliformes	Phasianidae	<i>Francolinus pictus</i>	Painted Francolin	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
57	Falconiformes	Falconidae	<i>Falco peregrinus</i>	Peregrine Falcon	LC	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
58	Charadriiformes	Jacaniidae	<i>Hydrophasianus chirurgus</i>	Pheasant-tailed Jacana	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
59	Cuculiformes	Cuculidae	<i>Clamator jacobinus</i>	Pied Cuckoo	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

60	Galliformes	Phasianidae	<i>Coturnix coromandelica</i>	Rain Quail	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
61	Passeriformes	Muscicapidae	<i>Ficedula parva</i>	Red-breasted Flycatcher	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
62	Passeriformes	Emberizidae	<i>Emberiza bruniceps</i>	Red-headed Bunting	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
63	Falconiformes	Falconidae	<i>Falco chicquera</i>	Red-necked Falcon	NT	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
64	Passeriformes	Motacillidae	<i>Anthus cervinus</i>	Red-throated Pipit	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
65	Charadriiformes	Scolopacidae	<i>Calidris pugnax</i>	Ruff	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
66	Passeriformes	Hirundinidae	<i>Riparia riparia</i>	Sand Martin	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
67	Passeriformes	Estrildidae	<i>Lonchura punctulata</i>	Scaly-breasted Munia	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
68	Accipitriformes	Accipitridae	<i>Circaetus gallicus</i>	Short-toed Snake Eagle	LC	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
69	Cuculiformes	Cuculidae	<i>Taccocua leschenaultii</i>	Sirkeer Malkoha	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

70	Charadriiformes	Laridae	<i>Chroicocephalus genei</i>	Slender-billed Gull	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
71	Charadriiformes	Glareolidae	<i>Glareola lactea</i>	Small Pratincole	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
72	Passeriformes	Muscicapidae	<i>Muscicapa striata</i>	Spotted Flycatcher	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
73	Charadriiformes	Scolopacidae	<i>Tringa erythropus</i>	Spotted Redshank	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
74	Accipitriformes	Accipitridae	<i>Aquila nipalensis</i>	Steppe Eagle	EN	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
75	Passeriformes	Hirundinidae	<i>Petrochelidon fluvicola</i>	Streak-throated Swallow	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
76	Pelecaniformes	Ardeidae	<i>Butorides striata</i>	Striated Heron	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
77	Charadriiformes	Scolopacidae	<i>Calidris temminckii</i>	Temminck's Stint	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
78	Charadriiformes	Scolopacidae	<i>Xenus cinereus</i>	Terek Sandpiper	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
79	Passeriformes	Muscicapidae	<i>Cyornis tickelliae</i>	Tickell's Blue Flycatcher	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022

80	Passeriformes	Motacillidae	<i>Anthus trivialis</i>	Tree Pipit	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
81	Anseriformes	Anatidae	<i>Aythya fuligula</i>	Tufted Duck	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
82	Passeriformes	Muscicapidae	<i>Oenanthe picata</i>	Variable Wheatear	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
83	Charadriiformes	Laridae	<i>Chlidonias hybrida</i>	Whiskered Tern	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
84	Passeriformes	Motacillidae	<i>Motacilla maderaspatensis</i>	White-browed Wagtail	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
85	Accipitriformes	Accipitridae	<i>Butastur teesa</i>	White-eyed Buzzard	LC	I	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
86	Charadriiformes	Charadriidae	<i>Vanellus leucurus</i>	White-tailed Lapwing	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
87	Charadriiformes	Laridae	<i>Chlidonias leucopterus</i>	White-winged Tern	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
88	Pelecaniformes	Ardeidae	<i>Ixobrychus sinensis</i>	Yellow Bittern	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
89	Passeriformes	Paradoxornithidae	<i>Chrysomma sinense</i>	Yellow-eyed Babbler	LC	IV	Bhavnagar (Gaurishankar Lake)	Makwana & Dodia, 2022
90	Columbiformes	Columbidae	<i>Streptopelia orientalis</i>	Oriental Turtle Dove	LC	IV	Mahi estuary	Pandya & Vachhrajani, 2010

91	Passeriformes	Acrocephali dae	<i>Arudinax aedon</i>	Thick billed Warbler	LC	IV	Mahi estuary	Pandya & Vachhrajani, 2011
92	Falconiformes	Falconidae	<i>Falco cherrug</i>	Saker Falcon	EN	I	Bhal region	Dharmkumarsinhji, 1955
93	Passeriformes	Estrildidae	<i>Lonchura atricapilla</i>	Chestnut Munia	LC	IV	Tarapur	Ganpule, 2020
94	Otidiformes	Otididae	<i>Sypheotides indicus</i>	Lesser Florican	CR	I	Bhal region	Gadhvi, 2003
95	Charadriiforme s	Scolopacida e	<i>Phalaropus lobatus</i>	Red-necked Phalarope	LC	IV	Bhavnagar (Nava Bandar Rd.)	https://ebird.org/species/renpha/L3234632

2.7.4 Mammals

The study on mammals from this region dates back to 1912 when Wroughton (1912) reported the first authenticated record of the Northern Soft-furred Field Rat from the Bharuch district. Ryley (1913; 1914) in his studies recorded about seven species, the Indian false vampire, Indian pygmy pipistrelle, Common palm civet, Northern field mouse, Indian desert gerbil, Indian long-tailed tree mouse and large bandicoot rat from this area. According to Government of India (GOI, 1961 and 1969) published documents, a total of 13 different mammals, viz. Leopard cat, Indian leopard, Jungle cat, Honey Badger, Four-horned antelope, Large flying squirrel, Sambhar, spotted deer, Indian muntjac (Barking Deer), Indian Gazel (Chinkara), Indian mole rat and Indian crested porcupine were recorded from the area. Pocock (1941) recorded the first sighting of Indian grey mongoose in the Ahmedabad district followed by another sighting of the species in the Bharuch area in 1961 (GOI, 1961). Similarly, the evidence of presence of the Indian desert cat was recorded by Dharmakumarsinhji (1931). Three different studies conducted in Ahmedabad, Bharuch and Vadodara districts recorded the presence of Smooth-coated otter (Bhargava and Prasad, 1975; Rajyagor, 1975; GOI, 1979). The carnivores, Golden Jackal, Indian flying fox, and Indian wolf and Jungle cat have been reported from these districts (ZSI, 2002; Jethva and Jhala, 2004; Aiyadurai et al. 2006). Totally 47 mammal species (ZSI, 2002) have been recorded from the five districts that encompass the proposed the Kalpasar project area. The important species reported are the Nilgai, Indian hare, wild boar, Black buck, Indian grey langur, etc. (ZSI, 2000) (Table 2.8). The main populations of blackbuck and Indian wolf are restricted to the Blackbuck (Velvadar) National Park. However, some of their satellite populations are observed in the Kala talav or Dholera region of the study area. Among domestic animals different varieties of cow, goat, cat, buffalo, donkey, and pigs are very common in the village across the study area.

Table2.8: Checklist of species for Mammals

Class: Mammalia

Sl. no.	Order	Family	Zoological name	Common name	IUCN	WPA 1972	Area	Reference
1	Insectivora	Erinaceidae	<i>Hemiechinus auritus</i>	Long-eared Hedgehog	LC		Ahmedabad	ZSI
2	Eulipotyphla	Soricidae	<i>Suncus murinus sindensis</i>	Asian house Shrew	LC		Ahmedabad, Vadodara	ZSI
3	Chiroptera	Pteropodidae	<i>Rousettus leschenaultii</i>	Indian Fulvous Fruit Bat	NT	IV	Ahmedabad, Vadodara	ZSI
4			<i>Pteropus giganteus</i>	Indian flying fox	LC	IV	Throughout Gujarat	ZSI
5			<i>Cynopterus sphinx</i>	Greater short-nosed fruit bat	LC	IV	Bharuch (Jhagadiya, Netrang), Ahmedabad, Vadodara	ZSI
6		Rhinopomatidae	<i>Rhinopoma hardwickii</i>	lesser mouse-tailed bat	LC		Ahmedabad	ZSI
7		Megadermatidae	<i>Lyroderma lyra lyra</i>	Indian False Vampire	LC		Ahmedabad	Ryley, 1914c
8		Vespertilionidae	<i>Pipistrellus tenuis mimus</i>	Indian Pygmy Pispistrelle	LC		Vadodara (Sankheda); Ahmedabad	ZSI; Ryler, 1914c
9			<i>Pipistrellus ceylonicus indicus</i>	Kelaart's Pipistrelle	LC		Ahmedabad (Nandol Dahegam), Bharuch (Jhagadiya), Vadodara (Sankheda)	ZSI

10			<i>Scotozus dormeri</i>	Dormer's Bat	LC		Ahmedabad (Nandol Dahegam), Bharuch (Jhagadiya)	ZSI
11			<i>Scotophilus heathi heathi</i>	Greater Yellow Bat	LC		Throughout Gujarat	ZSI
12	Primates	Cercopithecidae	<i>Macaca mulatta mulatta</i>	Rhesus Macque	LC	II	Bharuch (Zajhpur)	ZSI
13	Pholidota	Manidae	<i>Manis crassicaudata</i>	Indian Pangolin	EN	I	Bhavnagar (Velavadar), Bharuch (Goraliya)	ZSI
14	Carnivora	Canidae	<i>Cuon alpinus dukhunensis</i>	Dhole	EN	II	Bharuch (Dediapara, Gora, Sagabara)	ZSI
15		Ursidae	<i>Melursus ursinus ursinus</i>	Sloth Bear	VU	I	Bharuch (Dhumkal)	Tikader, 1983
16		Mustelidae	<i>Mellivora capensis indica</i>	Honey Badger	LC	I	Ahmedabad, Bhavnagar, Bharuch	Govt. of Gujarat, 1961
17			<i>Lutrogale perspicillata</i>	Smooth- coated Indian Otter	VU	II	Ahmedabad; Bharuch; Vadodara	Bhargava & Prasad, 1975 ; Rajyagor, 1975 ; Govt. of India, 1979
18		Viverridae	<i>Viverricula indica indica</i>	Small Indian Civet	LC	II	Throughout Gujarat	ZSI
19			<i>Paradoxurus hermaphroditus</i>	Common Palm Civet	LC	II	Ahmedabad; Bharuch	Ryley, 1914c ; Govt. of India, 1961
20		Herpestidae	<i>Herpestes edwardsi nyula</i>	Indian Gray Mongoose	LC	II	Bharuch	Govt. of India, 1961
21			<i>Herpestes edwardsi ferrugineus</i>	Indian Gray Mongoose	LC	II	Ahmedabad	Pocock, 1941

22		Hyaenidae	<i>Hyaena hyaena hyaena</i>	Striped Hyena	NT	III	Bharuch; Bhavnagar; Vadodara	Govt. of India, 1961; Govt. of India, 1969; Govt. of India, 1979
23		Felidae	<i>Felis silvestris ornata</i>	Indian Desert Cat	LC	I	Bhavnagar	Dharmakumarsinhji, 1931
24			<i>Felis chaus kutas</i>	Jungle Cat	LC	II	Bharuch	Govt. of India, 1961
25			<i>Felis bengalensis bengalensis</i>	Leopard Cat	LC		Bharuch	Govt. of India, 1961
26			<i>Panthera pardus fusca</i>	Indian Leopard	VU	I	Ahmedabad, Bhavnagar, Bharuch	Govt. of India, 1961
27	Artiodactyla	Suidae	<i>Sus scrofa cristatus</i>	Indian Wild Boar	LC	III	Throughout Gujarat	ZSI
28		Cervidae	<i>Muntiacus muntjak</i>	Indian Muntjac	LC	III	Bharuch; Vadodara	Govt. of India, 1961; Crump in ryley, 1913, 1914c
29			<i>Axis axis axis</i>	Spotted Deer	LC	III	Bhavnagar; Bharuch	Govt. of India, 1969; Govt. of India, 1961
30			<i>Cervus unicolor niger</i>	Sambar	VU	III	Bhavnagar; Bharuch	Govt. of India, 1969; Govt. of India, 1961
31		Bovidae	<i>Tetracerus quadricornis</i>	Four-horned Antelope	VU	I	Bharuch	Govt. of India, 1961
32			<i>Gazella bennetti</i>	Indian Gazelle	LC	I	Bhavnagar; Bharuch	Govt. of India, 1969; Govt. of India, 1961
33	Rodentia	Sciuridae	<i>Petaurista philippensis</i>	Large Brown Flying Squirrel	LC	II	Bharuch	Govt. of India, 1961
34		Hystriidae	<i>Hystrix indica</i>	Indian Crested Porcupine	LC	IV	Ahmedabad; Bhavnagar; Vadodara	Patel, 1972; Govt. of India, 1961; Vadodara, 1979

35			<i>Tatera indica indica</i>	Indian Gerbill	LC	IV	Throughout Gujarat	ZSI
36			<i>Meriones hurrianae</i>	Indian Desert Gerbil	LC	IV	Ahmedabad; Bhavnagar	Ryley, 1913; Wroughton, 1912c
37			<i>Vandeleuria oleracea oleracea</i>	Indian Long-tailed Tree mouse	LC		Ahmedabad	Ryley, 1914a
38			<i>Millardia meltada pallidior</i>	Northern Soft-furred Fied Rat	LC	IV	Bharuch	Wroughton, 1912c
39			<i>Rattus rattus alexandrinus</i>	House Rat	LC	IV	Bharuch (Jhagadiya), Vadodara (Sankheda), Ahmedabad	ZSI
40		Muridae	<i>Golunda ellioti gujerati</i>	Indian Bush Rat	LC	IV	Throughout Gujarat	ZSI
41			<i>Cremnomys cutchicus cutchicus</i>	Cutch Rat	LC		Ahmedabad, Bharuch	ZSI
42			<i>Mus musculus tytleri</i>	House Mouse	LC	IV	Throughout Gujarat	ZSI
43			<i>Mus saxicola sadhu</i>	Brown Spiny Mouse	LC		Ahmedabad, Bhavnagar	ZSI
44			<i>Mus booduga booduga</i>	Common Indian Field Mouse	LC	IV	Throughout Gujarat	ZSI
45			<i>Mus dunni</i>	Northern field Mouse	LC		Bhavnagar	Ryley, 1913
46			<i>Bandicota bengalensis bengalensis</i>	Indian Mole Rat	LC	IV	Ahmedabad; Vadodara	Govt. of India, 1961; Govt. of India, 1979
47			<i>Bandicota indica indica</i>	Large Bandicoot Rat	LC	IV	Ahmedabad; Bharuch; Vadodara	Ryley, 1914c; Ellerman, 1961; ZSI

2.8 Mangroves

Mangroves are a taxonomic group of tropical plants including herbs, shrubs, trees etc. which are morphologically adapted to grow in the brackish environment of the intertidal zone (Abdul Azeez *et al.*, 2022; WCMC, 2021). Their adaptation to a higher level of salinity, wind, tides, and less availability of oxygen makes it a unique ecosystem in coastal areas (Kathiresan, 2018).

Indian mangroves cover approximately 3% of the global mangrove area (Devi and Pathak, 2016) which is India's 0.14% of the total geographical area. As the Gujarat state of India has the longest coastline, it accounts for 23 % of Indian mangroves (Devi and Pathak, 2016). The state of Gujarat has two gulfs out of a total of three gulfs in India. The Gulf of Kachchh is located in the Northwest part of Gujarat and the Gulf of Khambhat is located in South Gujarat. Both gulfs are with totally different climatic conditions such as a different range of tides, waves, and currents on which the biological conditions of the marine ecosystems are dependent. Although the Gulf of Kachchh accounts for about 71% of the State's mangrove cover, however, the plants have reduced height, smaller canopy and less girth size as compared to the South Gujarat and Gulf of Khambhat mangroves (Sawale and Thivakaran, 2013; Devi and Pathak, 2016; Singh, 2020a). Overall, the mangrove forest of Gujarat offers low biodiversity due to its arid and dry conditions and high salinity (Kathiresan, 2018).

Ecologically, the mangroves along with the associated species in this region are impacted by both, abiotic and biotic factors (Singh, 2020). The major abiotic factors include heavy discharge during the rainy season that carries along a high sediment level leading to erosion along the coastline owing to the tidal effects causing deposition (Nayak *et al.*, 1985). The biotic components include overgrazing by cattle, camel and domesticated livestock, shrimp farms extension by cutting mangroves and extensive cutting for fuel/fodder. Since the mangrove species need very specific environmental conditions for their survival and growth, they are found sparsely distributed along the coastal belt. However, in the Gulf of Khambhat region, due to the presence of rivers like Tapti, Sabarmati, Mahi, Narmada, etc., the flow of fresh water is high resulting in higher mangrove diversity as compared to the Saurashtra and Kachchh regions.

Mangroves in Gujarat are dominated by species *A. marina*. The other mangrove species, a few halophytes and mangrove associate plants, etc. can also be found in mangrove ecosystems. In Gujarat, total 15 mangrove species were reported *Avicenna marina*, *A. officinalis*, *A. alba*, *Acanthus ilicifolius*, *Aegiceras corniculatum*, *Bruguiera cylindrica*, *B. gymnorrhiza*, *Ceriops tagal*, *C. decandra*, *Excoecaria agallocha*, *Kandelia candel*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *R. apiculata*, *Sonneratia apetala*. However, the dominant species *A. marina* represents almost 97% of the total mangrove cover.

It has been reported that mangroves were present 30 years ago near villages Nada, Sigam, Malpore, and Zamdi (GSEAP, 2000). Currently, Nada village alone has a certain scrubby and sparse mangrove population. Earlier studies conducted by different agencies during 1875 to 1983 indicate a significant decrease (from 438 sq km to 13 sq km) in the mangrove cover in a majority parts of the GoK. A study conducted by ICMAM (2002), highlighted the changes in the mangrove cover/features around Piram Bet using satellite data of 1987 and 1999. It was noted that the marsh area reduced by 57% and the mangroves decreased marginally while the sandy area increased between 1988 and 1999.

Records of dense mangrove forests along the west coast of the Gulf of Khambhat have been obtained from the vegetation map of the Kathiawad region prepared by the French Institute of Pondicherry in 1960. A notable decline to the extent of 50% in the mangrove cover occurred between 1960 and 1970. This reduction continued further to 13 km² in 1993 which accounted for approximately 10% of the mangroves in 1970 (Table 2.8). Ashwini Kumar (1996) has done extensive study of the trends in mangrove area in Gulf of Khambhat based on past records and classified the findings into Bhal and non-Bhal regions. Past trends of mangroves in the Bhal region showed a decline in mangroves from 438 sq. km in 1870, to 325 sq. km in 1960, to 100 sq. km in 1980 (Table 11), and a mere 13 sq. km in 1993 (Ashwini Kumar 1996). A combination of natural processes and increased human activities were responsible for this decline in mangroves. The driving factor leading to the lowering of the natural regeneration process of mangroves is the loss of mangrove diversity due to the reduction in the freshwater influx thereby causing a rise in the salinity levels. In the Gulf of Khambhat, freshwater influxes from Mahi and Sabarmati have dwindled owing to the construction of dams. The degradation of mangroves in the Gulf of Khambhat might have

also occurred due to the erosion of the shoreline resulting from intense sea actions. The successive cyclones of the years 1998 and 1999 caused massive destruction of mangroves not only by uprooting them but also by causing blockage of the pneumatophores (GEC, 2012).

Table 2.8 - Changes recorded in area under mangrove cover over the years

Year	Source	Area (km ²)
1870	Survey of India	338
1960	FIP	325
1970	Survey of India	160
1980	Untawale	100
1987	Survey of India	105
1990	Fishery Survey of India	56
1993	Gujarat Environment and Ecology Research Institute	13
1998	Integrated Coastal and Marine Area Management – Project Directorate (ICMAM-PD)	54

(Source: ICMAM Report, 2002)

(note: specific data on mangrove cover for Gulf of Khambhat region is not available for the period 1999 to 2002 and thereafter district wise mangrove cover data is available from FSI).

Based on the Forest Survey of India (FSI, 2003 - 2021) reports, the Gulf of Khambhat region does not harbor very dense mangrove cover. However, moderately dense mangrove covers as well as sparse/open mangrove cover are present in the area. The changes in the mangrove cover in the Gulf of Khambhat region that have occurred in the last 20 years (2001-2021) is represented (Figure 2.1). An overall decrease in the mangrove cover was noted at Bharuch, Surat, Vadodara, and Bhavnagar districts. The mangrove forest habitat supports the occurrence of a total of 16 species (6 mangrove species and 10 associated plant species). Out of the six mangrove species, *Avicennia marina* was the most abundant species and was the only species that was recorded at all the study sites whereas, the occurrence of *Avicennia officinalis* and *Ceriops tagal* was site specific.

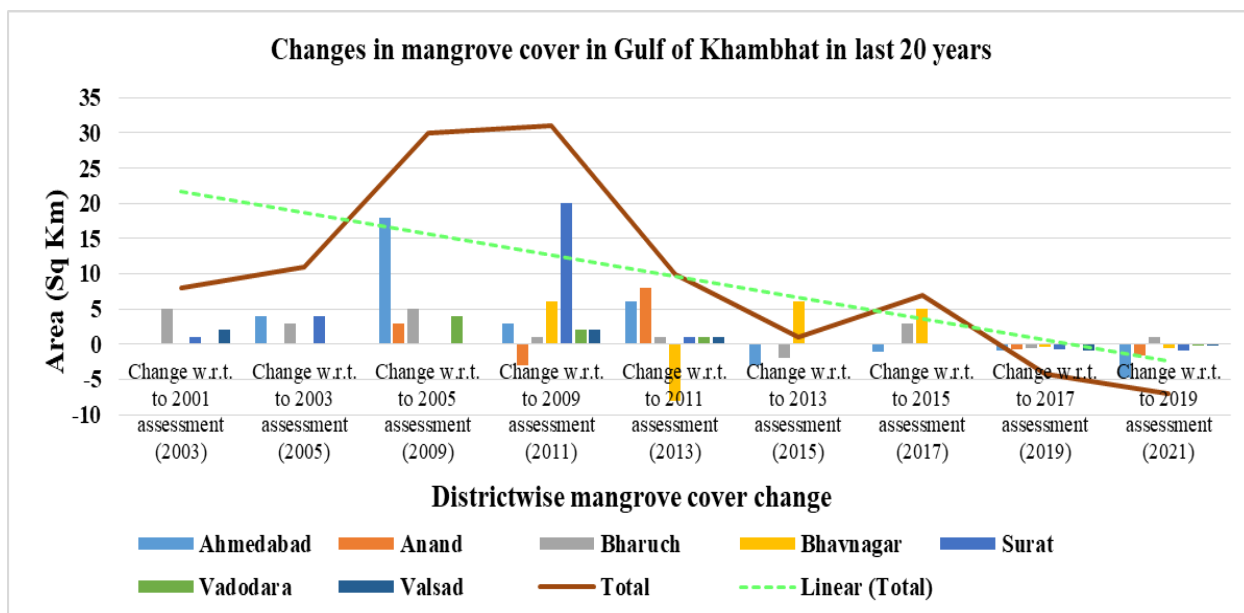


Figure 2.1. Changes in mangrove cover along the Gulf of Kachchh in last 20 years

An earlier study conducted in 1999 revealed the total area of mangrove was 52.46 sq km (Singh, 2000) of which Bhavnagar, Devla (Bharuch), Mangrol, Pardi, Jankhsi, and Dandi in Surat had the maximum mangrove cover. However, based on the study conducted by Kumar (1996), in several areas of the Gulf of Khambhat mangroves displayed a steep decline between 1975 -1983. A high density of *Avicennia marina* was noted in the Piri Island, Ghogha, and Mahuva areas. However, the growth was stunted in majority of the places except at Piri Island, where a few tall trees were noted. In contrast to this, between 1993 and 1998 the mangrove area augmented fourfold due to afforestation actions undertaken by State Government agencies (Geevan et al., 2012).

Avicennia marina well known for its extreme salt tolerance is the most common species in Khambhat area. Due to the varied geological conditions, the water availability to the mangrove was very much limited and receive the moisture only during spring tides which occurs once in 15 days. Mangroves need regular supply of water, twice daily during high tide and in the absence of which the growth is slowed down resulting in stunted growth. Similarly, the intermittent mixing of fresh water in the mangroves is required for the fast

growth of mangrove, otherwise the plants exhibit physiological adaptation, the tissue water potential of mangrove plants and also on the stomatal conductance resulting in stunted growth. The Gulf of Khambhat water salinity remains greater than the normal range (salinity >40 psu) only species which are extremely tolerant to salinity variations such as *A. marina* only survive and the persistence of same salinity level can affect the plant growth.

Halophytes are adapted to enduring elevated salinity levels and their fluctuations. They naturally bear some structural and regulatory mechanisms that support them to cope up with ionic stress. Therefore, they possess the ability to thrive in varied saline environments viz; salt flats, mudflats, coastal regions, salt marshes, deserts, etc. The salt tolerance level between different species varies and their classification is based on their growth conditions. Halophytes such as obligate halophytes, facultative halophytes, and habitat-indifferent halophytes are commonly found at different tide levels at the intertidal zone along the coasts. Scattered growth of marsh vegetation is noted in the intertidal mud flats between Tapi and Sabarmati estuaries while the vegetation is comparatively dense between the Dhadhar and Mahi estuaries. This vegetation comprises of *Salicornia brachiata*, *Suaeda* spp., *Aeluropus* spp., etc. The most plentiful and dominant mangrove associated species are *Sesuvium portulacastrum* and *Suaeda maritima* through out the project area and the adjoining buffer areas.

Studies conducted by CSMCRI (2011) on the terrestrial vegetation around the Gulf of Khambhat has stated the presence of 17 tree species with dominance of *Prosopis juliflora*, *Acacia nilotica*, *Salvadora persica* and *Azadirachta indica*. Apart from these 21 shrub/herbs reported from the sampling stations, *Tridax procumbens*, *Euphorbia nivulia*, *Acalypha indica*, *Phyllanthus niruri* are some of the common herbaceous species reported from the study area. Species like *Pergularia daemia*, *Heliotropium ovalifolium* reported in few places indicating its sparse distribution. Among the species of grass seven were reported from the area with dominance of *Aristida adscensionis* and *Cynodon dactylon*. *Cress cretica* was also reported from the supra tidal area.

CHAPTER 3 SPECIES DIVERSITY

3.1. Aquatic Biodiversity

Primary Data

The primary survey was undertaken for various groups both in the terrestrial and marine system as per the methodology described in the Chapter 1. A detailed account of the estimation of species diversity in the Gulf of Khambhat is described below in different sections.

The group wise representation of the fauna in the study area indicated that the fishes and molluscs are the dominant group as compared to the other seven groups reported (Fig 3.1). The vast intertidal area of Gulf of Khambhat sustains good population of molluscs and the fishery thriving in the area. The high turbid nature of the Gulf because of churning action of the sea bottom resultant of tidal amplitude accounted for low reporting of Cnidarian, sponges and worms.

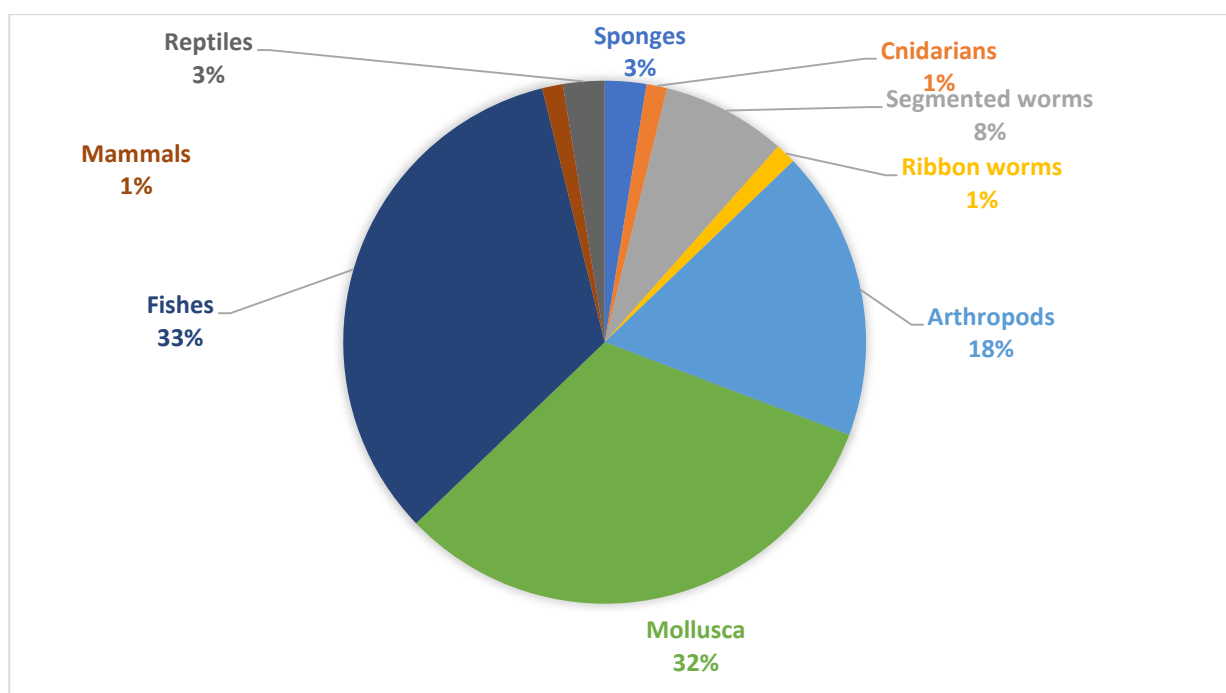


Figure 3.1: Group wise diversity Percentage) of the study area

Lower invertebrates include the species representing sponges, polychaete worms, crustaceans, gastropods and bivalves and others. Description of the species reported under the different groups is represented in the following section.

3.1.1. Lower Invertebrates/Benthos

Porifera (Sponges)

Two species of freshwater sponges was reported from the study area. As per the IUCN status these species belong to data deficient category (Table 3.1).

Table 3.1. List of Sponges species in the study area

Classification	Habitats			IUCN status
	FW	EW	MW	
Phylum: Porifera Class: Demospongiae Order: Spongillida Family: Spongillidae Genus: Corvospongilla <i>Corvospongilla lapidosa</i> (Annandale, 1908)	+	-	-	Data Deficient
<i>Corvospongilla ultima</i> (Annandale, 1910)	+	-	-	Data Deficient

Fresh water: FW; Estuarine water: EW; Marine water: MW

Cnidaria (Cnidarians)

Two cnidarians species sighted in the present study were *Diadumene lineata* and *Stephenson actisornata* occupying the estuarine and marine waters. *Diadumene lineata* is invasive in nature and categorised as Data deficient as per IUCN (2022) Red list (Table 3.2).

Table 3.2. List of Cnidarian species in the study area

Classification	Habitats			IUCN status	Remarks
	FW	EW	MW		
Phylum: Cnidaria Class: Anthozoa Order: Actiniaria Family: Diadumenidae Genus: Corvospongilla <i>Diadumene lineata</i> (Verrill, 1869)	-	+	+	Data Deficient	Invasive species
Family: Haliactinidae Genus: <i>Stephensonactis</i> <i>Stephenson actisornata</i> Panikkar, 1936	-	+	+	Data Deficient	

FW; Fresh water: EW: Estuarine: MW; Marine

Annelida

Annelids include the segmented worms, oligochaetes and polychaetes. Totally six species were reported from the study area. Four species of (Polychaetes), *Namalycastis* sp. and three unidentified *Neries* sp. represented the estuarine and marine waters and two species represented the oligochaetes recorded from the freshwater system. All the species fall in the category of data deficient (Table 3.3).

Table 3.3. List of Annelids (Segmented Worms) species in the study area

Classification	Habitats			IUCN status
	FW	EW	MW	
Phylum: Annelida Class: Polychaeta Order: Phyllodocida Family: Nereididae Genus: Namalycastis <i>Namalycastis</i> sp.	+	-	-	Data Deficient
<i>Neries</i> sp1	-	+	+	Data Deficient
<i>Neries</i> sp2	-	+	+	Data Deficient
<i>Neries</i> sp3	-	+	+	Data Deficient
Class: Clitellata Order: Tubificida Family: Naididae Genus: Nais <i>Nais</i> sp.	+	-	-	Data Deficient
Order: <i>Hirudinea</i> Order: <i>Glossiphoniidae</i> Genus: <i>Oosthuizobdella</i> <i>Oosthuizobdella</i> sp.	+	-	-	Data Deficient

FW; Fresh water: EW: Estuarine: MW; Marine

Nemertea (Ribbon worms)

Ribbon worms are very slim, usually only a few millimeters wide, although a few have relatively short but wide bodies. Most nemerteans are marine animals that burrow in sediments, lurk in crevices between shells, stones or the holdfasts of algae or sessile animals (Table 3.4).

Table 3.4 List of Nemertea (Ribbon Worms) species in the study area

Classification	Habitats			IUCN status
	FW	EW	MW	
Phylum: Nemertea Class: Pilidiophora Order: Heteronemertea				

Family: Lineidae Genus: <i>Cerebratulus</i> <i>Cerebratulus</i> sp.	-	+	-	Data Deficient

FW; Fresh water: EW: Estuarine: MW; Marine

Arthropoda

A total of 12 arthropod species was reported from the study area, out of which nine species represent marine and estuarine waters and one species belong to the fresh water species. About five species are present both in the marine and estuarine waters. All the species reported are included under the data deficient category of IUCN (2022) status. There are commercially important species such as *Macrobrachium rosenbergii* (giant freshwater prawn), Crabs and marine shrimps (Table 3.5).

Table 3.5. List of Arthropods species (Crustaceans) reported in the study area

Classification	Habitats			IUCN status	Remarks
	FW	EW	MW		
Phylum: Arthropoda Class: Malacostraca Order: Decapoda Superfamily: Portunoidea Family: Portunidae Genus: <i>Scylla</i> <i>Scylla olivacea</i> (Herbst, 1796)	-	+	-	Data Deficient	Commercially important
<i>Scylla serrata</i> (Forskål, 1775)	-	+	-	Data Deficient	Commercially important
Superfamily: Grapsoidea Family: Sesarmidae Genus: <i>Parasesarma</i> <i>Parasesarma plicatum</i> (Latreille, 1803)	-	+	-	Data Deficient	Commercially important
<i>Metaplex indica</i> H. Milne Edwards, 1852	-	+	+	Data Deficient	
Superfamily: Ocypodoidea Family: Ocypodidae Genus: <i>Austruca</i> <i>Austruca iranica</i> (Pretzmann, 1971)	-	+	-	Data Deficient	
Superfamily: Calappoidea Family: Matutidae Genus: <i>Matuta</i> <i>Matuta victor</i> (JC Fabricius, 1781)	-	-	+	Data Deficient	
Superfamily: Pilumnoidea Family: Pilumnidae Genus: <i>Eurycarcinus</i>					

<i>Eurycarcinusorientalis</i> A. Milne-Edwards, 1867	-	+	+	Data Deficient	
Family: Galenidae Genus: <i>Galene</i> <i>Galenebi spinosa</i> (Herbst, 1783)	-	-	+	Data Deficient	
Superfamily: Penaeoidea Family: Penaeidae <i>Penaeus indicus</i> H. Milne Edwards, 1837	-	-	+	Data Deficient	Commercially important
<i>Penaeus semisulcatus</i> De Haan, 1844 [in De Haan, 1833-1850]	-	-	+	Data Deficient	Commercially important
Superfamily: Paguroidea Family: Diogenidae Genus: <i>Clibanarius</i> <i>Clibanariu slongitarsus</i> (De Haan, 1849 [in De Haan, 1833-1850])	-	+	+	Data Deficient	
Superfamily: Palaemonoidea Family: Palaemonidae Genus: Macrobrachium <i>Macrobrachium rosenbergii</i> (de Man, 1879)	+	-	-	Data Deficient	Commercially important
Class: Thecostraca Order: Balanomorphia Superfamily: Balanoidea Family: Balanidae Genus: <i>Amphibalanus</i> <i>Amphibalanu samphitrite</i> (Darwin, 1854)	-	+	+	Data Deficient	
<i>Megabalanus tintinnabulum</i> (Linnaeus, 1758)	-	+	+	Data Deficient	

FW; Fresh water: EW: Estuarine: MW; Marine

Molluscs

A total of 32 mollusc species was reported from the study area. There were 19 species belonging to marine habitat, 15 estuarine species and nine freshwater species. There are 13 species overlapping between the estuarine and the marine waters. All the species reported belong to the data deficient category of the IUCN (2022) Red list. *Octopus* is the commercially important species reported from the marine zone (Table 3.6).

Table 3.6. List of Molluscs reported from the study area

Classification	Habitats			IUCN status	Remarks
	FW	EW	MW		
Phylum: Mollusca Class: Gastropoda Order: Patellogastropoda Superfamily: Patelloidea Family: Nacellidae Genus: <i>Cellana</i> <i>Cellana karachiensis</i> (Winckworth, 1930)	-	-	+	Data Deficient	
Order: Seguenziida Superfamily: Seguenzioidea Family: Chilodontaidae Genus: <i>Euchelus</i> <i>Euchelus asper</i> (Gmelin, 1791)	-	-	+	Data Deficient	
Order: Trochida Superfamily: Trochoidea Family: Trochidae Genus: <i>Umbonium</i> <i>Umbonium vestiarius</i> (Linnaeus, 1758)	-	+	+	Data Deficient	
Genus: <i>Trochus</i> <i>Trochus erithreus</i> Brocchi, 1821	-	-	+	Data Deficient	
Family: Turbinidae Genus: <i>Turbo</i> <i>Turbo bruneus</i> (Röding, 1798)	-	-	+	Data Deficient	
Order: Cycloneritida Superfamily: Neritoidea Family: Neritidae Genus: <i>Nerita</i> <i>Nerita albicilla</i> Linnaeus, 1758	-	-	+	Data Deficient	
Order: Caenogastropoda Superfamily: Cerithioidea Family: Cerithiidae Genus: <i>Clypeomorus</i> <i>Clypeomorus bifasciata</i> (G. B. Sowerby II, 1855)	-	+	+	Data Deficient	
Superfamily: Littorinoidea Family: Pomatiidae Genus: <i>Rochebrunia</i> <i>Rochebrunias</i> p.	+	-	-	Data Deficient	
Genus: <i>Pirenella</i>	-	+	+	Data Deficient	

<i>Pirenella cingulata</i> (Gmelin, 1791)					
Genus: <i>Telescopium</i> <i>Telescopium telescopium</i> (Linnaeus, 1758)	-	+	+	Data Deficient	
Family: Thiaridae Genus: <i>Tarebia</i> <i>Tarebia granifera</i> (Lamarck, 1816)	+	-	-	Data Deficient	
Order: Architaenioglossa Superfamily: Viviparoidea Family: Viviparidae Genus: <i>Filopaludina</i> <i>Filopaludina bengalensis</i> (Lamarck, 1822)	+	-	-	Data Deficient	
Order: Hygrophila Superfamily: Lymnaeoidea Family: Planorbidae Genus: <i>Gyraulus</i> <i>Gyraulus convexiusculus</i> (T. Hutton, 1849)	+	-	-	Data Deficient	
<i>Gyraulus</i> sp.	+	-	-	Data Deficient	
Genus: <i>Planorbis</i> <i>Planorbis</i> sp.	+	-	-	Data Deficient	
Family: Lymnaeidae Genus: <i>Radix</i> <i>Radix</i> sp.	+	-	-	Data Deficient	
Order: Littorinimorpha Superfamily: Calyptraeidea Family: Calyptraeidae Genus: <i>Calyptraea</i> <i>Calyptraea edgariana</i> Melvill, 1898	-	+	+	Data Deficient	
Superfamily: Truncatelloidea Family: Bithyniidae Genus: <i>Digoniostoma</i> <i>Digoniostoma</i> sp.	+	-	-	Data Deficient	
Family: Stenothyridae Genus: <i>Stenothyra</i> <i>Stenothyra blanfordiana</i> G. Nevill, 1880	+	-	-	Data Deficient	
Family: Assimineidae Genus: <i>Optedicerus</i> <i>Optedicerus breviculum</i> (L. Pfeiffer, 1855)	-	+	-	Data Deficient	
Superfamily: Muricoidea Family: Muricidae Genus: <i>Indothais</i> <i>Indothais lacera</i> (Born, 1778)	-	+	+	Data Deficient	

Order: Ellobiida Superfamily: Ellobioidea Family: Ellobiidae Genus: <i>Melampus</i> <i>Melampus fasciatus</i> (Deshayes, 1830)	-	+	-	Data Deficient	
Genus: <i>Auriculastra</i> <i>Auriculastra saccata</i> (L. Pfeiffer, 1855)	-	+	+	Data Deficient	
Class: Bivalvia Order: Cardiida Superfamily: Tellinoidea Family: Tellinidae Genus: <i>Tellina</i> <i>Tellina macassariensis</i> Prashad, 1932	-	+	+	Data Deficient	
Order: Venerida Superfamily: Veneroidea Family: Veneridae Genus: <i>Gafrarium</i> <i>Gafrarium pectinatum</i> (Linnaeus, 1758)	-	+	+	Data Deficient	
Superfamily: Cyrenoidea Family: Glauconomidae Genus: <i>Glauconome</i> <i>Glauconome angulata</i> Reeve, 1844	-	+	+	Data Deficient	
<i>Glauconomecerea</i> Reeve, 1844	-	+	+	Data Deficient	
Family: Cyrenidae Genus: <i>Corbicula</i> <i>Corbicula peninsularis</i> Prashad, 1928	+	-	-	Data Deficient	
Order: Unionida Superfamily: Unionoidea Family: Unionidae Genus: <i>Radiatula</i> <i>Radiatula</i> sp.	+	-	-	Data Deficient	
Family: Laternulidae Genus: <i>Laternula</i> <i>Laternula anatine</i> (Linnaeus, 1758)	-	+	+	Data Deficient	
Order: Myida Superfamily: Pholadoidea Family: Pholadidae Genus: <i>Pholas</i> <i>Pholas orientalis</i> Gmelin, 1791	-	+	+	Data Deficient	
Class: Cephalopoda					

Order: Octopoda Superfamily: Octopodoidea Family: Octopodidae Genus: <i>Octopus</i> <i>Octopus</i> sp.	-	-	+	Data Deficient	Commercially important

FW; Fresh water: EW: Estuarine: MW; Marine

3.1.2. Plankton

The plankton comprises of phytoplankton (primary producer) and zooplankton (primary consumers). The data set is divided into three major habitats viz., gulf, estuary and riverine zones. Accordingly, each of the component is described based on the species distribution and density.

3.1.2.1 Phytoplankton

Gulf zone: The study area was divided into 33 grids and were classified into three segments of the Gulf of Khambhat. The Dhadar river confluence area constituted of G-12, G-26, G-29, G-31 and G-32 grids. There were twenty genera of phytoplankton belonging to the four major groups viz., Bacillariophyceae, Cyanophyceae, Chlorophyceae and Dinophyceae (Fig 3.2) recorded. The number of diatom species was predominant varying between 16 -20, and contributed the maximum representation in this area.

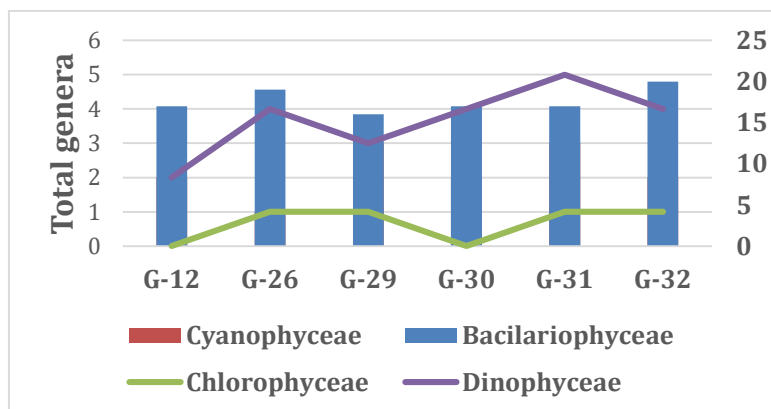


Figure 3.2: Phytoplankton genera in the inner gulf at the Dhadar Confluence

The Sabarmati and Mahi river confluence area consists of 10 sampling grids viz., G-17, G-20, G-21, G-22, G-23, G-24, G-25, G-33, G-27 and G-28. A total of 19 phytoplankton genera were recorded in this area and Bacillariophyceae showed the maximum representation (14-19). Cynaophyceae and Cholophyceae members are generally represented by the filamentous genera.

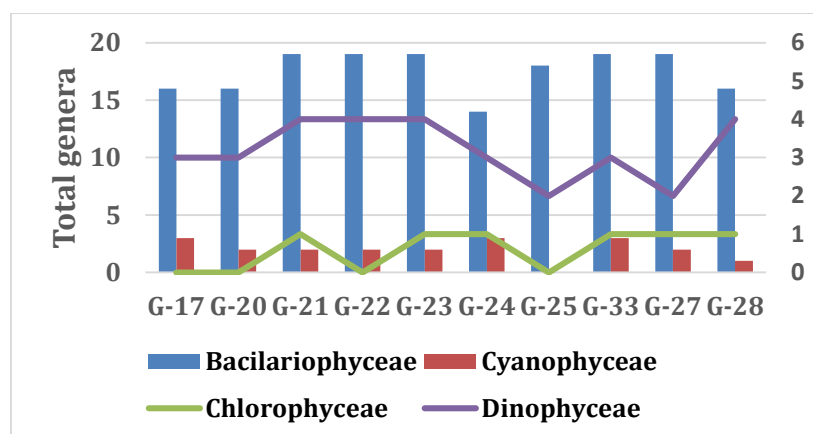


Figure 3.4: Phytoplankton genera in the inner gulf at the Sabarmati and Mahi Confluence

The phytoplankton density of Dhadar river confluence varied from 320 No/l to 21,120 No/L. Among the diatoms *Coscinodiscus* sp. had the highest density and *Prorocentrum* sp. had the lowest density of species (Fig 3.5).

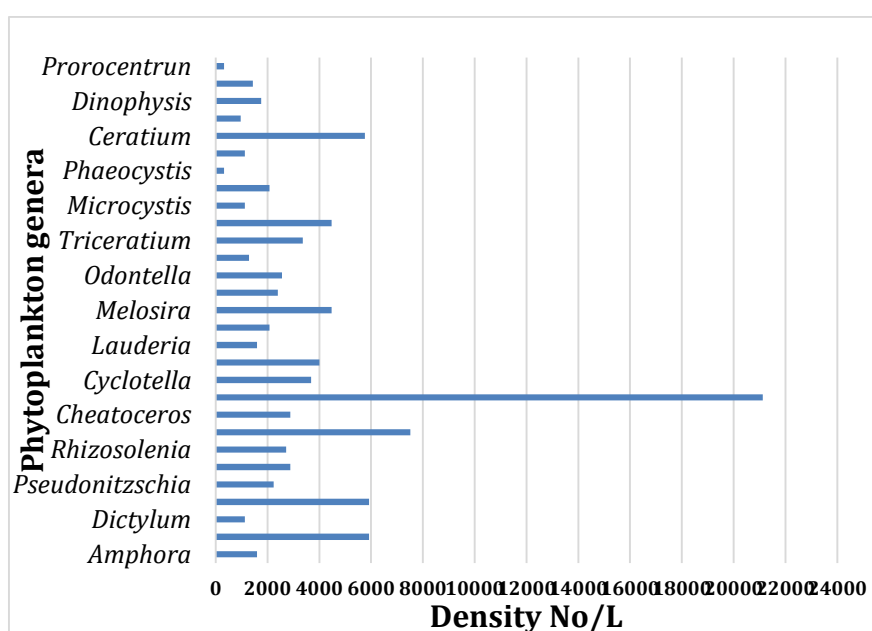


Figure 3.5: Phytoplankton density in the inner gulf at the Dhadar Confluence

The phytoplankton density of Sabarmati and Mahi river confluence ranged from 320 no/l to 55,360 No/L. In this zone also, *Coscinodiscus* was found to have high density and *Prorocentrum* sp showed the least density (Fig 3.6).

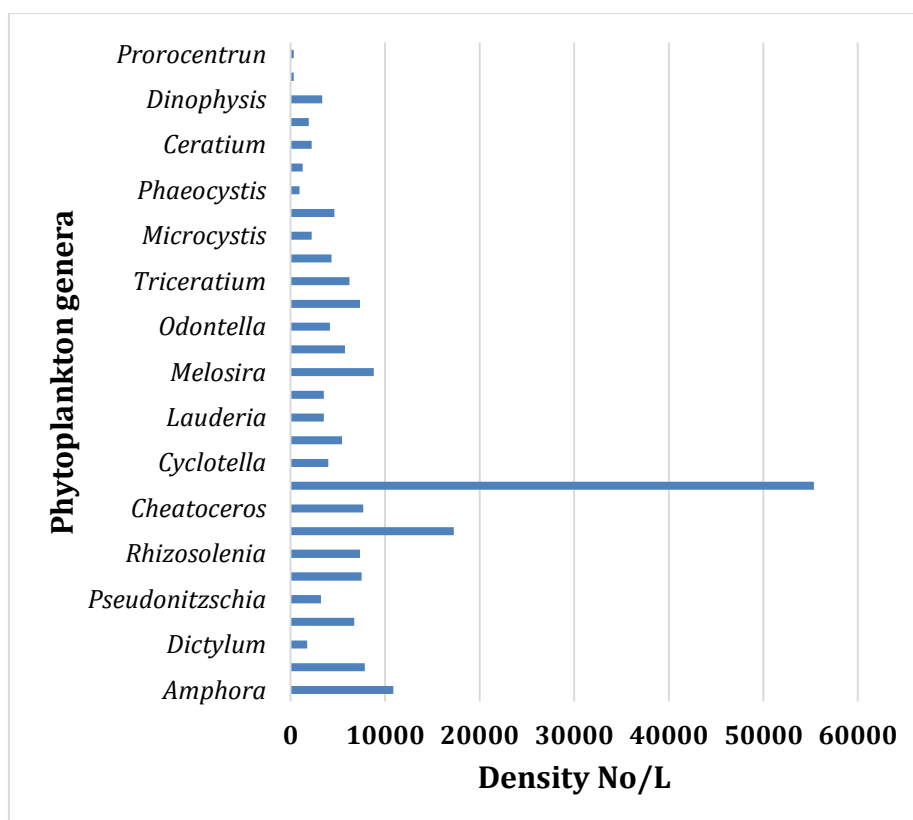


Figure 3.6: Phytoplankton density at the Sabarmati and Mahi Confluence

Similarly, outer gulf environment consists of total 17 grid and a total of 20 genera were sighted (fig 3.7). The highest number of genera was contributed by Bacillariophyceae (13-20) followed by Dinophyceae (1-5). The Chlorophyceae group found to be very negligible all the grid of Gulf of Khambhat (Fig 3.7).

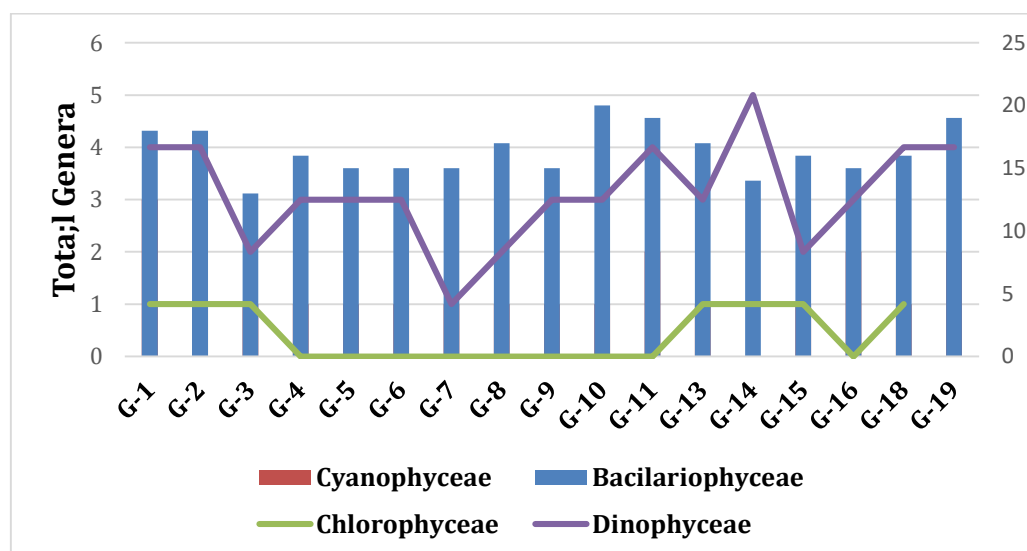


Figure 3.7: Phytoplankton genera in the outer gulf

The phytoplankton density of outer gulf varied from 480 no/l to 60,160 no/L. Here also *Coscinodiscus* species showed highest density and *Prorocentrum* the lowest density among the species sighted (Fig 3.8).

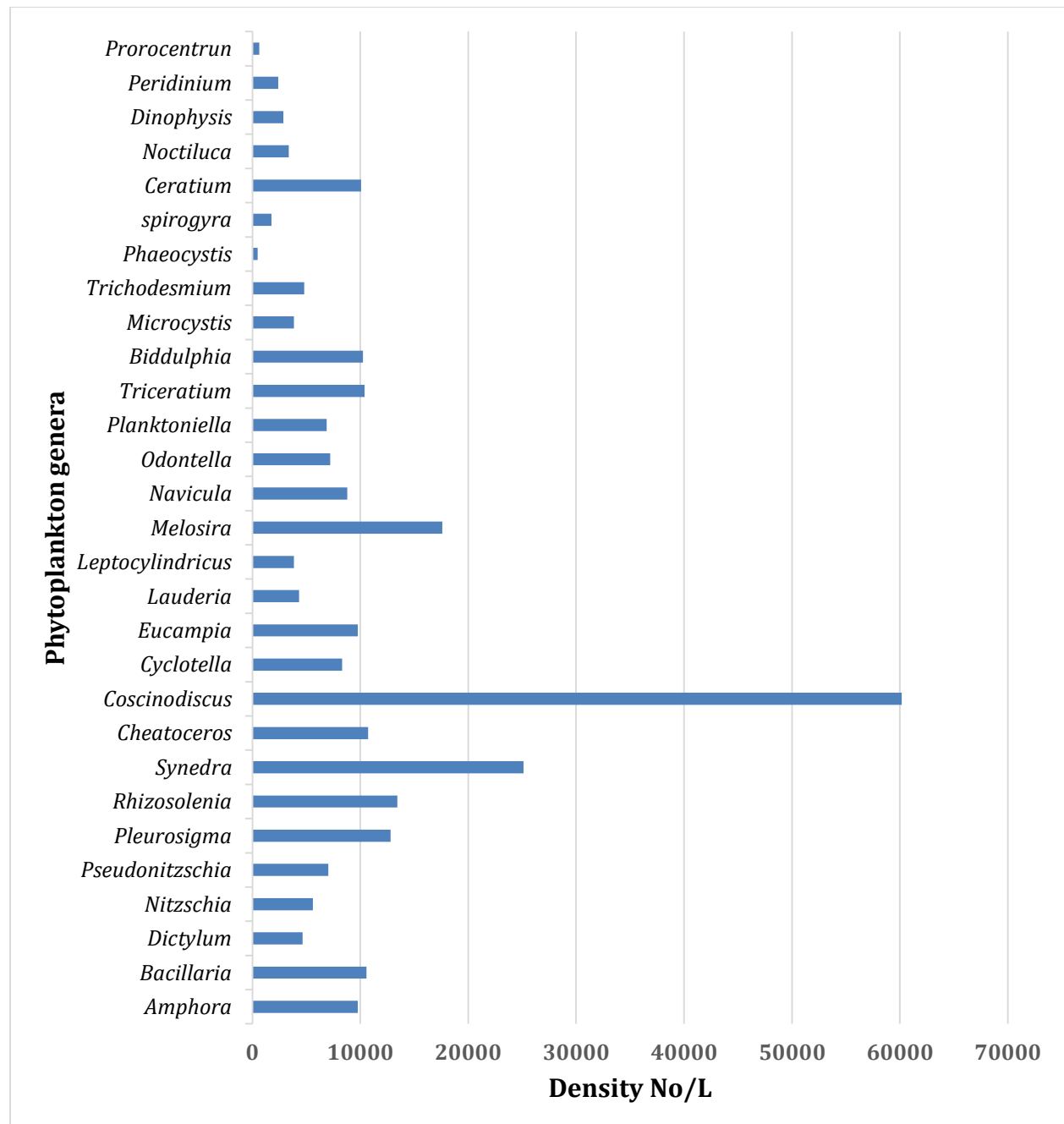


Figure 3.8: Phytoplankton density in the outer gulf at the Dhadar Confluence

Fresh water: The phytoplankton generic status of the 3 riverine systems mainly consists of Bacillariophyceae, Cyanophyceae, Chlorophyceae and Euglenophyceae.

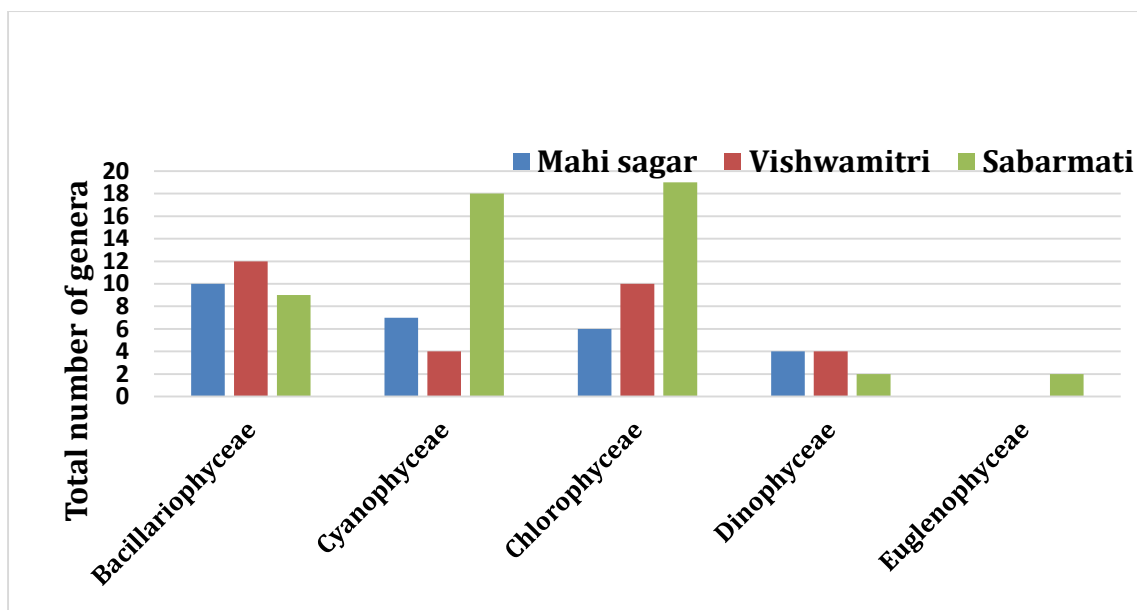


Figure 3.9: Groupwise phytoplankton genera in the riverine system

The generic number ranged from 1-19, where the Bacillariophyceae (9-12), Cyanophyceae (7-18), Chlorophyceae (6-19) and Euglenophyceae (2) in number (3.9).

The percentage representation of phytoplankton species was high for Chlorophyceae (33%), followed by Bacillariophyceae (29%) and Cyanophyceae (27%) members (Fig 3.10).

Phytoplankton density of riverine system ranged from 160 No/L to 4,160 No/L. *Spirogyra* (3,360 No /L) showed the highest plankton density, followed by *Synedra* (4,160 No/L) and *Coscinodiscus* (3840 No /L).

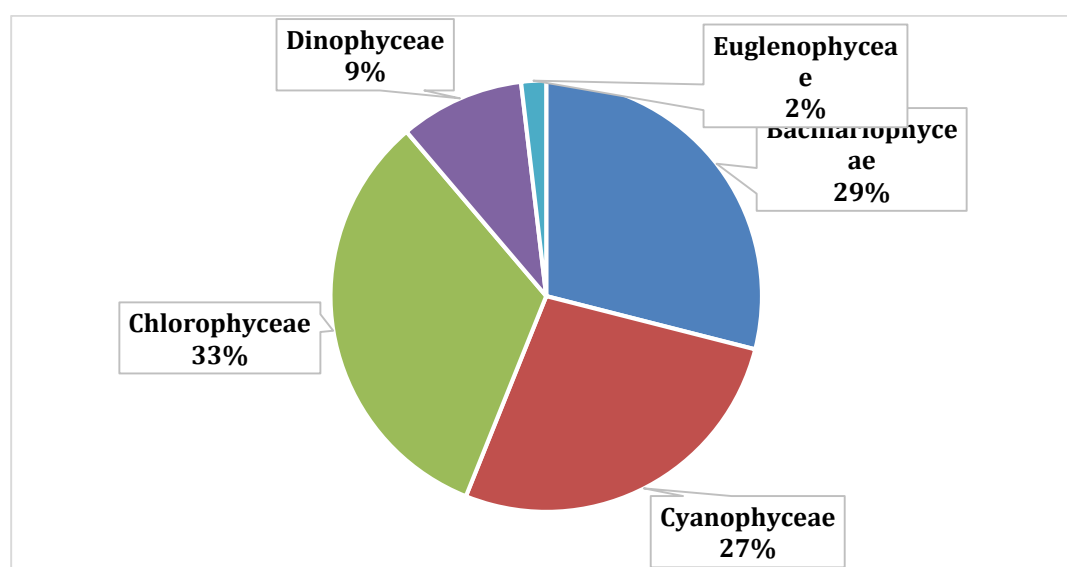


Figure 3.10: Percentage composition of phytoplankton groups in the riverine system

Estuarine system: The estuary of the major rivers was dominated by five groups Chlorophyceae (6-19), followed by Cyanophyceae (7-18) and Bacillariophyceae (9-12). Sabarmati estuary showed presence of only Euglenophyceae members indicative of disturbed ecosystem and absence of primary producers in the system. The phytoplankton production in the estuary higher than the marine system, however the Sabarmati estuary fails to show the productivity (Fig 3.11).

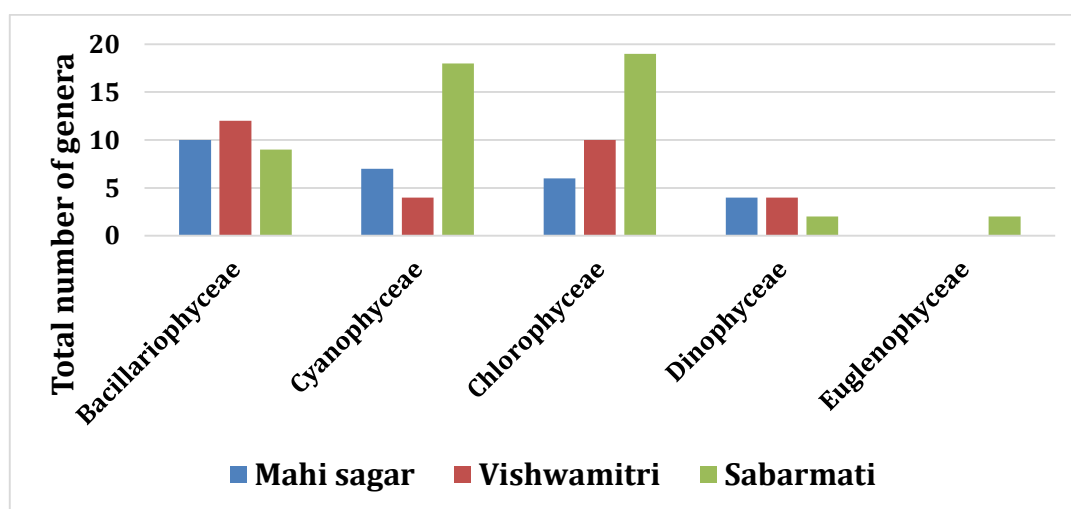


Figure 3.11: Group wise phytoplankton genera in the estuarine system

Phytoplankton density of estuarine system varied from 160 no/L to 4160 No/L. The highest density was contributed by genera *Spirogyra* (3360 No /L) followed by *Synedra* (4,160 No /L) and *Coscinodiscus* (3,840 No /L) (Fig 3.12). The filamentous alga, *Spirogyra* tends to grow profusely in the nutrient rich water conditions and forms a scum on the surface.

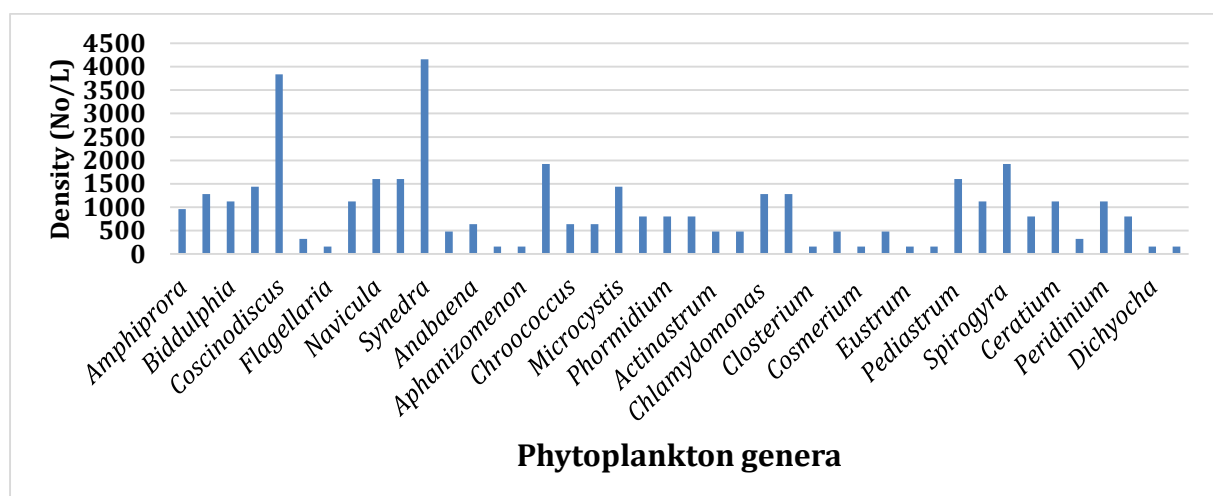


Figure 3.12: Groupwise phytoplankton density in the estuarine system

3.1.2.2. Zooplankton

Gulf waters: The inner gulf grids are included into the three segments viz., Dhadar, Mahi and Sabarmati confluence. The Dhadar river confluence consists of grid G-12, G-26, G-29, G-31 and G-32. A total of 43 genera were reported from the 5 grids and constituted five major groups viz., Protozoa, Calanoida, Harpacticoida, Cyclopoida, Decapoda (Fig 3.13) and the category 'others' was added which had representation of 1 to 2 species. This "Other" category included Malacostraca, Appendicularia, Polychaete larvae, Gastropod larval forms, Bivalve larvae, Porifera, Coelenterates, Cladoceran, *Tornaria* larva, *Bipinaria* larva, *Cyphonutes* larva, *Nemadodes*, *Sagitta*, fish larvae.

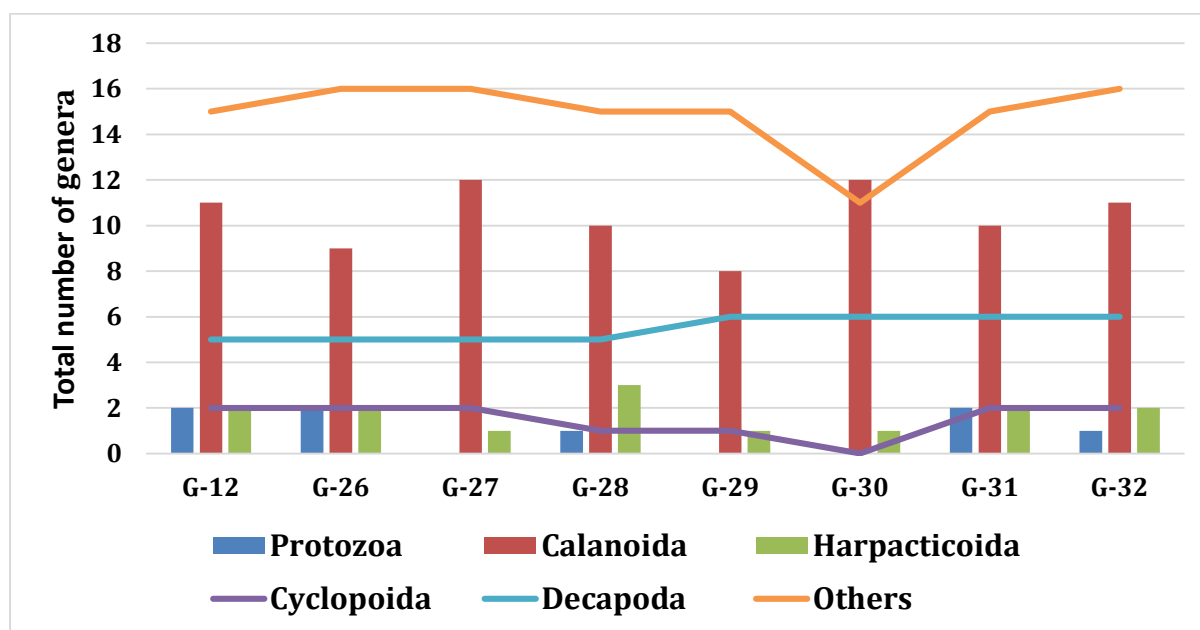


Figure 3.13: Total number of Zooplankton genera in Dadhar confluence

The Zooplankton density of Dhadar river confluence varied from 480 No/l to 42,240 No /L. Calanoida reported the highest density followed by Decapoda group and the least density was observed for Porifera (Fig 3.14).

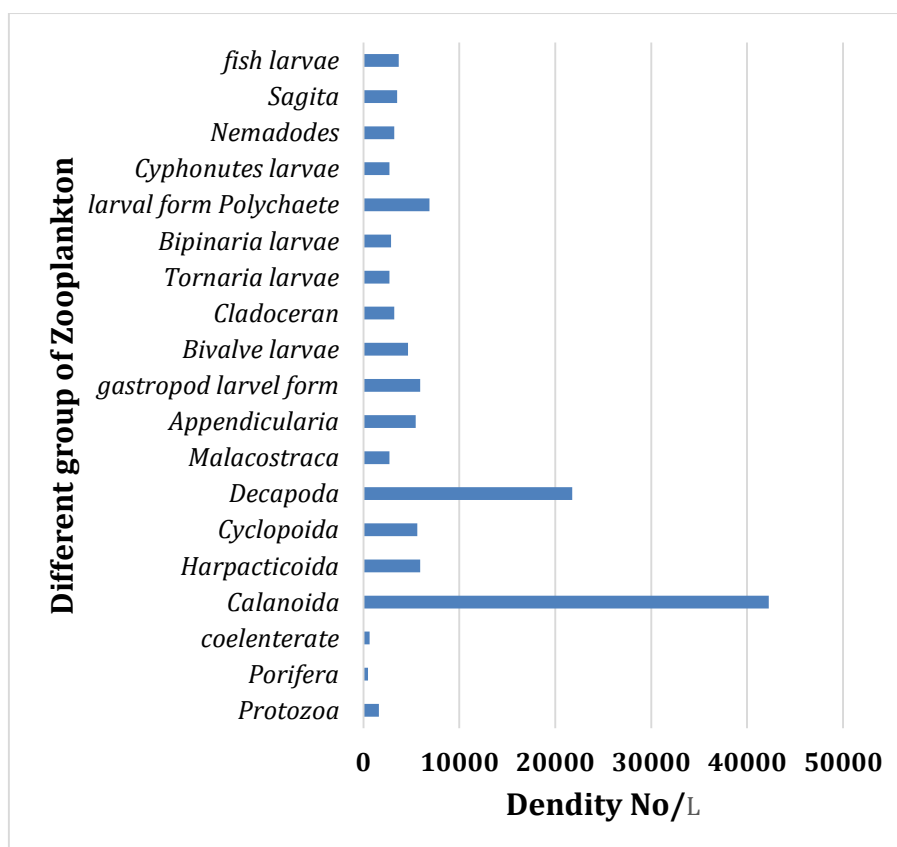


Figure 3.14: Groupwise density of zooplankton in Dadhar confluence

In Sabarmati and Mahi river confluence consist of 10 sampling grids G-17, G-20, G-21, G-22, G-23, G-24, G-25, G-33, G-27 and G-28. A total of 42 Zooplankton genera was observed, of which Calanoida-copepod (9-12), followed by Decapoda (4-6) and the “other” group contributed 14 genera (Fig 3.15).

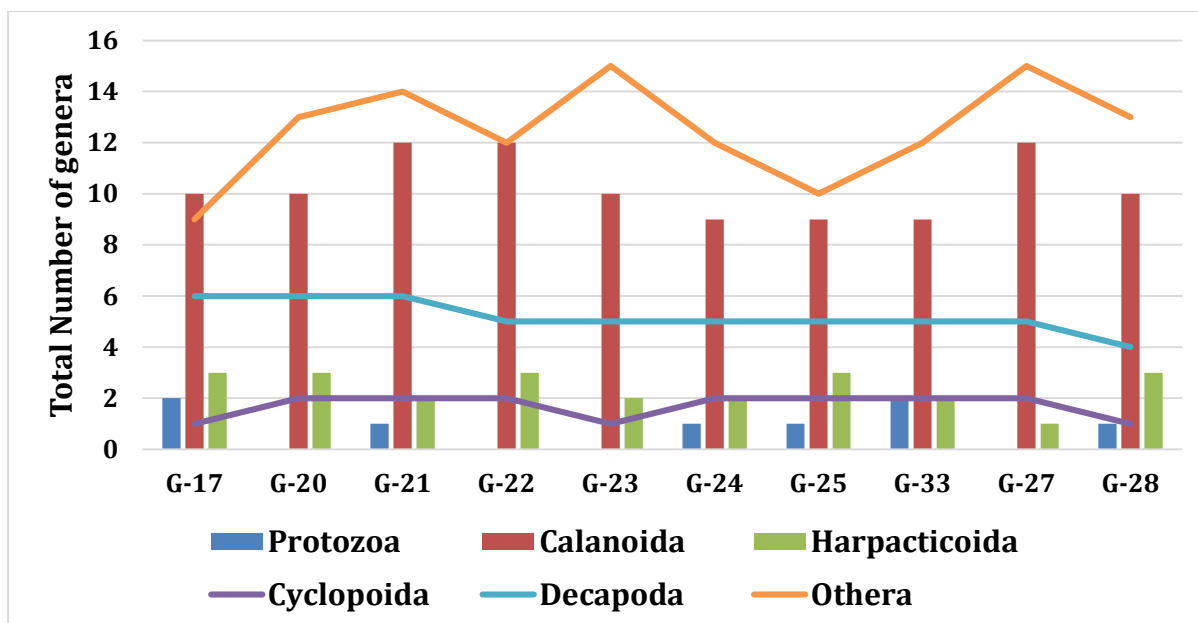


Figure 3.15: Total number of Zooplankton genera in Mahisagar and Sabarmati confluence

The Zooplankton of Mahi and Sabarmati confluence varied from 480 No /l to 56,800 No /L. Calanoida reported the highest density followed by Decapoda and the other group such as Porifera and Coelenterates showed low density (Fig 3.16). The Gulf of Khambhat has the World's second highest tidal amplitude which results in high turbidity not suitable for Porifera and Coelentrates which prefer calm waters with low turbidity.

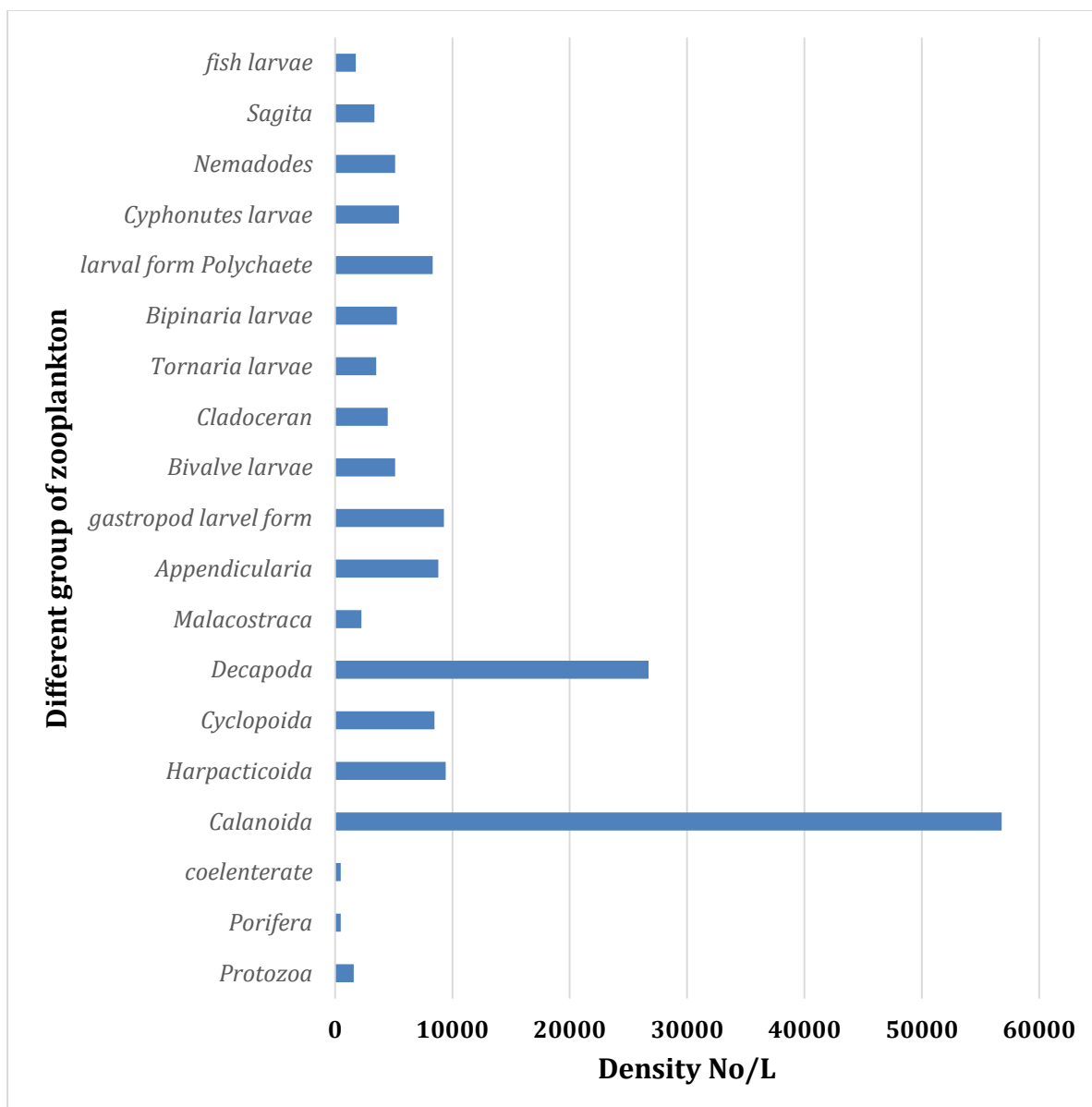


Figure 3.16: Groupwise density of zooplankton in mahisagar and Sabarmati confluence

Outer gulf: The outer gulf consists of 17 grid G-1, G-2, G-3, G-4, G-5, G-6, G-7, G-8, G-9, G-10, G-11, G-13, G-14, G-15, G-16, G-18, G-19. A total of 43 genera was recorded and highest number was contributed by Calanoid copepod (6-12), followed by Decapoda (1-6). The others contributed by 14 groups such as Malacostraca, Appendicularia, Polychaete larval form, Gastropod larval form, Bivalve larvae, Porifera, Coelenterates, Cladoceran, Tornaria larva, Bipinnaria larva, Cyphonutes larva, Nematodes, *Sagitta* and fish larvae (Fig 3.17).

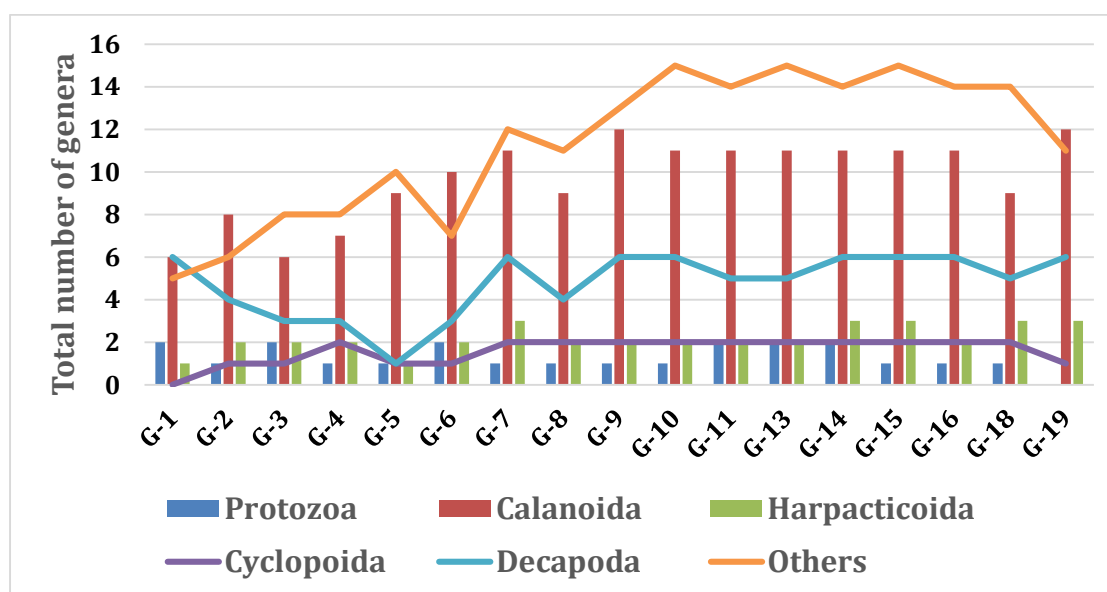


Figure 3.17: Total number of genera in Gulf environment

The Zooplankton of outer Gulf varied from 1920 No/l to 1,25,760 No/L. Calanoida was found in high density followed by Decapoda while the Coelenterates showed low density (Fig 3.18).

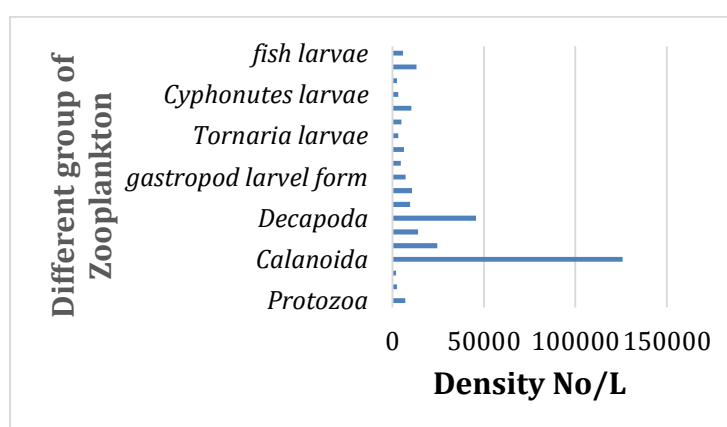


Figure 3.18: Groupwise density of zooplankton in outer gulf

3.1.3 Seaweeds

Seaweeds is one of the important component of intertidal region and have high commercial importance. In the study area *Ulva lactuca* was sighted in the intertidal region. The species is listed as data deficient as per the IUCN Red list.

S. No	Classification	Habitats			IUCN status	Remarks
		FW	EW	MW		
1.	Phylum: Chlorophyta Class: Ulvophyceae Order: Ulvales Family: Ulvaceae Genus: Ulva <i>Ulva lactuca</i> Linnaeus, 1753	-	-	+	Data Deficient	Commercially important

Fresh water: FW; Estuarine water: EW; Marine water: MW

3.1.4 Fishes

A total of 51 species were recorded. Out of which 32 species are marine, 10 species represent estuarine, and 19 species are freshwater fishes. Ten species share estuarine and marine environments. *Boleophthalmus dussumieri* is the dominant species present in both marine and estuarine waters. *Puntius sophor* is the dominant species reported in the freshwater systems (Table 3.7).

Table 3.7: The fishes count from the project area

S NO.	Name of the species	Marine water	Estuarine water	Fresh water
1	<i>Maculabatisbineeeshi</i>	3		
2	<i>Maculabatis arabica</i>	2		
3	<i>Himantura uarnak</i>	1		
4	<i>Brevitrygonwalga</i>	3	0	0
5	<i>Urogymnusgranulatus</i>	2	0	0
6	<i>Urogymnusasperrimus</i>	2	0	0
7	<i>Pateobatisbleekeri</i>	1	0	0
8	<i>Gymnurapoecilura</i>	2	0	0
9	<i>Scoliodonlaticaudus</i>	19	0	0
10	<i>Carcharhinus limbatus</i>	3	0	0

11	<i>Carcharhinus macloiti</i>	2	0	0
12	<i>Negaprio nacutidens</i>	1	0	0
13	<i>Chiloscyllium griseum</i>	2	0	0
14	<i>Chiloscyllium marabicum</i>	3	0	0
15	<i>Anoxypristis cuspidata</i>	4	0	0
16	<i>Harpadon nehereus</i>	2	0	0
17	<i>Boleophthalmus dussumieri</i>	189	286	0
18	<i>Glossogobius giuris</i>	0	0	19
19	<i>Cynoglossus arel</i>	11	6	
20	<i>Cynoglossus bilineatus</i>	9	11	
21	<i>Cynoglossus sp.</i>	3	0	0
22	<i>Brachirus orientalis</i>	11	2	
23	<i>Solea elongata</i>	2	1	
24	<i>Zebrias quagga</i>	3	1	
25	<i>Eleutheronema tetradactylum</i>	11	26	
26	<i>Otolithoides biauritus</i>	3	2	
27	<i>Otolithoides sp1.</i>	2	0	0
28	<i>Otolithoides sp2.</i>	2	0	0
29	<i>Eleutheronema sp.</i>	3	0	0
30	<i>Lates calcarifer</i>	2	1	
31	<i>Amblypharyngodon mola</i>	0	0	17
32	<i>Gibelion catla</i>	0	0	9
33	<i>Labeo gonius</i>	0	0	36
34	<i>Labeo rohita</i>	0	0	1
35	<i>Puntius sophor</i>	0	0	89
36	<i>Salmostoma bacaila</i>	0	0	55
37	<i>Systomussa rana</i>	0	0	26
38	<i>Aplocheilichthys panchax</i>	0	0	23
39	<i>Anabas testudineus</i>	0	0	32
40	<i>Channa striata</i>	0	0	11
41	<i>Macrognathus pancalus</i>	0	0	6
42	<i>Mystus tengara</i>	0	0	31
43	<i>Mystus vittatus</i>	0	0	39
44	<i>Ompok pabda</i>	0	0	19
45	<i>Wallago attu</i>	0	0	3
46	<i>Arius jella</i>	11	6	
47	<i>Arius arius</i>	19	4	
48	<i>Oreochromis mossambicus</i>	0	0	39
49	<i>Parambassis ranga</i>	0	0	11
50	<i>Xenentodon cancila</i>	0	0	12
51	<i>Chanos chanos</i>	28	28	

There were 15 species of Elasmobranchs which includes eight rays, six sharks and one saw fish. All the species are commercially important and collected from the marine zone in the project area. Among rays, two are critically endangered viz., *Maculabatis bineeshi* (short-tail whipray) and *Maculabatis arabica* (Arabic whip ray). According to IUCN Red data book list the two species are endangered and the rest are vulnerable. There were three sharks which are nearly endangered and the others are most vulnerable.

Diversity index was high in fresh water (2.748) as compared to the other two habitats. The estuarine habitat showed a low score of 1.407, indicative of low species diversity (Table 3.8).

Table 3.8. Density and Diversity of fish species of the project area

Parameters	Fresh water	Estuarine water	Marine water
Taxa_S	19	10	32
Individuals	535	438	850
Dominance_D	0.0782	0.4436	0.2168
Simpson_1-D	0.9218	0.5564	0.7832
Shannon_H	2.748	1.407	2.031
Evenness_e^H/S	0.7433	0.2402	0.2006
Brillouin	2.663	1.345	1.959
Menhinick	0.9079	0.8123	1.303
Margalef	3.184	2.631	5.485
Equitability_J	0.9026	0.4965	0.5584
Fisher_alpha	4.358	3.518	8.163
Berger-Parker	0.1664	0.653	0.3365
Chao-1	21	19	38.21

Totally nine species are found in all the three habitats. These species have wide range of ecological adaptations and utilize the three habitats for their reproductive purposes (Table 3.9).

Table 3.9. Fishes reported from fresh water, estuarine and marine waters

1	<i>Anguilla bengalensis</i> (Gray, 1831)
2	<i>Aphanius dispar</i> (Rüppell, 1829)
3	<i>Gudusia chapra</i> (Hamilton, 1822)
4	<i>Hilsa kelee</i> (Cuvier, 1829)
5	<i>Megalops cyprinoides</i> (Broussonet, 1782)
6	<i>Mugil cephalus</i> (Linnaeus, 1758)
7	<i>Odontamblyopus rubicundus</i> (Hamilton, 1822)
8	<i>Tenualosa ilisha</i> (Hamilton, 1822)
9	<i>Tenualosa toli</i> (Valenciennes, 1847)

A total of 14 species are found overlapping between the fresh and estuarine waters as shown in the Table 3.10. Important once include *Hilsa kelee*, *Tenualosa ilisha*.

Table 3.10. Fishes reported from fresh water, estuarine and marine waters

1	<i>Anguilla bengalensis</i> (Gray, 1831)
2	<i>Oryzias setnai</i> (Kulkarni, 1940)
3	<i>Gudusia chapra</i> (Hamilton, 1822)
4	<i>Hilsa kelee</i> (Cuvier, 1829)
5	<i>Tenualosa ilisha</i> (Hamilton, 1822)
6	<i>Tenualosa toli</i> (Valenciennes, 1847)
7	<i>Mugil cephalus</i> (Linnaeus, 1758)
8	<i>Rhinomugil corsula</i> (Hamilton, 1822)
9	<i>Notopterus notopterus</i> (Pallas, 1769)
10	<i>Oreochromis mossambicus</i> (Peters, 1852)
11	<i>Odontamblyopus rubicundus</i> (Hamilton, 1822)
12	<i>Pseudapocryptes elongatus</i> (Cuvier, 1816)
13	<i>Taenioides anguillaris</i> (Linnaeus, 1758)
14	<i>Leptomelanosoma indicum</i> (Shaw, 1804)

The only saw fish, *Anoxypristis cuspidata* the commercially important species is enlisted as endangered primarily due to exploitation, by-catch and to a lesser extent, habitat loss and degradation. The bony fishes reported from the marine fishes are helpful to sustain the livelihood of the fishermen. However, the most common Bombay duck, *Harpodon nehereus*, is being considered as nearly endangered as the catch has been declined in the recent years from the study area. Many of the fishes caught from the marine zone are also inhabits the estuarine section as well as they are euryhaline in nature and tend move between the Gulf mouth and the low saline upper estuarine zone. The mudskippers are also found in the mangrove and muddy shores located in the rear end of the Gulf proper and are also considered as vulnerable due to over exploitation and the habitat degradation. The fishes collected from the riverine section were the minor and major carps and the catfishes. Totally there were 21 species collected from the rivers, Mahi, and some tributaries (Table 3.11).

Table 3.11: List of fish species recorded from the study area with IUCN status and importance

Classification	Common Name	Habitats			IUCN status	Remarks
		FW	EW	MW		
Phylum: Chordata Class: Elasmobranchii Order: Myliobatiformes Family: Dasyatidae Genus: <i>Maculabatis</i> <i>Maculabatis bineeshi</i> Manjaji Matsumoto & Last, 2016	Short tail whipray	-	-	+	Critically Endangered	Commercially important
<i>Maculabatis arabica</i> Manjaji- Matsumoto & Last, 2016	Pakistan whipray or Arabic whipray	-	-	+	Critically Endangered	Commercially important
Genus: <i>Himantura</i> <i>Himantura uarnak</i> (Gmelin, 1789)	Honeycomb stingray	-	-	+	Vulnerable	Commercially important
Genus: <i>Brevitrygon</i> <i>Brevitrygon walga</i> (Müller & Henle, 1841)	Dwarf whipray or mangrove whipray	-	-	+	Vulnerable	Commercially important
Genus: <i>Urogymnus</i> <i>Urogymnus granulatus</i> (Macleay, 1883)	Mangrove whipray	-	-	+	Vulnerable	Commercially important
<i>Urogymnus asperrimus</i> (Bloch & Schneider, 1801)	Porcupine whipray	-	-	+	Vulnerable	Commercially important
Genus: <i>Pateobatis</i> <i>Pateobatis bleekeri</i> (Blyth, 1860)	Bleeker's whipray	-	-	+	Endangered	Commercially important
Family: Gymnuridae Genus: <i>Gymnura</i> <i>Gymnurapoecilura</i> (Shaw, 1804)	Long-tailed butterfly ray	-	-	+	Vulnerable	Commercially important

Order: Carcharhiniformes Family: Carcharhinidae Genus: <i>Scoliodon</i> <i>Scoliodon laticaudus</i> Müller & Henle, 1838	Spade nose shark	-	-	+	Near Threatened	Commercially important
Genus: <i>Carcharhinus</i> <i>Carcharhinus limbatus</i> (Valenciennes, 1839)	Blacktip shark	-	-	+	Vulnerable	Commercially important
<i>Carcharhinus macroti</i> (Müller & Henle, 1839)	Hardnose shark	-	-	+	Near Threatened	Commercially important
Genus: <i>Negaprion</i> <i>Negaprion acutidens</i> (Rüppell, 1837)	Sickle fin lemon shark	-	-	+	Endangered	Commercially important
Order: Orectolobiformes Family: Hemiscylliidae Genus: <i>Chiloscyllium</i> <i>Chiloscyllium griseum</i> Müller & Henle, 1838	Grey bamboo shark	-	-	+	Vulnerable	Commercially important
<i>Chiloscyllium arabicum</i> Gubanov, 1980	Arabian carpet shark	-	-	+	Near Threatened	
Genus: <i>Anoxypristis</i> <i>Anoxypristis cuspidata</i> (Latham, 1794)	Knife tooth sawfish	-	-	+	Endangered	Commercially important
Class: Actinopterygii Order: Aulopiformes Family: Synodontidae Genus: <i>Harpadon</i> <i>Harpadon nehereus</i> (Hamilton, 1822)	Bombay Duck	-	-	+	Near Threatened	Commercially important

Order: Gobiiformes Family: Oxudercidae Genus: <i>Boleophthalmus</i> <i>Boleophthalmus dussumieri</i> Valenciennes, 1837	Mudskipper	-	+	+	Least Concern	Commercially important
Family: Gobiidae Genus: <i>Glossogobius</i> <i>Glossogobius giuris</i> (Hamilton, 1822)	Glass Fish	+	-	-	Least Concern	Commercially important
Order: Pleuronectiformes Family: Cynoglossidae Genus: <i>Cynoglossus</i> <i>Cynoglossus arel</i> (Bloch & Schneider, 1801)	Largescale tongue sole	-	+	+	Data Deficient	Commercially important
<i>Cynoglossus bilineatus</i> (Lacepède, 1802)	Four lined tongue sole	-	+	+	Data Deficient	Commercially important
<i>Cynoglossus</i> sp.	Sole fish	-	-	+	Data Deficient	Commercially important
Family: Soleidae Genus: <i>Brachirus</i> <i>Brachirus orientalis</i> (Bloch & Schneider, 1801)	Oriental sole	-	+	+	Least Concern	Commercially important
Genus: <i>Solea</i> <i>Solea elongata</i> Day, 1877	Elongate sole	-	-	+	Least Concern	Commercially important
Genus: <i>Zebrias</i> <i>Zebrias quagga</i> (Kaup, 1858)	Fringe fin zebra sole	-	-	+	Least Concern	Commercially important
Order: Polynemidae Family: Polynemidae						

Genus: <i>Eleutheronema</i> <i>Eleutheronema tetradactylum</i> (Shaw, 1804)	Forefinger threadfin	-	+	+	Least Concern	Commercially important
Order: Eupercaria Family: Sciaenidae Genus: <i>Otolithoides</i> <i>Otolithoides biauritus</i> (Cantor, 1849)	Bronze croaker fish	-	+	+	Data Deficient	Commercially important
<i>Otolithoides</i> sp1.	Croaker Fish	-	-	+	Data Deficient	Commercially important
<i>Otolithoides</i> sp2.	Croaker Fish	-	-	+	Data Deficient	Commercially important
Order: Carangaria Family: Polynemidae Genus: <i>Eleuthronema</i> <i>Eleuthronema</i> sp.	Croaker Fish	-	-	+	Data Deficient	Commercially important
Family: Latidae Genus: <i>Lates</i> <i>Lates calcarifer</i> (Bloch, 1790)	Barramundi, Sea Bass	-	+	+	Least Concern	Commercially important
Order: Cypriniformes Family: Cyprinidae Genus: Amblypharyngodon <i>Amblypharyngodon mola</i> (Hamilton, 1822)	Mola carpet	+	-	-	Least Concern	Commercially important
Genus: <i>Gibelion</i> <i>Gibelion catla</i> (Hamilton, 1822)	Catla	+	-	-	Least Concern	Commercially important
Genus: <i>Labeo</i> <i>Labeo gonius</i> (Hamilton, 1822)	Kuria labeo	+	-	-	Least Concern	Commercially important

<i>Labeo rohita</i> (Hamilton, 1822)	Rohu	+	-	-	Least Concern	Commercially important
Genus: <i>Puntius</i> <i>Puntius sophore</i> (Hamilton, 1822)	Pool Barb	+	-	-	Least Concern	Ornamentally valuable
Genus: <i>Salmostoma</i> <i>Salmostomabacaila</i> (Hamilton, 1822)	Large razor belly minnow	+	-	-	Least Concern	Commercially important
Genus: <i>Systomus</i> <i>Systomus sarana</i> (Hamilton, 1822)	Olive barb	+	-	-	Least Concern	Commercially important
Family: Aplocheilidae Genus: <i>Aplocheilus</i> <i>Aplocheilus panchax</i> (Hamilton, 1822)	Blue panchax	+	-	-	Least Concern	Ornamentally valuable
Order: Anabantiformes Family: Anabantidae Genus: <i>Anabas</i> <i>Anabas testudineus</i> (Bloch, 1792)	Climbing Perch	+	-	-	Least Concern	Commercially important
Family: Channidae Genus: <i>Channa</i> <i>Channa striata</i> (Bloch, 1793)	Striped snakehead or Murrell	+	-	-	Least Concern	Commercially important
Order: Synbranchiformes Family: Mastacembelidae Genus: <i>Macrognathus</i> <i>Macrognathus pancalus</i> Hamilton, 1822	Barred spiny eel	+	-	-	Least Concern	Commercially important
Order: Siluriformes Family: Bagridae Genus: <i>Mystus</i> <i>Mystustengara</i> (Hamilton, 1822)	Tangara catfish	+	-	-	Least Concern	

						Commercially important
<i>Mystus vittatus</i> (Bloch 1794)	Striped dwarf catfish	+	-	-	Least Concern	Commercially important
Family: Siluridae Genus: <i>Ompok</i> <i>Ompok pabda</i> (Hamilton, 1822)	Pabdah catfish	+	-	-	Near Threatened	Commercially important
Genus: <i>Wallago</i> <i>Wallago attu</i> (Bloch & Schneider, 1801)	Helicopter catfish	+	-	-	Vulnerable	Commercially important
Family: Ariidae Genus: <i>Arius</i> <i>Arius jella</i> Day, 1877	Blackfin sea catfish	-	+	+	Least Concern	Commercially important
<i>Arius arius</i> (Hamilton, 1822)	Threadfin sea catfish	-	+	+	Least Concern	Commercially important
Order: Cichliformes Family: Cichlidae Genus: <i>Oreochromis</i> <i>Oreochromis mossambicus</i> (Peters, 1852)	Mozambique tilapia	+	-	-	Least Concern	Commercially important
Order: Ovalentaria Family: Ambassidae Genus: <i>Parambassis</i> <i>Parambassis ranga</i> (Hamilton, 1822)	Indian glassy fish	+	-	-	Least Concern	Ornamentally valuable
Order: Beloniformes Family: Belonidae Genus: <i>Xenentodon</i>						

<i>Xenentodon cancila</i> (Hamilton, 1822)	Freshwater garfish	+	-	-	Least Concern	Ornamentally valuable
Order: Gonorynchiformes Family: Chanidae Genus: <i>Chanos</i> <i>Chanos chanos</i> (Forsskål, 1775)	Milk fish	-	+	+	Least Concern	Commercially important

3.1.5 Reptiles

During the field visit three reptiles were sighted. Two represented marine and estuarine species viz., Beaked Sea snake and Bombay Sea snake (Table 3.12). Whereas in the fresh water system Mugger was sighted which is a vulnerable species and is listed in Schedule I of IWPA (1972).

Table 3.12. List of reptile species reported from the study area

Order	Family	Common name	Scientific name	IUCN status	FW	EW	MW
Squamata	Elapidae	Beaked sea snake or Hook-nosed Sea snake	<i>Hydrophis chistosus</i> (Daudin, 1803)	Least concern	-	+	+
Squamata	Elapidae	Bombay sea snake or Broad-banded sea snake	<i>Hydrophis mamillaris</i> (Daudin, 1803)	Least Concern	-	+	+
Crocodylia	Crocodylidae	Mugger	<i>Crocodylus palustris</i> (Lesson, 1831)	Vulnerable	+	-	-

FW: Freshwater; EW: Estuarine; MW: Marine

3.2. Terrestrial Biodiversity

3.2.1. Avifauna

The overall results on the distribution of avifaunal species in the habitats showed good number of diversity which is about 149 species. Out of which 95 species represented the scrub forest, 91 species in the agriculture area, 81 species in the coastal wetlands and 73 species in the freshwater habitats (Fig 3.19). The Shannon weiner (H') diversity index showed high diversity in scrubland (H'= 3.99) and least in the freshwater habitat (H'=2.836) (Table 3.13).

Table 3.13: Habitat-type wise different diversity parameters (avifauna) in the study area

Diversity Parameters	Agriculture	Coastal Wetlands	Freshwater Wetlands	Scrub	Total
Taxa (S)	91	81	73	95	149
Individuals (N)	1899	1591	4212	1773	9475
Dominance (D)	0.03723	0.06346	0.09284	0.02342	0.029
Simpson (1-D)	0.9628	0.9365	0.9072	0.9766	0.971
Shannon (H')	3.708	3.468	2.836	3.996	4.009
Margalef (R)	11.92	10.85	8.627	12.57	16.16
Equitability (J)	0.822	0.7891	0.6609	0.8775	0.8011

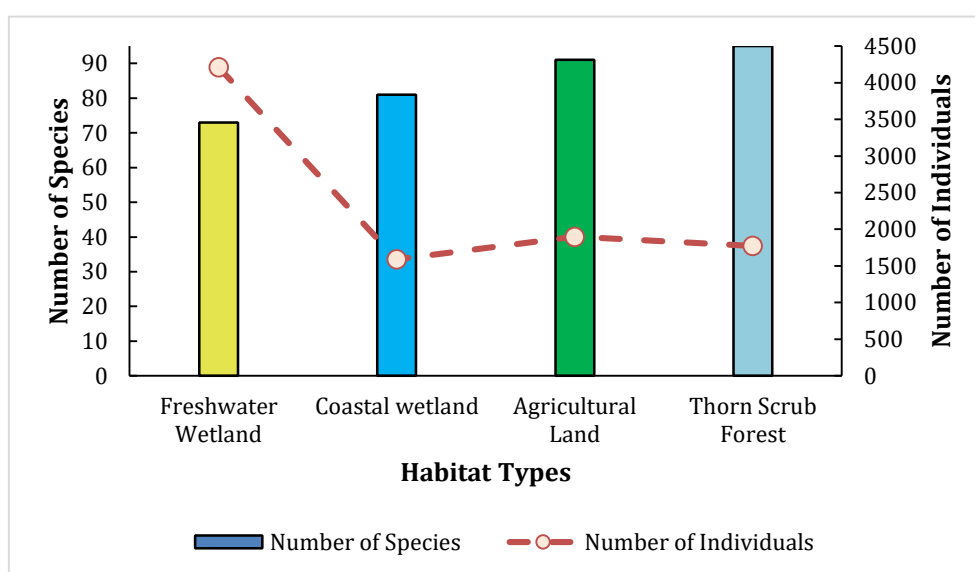


Figure 3.19: Habitat Wise Number of Species and Population of Birds Recorded in The Study Area

The species reported in avifaunal category represented in 55 families and are grouped into 25 orders. Species representation from Charadriiformes is highest which include waders and gulls (Fig 3.20).

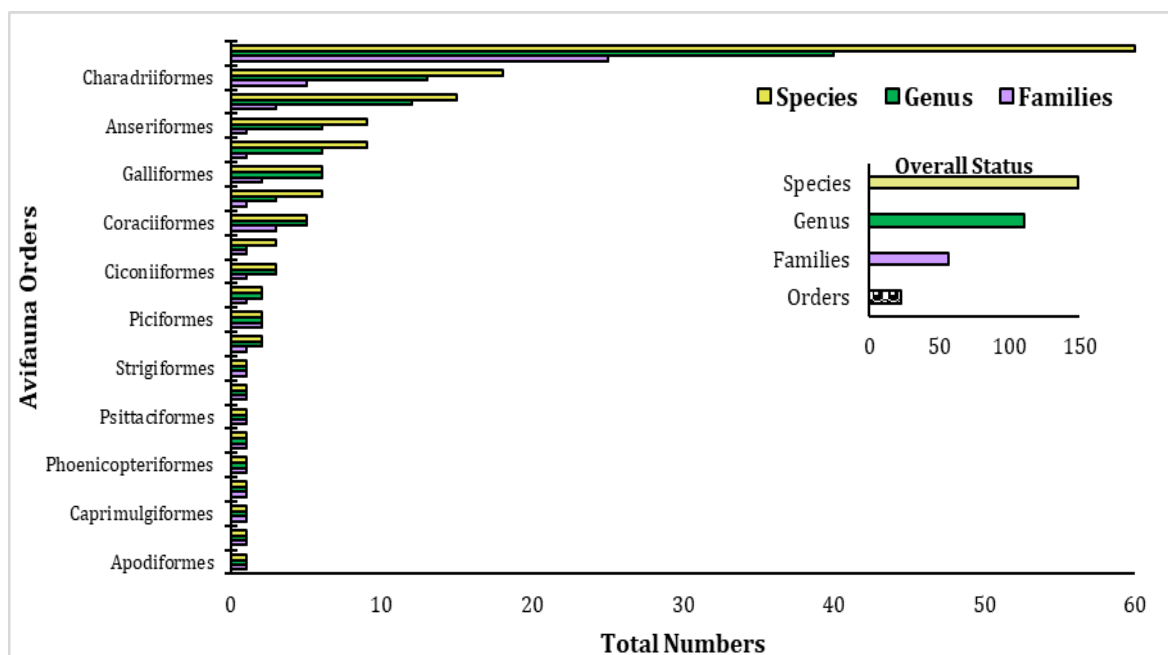


Figure 3.20: Avifauna recorded from the Study area

Based on the habit the avifaunal species showed representation of resident, local migrant and long-distance migrant. Resident birds dominated the agricultural land and scrub lands with 76% of species and 17% species represented long distance migrant reported from freshwater and coastal habitats. The region falls in Central Asian Flyway and thus the presence of long-distance migrant birds is observed in the study area. The long-distance migratory species were reported from fresh water and coastal wetlands habitats. Resident birds dominated the agricultural land and scrub lands (Fig 3.21).

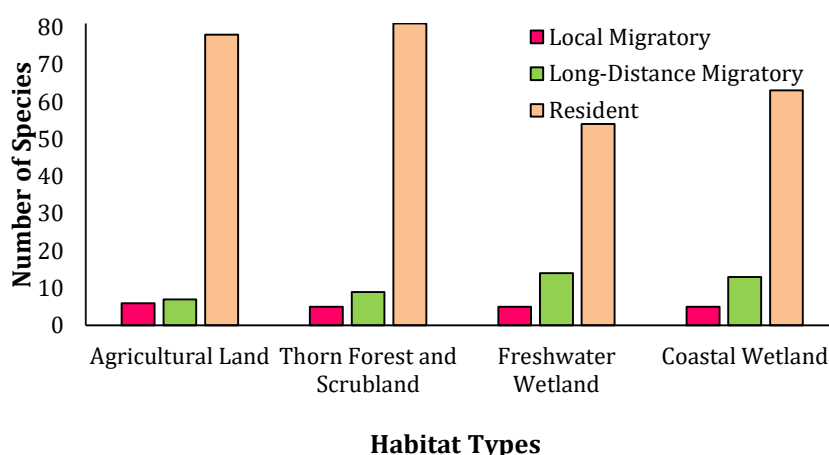


Figure 3.21: Migratory status of the different avifauna in various habitats from the study area

Protection status

Based on IWPA, (1972) there are 11 species representing Schedule I category with high degree of protection and conservation. About 138 species belong to the schedule IV category (Fig 3.22).

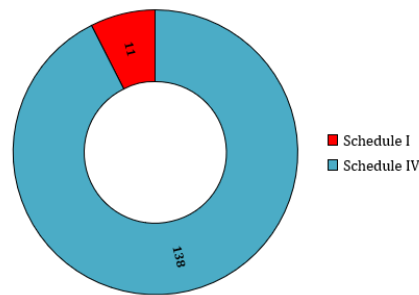


Figure 3.22: Avifaunal status based on IWPA (1972)

Based on IUCN Red list (2022), six species belong to Vulnerable category, eight species represent Near-Threatened category and rest are belong to Least Concern (Fig .3.23).

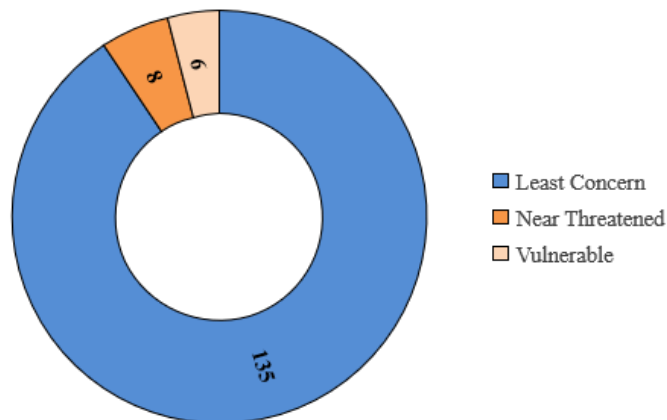


Figure 3.23: Status of avifauna based on IUCN criteria found in the study area

Distribution of the threatened species in different habitat indicates that Near-threatened species are represented more in the coastal and freshwater wetlands (Fig 3. 24).

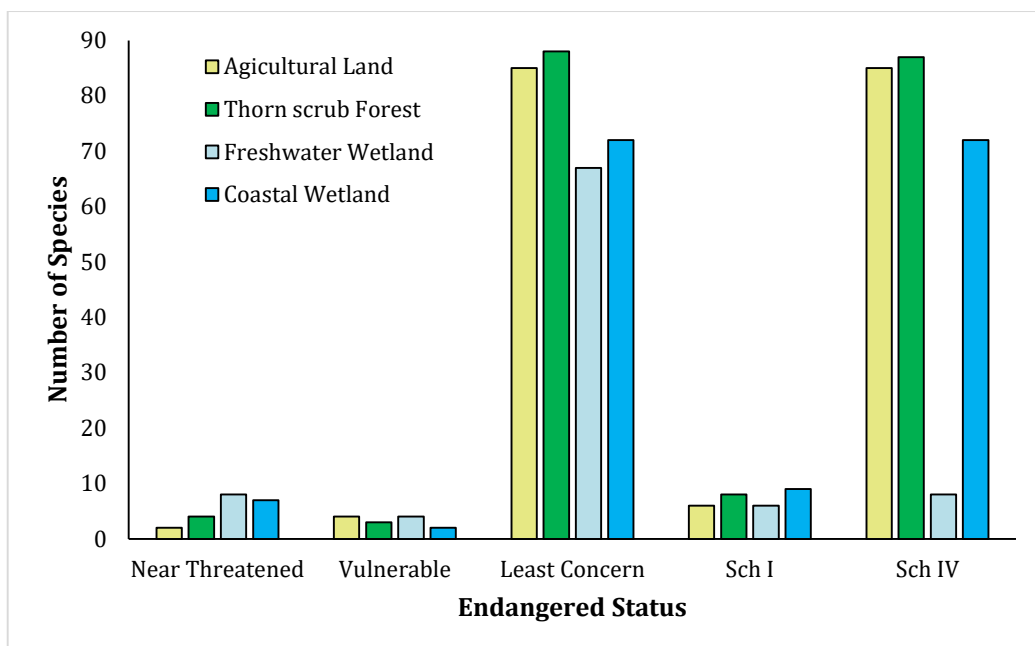


Figure 3.24: Status of avifauna in different habitats from the study area

Guild wise distribution

The species reported in the present study represented six guilds such as frugivores, piscivore, granivore, omnivore, carnivore and insectivore as indicated in the Fig. 3.25. Maximum representation of birds was present in the insectivore guild (32%) followed by carnivore guild (25%) (Fig 3.25).

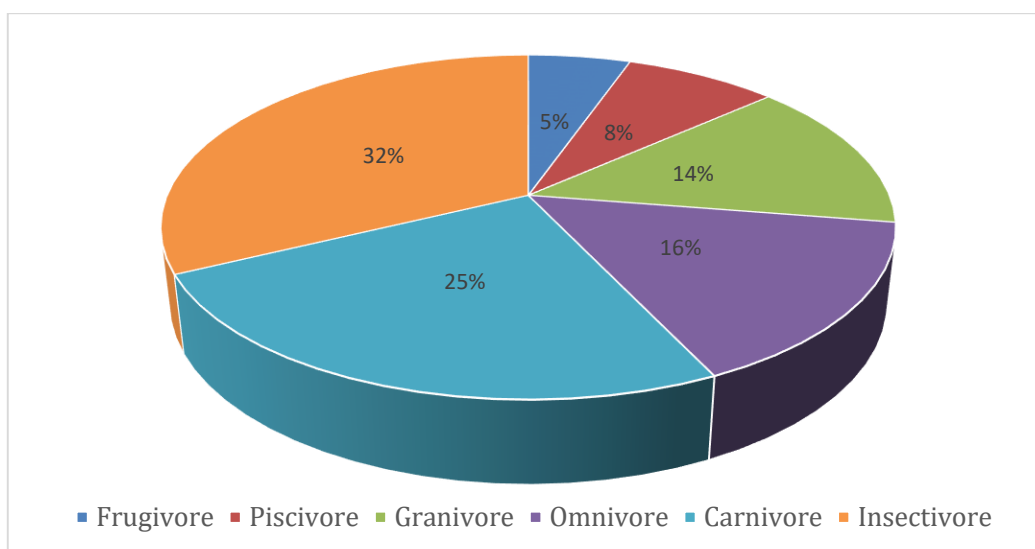


Figure 3.25: Percent of foraging guilds of the avifauna observed from the study area

Habitat wise representation of species in the guilds showed dominance of insectivore species in all the habitats except coastal wetlands, where the carnivore guilds species dominated (Fig 3.26).

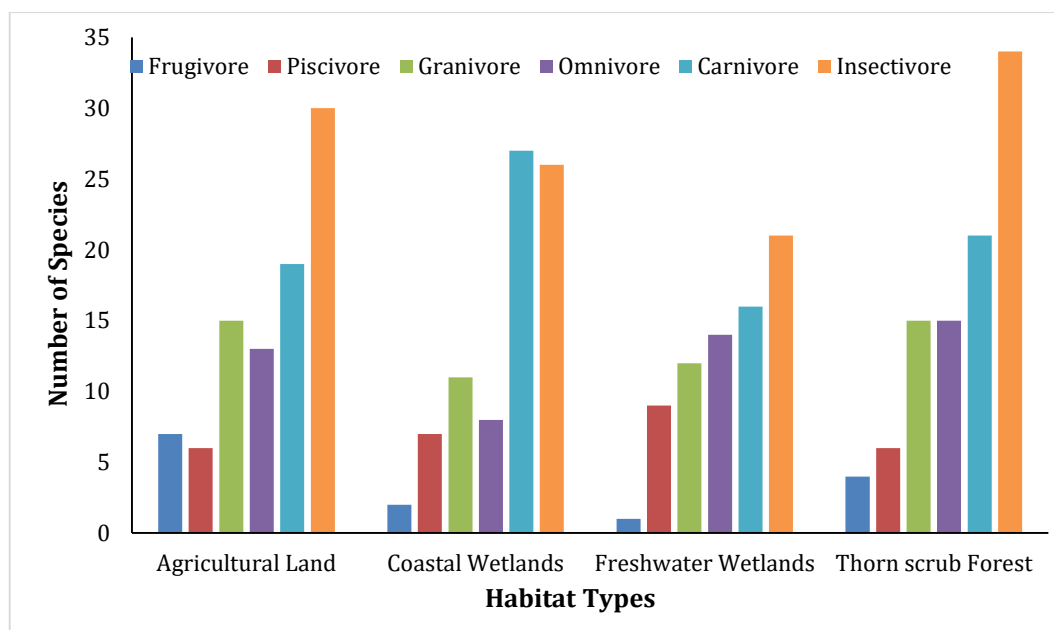


Figure 3.26: Avifauna foraging guilds from the different habitats of study area

The frequency and abundance of all the 149 species recorded is presented in the Table 3.14. The freshwater wetlands showed the maximum abundance of species dominated by Bar-headed Goose (*Anas indicus*), Eurasian Coot, Eurasian Wigeon (*Anas penelope*), Greylag Goose (*Anser anser*), Greater Flamingo (*Phoenicopterus roseus*), Northern Shoveler (*Anas clypeata*) and Ruddy Shelduck (*Tadorna ferruginea*) (Table 3.14).

Table 3.14: Frequency and Abundance of birds in all the habitats of the study area

Sr. No.	Species Name	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
1.	Ashy Drongo	0.04	0.07	0.00	0.00	0.00	0.00	0.03	0.21
2.	Ashy Prinia	0.04	0.04	0.00	0.00	0.11	0.67	0.07	0.14
3.	Ashy-crowned Sparrow-lark	0.18	0.43	0.33	1.10	0.00	0.00	0.21	1.14
4.	Asian Koel	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
5.	Asian Openbill	0.07	0.11	0.00	0.00	0.00	0.00	0.00	0.00
6.	Bar-headed Goose	0.00	0.00	0.00	0.00	0.11	33.33	0.00	0.00
7.	Barn Swallow	0.18	1.64	0.14	15.33	0.33	2.22	0.21	1.79
8.	Baya Weaver	0.04	0.36	0.00	0.00	0.00	0.00	0.10	1.21
9.	Bay-backed Shrike	0.00	0.00	0.00	0.00	0.11	0.11	0.10	0.10
10.	Black Drongo	0.71	3.29	0.43	2.38	0.44	1.11	0.59	2.10
11.	Black Kite	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
12.	Black-crowned night Heron	0.00	0.00	0.00	0.00	0.11	1.11	0.00	0.00
13.	Black-headed Bunting	0.04	0.04	0.00	0.00	0.00	0.00	0.03	0.07
14.	Black-headed Gull	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
15.	Black-headed Ibis	0.21	4.46	0.10	0.48	0.22	0.67	0.07	0.28
16.	Black-tailed Godwit	0.00	0.00	0.10	1.52	0.00	0.00	0.00	0.00
17.	Black-winged Kite	0.18	0.18	0.14	0.19	0.00	0.00	0.14	0.17
18.	Black-winged Stilt	0.04	0.14	0.14	1.24	0.56	3.78	0.21	1.66
19.	Blue-Throat	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10
20.	Booted Warbler	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00
21.	Brahminy Myna	0.04	0.07	0.00	0.00	0.00	0.00	0.03	0.34
22.	Bronze-winged Jacana	0.00	0.00	0.00	0.00	0.11	0.22	0.03	0.03
23.	Caspian Tern	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00
24.	Cattle Egret	0.43	7.32	0.10	0.33	0.44	1.67	0.21	2.45

Sr. No.	Species Name	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
25.	Chestnut-bellied Sandgrouse	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.34
26.	Citrine Wagtail	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00
27.	Clamorous Reed Warbler	0.00	0.00	0.00	0.00	0.22	0.56	0.00	0.00
28.	Common Babbler	0.36	2.82	0.24	1.05	0.22	1.00	0.31	1.93
29.	Common Crane	0.00	0.00	0.05	0.67	0.00	0.00	0.00	0.00
30.	Common Greenshank	0.00	0.00	0.05	0.10	0.11	0.11	0.00	0.00
31.	Common Iora	0.07	0.14	0.00	0.00	0.00	0.00	0.03	0.07
32.	Common Kingfisher	0.04	0.04	0.00	0.00	0.00	0.00	0.03	0.03
33.	Common Myna	0.11	0.36	0.00	0.00	0.00	0.00	0.07	0.28
34.	Common Pochard	0.00	0.00	0.00	0.00	0.22	31.11	0.00	0.00
35.	Common Redshank	0.04	0.04	0.10	1.24	0.22	1.00	0.00	0.00
36.	Common Sandpiper	0.11	0.25	0.19	0.33	0.22	1.22	0.17	0.79
37.	Common Tailorbird	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.14
38.	Common Woodshrike	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
39.	Coppersmith Barbet	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
40.	Crested Lark	0.14	1.39	0.52	2.38	0.00	0.00	0.21	0.72
41.	Dalmatian Pelican	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.62
42.	Demoiselle Crane	0.11	0.89	0.05	0.43	0.33	13.56	0.10	1.41
43.	Desert Wheatear	0.11	0.21	0.10	0.14	0.00	0.00	0.00	0.00
44.	Dunlin	0.00	0.00	0.05	0.29	0.00	0.00	0.00	0.00
45.	Dusky Crag-Martin	0.07	0.14	0.00	0.00	0.00	0.00	0.00	0.00
46.	Eurasian Collared Dove	0.36	1.64	0.29	0.86	0.44	1.67	0.31	0.90
47.	Eurasian Coot	0.00	0.00	0.00	0.00	0.22	88.89	0.00	0.00
48.	Eurasian Curlew	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
49.	Eurasian Hoopoe	0.07	0.07	0.05	0.10	0.00	0.00	0.07	0.07
50.	Eurasian Kestrel	0.04	0.04	0.14	0.14	0.00	0.00	0.00	0.00

Sr. No.	Species Name	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
51.	Eurasian Marsh Harrier	0.04	0.04	0.19	0.29	0.44	1.22	0.24	0.52
52.	Common Moorhen	0.04	0.04	0.00	0.00	0.00	0.00	0.03	0.69
53.	Eurasian Spoonbill	0.00	0.00	0.10	0.38	0.22	0.78	0.03	0.03
54.	Eurasian Wigeon	0.00	0.00	0.00	0.00	0.22	36.67	0.00	0.00
55.	Blue rock Pigeon	0.21	1.36	0.19	1.43	0.11	2.89	0.07	0.93
56.	Garganey	0.00	0.00	0.00	0.00	0.11	5.56	0.00	0.00
57.	Glossy Ibis	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00
58.	Grey Francolin	0.29	0.54	0.24	0.62	0.22	0.67	0.24	0.38
59.	Grey Heron	0.14	0.32	0.10	0.10	0.33	0.33	0.07	0.10
60.	Grey Wagtail	0.04	0.07	0.05	0.10	0.11	0.44	0.00	0.00
61.	Grey-breasted Prinia	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.21
62.	Grey-headed Swamphen	0.04	0.21	0.05	0.05	0.44	6.78	0.00	0.00
63.	Greylag Goose	0.00	0.00	0.00	0.00	0.22	42.22	0.00	0.00
64.	Great Cormorant	0.00	0.00	0.00	0.00	0.11	1.33	0.00	0.00
65.	Great Egret	0.11	0.18	0.29	2.52	0.00	0.00	0.10	0.28
66.	Great Thick-Knee	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00
67.	Great White Pelican	0.00	0.00	0.00	0.00	0.22	7.67	0.00	0.00
68.	Greater Coucal	0.14	0.18	0.00	0.00	0.22	0.44	0.03	0.03
69.	Greater Flamingo	0.00	0.00	0.10	4.14	0.22	66.67	0.00	0.00
70.	Greater Spotted Eagle	0.04	0.04	0.05	0.05	0.11	0.22	0.07	0.17
71.	Green Bee-eater	0.36	0.82	0.29	1.33	0.22	0.33	0.34	1.03
72.	Greenish Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
73.	Green-winged Teal	0.00	0.00	0.00	0.00	0.11	11.11	0.00	0.00
74.	Gull-billed Tern	0.04	0.14	0.29	0.76	0.00	0.00	0.03	0.07
75.	House Crow	0.32	1.86	0.24	1.81	0.22	1.22	0.28	2.10
76.	House Sparrow	0.25	3.93	0.19	0.95	0.00	0.00	0.03	0.52
77.	Indian Paradise-Flycatcher	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00

Sr. No.	Species Name	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
78.	Indian Peafowl	0.00	0.00	0.05	0.10	0.11	0.22	0.14	0.24
79.	Indian Robin	0.36	0.61	0.19	0.29	0.33	0.89	0.34	0.72
80.	Indian Roller	0.14	0.18	0.00	0.00	0.00	0.00	0.14	0.17
81.	Indian Silverbill	0.11	0.71	0.00	0.00	0.00	0.00	0.00	0.00
82.	Spot-billed Duck	0.04	0.11	0.00	0.00	0.11	0.89	0.03	0.10
83.	Spotted Eagle	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
84.	Oriental White-eye	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00
85.	Indian-pond Heron	0.21	0.36	0.14	1.52	0.44	1.33	0.34	2.03
86.	Intermediate Egret	0.04	0.04	0.24	1.52	0.22	1.44	0.21	0.90
87.	Isabelline Shrike	0.04	0.04	0.05	0.05	0.00	0.00	0.03	0.03
88.	Jungle Babbler	0.07	0.57	0.00	0.00	0.11	1.56	0.07	0.38
89.	Large Grey Babbler	0.04	0.11	0.00	0.00	0.00	0.00	0.03	1.03
90.	Large-billed Crow	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00
91.	Laughing Dove	0.36	0.75	0.33	1.33	0.44	2.00	0.52	1.21
92.	Lesser Sandplover	0.00	0.00	0.14	2.19	0.00	0.00	0.00	0.00
93.	Little Cormorant	0.14	1.43	0.14	1.29	0.56	1.89	0.24	2.14
94.	Little Egret	0.07	1.14	0.10	0.24	0.11	0.11	0.28	0.93
95.	Little Grebe	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10
96.	Little Swift	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00
97.	Long-tailed Shrike	0.50	1.29	0.19	0.29	0.22	0.33	0.41	0.97
98.	Marsh Sandpiper	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00
99.	Montagu's Harrier	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
100.	Northern Shoveler	0.00	0.00	0.00	0.00	0.11	33.33	0.00	0.00
101.	Oriental Honey Buzzard	0.14	0.18	0.05	0.14	0.11	0.33	0.07	0.07
102.	Oriental Magpie-robin	0.11	0.11	0.00	0.00	0.00	0.00	0.07	0.10
103.	Oriental Skylark	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00
104.	Paddyfield Pipit	0.14	2.25	0.05	0.05	0.00	0.00	0.14	0.76
105.	Painted Stork	0.07	0.46	0.43	6.10	0.44	2.00	0.10	0.17

Sr. No.	Species Name	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
106.	Pallas's Gull	0.00	0.00	0.05	0.38	0.00	0.00	0.00	0.00
107.	Pallid Harrier	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00
108.	Pied Bushchat	0.11	0.11	0.19	0.19	0.00	0.00	0.14	0.38
109.	Pied Kingfisher	0.04	0.07	0.05	0.10	0.22	0.22	0.00	0.00
110.	Plain Prinia	0.32	0.93	0.24	0.52	0.22	0.33	0.41	2.24
111.	Purple Heron	0.07	0.14	0.00	0.00	0.33	0.89	0.03	0.03
112.	Purple Sunbird	0.46	1.50	0.33	1.38	0.44	1.56	0.41	1.55
113.	Red Avadavat	0.00	0.00	0.00	0.00	0.00	0.00	0.03	1.72
114.	Red Collared-Dove	0.04	1.43	0.00	0.00	0.00	0.00	0.07	0.21
115.	Red-naped Ibis	0.00	0.00	0.05	0.05	0.22	2.00	0.07	0.17
116.	Red-rumped Swallow	0.14	0.71	0.05	0.95	0.00	0.00	0.14	2.03
117.	Red-vented Bulbul	0.32	1.46	0.05	0.05	0.22	0.44	0.55	2.28
118.	Red-wattled Lapwing	0.36	2.39	0.62	3.52	0.56	5.56	0.41	1.86
119.	Red-whiskered Bulbul	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.24
120.	River Tern	0.00	0.00	0.10	0.24	0.11	0.33	0.10	0.28
121.	Rose-ringed Parakeet	0.21	1.32	0.10	0.24	0.00	0.00	0.14	0.76
122.	Rosy Starling	0.07	1.86	0.00	0.00	0.00	0.00	0.10	0.38
123.	Ruddy Shelduck	0.07	0.36	0.14	1.14	0.22	33.33	0.07	0.24
124.	Rufous Treepie	0.04	0.04	0.05	0.05	0.00	0.00	0.03	0.03
125.	Rufous-tailed Lark	0.14	0.54	0.38	1.95	0.00	0.00	0.17	0.48
126.	Sand Lark	0.00	0.00	0.05	0.38	0.00	0.00	0.00	0.00
127.	Sarus Crane	0.07	0.46	0.00	0.00	0.00	0.00	0.00	0.00
128.	Shikra	0.07	0.07	0.10	0.10	0.11	0.11	0.24	0.28
129.	Siberian Stonechat	0.57	1.75	0.33	0.62	0.22	0.22	0.41	1.59
130.	Small Minivet	0.00	0.00	0.00	0.00	0.11	0.22	0.03	0.07
131.	Spotted Dove	0.04	0.07	0.00	0.00	0.00	0.00	0.07	0.14
132.	Spotted Owlet	0.00	0.00	0.10	0.24	0.11	0.11	0.03	0.07
133.	Sulphur-bellied Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.21

Sr. No.	Species Name	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
134.	Tawny Lark	0.00	0.00	0.05	0.19	0.00	0.00	0.00	0.00
135.	Tawny Pipit	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
136.	Thick-billed Flowerpecker	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
137.	Western Reef Heron	0.00	0.00	0.24	0.52	0.00	0.00	0.03	0.03
138.	Western Yellow Wagtail	0.07	0.29	0.10	0.24	0.33	0.67	0.00	0.00
139.	Whimbrel	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00
140.	White Wagtail	0.00	0.00	0.14	0.19	0.11	0.22	0.14	0.21
141.	White-breasted Waterhen	0.14	0.18	0.05	0.05	0.00	0.00	0.03	0.07
142.	White-browed Fantail	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.31
143.	White-eared Bulbul	0.25	0.86	0.29	1.76	0.11	0.44	0.45	2.38
144.	White-throated Kingfisher	0.43	0.46	0.19	0.19	0.33	0.44	0.17	0.24
145.	Wire-tailed Swallow	0.36	3.46	0.00	0.00	0.22	3.44	0.21	1.93
146.	Wood Sandpiper	0.04	0.04	0.05	0.05	0.00	0.00	0.14	0.28
147.	Wooly-necked Stork	0.04	0.04	0.00	0.00	0.00	0.00	0.03	0.03
148.	Yellow-crowned Woodpecker	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
149.	Yellow-footed Green-pigeon	0.07	0.61	0.00	0.00	0.00	0.00	0.00	0.00
Overall		13.29	67.82	12.19	75.76	16.78	468.00	13.59	61.10
Fr = Frequency and Ab = Abundance									

The frequency and abundance of the local migratory birds in different habitat indicates presence of more freshwater wetlands species dominated by Bar-headed Goose and Ruddy Shelduck. These species are winter migrant and migrate from upper stretches of India to Gujarat (Table 3.15).

Table 3.15. Frequency and Abundance Local Migratory birds in the various habitats of the study area

Sr. no.	Species	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and Scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
1	Ashy Drongo	0.04	0.07	0.00	0.00	0.00	0.00	0.03	0.21
2	Bar-headed Goose	0.00	0.00	0.00	0.00	0.11	33.33	0.00	0.00
3	Blue-Throat	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10
4	Citrine Wagtail	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00
5	Desert Wheatear	0.11	0.21	0.10	0.14	0.00	0.00	0.00	0.00
6	Grey Wagtail	0.04	0.07	0.05	0.10	0.11	0.44	0.00	0.00
7	Indian Paradise-Flycatcher	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
8	Lesser Sandplover	0.00	0.00	0.14	2.19	0.00	0.00	0.00	0.00
9	Ruddy Shelduck	0.07	0.36	0.14	1.14	0.22	33.33	0.07	0.24
10	Siberian Stonechat	0.57	1.75	0.33	0.62	0.22	0.22	0.41	1.59
11	Sulphur-bellied Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.21
Grand Total		0.86	2.50	0.76	4.19	0.78	67.44	0.62	2.34
Fr = Frequency and Ab = Abundance									

The diversity indices reported above in three habitats viz. agriculture, coastal wetlands and scrublands indicative of good diversity. Whereas, the freshwater wetlands were low in diversity index indicating presence of few species (Table 3.16).

Table 3.16. Diversity parameters of the resident birds in the different habitat types

Diversity parameter	Agricultural land	Coastal Wetlands	Freshwater Wetlands	Scrublands
Taxa (S)	78	63	54	81
Individuals (N)	1740	1449	1951	1597
Dominance (D)	0.04238	0.07495	0.2662	0.02702
Simpson (1-D)	0.9576	0.9251	0.7338	0.973
Shannon (H)	3.574	3.258	2.069	3.836
Margalef (R)	10.32	8.518	6.996	10.85
Equitability (J)	0.8204	0.7864	0.5186	0.8729

In case of long distance migratory birds highest abundance was found in the freshwater wetlands which includes Common Pochard, Demoiselle Crane, Eurasian Wigeon, Greylag Goose and Northern Shoveler (Table 3.17).

Table 3.17 Frequency and Abundance of long-distance Migratory birds of the study area

Sr. no.	Species	Agricultural Land		Coastal Wetlands		Freshwater Wetlands		Thorn Forest and Scrublands	
		Fr	Ab	Fr	Ab	Fr	Ab	Fr	Ab
1	Black-headed Bunting	0.04	0.04	0.00	0.00	0.00	0.00	0.03	0.07
2	Booted Warbler	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00
3	Common Crane	0.00	0.00	0.05	0.67	0.00	0.00	0.00	0.00
4	Common Greenshank	0.00	0.00	0.05	0.10	0.11	0.11	0.00	0.00
5	Common Pochard	0.00	0.00	0.00	0.00	0.22	31.11	0.00	0.00
6	Dalmatian Pelican	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.62
7	Demoiselle Crane	0.11	0.89	0.05	0.43	0.33	13.56	0.10	1.41
8	Dunlin	0.00	0.00	0.05	0.29	0.00	0.00	0.00	0.00
9	Eurasian Marsh Harrier	0.04	0.04	0.19	0.29	0.44	1.22	0.24	0.52
10	Eurasian Wigeon	0.00	0.00	0.00	0.00	0.22	36.67	0.00	0.00
11	Garganey	0.00	0.00	0.00	0.00	0.11	5.56	0.00	0.00
12	Greylag Goose	0.00	0.00	0.00	0.00	0.22	42.22	0.00	0.00

13	Great White Pelican	0.00	0.00	0.00	0.00	0.22	7.67	0.00	0.00
14	Greater Spotted Eagle	0.04	0.04	0.05	0.05	0.11	0.22	0.07	0.17
15	Greenish Warbler	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
16	Green-winged Teal	0.00	0.00	0.00	0.00	0.11	11.11	0.00	0.00
17	Montagu's Harrier	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
18	Northern Shoveler	0.00	0.00	0.00	0.00	0.11	33.33	0.00	0.00
19	Pallid Harrier	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00
20	Rosy Starling	0.07	1.86	0.00	0.00	0.00	0.00	0.10	0.38
21	Tawny Pipit	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00
22	Western Yellow Wagtail	0.07	0.29	0.10	0.24	0.33	0.67	0.00	0.00
23	Whimbrel	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00
24	White Wagtail	0.00	0.00	0.14	0.19	0.11	0.22	0.14	0.21
25	Wood Sandpiper	0.04	0.04	0.05	0.05	0.00	0.00	0.14	0.28
Grand Total		0.39	3.18	0.95	2.57	2.78	183.78	0.90	3.69
Fr = Frequency and Ab = Abundance									

The diversity indices of long-distant migrants showed high values in the coastal wetlands ($H'=1.177$) followed by scrublands ($H'= 1.065$) and agriculture lands ($H'= 1.002$) (Table 3.18). Thereby, indicating relevance of the coastal wetlands for the long-distance migrants.

Table 3.18. Diversity parameters of the long-distance migratory birds from the habitat types

Diversity Parameters	Agricultural land	Coastal Wetlands	Freshwater Wetlands	Scrublands
Taxa_S	6	5	5	5
Individuals	70	88	607	68
Dominance_D	0.5196	0.3711	0.4886	0.4857
Simpson_1-D	0.4804	0.6289	0.5114	0.5143
Shannon_H	1.002	1.177	0.7591	1.065
Margalef	1.177	0.8934	0.6242	0.948
Equitability_J	0.5593	0.7314	0.4717	0.6615

Annexure 1. Checklist of the avifauna observed in the study area

S. No.	Order	Family	Common Name	Species	Migratory Status	IUCN Red list status	IWPA, 1972	Foraging guild
1	Passeriformes	Dicruridae	Ashy Drongo	<i>Dicrurusleucophaeus</i>	Migratory-Local	LC	Sch IV	Insectivore
2	Passeriformes	Cisticolidae	Ashy Prinia	<i>Priniasocialis</i>	Resident	LC	Sch IV	Insectivore
3	Passeriformes	Alaudidae	Ashy-crowned Sparrow-lark	<i>Eremopterix grisea</i>	Resident	LC	Sch IV	Granivore
4	Cuculiformes	Cuculidae	Asian Koel	<i>Eudynamysscolopaceus</i>	Resident	LC	Sch IV	Frugivore
5	Ciconiiformes	Ciconiidae	Asian Openbill	<i>Anastomusoscitans</i>	Resident	LC	Sch IV	Molluscivore
6	Anseriformes	Anatidae	Bar-headed Goose	<i>Anser indicus</i>	Migratory-Local	LC	Sch IV	Granivore
7	Passeriformes	Hirundinidae	Barn Swallow	<i>Hirundo rustica</i>	Resident	LC	Sch IV	Insectivore
8	Passeriformes	Ploceidae	Baya Weaver	<i>Ploceusphilippinus</i>	Resident	LC	Sch IV	Granivore
9	Passeriformes	Laniidae	Bay-backed Shrike	<i>Laniusvittatus</i>	Resident	LC	Sch IV	Insectivore
10	Passeriformes	Dicruridae	Black Drongo	<i>Dicrurusmacrocerus</i>	Resident	LC	Sch IV	Insectivore
11	Accipitriformes	Accipitridae	Black Kite	<i>Milvus migrans</i>	Resident	LC	Sch I	Carnivore
12	Pelecaniformes	Ardeidae	Black-crowned night Heron	<i>Nycticoraxnycticorax</i>	Resident	LC	Sch IV	Carnivore
13	Passeriformes	Emberizidae	Black-headed Bunting	<i>Emberizamelanocephala</i>	Migratory-Long-Distance	LC	Sch IV	Granivore
14	Pelecaniformes	Threskiornithidae	Black-headed Ibis	<i>Threskiornismelanocephalus</i>	Resident	NT	Sch IV	Carnivore
15	Charadriiformes	Scolopacidae	Black-tailed Godwit	<i>Limosalimosa</i>	Resident	NT	Sch IV	Carnivore
16	Accipitriformes	Accipitridae	Black-winged Kite	<i>Elanuscaerulus</i>	Resident	LC	Sch I	Carnivore

17	Caprimulgiformes	Recurvirostridae	Black-winged Stilt	<i>Himantopus himantopus</i>	Resident	LC	Sch IV	Carnivore
18	Passeriformes	Muscicapidae	Bluethroat	<i>Luscinia svecica</i>	Migratory-Local	LC	Sch IV	Insectivore
19	Passeriformes	Sturnidae	Brahminy Myna	<i>Sturniapagodarum</i>	Resident	LC	Sch IV	Insectivore
20	Charadriiformes	Jacaniae	Bronze-winged Jacana	<i>Metopidius indicus</i>	Resident	LC	Sch IV	Granivore
21	Charadriiformes	Laridae	Caspian Tern	<i>Hydroprogne caspia</i>	Resident	LC	Sch IV	Piscivore
22	Pelecaniformes	Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>	Resident	LC	Sch IV	Carnivore
23	Pterocliiformes	Pteroclididae	Chestnut-bellied Sandgrouse	<i>Pteroclesexustus</i>	Resident	LC	Sch IV	Granivore
24	Passeriformes	Motacillidae	Citrine Wagtail	<i>Motacillacitreala</i>	Migratory-Local	LC	Sch IV	Insectivore
25	Passeriformes	Acrocephalidae	Clamorous Reed Warbler	<i>Acrocephalus tentorius</i>	Resident	LC	Sch IV	Insectivore
26	Passeriformes	Leiothrichidae	Common Babbler	<i>Argyacaudata</i>	Resident	LC	Sch IV	Omnivore
27	Gruiformes	Gruidae	Common Crane	<i>Grus grus</i>	Migratory-Long-Distance	LC	Sch IV	Omnivore
28	Charadriiformes	Scolopacidae	Common Greenshank	<i>Tringanebularia</i>	Migratory-Long-Distance	LC	Sch IV	Insectivore
29	Passeriformes	Aegithinidae	Common Iora	<i>Aegithina tiphia</i>	Resident	LC	Sch IV	Insectivore
30	Coraciiformes	Alcedinidae	Common Kingfisher	<i>Alcedo atthis</i>	Resident	LC	Sch IV	Piscivore
31	Passeriformes	Sturnidae	Common Myna	<i>Acridotheres tristis</i>	Resident	LC	Sch IV	Omnivore
32	Anseriformes	Anatidae	Common Pochard	<i>Aythya ferina</i>	Migratory-Long-Distance	VU	Sch IV	Omnivore
33	Charadriiformes	Scolopacidae	Common Redshank	<i>Tringatotanus</i>	Resident	LC	Sch IV	Insectivore
34	Charadriiformes	Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	Resident	LC	Sch IV	Insectivore
35	Passeriformes	Cisticolidae	Common Tailorbird	<i>Orthotomus sutorius</i>	Resident	LC	Sch IV	Insectivore

36	Passeriformes	Vangidae	Common Woodshrike	<i>Tephrodornis pondicerianus</i>	Resident	LC	Sch IV	Insectivore
37	Piciformes	Megalaimidae	Coppersmith Barbet	<i>Psilopogon haemaphysallus</i>	Resident	LC	Sch IV	Frugivore
38	Passeriformes	Alaudidae	Crested Lark	<i>Galerida cristata</i>	Resident	LC	Sch IV	Granivore
39	Pelecaniformes	Pelecanidae	Dalmatian Pelican	<i>Pelecanus crispus</i>	Migratory-Long-Distance	NT	Sch IV	Piscivore
40	Gruiformes	Gruidae	Demoiselle Crane	<i>Grus virgo</i>	Migratory-Long-Distance	LC	Sch IV	Granivore
41	Passeriformes	Muscicapidae	Desert Wheatear	<i>Oenanthe deserti</i>	Migratory-Local	LC	Sch IV	Insectivore
42	Charadriiformes	Scolopacidae	Dunlin	<i>Calidris alpina</i>	Migratory-Long-Distance	LC	Sch IV	Carnivore
43	Passeriformes	Hirundinidae	Dusky Crag-Martin	<i>Ptyonoprogne concolor</i>	Resident	LC	Sch IV	Insectivore
44	Columbiformes	Columbidae	Eurasian Collared Dove	<i>Streptopelia decaocta</i>	Resident	LC	Sch IV	Granivore
45	Galliformes	Rallidae	Eurasian Coot	<i>Fulica atra</i>	Resident	LC	Sch IV	Omnivore
46	Charadriiformes	Scolopacidae	Eurasian Curlew	<i>Numenius arquata</i>	Resident	NT	Sch IV	Carnivore
47	Bucerotiformes	Upupidae	Eurasian Hoopoe	<i>Upupa epops</i>	Resident	LC	Sch IV	Insectivore
48	Falconiformes	Falconidae	Eurasian Kestrel	<i>Falco tinnunculus</i>	Resident	LC	Sch IV	Carnivore
49	Accipitriformes	Accipitridae	Eurasian Marsh Harrier	<i>Circus aeruginosus</i>	Migratory-Long-Distance	LC	Sch I	Carnivore
50	Galliformes	Rallidae	Eurasian Moorhen	<i>Gallinula chloropus</i>	Resident	LC	Sch IV	Omnivore
51	Pelecaniformes	Threskiornithidae	Eurasian Spoonbill	<i>Platalea leucorodia</i>	Resident	LC	Sch I	Carnivore
52	Anseriformes	Anatidae	Eurasian Wigeon	<i>Mareca penelope</i>	Migratory-Long-Distance	LC	Sch IV	Granivore
53	Columbiformes	Columbidae	Feral Pigeon	<i>Columba livia</i>	Resident	LC	Sch IV	Granivore

54	Anseriformes	Anatidae	Garganey	<i>Spatula querquedula</i>	Migratory-Long-Distance	LC	Sch IV	Omnivore
55	Pelecaniformes	Threskiornithidae	Glossy Ibis	<i>Pelegadis falcinellus</i>	Resident	LC	Sch IV	Carnivore
56	Galliformes	Phasianidae	Grey Francolin	<i>Francolinus pondicerianus</i>	Resident	LC	Sch IV	Granivore
57	Pelecaniformes	Ardeidae	Grey Heron	<i>Ardea cinerea</i>	Resident	LC	Sch IV	Piscivore
58	Passeriformes	Motacillidae	Grey Wagtail	<i>Motacilla cinerea</i>	Migratory-Local	LC	Sch IV	Insectivore
59	Passeriformes	Cisticolidae	Grey-breasted Prinia	<i>Prinia hodgsonii</i>	Resident	LC	Sch IV	Insectivore
60	Galliformes	Rallidae	Grey-headed Swampphen	<i>Porphyriopolioccephalus</i>	Resident	LC	Sch IV	Granivore
61	Anseriformes	Anatidae	Greylag Goose	<i>Anser anser</i>	Migratory-Long-Distance	LC	Sch IV	Granivore
62	Suliformes	Phalacrocoracidae	Great Cormorant	<i>Phalacrocorax carbo</i>	Resident	LC	Sch IV	Piscivore
63	Pelecaniformes	Ardeidae	Great Egret	<i>Ardea alba</i>	Resident	LC	Sch IV	Carnivore
64	Charadriiformes	Burhinidae	Great Thick-Knee	<i>Esacus recurvirostris</i>	Resident	NT	Sch IV	Carnivore
65	Pelecaniformes	Pelecanidae	Great White Pelican	<i>Pelecanus onocrotalus</i>	Migratory-Long-Distance	LC	Sch IV	Piscivore
66	Cuculiformes	Cuculidae	Greater Coucal	<i>Centropus sinensis</i>	Resident	LC	Sch IV	Omnivore
67	Phoenicopteriformes	Phoenicopteridae	Greater Flamingo	<i>Phoenicopus ruber</i>	Resident	LC	Sch IV	Granivore
68	Accipitriformes	Accipitridae	Greater Spotted Eagle	<i>Clanga clanga</i>	Migratory-Long-Distance	VU	Sch IV	Carnivore
69	Coraciiformes	Meropidae	Green Bee-eater	<i>Merops orientalis</i>	Resident	LC	Sch IV	Insectivore
70	Passeriformes	Phylloscopidae	Greenish Warbler	<i>Phylloscopus trochiloides</i>	Migratory-Long-Distance	LC	Sch IV	Insectivore

71	Anseriformes	Anatidae	Green-winged Teal	<i>Anas crecca</i>	Migratory-Long-Distance	LC	Sch IV	Omnivore
72	Charadriiformes	Laridae	Gull-billed Tern	<i>Gelochelidonnilotica</i>	Resident	LC	Sch IV	Carnivore
73	Passeriformes	Corvidae	House Crow	<i>Corvus splendens</i>	Resident	LC	Sch IV	Omnivore
74	Passeriformes	Passeridae	House Sparrow	<i>Passer domesticus</i>	Resident	LC	Sch IV	Granivore
75	Passeriformes	Monarchidae	Indian Paradise-Flycatcher	<i>Terpsiphone paradisi</i>	Migratory-Local	LC	Sch IV	Insectivore
76	Galliformes	Phasianidae	Indian Peafowl	<i>Pavocristatus</i>	Resident	LC	Sch I	Omnivore
77	Passeriformes	Muscicapidae	Indian Robin	<i>Copsychusfulicatus</i>	Resident	LC	Sch IV	Insectivore
78	Coraciiformes	Coraciidae	Indian Roller	<i>Coracias benghalensis</i>	Resident	LC	Sch IV	Carnivore
79	Passeriformes	Estrildidae	Indian Silverbill	<i>Euodice malabarica</i>	Resident	LC	Sch IV	Granivore
80	Anseriformes	Anatidae	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	Resident	LC	Sch IV	Granivore
81	Accipitriformes	Accipitridae	Indian Spotted Eagle	<i>Clangahastata</i>	Resident	VU	Sch I	Carnivore
82	Passeriformes	Zosteropidae	Oreintal White-eye	<i>Zosteropsaiepbrosus</i>	Resident	LC	Sch IV	Frugivore
83	Pelecaniformes	Ardeidae	Indian-pond Heron	<i>Ardeolagrayii</i>	Resident	LC	Sch IV	Carnivore
84	Pelecaniformes	Ardeidae	Intermediate Egret	<i>Mesophoyx intermedia</i>	Resident	LC	Sch IV	Piscivore
85	Passeriformes	Laniidae	Isabelline Shrike	<i>Laniusisabellinus</i>	Resident	LC	Sch IV	Insectivore
86	Passeriformes	Leiothrichidae	Jungle Babbler	<i>Argya striata</i>	Resident	LC	Sch IV	Omnivore
87	Passeriformes	Leiothrichidae	Large Gray Babbler	<i>Argyamalcolmi</i>	Resident	LC	Sch IV	Omnivore
88	Passeriformes	Corvidae	Large-billed Crow	<i>Corvus macrohynchos</i>	Resident	LC	Sch IV	Omnivore
89	Columbiformes	Columbidae	Laughing Dove	<i>Streptopelia senegalensis</i>	Resident	LC	Sch IV	Granivore

90	Charadriiformes	Charadriidae	Lesser Sandplover	<i>Charadrius mongolus</i>	Migratory-Local	LC	Sch IV	Carnivore
91	Suliformes	Phalacrocoracidae	Little Cormorant	<i>Microcarboniger</i>	Resident	LC	Sch IV	Piscivore
92	Pelecaniformes	Ardeidae	Little Egret	<i>Egretta garzetta</i>	Resident	LC	Sch IV	Carnivore
93	Podicipediformes	Podicipedidae	Little Grebe	<i>Tachybaptus ruficollis</i>	Resident	LC	Sch IV	Insectivore
94	Apodiformes	Apodidae	Little Swift	<i>Apus affinis</i>	Resident	LC	Sch IV	Insectivore
95	Passeriformes	Laniidae	Long-tailed Shrike	<i>Lanius schach</i>	Resident	LC	Sch IV	Insectivore
96	Charadriiformes	Scolopacidae	Marsh Sandpiper	<i>Tringastagnatalis</i>	Resident	LC	Sch IV	Carnivore
97	Accipitriformes	Accipitridae	Montagu's Harrier	<i>Circus pygargus</i>	Migratory-Long-Distance	LC	Sch I	Carnivore
98	Anseriformes	Anatidae	Northern Shoveler	<i>Anas clypeata</i>	Migratory-Long-Distance	LC	Sch IV	Omnivore
99	Accipitriformes	Accipitridae	Oriental Honey Buzzard	<i>Pernis ptilorhynchus</i>	Resident	LC	Sch I	Insectivore
100	Passeriformes	Muscicapidae	Oriental Magpie-robin	<i>Copsychus saularis</i>	Resident	LC	Sch IV	Insectivore
101	Passeriformes	Alaudidae	Oriental Skylark	<i>Alauda gulgula</i>	Resident	LC	Sch IV	Insectivore
102	Passeriformes	Motacillidae	Paddyfield Pipit	<i>Anthus rufus</i>	Resident	LC	Sch IV	Insectivore
103	Ciconiiformes	Ciconiidae	Painted Stork	<i>Mycteria leucocephala</i>	Resident	NT	Sch IV	Carnivore
104	Charadriiformes	Laridae	Pallas's Gull	<i>Larus ichthyaetus</i>	Resident	LC	Sch IV	Piscivore
105	Accipitriformes	Accipitridae	Pallid Harrier	<i>Circus macrourus</i>	Migratory-Long-Distance	NT	Sch I	Carnivore
106	Passeriformes	Muscicapidae	Pied Bushchat	<i>Saxicola caprata</i>	Resident	LC	Sch IV	Insectivore
107	Coraciiformes	Alcedinidae	Pied Kingfisher	<i>Ceryle rudius</i>	Resident	LC	Sch IV	Piscivore
108	Passeriformes	Cisticolidae	Plain Prinia	<i>Prinia inornata</i>	Resident	LC	Sch IV	Insectivore

109	Pelecaniformes	Ardeidae	Purple Heron	<i>Ardea purpurea</i>	Resident	LC	Sch IV	Piscivore
110	Passeriformes	Nectariniidae	Purple Sunbird	<i>Cinnyris asiaticus</i>	Resident	LC	Sch IV	Nectarivore
111	Passeriformes	Estrildidae	Red Avadavat	<i>Amandava amandava</i>	Resident	LC	Sch IV	Omnivore
112	Columbiformes	Columbidae	Red Collared-Dove	<i>Streptopelia tranquebarica</i>	Resident	LC	Sch IV	Granivore
113	Pelecaniformes	Threskiornithidae	Red-naped Ibis	<i>Pseudibis papillosa</i>	Resident	NT	Sch IV	Carnivore
114	Passeriformes	Hirundinidae	Red-rumped Swallow	<i>Hirundo daurica</i>	Resident	LC	Sch IV	Insectivore
115	Passeriformes	Pycnonotidae	Red-vented Bulbul	<i>Pycnonotus cafer</i>	Resident	LC	Sch IV	Omnivore
116	Charadriiformes	Charadriidae	Red-wattled Lapwing	<i>Vanellus indicus</i>	Resident	LC	Sch IV	Insectivore
117	Passeriformes	Pycnonotidae	Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>	Resident	LC	Sch IV	Omnivore
118	Charadriiformes	Laridae	River Tern	<i>Sterna aurantia</i>	Resident	VU	Sch IV	Piscivore
119	Psittaciformes	Psittaculidae	Rose-ringed Parakeet	<i>Psittacula krameri</i>	Resident	LC	Sch IV	Frugivore
120	Passeriformes	Sturnidae	Rosy Starling	<i>Pastor roseus</i>	Migratory-Long-Distance	LC	Sch IV	Omnivore
121	Anseriformes	Anatidae	Ruddy Shelduck	<i>Tadorna ferruginea</i>	Migratory-Local	LC	Sch IV	Omnivore
122	Passeriformes	Corvidae	Rufous Treepie	<i>Dendrocitta vagabunda</i>	Resident	LC	Sch IV	Omnivore
123	Passeriformes	Alaudidae	Rufous-tailed Lark	<i>Ammomanes phoenicurus</i>	Resident	LC	Sch IV	Granivore
124	Passeriformes	Alaudidae	Sand Lark	<i>Calandrella aryal</i>	Resident	LC	Sch IV	Carnivore
125	Gruiformes	Gruidae	Sarus Crane	<i>Grus antigone</i>	Resident	VU	Sch IV	Omnivore
126	Accipitriformes	Accipitridae	Shikra	<i>Accipiter badius</i>	Resident	LC	Sch I	Carnivore

127	Passeriformes	Muscicapidae	Siberian Stonechat	<i>Saxicola rubicola</i>	Migratory-Local	LC	Sch IV	Insectivore
128	Passeriformes	Campephagidae	Small Minivet	<i>Pericrocotuscinnaeomeus</i>	Resident	LC	Sch IV	Insectivore
129	Columbiformes	Columbidae	Spotted Dove	<i>Streptopelia chinensis</i>	Resident	LC	Sch IV	Frugivore
130	Strigiformes	Strigidae	Spotted Owlet	<i>Athene brama</i>	Resident	LC	Sch IV	Carnivore
131	Passeriformes	Phylloscopidae	Sulphur-bellied Warbler	<i>Phylloscopusgriseolus</i>	Migratory-Local	LC	Sch IV	Insectivore
132	Passeriformes	Alaudidae	Tawny Lark	<i>Galerida deva</i>	Resident	LC	Sch IV	Insectivore
133	Passeriformes	Motacillidae	Tawny Pipit	<i>Anthus campestris</i>	Migratory-Long-Distance	LC	Sch IV	Insectivore
134	Passeriformes	Dicaeidae	Thick-billed Flowerpecker	<i>Dicaeum agile</i>	Resident	LC	Sch IV	Frugivore
135	Pelecaniformes	Ardeidae	Western Reef Heron	<i>Egrettaagarularis</i>	Resident	LC	Sch IV	Carnivore
136	Passeriformes	Motacillidae	Western Yellow Wagtail	<i>Motacilla flava</i>	Migratory-Long-Distance	LC	Sch IV	Insectivore
137	Charadriiformes	Scolopacidae	Whimbrel	<i>Numenius phaeopus</i>	Migratory-Long-Distance	LC	Sch IV	Carnivore
138	Passeriformes	Motacillidae	White Wagtail	<i>Motacilla alba</i>	Migratory-Long-Distance	LC	Sch IV	Insectivore
139	Galliformes	Rallidae	White-breasted Waterhen	<i>Amaurornisphoenicurus</i>	Resident	LC	Sch IV	Carnivore
140	Passeriformes	Rhipiduridae	White-browed Fantail	<i>Rhipiduraaureola</i>	Resident	LC	Sch IV	Insectivore
141	Passeriformes	Pycnonotidae	White-eared Bulbul	<i>Pycnonotusleucotis</i>	Resident	LC	Sch IV	Omnivore
142	Coraciiformes	Alcedinidae	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	Resident	LC	Sch IV	Carnivore
143	Passeriformes	Hirundinidae	Wire-tailed Swallow	<i>Hirundosmithii</i>	Resident	LC	Sch IV	Insectivore
144	Charadriiformes	Scolopacidae	Wood Sandpiper	<i>Tringaglareola</i>	Migratory-Long-Distance	LC	Sch IV	Insectivore

145	Ciconiiformes	Ciconiidae	Wooly-necked Stork	<i>Ciconia episcopus</i>	Resident	VU	Sch IV	Carnivore
146	Piciformes	Picidae	Yellow-crowned Woodpecker	<i>Leiopicus mahrattensis</i>	Resident	LC	Sch IV	Insectivore
147	Columbiformes	Columbidae	Yellow-footed Green-pigeon	<i>Treron phoenicopterus</i>	Resident	LC	Sch IV	Frugivore
148	Charadriiformes	Laridae	Black-headed Gull	<i>Larus ridibundus</i>	Resident	LC	Sch IV	Carnivore
149	Passeriformes	Acrocephalidae	Booted Warbler	<i>Iduna caligata</i>	Migratory-Long-Distance	LC	Sch IV	Insectivore

3.2.2.Mammals

Gulf of Khambhat is unique as there is presence of both terrestrial and marine mammals.

Marine mammals

Sousa plumbea is the only marine mammals reported from the study area. This Dolphin species is categorised as endangered species and moves in the deep waters of the Gulf area sometimes sighted near shore. A total of four individuals were sighted, in which three from the marine waters and one nearshore.

S. No.	Classification	Common Name	Habitats			IUCN status
			FW	EW	MW	
1.	Class: Mammalia Order: Cetartiodactyla Family: Delphinidae Genus: <i>Sousa</i> <i>Sousa plumbea</i> (G. Cuvier, 1829)	Indian Ocean humpback dolphin	-	+	+	Endangered species

Freshwater: FW; Estuarine water: EW; Marine water: MW

Terrestrial Mammals

A total of six mammals were sighted from the terrestrial ecosystems studied. The diversity indices of the mammals are very low and stand less than 1.5 (Table 3.19). This indicates absence of major mammalian species in the area.

Nilgai was omnivorous indicating its adaptability to different terrain and ecosystems. Golden jackal is also reported in three of the major habitats except freshwater habitat (Table 3.20). The presence of thickets of *Prosopis juliflora* which provide hiding place for this species is the main reason for presence of the species. The other species are found in one particular habitat based on its food availability.

Table 3.19. Diversity of mammalian fauna across different habitat types

Diversity Parameters	Agricultural Land	Coastal Habitat	Freshwater Habitat	Scrubland
Taxa_S	4	3	3	5
Individuals	21	5	9	26
Dominance_D	0.4512	0.36	0.358	0.2426
Simpson_1-D	0.5488	0.64	0.642	0.7574
Shannon_H	1.007	1.055	1.061	1.507
Evenness_e^H/S	0.6847	0.9572	0.9629	0.9025
Margalef	0.9854	1.243	0.9102	1.228
Equitability_J	0.7267	0.9602	0.9656	0.9362
Chao-1	4	3	3	5

Table 3.20. Abundance Status of the mammals

Species	Agricultural Land		Coastal Habitat		Freshwater Habitat		Scrubland Habitat	
	Abundance $\pm$ SE	Frequency	Abundance $\pm$ SE	Frequency	Abundance $\pm$ SE	Frequency	Abundance $\pm$ SE	Frequency
Nilgai	1.71 $\pm$ 0.64	0.71	1 $\pm$ 1	1.00	1.75 $\pm$ 0.85	0.75	3.1 $\pm$ 0.5	0.90
Golden Jackal	0.29 $\pm$ 0.18	0.29	2.5 $\pm$ 0.5	0.50	-	-	0.5 $\pm$ 0.22	0.40
Jungle Cat	0.14 $\pm$ 0.14	0.14	-	-	-	-	-	-
Indian Hare	-	-	-	-	-	-	0.5 $\pm$ 0.27	0.30
Wild Boar	-	-	-	-	-	-	0.3 $\pm$ 0.15	0.30
Indian Langur	-	-	-	-	6 $\pm$ 3.56	0.50	-	-
Total	2.14 $\pm$ 0.55	1.14	3.5 $\pm$ 1.5	1.50	7.75 $\pm$ 3.33	1.25	4.4 $\pm$ 0.67	1.90

3.2.3. Mangroves

All the mangrove sites were dominated by *A. marina* species. In the sampling sites, however, tree class mangrove (height with more than 1 m and girth as GBH is more than 7 cm) were meagre in density. The mangrove plants found at Dhadar estuary, Lockgate and Vadgaon sites are of matured sapling class, height greater than 1 meter (>1 m) but girth is less than 7

cm. At all other sites, regeneration class and / or mature sapling with height less than 1 m was observed.

The whole Khambhat area was divided into three parts as shown in Table 3.21 for the convenience of presentation of the results. Among all the sites, Vadgam is the plantation site, and rest is natural sites.

Table 3.21: Areas sampled in the Gulf of Khambhat

Station No.	Areas	Site name
1	West Khambhat	Ghoga
2		Lockgate
3		Ganeshgad
4	Sabarmati	Dhadhuka
5		Vadgam
6	East Khambhat	Kavi Kamboi
7		Dehgam
8		Ishanpur
9		Nada
10		Dhadar

The description of the sites surveyed for mangroves is described in the following section:

1. West Khambhat area: West Khambhat area comprises of three sites located at Ghogha village of Bhavnagar Taluka. The coastal area is generally muddy as well as rocky in a few parts. *A. marina* is dominant, and *Avicenna officinalis* is also reported in this area. The mangroves observed are generally stunted and stands with a height less than 50 cm. Patches of *Sesuvium portulacastrum* and *Suaeda maritima* were also found in few of the locations. Fishing activities including crab collection, mudskipper fishing by pagadiya fisher were reported from this site. The mangrove associated plants and halophytes such as *Sesuvium portulacastrum*, *Salvadora persica* and *Suaeda sp.* were also observed in the sampling site. Ganeshgarh site showed the regeneration class mangroves only and no mature class plant.

2. Sabarmati: The first site surveyed in this area is nearby Meldi-ma temple located in Mingalpur of Dhandhuka Taluka in Ahmadabad. There is a creek in the area with low fresh water inflow and hence the mangroves observed are in small patches representing regeneration class. A few halophytes species like *Salvadora persica* and *Suaeda sp* were

observed in the site. The second site is located in the Vadgam in Khambhat Taluka of Anand district. The site shows rocky shore and presence of many saltpans. Only a few individuals of *A. marina* were found in naturally growing stage. Also, there are plantation sites where *A. marina* are raised by *Otla* method of plantation which covers a vast coastal stretch. In vadgam, the few area showed mature plants with height more than 2 meters.

Otla method is also known as Raised Bed Method (RBM), is unique system for mangrove plantation observed in Gujarat only and not in practice in any other coastal states of India. In this method, earthen mounts of approximately 10–15 cm are raised to form a raised bed, on the surface of that 15 to 20 propagules are sown. Although 400 number of raised beds are expected per hectare, it may go up to 1500 beds. This method is successfully adopted for mangrove plantation in Gulf of Kachchh and Gulf of Khambhat. Generally, per hectare almost 400 otlas which approximately consist of 2500 planted saplings could be possible to be planted through nursery or direct dibbling method. In Gujarat state coastal area, particularly, this method showed better results in the plantation of mangroves. This resulted in the popularity of this method in majority of the plantation ventures as it is useful to counter the higher tidal currents.

3. East Khambhat: A total of 4 sites were surveyed in this area. Kavi site is located in Jambusar Taluka of Bharuch, and is unique as it represents union of the Mahisagar and the Sabarmati River. The site was characterized by the vast mudflats and showed the dominance of *A. marina*. The mangroves were stunted with height about a meter. The second site was Dehgam estuary area located in the Gangva village of Dehgam of Bharuch district. The site showed dominance of *A. marina* species with patches of halophytes such as *Sesuvium portulacastrum*. The third site was located in Ishanpur of Jambusar Taluka in Bharuch district near the mouth Mahisagar River. The site is characterized by the vast mudflats with dominance of *A. marina* species with patches of halophytes. Mudskipper fishing is important activity and various small fishing boats and fishing nets could be observed in the area. The fourth site was located in Nada village of Jambusar taluka in Bharuch district and the coastal area is occupied by salt pans. There is few sparse mangrove patches of *A. marina* belonging to the regeneration class along with mangrove associated species such as *Sueada maritima*.

The last site is in Dhadar estuary which is located in the Gandhar village. The site area showed the presence of vast mudflats and many small and large creeks along the coastline. *A. marina* is the dominant species with higher density towards the seaward side. The mangrove covers approximately 500 ha and due to the river water influx, the mangrove density is higher. However, sparse mangroves with the patches of halophytes such as *Sesuvium portulacastrum* are more prevalent in this area. The development of Saltpans and mudskipper fishing were observed in the area, exerting pressure on the mangroves.

Density: The Gulf of Khambhat has large intertidal area, however due to anthropogenic pressure like mangrove cutting for fodder, camel grazing and salt pan expansion have resulted in the absence of mature mangrove individuals and has affected the density as well. In the present study, no tree class mangrove was observed and overall average density of *A. marina* is higher in the West Khambhat area (55,836 individuals/ ha) compared to other sites. The East Khambhat area showed comparatively low overall average density (31,433 individuals / ha) and the Sabarmati area showed the lowest density (8,542 individuals / ha) (Fig 3.27).

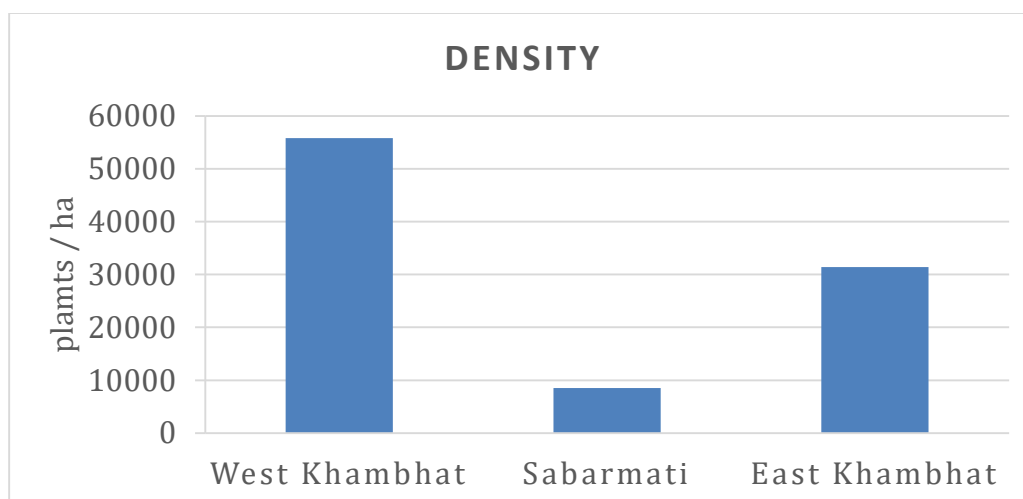


Figure 3.27: Density of mangrove in Khambhat area of Kalpasar project.

(This density included all classes of *A. marina* including regeneration class)

Sitewise mangrove density was highest at Dhadar of East Khambhat (8,999 individuals /ha), followed by Lockgate at East Khambhat (2,509 individuals /ha) and lowest at Vadgam at Sabarmati area (1000 individuals /ha), which is plantation site by ota method (Fig 3.28).

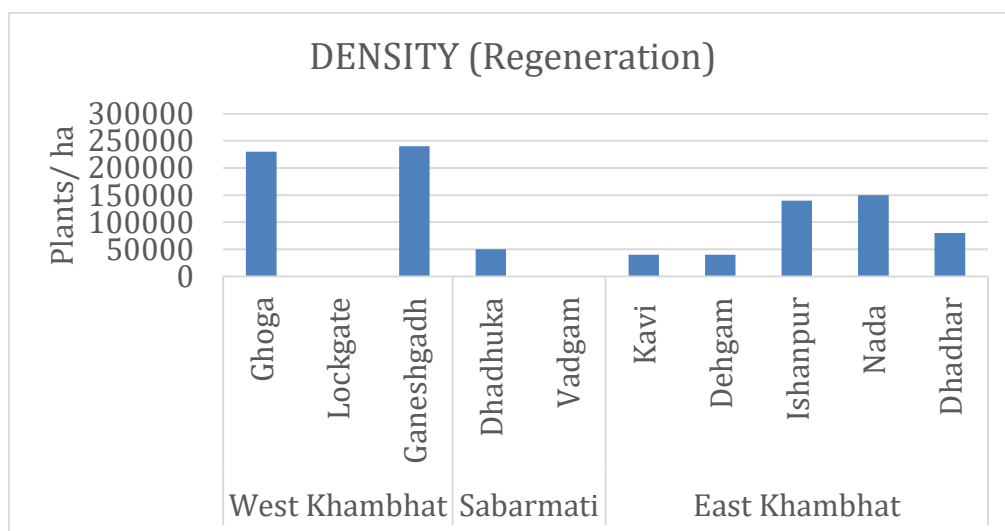


Figure 3.28: Density of regeneration class of *A. marina* in the Kalpasar area.

In case of the regeneration class, the overall maximum average density was found at Ganeshgad (2,40,000 individuals /ha), followed by Ghogha (2,30,000 individuals /ha) sites. However, the Lockgate and, Vadgam sites no regeneration class mangroves were recorded. The natural regeneration of mangroves is generally dependent on the ecological and phenological requirements of tree growth and overall environmental conditions. The abiotic

factors like optimum sunshine, soil chemicals, hydrology of site control the regeneration class.

Morphological features - Height and canopy coverage

Survey for mature seedlings with the height more than 1 meter was conducted separately and it was reported only from three sites viz., Lockgate, Vadagam and Dhadar from West Khambhat, Sabarmati and East Khambhat. However, at all these sites GBH was reported less than 7 cm. The average height of *A. marina* was recorded higher at Lockgate (145 cm) site compared to other two sites, Dhadar (123cm) and Vadgam (115cm). The canopy coverage was reported maximum (>3m) at the site located in Vadgaon as compared to other two sites. Canopy cover of mangroves is one of the most important parameters to determine the condition of mangrove vegetation. If the canopy cover is dense, the mangroves are in good condition. The higher percentage of canopy closure represents low anthropogenic activity.

The sapling (height <50 cm) to mature sapling (height >50 cm) was observed higher in the Sabarmati area than other, which denotes than the habitat is suitable for the occurrence of younger class (Table 3.22). At many sites the higher anthropogenic pressure like camel grazing was observed. Trampling of mangroves during the collection of fishes and crabs by fishermen was reported.

Table 3.22: Sapling (height <50 cm) to mature sapling (height >50 cm) ratio

Site name	Ratio Sapling: Mature sapling
Ghoga	26 : 1
Lockgate	0
Ganeshgadh	64 : 1
West Khambhat	29 : 1
Dhadhuka	400 : 1
Vadgam	0
Sabarmati	80 : 1
Kavi Kamboi	32 : 1
Dehgam	0
Ishanpur	0
Nada	120 : 1
Dhadar	10 : 1
East Khambhat	42 : 1



Plate 1: Mangrove in Khambhat area. a. Lockgate, b. Vadgam and, c. Dhadar sites

The figure 3.29 shows the distribution of mangroves in the upstream and downstream of the proposed dam. The good mangrove cover is present in western side of the Gulf as seen in the figure. These mangroves are secluded from anthropogenic activity with low approachability making them thrive in good conditions. The mangrove cover in the upstream area is estimated to be 36.76 Km² and that of the downstream was 10.67 Km² (Figure 3.29).

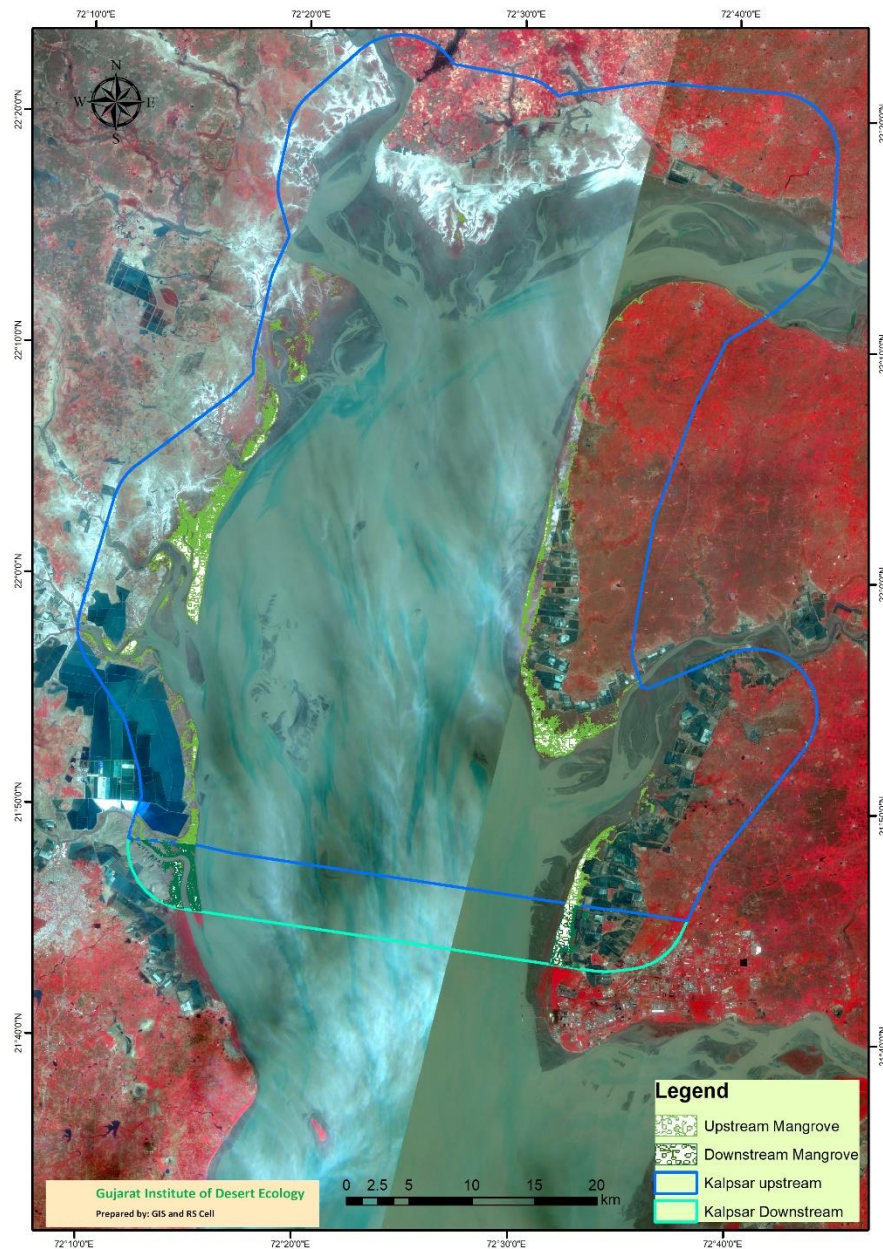


Figure 3.29: Map Showing the mangrove area in the proposed dam

3.2.4. Terrestrial Vegetation

A total of 191 species was reported from the study area spread in five different habitats viz., coastal area, riverines, coastal wetlands, scrubland and agriculture. The region falls in the semi-arid region and with harsh temperature regimes prompted growth of species adapted to the system. Among the various habit, herbs are the dominating features of the landscape with representation from 62 families (Fig 3.30). None of the species recorded in the present study fall under IUCN Red list data.

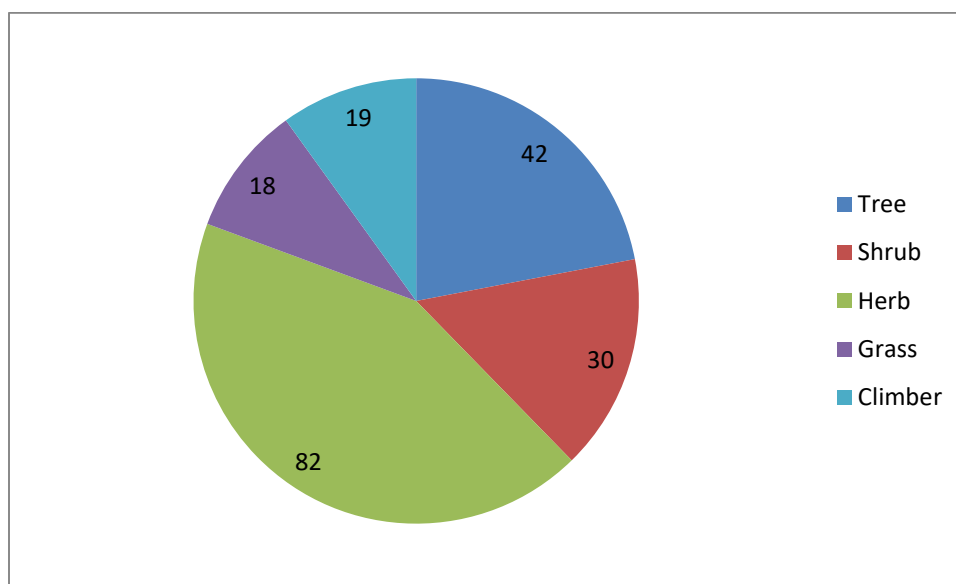


Figure 3.30: Representation of floral species in different habits

Coastal area

A total of 71 species were reported in the coastal region of the study area with Shanon Weiner indices (H') of 3.25, which is good score for the system (Table 3.23). Important dominant species in the area include *Suaeda nudiflora*, *Aeluropus lagopoides*, *Prosopis juliflora*, *Cressa cretica*. *Suaeda nudiflora* and *Aeluropus lagopoides* are salt tolerant species and therefore found in abundance in the region. The salinity of the coastal region is high and therefore the density of *Prosopis juliflora* in this region is only 3.25/m².

Table 3.23: Frequency, abundance and density of species in the coastal area

Name of the species	Frequency	Abundance	Density/m ²
<i>Abutilon indicum</i> (L.) Sw.	0.0625	3.00	0.19
<i>Achyranthes aspera</i> L.	0.0625	3.00	0.19
<i>Aeluropus lagopoides</i> (L.) Trin. ex Thw.	0.8750	4.21	3.69
<i>Alhagi maurorum</i> Medikus	0.0625	1.00	0.06
<i>Aloe barbandensis</i> Mill.	0.0625	1.00	0.06
<i>Alternanthera pungens</i> H. B. & K.	0.1250	4.00	0.50
<i>Alternanthera sessilis</i> (L.) DC.	0.1250	2.00	0.25
<i>Alysicarpus monilifer</i> (L.) DC. var. <i>monilifer</i>	0.0625	2.00	0.13
<i>Amaranthus spinosus</i> L.	0.0625	2.00	0.13
<i>Apluda mutica</i> L.	0.0625	3.00	0.19
<i>Avicennia marina</i> (Forsk.) Vierh.	0.2500	2.75	0.69
<i>Azadirachta indica</i> A. Juss.	0.1250	1.50	0.19
<i>Balanites aegyptiaca</i> (L.) Del.	0.0625	1.00	0.06
<i>Bambusa valgeris</i>	0.0625	1.00	0.06
<i>Blumea lacera</i> (Burm f.) DC.	0.0625	2.00	0.13
<i>Boerhavia diffusa</i> L.	0.0625	1.00	0.06
<i>Bougainvillea spectabilis</i> Willd.	0.0625	1.00	0.06
<i>Calotropis procera</i> (Ait.) R. Br.	0.1875	1.33	0.25
<i>Canavalia gladiata</i> (Jacq.) DC.	0.0625	1.00	0.06
<i>Capparis decidua</i> (Forsk.) Edgew.	0.2500	1.50	0.38
<i>Carica papaya</i>	0.0625	1.00	0.06
<i>Chenopodium album</i> L.	0.0625	2.00	0.13
<i>Chloris barbata</i> Sw.	0.5625	3.00	1.69
<i>Clerodendron ruminerme</i> (L. f.) Gaertn.	0.0625	1.00	0.06
<i>Cocculus hirsutus</i> (L.) Diels	0.0625	1.00	0.06
<i>Corchorus depressus</i> (L.) Stocks	0.0625	1.00	0.06
<i>Cordia monoica</i> Roxb.	0.1250	1.00	0.13
<i>Cressa cretica</i> L.	0.6875	3.91	2.69
<i>Cuscuta reflexaroxb.</i>	0.0625	2.00	0.13
<i>Cynodon dactylon</i> (L.) Pers.	0.1875	2.67	0.50
<i>Datura innoxia</i> Mill.	0.0625	1.00	0.06
<i>Dichanthium annulatum</i> (Forak.) Stapf	0.0625	2.00	0.13
<i>Echinop sechinatus</i> Roxb.	0.0625	1.00	0.06
<i>Ficus religiosa</i> L.	0.0625	1.00	0.06
<i>Fimbristylis dichotoma</i> (L.) Vahl	0.1875	5.33	1.00
<i>Holoptelea integrifolia</i> (Roxb.) Planch.	0.0625	1.00	0.06
<i>Indigofera cordifolia</i> Heyne ex Willd.	0.0625	2.00	0.13
<i>Ipomoea aquatica</i> Forsk.	0.0625	1.00	0.06

Name of the species	Frequency	Abundance	Density/m²
<i>Launaea resedifolia</i> (L.) Druce	0.0625	2.00	0.13
<i>Mangifera indica</i> L.	0.0625	2.00	0.13
<i>Moringa oleifera</i> Lam.	0.0625	1.00	0.06
<i>Ocimum canum</i> Sims in bot.Mag.	0.0625	2.00	0.13
<i>Pentatropis capensis</i> (L. f.) Bullock	0.0625	1.00	0.06
<i>Peristrophe bicalyculata</i> (Retz.) Nees	0.0625	2.00	0.13
<i>Physalis minima</i> L.	0.1250	2.00	0.25
<i>Pithecellobium dulce</i> (Roxb.) Bth.	0.0625	1.00	0.06
<i>Pluchea lanceolata</i>	0.0625	1.00	0.06
<i>Prosopis cineraria</i> (L.) Druce	0.1875	1.00	0.19
<i>Prosopis juliflora</i> (Sw) DC.	0.7500	4.33	3.25
<i>Ricinus communis</i> L.	0.0625	1.00	0.06
<i>Salvadora persica</i> L.	0.4375	2.00	0.88
<i>Sesbania sesban</i> (L.) Meer. subsp.	0.0625	1.00	0.06
<i>Sesuvium portulacastrum</i>	0.0625	2.00	0.13
<i>Solanum indicum</i>	0.0625	3.00	0.19
<i>Solanum surattense</i> Burm. f.	0.1250	1.50	0.19
<i>Sporobolus helvolus</i> (Trin.) Th. Dur.	0.3125	4.40	1.38
<i>Suaeda fruticosa</i> (L.) Forsk. ex Gmel.	0.0625	1.00	0.06
<i>Suaeda maritima</i>	0.1250	2.50	0.31
<i>Suaeda nudiflora</i> (Willd.) Moq.	1.0000	3.50	3.50
<i>Tamarix aphylla</i> (L.) Karst.	0.7500	1.75	1.31
<i>Tecoma stans</i> (L.) H. B. & K.	0.0625	1.00	0.06
<i>Tectona grandis</i> L.f.	0.0625	2.00	0.13
<i>Terminalia catappa</i> L.	0.0625	1.00	0.06
<i>Thespesia populnea</i> (L.) Sol. ex Corr.	0.0625	1.00	0.06
<i>Tinospora cordifolia</i> Roxb.	0.0625	1.00	0.06
<i>Tribulus terrestris</i> L.	0.0625	1.00	0.06
<i>Vernonia cinerea</i> (L.) Less.	0.1875	2.00	0.38
<i>Withaniasomnifera</i> (L.) Kurz	0.0625	1.00	0.06
<i>Xanthium strumarium</i> L.	0.0625	1.00	0.06
<i>Zaleyadecandra</i> Burm.	0.0625	1.00	0.06
<i>Zizyphus nummularia</i> (Burm. F.) W. & A.	0.1875	2.00	0.38

Table 3.24. Diversity of mangrove species recorded in the study area

Taxa_S	71
Individuals	452
Dominance_D	0.0678
Simpson_1-D	0.9322
Shannon_H	3.2500
Evenness_e^H/S	0.3632
Brillouin	3.0340
Menhinick	3.3400
Margalef	11.4500
Equitability_J	0.7624
Fisher_alpha	23.6600
Berger-Parker	0.1305
Chao-1	102

Riverine area

The area includes the grids falling in the riverine stretches of the study area. A total of 59 species was reported from this area with Diversity index (H') score of 3.69, which is good diversity score. The density of invasive *Prosopis juliflora* was high in this riverine stretch indicating low salinity regimes due to presence of freshwater flow in the river. The other dominating species in this region includes *Suaeda nudiflora* and *Cynodon dactylon* (Table 3.25).

Table 3.25: Frequency, abundance, and density of species in the riverine area

Name of the species	Frequency	Abundance	Density/m ²
<i>Acacia nilotica</i> (L.) Del.	0.7143	1.80	1.29
<i>Achyranthes aspera</i> L.	0.7143	1.80	1.29
<i>Aeluropus lagopoides</i> (L.) Trin. ex Thw.	0.5714	3.00	1.71
<i>Ailanthus excelsa</i> Roxb.	0.1429	1.00	0.14
<i>Albizia lebbek</i> (L.) Bth.	0.1429	1.00	0.14
<i>Alternanthera pungens</i> H. B. & K.	0.4286	1.67	0.71
<i>Alternanthera sessilis</i> (L.) DC.	0.1429	2.00	0.29
<i>Anisomeles indica</i> (L.) O. Ktze.	0.1429	2.00	0.29
<i>Argemone mexicana</i> L.	0.2857	2.00	0.57
<i>Aristida adscensionis</i>	0.2857	2.00	0.57
<i>Azadirachta indica</i> A. Juss.	0.4286	1.67	0.71
<i>Bambusa valgeris</i>	0.1429	2.00	0.29

Name of the species	Frequency	Abundance	Density/m ²
<i>Basella rubra</i>	0.1429	1.00	0.14
<i>Blumeaobliqua</i> (L.) Druce	0.4286	2.33	1.00
<i>Butea monosperma</i>	0.4286	1.00	0.43
<i>Caesalpinia crista</i> L.	0.1429	1.00	0.14
<i>Calotropis procera</i> (Ait.) R. Br.	0.7143	1.80	1.29
<i>Capparis decidua</i> (Forsk.) Edgew.	0.2857	2.00	0.57
<i>Cassia angustifolia</i> Vahl	0.1429	2.00	0.29
<i>Cassia auriculata</i> L.	0.4286	3.67	1.57
<i>Cassia occidentalis</i> L.	0.5714	1.25	0.71
<i>Chloris barbata</i> Sw.	0.1429	1.00	0.14
<i>Cleome viscosa</i> L.	0.1429	2.00	0.29
<i>Cocculus hirsutus</i> (L.) Diels	0.1429	2.00	0.29
<i>Convolvulus microphyllus</i>	0.4286	1.67	0.71
<i>Corchorus depressus</i> (L.) Stocks	0.4286	1.67	0.71
<i>Cordia dichotoma</i> Forst.	0.2857	1.00	0.29
<i>Cressa cretica</i> L.	0.7143	1.80	1.29
<i>Cynodon dactylon</i> (L.) Pers.	0.8571	2.83	2.43
<i>Dalechampia scandens</i> L.	0.4286	1.00	0.43
<i>Derris indica</i> (Lam.) Bennet	0.1429	1.00	0.14
<i>Eucalyptus globulus</i> Labill.	0.2857	2.00	0.57
<i>Fimbristylis dichotoma</i> (L.) Vahl	0.1429	4.00	0.57
<i>Glinus lotoides</i>	0.2857	2.00	0.57
<i>Gossypium herbaceum</i>	0.2857	2.00	0.57
<i>Grangea maderaspatana</i> (L.) Poir.	0.4286	1.67	0.71
<i>Holoptelea integrifolia</i> (Roxb.) Planch.	0.4286	2.00	0.86
<i>Indigofera cordifolia</i> Heyne ex Willd.	0.1429	2.00	0.29
<i>Ipomoea carica</i> (L.) Sw.	0.1429	1.00	0.14
<i>Lantana camara</i> auct. Non L.	0.2857	2.00	0.57
<i>Launaea resedifolia</i> (L.) Druce	0.1429	1.00	0.14
<i>Leucas cephalotes</i> (Roxb. Ex Rothui) Spr.	0.2857	2.00	0.57
<i>Limonia acidissima</i> L	0.2857	2.00	0.57
<i>Maytenus emarginata</i> (Willd.) D. Hou	0.2857	1.00	0.29
<i>Mucana prurita</i> Hk. f.	0.4286	2.67	1.14
<i>Peltophorum pterocarpum</i> (DC.) Baker.	0.2857	2.00	0.57
<i>Peristrophe bicalyculata</i> (Retz.) Nees	0.2857	3.00	0.86
<i>Prosopis juliflora</i> (Sw) DC.	1.0000	5.43	5.43
<i>Salvadora persica</i> L.	0.8571	2.33	2.00
<i>Sida ovata</i>	0.1429	3.00	0.43
<i>Solanum surattense</i> Burm. f.	0.5714	2.75	1.57
<i>Sporobolus helvolus</i> (Trin.) Th. Dur.	0.1429	2.00	0.29

Name of the species	Frequency	Abundance	Density/m ²
<i>Suaeda nudiflora</i> (Willd.) Moq.	0.7143	3.60	2.57
<i>Syzygium cumini</i> (L.) Skells	0.2857	1.00	0.29
<i>Tamarix aphylla</i> (L.) Karst.	0.1429	1.00	0.14
<i>Tephrosia purpurea</i> (L.) Pers.	0.2857	2.00	0.57
<i>Vernonia cinerea</i> (L.) Less.	0.2857	3.00	0.86
<i>Xanthium strumarium</i> L.	0.4286	1.00	0.43
<i>Zizyphus nummularia</i> (Burm. F.) W. & A.	0.4286	3.00	1.29

Table 3.25. Diversity across riverine vegetation recorded in the study area

Taxa_S	59
Individuals	320
Dominance_D	0.0361
Simpson_1-D	0.9639
Shannon_H	3.6980
Evenness_e^H/S	0.6840
Brillouin	3.4130
Menhinick	3.2980
Margalef	10.0500
Equitability_J	0.9069
Fisher_alpha	21.2500
Berger-Parker	0.1188
Chao-1	62

Freshwater Wetlands

The freshwater wetland habitats were surveyed in the entire study region and showed presence of 67 species with diversity index of 3.773. The index is high indicating good representation of population within a species. The dominating species in this category includes *Prosopis juliflora*, *Prosopis cineraria*, *Vernonia cinerea*, *Cynodon dactylon*, *Aeluropus lagopoides*, *Calotropis procera*, *Capparis decidua* and *Cressa cretica* (Table 3.26).

Table 3.26: Frequency, abundance, and density of species in the wetland area

Name of the species	Frequency	Abundance	Density/m ²
<i>Acacia nilotica</i> (L.) Del.	0.6667	1.00	0.67
<i>Achyranthes aspera</i> L.	0.5000	3.33	1.67
<i>Aeluropus lagopoides</i> (L.) Trin. ex Thw.	0.5000	4.33	2.17
<i>Alhagi maurorum</i> Medikus	0.5000	1.00	0.50

Name of the species	Frequency	Abundance	Density/m ²
<i>Aloe barbandensis</i> Mill.	0.1667	1.00	0.17
<i>Alternanthera pungens</i> H. B. & K.	0.3333	2.50	0.83
<i>Alysicarpus monilifer</i> (L.) DC. var. monilifer	0.1667	2.00	0.33
<i>Amaranthus viridis</i> L.	0.1667	3.00	0.50
<i>Aristida funiculata</i> Trin. & Rupr.	0.6667	2.75	1.83
<i>Avicennia marina</i> (Forsk.) Vierh.	0.1667	3.00	0.50
<i>Azadirachta indica</i> A. Juss.	0.5000	2.00	1.00
<i>Balanites aegyptiaca</i> (L.) Del.	0.1667	1.00	0.17
<i>Boerhavia diffusa</i> L.	0.1667	1.00	0.17
<i>Bougainvillea spectabilis</i> Willd.	0.1667	1.00	0.17
<i>Calotropis procera</i> (Ait.) R. Br.	1.0000	2.00	2.00
<i>Capparis decidua</i> (Forsk.) Edgew.	0.8333	2.40	2.00
<i>Cassia auriculata</i> L.	0.3333	1.50	0.50
<i>Chenopodium album</i> L.	0.1667	2.00	0.33
<i>Chloris barbata</i> Sw.	0.3333	4.00	1.33
<i>Cordia monoica</i> Roxb.	0.1667	1.00	0.17
<i>Cressa cretica</i> L.	0.3333	6.50	2.17
<i>Cryptostegia grandiflora</i> R. Br.	0.3333	1.00	0.33
<i>Ctenolepis cerasiformis</i> (Stocks) Hk. f.	0.3333	1.00	0.33
<i>Cynodon dactylon</i> (L.) Pers.	0.6667	4.75	3.17
<i>Cyperus rotundus</i> L.	0.1667	2.00	0.33
<i>Datura innoxia</i> Mill.	0.1667	1.00	0.17
<i>Derris indica</i> (Lam.) Bennet	0.3333	2.00	0.67
<i>Echinopse chinatus</i> Roxb.	0.3333	1.50	0.50
<i>Eclipta prostrata</i> (L.) L. Mant.	0.1667	2.00	0.33
<i>Eucalyptus globulus</i> Labill.	0.1667	1.00	0.17
<i>Euphorbia caducifolia</i> Hains.	0.1667	1.00	0.17
<i>Euphorbia hirta</i> L.	0.1667	2.00	0.33
<i>Ficus religiosa</i> L.	0.1667	1.00	0.17
<i>Fimbristylis dichotoma</i> (L.) Vahl	0.1667	3.00	0.50
<i>Glinuslotoides</i>	0.1667	2.00	0.33
<i>Grangea maderaspatana</i> (L.) Poir.	0.1667	2.00	0.33
<i>Indigofera cordifolia</i> Heyne ex Willd.	0.1667	2.00	0.33
<i>Ipomoea aquatica</i> Forsk.	0.1667	2.00	0.33
<i>Ipomoea carica</i> (L.) Sw.	0.3333	1.50	0.50
<i>Leucas aspera</i> (Willd.) Spr.	0.1667	2.00	0.33
<i>Manilkara hexandra</i> (Roxb.) Dub	0.5000	1.00	0.50
<i>Medicago sativa</i> L.	0.1667	3.00	0.50
<i>Moringa oleifera</i> Lam.	0.1667	1.00	0.17

Name of the species	Frequency	Abundance	Density/m ²
<i>Ocimum canum</i> Sims in bot.Mag.	0.1667	2.00	0.33
<i>Pentatropis capensis</i> (L. f.) Bullock	0.1667	1.00	0.17
<i>Peristrophe bicalyculata</i> (Retz.) Nees	0.3333	3.00	1.00
<i>Phoenix sylvestris</i> (L.) Roxb.	0.3333	2.00	0.67
<i>Phyllanthus fraternus</i> Webst.	0.3333	1.50	0.50
<i>Pithecellobium dulce</i> (Roxb.) Bth.	0.5000	1.33	0.67
<i>Prosopis cineraria</i> (L.) Druce	0.8333	2.60	2.17
<i>Prosopis juliflora</i> (Sw) DC.	0.8333	4.60	3.83
<i>Ricinus communis</i> L.	0.3333	4.00	1.33
<i>Salvadora persica</i> L.	0.3333	1.00	0.33
<i>Solanum albicaule</i> Kotschy ex Dunal	0.3333	1.00	0.33
<i>Solanum surattense</i> Burm. f.	0.6667	2.75	1.83
<i>Suaeda nudiflora</i> (Willd.) Moq.	0.5000	2.00	1.00
<i>Tamarix aphylla</i> (L.) Karst.	0.1667	2.00	0.33
<i>Tecoma stans</i> (L.) H. B. & K.	0.1667	1.00	0.17
<i>Thespesia populnea</i> (L.) Sol. ex Corr.	0.1667	1.00	0.17
<i>Tinospora cordifolia</i> Roxb.	0.1667	1.00	0.17
<i>Trianthema portulacastrum</i> L.	0.3333	2.00	0.67
<i>Tribulus terrestris</i> L.	0.1667	1.00	0.17
<i>Vernonia cinerea</i> (L.) Less.	0.8333	2.60	2.17
<i>Withania somnifera</i> (L.) Kurz	0.1667	1.00	0.17
<i>Xanthium strumarium</i> L.	0.1667	1.00	0.17
<i>Zizyphus mauritiana</i> Lam.	0.1667	1.00	0.17
<i>Zizyphus nummularia</i> (Burm. F.) W. & A.	0.3333	2.00	0.67

Table 3.27. Diversity of freshwater plants recorded in the study area

Taxa_S	67
Individuals	293
Dominance_D	0.0317
Simpson_1-D	0.9683
Shannon_H	3.7730
Evenness_e^H/S	0.6493
Brillouin	3.4470
Menhinick	3.9140
Margalef	11.6200
Equitability_J	0.8973
Fisher_alpha	27.1600
Berger-Parker	0.0785
Chao-1	76

Scrubland

Scrubland habitat had the maximum representation of terrestrial vegetation and about 106 species was recorded. The Shannon diversity index (H') was high with a score of 3.637 indicating good presence of species. Important species present in the area includes *Aeluropus lagopoides*, *Chloris barbata*, *Cressa cretica*, *Fimbristylis dichotoma*, *Suaeda nudiflora*, *Prosopis juliflora*. The density of *Prosopis juliflora* (6.6/m²) recorded was high in the scrubland, when compared to other habit (Table 3.28).

Table 3.28: Frequency, abundance, and density of species in the scrubland area

Name of the species	Frequency	Abundance	Density/m ²
<i>Abutilon indicum</i> (L.) Sw.	0.1111	1.67	0.19
<i>Acacia nilotica</i> (L.) Del.	0.4074	1.55	0.63
<i>Achyranthes aspera</i> L.	0.5926	2.63	1.56
<i>Aeluropuslagopoides</i> (L.) Trin. ex Thw.	0.5556	6.87	3.81
<i>Ageratum conyzoides</i> L.	0.0741	2.00	0.15
<i>Alhagimaurorum</i> Medikus	0.0741	2.00	0.15
<i>Alternanthera pungens</i> H. B. & K.	0.1111	6.00	0.67
<i>Amaranthus viridis</i> L.	0.0370	3.00	0.11
<i>Anisomeles indica</i> (L.) O. Ktze.	0.0370	3.00	0.11
<i>Apludamutica</i> L.	0.0370	2.00	0.07
<i>Aristida funiculata</i> Trin. & Rupr.	0.2963	6.00	1.78
<i>Asparagus racemosus</i> Willd.	0.0741	1.50	0.11
<i>Avicennia marina</i> (Forsk.) Vierh.	0.1111	3.00	0.33
<i>Azadirachta indica</i> A. Juss.	0.2222	1.83	0.41
<i>Balanites aegyptiaca</i> (L.) Del.	0.0741	1.50	0.11
<i>Bambusavalgeris</i>	0.0370	2.00	0.07
<i>Barleriaprionitis</i> L.	0.0370	2.00	0.07
<i>Bauhinia variegata</i> L.	0.0370	1.00	0.04
<i>Blumeaobliqua</i> (L.) Druce	0.1481	2.00	0.30
<i>Boerhaviadiffusa</i> L.	0.0741	1.50	0.11
<i>Calotropis procera</i> (Ait.) R. Br.	0.4815	2.46	1.19
<i>Canavalia gladiata</i> (Jacq.) DC.	0.1111	3.00	0.33
<i>Canna indica</i> L.	0.0370	3.00	0.11
<i>Capparis decidua</i> (Forsk.) Edgew.	0.5556	2.20	1.22
<i>Capparis grandis</i> L. f.	0.0370	1.00	0.04
<i>Cassia angustifolia</i> Vahl	0.0370	1.00	0.04
<i>Cassia auriculata</i> L.	0.0741	2.00	0.15
<i>Chloris barbata</i> Sw.	0.6667	4.44	2.96

Name of the species	Frequency	Abundance	Density/m ²
<i>Cleome viscosa</i> L.	0.0370	2.00	0.07
<i>Clerodendrum inerme</i> (L. f.) Gaertn.	0.0370	2.00	0.07
<i>Coccinia grandis</i> (L.) Voigt	0.0370	2.00	0.07
<i>Cocculus hirsutus</i> (L.) Diels	0.1852	1.40	0.26
<i>Cocos nucifera</i> L.	0.0370	1.00	0.04
<i>Convolvulus microphyllus</i>	0.0370	1.00	0.04
<i>Corchorus capsularis</i> L.	0.1481	2.25	0.33
<i>Corchorus depressus</i> (L.) Stocks	0.1852	2.20	0.41
<i>Corchorus olitorius</i> L.	0.0370	2.00	0.07
<i>Cordia dichotoma</i> Forst.	0.0370	2.00	0.07
<i>Cordia monoica</i> Roxb.	0.0370	1.00	0.04
<i>Cressacretica</i> L.	0.5926	5.38	3.19
<i>Cryptostegia grandiflora</i> R. Br.	0.0370	1.00	0.04
<i>Ctenolepis cerasiformis</i> (Stocks) Hk. f.	0.0370	1.00	0.04
<i>Cynodondactylon</i> (L.) Pers.	0.4074	3.27	1.33
<i>Cyperus rotundus</i> L.	0.2222	2.67	0.59
<i>Dactyloctenium indicum</i> Boiss.	0.0741	7.00	0.52
<i>Dalechampia scandens</i> L.	0.0370	1.00	0.04
<i>Delonix elata</i> (L.) Gamble	0.0741	1.00	0.07
<i>Derris indica</i> (Lam.) Bennet	0.0370	1.00	0.04
<i>Digera muricata</i> (L.) Mart.	0.0370	2.00	0.07
<i>Echinops echinatus</i> Roxb.	0.0370	2.00	0.07
<i>Enicostema axillare</i> (Lamk.) Roynal	0.0741	3.50	0.26
<i>Eucalyptus globulus</i> Labill.	0.0370	3.00	0.11
<i>Euphorbia caducifolia</i> Hains.	0.0741	1.00	0.07
<i>Ficus microcarpa</i> L. f.	0.1111	1.67	0.19
<i>Ficus racemosa</i> L.	0.0370	1.00	0.04
<i>Fimbristylis dichotoma</i> (L.) Vahl	0.4074	5.27	2.15
<i>Glinus lotoides</i>	0.0370	2.00	0.07
<i>Heliotropium curassavicum</i> L.	0.0741	4.00	0.30
<i>Holoptelea integrifolia</i> (Roxb.) Planch.	0.0370	1.00	0.04
<i>Hygrophila auriculata</i> (Schum.) Heine	0.0370	1.00	0.04
<i>Indigofera cordifolia</i> Heyne ex Willd.	0.1111	2.67	0.30
<i>Ipomoea carica</i> (L.) Sw.	0.1111	1.00	0.11
<i>Justicia simplex</i> Don	0.0370	2.00	0.07
<i>Lantana camara</i> auct. Non L.	0.0370	3.00	0.11
<i>Launaea resedifolia</i> (L.) Druce	0.0741	2.00	0.15
<i>Lepidagathis trinervis</i> Wall.	0.1111	3.00	0.33
<i>Leucas aspera</i> (Willd.) Spr.	0.0370	2.00	0.07
<i>Maerua oblongifolia</i> (Forsk.) A. Rich.	0.0370	1.00	0.04

Name of the species	Frequency	Abundance	Density/m ²
<i>Manilkara hexandra</i> (Roxb.) Dub	0.0370	1.00	0.04
<i>Nicotiana tabacum</i> L.	0.0370	4.00	0.15
<i>Ocimum sanctum</i>	0.0370	3.00	0.11
<i>Oxystelma esculentum</i>	0.0741	1.00	0.07
<i>Parkinsonia aculeata</i> L.	0.0370	1.00	0.04
<i>Parthenium hysterophorus</i> L.	0.0370	2.00	0.07
<i>Pentatropis capensis</i> (L. f.) Bullock	0.2593	1.43	0.37
<i>Peristrophe bicalyculata</i> (Retz.) Nees	0.1852	3.00	0.56
<i>Phragmites karka</i> (Retz.) Trin. Ex Steud.	0.0741	1.00	0.07
<i>Phyllanthus fraternus</i> Webst.	0.1111	2.33	0.26
<i>Pithecellobium dulce</i> (Roxb.) Bth.	0.0741	1.00	0.07
<i>Pluchea lanceolata</i>	0.0370	2.00	0.07
<i>Portulaca oleracea</i> L.	0.0370	3.00	0.11
<i>Prosopis cineraria</i> (L.) Druce	0.3333	1.78	0.59
<i>Prosopis juliflora</i> (Sw) DC.	0.8889	7.50	6.67
<i>Pulicaria crispa</i> Sch.-Bip.	0.0370	4.00	0.15
<i>Rhynchosia minima</i> (L.) DC.	0.0741	2.00	0.15
<i>Salvadora oleoides</i> Decne.	0.0370	1.00	0.04
<i>Salvadora persica</i> L.	0.6296	2.76	1.74
<i>Sida cordata</i> (Burm. f.) Borss	0.1111	1.33	0.15
<i>Solanum surattense</i> Burm. f.	0.0741	1.50	0.11
<i>Sphaeranthus senegalensis</i> DC.	0.0370	2.00	0.07
<i>Sporobolus helvolus</i> (Trin.) Th. Dur.	0.2593	4.29	1.11
<i>Stemodia viscosa</i> Roxb	0.0370	4.00	0.15
<i>Suaeda fruticosa</i> (L.) Forsk. ex Gmel.	0.0370	2.00	0.07
<i>Suaeda maritima</i>	0.0370	1.00	0.04
<i>Suaeda nudiflora</i> (Willd.) Moq.	0.5185	4.14	2.15
<i>Syzygium cumini</i> (L.) Skells	0.0370	1.00	0.04
<i>Tamarix aphylla</i> (L.) Karst.	0.2963	2.00	0.59
<i>Taverniera cuneifolia</i> (Roth) Arn.	0.0370	3.00	0.11
<i>Terminalia catappa</i> L.	0.0370	1.00	0.04
<i>Thevetia peruviana</i> (Pers.) Merr.	0.0370	1.00	0.04
<i>Tridax procumbens</i> L.	0.1481	3.00	0.44
<i>Vernonia cinerea</i> (L.) Less.	0.2593	4.29	1.11
<i>Withania somnifera</i> (L.) Kurz	0.0370	1.00	0.04
<i>Xanthium strumarium</i> L.	0.0741	2.00	0.15
<i>Zizyphus mauritiana</i> Lam.	0.0370	2.00	0.07
<i>Zizyphus nummularia</i> (Burm. F.) W. & A.	0.4815	2.77	1.33

Table 3.29: Diversity of scrubland vegetation in the study area

Taxa_S	106
Individuals	1293
Dominance_D	0.04768
Simpson_1-D	0.9523
Shannon_H	3.637
Evenness_e^H/S	0.3582
Brillouin	3.502
Menhinick	2.948
Margalef	14.66
Equitability_J	0.7799
Fisher_alpha	27.34
Berger-Parker	0.1392
Chao-1	115.6

Agriculture

Agriculture is the man made ecosystem where different crops are cultivated. There are about 142 species from this area with diversity index score of 4.07, which is high considering the agriculture ecosystem. Important dominant species in this region includes *Aristida funiculata*, *Chloris barbata*, *Cynodon dactylon*, *Cressa cretica*, *Prosopis juliflora*. *Prosopis juliflora* (5/m²) is the most dominant species in this region and indicates its invasive nature (Table 3.29).

Table 3.29: Frequency, abundance, and density of species in the scrubland area

Name of the species	Frequency	Abundance	Density/m ²
<i>Abelmoschus manihot</i>	0.1290	2.00	0.2581
<i>Abrusprecatorius L.</i>	0.0323	1.00	0.0323
<i>Abutilon indicum (L.) Sw.</i>	0.1935	2.67	0.5161
<i>Acacia leucophloea (Roxb.) Willd.</i>	0.0323	6.00	0.1935
<i>Acacia nilotica (L.) Del.</i>	0.6129	2.05	1.2581
<i>Achyranthes aspera L.</i>	0.5484	2.71	1.4839
<i>Aeluropus lagopoides (L.) Trin. ex Thw.</i>	0.3226	4.80	1.5484
<i>Ailanthus excels Roxb.</i>	0.0323	1.00	0.0323
<i>Albizia lebbeck (L.) Bth.</i>	0.0968	3.00	0.2903
<i>Alhagimaurorum Medikus</i>	0.0645	2.00	0.1290
<i>Alstoniascholaris (L.) R. Br.</i>	0.0323	1.00	0.0323

<i>Alternanthera pungens</i> H. B. & K.	0.1935	3.00	0.5806
<i>Alternanthera sessilis</i> (L.) DC.	0.0323	3.00	0.0968
<i>Amaranthus spinosus</i> L.	0.0323	2.00	0.0645
<i>Amaranthus viridis</i> L.	0.2581	2.25	0.5806
<i>Anagallis arvensis</i> L.	0.0323	2.00	0.0645
<i>Anisomeles indica</i> (L.) O. Ktze.	0.0968	1.33	0.1290
<i>Apluda mutica</i> L.	0.0323	4.00	0.1290
<i>Argemone mexicana</i> L.	0.0645	1.50	0.0968
<i>Aristida funiculata</i> Trin. & Rupr.	0.4194	5.38	2.2581
<i>Asparagus racemosus</i> Willd.	0.0323	3.00	0.0968
<i>Azadirachta indica</i> A. Juss.	0.4839	2.33	1.1290
<i>Balanites aegyptiaca</i> (L.) Del.	0.1290	2.25	0.2903
<i>Bauhinia variegata</i> L.	0.0323	1.00	0.0323
<i>Blumea lacera</i> (Burm f.) DC.	0.0645	2.00	0.1290
<i>Blumea obliqua</i> (L.) Druce	0.0968	1.33	0.1290
<i>Boerhavia diffusa</i> L.	0.1290	1.50	0.1935
<i>Bombax malabaricum</i> DC.	0.0323	1.00	0.0323
<i>Bougainvillea spectabilis</i> Willd.	0.0645	1.50	0.0968
<i>Caesalpinia crista</i> L.	0.0323	1.00	0.0323
<i>Calotropis procera</i> (Ait.) R. Br.	0.4839	2.27	1.0968
<i>Canavalia gladiata</i> (Jacq.) DC.	0.0645	1.50	0.0968
<i>Capparis decidua</i> (Forsk.) Edgew.	0.6774	2.71	1.8387
<i>Capparis grandis</i> L. f.	0.0323	2.00	0.0645
<i>Cassia angustifolia</i> Vahl	0.0645	1.00	0.0645
<i>Cassia auriculata</i> L.	0.2903	2.89	0.8387
<i>Cassia fistula</i> L.	0.0323	2.00	0.0645
<i>Cassia occidentalis</i> L.	0.0323	2.00	0.0645
<i>Cassia roxburghii</i> DC.	0.0323	1.00	0.0323
<i>Cassia tora</i> L.	0.0645	4.00	0.2581
<i>Ceiba pentandra</i>	0.0323	1.00	0.0323
<i>Celosia argentea</i> L.	0.0323	2.00	0.0645
<i>Chenopodium album</i> L.	0.0323	2.00	0.0645
<i>Chloris barbata</i> Sw.	0.6129	4.89	3.0000
<i>Cleome viscosa</i> L.	0.0323	3.00	0.0968
<i>Clitoratene L.</i>	0.0323	1.00	0.0323
<i>Coccinia grandis</i> (L.) Voigt	0.1290	1.00	0.1290
<i>Cocculus hirsutus</i> (L.) Diels	0.0968	1.33	0.1290
<i>Cocos nucifera</i> L.	0.0968	1.00	0.0968
<i>Corchorus capsularis</i> L.	0.1613	1.40	0.2258
<i>Corchorus depressus</i> (L.) Stocks	0.1290	1.50	0.1935
<i>Corchorus olitorius</i> L.	0.0323	2.00	0.0645

<i>Cordia dichotoma</i> Forst.	0.1290	1.50	0.1935
<i>Cordia monoica</i> Roxb.	0.1613	1.20	0.1935
<i>Cressa cretica</i> L.	0.3871	6.33	2.4516
<i>Cynodon dactylon</i> (L.) Pers.	0.6129	5.32	3.2581
<i>Cyperus rotundus</i> L.	0.1935	5.50	1.0645
<i>Datura innoxia</i> Mill.	0.1290	2.25	0.2903
<i>Delonixelata</i> (L.) Gamble	0.0323	1.00	0.0323
<i>Dichanthium annulatum</i> (Forak.) Stapf	0.0323	3.00	0.0968
<i>Digitaria adscendens</i> (H.B.&K.) Henr.	0.0323	5.00	0.1613
<i>Echinops echinatus</i> Roxb.	0.2581	2.38	0.6129
<i>Eclipta prostrata</i> (L.) L. Mant.	0.0323	2.00	0.0645
<i>Enicostema axillare</i> (Lamk.) Roynal	0.0645	3.00	0.1935
<i>Eragrostis tenella</i> (L.) P. Beauv.	0.1290	2.25	0.2903
<i>Eucalyptus globulus</i> Labill.	0.0645	2.00	0.1290
<i>Euphorbia caducifolia</i> Hains.	0.0323	1.00	0.0323
<i>Euphorbia hirta</i> L.	0.0645	2.50	0.1613
<i>Euphorbia thymifolia</i> L.	0.1613	2.00	0.3226
<i>Ficus benghalensis</i> L.	0.0645	1.00	0.0645
<i>Ficus microcarpa</i> L. f.	0.1613	1.40	0.2258
<i>Ficus religiosa</i> L.	0.0968	1.33	0.1290
<i>Fimbristylis dichotoma</i> (L.) Vahl	0.1290	5.00	0.6452
<i>Flacourtia indica</i> (Burm. F.) Merr.	0.0323	1.00	0.0323
<i>Glinus lotoides</i>	0.0645	1.00	0.0645
<i>Goniogyna hirta</i> (Willd.) Ali	0.0323	2.00	0.0645
<i>Heliotropium curassavicum</i> L.	0.0323	2.00	0.0645
<i>Hibicus ovalifolius</i> (Forsk.) Vahl.	0.0323	2.00	0.0645
<i>Hibiscus rosa-sinensis</i> L.	0.0323	1.00	0.0323
<i>Holoptelea integrifolia</i> (Roxb.) Planch.	0.0323	1.00	0.0323
<i>Hygrophila auriculata</i> (Schum.) Heine	0.0968	2.00	0.1935
<i>Indigofera cordifolia</i> Heyne ex Willd.	0.1290	2.00	0.2581
<i>Indigofera linifolia</i>	0.0323	8.00	0.2581
<i>Indigofera oblongifolia</i> Forsk.	0.0323	1.00	0.0323
<i>Ipomoea carica</i> (L.) Sw.	0.1290	1.00	0.1290
<i>Lantana camara</i> auct. Non L.	0.0968	2.00	0.1935
<i>Lepidagathis trinervis</i> Wall.	0.0323	8.00	0.2581
<i>Leucaena latisiliqua</i> (L.) Wt. & Arn.	0.0645	1.00	0.0645
<i>Leucas aspera</i> (Willd.) Spr.	0.0323	3.00	0.0968
<i>Leucas cephalotes</i> (Roxb. Ex Rothui) Spr.	0.0968	2.00	0.1935

<i>Mangifera indica</i> L.	0.0645	2.00	0.1290
<i>Manilkara hexandra</i> (Roxb.) Dub	0.0968	1.00	0.0968
<i>Maytenus emarginata</i> (Willd.) D. Hou	0.0645	1.00	0.0645
<i>Melia azedarach</i> L.	0.0968	1.67	0.1613
<i>Moringa oleifera</i> Lam.	0.0323	1.00	0.0323
<i>Mucana prurita</i> Hk. f.	0.0323	2.00	0.0645
<i>Nicotiana tabacum</i> L.	0.0645	3.00	0.1935
<i>Ocimum canum</i> Sims in bot. Mag.	0.0968	1.67	0.1613
<i>Oligochaeta ramosa</i> (Roxb.) Wagenitz	0.0323	1.00	0.0323
<i>Opuntia elatior</i> Mill.	0.0645	1.50	0.0968
<i>Parkinsonia aculeata</i> L.	0.0645	1.00	0.0645
<i>Parthenium hysterophorus</i> L.	0.1613	2.00	0.3226
<i>Pavonia arabica</i>	0.0323	2.00	0.0645
<i>Peltophorum pterocarpum</i> (DC.) Baker.	0.0323	1.00	0.0323
<i>Pentatropis capensis</i> (L. f.) Bullock	0.0968	1.33	0.1290
<i>Pergularia daemia</i> (Forsk.) Chiov.	0.0323	1.00	0.0323
<i>Peristrophe bicalyculata</i> (Retz.) Nees	0.3226	2.50	0.8065
<i>Phoenix sylvestris</i> (L.) Roxb.	0.0323	2.00	0.0645
<i>Phragmites karka</i> (Retz.) Trin. Ex Steud.	0.0645	2.50	0.1613
<i>Phyllanthus fraternus</i> Webst.	0.1613	3.60	0.5806
<i>Physalis minima</i> L.	0.0323	3.00	0.0968
<i>Pithecellobium dulce</i> (Roxb.) Bth.	0.2258	1.43	0.3226
<i>Polyalthia longifolia</i> (Sonn.) Thw.	0.1290	1.75	0.2258
<i>Prosopis cineraria</i> (L.) Druce	0.4516	1.43	0.6452
<i>Prosopis juliflora</i> (Sw) DC.	0.8387	5.96	5.0000
<i>Pulicaria crispa</i> Sch.-Bip.	0.0968	2.67	0.2581
<i>Salvadora persica</i> L.	0.4194	1.85	0.7742
<i>Sesbania sesban</i> (L.) Meer. subsp.	0.0323	3.00	0.0968
<i>Sida cordata</i> (Burm. f.) Borss	0.0968	1.67	0.1613
<i>Solanum albicaule</i> Kotschy ex Dunal	0.1613	2.00	0.3226
<i>Solanum surattense</i> Burm. f.	0.2581	1.50	0.3871
<i>Sporobolus helvolus</i> (Trin.) Th. Dur.	0.0645	2.00	0.1290
<i>Stemodia viscosa</i> Roxb	0.0645	2.50	0.1613
<i>Sterculia foetida</i> L.	0.0323	1.00	0.0323
<i>Suaeda nudiflora</i> (Willd.) Moq.	0.3226	4.70	1.5161
<i>Syzygium cumini</i> (L.) Skells	0.0645	1.50	0.0968
<i>Tamarix aphylla</i> (L.) Karst.	0.1613	3.00	0.4839
<i>Taverniera cuneifolia</i> (Roth) Arn.	0.0968	2.00	0.1935
<i>Tectona grandis</i> L.f.	0.0645	2.00	0.1290

<i>Tephrosia purpurea</i> (L.) Pers.	0.0323	3.00	0.0968
<i>Terminalia catappa</i> L.	0.0645	1.00	0.0645
<i>Tribulus terrestris</i> L.	0.0323	3.00	0.0968
<i>Trichodesma indicum</i> (L.) R. Br.	0.0323	2.00	0.0645
<i>Tridaxprocumbensi</i> L.	0.1613	2.00	0.3226
<i>Triticum aestivum</i> L.	0.0323	10.00	0.3226
<i>Triumfetta rhomboidea</i> Jacq.	0.0323	1.00	0.0323
<i>Urochondra setulosa</i>	0.0323	1.00	0.0323
<i>Vernonia cinerea</i> (L.) Less.	0.3871	3.08	1.1935
<i>Xanthium strumarium</i> L.	0.0968	3.33	0.3226
<i>Zanthoxylum armatum</i>	0.0323	1.00	0.0323
<i>Zizyphus mauritiana</i> Lam.	0.0323	2.00	0.0645
<i>Zizyphus nummularia</i> (Burm. F.) W. & A.	0.5484	2.94	1.6129

Table 3.29: Diversity of plant species in the agricultural habitat

Taxa_S	142
Individuals	1603
Dominance_D	0.0310
Simpson_1-D	0.9690
Shannon_H	4.0680
Evenness_e^H/S	0.4116
Brillouin	3.9170
Menhinick	3.5470
Margalef	19.1100
Equitability_J	0.8209
Fisher_alpha	37.6100
Berger-Parker	0.0967
Chao-1	152.1

CHAPTER 4 PREDICTION OF THE CHANGES

4.1 Overall Scenario

The transition of the marine and estuarine regime of the Gulf of Khambhat into an absolutely fresh water regime of 2000 Km² will take some time, depending on the rate of impoundment, inflow of riverine floods and other factors. It is estimated that this time span could be about five years from the beginning of the project. The discharge of freshwater during monsoon to Gulf of Khambhat from various rivers and low salinity plumes during post-monsoon period which are generally observed (Rao *et al.*, 2009). This condition may be changed after the success of dyke and this will be an opportunity for changes in the overall ecosystem in that area. The overall ecosystem will be shifted from marine to estuarine and further to freshwater ecosystem in the dam area.

There will be alteration in the physico-chemical properties of the sediment as the diurnal tides will not be available to flush over excess salt in the mudflat area. Considering high rate of evaporation in the area there could be salt deposition in the fringe area of the Kalpasar dam. The area belongs to the Bhal area which is known for inherent soil salinity as this area was below the sea before the Saurashtra plate joined with the mainland. Over the years with good rainfall and drain out of surface water, the land properties will improve, but there is need to evaluate the quantum of rainfall and the volume of water that is allowed to move freely. The construction of roads and dams on the catchment area of the major rivers is likely to hamper the envisaged quantum of free flow of water into the system.

Basically a few Physico-Chemical changes such as decline in salinity level of water and nearby soil, increase in the quantity and quality of sediment, etc. are expected, which will play further role to ensure the changes in the ecosystem. The possible overall changes are presented in the schematic diagram. Present day salinity regimes of the marine environment ranges from 28 to 33 ppt and that of estuarine system varies from 22 – 27 ppt. In the post construction of dyke scenario, the tidal waters in the system will remain cut off from the sea and the reservoir will not receive any saline water. The fresh water flow from the rivers will continue to drain into the impoundment structures (Figure 4.1).

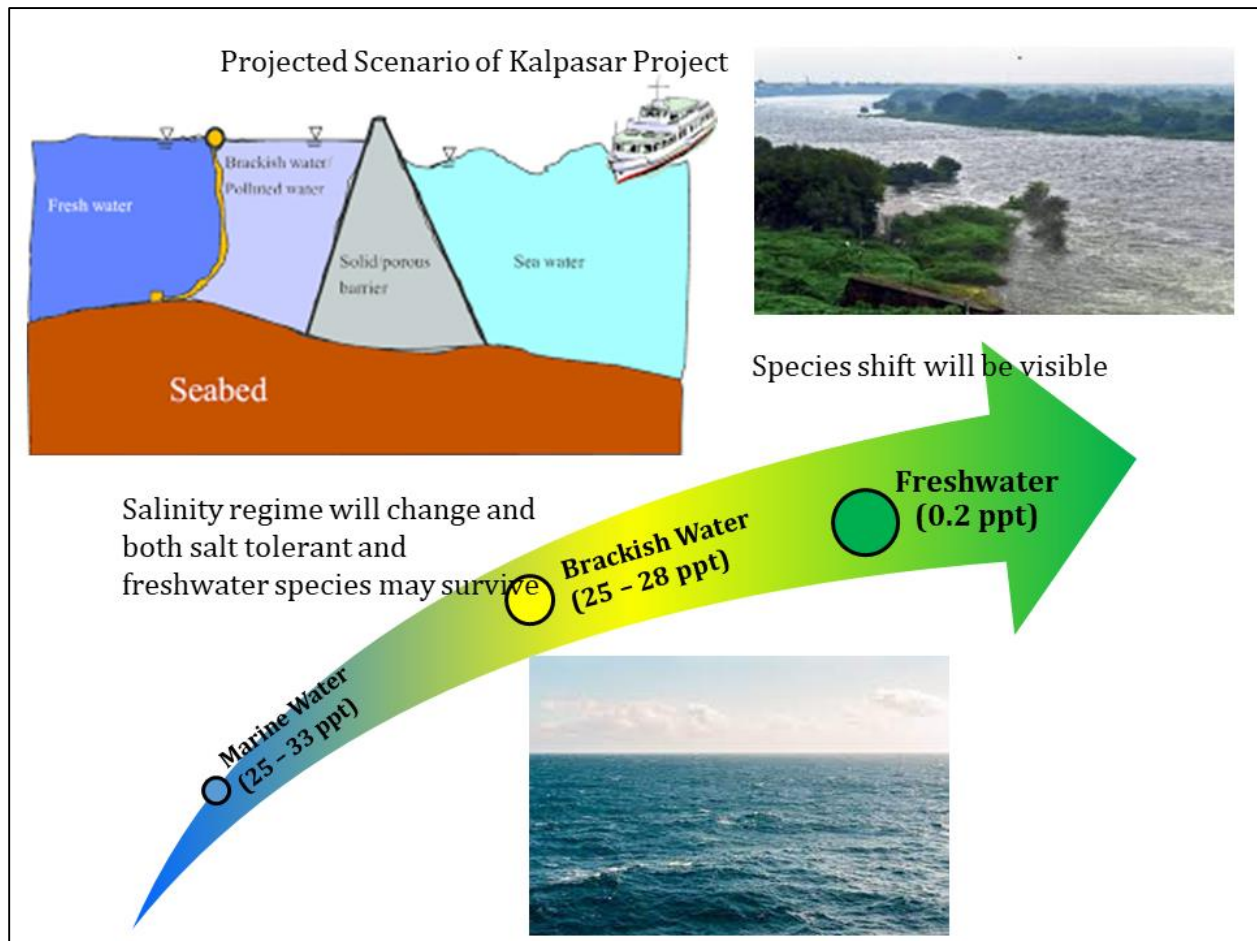


Figure 4.1: Schematic diagram showing the possible changes in the Kalpasar dam

The area has high rate of evaporation due to its geographic location and the concentration of salts within the system will enhance during the summer months. However, with the inflow of freshwater from the rivers and small creeks will push the saline water down and the surface water will remain sweet. This kind of mechanism is prevalent in the coastal wetlands of Gujarat. Under the changing salinity regime, it will be important to understand the change in the species composition for each of the trophic levels viz., primary producers (phytoplankton), secondary consumers (zooplankton and benthos) and tertiary consumers (fishes, avifauna). Apart from this, the landward vegetation characteristics will alter with the changing scenario especially the mangroves and coastal vegetation.

The chapter describes the possible changes in the species composition for each of the trophic levels in separate sections. For the purpose of prediction of the likely changes occurring as the system changes from marine to brackish to fresh water, the data on present distribution of species in the three habitat classes, viz. marine, brakish and freshwater was used and the species which will get vulnerable were identified. Statistical software's like Past (Version 3) and R was used for data analysis. Plot matrix was used to depict the changes in the species composition that would occur when the system changes from marine to fresh water. Simper analysis result was used to identify the species distribution change.

4.2 Phytoplankton

The plot matrix indicates that there are marine species exclusively found in the study area and these species will disappear from the system post Kalpasar reservoir (Figure 4.2). On the other hand, the fresh water and the estuarine phytoplankton species have some overlap which indicates that sharing of species in both the habitats.

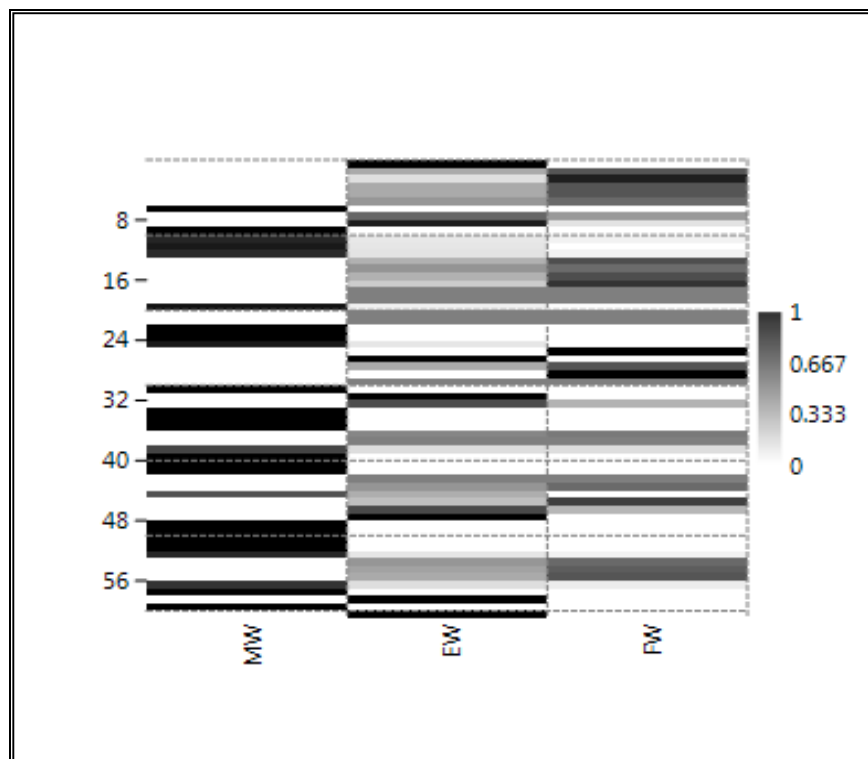


Figure 4.2: Plot matrix indicating the distribution of phytoplankton species in different habitats. Where MW denotes Marine water; EW- estuarine water; FW – Freshwater the

relative density of the species given in 0-1 scale and the species name is represented in numbers along the Y axis

List of species mentioned in plot matrix	Name of the species	List of species mentioned in plot matrix	Name of the species
1	<i>Actinastrum</i>	32	<i>Flagellaria</i>
2	<i>Anabaena</i>	33	<i>Grammatophora</i>
3	<i>Anacystis</i>	34	<i>Lauderia</i>
4	<i>Ankistrodesmus</i>	35	<i>Leptocylindricus</i>
5	<i>Aphanizomenon</i>	36	<i>Melosira</i>
6	<i>Aphanocapsa</i>	37	<i>Microcystis</i>
7	<i>Amphora</i>	38	<i>Microspor</i>
8	<i>Amphiprora</i>	39	<i>Navicula</i>
9	<i>Astrionella</i>	40	<i>Nitzschia</i>
10	<i>Bacillaria</i>	41	<i>Noctiluca</i>
11	<i>Biddulphia</i>	42	<i>Odontella</i>
12	<i>Ceratium</i>	43	<i>Oscillatoria</i>
13	<i>Cheatoceros</i>	44	<i>Pediastrum</i>
14	<i>Chlamydomonas</i>	45	<i>Peridinium</i>
15	<i>Chlorella s</i>	46	<i>Phacus</i>
16	<i>Chroococcus</i>	47	<i>Phormidium</i>
17	<i>Closterium</i>	48	<i>Prorocentrum</i>
18	<i>Coelestrum</i>	49	<i>Phaeocystis</i>
19	<i>Coelosphaerium</i>	50	<i>Planktoniella</i>
20	<i>Coscinodiscus</i>	51	<i>Pleurosigma</i>
21	<i>Cosmerium</i>	52	<i>Pseudonitzschia</i>
22	<i>Cylindrotheca</i>	53	<i>Rhizosolenia</i>
23	<i>Cyclotella</i>	54	<i>Scenedesmus</i>
24	<i>Dictylum</i>	55	<i>Spirogyra</i>
25	<i>Dinophysis</i>	56	<i>Spirulina</i>
26	<i>Diatoma</i>	57	<i>Synedra</i>
27	<i>Dichyocha</i>	58	<i>Triceratium</i>
28	<i>Eudorina sp</i>	59	<i>Thalassiosira</i>
29	<i>Euglena</i>	60	<i>Trichodesmium</i>
30	<i>Eustrum</i>	61	<i>Ulothrix</i>
31	<i>Eucampia</i>		

The dissimilarity analysis through SIMPER of phytoplankton showed an overall dissimilarity of 57.33% among the 62 species between the three habitats. The phytoplankton species such as *Melosira*, *Pleurosigma*, *Dictylum*, *Noctiluca*, and *Dinophysis*

will totally be wiped out when the ecosystem shift from Marine to fresh water ecosystem. In Mahisagar, the average dissimilarity from marine system was 52.28%, where the top species contribute highest dissimilarity was *Trichodesmium* (26.17%) and *Coscinodiscus* (22.16%). In Dhadhar river, the average dissimilarity from marine system was (48.15%) and the top contributing to species dissimilarity was *Microcystis* (27.2%) and *Coscinodiscus* (14.76%) (Annexure 1). In the estuarine zone, the average dissimilarity from marine ecosystem was (73.94%) where top contributing to species dissimilarity belongs to *Synedra* (4.28%) & *Coscinodiscus* (4.24%). Similarly, in fresh water ecosystem average dissimilarity from marine system was 100%.

Some of the marine species which are likely to disappear include *Amphora*, *Bacillaria*, *Biddulphia*, *Ceratium*, *Cyclotella*, *Dictylum*, *Lauderia*, *Eucampia*, *Leptocylindricus*, *Odontella*, *Planktoniella*, *Pleurosigma*, *Triceratium*. These species generally belong to the Bacillariophyceae members and play an important role in the food chain of the marine species (Figure 4.3). *Chlorella*, *Chlamydomonas*, *Cheatoceros*, *Coscinodiscus*, *Grammatophora*, *Navicula*, *Pediastrum*, *Peridinium*, *Rhizosolenia*, *Synedra*, *Ulothrix* are the opportunistic species and will proliferate in the enclosure system as part of the brackish waste system.

Fresh water species like *Anabaena*, *Aphanocapsa*, *Chlamydomonas*, *Eudorina sp*, *Spirogyra*, *Spirulina*, *Scenedesmus*, *Microcystis* will dominate the areas wherever there is presence of fresh water. Generally, these species are filamentous and tend to form scum on the water surface and are responsible for algal bloom resultant of high nutrient load. The treated and untreated waste from the city areas will promote the growth of these species.

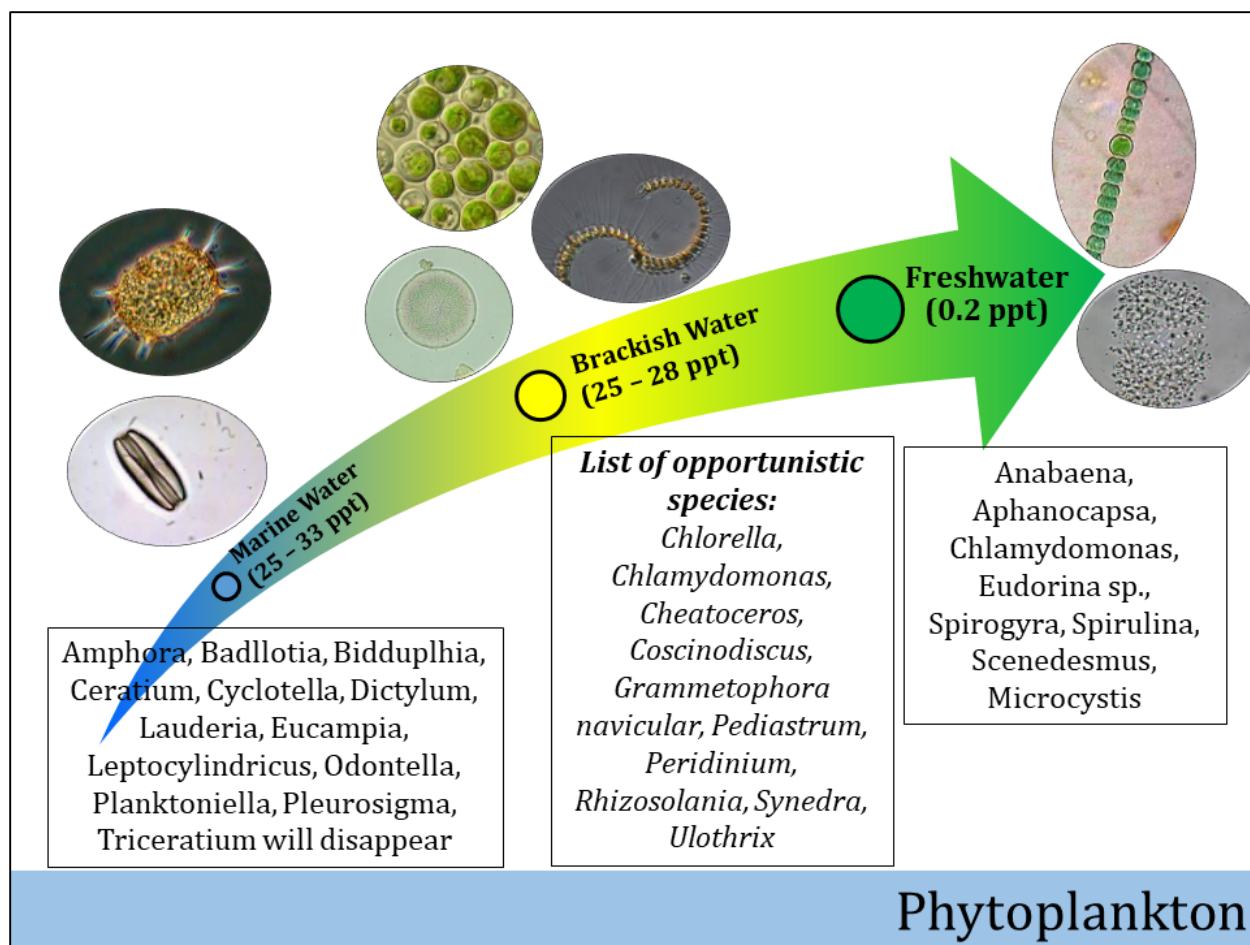


Figure 4.3: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for phytoplankton.

4.3 Zooplankton

The Simper analysis of Zooplankton community showed the overall dissimilarity of 63.74%. The zooplankton group such as *Paracalanus*, *Lucifer*, *Eucalanus*, *Euphausia*, *Labidocera*, *Tornaria* larvae will totally wiped out when the ecosystem shift from Marine to fresh water ecosystem (Figure 4.4). In between Mahisagar and Sabarmati the average dissimilarity was 63.39%, where the top group contribute highest dissimilarity was *Nauplius* larvae (15.96%) and *Calanopia* (10.09%). In between Dhadar River and marine system the average dissimilarity was 62.13% and the top contributing species for the dissimilarity was *Nauplius* larvae (16.02%) and *Calanopia* (10.37%). In between the estuarine zone and marine zone, the average dissimilarity was (85.9%) where top contributing to group imparting the dissimilarity belongs to *Nauplius* larvae (11.69%) and

Calanopia (7.32%). Similarly in between the fresh water and marine ecosystem average dissimilarity was 87.36% and top contributing species imparting dissimilarity belongs to same group *Nauplius* larvae (11.64%) and *Calanopia* (7.25%) (Annexure 2).

In the initial phase as the system turns brackish *Nauplius* larvae and *Calanopia* will proliferate. Further, *Nauplius* larvae and *Calanopia* these species will dominate the fresh water systems as well. *Nauplius* larvae is the larval stage of arthropods and play an important role in food chain. It feeds on phytoplankton and forms food for fishes, birds and marine mammals. The proliferation of this species will be food for the higher food web species. *Calanopia* represents copepods which is indicator of pollution and eutrophic conditions.

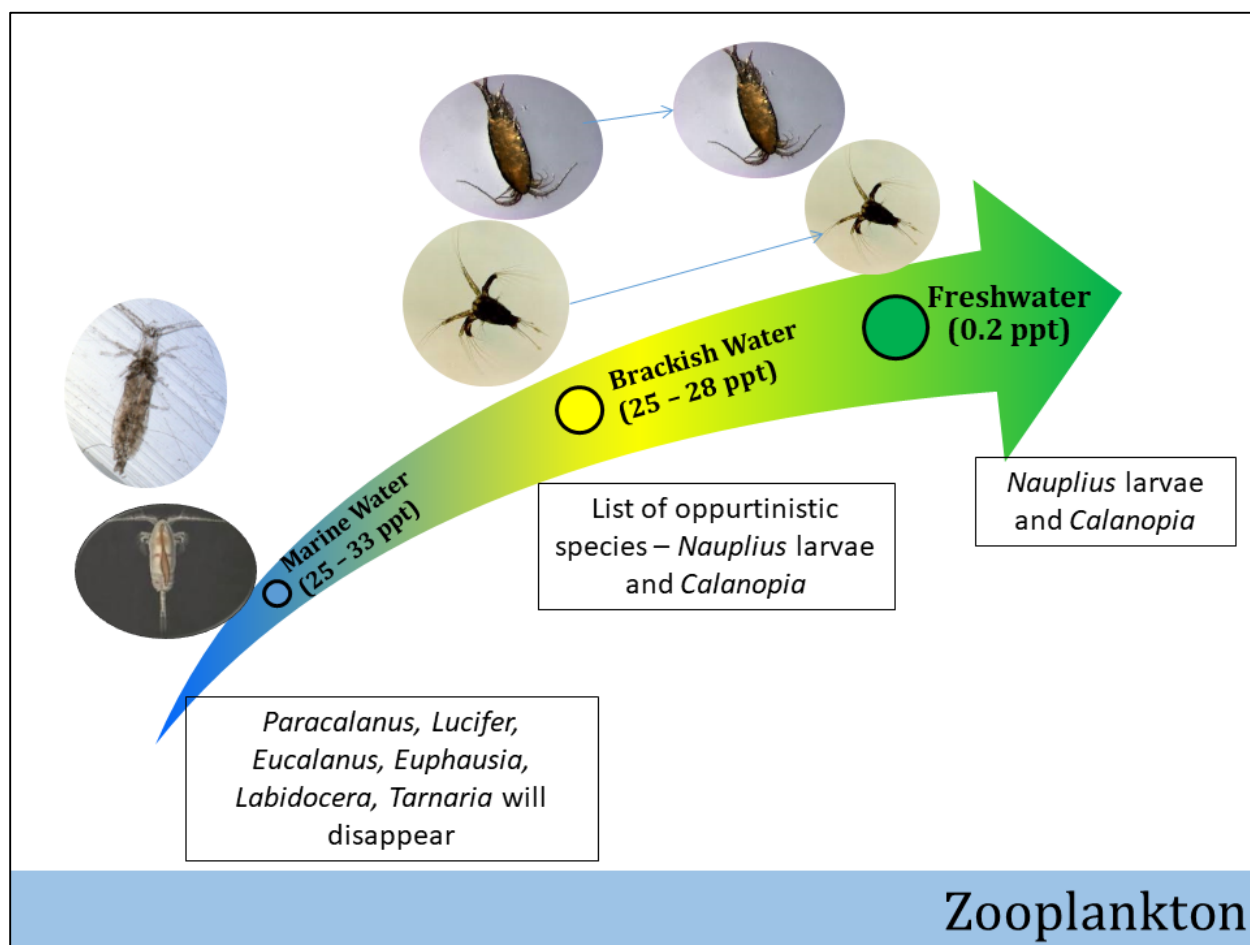


Figure 4.4: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for zooplankton

Study by Park and Huh (1997) reported a predominance of *Sinocalanus tenellus* during the operation of the Shihwa Lake and after the construction of the dyke brackish water copepods dominated the enclosure. Likewise, in the Kalpsar dam the opportunistic species like *Nauplius* larvae and *Calanopia* will proliferate and dominate the enclosure.

4.4 Benthos

The benthic fauna is integral component in the aquatic ecosystem towards the ecosystem homeostasis is concerned. The expected changes in the physical and chemical status of the water affect the benthic life even though the species have high tolerance through physiological adaptations.

Flow regulation circumvents floods, which are important physical and biological structuring mechanisms in riverine systems by transporting large amounts of sediment through the estuary, providing physical energy for circulation, and promoting biological production. With the increase in downstream sediment transportation estuarine production may increase but the siltation rate increases leading to shift in the benthic population and the more tolerant fresh water species replace the marine counterparts. Thus, there is a greater diversity of insect larvae and gastropods and oligochaetes which are indicators of environmental stress.

Based on the present species distribution in the three major habitats viz., freshwater estuarine and marine, indicate distant relation between the three habitat (Figure 4.5). The species occurrence in the fresh water is different from the other two habitats.

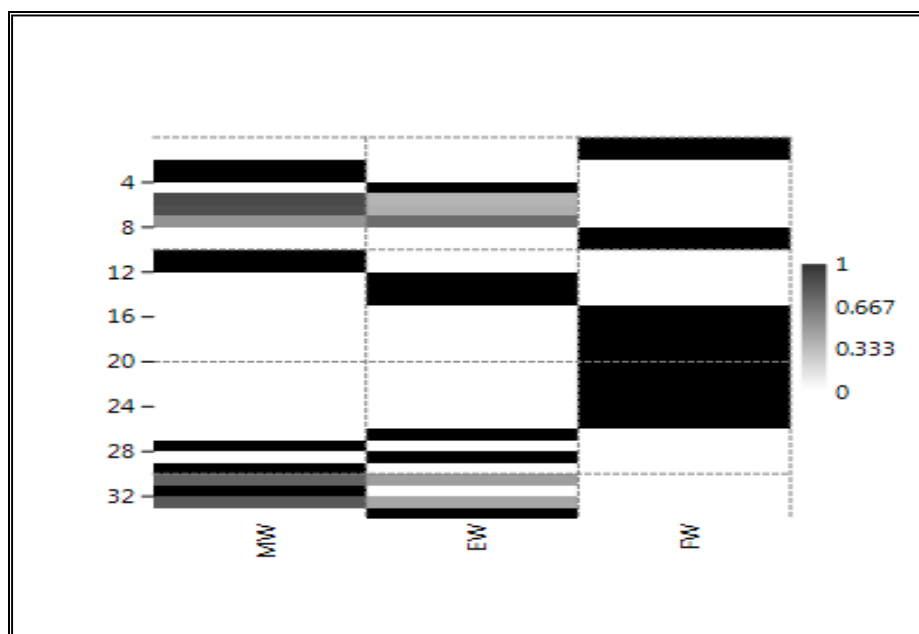


Figure 4.5: Plot matrix indicating the distribution of benthos species in different habitats. Where MW denotes Marine water; EW- estuarine water; FW - Freshwater

Species list mentioned in the plot matrix S. No	Species	S. No	Species	S. No	Species
1	<i>Corvospongilla lapidosa</i>	13	Amphipod 3	24	<i>Stenothyra blanfordiana</i>
2	<i>Corvospongilla ultima</i>	14	Dotilla sp	25	<i>Corbicula peninsularis</i>
3	Nematoda sp1	15	Crustacean larvae	26	<i>Radiatula sp.</i>
4	Nematoda sp2	16	<i>Rochebrunia sp.</i>	27	<i>Donax sp</i>
5	Nematoda sp3	17	<i>Tarebia granifera</i>	28	<i>Tellina macassariensis</i>
6	<i>Neries sp1</i>	18	<i>Filopaludina bengalensis</i>	29	<i>Tellina sp</i>
7	<i>Neries sp2</i>	19	<i>Gyraulus convexiusculus</i>	30	<i>Gafrarium pectinatum</i>
8	<i>Neries sp3</i>	20	<i>Gyraulus sp.</i>	31	<i>Glaucanome angulata</i>
9	<i>Namalycastis sp.</i>	21	<i>Planorbis sp.</i>	32	<i>Glaucanome cerea</i>
10	<i>Nais sp.</i>	22	<i>Radix sp.</i>	33	<i>Laternula anatina</i>
11	Amphipod 1	23	<i>Digoniostoma sp.</i>	34	<i>Indosphenia sp</i>
12	Amphipod 2				

There are 12 species present in the estuarine water out of which five are overlapping with the marine habitat viz., 3 species of genus *Neries*, *Glaucanome angulata* and *Laternula anatine*. In the initial years when the system will be more of marine characteristics these

species will be dominating found in the salinity regimes varying from 22 to 28 ppt (Figure 4.6). The other species present purely in the estuarine water will also proliferate on finding of congenial environment. These species include Nematoda, Amphipod, *Dotilla* sp, *Donax* sp, *Tellina* sp, and *Indosphenia* sp (Bivalave).

In the freshwater system there are 15 species reported and these are exclusive for the habitat of fresh water with low salinity below 1 ppt. These species may not tolerate the high salinity of the estuarine and marine environments.

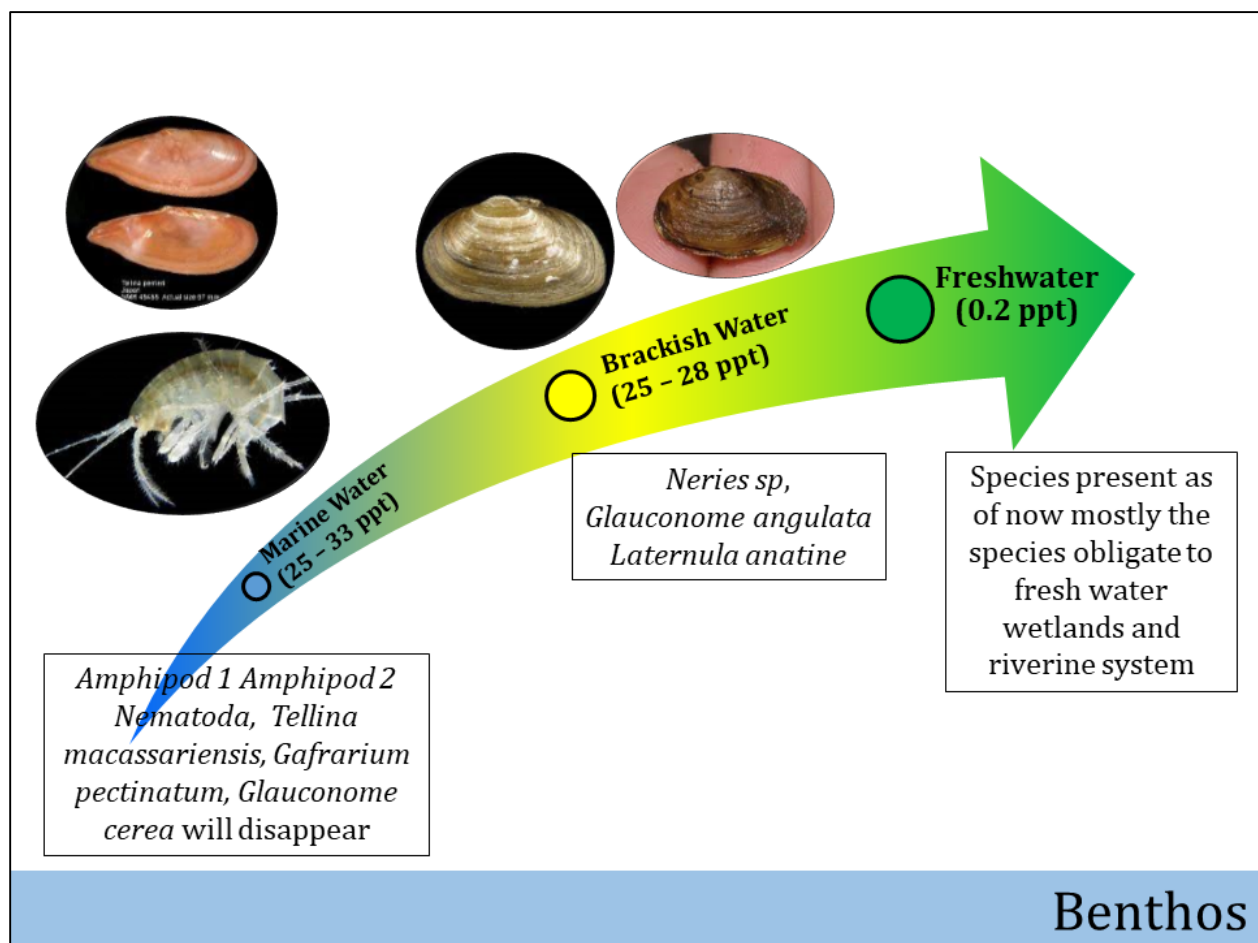


Figure 4.6: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for benthos

4.5 Other Invertebrates

Lower invertebrates include the species representing sponges, worms, shelled animals and others. In the proposed Kalpasar dam the marine species belonging to arthropod (9) and mollusks (19) species will be lost including the octopus. When the system is brackish in nature the species under Cnidaria (*Diadumene lineate*; *Stephenson actisornata*), Annelids- (*Neries 3 spp*), Ribbon worms (*Cerebratulus sp.*) Arthropod (9 species.), Molluscs (15 species) will be benefitted. Fresh water species will thrive including species like *Namalycastis*, *Oosthuizobdella sp*, some Annelid species; *Macrobrachium rosenbergii* and about 9 species of Mollusks (Figure 4.7).

Macrobrachium rosenbergii, giant fresh water prawn has high commercial value and will occupy new areas with fresh water availability.

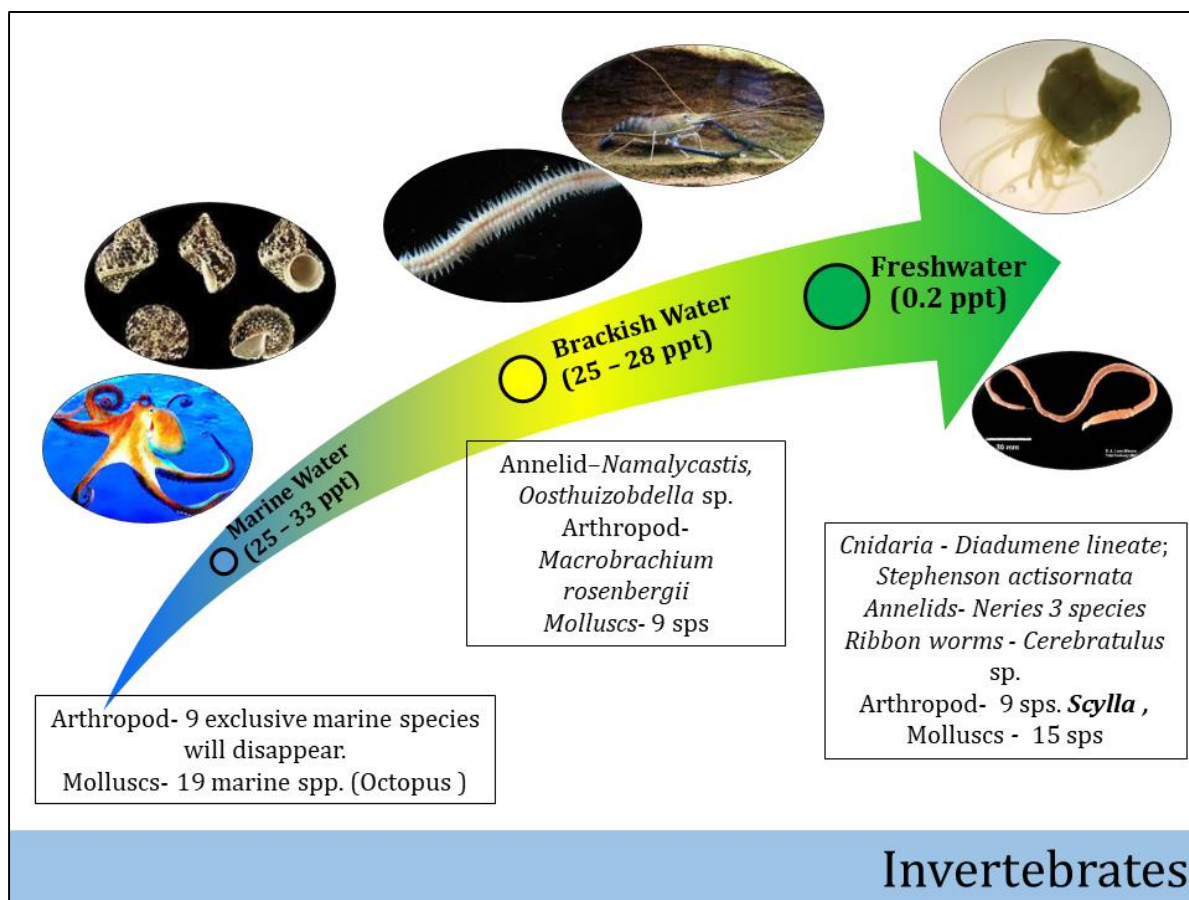


Figure 4.7: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for cnidarian, arthropod, annelid and mollusks group.

A similar study was undertaken for the community changes of benthic fauna before and after dike construction in Lake Shihwa in South Korea (lee *et al.*, 2014). The study reported that due to formation of an anoxic layer associated with the increased influx of the organic matter after the completion of the dike, particularly at water depths of less than 6 m was observed. This resulted in presence of opportunistic species, such as *Pseudopolydora kemp* Southern, 1921 and *Polydora cornuta* Bosc, 1802 communities near the dike. The predominant animals were nematodes, followed by sarcomastigophorans, crustacean nauplii, benthic harpacticoid copepods, and polychaetes. The ratio of nematodes to benthic harpacticoids (N/C) was lower around the dyke and higher in the inner area of the lake. This observation indicates that the inner areas of the lake became unsuitable habitats for meiobenthos due to major pollution levels, with similar results being obtained for the macrobenthos. Similar conditions are likely to take place in the present proposed Kalpasar dam.

4.6 Fishes

The migratory fishes which form a constituent of the estuarine catch such as eels, Hilsa and mullets, Chanos, Megalops and other species will tend to adapt to towards the lower limits of the reservoir where salinity is optimum and the preferred food is available however, their recruitment may not be successful.

In case of fishes there are about 22 marine fishes as reported in the primary survey that will disappear. Species like *Boleophthalmus dussumieri*, *Scylla olivacea*, *Scylla serrata* found dominantly in the estuarine system will get benefitted when the system turns brackish. Apart from these there are total of 16 species reported from the estuarine system that will proliferate in the brackish water system. Presently there are 19 species are reported in the fresh water system and species like *Puntius sophor* and *Salmostoma bacaila* will dominate (Figure 4.8).

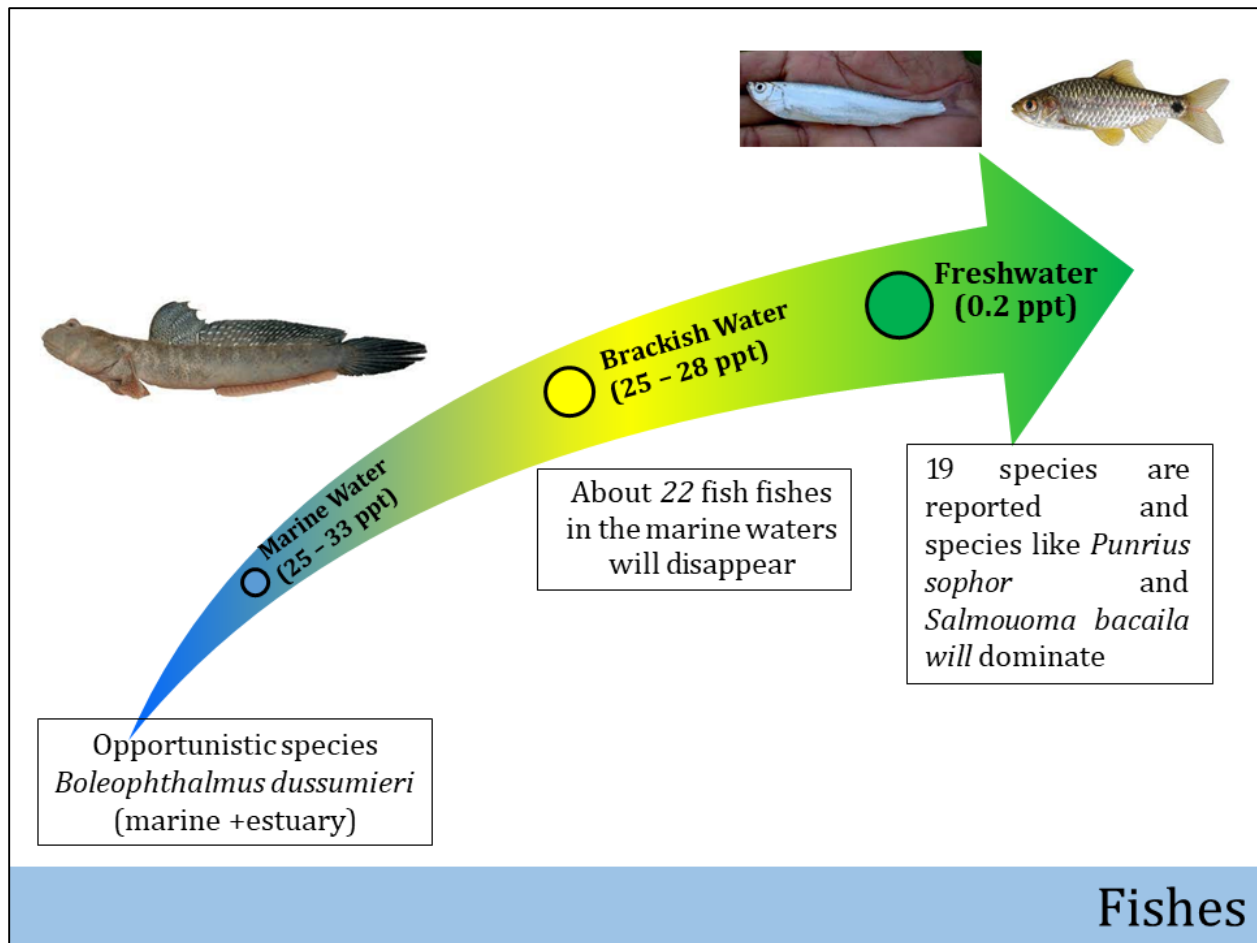


Figure 4.8: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for fishes

4.7 Reptiles

Mugger (*Crocodylus palustris*), reported in the fresh water wetlands of Anand and Vadodara district and in the Dhadhar estuary will proliferate and expand its territory post closure of proposed Kalpasar dam. Mugger is most adaptive species and during the breeding season it will invade into new areas in the fringes of the proposed Kalpasar dam. The soft mud available and absence of tidal currents will assist the species to proliferate into new areas. The population will be benefited from the increase in food availability through the increase in the bird population predicted. A win-win situation for the species to glorify. The expansion of the crocodile territory could be a threat to the coastal communities and

fisheries that is being proposed. This could also lead to human wildlife conflict though problem of depredation on the livestock by the Crocodiles.

It is envisaged that the terrestrial snake population will increase particularly in the thorn forest and scrubland habitats. This could rise to increase in rate of snake bites for the residents close to the coast. This issues needs to be tackled carefully as the negative attitude will lead to killing of snakes and lot of awareness has to be generated among the local people on the ecological significance of snakes.

4.8 Avifauna

SIMPER analysis was performed to understand the dissimilarity between the various habitats and the results are presented herewith. The overall dissimilarity between the Coastal and Freshwater habitat was 68.57%. the bird species contributing for most (50%) of the dissimilarities within the two communities were Eurasian Coot, Greater Flamingo, Barn Swallow, Graylag Goose, Wurasian Wigeon, Cattle Egret, Ruddy Shelduck, Bar headed Goose, Northern Shoveler, and Common Pochard (Annexure 3).

The overall dissimilarities between the bird communities of agricultural and Coastal habitats were 60.86%. The bird species contributing the dissimilarities between the two communities were Barn swallow, Cattle Egret, Black headed Ibis, Painted Stork, Wire-tailed Swallow, House Sparrow, Greater Flamingo, Paddy field Pipit, and Common Babbler.

The bird species influencing the differences in the community structure of Agriculture and Freshwater habitat were Eurasian Coot, Greater Flamingo, Graylag Goose, Eurasian Wigeon, Bar Headed Goose, and Northern Shoveler.

The bird species contributing for the differences in the communities between Agriculture and scrubland habitat were Cattle egret, Black headed Ibis, House Sparrow, Red Avadavat, Indian Pond Heron, White Eared Bulbul, Black Winged Stilt, Rosy Starling, Wire-tailed Swallow, Paddyfield Pipit, Plain Prinia, and Red Rumped Swallow.

Overall Dissimilarity between Coastal and Freshwater habitats was 83.42%. The bird species contributing for the dissimilarities between the Coastal and Freshwater habitats were Eurasian Coot, Greater Flamingo, Graylag Goose, Eurasian Wigeon, Barn Swallow, Bar Headed Goose and Northern Shoveler.

Overall Dissimilarity of Bird community between the Coastal and Scrubland habitat was 55.65%. The species which are contributing for the dissimilarities includes Barn Swallow, Painted Stork, Greater Flamingo, Red vented Bulbul, Cattle Egret, Wire tailed Swallow, Plain Prinia, Red Avadavat, Lesser Sandplover, Great Egret, Red Rumped Swallow, Baya Weaver, and Little Cormorant.

Overall Dissimilarity of bird communities of Freshwater and Scrubland habitat was 84.63%. The bird species contributing for the overall dissimilarities between the Freshwater and Scrubland habitat include Eurasian Coot, Greater Flamingo, Graylag Goose, Eurasian Wigeon, Bar Headed Goose, and Northern Shoveler.

The schematic diagram (Figure 4.9) showing the alteration in the species as the system changes from coastal habitat to brackish water. The species are Lesser Sand plover, Black Tailed Godwit, Gull billed Tern, Western Reef Heron, Pallas's Gull Dunlin likely to disappear. The species in the fresh water wetland and the coastal water wetlands will be benefitted and include Gull billed Tern Western Reef Heron, Barn Swallow, Painted Stork, Lesser Sand plover, Eurasian Coot, Greater Flamingo, Gray lag Goose, Eurasian Wigeon, Barn Swallow, Bar Headed Goose and Northern Shoveler. The list includes both resident and distant migrant.

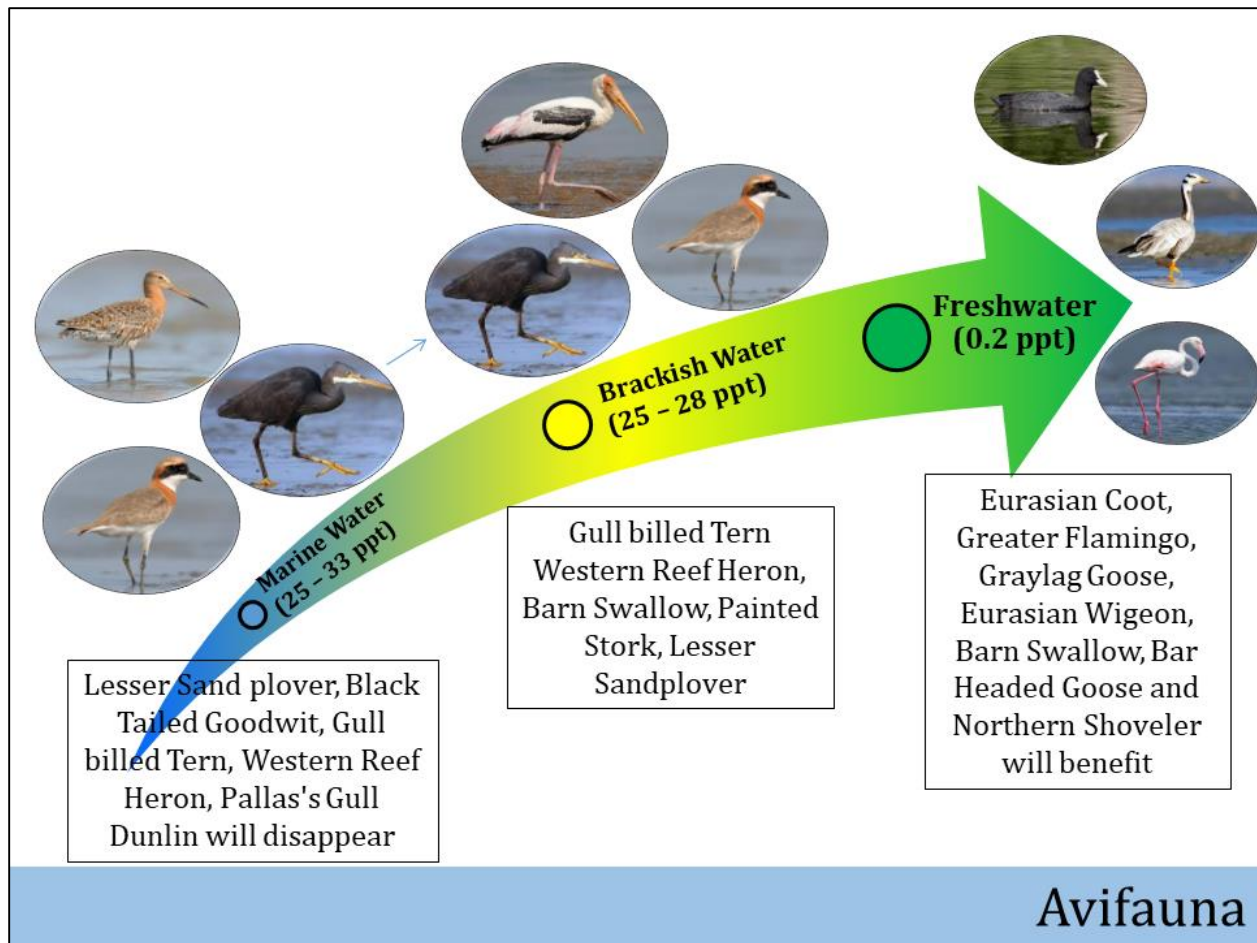


Figure 4.9: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for avifaunal diversity

Apart from the above species composition alterations there were few other positive and negative impacts on avifauna. With the change in the vegetation structure and land use pattern of the terrestrial system the food availability will increase for raptors and crows along the roads though road kills. Open space generated in virtue of land exposed will benefit species like Shrikes and Robins. Marginal habitats created along roadsides will offer perch structures, feeding habitat and nesting structures and will benefit agricultural & farmland birds. The altered habitat can provide roosting place to gregarious species like cormorants and terns.

4.9 Mammals

The only marine mammal present is *Sousa plumbea*, the Indian Ocean humpback dolphin which is sighted in both the estuarine and marine waters. The dolphin generally prefers open seas but sometime sighted near shore in search of food. The species might proliferate in the changed scenario with the availability of fish, but in the initial phase the population might decline as the species composition changes from marine to brackish water. Perhaps it needs to be reintroduced once the fish population is established in the area.

When the system turns brackish and vegetation will establish in the fringes of the enclosure then the species like Nilgai and Golden jackal will increase their territory range and occupy maximum areas. Reappearance of species like Indian gazelle (Chinkara), Indian Fox and Striped Hyena seems to be prospective in the context of biodiversity. The increase in the population of Nilgai will pose threat to the agriculture as it is known for crop degradation, leading to possible human wildlife conflict.

There will establishment of *Prosopis juliflora* as explained in the vegetation section and this will boost the habitat requirement of golden jackal and wolf might also re-establish in the area (Figure 4.10). The Indian wolf (*Canis lupus pallipes*) is widely distributed in India, but is listed as data deficient in Gujarat. And the species is preferred to inhabit thorn forests, scrub-lands, arid and semi-arid grassland habitats. In the study area the species is reported from western part viz., Bhavnagar district. With the change in the land use pattern (vegetation coming up in the new exposed mudflats) there is possibility of increase in the population of the wolf. There will be need to formalize management strategies and assist in formulating a landscape-level wolf conservation strategy.

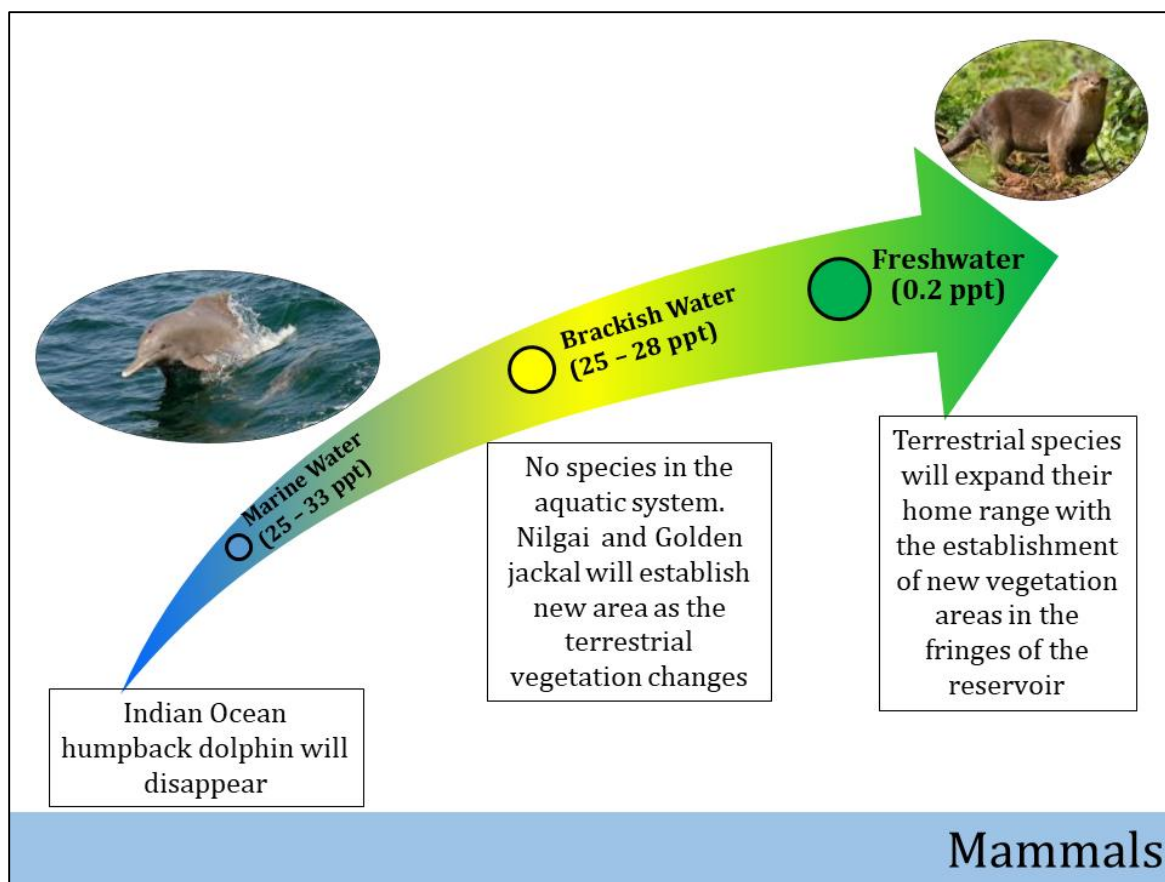


Figure 4.10: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for mammals

4.10. Threatened species and species which will get affected (higher vertebrates)

A total of 27 species were listed in schedule I and Schedule II (Part I and II) as per the Indian Wildlife (Protection) Act, 1972 (IWPA hereafter) and also enlisted in different threat category according to IUCN red list of threatened species. Mugger (*Crocodylus palustris*), Black winged kite (*Elanus caeruleus*), Eurasian March Harrier (*Circus aeruginosus*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), Indian Peafowl (*Pavo cristatus*) are among the 11 species that are under Schedule I of IWPA 1972 (Table 1). Three mammal species, the Jungle cat (*Felis chaus*), Indian Golden Jackal (*Canis aureus*) and Indian Gray Langur (*Semnopithecus entellus*) are enlisted in Schedule II (Part I and Part II). The Indian Ocean Humpback Dolphin (*Sousa plumbea*) was the only endangered species found during the

survey. Along with that seven vulnerable species including the Mugger, Eight Near Threatened and 11 Least Concerned species (Schedule I in IWPA) was also listed (Table 1)

The list of facultative and obligatory species pertaining to higher animal groups, i.e., reptiles, birds, and mammals, was prepared considering SIMPER analysis results and species ecological requirements. Facultative species can adapt with environmental variation and thus thrive in different habitats with varied environmental and physiognomic parameters. while obligatory species used to confine themselves within some particular habitat with a limited environmental and physiognomic variation. About fourteen highly ecologically important species were found to be significantly (positive and negative) affected resulting from phase-wise habitat transformation following the Kalpasar dam establishment. Among these species, three species, namely Black-headed Ibis (*Threskiornis melancephalus*), Painted Stork (*Mycteria leucocephala*), and Greater Flamingo (*Phoenicopterus roseus*) were facultative species (found in all the three habitats) while the rest were obligatory. Among obligatory species, seven species, viz., Mugger (*Crocodylus palustris*), Bar-headed Goose (*Anser indicus*), Northern Shoveler (*Anas clypeata*), Common Pochard (*Aythya ferina*), Graylag Goose (*Anser anser*), Eurasian Coot (*Fulica atra*), and Eurasian Wigeon (*Mareca penelope*) are exclusively found in freshwater habitats. The two Bird species, Little Cormorant (*Microcarbo niger*) and Ruddy Shelduck (*Tadorna ferruginea*) were obligatory for brackish and freshwater habitats whereas, the Indian Humpback Dolphin (*Sousa plumbea*) and Lesser Sand Plover (*Charadrius mongolus*) were obligatory for the marine and brackish water habitats (Table 2). The facultative species will thrive after the expected shift of the salinity regime but the obligatory marine and brackish water species will be shifted to new areas due to the salinity shift.

Table 2: The List of Obligatory and Facultative species imparting dissimilarities in the Community

Species Name	Scientific Name	Facultative /Obligatory	Marine	Brakish	Fresh
Mugger	<i>Crocodylus palustris</i>	Obligatory	-	-	+
Indian Ocean humpback dolphin	<i>Sousa plumbea</i>	Obligatory	+	+	-
Eurasian Coot	<i>Fulica atra</i>	Obligatory	-	-	+
Greater Flamingo	<i>Phoenicopterus roseus</i>	Facultative	+	+	+
Graylag Goose	<i>Anser anser</i>	Obligatory	-	-	+
Eurasian Wigeon	<i>Mareca penelope</i>	Obligatory	-	-	+
Ruddy Shelduck	<i>Tadorna ferruginea</i>	Obligatory	-	+	+
Bar-headed Goose	<i>Anser indicus</i>	Obligatory	-	-	+
Northern Shoveler	<i>Anas clypeata</i>	Obligatory	-	-	+
Common Pochard	<i>Aythya ferina</i>	Obligatory	-	-	+
Black-headed Ibis	<i>Threskiornis melancephalus</i>	Facultative	+	+	+
Painted Stork	<i>Mycteria leucocephala</i>	Facultative	+	+	+
Little Cormorant	<i>Microcarbo niger</i>	Obligatory	-	+	+
Lesser Sand Plover	<i>Charadrius mongolus</i>	Obligatory	+	+	-

4.11 Mangrove Ecosystem

There is need to understand the past mangrove cover in the area to bring out the relation between the present mangrove status before predicting what the future conditions would be in the Kalpsar dam.

There are three types of mangrove ecosystems such as deltaic mangrove ecosystem, coastal mangrove ecosystem and island mangrove ecosystem. Deltaic mangroves ecosystems are located along the mouth of estuaries where they get frequent freshwater supply. The coastal mangrove ecosystems are generally found in minor river mouths, creeks, intertidal areas etc which counts more in the Gujarat (Ingole, 2005). Mangroves in the Gulf of Khambhat have evolved for salt tolerance but their capacity to tolerate the salinity level can

be vary species to species (Singh et al., 2012). There are three types of mangroves as per salt tolerance mechanisms (Parida and Jha, 2019), which are (1) Salt excluders which eliminate excess salt by ultra-filtration eg., species of *Rhizophora*, *Ceriops*, *Bruguiera* (Wang et al., 2002), (2) Salt secretors which secrete the excess salt through foliar glands and regulate the internal salt level. eg., species of *Acanthus*, *Avicennia*, *Aegiceras*, and *Aegialitis* (Selvam, 2003). (3) Salt accumulators which accumulate salts at higher concentrations in their cells (Aziz and Khan, 2001). eg., species of *Lumnitzera* and *Excoecaria*.

In Gulf of Khambhat, the species of Avicenniaceae which are salt secretors are found dominant. Off-course *A. marina* is dominant throughout Gujarat and may be tolerance to various disturbances such as hydrological changes, oil spills and impacts of climate change (Devi and Pathak, 2016). As *A. marina* shows higher tolerance to salinity, it also showed stunted growth in absence of freshwater available in that area.

The compensation of the loss of total mangrove area due to the project will need at least a few times mangrove plantation in the nearby coastal areas as per the governmental norms. Already mangrove in the Gulf of Khambhat is comparatively very less compare to the mangrove present in the Gulf of Kachchh. The possible reason behind that is natural as well as anthropogenic pressures such as developmental activities, use of mangrove as feed, etc. The species of mangroves will probably disappear as the salinity regimes will change (Figure 4.11). Availability of freshwater input to the proposed dam area will provide the opportunity to other mangrove species which have less salt tolerance to grow and dominance of monotonous species (*A. marina*) will be finished in the Gulf of Khambhat. This will be opportunity to various mesophytes and halophytes too to grow in the area as they are tolerant to various salinity levels. As the salinity tolerance mechanism of mangroves is dependent on the morphological, anatomical, physiological and biochemical adaptations of mangrove species, they will show simultaneous changes in their availability in the project area. Probably, *A. marina* will be replaced by other low salt tolerance mangrove species. In worst case it may possible that all mangrove in the project area (upstream area) will be disappeared due to fresh water influx. We estimated that the mangrove of approximately 36 km² area will be vulnerable and expected to be abolished in upstream of this project. Along with this, 10.68 km² mangrove area in the downstream will also be affected during the construction and

operational phase. Already total South Gujarat including Gulf of Khambhat accounts for approximately 12 % of the total mangrove cover of Gujarat. On this background the affected mangrove area is quite high.

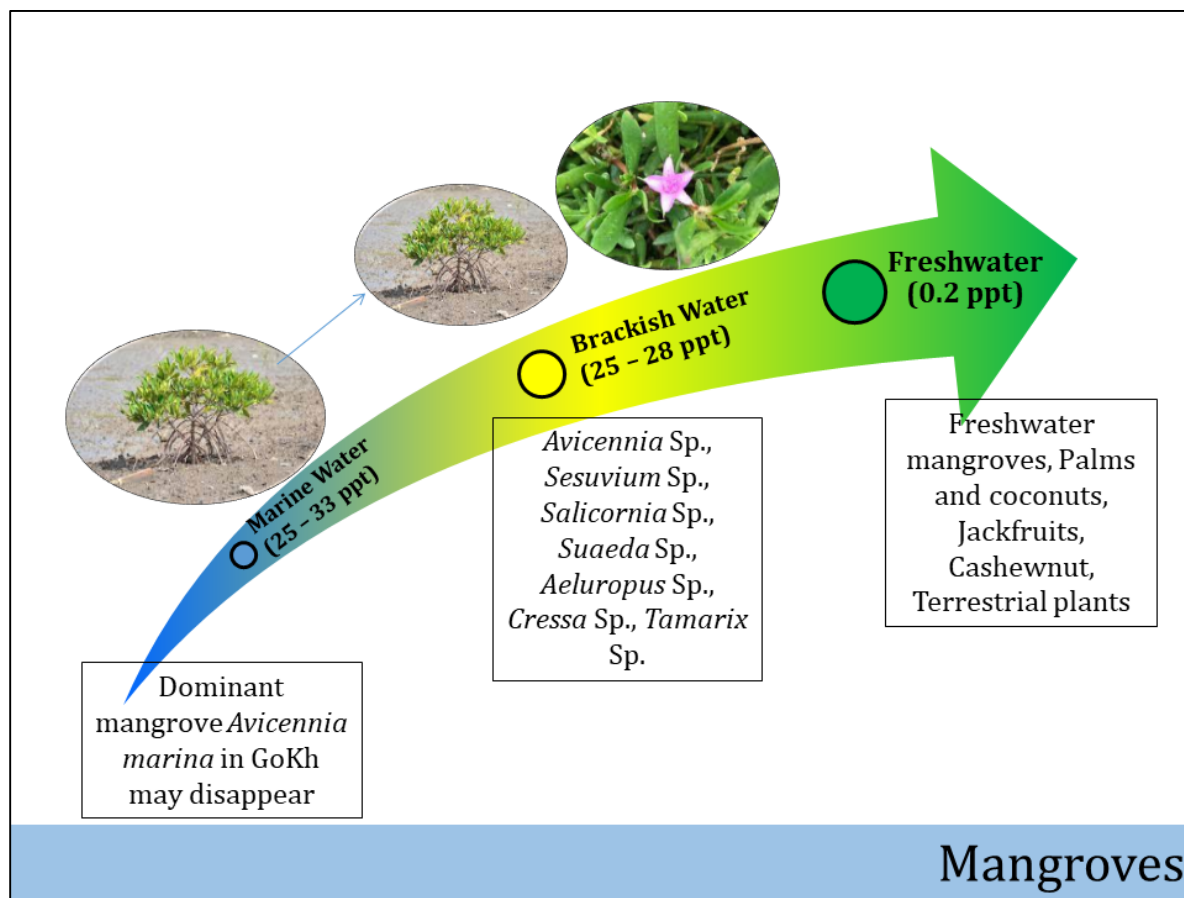


Figure 4.11: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for mangrove ecosystem

The downside of the reservoir area will be a marine ecosystem area and will increase as the water expanse will inundate new areas. This can increase the temporary change in the sea level. This rising sea level can create an opportunity for mangroves currently present in the local ecosystem to grow in a wide area. Although mangroves are known as sensitive to the changes in inundation and its frequency due to the increase in salinity, the *A. marina* species present in that area is the most salinity tolerant species. However, it may possible that mangrove species will be shifted to more saline tolerant species in case of flooding.

The mangrove ecosystem will serve and support nearby areas by promoting sediment trapping. It will slow water flow speed through their aerial roots and which can result in the deposition of sediments (Furukawa and Wolanski 1996). However, accumulation of anthropogenic and natural waste in the nearby area may be possible, such as litter, nets, debris, free-floating seaweed, etc.

Kalpasar dam may increase sedimentation in the area of reservoirs with higher in freshwater. It is envisaged that conversion of marine ecosystem to estuarine ecosystem, and the biodiversity of mangrove species will be increased in the project area, with increase other mesophytic plants. If the different patches were farmed in this area then wetland ecosystem will be appears in various places. The ecological succession of wetland ecosystem will be taken place to terrestrial ecosystem in which various terrestrial plants such as neem, babul will be seen around the area. The ground water channels in the nearby area can also impacts on these ecosystems and can keep continue the presence of marine or estuarine ecosystem.

4.12 Terrestrial Vegetation

Terrestrial species include the species that were studied from the supra tidal point onwards and therefore the species alterations will not be reflected much as the system changes from marine to fresh water. However, there are 20 species reported that are common to all the four habitats namely coastal, riverine, wetlands and scrublands (Figure 4.12).

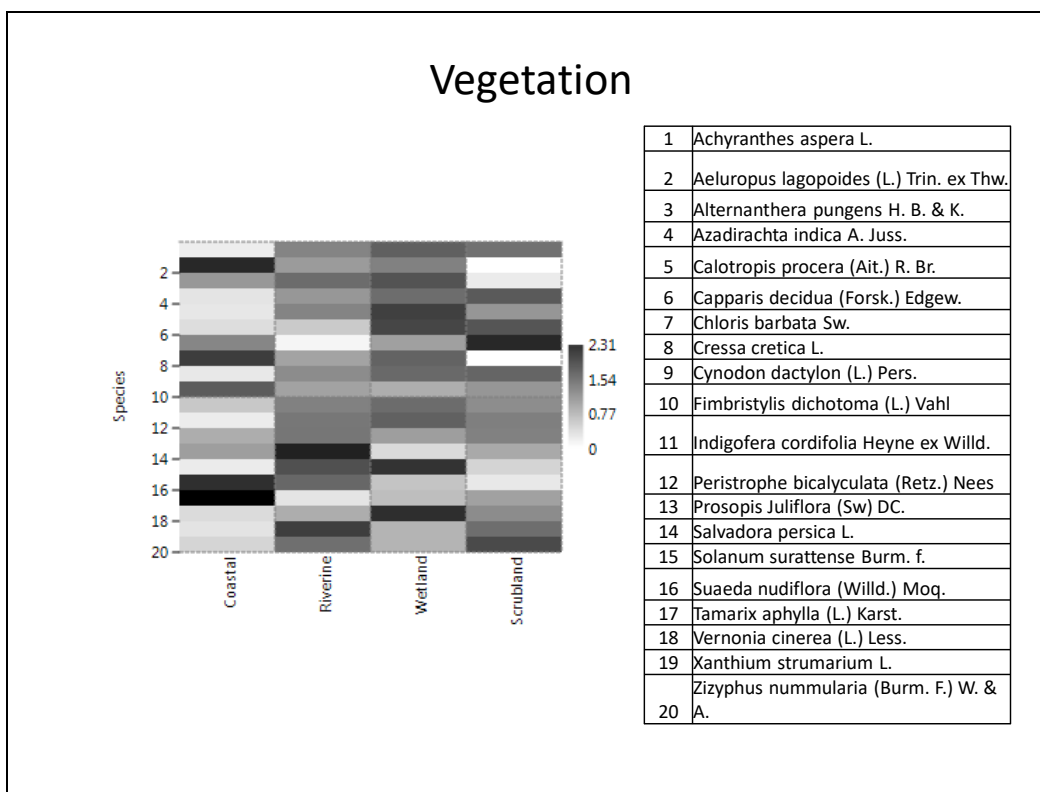


Figure 4.12: Matrix plot indicating distribution of species in different habitat studied

Species like *Tamarix aphylla*, *Chloris barbata*, *Cressa cretica* occupying the coastal fringes are able to sustain in high salinity regime will thrive. These species have high adaptability and will increase in their area of establishment in the initial years. However, as the system turns brackish *Calotropis procera*, *Tamarix aphylla*, *Capparis decidua*, *Prosopis juliflora* will establish. *Prosopis juliflora* present with high density in the riverine area will start occupying the areas where there will be drop in the soil salinity (Figure 4.13).

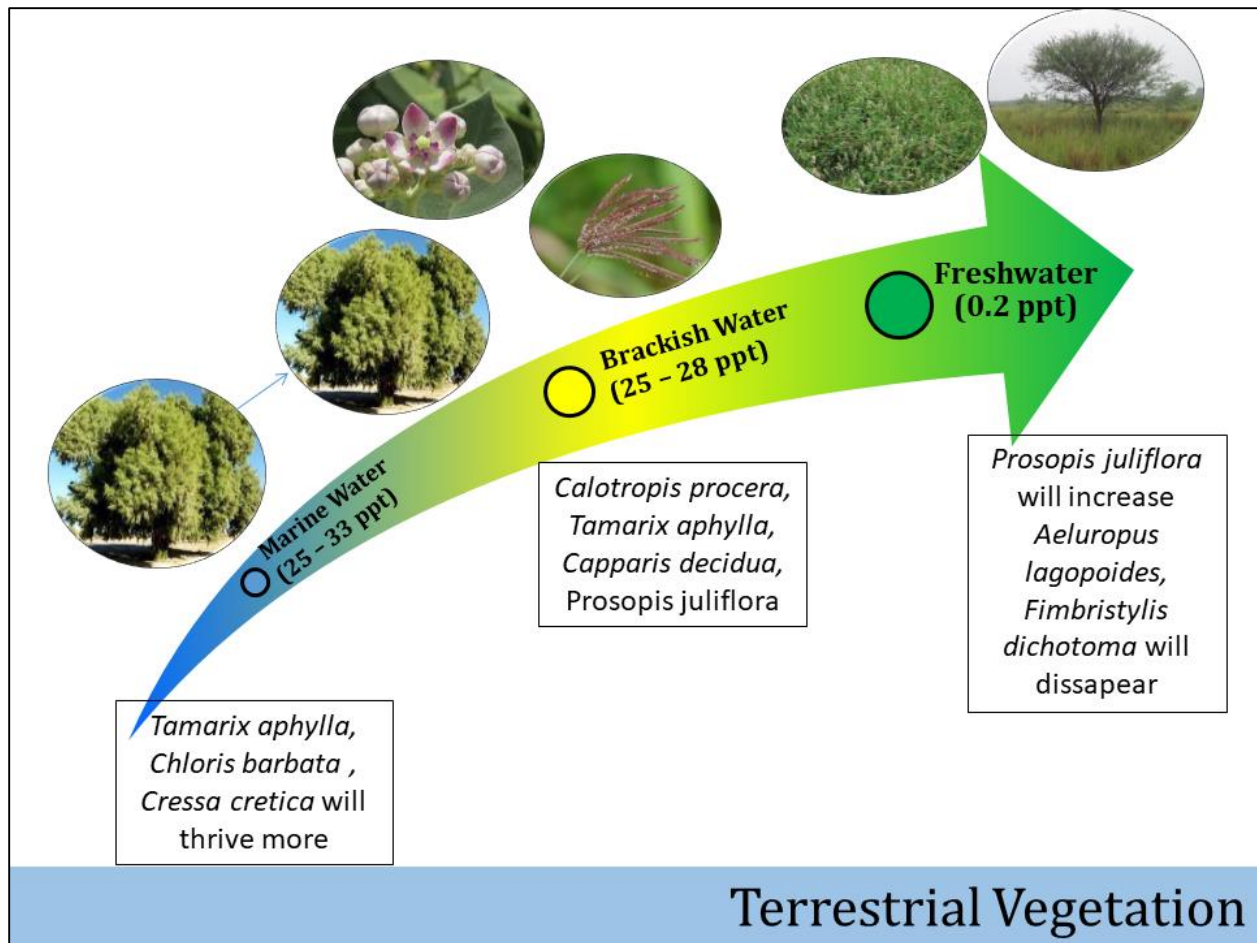


Figure 4.13: Schematic diagram showing probable change in species composition as the system changes from marine to freshwater for terrestrial plant species

4.13 Overall Change

As the system changes from marine to freshwater the species belonging to pure marine will disappear and, in the beginning, opportunistic species will take over. These species generally represent the estuarine species and depending on the water quality status other species in the freshwater regimes will occupy the areas of the estuarine habitat. This will hold more relevant for the phytoplankton, zooplankton and benthos.

Considering the transformations and new avenues for fisheries will open up like aquaculture farms and others. During this process we need to consider the predator species like crocodile, smooth coated otter and carnivorous mammals (wolf, jackal) whose population is low at present, but on finding congenial environment their population bloom

will take place. There is every possibility of increase in human wildlife conflict in the area. Increase in population of nilgai will result in crop depredation and will require management interventions.

Annexure 1: Dissimilarity percentage between the phytoplankton species for the gulf, estuary and fresh waters

Taxon	Av. dissim	Contrib. %	Cumulative %	Mean OFFSHORE	Mean ESTUARY	Mean FRESHWATER
Microcystis	7.077	12.34	53.78	1.41	9	10
Synedra	2.295	4.003	57.79	9.24	26	14
Amphora	1.532	2.672	60.46	3.59	0	0
Melosira	1.356	2.365	62.82	6.47	0	0
Pleurosigma	1.355	2.364	65.19	4.71	0	0
Rhizosolenia	1.288	2.247	67.43	4.94	10	5
Ceratium	1.146	1.998	69.43	3.71	0	0
Bacillaria	1.082	1.888	71.32	3.88	0	0
Nitzschia	1.079	1.883	73.2	2.06	0	0
Eucampia	1.048	1.827	75.03	3.59	0	0
Planktoniella	1.042	1.817	76.85	2.53	0	0
Biddulphia	1.034	1.803	78.65	3.76	7	4
Cyclotella	1.011	1.764	80.41	3.06	7	0
Triceratium	0.9482	1.654	82.07	3.82	0	0
Navicula	0.8804	1.536	83.6	3.24	10	10
Odontella	0.8739	1.524	85.13	2.65	0	0
Ceratoceros	0.8353	1.457	86.58	3.94	9	4
Pseudonitzschia	0.7572	1.321	87.91	2.59	0	0
Lauderia	0.675	1.177	89.08	1.59	0	0
Dictylum	0.626	1.092	90.17	1.71	0	0
Leptocylindricus	0.6077	1.06	91.23	1.41	0	0
Peridinium	0.5424	0.9461	92.18	0.882	7	0
Noctiluca	0.4885	0.852	93.03	1.24	0	0
Dinophysis	0.3704	0.6461	93.68	1.06	2	0
spirogyra	0.3353	0.5849	94.26	0.647	0	0
Spirogyra	0.2573	0.4487	94.71	0	12	21
Aphanocapsa	0.2573	0.4487	95.16	0	12	17
Prorocentrum	0.2309	0.4027	95.56	0.235	5	0
Pediastrum	0.2144	0.3739	95.94	0	10	14
Phaeocystis	0.2068	0.3607	96.3	0.176	0	0
Chlamydomonas	0.1715	0.2991	96.6	0	8	18
Chlorella s	0.1715	0.2991	96.9	0	8	11
Astrionella	0.1715	0.2991	97.2	0	8	1

Scenedesmus	0.1501	0.2617	97.46	0	7	10
Grammatophora	0.1501	0.2617	97.72	0	7	3
Amphiprora	0.1286	0.2244	97.94	0	6	4
Spirulina	0.1072	0.187	98.13	0	5	10
Ulothrix	0.1072	0.187	98.32	0	5	9
Oscillatoria	0.1072	0.187	98.5	0	5	5
Phormidium	0.1072	0.187	98.69	0	5	2
Chroococcus	0.0857 5	0.1496	98.84	0	4	9
Anabaena	0.0857 5	0.1496	98.99	0	4	8
Coelosphaerium	0.0857 5	0.1496	99.14	0	4	4
Eudorinasp	0.0643 1	0.1122	99.25	0	3	6
Ankistrodesmus	0.0643 1	0.1122	99.36	0	3	6
Coelestrum	0.0643 1	0.1122	99.48	0	3	2
Thalassiosira	0.0643 1	0.1122	99.59	0	3	0
Cylindrotheca	0.0428 8	0.0747 9	99.66	0	2	2
Anacystis	0.0214 4	0.0373 9	99.7	0	1	7
Closterium	0.0214 4	0.0373 9	99.74	0	1	4
Phacus	0.0214 4	0.0373 9	99.78	0	1	3
Aphanizomenon	0.0214 4	0.0373 9	99.81	0	1	2
Microspor	0.0214 4	0.0373 9	99.85	0	1	1
Eustrum	0.0214 4	0.0373 9	99.89	0	1	1
Cosmerium	0.0214 4	0.0373 9	99.93	0	1	1
Dichyocha	0.0214 4	0.0373 9	99.96	0	1	0
Flagellaria	0.0214 4	0.0373 9	100	0	1	0
Euglenophyceae	2.67E- 08	4.66E- 08	100	0	0	7
Diatoma	3.81E-	6.65E-	100	0	0	1

	09	09				

Annexure 2: Dissimilarity percentage between the zooplankton species for the gulf, estuary and fresh waters

Taxon	Av. dissim	Contrib. %	Cumulative %	Offshore	Estuary	Freshwater
Centropages	1.338	2.1	51.9	4.82	0	0
Microsetella	1.338	2.099	54	4.65	0	0
Fish larvae	1.32	2.07	56.07	2.12	14	7
Cladoceran	1.297	2.036	58.11	2.35	9	12
Creseissp	1.222	1.917	60.03	1.47	0	0
Lucifer	1.116	1.751	61.78	3.29	0	0
Eucalanus	1.08	1.694	63.47	2.59	0	0
Phyllosoma	1.05	1.648	65.12	2.18	0	0
Euphausia	1.048	1.644	66.76	2.59	0	0
Tomopteris	1.015	1.592	68.35	1.06	0	0
Temora	1.011	1.586	69.94	3.29	0	0
Bivalve larvae	1.01	1.585	71.53	1.71	0	0
Brachyuran larvae	1.008	1.581	73.11	3.53	0	0
Bipinaria larvae	0.964	1.513	74.62	1.82	2	0
Copelata	0.9422	1.478	76.1	2.12	0	0
Cyphonutes larvae	0.9292	1.458	77.56	1.18	0	0
Euterpina	0.9289	1.457	79.01	2.82	0	0
Oncaea	0.9153	1.436	80.45	1.06	0	0
Oikopleura	0.9103	1.428	81.88	1.82	0	0
Aetideus	0.9084	1.425	83.3	2.41	0	0
Nemadodes	0.855	1.342	84.64	0.941	0	0
Labidocera	0.8401	1.318	85.96	1.41	0	0
Caridean larvae	0.7831	1.229	87.19	1.71	0	0
Tornaria larvae	0.697	1.094	88.28	1.18	0	0
Rotifera	0.6122	0.9605	89.25	0	11	11
Harpacticoida	0.6097	0.9565	90.2	0	13	9
Corycaeus	0.6089	0.9554	91.16	1.53	0	0
Gastropod larvae	0.6054	0.9499	92.11	1.18	0	0
Acartia	0.5947	0.9331	93.04	1.88	0	0
Tintinnopsis	0.5712	0.8962	93.94	0.882	6	5
Ostracoda	0.5439	0.8534	94.79	0	6	13
Foraminifera	0.5371	0.8427	95.63	1.71	4	2
Zoea larvae	0.5281	0.8286	96.46	0	10	9

Cyclopoida	0.4712	0.7392	97.2	0	10	7
Daphnia	0.3896	0.6113	97.81	0	7	7
Megalopa larvae	0.3383	0.5308	98.34	0	5	7
Obelia	0.327	0.5131	98.86	0.941	0	0
Amphipoda	0.277	0.4346	99.29	0	6	4
Physalia	0.2338	0.3668	99.66	0.706	0	0
Veliger larvae	0.11	0.1726	99.83	0	3	1
Planula larvae	0.1088	0.1706	100	0	4	0

Annexure 3. Contribution of different avian species to the dissimilarity among different habitats

Species	Av. dissim	Cont rib. %	Cumu lative %	Mean Agricul ture	Mean Coastal Habitat	Mean Freshwater Habitat	Mean Scrubl and
Common Pochard	2.35	3.42	50.32	0	0	280	0
Painted Stork	1.56	2.28	52.6	13	128	18	5
Black-headed Ibis	1.43	2.09	54.69	125	10	6	8
House Sparrow	1.29	1.87	56.56	110	20	0	15
Wire-tailed Swallow	1.27	1.85	58.41	97	0	31	56
Demoiselle Crane	1.12	1.64	60.04	25	9	122	41
Red-vented Bulbul	0.91	1.33	61.37	41	1	4	66
Common Babbler	0.90	1.32	62.69	79	22	9	56
Black Drongo	0.88	1.28	63.96	92	50	10	61
Green-winged Teal	0.84	1.22	65.19	0	0	100	0
Paddyfield Pipit	0.82	1.20	66.39	63	1	0	22
Plain Prinia	0.77	1.13	67.52	26	11	3	65
White-eared Bulbul	0.76	1.10	68.62	24	37	4	69
Rosy Starling	0.66	0.96	69.58	52	0	0	11
Indian-pond Heron	0.66	0.96	70.54	10	32	12	59
Great Egret	0.65	0.95	71.49	5	53	0	8
Red-rumped Swallow	0.65	0.94	72.43	20	20	0	59
Siberian Stonechat	0.63	0.92	73.35	49	13	2	46
Red Avadavet	0.61	0.90	74.25	0	0	0	50
Crested Lark	0.59	0.86	75.1	39	50	0	21
Lesser Sandplover	0.58	0.85	75.95	0	46	0	0
Great White	0.58	0.84	76.79	0	0	69	0

Species	Av. dissim	Cont rib. %	Cumu lative %	Mean Agricul ture	Mean Coastal Habitat	Mean Freshwater Habitat	Mean Scrubl and
Pelican							
Black-winged Stilt	0.56	0.81	77.61	4	26	34	48
Little Cormorant	0.55	0.81	78.41	40	27	17	62
House Crow	0.55	0.80	79.21	52	38	11	61
Gray-headed Swamphen	0.55	0.80	80.01	6	1	61	0
Red Collared-Dove	0.50	0.73	80.74	40	0	0	6
Rose-ringed Parakeet	0.48	0.70	81.45	37	5	0	22
Rufous-tailed Lark	0.46	0.67	82.12	15	41	0	14
Baya Weaver	0.46	0.67	82.79	10	0	0	35
Long-tailed Shrike	0.46	0.67	83.45	36	6	3	28
Little Egret	0.43	0.63	84.08	32	5	1	27
Garganey	0.42	0.61	84.69	0	0	50	0
Intermediate Egret	0.41	0.60	85.3	1	32	13	26
Black-tailed Godwit	0.40	0.59	85.88	0	32	0	0
Ashy-crowned Sparrow-lark	0.39	0.57	86.45	12	23	0	33
Eurasian Collared Dove	0.39	0.57	87.02	46	18	15	26
Large Gray Babbler	0.38	0.55	87.57	3	0	0	30
Purple Sunbird	0.36	0.53	88.09	42	29	14	45
Common Redshank	0.35	0.51	88.6	1	26	9	0
Red-wattled Lapwing	0.32	0.46	89.06	67	74	50	54
Green Bee-eater	0.27	0.39	89.45	23	28	3	30
Eurasian Moorhen	0.25	0.36	89.82	1	0	0	20
Indian Silverbill	0.24	0.35	90.17	20	0	0	0
Dalmatian Pelican	0.22	0.32	90.49	0	0	0	18
Laughing Dove	0.22	0.31	90.8	21	28	18	35
Indian Robin	0.21	0.31	91.11	17	6	8	21
Common Sandpiper	0.21	0.30	91.41	7	7	11	23
Jungle Babbler	0.21	0.30	91.72	16	0	14	11
Yellow-footed Green-pigeon	0.20	0.30	92.02	17	0	0	0

Species	Av. dissim	Cont rib. %	Cumu lative %	Mean Agricul ture	Mean Coastal Habitat	Mean Freshwater Habitat	Mean Scrubl and
Gull-billed Tern	0.20	0.29	92.31	4	16	0	2
Eurasian Marsh Harrier	0.18	0.27	92.57	1	6	11	15
Red-naped Ibis	0.18	0.26	92.84	0	1	18	5
Common Crane	0.18	0.26	93.1	0	14	0	0
Sarus Crane	0.16	0.23	93.32	13	0	0	0
Feral Pigeon	0.15	0.22	93.54	38	30	26	27
Common Myna	0.15	0.21	93.76	10	0	0	8
Western Reef Heron	0.14	0.21	93.96	0	11	0	1
Brahminy Myna	0.13	0.19	94.15	2	0	0	10
Pied Bushchat	0.13	0.18	94.33	3	4	0	11
Chestnut-bellied Sandgrouse	0.12	0.18	94.51	0	0	0	10
White-throated Kingfisher	0.12	0.17	94.68	13	4	4	7
Eurasian Spoonbill	0.12	0.17	94.85	0	8	7	1
White-browed Fantail	0.11	0.16	95.02	0	0	0	9
River Tern	0.10	0.15	95.17	0	5	3	8
Sand Lark	0.10	0.15	95.31	0	8	0	0
Pallas's Gull	0.10	0.15	95.46	0	8	0	0
Great Cormorant	0.10	0.15	95.61	0	0	12	0
Western Yellow Wagtail	0.10	0.15	95.75	8	5	6	0
Gray Francolin	0.10	0.14	95.89	15	13	6	11
Wood Sandpiper	0.09	0.14	96.03	1	1	0	8
Purple Heron	0.09	0.13	96.16	4	0	8	1
Red-whiskered Bulbul	0.09	0.13	96.29	0	0	0	7
Indian Peafowl	0.09	0.12	96.41	0	2	2	7
Gray Heron	0.08	0.12	96.54	9	2	3	3
Black-crowned night Heron	0.08	0.12	96.66	0	0	10	0
Shikra	0.08	0.12	96.78	2	2	1	8
Desert Wheatear	0.08	0.12	96.9	6	3	0	0
Indian Spot-billed Duck	0.08	0.12	97.01	3	0	8	3
Ashy Drongo	0.08	0.12	97.13	2	0	0	6
White Wagtail	0.08	0.11	97.24	0	4	2	6

Species	Av. dissim	Cont rib. %	Cumu lative %	Mean Agricul ture	Mean Coastal Habitat	Mean Freshwater Habitat	Mean Scrubl and
Indian Roller	0.08	0.11	97.36	5	0	0	5
Dunlin	0.08	0.11	97.47	0	6	0	0
Ashy Prinia	0.07	0.11	97.57	1	0	6	4
Gray-breasted Prinia	0.07	0.11	97.68	0	0	0	6
Sulphur-bellied Warbler	0.07	0.11	97.79	0	0	0	6
Greater Coucal	0.07	0.10	97.89	5	0	4	1
Spotted Owlet	0.06	0.09	97.99	0	5	1	2
White-breasted Waterhen	0.06	0.09	98.07	5	1	0	2
Spotted Dove	0.06	0.08	98.15	2	0	0	4
Common Iora	0.05	0.08	98.23	4	0	0	2
Greater Spotted Eagle	0.05	0.08	98.31	1	1	2	5
Tawny Lark	0.05	0.07	98.38	0	4	0	0
Common Tailorbird	0.05	0.07	98.45	0	0	0	4
Black-winged Kite	0.05	0.07	98.52	5	4	0	5
Dusky Crag- Martin	0.05	0.07	98.59	4	0	0	0
Oriental Magpie- robin	0.05	0.07	98.66	3	0	0	3
Clamorous Reed Warbler	0.04	0.06	98.72	0	0	5	0
Gray Wagtail	0.04	0.06	98.78	2	2	4	0
Eurasian Kestrel	0.04	0.06	98.84	1	3	0	0
Bay-backed Shrike	0.04	0.06	98.9	0	0	1	3
Little Grebe	0.04	0.05	98.95	0	0	0	3
Blue-Throat	0.04	0.05	99.01	0	0	0	3
Oriental Honey Buzzard	0.04	0.05	99.06	5	3	3	2
Asian Openbill	0.04	0.05	99.11	3	0	0	0
Small Minivet	0.03	0.04	99.16	0	0	2	2
Common Greenshank	0.03	0.04	99.2	0	2	1	0
Black-headed Bunting	0.03	0.04	99.24	1	0	0	2
Pallid Harrier	0.03	0.04	99.27	0	2	0	0
Oriental Skylark	0.03	0.04	99.31	0	2	0	0

Species	Av. dissim	Cont rib. %	Cumu lative %	Mean Agricul ture	Mean Coastal Habitat	Mean Freshwater Habitat	Mean Scrubl and
Booted Warbler	0.03	0.04	99.35	0	2	0	0
Great Thick-Knee	0.03	0.04	99.38	0	2	0	0
Pied Kingfisher	0.02	0.04	99.42	2	2	2	0
Glossy Ibis	0.02	0.04	99.46	2	0	0	0
Little Swift	0.02	0.04	99.49	2	0	0	0
Indian White-eye	0.02	0.04	99.53	2	0	0	0
Indian Spotted Eagle	0.02	0.04	99.56	2	0	0	0
Asian Koel	0.02	0.04	99.6	2	0	0	0
Bronze-winged Jacana	0.02	0.03	99.63	0	0	2	1
Eurasian Hoopoe	0.02	0.02	99.65	2	2	0	2
Wooly-necked Stork	0.02	0.02	99.68	1	0	0	1
Common Kingfisher	0.02	0.02	99.7	1	0	0	1
Black-headed Gull	0.01	0.02	99.72	0	1	0	0
Montagu's Harrier	0.01	0.02	99.74	0	1	0	0
Eurasian Curlew	0.01	0.02	99.75	0	1	0	0
Tawny Pipit	0.01	0.02	99.77	0	1	0	0
Isabelline Shrike	0.01	0.02	99.79	0	0	0	1
Black Kite	0.01	0.02	99.81	0	0	0	1
Coppersmith Barbet	0.01	0.02	99.83	0	0	0	1
Yellow-crowned Woodpecker	0.01	0.02	99.84	0	0	0	1
Greenish Warbler	0.01	0.02	99.86	0	0	0	1
Indian Paradise-Flycatcher	0.01	0.02	99.88	1	0	0	0
Common Woodshrike	0.01	0.02	99.9	1	0	0	0
Thick-billed Flowerpecker	0.01	0.02	99.91	1	0	0	0
Rufous Treepie	0.01	0.01	99.93	1	1	0	1
Citrine Wagtail	0.01	0.01	99.94	0	0	1	0
Marsh Sandpiper	0.01	0.01	99.95	0	0	1	0
Caspian Tern	0.01	0.01	99.96	0	0	1	0
Large-billed Crow	0.01	0.01	99.98	0	0	1	0
Isabelline Shrike	0.01	0.01	99.99	1	1	0	1
Whimbrel	0.01	0.01	100	0	0	1	0

CHAPTER 5 SOCIO-ECONOMIC STUDIES

Developmental activities are required not only for the economic development for the countries like India, but also for catering the basic needs of the people and society for the overall improvement (Human development) of the area/region. Some mega projects also have several long-term impacts on the natural resources and biodiversity (Ali and Butcher, 2021) and thus create some level of impacts on the people dependent on the common pool resources. The socio-economic condition of the local people is thus important to evaluate for envisaging the future consequences of the mega projects and to conceptualize the probable policy implementation prospects as an adaptation strategy.

Socio-economic assessment is the analysis of “social, cultural, economic and political conditions of individuals, groups, communities and organizations (Brunce, 2000). A socio-economic survey is one of the most important sources of statistical data on household expenditure and income as well as other data on the status of housing, individual and household characteristics and living conditions. Socio-economic survey was conducted with special emphasis on the fishing community. The primary group to be affected due to construction of Kalpasar dam is the fishing community and Socio-economic survey will indicate their present livelihood issues. The study will enable towards designing better rehabilitation plan and the training needs to adjust to the changing scenario.

Landscape level changes due to developmental activity imparts significant effect on the natural resources (Frissell *et al.*, 1986; Jones and Clark, 1987) flows, and modified in stream habitat and substrate (Richards and Host, 1994; Richards *et al.*, 1997) complexity (Klein, 1979; Schueler, 1994; Booth and Lammert and Allan 1999; Kennen and Ayers, 2002; Jackson, 1997; Wang *et al.*, 2000, 2001; Kennen and Roy *et al.*, 2003). The aquatic system specially the fisheries sector also gets affected due to the change in hydrological regimes and changes of lentic to lotic system and vice-versa. Long term modification due to dam construction affects fish diversity (Loures and Pompeu, 2019; Bunn and Arthington, 2002). The Kalpasar Project activities intend to bring future changes in hydrological regimes which subsequently effect the fisheries sector. Therefore, a survey was undertaken to assess the socio-economic dependency on the fisheries sector and the financial risk associated with fishing community thriving in the

project impact area. The primary survey along with the secondary data source was used to generate baseline information on the fishing community and their financial dependency in the fisheries sector within the project area.

5.1 Secondary Data

Fishes are an important biological resource and fishing is a livelihood for mankind over a long period of time (Tursi, *et al.*, 2015). In the project area, a sizable population of the fishing communities is involved in fishing along the entire stretch of Gulf of Khambhat and also a large number of people are involved in fish culture activities. The proposed project will create considerable changes in the ecosystem which shall impact the fishery resources, its diversity, composition and productivity. This will subsequently lead to an impeccable impact on the socio-economics of the fishing communities and other people involved in the fish culture and related trade/industry. The secondary data on various fishery related parameters from the project influencing area are collected from the State Department of Fisheries, Research institutes working on fishery and allied resources along with published documents.

Fishery statistics of Gujarat showed that there are about 5.6 Lakh fishermen population within the state representing both the inland and coastal fisheries. The marine fishery production of the State stands at 7.01 Lakh Metric Tons as on 2020 (Table 5.1). With the longest coastline of the country, Gujarat has about 107 landing centers and 260 marine fishing villages spread all along the State (GOI, 2020).

Table 5.1: Fishery statistics of Gujarat

Fishermen Population of Gujarat	5,58,691
Fishermen Population per District	16,930
Marine (In Lakh Metric Tons)	7.01
Yearly Fish Consumption (Per Capita/Kg.)	9.55
Coastal length (km)	1600
Landing centres	107
Fishing villages	260

(Source: Handbook on Fisheries Statistics, 2020, Department of Fisheries, Ministry of Fisheries, Animal Husbandry & Dairy, Govt. of India, New Delhi)

In the entire study area there are 191 fish landing centers and Vadodara is the only district within the study area with no marine landing centers (Table 5.2). The total

fishermen population which includes the marine (24,617) as well as inland (57,823) population of these five districts sums up to 82,440. Out of the five adjoining districts, the marine fishermen population is distributed in Bharuch, Anand, Ahmedabad and Bhavnagar districts. The fishermen population in Vadodara is mainly associated with inland fishery. The fishermen population associated with marine fisheries is highest in Ahmedabad district (9642), followed by Bhavnagar district (6862), Bharuch district (6419) and lastly Anand (1694) as per the 2011 data (Census India, 2011). The total number of active fisher families is high in Bharuch district, followed by Ahmedabad district (Table 5.2). Ahmedabad has the highest number of *Pagadiya* fishermen fishing in the vast mudflats.

Table 5.2: Summary of the Overall Fishery (Marine & Inland) statistics of adjoining districts of the Gulf of Khambhat (2019-2020)

District	Approximate Length of coastline (kms)	Number of landing centers	Total Number of fishing boats			Total No. of fisher men families	Total Fisher Folk Population
			Mechanized	Non - mechanized	Total		
Bharuch	127	74	747	940	1687	5352	26640
Anand	51	37	0	154	154	1729	8513
Bhavnagar	152	33	267	20	287	1852	9634
Vadodara	-	-	31	447	478	2819	14256
Ahmedabad	46	47	0	359	359	5117	23397

(Source: Fisheries Statistics of Gujarat State, 2018-19 & 2019-20, Commissioner of Fisheries, Government of Gujarat, Gandhinagar)

However, the inland fishermen population is distributed across all the five districts of interest. The fishermen population associated with inland fisheries is highest in Bharuch district (20,221), followed by Vadodara (14256), Ahmedabad (13755), Anand (6819) and lastly Bhavnagar (2772) as per the 2011 data (Census India, 2011). The inland fish production for the year 2019-20, was around 41,814 metric tons across all the five districts along the project area. The total district wise inland fish production recorded for the last decade (2010-2020) is given in Table 5.3.

The marine fish production for the year 2019-20, was around 7,645 metric tons from the three districts (Bharuch, Anand & Bhavnagar) of the project area. The total district wise marine fish production recorded from these three districts for the last decade (2010 to 2020) is given in Table 5.4.

Fig 5.3 shows the overall trend of both marine as well as inland fisheries over the last decade. The trend for both the types of fisheries has decreased in the Gulf of Khambhat region.

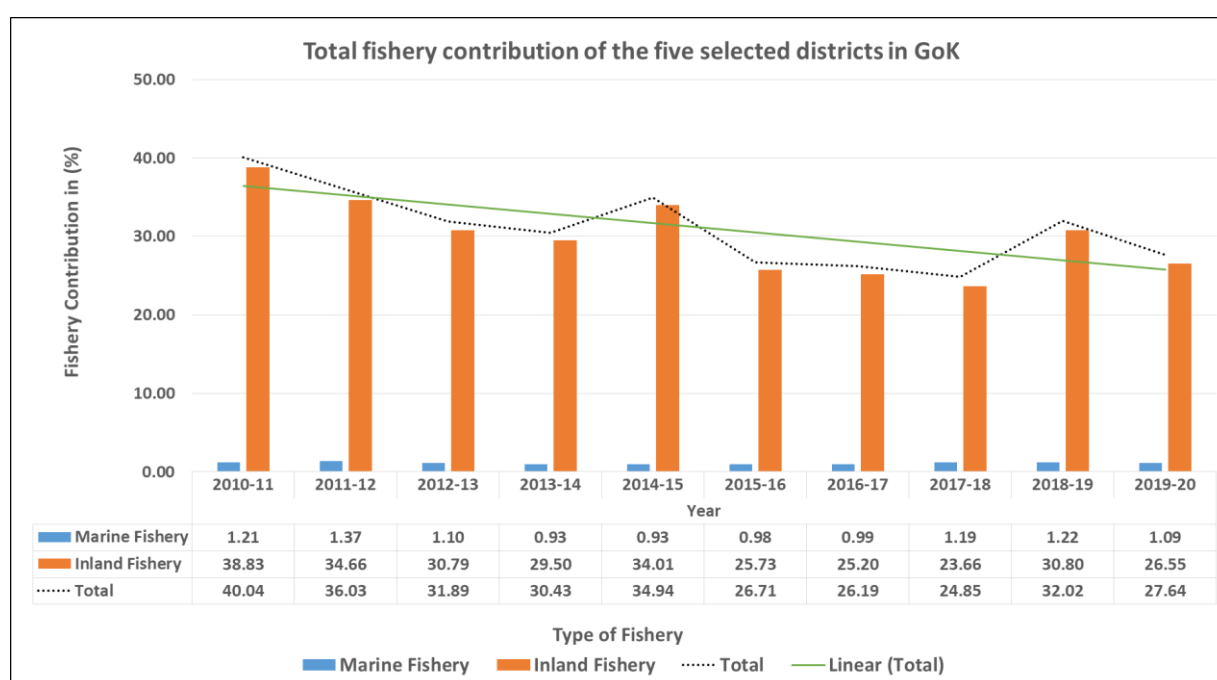


Fig.5.3 The overall marine and inland fisheries contribution and trend of the Gulf of Khambhat during the last decade (2010-11) to (2019-2020)

Table 5.3: District wise and Year wise Inland Fish Production in Gujarat State (2010-11) to (2019-20) Production in (Metric Tons)

Name of the District	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Bhavnagar	209	898	927	668	909	758	712	2305	3605	3205
Bharuch	14869	12915	11390	10000	18812	11243	11728	11408	20687	19881
Vadodara	8798	7369	7141	7683	7691	7100	7261	7357	7522	8226
Anand	5915	6021	5556	6527	6552	6312	6527	9610	8136	8581
Ahmedabad	3337	4184	4615	7717	5812	5745	5476	1902	4062	1921

Table 5.4: Year wise & District wise Marine Production since (2010-11) to (2019-20) Production in (Metric Tons)

Year	Bharuch	Anand	Bhavnagar	Gujarat
2010-11	5804	314	2233	688930
2011-12	6405	456	2640	692488
2012-13	4793	422	2421	693560
2013-14	4045	336	2103	695580
2014-15	3453	270	2774	698450
2015-16	3583	298	2973	697328
2016-17	3616	298	3025	698832
2017-18	4842	228	3296	700743
2018-19	4981	228	3320	699230
2019-20	5150	244	2251	700809

(Source: Fisheries Statistics of Gujarat State, 2018-19 & 2019-20, Commissioner of Fisheries, Government of Gujarat, Gandhinagar)

The district wise percentage production of all types of fishes (marine, brackish, estuarine, pond etc.) across the area of interest has been shown in Table 5.5.

The District wise Marine Fish Production of important species and their economic status in (2010-11) & (2019-20) is depicted in Table 5.6. These species are likely to be the most affected due to the habitat change that shall follow the Kalpasar project implementation in future. These species are of economic importance and hence are directly associated with the livelihood of fishermen of that area. Therefore, it is important to provide alternative/s to such individuals. However, the habitat change that is predicted to occur shall pave way for the rise in the number of inland fishes. The District wise Inland Fish Production of important species and their economic status in (2010-11) & (2019-20) is given in Table 5.7. The production of these important inland fishes is predicted to increase post Kalpasar.

The total number of the *Pagadia* fishermen was recorded around 1467, in the year 2019-20. The Anand district was reported to have the highest number of *Pagadia* fishermen (484) followed by Bharuch (410), Bhavnagar (325), Ahmedabad (192) and Vadodara (55) districts. Table 5.8 shows the number of active fishermen in both, marine as well as inland fishery activity. The total number of active fishermen were found to be highest in Bharuch (15960) followed by Ahmedabad (6214), Bhavnagar (3803), Vadodara, (3619) and Anand (2474). The maximum number of active fishermen engaged in marine as well as inland fishery were noted for Bharuch district. The details on the number and the types of fishing boats used by the fishermen during (2010-11) and (2019-2020) have been given in Table 5.9.

The district wise export of fishes and its products from the Gujarat state during the year 2010-11 and 2019-20 has been given in Table 5.10. The export of marine and inland fishes is done either in the form of either fresh form or dry form. The export of Bharuch district increased over the last decade while the export quantity decreased for Vadodara district. However, the value/rate of the fishes increased over the decade. The export of fishes in the form of dry fishes was not practiced during 2010-11, while it was noted during 2019-20, thereby boosting the area's economy.

5.5: Year wise & District wise Marine Production since (2010-11) to (2019-20) Production in (Metric Tons)

Name of the District/ Centers	district wise % Production of Inland Fishes	District wise % Production of Marine Fishes	district wise % Production of Estuarine Fishes	district wise % Production of Riverine Fishes	district wise % Production of Brackish Fishes	district wise % Production of Reservoir Fishes	district wise % Production of Ponds and Tanks Fishes
Bhavnagar	2.03%	0.32%	0	0.00	3.32%	1.45%	0.07%
Bharuch	12.62%	0.73%	16.52%	17.45%	16.73%	3.23%	4.04%
Vadodara	5.22%	0	27.37%	13.84%	0.00	2.31%	6.62%
Anand	5.44%	0.03%	8.26%	8.57%	1.65%	2.82%	38.30%
Ahmedabad	1.21%	0	6.78%	0.00	0.00	0.00	0.00
Total	26.52%	1.08%	58.93%	39.86%	21.70%	9.81%	49.03%

Source: Fisheries Statistics of Gujarat State (2018-19 and 2019-20), Commissioner of Gujarat, Government of Gujarat, Gandhinagar.

Table5.6: District wise and Species wise Marine Fish Production of important species and their economic status in (2010-11) & (2019-20)

District wise and species wise Marine fish production for the year 2010-2011 & 2019-20 in M.T								
NAME OF SPECIES	DISTRICT NAME							
	(2010-2011)				(2019-2020)			
	Bharuch	Anand	Bhavnagar	Avg. Price Rs. /Kg	Bharuch	Anand	Bhavnagar	Avg. Price Rs. /Kg
White pomfret	0	0	6	199.12	0	0	8	432.73
Black pomfret	0	0	0	102.25	0	0	11	285.88
Bombay duck	1068	109	218	31.45	635	23	280	40.56
Thread fin	0	0	0	172.3	0	0	9	246.24
Jew fish (sea bass)	0	0	0	215.45	0	0	0	463.58

Hilsa	606	0	232	110.6	19	39	32	209.32
Mullet	765	24	216	51.28	688	16	149	73.1
Cat fish	0	21	67	29.15	369	0	292	46.53
Prawns(medium)	59	12	160	111.09	81	9	442	163.95
Prawns(jumbo)	390	0	2	240.94	0	0	2	324.04
Miscellaneous	948	62	26	19.4	629	82	308	28.28
Total	3836	228	927	116.63	2421	169	1533	210.38

Source: Fisheries Statistics of Gujarat State (2018-19 and 2019-20), Commissioner of Gujarat, Government of Gujarat, Gandhinagar.

Table5.7: District wise and Species wise Inland Fish Production of important species and their economic status in (2010-11) & (2019-20)

Species wise Inland Fish Production in Gujarat State (2010-2020) Production in (Metric Tons)						
	2010-2011			2019-2020		
Name of the fish	Production in Metric Tons	Value (Rs. In Lakhs)	Avg. market price/Kg)	2019-2020	Value (Rs. In Lakhs)	Avg. market price/Kg)
Prawn (Medium)	6559	58684.73	68.26	76231	228351.88	145.02
Rohu	11634			14325		
Catla	8583			13869		
Mrigal	9901			12801		
Catfish	8018			4325		
Mullets	2587			2585		
Murrel	3257			2380		

Prawn (Shrimp)	2956			2192		
Wallago attu	3198			1752		
Eel	486			1547		
Calbasu	1056			1402		
Mahasheer	38			0		
Miscellaneous	25292			20113		
Total	85,972			1,57,463		

Source: Fisheries Statistics of Gujarat State (2018-19 and 2019-20), Commissioner of Gujarat, Government of Gujarat, Gandhinagar.

Table 5.8: Details of Fishermen Census 2007 (18th Census of Fishermen – 2007)

District	Centres	Family	Fishermen Population			Marine Population	Inland Population	Active Fishermen			No. of <i>Pagadiya</i> Fishermen (2019-2020)
			Male	Female	Total			Marine	Inland	Total	
Bharuch	74	5352	14045	12595	26640	6419	20221	3601	12359	15960	410
Vadodara	75	2819	7523	6733	14256	0	14256	0	3619	3619	55
Anand	37	1729	4418	4095	8513	1694	6819	461	2013	2474	485
Ahmedabad	47	5117	12473	10924	23397	9642	13755	2124	4090	6214	192
Bhavnagar	33	1852	5042	4592	9634	6862	2772	2872	931	3803	325

Table 5.9: District wise Number of Fishing Boats in Gujarat State (2010-11) & (2019-2020)

District	Mechanized Boats														Non mechanized Boats		Total Boats	
	Trawler		Gillnetter		FRP IBM		FRP OBM		Wooden OBM		Dolneters/ Others		Total		Total			
	2010-11	2019-20	2010-11	2019-20	2010-11	2019-20	2010-11	2019-20	2010-11	2019-20	2010-11	2019-20	2010-11	2019-20	2010-11	2019-20	2010-11	2019-20
Bharuch	0	0	250	250	422	497	0	0	0	0	0	0	672	747	940	940	1612	1687
Vadodara	0	0	0	0	4	3	3	0	28	28	0	0	35	31	495	447	530	478
Anand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	168	154	168	154
Ahmedabad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	359	359	359	359
Bhavnagar	0	0	0	0	206	267	0	0	0	0	0	0	206	267	20	20	226	287

Source: Fisheries Statistics of Gujarat State (2018-19 and 2019-20), Commissioner of Gujarat, Government of Gujarat, Gandhinagar.

Table 5.10: Inter State export of Fish and Fish products from Gujarat (2010-11) & (2019-2020) (Quantity in Metric Tons and Value in Lakh Rs.)

	2010-2011								2019-2020							
District	Fresh Fish				Dry Fish		Total		Fresh Fish				Dry Fish		Total	
	Marine		Inland						Marine		Inland					
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Bharuch	0	0	56	177.45	0	0	56	177.45	0	0	110	146.11	0	0	110	146.11
Vadodara	0	0	317.97	234.06	0	0	317.97	234.06	0	0	276	308.62	0	0	276	308.62
Anand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ahmedabad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bhavnagar	0	0	0	0	0	0	0	0	0	0	0	0	107	323.17	107	323.17

The Fisheries Statistics of Gujarat State, conducted during 2018-19 & 2019-20 revealed the district wise distribution of fisheries co-operative societies. The details have been given in Table 5.11.

Table 5.11: District wise Fisheries Co-operative Societies

District	Total No. of Society	Total No. of Members	Tribal		Non-tribal		Kind of Societies			
			No.	Members	No.	Members	Marine	Inland	Active	Inactive
Ahmedabad	15	1518	4	678	11	840	2	13	15	0
Bhavnagar	14	1186	0	0	14	1186	7	7	8	6
Vadodara	25	1463	13	707	12	756	0	25	22	3
Bharuch	22	1670	16	1283	6	387	3	19	20	2
Anand	5	442	0	0	5	442	0	5	2	3

(Source: Fisheries Statistics of Gujarat State, 2018-19 & 2019-20, Commissioner of Fisheries, Government of Gujarat, Gandhinagar)

The overall consumption of fishes in Gujarat state is lower in comparison to other states across India. The consumption of fishes has decreased over the last five years in the State based on the report of Government of Gujarat. The percentage share of fish consumption of Gujarat state in India is less than 6% (Table 5.12).

Table 5.12: Gujarat State Fish Consumption with respect to India

Year	Unit	Gujarat	India	% share of Gujarat
2015-16	Quantity in Metric Tons	545	9850	5.53
2016-17		568	10287	5.52
2017-18		524	11248	4.66
2018-19		535	12131	4.41
2019-20		576	N.A.	-

(Source: Fisheries Statistics of Gujarat State, 2018-19 & 2019-20, Commissioner of Fisheries, Government of Gujarat, Gandhinagar)

Marine fish production in the Gulf of Khambhat is dominated in three districts Anand, Bharuch and Bhavnagar. Bharuch and Bhavnagar lies outside the proposed Kalpasar dam. The fish catch data in the Anand district has drastically declined from 2006-07 onwards (Fig. 5.3). The major fishery in the Anand district is by the *Pagadiya* and small

boats in the Gulf of Khambhat. However, post construction of the Sabarmati river front there is reduction in the e-flow from the river which is detrimental for the marine fish production in the area. The Sabarmati river front was finally commissioned in 2012.

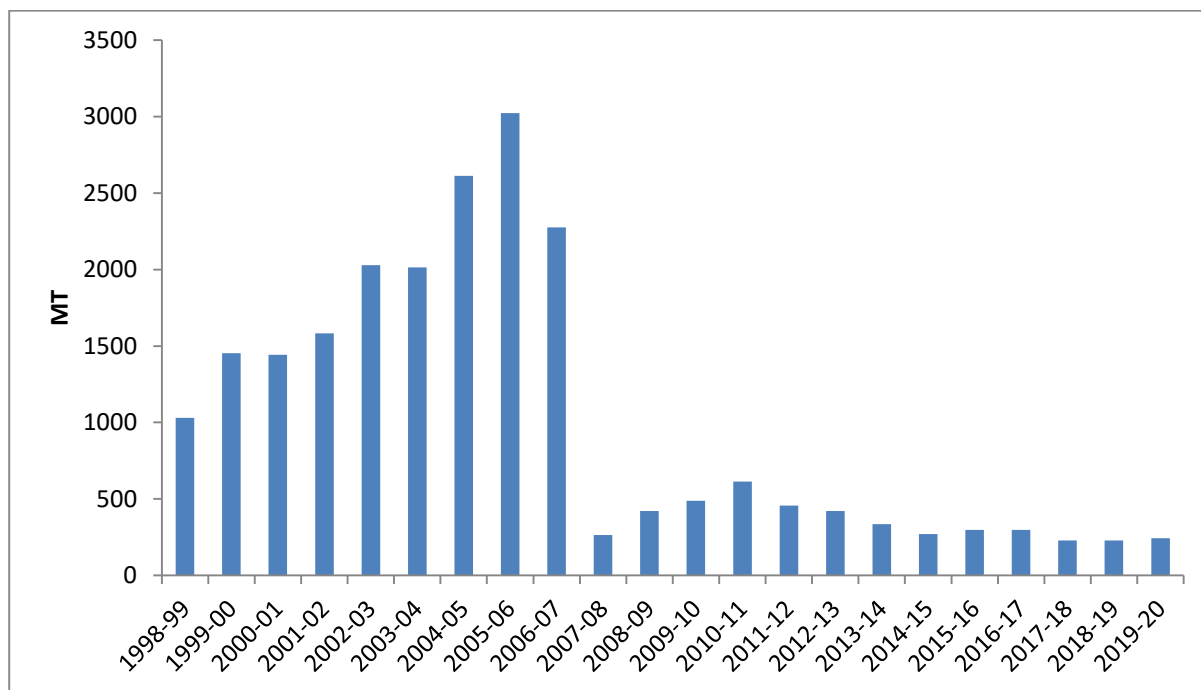


Fig. 5.3: Marine Fish production (MT) in Anand district from 1998-89 to 2019-20

Source: Gavali et al., (2021)

The marine fish catch in the region downstream of the Kalpasar dam for Bharuch and Bhavnagar districts indicate fluctuations from 1998-89 to 2019-20 (Fig. 5.4). In case of Bharuch the marine fisheries increased from 2006-07 onwards and Bhavnagar district showed decline in the fish production in the same period where increase in marine fish production was observed in Bharuch.

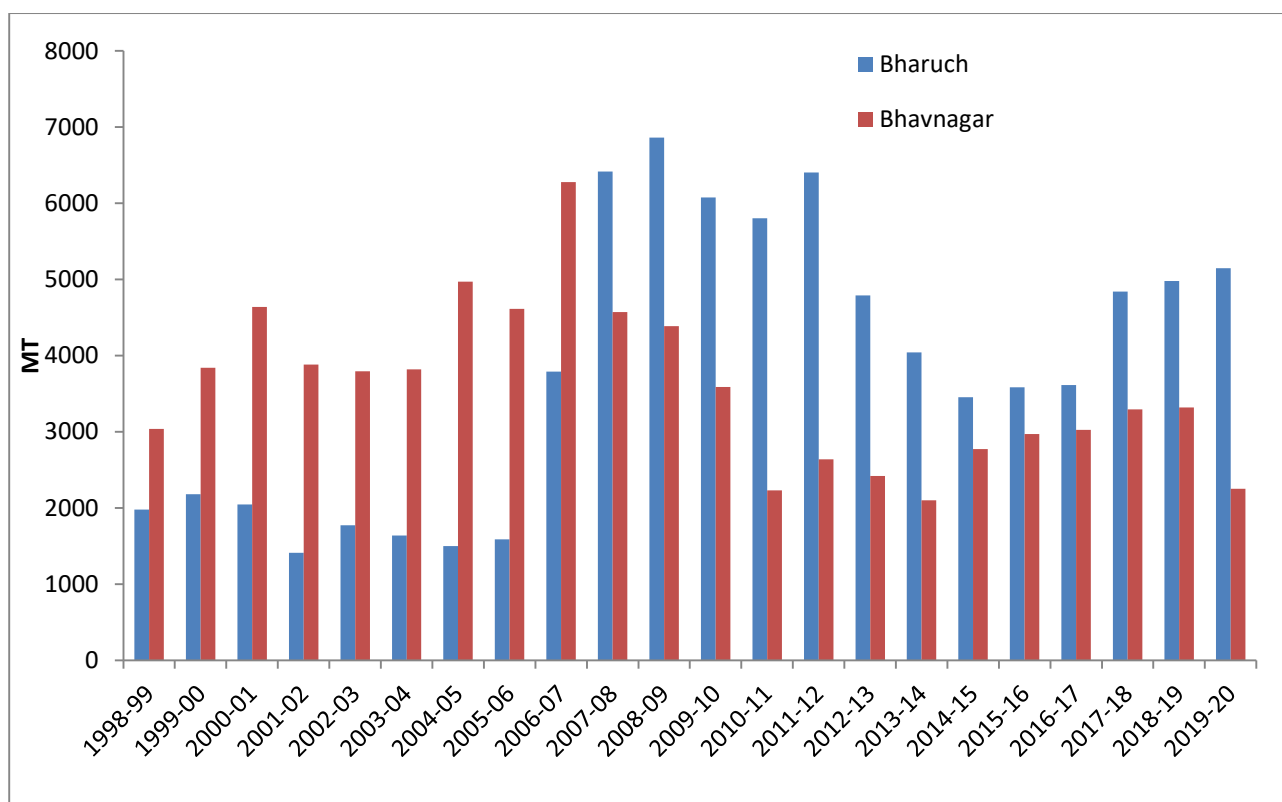


Fig. 5.4 Marine Fish production (MT) in Anand district from 1998-89 to 2019-20

Post dam construction the marine fish production will decline in Anand district. The marine fish catch downstream of Kalpasar project area will have production based on the flow of the fresh water maintained and pollution control measures taken. The area of marine fishing will be below the dam area and the behavior of tides needs to be assessed to understand the turbulence faced and the ability of the fishermen to reach out to the sea for fishing in the changed tidal regimes.

5.2 Primary Survey

The three major fish landing centers (Ghogha, Khambhat and Kavi) within the periphery of Gulf of Khambhat (GoK hereafter) were visited during the survey and the baseline information on the livelihood and dependency on the fishery resources by the fishing community was collected (Table 5.13).

Table 5.13: Demographic Profile of the Surveyed Fishery Villages and Landing Centers around the GoK

Districts	Fishery villages	Total Population	<i>Pagadiya</i>	by boat	Total
Bhavnagar	Ghogha*	12,208	175	400	575
	Kalatalav	1483	15	0	15

	Khetakhatli	220	12	0	12
	Ganeshgadh	1202	10	0	10
	Narbad	624	15	0	15
	Nava Madhiya	1949	12	0	12
	Jashvantpura	597	45	0	45
	Madhiya	1170	15	0	15
	Gundala	3155	13	0	13
	Kotada	3,279	45	0	45
Ahmedabad	Anadpur	661	15	0	15
	Bavdiyari	3010	17	0	17
	Bhangadh	2330	20	0	20
	Dholera	3,057	14	0	14
	Rahtalav	1,447	12	0	12
	Mingalpur	2,734	15	0	15
	Mahadevpura	1,412	15	0	15
	Zankhi	932	10	0	10
Anand	Khambhat*	99164	102	12	114
	Dhuvaran	8043	35	0	35
	Neja	1,981	17	0	17
Bharuch	Zamdi	1107	20	0	20
	Sarod	7854	12	0	12
	Kavi*	10428	180	200	380
	Degam	5802	20	0	20
	Muler	1,735	50	0	50
	Gandhar	2121	60	12	72
	Dahej	13495	65	0	65
	Suva	1920	68	10	78
	Ambheta	1552	22	0	22
	Luvara	1663	100	10	110
	Lakhigam	4938	70	2	72
	Paniadara	2563	70	0	70
	Kapuria	413	40	0	40
	Nada	2697	80	4	84
	Devla	4435	35	0	35
	Tankari	4415	30	0	30
	Total	2,17,796	1551	650	2201

*: Fish Landing Center

5.3 Results

The coastal belt around the Gulf of Khambhat has a substantial number of people belonging to the *Pagadiya* who are mainly involved in fishing from the estuarine and marine zones in the project influencing section. There are two common types of fishing method employed by the fishermen: 1) collecting the fishes and shell fishes by hand picking from the bottom sediment from the intertidal zone when the tide is out/low and 2) by deploying large stake nets / bottom set bag nets. A third method is using large gill nets or seines from boats, targeting the fishery resources from the central deeper areas of the Gulf by a few numbers of influential men in which the *Pagadiya* fishermen work as laborers.

It is important to note that there are substantial numbers of *Pagadiya* fishermen in the study area. These *Pagadiyas* sustain on fishing in the creek areas of the Gulf region. Ghogha taluka has the highest number of *Pagadiya* fishermen among the region followed by the Kavi area in the Bharuch district. The Ahmadabad taluka has small number of *Pagadiya* fishermen, and the dependency was generally on the mudskippers, crabs and mollusks as per the survey analysis.

The survey was conducted in 37 villages of the four districts, Bharuch, Anand, Ahmadabad and Bhavnagar with a total population of around 2,17,796 (Table 5.13). There are a total of 2201 fishermen engaged in fishing from the marine and estuarine zones within the Gulf of Khambhat of which the number of traditional fishermen using non-mechanized fishing gear or hand picking are predominant (1551). They predominantly depend on the collection of mudskipper, crabs and certain benthic fishes. Totally 650 men employed gillnets and other large nets for deeper waters for which they used boats. Out of the total population, an average of 1.01% people are engaged in fishing (Figure 5.5). This is represented by 1551 *Pagadiya* fishermen (Traditional) and around 650 fishermen who use fishing boats.

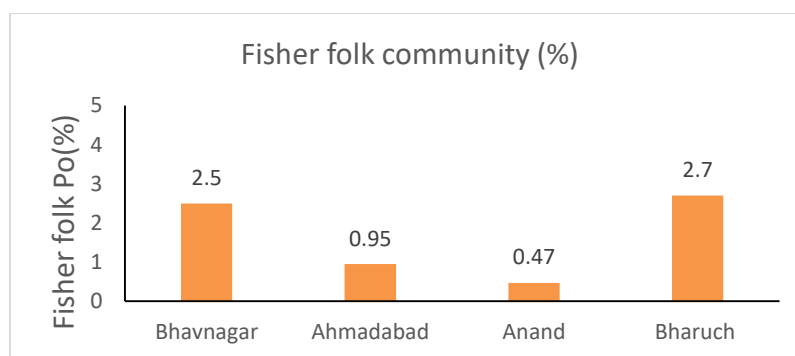


Figure 5.5: District Wise Fisher Folk Population (%) Around the GoK

5.3.1 Economics of fishing Activity

A baseline survey was conducted in three major fish landing centers viz., Khambhat, Ghogha and Kavi for obtaining information on the income of the fishermen from the three main types of fishing activity and to record the fishery resources available during the study period.

5.3.1.1. Khambhat Region

The details of the fishing activity, fishes caught, biomass and price of the different groups in the Khambhat fish landing center is presented in tables 5.14, 5.15 and 5.16. The average expenditure related to the fishing activity per day and the associated cost and income obtained are given in the Box 1. The results depicted that there were both fin and shell fishes representing the fish catch. Bombay duck and mudskipper are the dominant species within the fish catch (Annexure 1). The average amount of revenue earned was Rs. 2000-3000/ day /person (Table 5.14) based on the season. The income varies with the size of the fish and the species and total income generated per day varies with seasons.

Table 5.14. Catch Details (per boat) Using large Nets in the Gulf of Khambhat

Boats landed	No of Workers	Type of Fishery	No of Species	Approximate Weight/kg	Price/Kg	Total Price in Rupees
Boat 1	6	Fin fishes	9	40	100/-	4,000/-
		Shell fishes	4	210	120/-	25,200/-
Boat 2	7	Fin fishes	6	25	100/-	2,500/-
		Shell fishes	4	270	120/-	32,400/-
Boat 3	6	Fin fishes	10	55	100/-	5,500/-
		Shell fishes	4	230	120/-	27,600/-

Boat 4	6	Fin fishes	4	12	100/-	1,200/-
		Shell fishes	4	220	120/-	26,400/-
Boat 5	5	Fin fishes	11	38	100/-	3,800/-
		Shell fishes	4	235	120/-	28,200/-
Boat 6	6	Fin fishes	8	65	100/-	6,500/-
		Shell fishes	4	245	120/-	29,400/-
Total	36			1645		192,700/-

Box 1 – Average Expenditure and Associated Cost and Income Per Boat

Approximate Expenditure / Boat

Fuel/Boat (Diesel): 50 to 60L= Rs. 6000/-

Food/Boat: Rs.1000/-

Cold Storage /Boat (Ice): Rs.2000/-

Fishing Time (hrs.): 16-20

Average Income by Boat: Rs. 31200/-

Fisherman Salary Per Day: * Rs. 2000-3000/-

*Income Depends on the Catch, Varying by Season

The survey result indicated that the catch by the *Pagadiya* fishermen using stack nets in the estuarine sections of the project area was constituted by 2-5 species of finned or shellfishes. The average income per day estimated was Rs. 530/- during the survey in the present study (Table 5.15.). The income varies with seasons depending on the biomass of the catch and the size of the individual species.

Table 5.15. Income by *Pagadiya* fishermen through Stake Net fishing in Khambhat Region

Stake Net	No of Fishermen Involved	Type of Fishery	No of Species	Approximate Weight/kg	Price/Kg	Total Price in Rupees
1	1	Fin fishes	5	3.5	100/-	350/-
		Shell fishes	2	1.25	120/-	150/-
2	1	Fin fishes	4	3.6	100/-	360/-
		Shell fishes	2	1.7	120/-	204/-
3	1	Fin fishes	5	3.75	100/-	375/-
		Shell fishes	2	1.3	120/-	156/-
4	1	Fin fishes	5	4.1	100/-	410/-
		Shell fishes	2	1.3	120/-	156/-
5	1	Fin fishes	4	3.45	100/-	345/-
		Shell fishes	2	1.4	120/-	168/-

The list of the fish species caught using different methods is given in Annexure 1.

The Stack net fishing is done generally in the shallow estuarine area and where nets are laid at the bottom of the water column during the low tide and removed after the high tide recedes. The biomass of the fish caught was very less compared to offshore fishing and only 7 species of fishes were caught.

The fishing carried out by hand picking is also practiced by the *Pagadiyas* in which the fish, crab and shrimps trapped in the mud are collected manually during the low tide. In this method of fishing and the mudskipper species predominates as it is easy to catch by hand. The average income per day estimated was Rs. 705/person (Table 5.16). Mudskipper fishing is at its peak for three months after the monsoon and thereafter the catch declines. The present data was obtained during the peak of fishing the season in the month of January and afterwards the catch declines during the lean season and this impacts the socio-economic status of the fishermen.

Table 5.16: Details of fishing by Hand Picking in Khambhat Region

Fisherman	Type of Fish	Approximate Weight/Kg	Price/Kg	Total Price in Rupees
1	Mudskipper	5	160	800/-
2	Mudskipper	3.7	160	592/-
3	Mudskipper	4.2	160	672/-
4	Mudskipper	3.7	160	592/-
5	Mudskipper	3.8	160	608/-
6	Mudskipper	4.3	160	688/-
7	Mudskipper	3.9	160	634/-
8	Mudskipper	4.3	160	688/-
9	Mudskipper	5.5	160	880/-
10	Mudskipper	5.6	160	896/-

Annexure 1 - Fish Species Caught by The Different Fishing Techniques in Khambhat Region

Species name	Common name	Remarks	Boat (Large nets)	Stake Net	Hand picking
List of Fin fishes					
<i>Harpadon nehereus</i> (Hamilton, 1822)	Bombay duck	Very common	√	√	
<i>Boleophthalmus dussumieri</i> Valenciennes, 1837	Mudskipper	Very common	√	√	√
<i>Cynoglossus</i> sp.	Flat Fish	Very common	√	√	
<i>Eleutheronema tetradactylum</i> (Shaw, 1804)	Four finger threadfin	Very common	√	√	
<i>Chanos chanos</i> (Forsskal, 1775)	Milkfish	Very common	√		
<i>Arius jella</i> Day, 1877	Blackfin sea catfish	Very common	√		
<i>Lates calcarifer</i> (Bloch, 1790)	Barramundi or Asian sea bass	Very common	√		
<i>Otolithoides biauritus</i> (Cantor, 1849)	Bronze croaker	Very common	√	√	
<i>Otolithoides</i> sp.	Croaker	Very common	√		
<i>Brevitrygon walga</i> (Müller & Henle, 1841)	Scaly whipray	Common	√		
<i>Scoliodon laticaudus</i> Müller & Henle, 1838	Spadenose shark	Rare	√		
List of Shell Fishes					
<i>Metapenaeus dobsoni</i> (Miers, 1878)	Kadal shrimp	Very common	√	√	
<i>Metapenaeus monoceros</i> (Fabricius, 1798)	speckled shrimp, brown shrimp and pink shrimp	Very common	√	√	
<i>Mierspenaeopsis sculptilis</i> (Heller, 1862)	Rainbow shrimp	Very common	√		
<i>Penaeus indicus</i> H. Milne Edwards, 1837	Indian prawn	Very common	√		

5.3.2. Ghogha Region

It is one of the largest fish landing centers in the Gulf of Khambat where large number of fishermen are involved in fishing from the inshore and offshore areas. The fish catch as per the boat in the offshore area at Ghogha showed that the average income per trip is Rs. 1500 to 3000/- and varies based on the season (Table 5.17). During the survey Whip ray (*Maculabatis bineeshi*, Manjaji (Matsumoto and Last, 2016), an endemic and threatened species, landed was recorded. The average income earned by *Pagadiya* fishermen through stack net operation during the high tide was approximately Rs 402/- at the time of the present study (Table 5.18). The details of the expenditure per boat in the Ghogha region (Bhavnagar) is given in the Box 2. The checklist of fishes recorded from Ghogha region is given in Annexure 2.

Table 5.17: Fish Landing at Ghogha (Bhavnagar) as per the boat catch

Boats Landed	No of Workers	Type of Fishery	No of Species	Approximate Weight/kg	Price/Kg	Total Price in Rupees
Boat 1	6	Fin fishes	6	29	140/-	4060/-
		Shell fishes	4	160	120/-	19,200/-
Boat 2	7	Fin fishes	8	55	140/-	7700/-
		Shell fishes	4	180	120/-	21,600/-
Boat 3	6	Fin fishes	4	45	140/-	6300/-
		Shell fishes	4	170	120/-	20,400/-
Boat 4	6	Fin fishes	7	45	140/-	6300/-
		Shell fishes	4	155	120/-	18600/-
Boat 5	5	Fin fishes	6	21	140/-	2940/-
		Shell fishes	4	135	120/-	16200/-
	Total		13	1645		123,300/-

Box 2

Expenditures Approximately/ Boat

Fuel/Boat (Diesel): 40 to 50L= Rs. 5000/-

Food/Boat: Rs. 1000/-

Cold Storage /Boat (Ice): Rs. 1200/-

Fishing Time (hrs.): 14-18

Average Income by Boat: Rs. 31200/-

Fisherman Salary Per Day: * Rs. 1500-3000/-

*Income Depends on the Catch, Varying by Season

Annexure 2: Fish species caught by the different fishing techniques in Ghogha

Species name	Common Name	Remarks	Boat(Large nets)	Stake net	Hand picking
Fin Fishes					
<i>Harpadonnehereus</i> (Hamilton, 1822)	Bombay duck Fish	Very common	√	√	
<i>Cynoglossus</i> sp.	Flat Fish	Very common	√	√	
<i>Eleutheronematetractylum</i> (Shaw, 1804)	Four finger threadfin Fish	Very common	√	√	
<i>Arius jella</i> Day, 1877	Blackfin sea catfish	Very common	√		
<i>Lates calcarifer</i> (Bloch, 1790)	Barramundi or Asian sea bass	Very common	√		
<i>Otolithoides biauritus</i> (Cantor, 1849)	Bronze croaker	Very common	√		
<i>Otolithoides</i> sp.	Croaker	Very common	√	√	
<i>Brevitrygon walga</i> (Müller & Henle, 1841)	Scaly whipray	Common	√		
<i>Maculabatis bineeshi</i> Manjaji-Matsumoto & Last, 2016	Whip ray	Rare (Endemic to Gujarat)	√		
<i>Scoliodo nlaticaudus</i> Müller & Henle, 1838	Spadenose shark	Rare	√		
<i>Boleophthalmus dussumieri</i> Valenciennes, 1837	Mudskipper Fish	Very common			√
Shell fishes					
<i>Metapenaeu sdobsoni</i> (Miers, 1878)	Kadal shrimp	Very common	√	√	
<i>Metapenaeus monoceros</i> (Fabricius, 1798)	speckled shrimp, brown shrimp and pink shrimp	Very common	√	√	
<i>Mierspenaeopsis sculptilis</i> (Heller, 1862)	Rainbow shrimp	Very common	√		
<i>Penaeus indicus</i> H. Milne Edwards, 1837	Indian prawn	Very common	√		

Table 5.18. Details of stake net fishing by *Pagadiya* Fishermen in Ghogha

<i>Pagadiya</i> Fishing Net	No of Fisherman's Involved	Type of Fishery	No of Species	Approximate Weight/Kg	Price/Kg	Total Price in Rupees
1	1	Fin fishes	5	5	100/-	500/-
		Shell fishes	2	2	120/-	240/-
2	1	Fin fishes	4	6	100/-	600/-
		Shell fishes	2	2.5	120/-	300/-
3	1	Fin fishes	5	5.5	100/-	550/-
		Shell fishes	2	2	120/-	240/-
4	1	Fin fishes	5	4.5	100/-	450/-
		Shell fishes	2	2.5	120/-	300/-
5	1	Fin fishes	4	6	100/-	600/-
		Shell fishes	2	2	120/-	240/-

The average income of *Pagadiya* fishermen through hand picking of fishes and other marketable species was Rs. 784/- which is higher when compared to Khambhat region (Table 5.19). The species collected through the hand picking comprises of the mudskippers and mud crab.

Table 5.19. Details of catch and income of Hand Picking by *Pagadiyas* in Ghogha

<i>Pagadiya</i> Fisher Man/	Type of Fishery	No of Species	Approximate weight/kg	Price/kg	Total Price in Rupees
1	Mudskipper	1	6	160	960/-
2	Mudskipper	1	5.5	160	880/-
3	Mudskipper	1	4	160	640/-
4	Mudskipper	1	5	160	800/-
5	Mudskipper	1	4.5	160	720/-
6	Mudcrab	1	2	300	600/-
7	Mudcrab	1	2.5	300	750/-
8	Mudcrab	1	2.8	300	840/-
9	Mudcrab	1	2.6	300	780/-
10	Mudcrab	1	3	300	900/-

5.3.3. Stations in the estuarine zone of major rivers that drain into the Gulf of Khambat

Sarthanpur (Kavi) fishing village was considered for recording the fish catch and economic analysis, as it lies outside the proposed Kalpasar dam enclosure. In this village the fishermen earned an average of Rs 1500-2500/- based on the fish catch composition (Table 5.20). The amount varies from season to season based on the catch biomass and the species caught. Even though, this station lies on the interior estuarine segment of the Gulf area, few specimens of scaly whip ray, whip ray and Spade nose shark were observed at the time of the study. The Spade nose shark is categorized as rare species by IUCN list.

Table 5.20. Details of fish catch by boats at Sarthanpur (Kavi)

Boats Landed	No of Workers	Type of Fishes	No of Species	Approximate Weight/kg	Price/Kg	Total Price in Rupees
Boat 1	6	Fin fishes	9	50	100/-	5,000/-
		Shell fishes	4	160	120/-	19,200/-
Boat 2	7	Fin fishes	6	46	100/-	4,600/-
		Shell fishes	4	210	120/-	25,200/-
Boat 3	6	Fin fishes	10	60	100/-	6,000/-
		Shell fishes	4	220	120/-	26,400/-
Boat 4	6	Fin fishes	4	40	100/-	4,000/-
		Shell fishes	4	230	120/-	27,600/-
Boat 5	5	Fin fishes	11	55	100/-	5,500/-
		Shell fishes	4	180	120/-	21,600/-
Boat 6	6	Fin fishes	8	52	100/-	5,200/-
		Shell fishes	4	140	120/-	16,800/-
Total	36			1443		167100/-

The fish catch by *Pagadiya* fishermen through stack net includes both shell and fin fishes. The average income earned was Rs. 534/- during the present survey (Table 5.21). The figures are likely to change during the other seasons. On the other hand, the details of fish catch by hand picking and the income received by the *Pagadiya* fishermen at Sarthanpur was approximately Rs. 870/ (Table 5.22). The profit from the fish catch by hand picking is comparatively high and it depends on size and the demand in the market also.

Table 5.21 Catch composition and revenue of stack net fishing by *Pagadiya* fishermen at Sarthanpur

Stake Net	No of Fishermen	Type of Fishery	No of Species	Approximate Weight/Kg	Price/Kg	Total Price in Rupees
1	1	Fin fishes	5	3.5	100/-	350/-
		Shell fishes	2	1.25	120/-	150/-
2	1	Fin fishes	4	3.6	100/-	360/-
		Shell fishes	2	1.7	120/-	204/-
3	1	Fin fishes	5	3.75	100/-	375/-
		Shell fishes	2	1.3	120/-	156/-
4	1	Fin fishes	5	4.1	100/-	410/-
		Shell fishes	2	1.3	120/-	156/-
5	1	Fin fishes	4	3.45	100/-	345/-
		Shell fishes	2	1.4	120/-	168/-

Table 5.22. Details of fish catch by Hand Picking at Sarthanpur

Number of persons	Type of Fishes	No of Species	Approximate Weight/kg	Price/Kg	Total Price in Rupees
1	Mudskipper	1	5	160	800/-
2	Mudskipper	1	6	160	960/-
3	Mudskipper	1	8	160	1280/-
4	Mudskipper	1	6	160	960/-
5	Mudskipper	1	5	160	800/-
6	Mud crab	1	2	300	600/-
7	Mud crab	1	2.5	300	750/-
8	Mud crab	1	3	300	900/-
9	Mud crab	1	2.5	300	750/-
10	Mud crab	1	3	300	900/-

The data on the interview /interactions conducted with the selected fishermen on the quantity of fish catch from the different methods of fishing, expenditure incurred and the profit, the average income per person was calculated. To summarize, the interaction with the fishermen in all the 37 villages surrounding the Gulf of Khambhat indicated that currently the average fish catch per fisherman was estimated as 3.76 kg/day (Fig. 5.6). Thus, the average income was estimated to be Rs. 453.2/day/fisherman of the surveyed villages. Based on the data generated, the average monthly income of the fisherman was estimated Rs. 9,064 (based on the involvement of approximately 20 days/month in fishing) in the surveyed villages. While, the average monthly per capita income of India is Rs. 10974/-. Thus, the fishermen earn less compared to the average

monthly income of India and need to be considered as families under Below Poverty Level (BPL). The income of fishermen in the other districts are comparatively less (Fig 5.7)

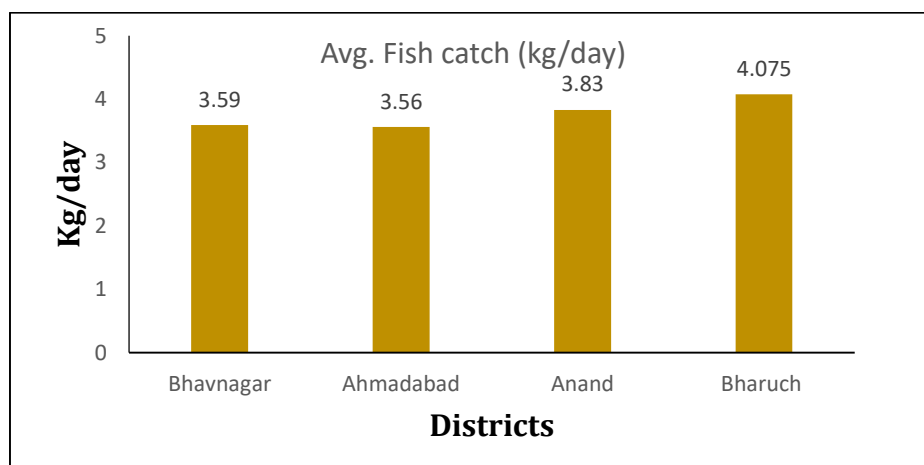


Figure 5.6: District wise Fish catch per fisherman around the GoK

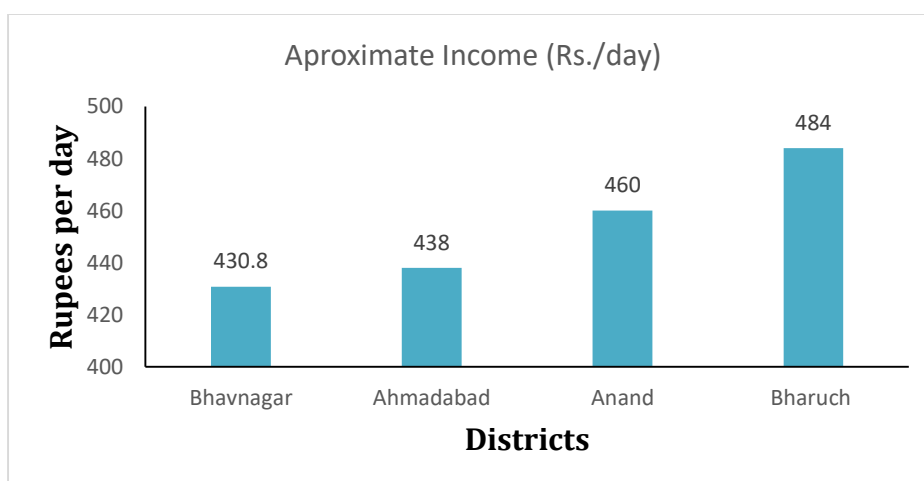


Figure 5.7: District wise fisherman income around the GoK

The average income of the area was estimated Rs. 4,96,108/day from Gulf of Khambhat based on the surveyed village and sample size which amounts to approximately Rs. 23 Crores/Year. On the other hand, these fishermen populations have to sustain the impact of climate change in the form of cyclones and western disturbance sea level rise when they cannot venture into the sea. There are some aquaculture farms and the fishermen work as laborers. Few have marine aquaculture farms and earn around Rs. 25000/pond/month when the production in full swing after seeding. The average revenue generated is Rs. 3 Crores based on approximately 1200 cultivation ponds present in the entire GoK.

To sustain their families, the fishermen during the off season of fishing that is in the month of May to August, migrate to nearby towns and work as daily wagers. During this time the children and women are left behind in the villages and only the men migrate out of the village.

5.3.4. Impact on *Pagadiya* fishermen

Based on Socio-economic survey of coastal villages (37) of project area, it is highlighted that 77% of fisher folk community are *Pagadiyas* and have low income through fishing activity. The fish catch in the estuaries have reduced and time has come to find other livelihood option for their sustenance. The fishermen who own boat have some income and only 23% of the fishermen have the same. Thus, the *Pagadiya* fishermen need to adopt to the alternate fishing options and extensive training is required to bring them to the new fishing techniques.

5.4 Benefits on the Closure of Gulf of Khambhat Region on Biodiversity and Fisheries

India has an extensive coastline of 7517 km of length, of which 5423 km is in Peninsular India and the EEZ is extending over 2.02 million km² (WII 2014). The coastline supports a huge human population, depending on the rich coastal and marine resources (WII 2014). Nearly 25 crore people living within the 50 km width along the coastline of India (UNDP, 2012). Therefore, the ecological services of the marine and coastal ecosystems of India play a vital role in sustaining India's economic growth (Sivakumar *et. al.*, 2012). The construction of dam across rivers is the common solution to store water and recently storage of water at the coastal environments is getting popularity with the advancement of engineering technology. The proposed dike on the Gulf of Khambhat just below the confluence of the important rivers such as Mahisagar, Dhadhar and Sabarmati is aimed primarily to store the freshwater discharges from the rivers for the multiple uses. The land-based water reservoirs like dams have various advantages, however, there are a number of disadvantages too like land acquisition, clearing of forest area, loss of biodiversity, submergence of land and forests, diversion works during construction, etc. In this context it is appropriate to find alternate means of freshwater storage for its multipurpose use for long term even though there are certain ecological consequences in the coastal environment as well as its dependent communities. There are several examples of successful construction and use of

reservoirs in the coastal zones like the estuaries and gulf environments where the rivers merging into the sea supplying the fresh water. The availability of freshwater into the coastal ecosystems is inevitable for the sustenance of several species of fauna and flora and the nutrient cycling, however, this requirement can be met by providing provision for measured or regulated quantum of flow on a regular basis as well as whenever flood situation arises in the lower reaches of the reservoir.

5.4.1. Benefits of Fisheries

5.4.1.1. Culture of Estuarine Fishes and Shell Fishes

During the initial phase of the construction of the dike at the Gulf segment will be transformed to a brackish water status which is suitable for adoption of culture of euryhaline food fishes like seabass, milk fish, pearl spot and mullets etc. This less saline water can be beneficial for initiating the culture of shrimps, prawns and bivalve mollusks in the cages. Crab fattening is a lucrative business carried out in estuaries using net cages as well as land based impoundments closed to the mangroves and abandoned salt pans and fish culture ponds. There is scope for this type of farming as there are mangrove environments which are the major collection centers for the commercially important species such as *Scylla serrata* and *Portunus pelagicus* and so on. This activity can be taken up by the fisher folk in the mangrove and adjoining sections as long as the salinity of the water remains optimum for these crabs.

5.4.1.2. Fresh Water Fish Culture

The present scenario of the capture fisheries from the Gulf of Khambhat and the adjacent regions including the estuaries is relatively lower (*Catch per unit effort*) than the other coasts of Gujarat. Presently there are only subsistence level fisheries activities carried out by the backward and unskilled fisher-folk. The creation of a huge fresh water reservoir would open up avenues for farming of estuarine fish, prawn/shrimp and bivalves. With the creation of large fresh water regime (2000 Sq.Km.in area) the Kalpasar Project would enhance Inland fisheries, the riverine and the reservoir sector, augmenting the fishery potential of the State and developing the economy of the area of this project. Fresh water fish farming will be boosted in the suitable segments in the reservoir as well as the river or in the hinter land of the Gulf of Khambhat wherever water resources are available, with the seeds of Indian major carps, cat fishes and Tilapia. The tilapia species are generally considered as invasive in India since long back

its introduction in 1960. At present the Genetically Improved Farmed Tilapia (GIFT), is one of the important candidate species for aquaculture in India and is being successfully produced, consumed and marketed. This species takes only 6 months to reach to 600-900 gm size from 50-80 gm size while stocking providing small-scale farmers with an income and households with a sustainable source of food and nutrition. Through selective breeding program that began in 1988, the GIFT strain was developed to be fast growing and adaptable to a wide range of environments. The Nile tilapia *Oreochromis niloticus* and GIFT can be recommended for farmers who follow responsible fish farming, not allowing them to enter into the natural water bodies. Since these fishes grow faster and adaptable to varied salinity, have good disease resistance, in the states like Kerala and Tamilnadu GIFT tilapia farming is practiced using genetically improved all male population in bio-secured ponds commercially. The Steering Committee at National level under Ministry of Agriculture (MoA), Govt. of India, oversee and monitor the tilapia seed and grow-out along with the State fisheries department on Tilapia farming as they are very much prolific in natural environmental conditions. Rajiv Gandhi Centre for Aquaculture (RGCA), the R&D arm of MPEDA, is engaged in the large scale production of this species and providing assistance to the farmers of GIFT farming and involved in formal breeding program to further improve its genetic performance within the local environment. However, for small scale farming this species is very much profitable than carps, provided the farmers should be more responsible for protecting them. In Southeast Asian Countries, its farming has brought prosperity to the farmers besides augmenting production for domestic consumption as well as exports. GIFT has become popular in Bangladesh and Sri Lanka with no reported adverse impacts (ADB, 2005).

The carps and cat fishes are cultured in net enclosures installed inside the reservoir and rivers or in land-based ponds and tanks following semi-intensive principle which is more advantageous. In this regard extensive training and awareness creating campaign would be undertaken during the transformation period of this project by the responsible departments and government agencies so that beneficiaries develop confidence and will be equipped technologically and financially to take up fish farming.

The Indian major carps (*Labeo rohita*, *L. calbasu*, *L. fimbriatus*, *Cirrhinus mrigala*, *Catla catla*) and the cat fishes are popularly cultured in reservoir on cages as well as their

wild population is enhanced through regular ranching of the fingerlings of them in the freshwater systems. There are a number of indigenous fishes (*Cirrhinus cirrhosa*, *C. reba*, *Labeo kontius*, *L. bata*, *Puntius sarana*, *P. dubius*, *P. carnaticus*, *P. kolus*, *P. dobsoni*, *P. chagunio*, *Schizothorax plagiostomus*, *Thynnichthyes sandkhol*, *Osteobrama vigorsii*), Air breathing catfishes (*Heteropneustes fossilis*, *Clarias batrachus*) and Murrels (*Channa marulus*, *C. grooves*, *C. punctata*, *C. gachua*) which grow in the lotic and lentic systems are commercially important. The state fisheries can involve in the fish culture and hatchery production of the fish seeds and take up extension services to the stakeholders towards fish culture and marketing. A list of commercially important fish species that are captured from Gulf of Khambat is given in Annexure 3.

5.4.1.3. Fresh Water Mussel Culture

When the reservoir transforms into truly fresh water system, culture of other indigenous food fishes and fresh water mussels can be introduced so that the income from fish farming can be augmented as well as the employment scope will be increased. As of present day scenario, the ready market for fresh water mussel is low and options needs for preservation and value addition can be included. Cultured pearls have an important place in international trade and also in the national market. The ICAR-Central Institute of Freshwater Aquaculture (CIFA), Kausalyaganga, Bhubaneswar, India, has created a base technology for cultivating pearls in freshwater habitats, recognizing the scope and value of freshwater pearl production. Indian pond mussel, *Lamellidens marginalis* is the major species used in freshwater pearl aquaculture. ICAR-CIFA has taken the lead in disseminating freshwater pearl culture technology to the country's fish farming communities, entrepreneurs, researchers, to build a sustainable model for the country's socio-economic development (Sourabh *et al.*, 2021). Under the Unionidae family i.e., *L. marginalis*, *L. corrianus* and *Parreysia corrugata* are commercially cultivated for pearl production in India (Sourabh *et al.*, 2014).

5.4.1.4. Fish and Shellfish Hatcheries for Seed Production

The inland fish culture is dependent on the supply of quality fish seeds/fingerlings at the appropriate seasons for stocking in the controlled systems like tanks and cages as well as to augment the natural stock in the water bodies. It is very much necessary to enhance the wild stocks of these commercially important species through ranching programs so that the livelihood of the fishermen depending on the natural population

will be sustained. In order to meet the demand for seeds from the culture and capture sector, hatcheries to be established nearer to the culture sites and the required infrastructure facilities are to be established. The project would facilitate advancement of the capture and culture fisheries sectors through the proper and sincere interventions from the State department of fisheries and Central government institutions through effective extension education and technological dissemination efforts to support the fishermen community.

5.4.1.5. Fish Processing Centers and Market

There has been a substantial increase in the price of fish and the new developmental phase in the inland fisheries sector will boost up the market potential of the cultured fishes. The fish processing centers produce variety of high-quality products for the domestic consumption as well as export for high income. There is ample scope for employment in this business. The Governmental agencies have already developed various types of infrastructure for the effective fishery operations, fish handling, storing and packing and so on in the state, however, more such establishments are to be planned and implemented in the surrounding areas of Kalpasar project.

5.4.1.6. Fishing Gear and Craft Manufacturing and Maintenance

At present the fishing activities in the gulf of Khambhat as well as in the rivers, by the fishermen are simply subsistence oriented by making use of the traditional gears and basic fishing tools and with limited facilities or infrastructure for handling and marketing/vending the small size catch. The small-scale fishing operations are not sufficient for the fishermen to satisfy their basic needs. There is scope for development of the fishing gear production units and supply of materials and allied business centers in the project area to support the fish culture and capture activities and thereby promote the livelihood status of the people.

5.4.1.7. Development of Ornamental Fish Production and Trade

The ever-increasing demand for aquarium fishes has paved the way towards opportunities for large scale employment for small scale farmers through commercial production of fresh water indigenous ornamental fish and their export. It can be practiced in rural as well as in urban areas and women are also involved in rearing and

culture of different indigenous and exotic ornamental fish. Many freshwater species can be collected from the rivers and reared for this activity.

5.4.1.8. Recreational Fishing and Ecotourism Promotion

Recreational fisheries can play a major role in promoting the socio-economic conditions of the population in the coastal and inland areas, surrounding the project area. The government can plan to have more ecotourism spots in the project areas which are suitable for establishing recreational fishing, boating and resorts serving fish food can boost the inland fishery sector in many ways and also this will create employment for the rural and urban people.

5.4.1.9. Alternative livelihood

Aquaponics: Aquaponics is the integration of hydroponics with aquaculture in a recirculating system, where the wastes and metabolites produced by cultured fish are removed by nitrification and taken up by the plants (El Sayed, 2020). Aquaponics is an emerging type of aquaculture that uses the natural interaction between bacteria, fish and plants to transform waste into clean water. Aquaponics is an integrated approach to efficient and sustainable intensification of agriculture that meets the needs of water scarcity initiatives. It has become a popular technique because of its similarities to natural ecosystem, where the only difference is that it is a controlled system. This system is suitable for year-round farming and can produce high-quality vegetables at a much higher yield rate. Vegetables grow at a much faster rate using this technique, compared traditional farming techniques. Aquaponics takes place in a closed system and there is no discharge of waste into the stream. This system produces up to 30% more production compared to traditional farming using the same amount of space. This system requires less water compared to traditional farming (Figure 5.8).

Aquaponics can be used on non-arable lands such as deserts, degraded soil or salty, sandy islands but requires deep expertise in the natural world. In order to be successful, farmers need to have knowledge not only on growing vegetables but also on how fish and bacteria work. And technical skills regarding plumbing or wiring are also needed. A system of trained manpower to run the aquaponics can be created as the new generation of fishing community has exposure to education and are better placed

compared to their parents. The corporate sector can pick up this opportunity as challenges in the land-based activity is always there.

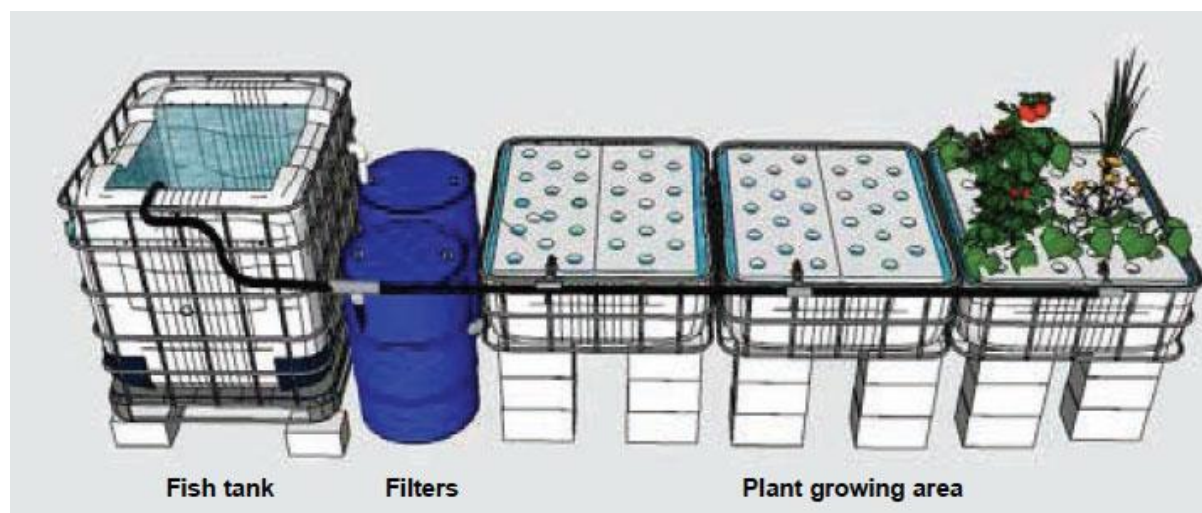


Figure 5.8: Flow diagram showing the intertwined structure of Aquaponics system

All these activities should be considered after conducting extensive feasibility study for each of the anticipated locations considering the socio-economic situation and the community's interest.

5.5 Impact on Hilsa Fishery

Hilsa has a prominent economic, cultural and ecological implication. It is a marine fish that migrates upstream and arrives in the brackish water of the Narmada estuary near Bharuch for spawning usually during the monsoon months of July and August and continues doing so till November. Hilsa (*Tenualosa ilisha*) migrates from the Arabian Sea to the freshwater habitats in the Narmada River for reproduction and population growth. This species was once the major fish of the Narmada River. However, after the formation of the Narmada dam, a steady decline was observed in the population. Instead of moving up to 160 km upstream, the brood-stock of Hilsa only ascended to 110 km and breed within 100 km of the Gulf of Khambhat (Bhaumik *et al.*, 2017). Currently, the fishing grounds have shifted downwards to the Gulf of Khambhat, where about 90% of the catch is now harvested. It was noted that the annual catch of Hilsa fluctuated and higher catches concurred with high floods in the river. This species has shown a decline from 2006-07 onwards to 2014-15 along the Narmada estuary (Fig. 5.9). The production has reduced owing to the operation of the Narmada dam (138 m) and lowering down of the flow in the river. The lack of controlled discharge has adversely affected the migration of Hilsa in turn declining their abundance in the river. Variations in the

salinity configurations and continuing shrinkage of freshwater habitats have cumulatively affected the survival of this species. As a consequence, prices have inflated and availability has lowered. Due to this, the volume of consumption has reduced considerably over time. However, the demand for Hilsa has not fallen.

Unfortunately, there is no domesticated Hilsa brood-stock currently available (Sahoo *et al.*, 2016). Thus, current Hilsa culture efforts depend entirely on wild caught brood-stock for artificial breeding. Therefore, integrated multidisciplinary collaborative research approaches need to be adopted to optimize the Hilsa brood-stock husbandry on a priority basis. Hence, aquaculture may provide a partial alternative to Hilsa capture fisheries, with the potential to generate incomes and improve the fish's accessibility to masses. Recently, Kumar *et al.*, 2019., reported the investigation of the chronological developmental stages during ontogeny and organogenesis of Hilsa, (*T. ilihsa*) which may provide useful insights to the artificial propagation of this species.

Consumptive uses of river water are increasing rapidly and cannot be replaced unless suitable alternative sources are found. Given this situation, it is imperative to develop and implement effective measures for the conservation of available riverine resources, as well as the river's productivity and production functions. There is a need to improve and conserve the river water resources for the protection of the natural flora and fauna through the restoration of their habitats. Natural basin characteristics should not be altered, in view of their important role in providing necessary breeding and feeding habitats for a number of commercial species. The production trend of Hilsa in the Narmada estuary (2006-07 to 2014-15) has been given in Fig. 5.9.

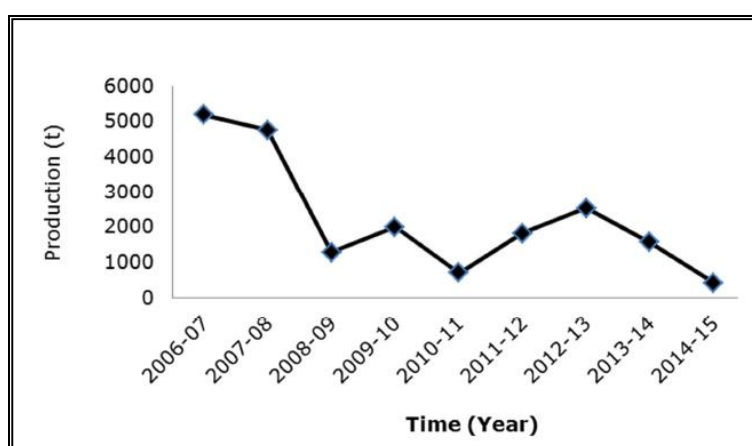


Figure: 5.9 Production trend of Hilsa in Narmada estuary
Source: Bhakta et al., (2018)

However, after construction of Kalpasar dike, the production of Hilsa will further decline as the sea water intrusion will be more into the river channel due to lateral rise in the sea water. This will shift the existing estuarine zone further inside the river channel and this will affect the breeding of Hilsa which migrates from sea into the river for laying eggs. Absence of adequate freshwater zone will impact its breeding and the species might migrate to other estuaries downstream of Narmada

5.6 Salt Pans

The salt pans in the area of Gandhar, Paniyadra, Jambusar and Khambhat will be affected (Table 5.23 and 5.24). However, the leases of these salt pans are not renewed after 2012 in this area. The activity of salt pans is low and already has shifted towards Little Rann of Kachchh or towards Bhavnagar side. Therefore, the impact on salt pans will be minimal within the enclosure area.

Table 5.23: Important salt pan areas across the districts of interest along the Gulf of Khambhat (2011)

Sr.No.	Name of the area	Number of salt pans	Salt production in Metric Tons
1	Gandhar	15	2,76,300
2	Dahej (Aladar)	25	7,46,600
3	Hansot	7	52,500
4	Paniyadra	5	71,000
5	Jambusar	28	3,54,200
6	Khambhat	2	25,000
7	Pipli-Dholera-Bhavnagar	41	17,03,854
	Total	123	32,29,454

CSMCRI (2011)

Table: 24 Number of salt plans and tentative area of operation of the salt pans in the taluka of Gulf of Khambhat

Taluka	Ha
Within proposed Kalapar dam	
Gandhar	2279.19
Paniyadra	310.39
Jambusar	3444.68
Khambhat	687.96
Outside Reservoir proposed Kalapar dam	

Dahej	3735.65
Hansot	614.71
Piple-Dholera-Bhavnagar	13365.15

CSCMRI (2018)

Table 5.23 & Table 5.24 represents the important salt pan areas across the districts of interest along the Gulf of Khambhat (2011), (2018) and the overall salt production of these important districts over the period of years (Table 5.25) respectively. In general, the overall salt production has decreased in Anand and Bhavnagar districts.

However, Bharuch district has witnessed an increase in the salt production during the same year (2018-2019). Interestingly, as per a study conducted by Chandra *et. al.*, in 2020, the overall area in hectares covered by the salt pans has increased for both the districts viz; Bhavnagar as well as Anand when compared to that in 2015 (Table 5.26).

Table 5.25: Important districts w.r.t. salt production along the Gulf of Khambhat

SALT PRODUCTION IN GUJARAT STATE (TONS)							
District	2014-15	2015-16	2016-17	2017-18	2018-19	% in 2018	% Change
Anand	45	21	53	3	0		
Bharuch	2149	1932	2663	2377	2492	10.2	16
Bhavnagar	2963	3302	2936	3325	3077	12.6	3.8
TOTAL	5157	5255	5652	5705	5569		

Table 5.26: District wise changes in the salt pan area along the Gulf of Khambhat

SALT PAN AREA IN THE COASTAL DISTRICTS OF THE GUJARAT STATE USING SATELLITE DATA						
District	2015	2020	% of state 2020	change		
	ha	ha		ha	%	
Anand	3108	5603	3	2495	80.3	
Bharuch	18850	18360	10	-490	-2.6	
Bhavnagar	16715	21650	12	4935	29.5	
TOTAL	38673	45613				

The salt pan area that would be affected in the upstream is estimated around 17.86 sq km. However, the salt pan area present in the downstream that would be affected post

dam construction is estimated to be 194.80 sq km. These salt pans extract ground water for salt production and have less dependency on the sea water.

Rough estimate indicates that there are about 1100 salt pan workers in the area. The workers come from the nearby villages and there are no permanent settlements in the salt pan area. The salt pan work remains closed in the monsoon period from June to September.

Post dam construction the area under submergence along the downstream needs to be marked. The salt pans which are close to the sea or the estuaries will be submerged and will have to cease the operations. Hence, a study mapping the submergence of areas downstream needs to be undertaken to effective understanding of impact of salt pans downstream.

5.6.1 Salt Production

- Total Salt Production in Gujarat: (2010-11): 145.16 lakh metric tons
- Total Salt Production in Gujarat: (2015-16): 276.43 lakh metric tons
- Total Salt Production in Gujarat: (2018-19): 233 lakh metric tons
- Gulf of Khambhat (2019): 24% of the total salt production of Gujarat.

5.7 Habitat Restoration Through Plantation Programs

The construction of dike will lead to water storage and alteration of the present water level and will lead to habitat alteration also. The new area will be developed for vegetation growth. During the operation phase the land recovered will be utilized for various purposes and in the initial phases with high salinity the species selection becomes important for habitat restoration. The existing mangroves will be closer to the waterbody and the intertidal and supra tidal mangroves might be lost. The riverine stretches will attract the freshwater species and in the brackish water region the salinity tolerant grass species may appear. The plant species which can survive in medium saline soil should be preferred for plantation. The fast-growing plant species like *Neem* and *Acacia* might be preferred. Near the water-logged areas species of *Fimbristylis*, *Salvadora*, *Casuarina* may be preferred whereas in the nearby areas species such as *Phragmites*, *Chloris barbata*, *Halopyrum mucronatum* can be transplanted. The fresh water marshy plant *Heritiera fomes* which survive in water logged areas having

salinity ranging from 8-10ppt, especially in the Sundarbans, known as the Tidal Forest. This species is now on the brink of extinction in Indian Sundarbans due to overcutting and increased salinity.

A list of species which could be recommended for plantation is indicated herewith. The freshwater mangroves are the trees from *Barringtonia* genus of Lecythidaceae family can be grown. *Barringtonia acutangula* is native to Indian and Australian coastal wetlands. It is generally available from Afghanistan east to the Philippines and Queensland of Australia. In India, it has medicinal importance from ancient times. In Sanskrit, *Barringtonia* is called Hijja or Hijjala, and it has many names in Indian languages such as Pichul, Nichul, Abja, Adal, Neora, Injar, Jujar, Panniari. This is also known as samundar-phal (sea-fruit) tree and known as Indian Oak too in various locations. *Barringtonia acutangula* is one of the common species of freshwater mangroves, shows strong aromatic tiny red flowers. They can attract insects from long distance at their blooming time in spring. As these plants generally grow on the banks of the rivers and play important role in the ecosystem. Even the fallen flowers attract to various birds, bees and butterflies. Its domestic medicinal uses also titled it as a 'nurse's fruit'. A few people use its root in place of quinine. However, as it is also known as fish killer tree, its bark can be used for stupefying fish in fishing activities. It also can show the tanning properties and can be utilized as a tan. Although the habitat of these freshwater mangroves is generally the banks of streams, in moist places and wetlands, it can easily adapt to variety of soils and cultivated as a ornamental trees. This plant can grow as a big tree about 8–15 m high, with thick, smooth and oval leaves of 8–12 cm long and 4–5 cm wide. The younger leaves can be consumed as food, with other vegetables in a few countries.

Coconut and its tree also known as Shriphal and Kalpavrikshya respectively in India for its religious importance. It can grow in various climates, soil conditions and wide range of distribution of rainfall in Indian coastal areas. In last decade the coconut farmers and production of coconut in Gujarat is tremendously increased because the farmers in coastal areas are facing the problem of salinity ingress, which is favorable for the coconut farming. As Gujarat has higher potential for plantation and production of coconut due to largest coastal line in country and favorable climate. The coconut palms flourish well close to the seashore on the high tide level where there is circulating

ground water and ample rainfall. There are different varieties of coconut palms which can tolerate varied soil characteristics and climatic conditions. They survive in coastal sandy soil and reclaimed soil having pH ranging between 5.2 to 8.0. Recently the coconut development board, Govt of India, under Ministry of Agriculture has opened zonal office in Bhavnagar, Mahuva, and Junagadh for promotion coconut plantation in Gujarat. With the scientific and technical advice from the board it is possible to find suitable soil and locations for coconut farming.

Plants species such as *Salvadora persica*, *Salvadora oleriodes*, *Cayrrtia carnososa*, *Kyllinga bulbosa* could be grow in the areas. Many opportunistic plants species particularly halophytes and mangrove associated plants will cover the all-possible areas of Kalpasar project and occupy the land. These plants can serve as an easy source of fodder for livestock and can also reduce the pressure from mangroves due to camel grazing by providing them a few parts of their regular diet.

Salt tolerant aquatic species (Halophytes) *Haloxylon salicornicum*, *Salicornia brachiata*, *Sueada nudiflora*, *Sueda fruticosa*, *Aeluropus lagopoides*, *Sporobolus virginicus*, *Juncus maritimus*, *Haplopyrum mucronatum*, *Heleochloa setulosa* and others will establish in the area. There will be a chance of infestation of invasive species like *Prosopis* in the empty niches created, so special care to be given to stop the invasion.

5.8 Conclusion

The developmental projects are important for the socio-economic need of the society and for the smoothening of administration. The Kalpasar project was envisaged mostly to increase the per capita fresh water availability in the Gulf of Khambhat region and other associated benefits like generation of hydropower, availability of water for the industries and agriculture etc. There were always scope of alternative livelihood options associated with new development. So, there is a need of scope assessment and cost assessment study for the associated risk of the project for the socio-economics and the livelihood of the people resides in the project area. In the present study it was found that the local marine and estuarine fisheries sector will get affected during the construction and operational phases of the Kalpasar project, whereas several new opportunities will be developed after the primary resettlement of the landscape. Fishing communities like the *Pagadiyas* will be affected during the construction phase as their income from marine and estuarine fisheries will get affected. In the present study an

assessment of the income generation through different fishing strategies, traditional and mechanized methods, were assessed from the surrounding districts of the project area. Fish catch was highest in Bharuch as well as average income per day, compared to Anand, Bhavnagar and Ahmedabad. The income generation through boat per day varies from Rs. 1500-300/- whereas the income generated through fishing by fishnet used to vary between Rs. 400-530/- per day. The associated risk of fishing community due to the project development will be minimized through several alternative options envisaged like freshwater fisheries enhancement and culture of fast growing food fishes and other alternative livelihoods like, ornamental fish and processed fish products trades.

This chapter also focuses on the habitat restoration opportunity after the preliminary construction phase and the possible ways of utilization of the altered environmental conditions successfully. The probable shift of species was also discussed and the different species that might be recruited has also been highlighted.

Annexure 3: List of commercially important fishes from the project sites

S.No	Scientific name	Common Name
1.	<i>Glossogobius giuris</i> (Hamilton, 1822)	Glass Fish
2.	<i>Amblypharyngodon mola</i> (Hamilton, 1822)	Mola carpet
3.	<i>Gibelion catla</i> (Hamilton, 1822)	Catla
4.	<i>Labeo gonius</i> (Hamilton, 1822)	Kuria labeo
5.	<i>Labeo rohita</i> (Hamilton, 1822)	Rohu
6.	<i>Puntius sophore</i> (Hamilton, 1822)	Pool Barb
7.	<i>Salmostoma bacaila</i> (Hamilton, 1822)	Large razor belly minnow
8.	<i>Systomus sarana</i> (Hamilton, 1822)	Olive barb
9.	<i>Aplocheilus panchax</i> (Hamilton, 1822)	Blue panchax
10.	<i>Anabas testudineus</i> (Bloch, 1792)	Climbing Perch
11.	<i>Channa striata</i> (Bloch, 1793)	Striped snakehead or Murrell
12.	<i>Macrognathus pancalus</i> (Hamilton, 1822)	Barred spiny eel
13.	<i>Mystus tengara</i> (Hamilton, 1822)	Tangara catfish
14.	<i>Mystus vittatus</i> (Bloch 1794)	Striped dwarf catfish
15.	<i>Ompok pabda</i> (Hamilton, 1822)	Pabdah catfish
16.	<i>Wallago attu</i> (Bloch & Schneider, 1801)	Helicopter catfish
17.	<i>Oreochromis mossambicus</i> (Peters, 1852)	Mozambique tilapia
18.	<i>Parambassis ranga</i> (Hamilton, 1822)	Indian glassy fish
19.	<i>Xenentodon cancila</i> (Hamilton, 1822)	Freshwater garfish
20.	<i>Macrobrachium rosenbergii</i> (de Man, 1879)	Giant freshwater prawn

6.0 Geohydrology

6.1. Introduction

It is well known that any water is a part of hydrological cycle and that passes through various processes such as rainfall, overland flow, percolation, infiltration into groundwater, condensation, evaporation and evapotranspiration. These processes in nature are in equilibrium with each other depending upon local geological, geographical, physiological and climatological characteristics of the area. When the present study is concerned, the location of Kalpasar dam is in Gulf of Khambhat and river and marine water interface has been established and maintained naturally since its evolution. The proposed dam is going to be a harvest surface runoff from inflowing rivers and will not allow the water to get into marine system. Due to this phenomenon, the mixing of fresh water with tidal water on the surface and respective influence on groundwater is possibly going to have some impact. It is important to understand what will be the impact of this process in future and how it is going to impact in the surrounding areas in terms of upstream and downstream areas of the dam. The impact of this intervention may be direct and will also be reflected by changes in the groundwater levels and quality, soil quality, livelihood patterns, land use and many other factors.

With this background, it is important to understand the Geohydrological characteristics of the area with respect to current trends and status of equilibrium of Surface water - River and Marine and Groundwater in terms of spatial distribution, impact on various aquifers, surface and groundwater salinity at specific locations.

Keeping this in mind, the geo-hydrological study in the Upstream and Downstream areas on Eastern and Western banks of Gulf of Khambhat has been carried out with an aim to prepare a Detailed Project Report (DPR) to understand the status and changes happening with the groundwater flow directions, water quality, water levels, current water use practices, management practices by local stakeholders. Based on the developed understanding, possible mitigation and management strategies and actions for predicted changes in the respective areas around the dam is prepared. To fulfil the aim of Geohydrological study, the study area is categorized into three zones, *i.e.*, up-stream areas of the dam, western downstream areas mainly Saurashtra Coastal areas and Eastern downstream areas - South

Gujarat coastal areas. Altogether, the study has covered 9527 Sq.km. of the area and the sampling for data collection has been held at a grid size of 5 km by 5 km interval. Two to three wells have been invented along with the interviews of stakeholders like Farmers, Gram panchayat members, Academicians, Agriculture traders, NGO's. The main purpose of holding consultations and interviews is to understand the changes in the practices for water management and changes happening due to natural and manmade factors due to water resource developmental activities. The collected data was processed and compiled in the form of trend showing maps, hydrographs, developing conceptual sketch to prescribe changes in various types of geology and terrain. At the end, based on the status and predicted changes, strategies for land and water management has been defined and listed out along with the relevant solutions and estimated investments.

6.1.1. The Study and Study Area

A multipurpose dike has been proposed in Gulf of Khambhat known as Kalpasar project for the future development of the area. The proposed benefits from this project are as follows;

- ❖ Highest importance and priority to irrigation and drinking water for Saurashtra and Central Gujarat regions.
- ❖ The Reservoir will have the storage of more than double the Sardar Sarovar (Narmada Reservoir) capacity.
- ❖ More than 10.54 lakhs hectare land in 39 talukas of 6 districts of the Saurashtra region will get irrigation benefits including rejuvenation of rivers. More than 60 existing dams will get permanently filled up with water.
- ❖ The Wind and solar energy will be generated which can also be used for lifting fresh water from the reservoir to the canal.
- ❖ Bhavnagar port will get revived which will result in the speedy development of the region due to the Kalpasar Project.
- ❖ There will be a large saving in travel time and fuel due to the reduction in the distance by about 200 km between Bhavnagar to Surat-Mumbai.

- ❖ The saline groundwater of the coastal area of Saurashtra & Central Gujarat will get converted into fresh water with a reduction in soil salinity.
- ❖ Substantial improvement in groundwater quality as well as reduction in soil salinity of the coastal area of Saurashtra & Central Gujarat.
- ❖ About 2 lakh hectare land along the periphery of the reservoir will be opened up for development towards value-based land utilization.
- ❖ The enhanced benefit of world-class industrial estates like Dahej and Dholera will be available to Bhavnagar/Saurashtra region.

To understand the impact and concede to the mitigation plan in the form of a Detailed Project Report, various aspects including hydro-geology of the project area and its surrounding area have been set as one of the objectives. (Fig. 6.1) With this background, hydro-geological assessment on the upstream and downstream sides of Kalpasar dam has been undertaken. The entire project area is a stretch of about 9527 Km² starting from Diu in Saurashtra region to Daman in South Gujarat. So far, the width of an area is concerned it has fixed about 10 km from AMSL. Largely the area has been spread over coastal blocks of Districts Amreli, Bhavnagar, Ahmedabad, Anand, Vadodara, Narmada, Bharuch, Valsad, and Surat. A total of about 28 blocks have been covered under the study.

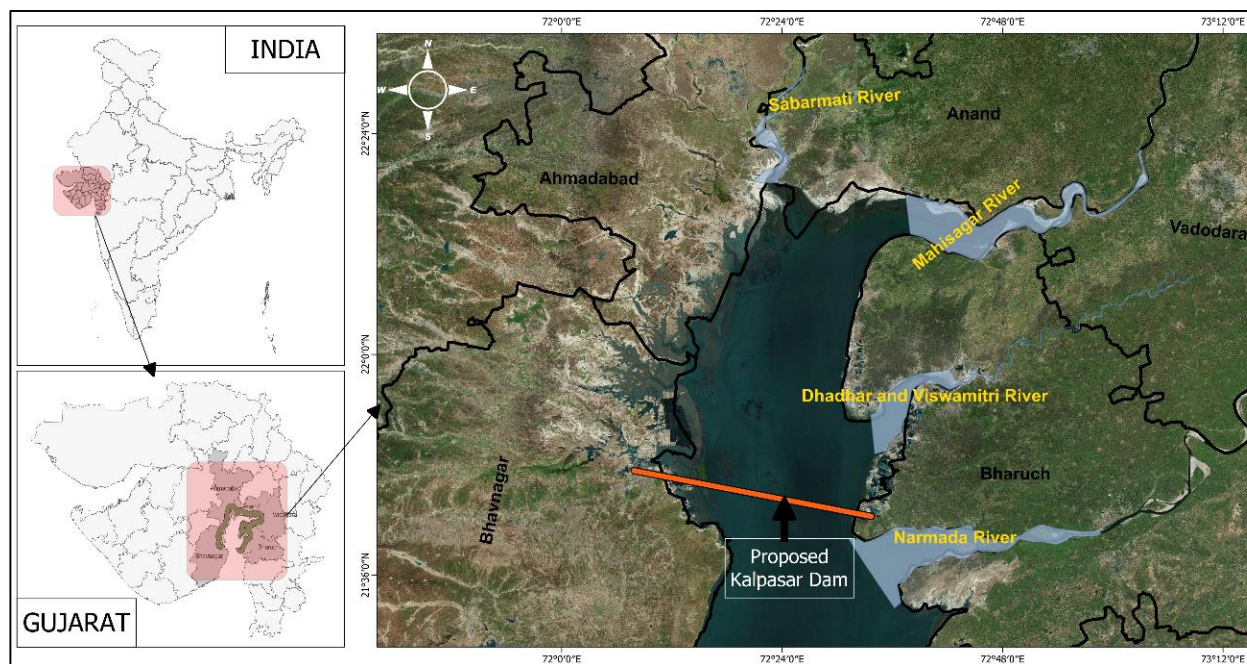


Fig. 6.1 Location of the Study Area

The study emphasized on geo-hydrological aspects viz., aquifers, the terrain in terms of landform and geomorphology, water level, water quality, and views of various stakeholders about on-going changes in water scenario in the area and seasonal water management. It also emphasizes how to cope with newly emerging trends after the completion of the Kalpasar dam and freshwater storage begins in it. Various feasible technologies for land and water management have been planned and respective investments estimated in revival planning. The study has been conducted with the help of primary as well as secondary data. Secondary data was obtained from government departments in custody of the respective data. The primary data especially socio-economic aspects and stakeholder's experiences on the usage of land and water resources, along with localized geo-hydrological scenarios was collected through interaction with the stakeholders/locals residing in the project area within the 10 km grid.

6.1.2. Objectives

The main aim of the geo-hydrological assessment is to prepare detailed project report on feasible solutions for any possible impact of Kalpasar Dam in the area on groundwater in terms of quality and or quantity along with its application in various usages. Therefore, the following objectives have been set for the preparation of the DPR.

- ❖ To understand the current groundwater scenario in terms of aquifer type, spread, water level fluctuation and water quality based on assessment of available literature on similar type of study and data
- ❖ To understand the water-use practices in the project area and their seasonal occurrence and availability.
- ❖ To assess the water quality and its impact on land resources.
- ❖ To identify the current trends on water level and quality and projection of changes during the post implementation of Kalpasar Dam and estimate the rate of gradual transaction of saline water into brackish to fresh water.
- ❖ To understand the socio-economic status in the project area and to assess possible changes in livelihood due to implementation of Kalpasar
- ❖ To understand the current practices for managing water / groundwater during lean period by the community.
- ❖ To understand the community perception on Kalpasar Dam and its impact and how it can be managed with decentralized solution.
- ❖ To carry out assessment of positive / negative impacts on land and water resources in the influencing area of Kalpasar.
- ❖ To carry out feasibility studies of various techniques for impact mitigation and map out feasible areas for respective technical solutions.
- ❖ To estimate investment for mitigation.

6.1.2.1. Approach and Methodology

For the present study, an integrated watershed management approach as depicted in Fig. 6.2 was adopted where qualitative and quantitative assessments of existing land and water resources was conducted. Followings are the detailed description for respective tools and techniques prescribed in the adopted methodology.

6.1.2.2. Data Collection

The initial part of planning began with a review of secondary literature related to the study and study area to develop a conceptual understanding of the area. As part of this, various study reports, published, and unpublished documents were reviewed related to the geology of the area, groundwater status of the area, water level, and water quality issues related information, as well as revival attempts made by various government and non-government organizations. Besides the review of literature, secondary data was obtained from various government departments especially the area adjacent to the coastal part. Gujarat Water Resource Corporation's groundwater monitoring data from the coastal block was procured through proper procedures for a sufficient period required for analysis *i.e.*, 2006 to 2021. In addition to this, basin level information has been downloaded from authentic government portals and websites. The secondary data collection phase was followed by developing some thematic zones and approaches for primary data collection of the area. The primary data collection phase was completed by acquiring primary data collected by various means and surveys such as Well Inventory. Specific comprehensive performance and questionnaires was prepared to maintain consistency in data collection. The aim of primary data collection was to understand existing water potential, land use practices, etc. so far as groundwater data are concerned and it was collected by holding a detailed inventory of sampling existing wells in various typologies of landforms in the study area. To understand the groundwater quality, water samples were collected for each invented well and TDS, pH analysis was undertaken for all wells, while one fourth well samples were used for detailed chemical analysis.

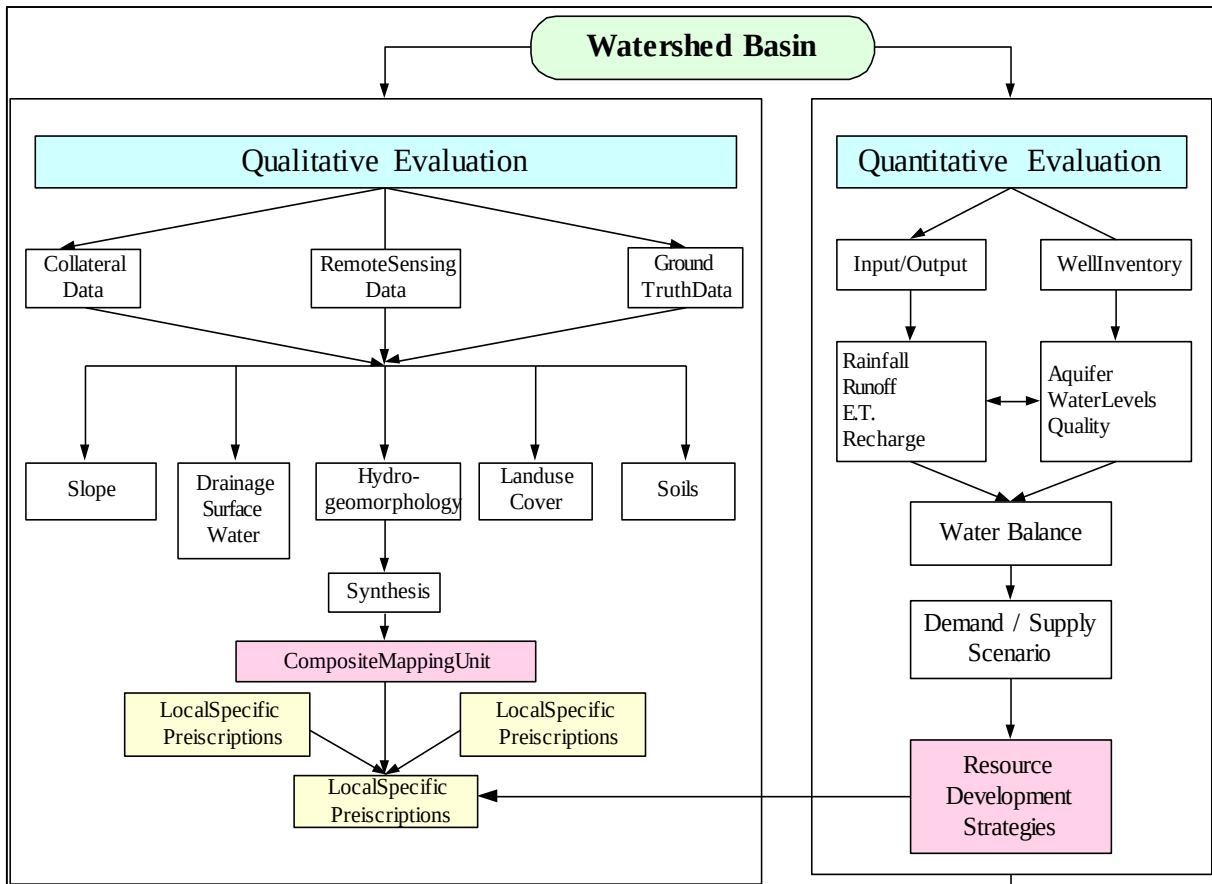


Fig. 6.2 Approach Methodology for Study

6.1.2.3. Thematic Mapping

To characterize terrain, thematic mapping for geology, aquifer, Lithology, drainage, slope, etc. was prepared to classify area according to recharge/runoff potential, seawater intrusion zones, and watershed characteristics. This will help to quantify the impact of Kalpasar project as well as develop area-specific mitigation measures to cope with land use changes. Satellite images of the area were used to efficiently carry out mapping exercises. A ground check of analyzed satellite data was held to produce accurate information about the area.

6.1.2.4. Groundwater Mapping

Groundwater mapping was done to understand groundwater flow directions and the status of water levels. Besides this, water quality maps were prepared based on occupied secondary data. All the maps were prepared with respect to Average Mean Sea Level (AMSL). To define the groundwater scenario, secondary data was obtained from Government departments and published documents and verified based on primary data collection by conducting well

inventory in the project areas within a 5 X 5 km grid. Well inventory was carried out in defined Proforma as shown in Table 6.1

Table 6.1. Data and Information Sources and Respective Groundwater Analysis Approach

Data	Information	Analysis
Subsurface Geological Data	Well, lithologs from GWRDC, CGWB of all coastal areas	Cross section across the Gulf and along the Gulf
Water Level Fluctuation	Groundwater department Pre and post monsoon water level data of last five years	ISO Water level maps Seasonal changes in water level and trend analysis
Water quality Fluctuation	Groundwater department Pre and post monsoon water level data of last five years Water quality parameter TDS, Chloride, pH,	ISO-TDS maps Seasonal changes in water quality and trend analysis Quality indices Drinking water and irrigation
Rainfall data	Rainfall analysis of catchment area and study area	Trend in overland flow
Land use data	Remote sensing analysis	Geomorphological categorization for developing mitigation strategies.
Landform	GIS analysis based on Satellite images and Google images	

6.1.2.5. Mitigation Planning

Based on thematic mapping and hydrogeological evaluation of area, strategies for different geohydrological typologies were prepared and a set of recommendations were made for incremental development and management of land and water resources of the area. Various recharge techniques, water harvesting techniques, and soil moisture conservation activities based on hydrogeological characteristics of the area were listed. The customized design and estimation have been prepared to estimate investments. To carry out community-centric planning, various consultations with stakeholders such as NGOs, experts, and experienced persons from the village were held. Besides these various successful interventions were documented and studied in or in similar areas where they were resulted in successful results.

Plate 6.1 : Field Photograph showing Primary Data Collection Methods



6.1.3. Objective wise Description of Methodology

In addition to the above description, objective-wise data and interpretation framework for DPR development was prepared as follows. To understand the current groundwater scenario in terms of aquifer type and its spread, water level fluctuation, and water quality based on an assessment of available data and literature on a similar type of study and data.

Data Source

- ❖ Groundwater assessment reports by CGWB of Bhavnagar, Junagadh, Ahmedabad, Anand, Vadodara, Bharuch, Surat Districts.
- ❖ India's water basin data.
- ❖ Project report on Geo-tectonic and morphological assessment of Gulf of Khambhat a study report by Department of Geology, The M.S. University of Baroda, Vadodara.
- ❖ EIA Reports of Kalpasar Project.
- ❖ Various published maps.
- ❖ Google and Remote sensing data.
- ❖ Lithology and geology of the area from different published reports by GWRDC.
- ❖ Rainfall data to understand rainwater inflow potential.

Analysis

- ❖ Prepared broad framework of study area.
- ❖ Categorization of study area.
- ❖ Base maps for further investigation.
- ❖ Aquifer potential.

To understand water-use practices in project area and their seasonal occurrence and availability

- Data from Census handbook and Minor Irrigation census to assess village wise available water resources – surface and / groundwater.

- Land use pattern data from census handbook to extract irrigation land by different sources e.g., tank irrigation, well irrigation, tube well irrigation, canal irrigation and irrigation by other sources like river flow.
- Agriculture practices assessment through primary sample survey by holding FGD and consultations with local stakeholder.

To assess water quality and its impact on land resources

- Groundwater quality monitoring data from GWRDC to analyse groundwater quality zones in project area and to assess changes due to impounding of fresh water in Kalpasar dam.

To identify current trend on water level and quality fluctuation and projection of changes during post implementation of Kalpasar and estimate rate at which gradual transaction of saline water into brackish to fresh water.

- Seasonal monitoring data from year 2006 to 2021 from GWRDC from piezometer
 - Lithology.
 - Groundwater level.
 - Groundwater quality.
- Lithological data were used for identification of
 - Potential aquifer system in various parts of project area.
 - Limits of aquifer in landward side and – extension wise and depth and Thickness wise where it abuts Gulf of Khambhat.
 - The analysis will help to determine impact of fresh water in upstream side aquifers and sea water in downstream side.
 - Various cross sections were prepared to visualize the impacts.
- Analysis of project area's groundwater depth in various parts to understand trends in groundwater depletion since last 15 years.

- Analysis of groundwater flow direction with respect to mean sea level to analyse groundwater and sea water level relationships in term of existing set up and to predict probable changes in water levels / groundwater recharge in project areas due to Kalpasar dam.
- Groundwater quality data to assess current salinization of groundwater and soil and zoning of the area based on sea water intrusion and assessment of future trend and respective area where possible changes may take place due to fresh water storage in the Kalpasar dam.

To understand the socio-economic analysis in project area and to assess possible changes in the livelihood due to implementation of Kalpasar.

- Census data was used for categorizing the HH engaged with various livelihoods especially linked with land and livestock.
- Cost benefit analysis of various livelihoods in present condition and to assess raise in income level due to improvement – deterioration in land and water resource quality.

To understand the current practices for managing water / groundwater during lean period by community.

To understand the community perception on Kalpasar impact and how it can be managed with decentralized solution.

To carry out the assessment of positive / negative impacts on land and water resources in influencing area of Kalpasar.

- The data was obtained through consultations and sample surveys in selected village in different zones of project areas.
 - The traditional practices will be used to customize and to find alternative solutions for water management in impact zones of Kalpasar.

To carry out feasibility studies of various techniques for impact mitigation and map out feasible areas for respective technical solutions.

- Identification of appropriate technologies for groundwater recharge with different methodology e.g., injection method, diffusion or spread method.
 - Defunct well / bore well recharge
 - Artificial recharge tube well
 - Sub surface dykes
 - Percolation tanks
 - Percolation wells/pits
 - Soil moisture conservation techniques
 - Soil amendments
 - Soil health improvement practices with various inputs
- Feasibility of these structures were assessed by various analytical models created based on assessment of various secondary as well as primary data and defined potential mapping by using Geological, Geo-morphological, land use, as well as trend maps and cross sections.

To estimate investment for mitigation

- Technology wise cost estimation for type design and projection of investment in various potential zones.

Table 6.2 Summarization of Objective wise Adopted Methodology

Objective	Data	Analysis/Conclusion
To understand the current groundwater scenario in terms of aquifer type, spread, water level fluctuation and water quality based on assessment of available literature on similar type of study and data	- Groundwater assessment reports by CGWB of Bhavnagar, Junagadh, Ahmedabad, Anand, Vadodara, Bharuch, Surat Districts - India's water basin data - Project report on geo-tectonic and morphological assessment of Gulf of Khambhat a study report by Department of Geology, M.S. University of Baroda - EIA Reports of Kalpasar Project - Various published maps - Google and Remote sensing data - Lithology and geology of the area from different published reports by GWRDC - Rainfall data to understand rainwater inflow potential	- Prepared broad framework of study area - Categorization of study area - Base maps for further investigation - List of potential aquifers
To understand the water use practices in the project area and their seasonal occurrence and availability	- Data from Census handbook and Minor Irrigation census to assess village wise available water resources – surface and / groundwater - Land use data from census handbook to extract irrigation land by different sources e.g. tank irrigation, well irrigation, tube well irrigation, canal irrigation and irrigation by other sources like river flow - Agriculture practices assessment through primary sample survey by holding FGD and consultations with local stakeholder	
To assess the water quality and its impact on land resources	Groundwater quality monitoring data from GWRDC to analyse groundwater quality zones in project area and to assess changes due to impounding of fresh water in Kalpasar dam	
To identify the current trends on water level and quality, fluctuation and projection of changes during post implementation of Kalpasar and estimate rate at which gradual transaction of saline water	Seasonal monitoring data from year 2006 to 2021 from GWRDC from piezometer – Lithology, Groundwater level and Quality	
	- Lithological data were used for identification of - Potential aquifer system in various parts of project area - Limits of aquifer in landward side and – extension wise and depth& Thickness wise where it abuts Gulf of Khambhat - The analysis will help to determine impact of fresh water in upstream side aquifers and sea water in downstream side - Various cross sections are prepared to visualize the impacts. - Analysis of project area's groundwater depth in various parts to understand trends in groundwater depletion since last 15 years. - Analysis of groundwater flow direction with respect to mean sea level to analyse groundwater and sea water level relationships in term of	

into brackish to fresh water	existing set up and to predict probable changes in water levels / groundwater recharge in project areas due to Kalpasar dam • Groundwater quality data to assess current salinization of groundwater and soil and zoning of the area based on sea water intrusion and assessment of future trend and respective area where possible changes may take place due to fresh water storage in Kalpasar dam	
To understand the socio-economic analysis in project area and to assess possible change in livelihood	Census data – Population, livelihood, land use categorization, irrigation by sources	Cost benefit analysis of various livelihoods in present condition and to assess raise in income level due to improvement – deterioration in land and water resource quality
To carry out feasibility studies of various techniques for impact mitigation and map out feasible areas for respective technical solutions	• Identification of appropriate technologies for groundwater recharge. • Assessing the Feasibility of these structures by using various analytical models created based on analysis of various secondary as well as primary data and defined potential mapping by using Geological, Geo morphological, land use, maps as well as trend showing maps and cross sections • Technology wise cost estimation for type design and projection of investment in various potential zones	technologies for groundwater recharge • Defunct well / bore well recharge • Artificial recharge tubewell • Sub surface dykes • Percolation tanks • Percolation wells/pits • Soil moisture conservation techniques • Soil amendments • Soil health improvement practices with various inputs

6.1.3. Previous Works

Past assessments of hydrogeology of the area have been made by many researchers. However, comprehensive account considering area's salinity issue has been studied by Joshi and Sahai (1993) where an attempt was made to analyse the coastal tract around the Gulf of Khambhat from Bhavnagar to Valsad during the period between 1977 and 1981, to understand salinity in various geomorphological setup and categorized the areas into three

categories viz., (01) S1 - Non-saline (02) S2 -Low saline to medium saline, and (03) S3 - Medium saline to highly saline soil (Fig. 6.3). Based on this analysis, Joshi and Sahai (1993) have made salinity status observations for respective landforms, which is summarized in table 6.3. From the analysis of the geomorphological map, the following are the observations.

- ❖ Flood plains, valley fills and sandy plains adjacent to river but away from the coast were identified as either free of salinity or negligible saline areas.
- ❖ Alluvial plains away from the coast were either non-saline or moderately saline. However, the locations where black soils exist are slightly saline (away from the coast) and saline to highly saline (close to the coast) as observed during the field verification.
- ❖ The areas under mud flats are saline. Old mud flats are either moderately saline or highly saline according to their drainage conditions and proximity to coast and, were classified accordingly.
- ❖ Saline flats and salt-encrusted areas were classed as salt-encrusted. The surface water spread map was used to identify salinity in:
 - Areas close to the creeks, covered by mud flats as highly saline,
 - Areas inundated by spring tides as highly saline and
 - Areas adjacent to big water tanks near the coast, whose water is used for irrigation, were categorized as non-saline or moderately saline depending upon the tonal variation/vegetation or crop density.

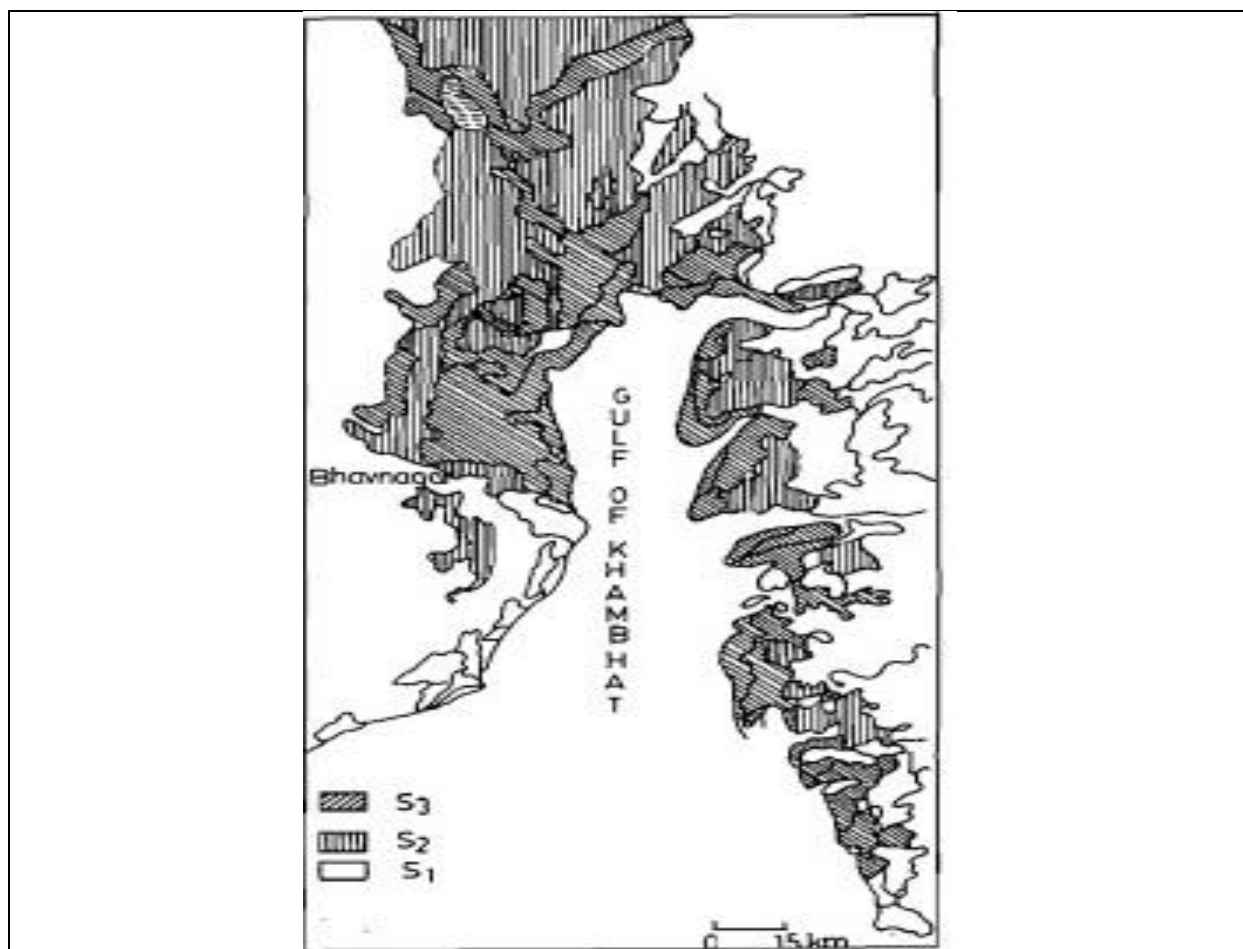


Fig. 6.3: Coastal Salinity Map of the Area Along Bhavnagar-Valsad Coast Based on Landsat-2 MSS Data (1977-81)

Table 6.3 Hydrogeological Characteristics of the Project Area

Soil		Physio-graphic unit	Topography	Surface-water spread/drainage	Salinity	Region	Geology
<i>Par to Kim River (district Valsad, part of Surat)</i>							
1	Heavy / shallow	Mud flat	Very flat	Gulf water/ moisture	Highly saline	Coastal patches /marshy land	Deccan trap
2	Brown to dark brown in colour	Alluvial Plain	Flat to very flat < 2 per cent	Mostly close to creeks & wet areas, tidal effect	Highly saline	Coastal plains	Deccan trap with dendritic drainage
3	Brown to dark brown in colour	Alluvial Plain	Flat	Away from creeks	Medium to slight	Coastal but away from creeks	Deccan trap
4	Brown to dark brown in colour	Alluvial Plain	Flat	Near rivers & rivulets	Negligible	Close to Railway (Surat to Bombay)	Deccan trap
5	Dark	Old Mud Flat	Flat	Tanks	Medium Salinity		Deccan trap
<i>Kim to Mahi River (district Surat, Bharuch and Vadodara)</i>							
1	Heavy clayey	Mud flats	Very flats	Gulf water	High	Along coast & river mouth, creeks	Deccan trap
2	Top surface black	Alluvial Plain	Very flats	Creeks or close to coast	High	Close to coast	Deccan trap
3	Medium to deep towards coast	Alluvial Plain	Flat	Away from coast	Medium to slight	Mostly away from coast	Deccan trap
4	Medium to black	Alluvial Plain/Flood Plain	Flat	Rivers or rivulets	Negligible salinity	Close to railway (Surat to Vadodara)	Deccan trap

5	Dark Black	Old Mud Flat	Flat	Tanks	Medium salinity		Deccan trap
<i>Mahi to Sabarmati River (district Kheda & Ahmedabad)</i>							
1	Medium clay profile	Mud flats	Very flats	Gulf water	High	South of Khambhat along Gulf E-W extent	Deccan trap
2	Medium to deep	Alluvial Plain	Flat	Canals & tanks	Negligible	Anand-Nadiad area up to N-W and W of Khambhat	Deccan trap
3	Dark	Old Mud Flat	Flat	Tanks	Medium salinity	N-W and W of Khambhat	Deccan trap
<i>Sabarmati to Bhogavo River (district Ahmedabad, Surendranagar and Bhavnagar)</i>							
1	Medium to deep	Mud flat	Very flat	Gulf water	High	Mud flats on the coastal area	Deccan trap
2	Loamy soil	Old Mud Flat	Very flat	Rivulets and canals	High	E of Sabarmati towards coast	Deccan trap
3	Loamy soil	Sandy Flat	Very flat	Rivulets	High	N of Bhavnagar	Deccan trap
4	Medium	Valley Fill	Flat	Rivulets	Medium/Slight	NW of Bhavnagar	Deccan trap

Source: Joshi and Sahai, 1993

For geological aspects, the area has been regularly studied by many researchers. Tiwari *et al.*, (2002) studied quaternary sedimentation history in the south Gujarat plains. Comprehensive geology of the area was described by Merh (1995), in Geology of Gujarat. The groundwater of coastal tracts of Gujarat is regularly monitored by Gujarat Water Resources Development Corporation Ltd. (GWRDC) and Central Groundwater Board (CGWB). Based on observations and monitored data, CGWB published groundwater yearbooks for each district. Considering the scale of the observation network GWRDC has relatively more observation locations and therefore, to build groundwater understanding GWRDC's data was procured, reviewed, and analyzed for the period of the year 2006 to 2021. To analyze groundwater of

the area, various approaches such as Iso-SWL, Iso-RWL, and Iso-TDS maps have been prepared for selected years for the pre-monsoon period for the entire area to understand changes in groundwater level, quality, and flow with respect to AMSL.

As far as water quality in the project area is concerned; many departments such as GPCB, CGWB, and academic institutions like The M.S University of Baroda have conducted various studies in different zones of the project area. However, due to different methodology and objectives, respective studies held in different areas need some more attempts to compile, organize and draw any conclusions about water quality status in the study area. So far as groundwater quality is concerned, the Dholera Project Area was studied by Central Ground Water Board (CGWB).

The study emphasized that Geo-morphologically, the area is occupied by old mudflats, patches of flood plains, recent mudflats, and salt pans. The Dholera Project Area (DPA) is located 110 km South of Ahmedabad, on the way to Bhavnagar, in the northeast fringe of the Saurashtra part of Gujarat State. It is a typical coastal plain with an elevation in the range of 3 to 9 m AMSL. The general slope of the area is from west to east. The area is drained by the small ephemeral Bhadar River and its tributaries. The eastern part is at the lowest level occupied by salt-encrusted soils, mud flats, and creeks and it gets inundated by a tidal front from the Gulf of Khambhat. DPA is underlain by Quaternary Alluvium, consisting of cyclic alternate units of silt, gravels, sand, clay - shale, etc of variable thickness and lateral continuation at depth. These Quaternary sediments having an aggregate thickness of more than 100 m are followed by another 500 - 600 m of Tertiary age sediments. All these marines to fluvio-marine type sediments of Quaternary and Tertiary age underlying DPA were deposited in subsiding Cambay Graben and rest on the very thin horizon of Laterite of Palaeocene age, a by-product of weathering process undergone on basement Deccan Trap (Basalt rock) of Upper Cretaceous to Lower Eocene Age at depth.

DPA is underlined with fluvio-marine sediments which have intrinsic constraints for the availability of fresh groundwater at sustainable measures. Various natural attributes such as a low relief coastal plain, proximity to sea towards eastern side and connate brackish / saline water in its subsurface system, etc. have resulted in brackish and saline groundwater stagnation in shallow aquifer systems of DPA since the geological past. As per the CGWB

groundwater monitoring database, this area has shallow brackish to saline groundwater conditions near Dholera (22°14'30" N Lat; 72°13'30" E Long). The GW has the EC of around 7156 $\mu\text{S}/\text{cm}$ at 25°C in a confined aquifer system at depth (258-310 m BGL). The Dholera thermal spring is located, falling over the West Coast lineament and little west of the West Marginal fault of the Cambay Basin. Over the high gravity areas indicating shallow mantle and the presence of granitic basement rocks, these springs are also situated. This indicates that there is no scope to divert or recharge storm water of DPA into its subsurface system. The data available with CGWB, on basis of the regional hydrogeological survey, groundwater exploration and periodic groundwater monitoring, etc., indicate that general groundwater levels in DPA and surrounding area varies from 2 to 10 m BGL and quality varies from marginal brackish to saline. At shallow depth aquifers, groundwater quality is from moderate to brackish (TDS in the range 3000 to 12000 mg/L). The deep confined aquifer has brackish to saline groundwater with piezometric levels near artesian to 20-30 m BGL. This area gets monsoonal runoff and flood water from its drainage system having a large catchment in the western highland. There is a scope to harness such fresh runoff in DPA.

Khambhat is situated near the Gulf of Khambhat. So, the water quality of this area is found degraded because of the influence of seawater intrusion during tidal and non-tidal periods. The Mahi River is one of the major west-flowing perennial rivers flowing through Central Gujarat into the Gulf of Khambhat near Kavi village. The area between Wanakbori and the Gulf of Khambhat is gently sloping to almost flat near the Gulf and is a fully developed and fertile alluvial tract. The type of soil is deep black coastal alluvium in Bharuch district and medium black in Vadodara and Anand districts. The geology is recent to sub-recent alluvium.

(Fig. 6.4)



Fig. 6.4: Locations Showing Water Sample Collection in Kavi River Basin

Source: Upadhyay, 2019

The pre-monsoon and post monsoon results of TDS showed that as the distance of well increases from the Kavi town, TDS values decreases in groundwater samples. The high pre-monsoon values of the TDS get normalized after the post-monsoon period because of the rainwater recharge and dilution. It was observed that the pre-monsoon TDS values of groundwater samples of Sarod, Kareli, and Dabka at 15, 24.8, and 32.9 km were 8472 mg/L, 13036 mg/L and 8076 mg/L, respectively. The high TDS values of Sarod and Kareli groundwater samples is because of their location near Kavi, Jambusar Taluka, close to the Gulf of Khambhat. All the tube wells in Jambusar taluka are affected by seawater intrusion. Kareli is at more distance from Kavi as compared to Sarod but a high TDS is observed at Kareli. This could be attributed to over withdrawal of groundwater or local geological formation. Dabka is situated 17.90 Km upstream of Sarod which has low TDS. During the post-monsoon, TDS values decreased more at Kareli as compared to Sarod. This may be due to the efficient monsoonal recharge. The decrease in TDS value at Dabka is less compared to Sarod and Kareli indicative of low water percolation and recharge in the area.

The Chloride analysis indicate that as the distance increases from the Kavi town *i.e.*, in the upstream the Cl value decreases during the pre-monsoon and post-monsoon sampling (Table 6.4).

- The high Cl values during the pre-monsoon season declines after the post-monsoon period because of the rainwater recharge.
- High values of Cl for pre-monsoon groundwater samples are observed as Kotana and Angadh similar to TDS trend. The post-monsoon values of Cl decreased more at Kotana as compared to Angadh.
- The pre-monsoon Cl values of groundwater samples of Tithor and Dabka at 25.05 and 32.90 km distances from Kavi are 7747.59 mg/L and 7197.76 mg/L respectively. The low Cl value at Dadka is because of its upstream location of 7.85 km from Tithor. Salinity ingress is the probable reason for presence of high Cl in the ground water of Tithor samples which is close to the estuarine region.

However, there is an improvement in the GW quality in terms of Cl during the post monsoon indicative of recharge and dilution due to presence of fresh water inflow.

Table: 6.4: Groundwater Quality in Villages of Mahi River

Village	Hardness mg/L			Ca ⁺² mg/L	Mg ⁺² mg/L	Cl ⁻² mg/L	SO ⁻⁴ mg/L	Zn ⁺² mg/L	pH
	Total	Permanent	Temporary						
Dhuvaran	510	240	270	251	265	232	268	3.5	7.38
Pandad	512	232	280	248	260	234	270	3.8	7.53
Vadgam	524	268	256	259	266	229	251	4.1	7.24
Mitli	536	243	293	249	264	231	254	4.4	7.38
Kalamsar	519	212	307	239	251	242	256	3.7	7.52
Lunej	498	210	288	233	252	249	250	3.9	6.66
Sokhda	484	214	270	221	241	223	229	4.2	6.86
Tamsa	491	218	273	232	249	228	234	4.8	6.98
Ralej	468	231	237	219	239	235	238	4.4	6.94
Vasna	451	229	222	224	238	236	241	4.9	6.92

Source: Upadhyay, 2019

The results of total hardness (TH) indicate increase in the TH values in the GW samples as one moves away from Kavi upstream which is reverse to the trend observed in case of TDS or Cl. High TH values for pre-monsoon groundwater water samples was observed at Kotana and Angadh. The post-monsoon TH values decreased much more at Kotana as compared to Angadh. The values of pre-monsoon and post-monsoon TDS of groundwater samples of villages located on the right bank of the river are observed less compared to the villages on the left bank of the river. This may be due to irrigation by MRBC from Wanakbori weir on the right bank of Mahi River. (Table 6.4)

6.2. Terrain Characteristics and Water Basins

Largely the study area is a narrow strip around the Gulf of Khambhat. The terrain of the study area has been evaluated from physiographic characteristics, slope aspect, and river basin that inflow water into the Gulf point of view. Physiographic features of the area represent their development as a result of the co-actions of river water and seawater. The main purpose is to evaluate the physiography of the area to understand the potential for the development of land and water management strategies to mitigate the impact of the Kalpasar dam. Further, the terrain of the study area has been evaluated.

6.2.1. Slope

The slope is such an aspect that helps to delineate potential areas for recharge - runoff and to characterize landforms in any area. For the present study, Digital Elevation Model (DEM) approach has been adopted to prepare the slope map and categorization of the area by using the approach suggested by Young, (1972). Slope wise the entire area has been categorized into seven categories *viz.*, (01) Very Gentle to Levels $< 2^\circ$; (02) Gentle slope $2^\circ - 5^\circ$; (03) Moderate $5^\circ - 10^\circ$; (04) Moderately Steep $10^\circ - 18^\circ$; (05) Steep $18^\circ - 30^\circ$; (06) Very Steep $30^\circ - 45^\circ$ and (06) Precipitous $> 45^\circ$. (Fig. 6.6) The study area shows a maximum slope percentage *i.e.*, 53° in some spots near Bhavnagar and south of Valsad, dominantly the area falls under very gentle to level slope categories except some areas *i.e.*, NW of Bhavnagar and SE of Navsari and Valsad, where some hilly tracts of Deccan Trap basalt show moderately steep to steep slopes. The quantitative and qualitative interpretations of the various slope categories (Young, 1972 and NATMO, 1996) are given in Table 6.5 and Figure 6.5.

Table 6.5 Slope Characterization of the Study Area

Slope	Degree	Percentage (%)	Geomorphic Characters
Very Gentle to Level	< 2°	< 4.8	Mud flats of Gulf of Khambhat
Gentle	2°-5°	4.8-12	Alluvium plains, River mouth bars
Moderate	5°-10°	12-24	Gently undulating terrain,
Moderately Steep	10°-18°	24-43.2	Creeks and river cliffs, sand dues
Steep	18°-30°	43.2-72	Plutons
Very steep	30°-45°	72-108	Steep hills
Precipitous	> 45°	>108	Scarps

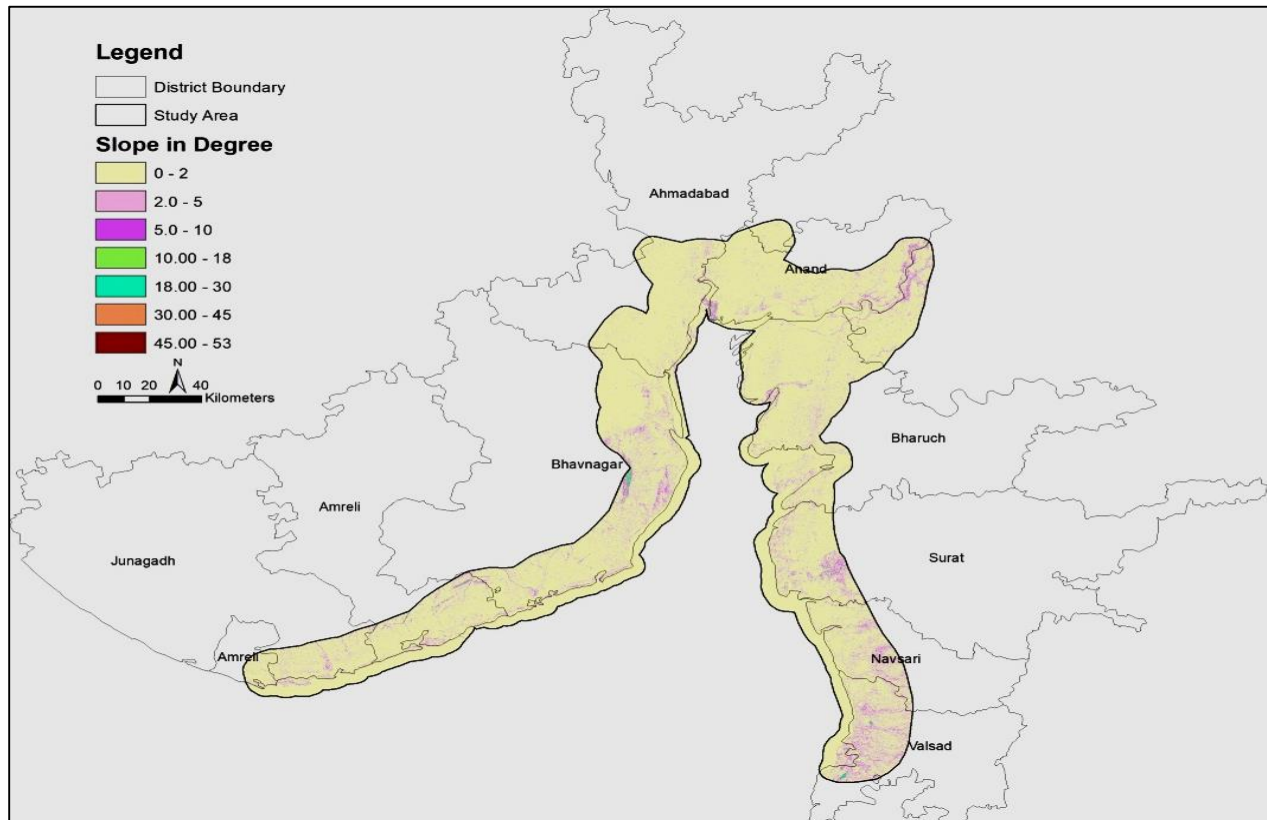


Fig 6.5: Slope of the Area

6.2.2. Physiography

The area shows three major physiographic divisions such as (01) Hilly Area; (02) Alluvial Plains and (03) Gulf adjoining mudflats and creeks. There are four areas where Hilly Areas are distributed *i.e.*, in the eastern part in the extreme south in the east part of Valsad and

Navsari district, whereas in the northeastern part of Vadodara district while in the western part of study area west of Bhavnagar district in the middle and west of Kodinar. The maximum elevation is about 250 m and dominantly the hilly region shows altitudes ranging from 100 to 250 m above AMSL.

Alluvial plains are the dominant landforms of the study area. Composition wise these plains show sandy alluvial to clayey alluvial plains deposited by major rivers like Ghoga, Bhadar, Sabarmati, Mahi, Narmada, Tapti, etc. flowing through the region and merging into the Gulf of Khambhat. In places, these plains are also showing flood plains, river scarps, meanders, river shoals, and ravine areas. Due to the nearness of coastal regions and mudflats sea abutting borders of these plains is suffering from soil salinity while heavy erosional issues during the flood as they are located in areas where all the rivers discharge into Gulf. Except for a few places *i.e.*, nearness of river courses the plain area shows a very gentle to gentle slope. Non-saline alluvial plains have a huge contribution to the sustainability of agriculture and animal husbandry livelihood of the entire coastal tracts (Fig. 6.6).

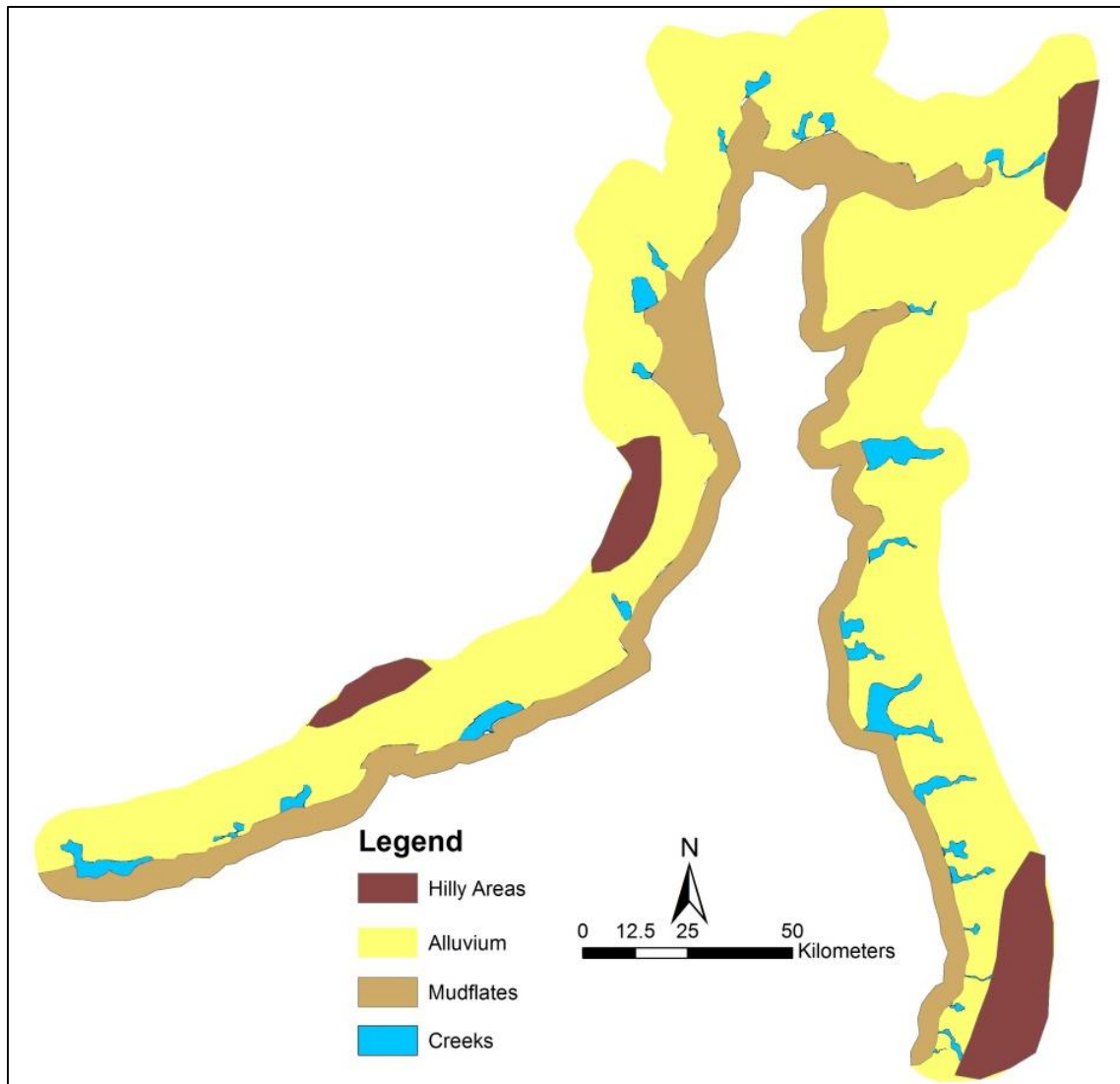


Fig. 6.6 Physiography of the Study Area

The third most important physiographic division of the area is Creeks and Mud flats. A creek is a natural stream of water normally smaller than and often tributary to a river. Mudflats are coastal wetlands that form when mud is deposited by tides or rivers. They are found in sheltered areas such as bays, bayous, lagoons, and estuaries.

6.2.3. River and River Basins

As the one of the objectives of the Kalpasar project is to prevent and store the over flow of various major basin's water into the sea, an account of major basins has also been taken into account to related issues and potential related to the study area. Further, to understand the hydrology of the study area is divided into two broad classes: upstream of Kalpasar Dam and

downstream of Kalpasar dam. Table 6.6. Shows zone-wise list of rivers contributing water inflows to the study area. Fig. 6.7 shows the major basins inflowing rainwater to the project area.

Table: 6.6 Zone wise List of Rivers Contributing Surface Water Inflows to the Study Area.

Area	Zone	River
Up stream	Western part from- Mahuva to Anand	Bhadar and Shetrunji
	Northern part from- Anand to Bharuch	Mahi and Sabarmati
	Eastern part from –Bharuch to Surat	Mahi and Narmada
Down stream	Western side from- Kodinar to Mahuva	Bhadar
	Eastern side from- Surat to Daman	Bhastol, Tapti, Vasishti

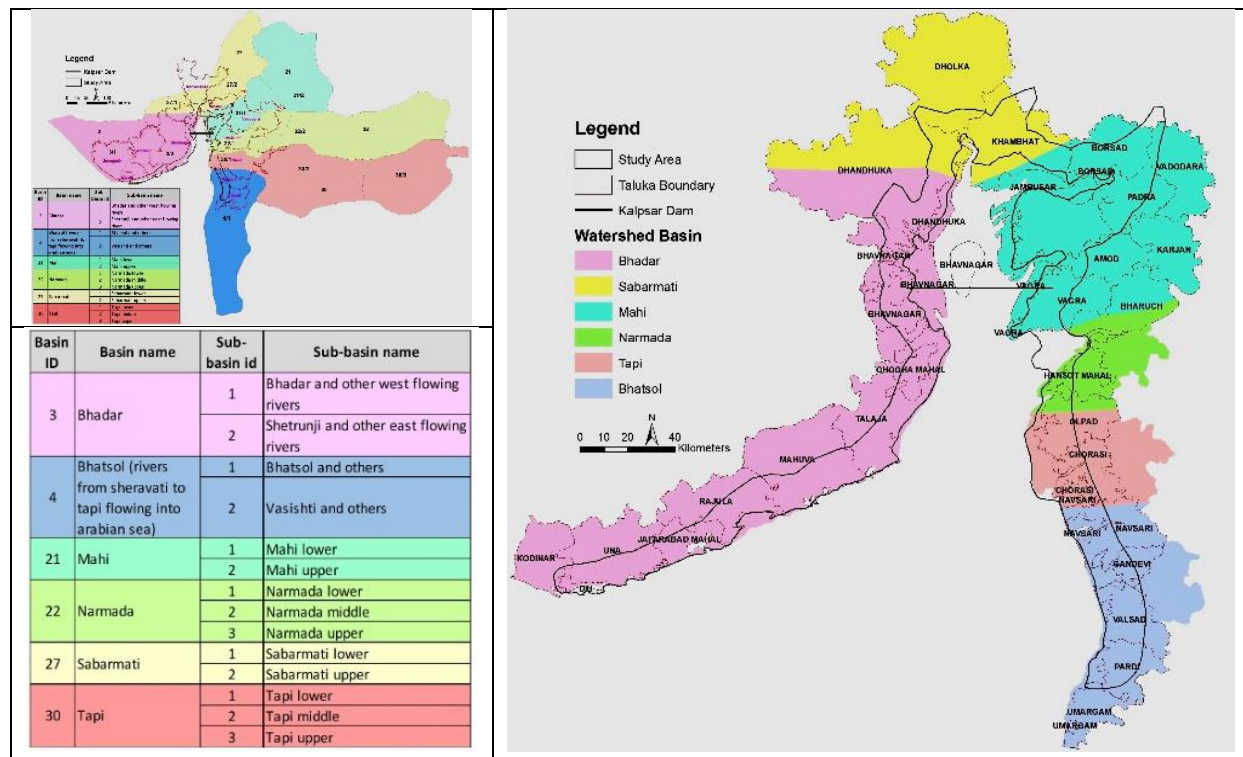


Fig. 6.7 Major River Basins Inflowing Rainwater to Project areas

6.3. Hydrogeological Characterization

Water resource development and management requires a proper understanding of surface as well as groundwater resources. Distributions, mode of occurrence, and chemical characteristics are some of the most important aspects that require in-depth knowledge and information on the various terrain-specific attributes. Hydro-geological characteristics of the project area can be understood through the encompassing mode of occurrence, distributions of groundwater, and hydrogeological categorization of the area based on its lithology, structure, and geomorphic characteristics. The data collection for the following thematic maps were collected considering these basic sub-areas of project areas. In the Upstream of Kalpasar dam, the data collection was carried out in five districts *viz.*, Bhavnagar, Ahmedabad, Anand, Vadodara, and Bharuch, while in the downstream areas, the data was collected from the Amreli district in the west and Surat district in the east of Gulf of Khambhat. However, the mapping exercise was concentrated in the delineated 10 km strip around the submergence of the Kalpasar dam, and the same in the downstream area. Geo-hydrological reviews of the area have been carried out keeping the following points in mind.

- ❖ Aquifer recharge areas extension.
- ❖ Exposure of aquifer on surface those are opening in Gulf of Khambhat.
- ❖ The area under influence of spring tide.

The occurrence of groundwater is a function of several variables related to the hydro-meteorological and hydro-geological setup of a region. The hydro-meteorological parameters that are appreciated regionally and contribute to water input, while the hydro-geological parameters create an environment for groundwater movement, storage, and quality.

To understand the hydrology, the study area has been divided into two broad classes; upstream of Kalpasar Dam and downstream of Kalpasar dam. As the inception, the study in the upstream side can be categorized into three categories based on location with respect to the Gulf of Khambhat *viz.*, (01) western part - from Bhavnagar to Dholera; (02) northern part - from Dholera to Jambusar and (03) Eastern part – from Jambusar to Dahej. So far hydrology of the study area is concerned, it receives surface water inflows from various rivers Table 6.6.

Shows zone wise list of rivers contributing water inflows to the study area. Fig.6.8 shows the major basins inflowing rainwater to project area.

6.3.1. Geology

The state of Gujarat comprises an area of approximately 1,96,000 sq. km and is enclosed within the North Latitude of 20°10' to 24° 50' and East Longitude of 68° 40' to 74° 40'. Geologically, Gujarat provides a wide spectrum of rock types of different ages. Whereas the Aravallis in the NE are as old as 2500 million years, the unconsolidated alluvium and beach material in its Central and Western parts date back to a few thousand years only. All the important lithological types Igneous, Sedimentary and Metamorphic occur within the state. So far, the geology of the study area is concerned it represents various rock formations ranging from the volcanic rock of Deccan Trap to Recent age loose fluvial originated sediments deposited by co-actions of the river and marine water.

The oldest rock formation in the study area is the Deccan trap of the late Cretaceous age with dominant rock types of basalt. The trap in coastal regions is overlain by a full Tertiary succession. The Eocene formations are well developed, followed by regressive Oligocene and transgressive Miocene formations followed by younger beds. Fig. 6.8 is a geological map of study area.

Formations deposited during the Cenozoic Era can further be classified into two periods *i.e.*, Tertiary and Quaternary. Table 6.7 shows the litho-stratigraphic sequence of the Saurashtra area.

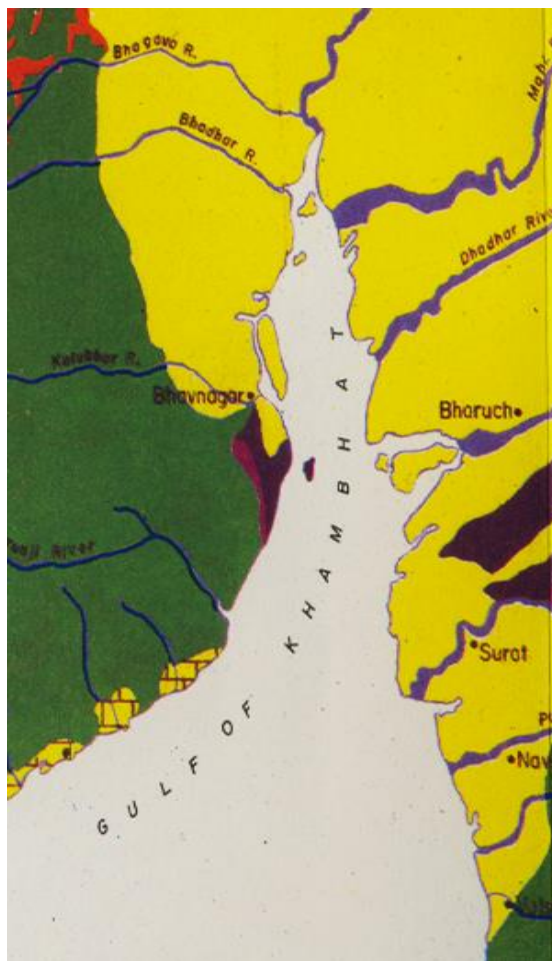
Cenozoic rocks are exposed all along the coastal areas in the western strip *i.e.*, Diu to Bhavnagar region. In the Saurashtra coast, rock formations of the Tertiary Periods are represented by Gaj and Dwarka formations. In Bhavnagar Near Ghogha, the exposed thickness of Gaj Formation has been reported to be around 600 m and decreases towards Jafrabad. Large shells of *Ostrea* fossil reported from Gaj beds near Bhavnagar area characterizes lowest Miocene age. While the clay bed Gaj formation are rich in microfossils. Along the Gulf of Khambhat, rocks of Piram beds overlie Gaj formation in the Ghogha area and Piram Island. These formations are equivalent to Dwarka Formation mainly consists of sequence of conglomerate, sand stone and clay. The lowermost band is of boulder

conglomerate is rich in mammalian fossils. Overall characteristics of Piram beds indicate its fluvio-littoral origin.

Tertiary formation of Mainland Gujarat form only small exposed portion of the Cambay Basin sediments, as the large part of the basin lies subsurface on the east and north of the Gulf of Khambhat.

Quaternary of Saurashtra are represented by Miliolite formation of Pleistocene are essentially consolidated biogenic sands dominantly consists of sand sized calcareous shell fragments and tests. Along the coast, the miliolite forms a 15 to 20 km wide belt from Porbandar to NW of Gopnath. North of Shetrunji River, occur the non-calcareous equivalents of miliolite. The formation is 5 m thick rests over laterite. It is overlain by Sub-recent sand dunes and beach material. The younger Holocene sediments of Saurashtra side include tidal flat sediments, unconsolidated sands of present-day beaches and fresh water alluvium of Bhadar and Shetrunji occupying large tracts of coastal plains.

The mainland Quaternary deposits, exposed in North and eastern coast is considered to owe its origin to a powerful Quaternary fluvial system of Narmada, Mahi and Sabarmati. The Holocene coastal deposits are represented by raised mudflats and coastal ridges are of Flandrian transgression (6000 years BP). The raised mudflats are well exposed between Mahi and Narmada River. South of Narmada, up to Tapi sandy ridges dominates.



Source: Mehr, (1995)

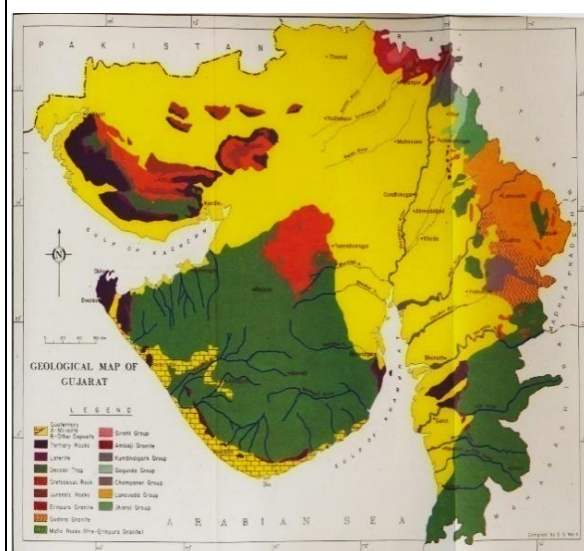


Fig. 6.8 Geological Map of the study area

Table 6.7: Litho-Stratigraphy of the Saurashtra Region (After Shrivastava, 1963, Mathur and Merh, 1975 and Bhatt, 2000)

Era	Period	Stratigraphic Unit	Lithology	Age	
C E N O Z O I C E R A	QUATERNARY PERIOD	Unclassified Holocene Deposits	Beach and dune sands, tidal clays, alluvium	Holocene	
		----- (Unconformity) -----			
		Chhaya Formation	Coral reef limestone Off white colored bioclastic limestones and conglomerate	Late Pleistocene	
		Miliolite Formation	White colored pelletoid limestone (Calcarenite) Alternating pelletoid limestone and micrite	Middle to Late Pleistocene Early Middle Pleistocene	
		----- (Unconformity) -----			
	TERTIART PERIOD	Dwarka Formation	Recrystallize fossiliferous limestone and sandy limestone Sandy clays and sandstones Bioclastic and coralline limestones with few dolomitic bands	Lower Pliocene Upper Miocene Middle Miocene	
		Piram Beds	Conglomerate, sand, clay		
		----- (Disconformity) -----			
		Gaj Formation	Yellow and brown fossiliferous limestone Grey clay, variegated clays, marls with some gypsum bands Tarkeshwar Clay	Lower to Middle Mioene	
		----- (Unconformity) -----			
M E S O Z O I C E R A	JURO-CRETACEOUS PERIOD	Laterite Rocks	Red Brown and Yellow Laterite and agate bearing formations	Paleocene	
		Deccan Trap Formation	Basalt and other derivatives covered at places by laterite and bauxite	Upper Cretaceous to Eocene	
		----- (Nonconformity) -----			
B A S E N O T E X P O S E D					

6.3.2. Groundwater Occurrence

The quality and availability of groundwater in Gujarat are variable and depend on rainfall, topography, and hydrogeological setting. It occurs in the major three physiographic settings as (01) Hilly track of mainland (02) Table land of “Saurashtra” and (03) Alluvial Plains. So far, the study area is concerned that groundwater occurrence takes place in various rocks all along the coastal line. Depth- wise both deeper confined aquifers and shallow phreatic aquifers are available in the study area. However, shallow aquifer systems are relatively dominant in comparison to deep aquifer systems. (Fig. 6.09) Formation-wise basalt, limestone, miliolite, sandstone, and alluvial deposits are chief aquifer systems in the study area. Following discussions describe various characteristics of these aquifers.

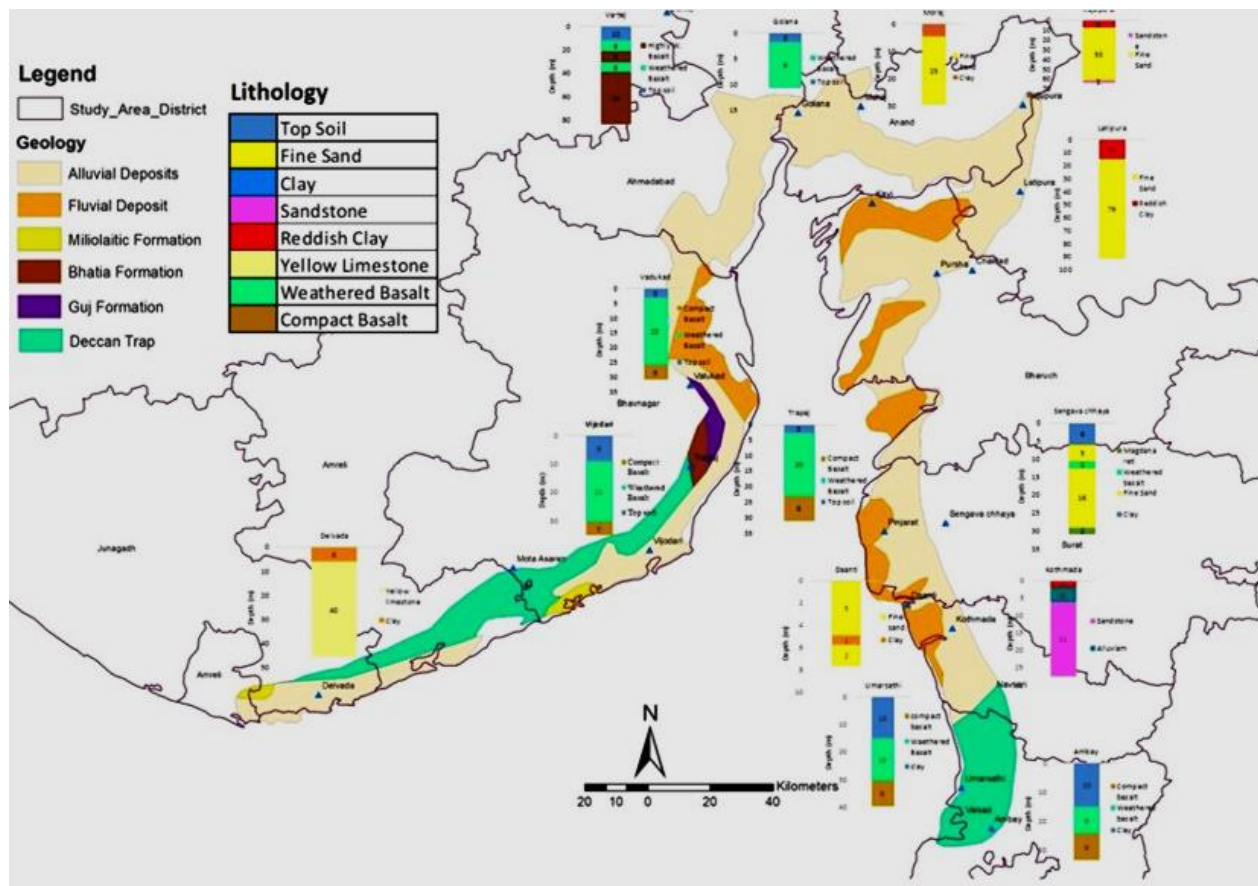


Fig. 6.9 Aquifer and Litholog Mapping for Downstream Western Zone

6.3.3 Deccan trap Aquifer System - Basalt

Weathered zones of Amygdaloidal basalt represent the aquifer system in all hilly areas. Aquifer thickness of basalt is about 22 m having variation of a few meters due to physiographic expression. As the basalt is considered to be consolidated rock the aquifer develops within it due to secondary fracture development or weathering processes. The static water levels in observation wells show variation in depth ranges from 14.5 m to 26 m BGL.



Plate 6.2. Field Photograph showing Open Well in Fractured Basalt. Block Una, Gir Somnath District

6.3.4. Tertiary Aquifer System - Limestone



Plate 6.3 Field Photograph showing Open Well in Limestone

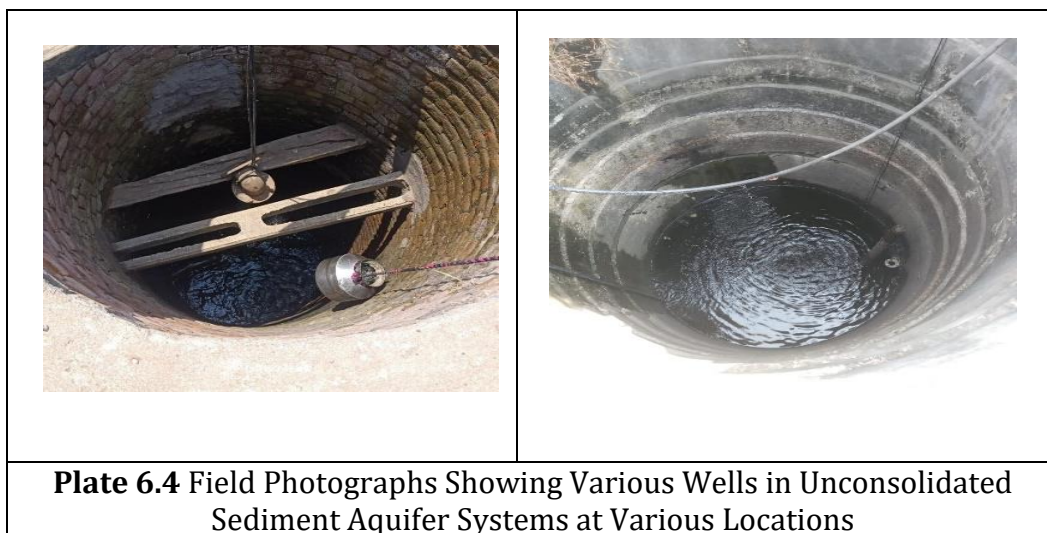
Limestone layers of Gaj formations of Tertiary formation characterize aquifer systems in western study areas especially downstream of Kalpasar Dam. Limestone in this zone occurs as intercalated stratification with clays. Well, lithology shows three different layers occurring at varying depths in the study area (Fig 6.10). Intercalated clay restricts rainwater percolation naturally in the second and third layers of limestone which results in

low discharge in post-monsoon seasons. Water level fluctuation in this area shows much more variation. Water level monitoring data shows a rise in water level takes place almost up to a ground level which drastically starts going down from January below 20 m in some areas. The uppermost layer of limestone is relatively more porous and permeable compared to the second and third layers. The second layer of limestone shows clay lances within this zone whereas limestone itself shows the development of secondary porosity due to the

development of solution cavities. The third and lowermost limestone layer due to its compactness shows very low porosity; only secondary porosity development has taken place in this limestone due to the development of fractures. People use terms like, “*Pilo Naram Bhathu*”, “*Tasiyu Bhathu*”, “*Kadak Bhathu*”, which means very fragile and highly cavern limestone and compact limestone respectively in the study area, whereas the term “met”, “varans” etc., are for color of clays.

6.3.5. Quaternary Aquifer System – Miliolite – Sandstone and Unconsolidated Sediments

A very small area in the western part of the study area represents this type of porous aquifer system. Some pockets in Amreli district and near Jafrabad show some wells developed in this aquifer. The thickness of miliolite is varying from 5 m to 16 m. In addition to primary porosity, development of secondary porosity is also more in comparison to other aquifers.



The unconsolidated sediments are the most dominant aquifer system all along the study area. Most of the wells in areas adjoining the coastline line are made in such unconsolidated sediments belong to Quaternary. Such sediments are stabilized dune sand and colluvial materials are the main aquifer constituents of this system. In spite of the abundance of wells in this area perennial usage of wells is restricted to limited areas. As these sediments are directly under the influence of seawater, groundwater quality is a major issue in this aquifer system.

6.3.6. Groundwater levels

Groundwater is considered to be a dynamic and renewable resource. The replenishment of water in the existing setup of the project area is primarily through precipitation. However, after the construction of the Kalpasar dam, replenishment may take place due to freshwater storage in the dam and canals. To evaluate the probable impact on groundwater in terms of quantity and quality it is important to understand current groundwater dynamics and relevant controlling factors in the area. The mechanism for groundwater replenishment involves complex input of various factors related to sediment nature, its spatial distribution pattern, the effect of surface and sub-surface processes, and of course the rainfall pattern. As the study area is predominantly characterized by all types of aquifers *i.e.*, consolidated, semi-consolidated, and unconsolidated sediments, the aquifers developed within these formations are phreatic in nature and subjected to wide fluctuation. Further, predominantly semi-arid climatic conditions and erratic rainfall patterns groundwater repositories remain underutilized. Therefore, adopting any developmental and management strategies for the study area's water resource; is a pre-requisite to having an appropriate assessment of the aquifer potential. The geo-hydrological study under this project in fact has been taken up for determining the various hydraulic characteristics of aquifers. Important aspects dealt with under this are (01) To understand seasonal water table fluctuations; (02) To characterize aquifers in terms of their hydraulic properties *viz.*, porosity, transmissivity, storage coefficient, specific yield, etc.; (03) To determine groundwater flow direction and gradient and (04) To assess the impact of rainfall on groundwater quantity and quality.

To accomplish the above aspects, attempts have been initiated based on using both primary and secondary data. Historical data on water level and chemical properties of groundwater were available in the form of records maintained by GWRDC from 2006 to 2021. The pre and post-monsoon data for these years have been collected and arranged on GIS platform systematically. Fig. 6.10 shows observations wells whose data have been used to evaluate groundwater trends in the project areas.

manner. Up to 2010, north-eastern part of the study area was having deeper water levels that also showed improvement or a rising trend in water level after 2010 till 2020.

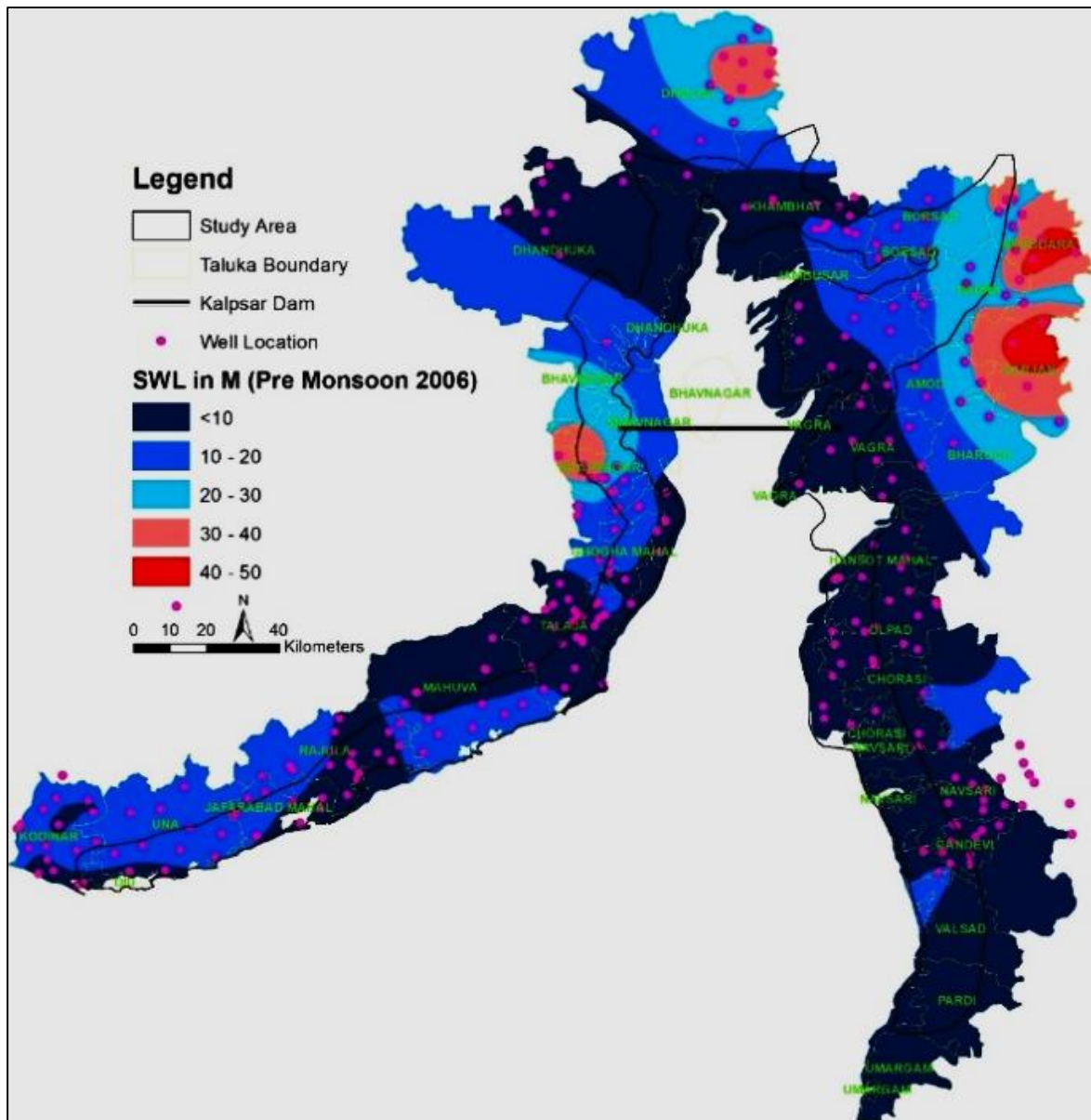


Fig. 6.11a: Static Groundwater Levels in Pre-Monsoon Season of Year 2006

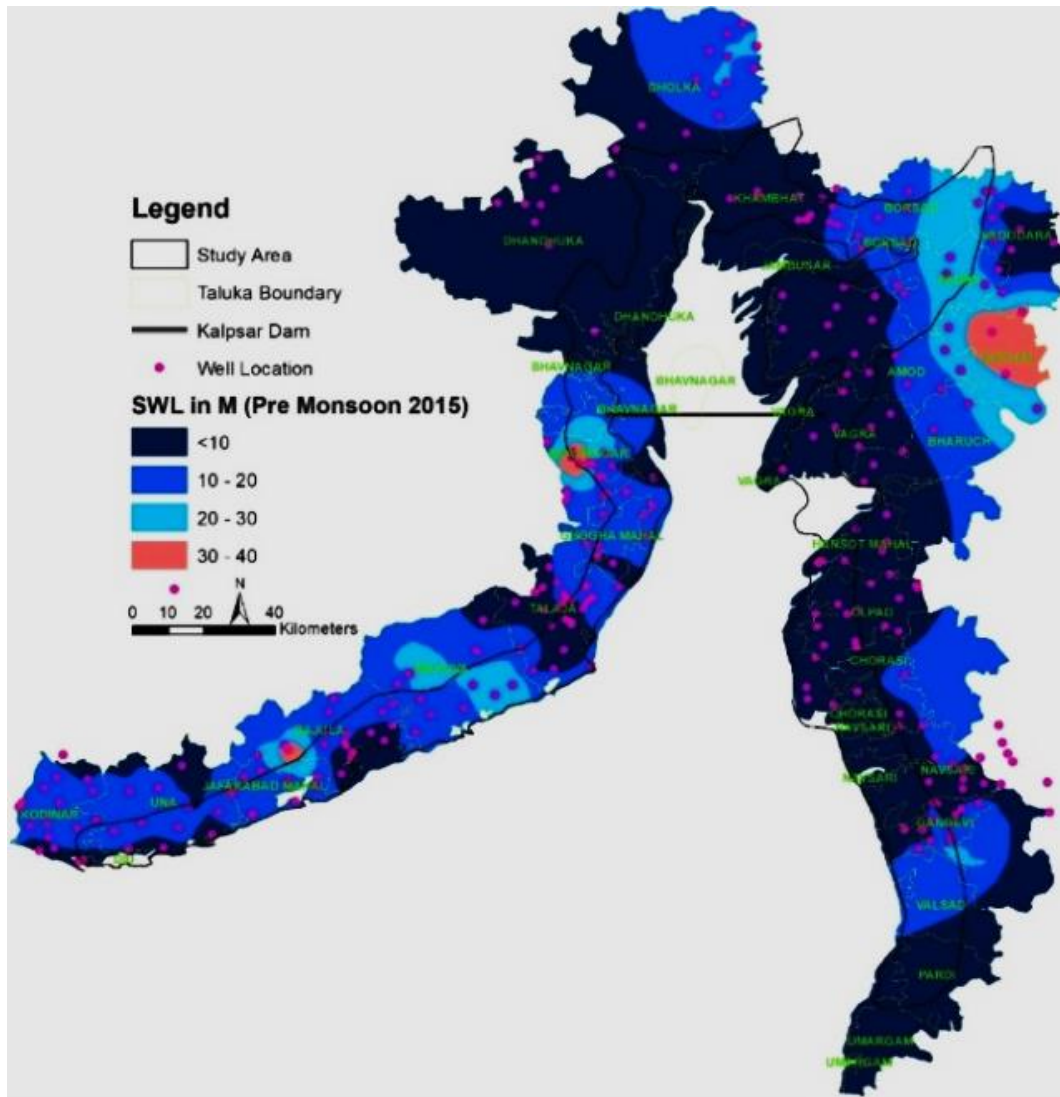


Fig. 6.11c: Static Groundwater Levels in Pre-Monsoon Season of Year 2015

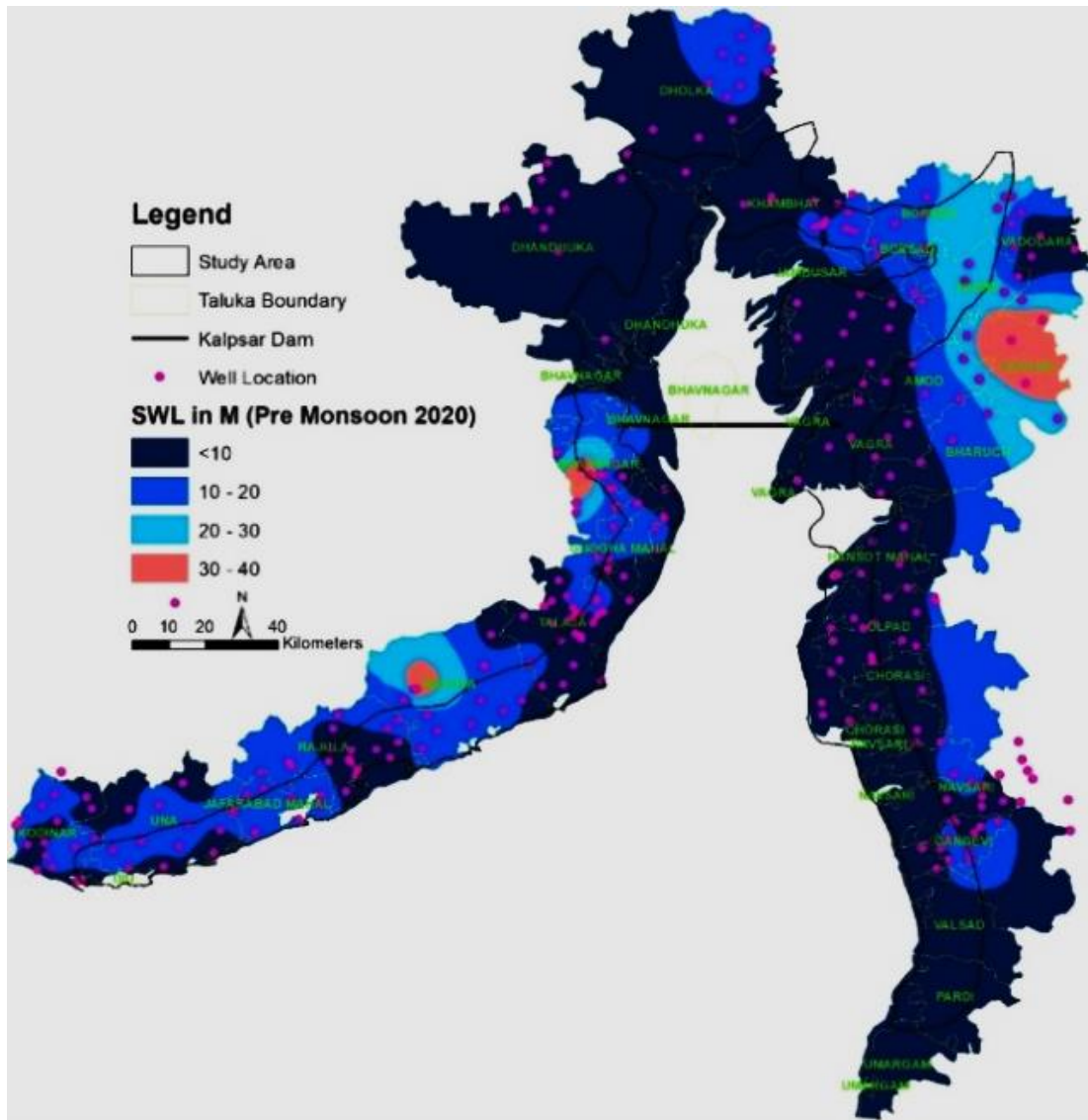


Fig. 6.11d: Static Groundwater Levels in Pre-Monsoon Season of Year 2020

6.3.7. Groundwater Table Elevation

To understand areas influenced by seawater intrusion in groundwater, Reduced Water Level (RWL) maps have been prepared from 2006 to 2020 and studied. Reduced Water Level is the Height of groundwater level with respect to average mean sea level (AMSL). Reduced water level contours below AMSL directly shows the potential threat of seawater intrusion into groundwater, especially in coastal areas.

Table 6.8 shows the change in areas of different RWL categories in the study area. In 2010 about 33 Km² area was below AMSL has become almost zero during the year 2020. The total area below MSL during 2006 has been reduced from 3947 Km² to 909 Km² in 2020.

Table 6.8 Changes in Reduced Water Level Areas

Sr. No.	RWL Category (M)	Area in Km ²			
		Pre-Monsoon Seasons of Years			
		2006	2010	2015	2020
1	-30 to -20	0	33	0	0
2	-20 to -10	418	297	12	0
3	-10 to 0	3529	3164	1105	909
4	0 to 10	9077	9826	9481	8774
5	10 to 20	5605	5545	6804	7335
6	>20	4989	4752	6217	6600
Total Area		23618	23618	23618	23618

Fig. 6.12 shows changes in reduced water levels since 2006. From 2006 (Fig. 6.12 a and b) to year 2010, there is an increase in ground water depth on the western side of Kalpasar Dam. From 2010 onward the water level shows rising trend in the entire study area. A year-wise and region-wise trend of groundwater is summarized below.

- ❖ In the NE region, in the year 2006 RWL ranges from 0m to -10 m can be considered as moderately safe, in 2010 it gradually decreased to -30m and fall into the deep zone leading high risk of salinity intrusion in to aquifers
- ❖ However, post 2010, RWL rose up and eventually become a safe zone
- ❖ NW part of the project area comprises a few patches of the deep saline zone of RWL ranging from 0m to -20m during years from 2006 to 2010. Through the years RWL increases up to -10m and the area of extent of decreased as well
- ❖ Negative sign of RWL indicates it lies below MSL and there could be high probability of sea water intrusion which eventually leads to an increase in TDS of freshwater
- ❖ In SE and SW regions of the project area, RWL ranges from 0m to 20m which could be considered a safe zone with respect to salinity intrusion. Over the years, RWL is

gradually increasing which could be attributed to increasing rainfall and irrigation in the region.

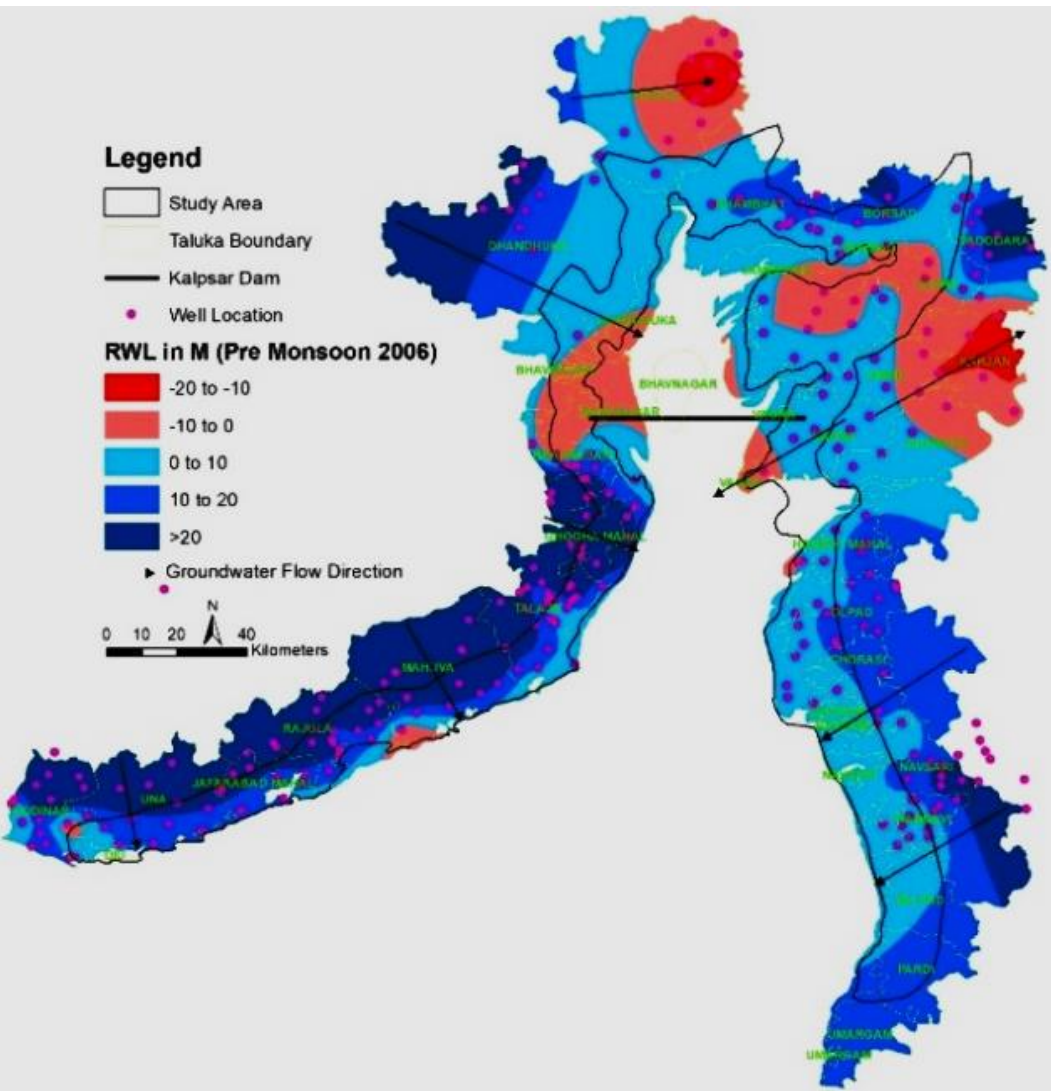


Fig. 6.12a Reduced Water Levels in Pre-Monsoon Season of Year 2006

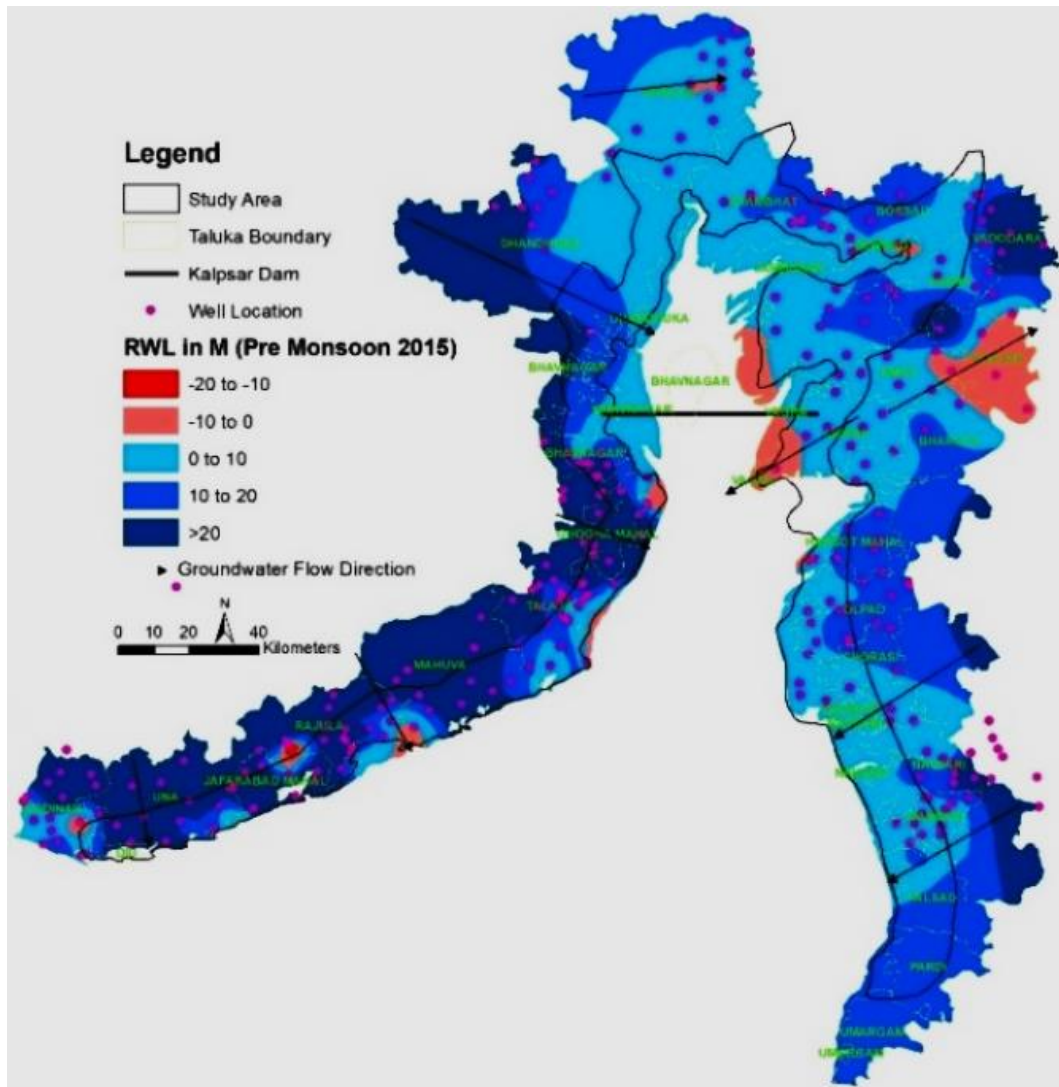


Fig. 6.12c Reduced Water Levels in Pre-Monsoon Season of Year 2015

6.3.8. Groundwater Quality

Reduced water level assessment is not only the parameter that gives an idea about sea water intrusion completely besides rising or depleting trends in water level one must need to study respective changing trends in groundwater quality too. The specific conductance of water provides a measure of the content of dissolved matter, which is popularly known as Total Dissolved Solids (TDS). It is an important basis for rapid assessment of water quality. By and large groundwater in the project area suffers from higher TDS content. In the study area, TDS varies between < 500 mg/L on the landward side and > 4000 on the seaward side. The objective on evaluation of seasonal and long-term changes in groundwater quality will not be accomplished due to lack of inadequate data in form of secondary data. Further, the area faces highly erratic and deficient rainfall, groundwater withdrawal for various purposes, and high salinity ingress from the seaward side. However, based on the available information, TDS content tends to decrease from pre-monsoon season of 2006 to pre-monsoon season of the year 2020, especially downstream side from eastern and western zones. (Fig. 6.13)

- ❖ The NW region of project areas shows high TDS values of more than 4000mg/L round the year.
- ❖ NE part shows two ranges of TDS one in the range of 2000-4000 mg/L and another range from <500mg/L to 2000 mg/L. This variation in TDS divides the NE region into two parts with respect to salinity difference. TDS values of this region (NE) have slightly increased over the years.
- ❖ In the SE realm of the project area, TDS values ranged from 2000 mg/L to 4000 mg/L in 2006, which decreased over the years up to a range of 500 mg/L to 2000 mg/L. This could be due to increase in rainfall over the years in the region.
- ❖ It is observed that area under high TDS (3000-4000 mg/L) has increased from 2006 to 2010 in the SW region of the project area. After that, the area of the extent of this TDS range decreased gradually. As a result, in 2020, there is only a small patch that has high TDS (2000 - 3000mg/L). Rest region of the SW region has lower TDS (500 - 1500mg/L).

Overall, the area shows a decreasing trend in total dissolved solids concentration since 2006, but the northwestern and the northern part of the study area show almost no or very negligible change in groundwater quality where the TDS concentration remains very high throughout the year.

Comparison between ISO-TDS and ISO-RWL maps very clearly divides area in to two *i.e.*, salinity affected areas or area under sea water intrusion are largely falls on upstream side *i.e.*, northwestern and northern fringes of Kalpasar Dam. Whereas downstream areas on both the sides of Gulf shows improved groundwater quality that may be due to increased groundwater recharge either by natural way during rainfall or due to interventions carried out under different programs during the previous years. Similarly, it can also be concluded through above discussions that upstream of Kalpasar dam may get benefitted over the years due to fresh water storage in dam as the area already shown reverse groundwater flow directions from seaward side.

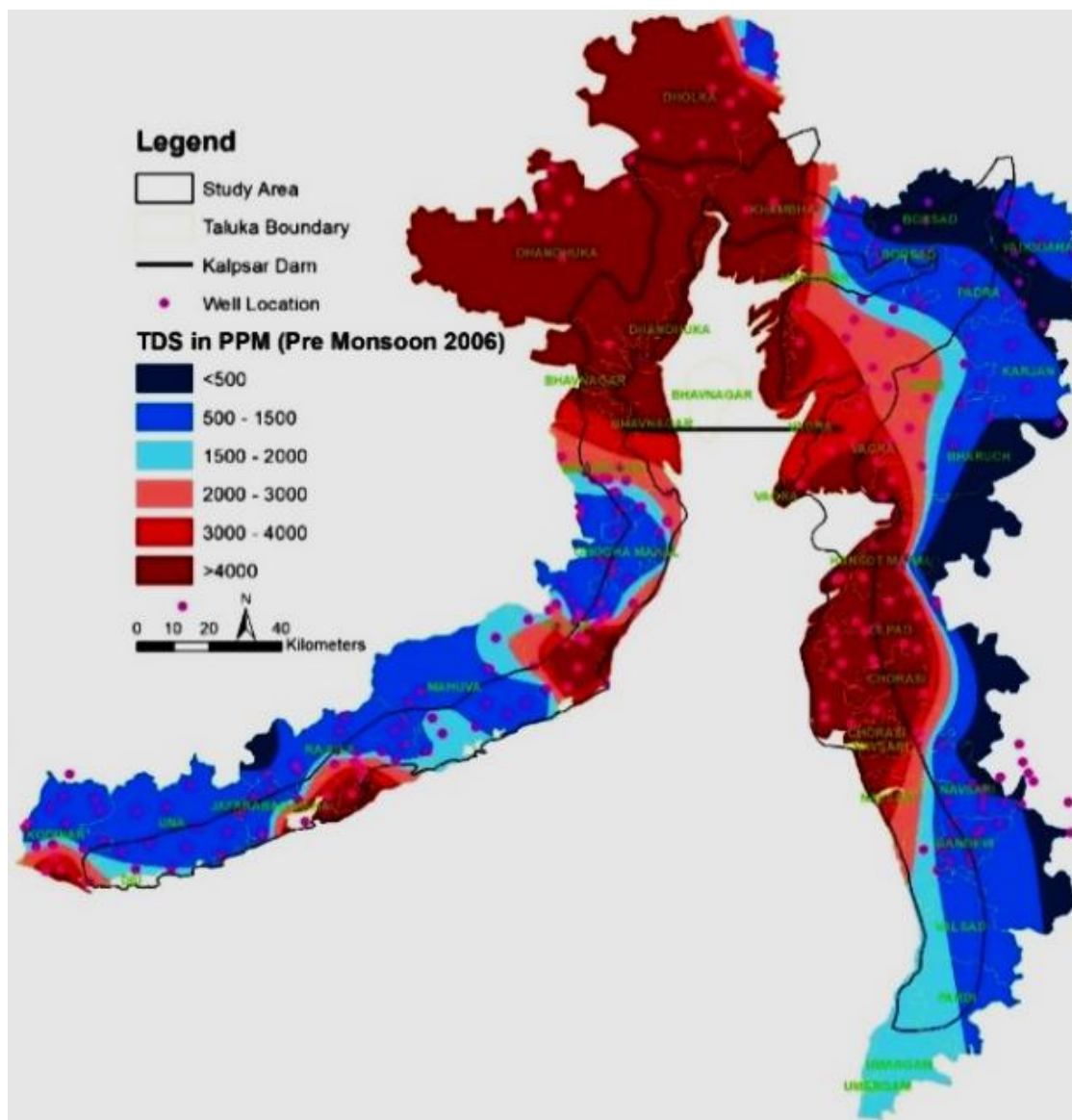


Fig. 6.13a: Total Dissolved Solid Concentrations during Pre-Monsoon Season of Year 2006

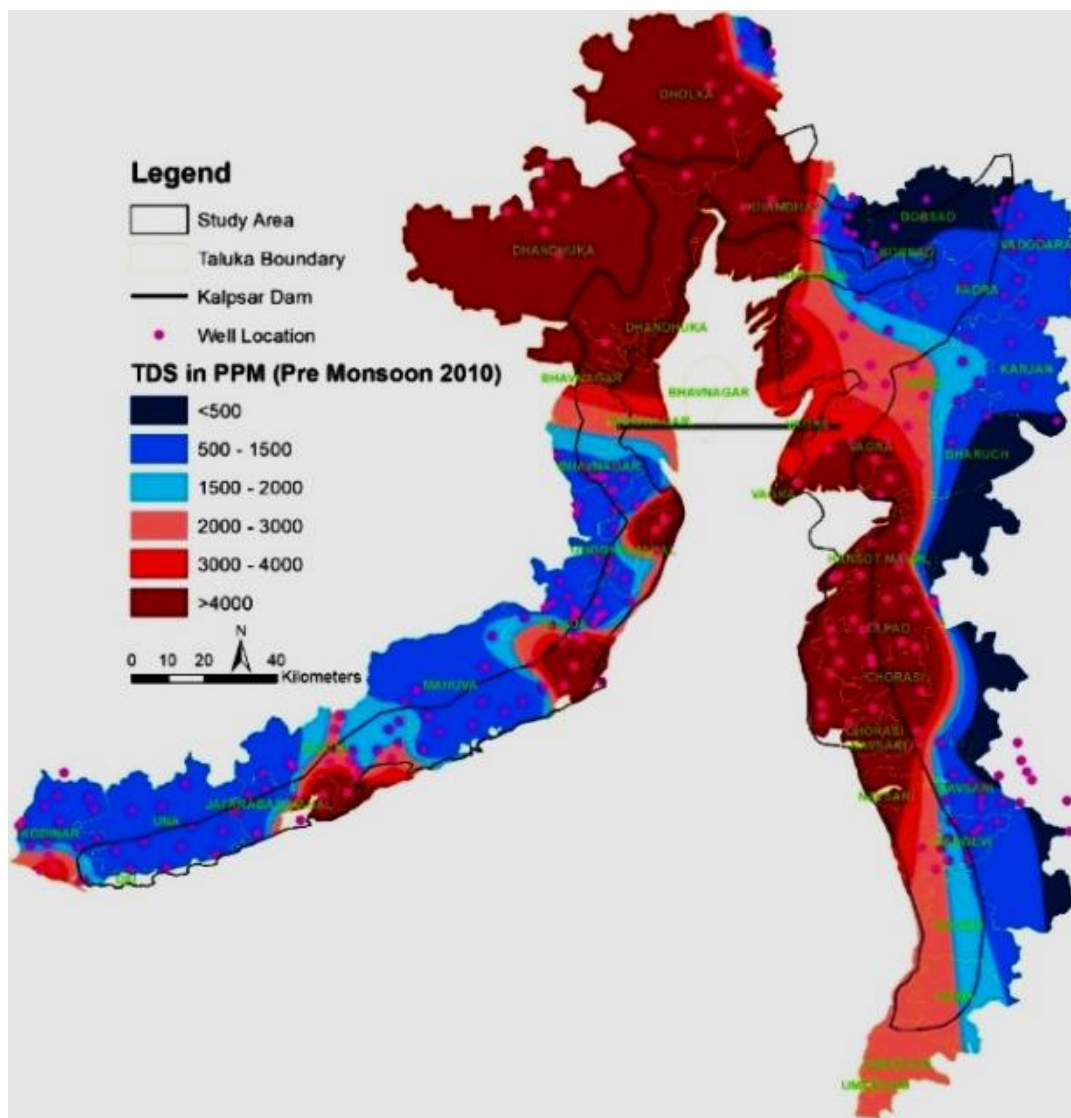


Fig. 6.13b: Total Dissolved Solid Concentrations during Pre-Monsoon Season of Year 2010

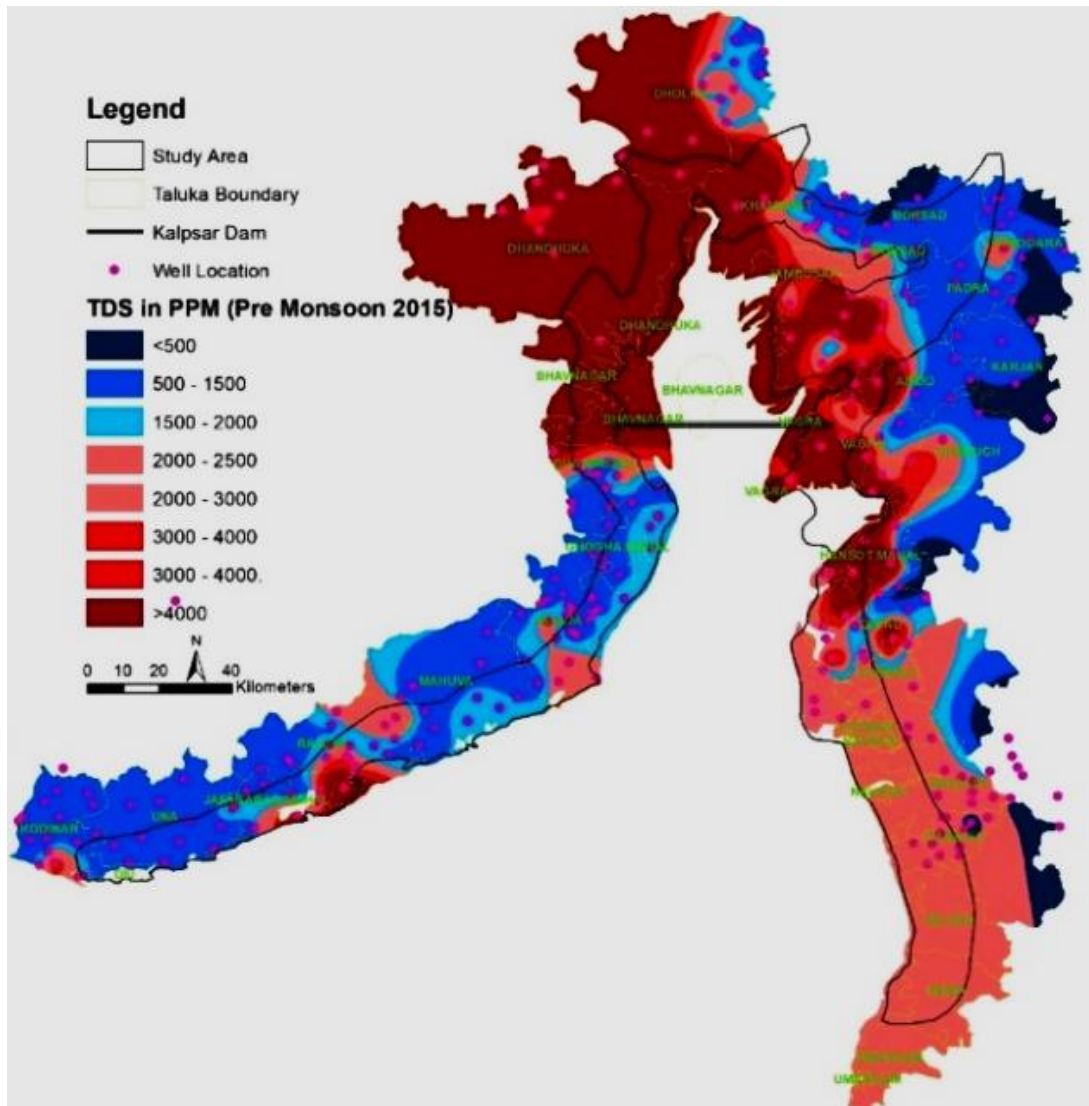


Fig. 6.13c: Total Dissolved Solid Concentrations during Pre-Monsoon Season of Year 2015

6.4 Socio-economic Assessment

6.4.1. Population and Households

To understand the socio-economic and demographic profile of the project area census hand book data of the year 2011 have been analyzed for 20 adjoining blocks of 09 districts, those about the Gulf of Khambhat in upstream and downstream defined study area of the Kalpasar dam. These blocks together cover 17282.76 Km² area distributed in as 755 Km² (Urban) and 15873 Km² (rural) as shown in Table 6.9.

Total population of entire study area is about 56.75 lakhs, distributed among 6,77,450 households. Among the total population, rural and urban population in the project area are 33.76 and 22.98 Lacs respectively that constitutes about 59.5% and 40.5 % shares of total population. So far population density in the project area is concerned it stands at 328.32 persons per sq. km. Maximum rural population is in Mahuva block (*i.e.*, 344815 persons) of Bhavnagar district while minimum population is in Jafrabad block (*i.e.*, 80835 persons) of Amreli district. Average person per household ratio stands at 8.4 person per family. (Table 6.10)

Table 6.9 District wise block wise area distribution

Table 4.1 District wise Block wise Area Distribution					
District	Block	Villages (No.)	Area (sq km)		
			Rural	Urban	Total
Amreli	Jafrabad	42	322.81	28.77	351.58
	Rajula	72	655.14	2.32	657.46
Bhavnagar	Mahuva	133	1307.64	13.63	1321.27
	Talaja	112	935.39	38.53	973.92
	Ghogha	48	687.50	11.94	699.44
	Bhavnagar	60	2187.26	105.96	2293.22
Ahmedabad	Dhandhuka	69	1784.48	62.66	1847.14
Anand	Khambhat	60	1030.52	80.77	1111.29
	Borsad	63	395.51	25.08	420.59
Vadodara	Padra	83	528.05	7.03	535.08
Bharuch	Jambusar	81	1405.01	38.70	1443.71
	Vagra	68	1644.00	0.00	1644.00
	Bharuch	95	590.79	42.94	633.73
	Hansot	46	550.34	7.46	557.80
Surat	Olpad	105	711.40	9.31	720.71
	Chorasi	51	203.87	106.95	310.82
Navsari	Jalalpore	72	494.73	7.12	501.85
	Gandevi	58	268.61	29.46	298.07
Valsad	Valsad	97	469.02	54.50	523.52
	Pardi	77	355.73	81.83	437.56
Total		1492	16527.80	754.96	17282.76

Table 6.10. Demographic characteristics of project area

District	Block	HH (No)	Population (No of Persons)							Literate		
			Rural	Urban	Total	Male	Female	SC	ST	Total	Male	Female
Amreli	Jafrabad	14032	80835	27167	108002	41501	39334	6335	117	40016	24786	15230
	Rajula	24038	137204	38489	175693	69767	67437	10451	185	77829	46464	31365
Bhavnagar	Mahuva	57654	344815	107196	452011	174726	170089	12147	764	192083	116006	76077
	Talaja	47264	271056	54611	325667	138613	132443	7338	146	159246	95259	63987
	Ghogha	15285	88769	12208	100977	45891	42878	1919	101	58985	33550	25435
	Bhavnagar	25303	144056	643263	787319	75130	68926	4307	721	91183	53791	37392
Ahmedabad	Dhandhuka	20572	112777	32475	145252	58783	53994	10043	217	69705	42156	27549
Anand	Khambhat	37102	186515	99164	285679	97225	89290	12838	860	126985	73880	53105
	Borsad	65384	316107	63543	379650	164655	151452	11938	1415	225182	130290	94892
Vadodara	Padra	45525	219241	46660	265901	114380	104861	13361	7417	152591	87430	65161
Bharuch	Jambusar	32277	153694	43344	197038	79981	73713	8412	19091	104243	59929	44314
	Vagra	21590	100044	0.00	100044	53489	46555	4450	25028	70505	41488	29017
	Bharuch	37642	185056	267461	452517	94641	90415	7544	52976	135048	73987	61061
	Hansot	12378	55832	5436	61268	28659	27173	3167	19510	40127	22096	18031
Surat	Olpad	35260	162884	33962	196846	84751	78133	6648	44361	118528	65258	53270
	Chorasi	19830	86225	143052	229277	49973	36252	2602	18261	64175	39707	24468
Navsari	Jalalpore	31605	136071	91994	228065	69486	66585	3431	30884	110911	57952	52959
	Gandevi	35565	154764	94500	249264	78000	76764	3268	57057	126292	65678	60614
Valsad	Valsad	50309	222682	192458	415140	113554	109128	5298	106966	174766	93850	80916
	Pardi	48835	217341	301473	518814	112227	105114	6123	135871	165051	91293	73758
Total		677450	3375968	2298456	5674424	1745432	1630536	141620	521948	2303451	1314850	988601

Literacy wise, about 40.6% of total people falls under literate category. Among total literate population, 57 % and 43 % of male and female are literate respectively. Borsad block of Anand district is having maximum literate population (*i.e.*, 2,25,182 persons) persons while Jafrabad of Amreli (*i.e.*, 40016 persons) has minimum literate population among study area.

6.4.2. Occupation and Working Classes

Occupations and livelihood in any area is dependent on availability of natural resources as well as an attempt made in development of the areas. As the Kalpasar project area's one of the objectives is to improve land-based livelihood of adjoining areas, the existing occupations have been evaluated for rural population based on census records. The occupation has been assessed based on working class such as (01) main cultivator; (02) agriculture labour (03) Mini household industries and (04) other working-class population (Table 6.11).

Out of total rural population 43.60 % are working class population. So far, the occupation is concerned, agriculture and its associated occupation like animal husbandry and agriculture labour are the dominant occupation in rural areas. About 66 % of total rural population is associated with occupation. The mini household industry category of occupation has engaged about 33 % of total rural population (Fig. 6.14).

Table 6.11 Types of working class and distribution of population

Working Class	Population (No of Person)		
	Total	Male	Female
Working	1472317	1018573	453744
Non- Working	1903651	726859	1176792
Main Cultivator	306441	262807	43634
Agriculture Labore	492281	328055	164226
Mini HH Industries	15683	12754	2641
Other Working	397070	326937	70133

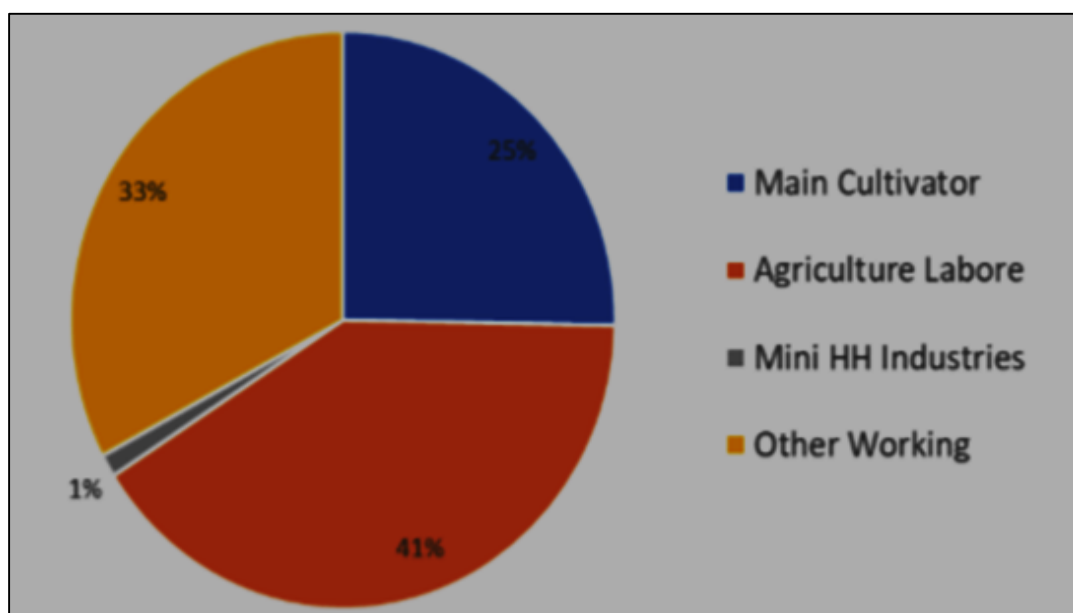


Fig 6.14 Occupation category wise distribution of rural population

Table 6.12 District wise and Block wise Working and Non-working population

District	Block	Working Population (No of Persons)			Non-Working Population (No of Persons)		
		Total	Male	Female	Total	Male	Female
Amreli	Jafrabad	37098	23249	13849	43737	18252	25485
	Rajula	61446	38574	22872	75758	31193	44565
Bhavnagar	Mahuva	148107	95569	52538	196708	79157	117551
	Talaja	124792	75457	49335	146264	63156	83108
	Ghogha	35391	25350	10041	53378	20541	32837
	Bhavnagar	59575	41513	18062	84481	33617	50864
Ahmedabad	Dhandhuka	46972	33137	13835	65805	25646	40159
Anand	Khambhat	80664	57055	23609	105851	40170	65681
	Borsad	140908	96639	44269	175199	68016	107183
Vadodara	Padra	90434	68264	22170	128807	46116	82691
Bharuch	Jambusar	65480	46889	18591	88214	33092	55122
	Vagra	39478	31044	8434	60566	22445	38121
	Bharuch	71534	54161	17373	113522	40480	73042
	Hansot	28171	18054	10117	27661	10605	17056
Surat	Olpad	75456	52851	22605	87428	31900	55528
	Chorasi	42812	34595	8217	43413	15378	28035
Navsari	Jalalpore	56430	40858	15572	79641	28628	51013
	Gandevi	68020	47190	20830	86744	30810	55934
Valsad	Valsad	97690	68350	29340	124992	45204	79788
	Pardi	101859	69774	32085	115482	42453	73029
Total		1472317	1018573	453744	1903651	726859	1176792

6.5. Groundwater Resources, Management and Planning

6.5.1. Existing Water Resources and Usages

It is important to carry out existing water use practices before carrying out any planning process in any area or region. Therefore, to develop appropriate planning to manage the impact of Kalpasar Dam, the existing practices of use of various water resources and problem associated with it have been understood by holding consultations with village communities in all three zones linked with Kalpasar dam, such as upstream area and eastern and western downstream areas. Under this process, two types of assessment have been attempted to carry out, i) types of water resources and its usage pattern and ii) second possible measures to manage resource health. The assessment has been carried out in about 216 villages in all three zones *viz.*, total 98 villages in Upstream zone, 55 villages in downstream western zone and 63 villages in downstream eastern zone. (Table 6.13) Groundwater through open well and tube well, Canal water from major and medium irrigation schemes, river water, and minor irrigation dams are major source of water for agriculture purposes and in some areas in downstream side especially in eastern part sewage water from urban areas are also utilized for agriculture purposes. For domestic water supply, surface as well as groundwater sources have been developed by village Panchayat as well as Urban legal bodies in respective areas.

Groundwater usage practices: Source wise, the dominant water sources across the region is groundwater in almost all the areas. The groundwater extraction in the study villages is being practices by developing dug well and tube wells. The depth, water level and quality are summarized and discussed in previous chapter on ground water potential of the areas. The dominant use of groundwater is for agriculture followed by domestic purposes. So far, irrigation point of view, flood and micro irrigation methods being adopted by farmers depending on availability across the different crop seasons around the year. However, broadly majority of farmers having open wells prefer the flood irrigation due to seasonal availability of water is dependent on rainfall. In addition to this, due to nearness of sea water quality also restricts round the year use of water from shallow aquifers.

Table 6.13. Zone Wise List of Villages Consulted and Type of Major Water Sources. Major Issues and Feasible Proposed Approach

Zone	Villages	Water Use Management		Major Issue	Feasible Approach
		Sources	Use for Crops		
Upstream Zone	Bharuch: Bhankhetar, Kavi, Kansagar, Pursa, Vadodara: Anagadh, Latipura, Gametha Dholka: Bholad, Vataman, Ghoga: Malekvadar, Padva, Tagadi, Valukad Khambhat: Golana, Gudel Talaja: Vejodari, Sartanpar, Talaja, Pavthi, Bhalar, Trapaj, Paniyali Kheda: Vastana, Nadhanpura, Jafarganj, Padchdej, Bhalada Anand: Moraj, Kalodara Nana, Druvaran, Vasana, Kasumbad, Sindhlay, Aasodar, Sherdi Moti, Sherdi Nani, Rajupura, Mogar, Anagadh, Ambavadi	Groundwater - Borewell & Dug Cum Borewell	Vegetable, Paddy and Wheat, Sorghum,	Brackish water and, Groundwater Pollution	Water use efficiency by adopting effective irrigation practices and Land management
		Canal Mostly in summer season	Vegetable, Banana, Tobacco, Millet, Fodder Crops	Water logging	
Eastern Down Stream Areas	Surat: Kharvasa, Umbar, Vanz, Dipla, Vansi, Borsi, Mangrol, Parsoli, Kolasana, Vada, Ponsara, Mahuar, Kadoli, Chokhana, Ichapor, Pinjrat, Olpad, Mandroi, Asnad, Morthan, Vadod, Bolav, Samli, Anklav, Ambheta, Kasva, Kesrol, Paniyadar, Sanchan, Mandala, Limdi, Samatpor, Chaklad, Nada Navsari: Dandi, Matwad, Salej, Ajrai, Pati, Bilimora, Dharasna, Sonvad, Balwad, Sarodhi, Kothamadi, Ambheta, Valsad: Tithal, Pali, Segvi, Magod, Chicuwada, Hariya, Umarasadi, Kolak, Kalai, Punat, Karaya, Ambach, Dungra, Valwada, Paria, Sonwada	Groundwater - Open wells	Sugarcane, Mango, Sapota and vegetable	Water Quality	Potential of Recharge in borewells & Lakes Storage Tank for Drinking water, Government Borewell should be Recharge, Potential to increase capacity of Village Lake Borewell in each House Hold, Rainwater quality is become Medium after 6 Month (TDS: from 200 to 250)
		Groundwater - Tube wells	Sorghum, Prawns	Water Quality	
		Canal and Lakes	Paddy, Grass	Dependency	
		Sewage Water	Paddy, Grass, Horticulture	Management	

Down Stream Western Zone	Mahuva: Kalsar, Dayal, Uncha Kotada, Nicha Kotada, Katkada, Bhatkada, Matalvav, Moti Jagdhar, Nani Jagdhar, Lingdi, Ranivada, Lilvan, Dantha, Manvav, Rojiya, Mangela, Bhungar, vavadi, Padri, Gadhesar, Pasvi, Borda, Bordi, Kundali, Vejudari, Valar, Tali, Banbhor, Methala, Madhuvan, Pratappara, Janjmer, Nava Rajpara, Gandhula, kerala, Aambala, Mithal patt	Groundwater Water - Dug Wells	Cotton, Groundnut, Sorghum, Chickpea, Wheat, Bajro, Vegetable,	Sea water ingress ion and scarcity	Recharge of shallow aquifers and improve water use efficiency by demand Side management

In short, groundwater is providing backbone support especially during the Kharif season of agriculture and ensures productivity. The major problem in some instances is scarcity of water during late winter season. Any intervention to increase efficiency of shallow aquifer water usage can have major impact on agriculture productivity especially in winter season. As per the community consultation, the recharge of such aquifer by using customized techniques can minimize the problem.

Dharoi, Sardar Sarovar Canal, Ukai, Karjan, Vanakbori, many tidal regulators (Bandharas) in Saurashtra coastal areas, and link canals and reverse canals from these tidal regulators are major source for surface water resources in the area for agriculture purpose. In addition to this, there are many small and minor irrigation structures developed by irrigation department which are serving the surface water for critical irrigation for agriculture. In addition to surface and groundwater, small contribution of water is also made by urban sewage water especially villages around major cities such as Surat, Bhavnagar, Vadodara where this is one of the important irrigation water sources.

6.5.2. Groundwater Management Planning

From the previous description it can be said that the major part of study area shows improvement in groundwater levels, decreasing trends in TDS concentrations depending on geology, geomorphology and water use pattern in the area. Therefore, to develop a detail planning for groundwater resource management, geological conditions especially aquifer status, and salinity status of the area are prime factors which need to be considered in developing planning strategies. So far geological environment is concerned, a conceptual framework considering local characteristics and freshwater-sea water interface has been prepared to describe respective impact on groundwater in project area in different geological conditions. Fig. 6.16 shows probable impact on various rocks abutting the Gulf of Khambhat as well as reservoir areas of Kalpasar dam. Generally, the freshwater level and sea water ration in coastal area is estimated as 1:40 due to specific density of freshwater and groundwater.

Based on this principle, Fig 6.16 depicts the submergence area will dilute the salinity in aquifers below the Kalpasar submergence areas whereas its peripheral areas adjoining to submergence may have impact based on characteristic rock formation. Again, it will have influence on groundwater recharge based on storage water level, *i.e.*, if the aquifer rock is exposed above the submergence will not have any major direct impact while the submerged rocks will show immediate impact on water level as well as quality. Other important aspect that will showcase impact is type of rock formation. As the project area has diverse rock ranging from consolidated to semi consolidated to unconsolidated sediments all will have characteristics impact based on their properties. Clayey as well as hard rock may have relatively low recharge impact while semi consolidated sediments and loose sandy alluvial areas will get immediate benefit by Kalpasar dam water. (Fig. 6.15) Another important aspect has considered for planning is a existing salinity status in the area. Therefore, based on trend analysis and salinity status map of pre monsoon season of 2020 has taken into considered and based on TDS concentration, the entire area has been divided into three zones, such as (01) Kalpasar dam Upstream zone – higher saline zone; (02) Kalpasar dam western downstream zone and (03) Kalpasar dam eastern downstream zone. (Fig. 6.16) Zoning exercise followed by characterization of these planning zone based on local groundwater

situation, aquifer characteristics, land use and land forms to narrow down the strategies to actions for development and management.

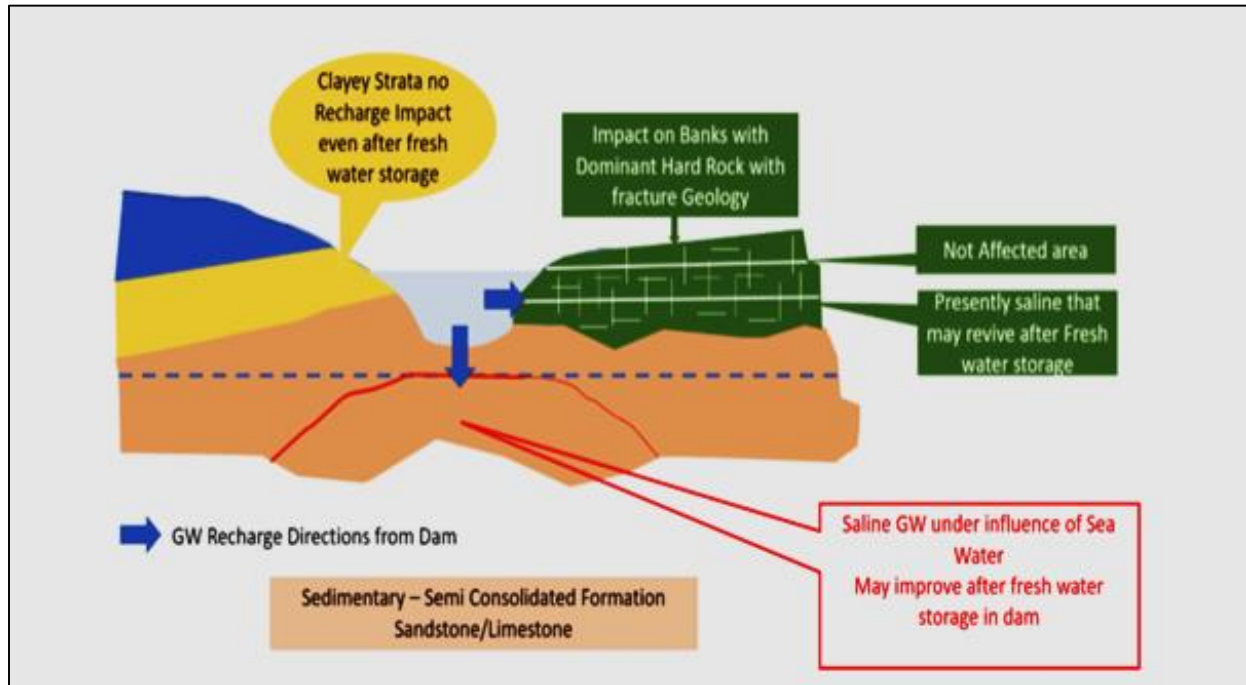


Fig. 6.15 Conceptual sketch for probable impact on Groundwater in Kalpasar Dam areas in different geological formations

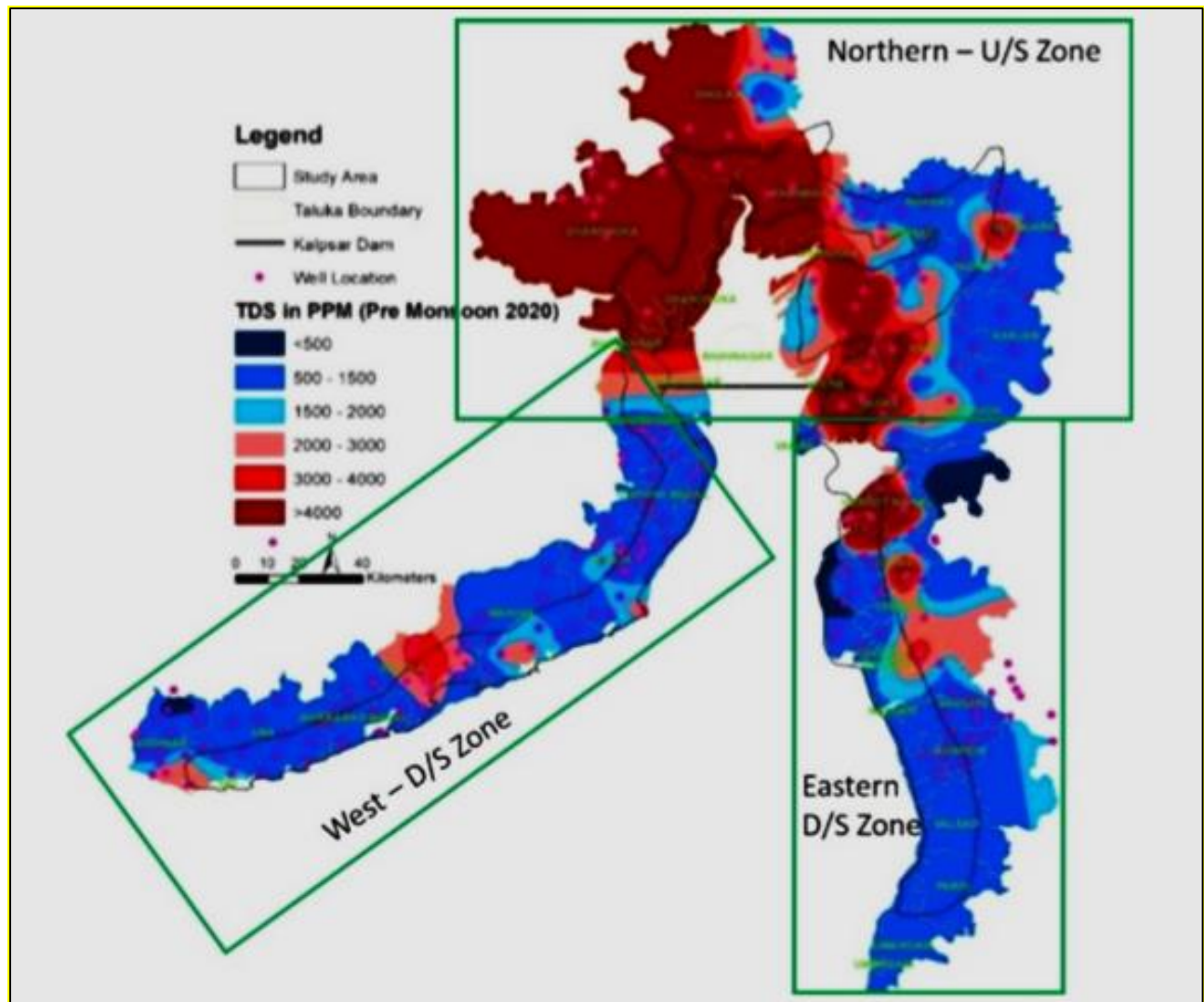


Fig. 6.16. Groundwater Management Planning zones

Table 6.14. Zone wise Geohydrological Characteristics, Issues and Proposed Strategies and Actions for Planning

Zone	Aquifer	Water Level (M)	Water Quality TDS (mg/L)	Issues	Strategies and Action for Planning
Northern U/S Zone	Alluvium/Find to Coarse grain sand	06 - 30	3000 - > 4000	Salinity ingress	Salt tolerant practices and improve bio inputs; Groundwater Recharge through injection method; Riverbed recharge through filter wells; Land management activities e.g. Land levelling; Soil moisture and critical irrigation structures e.g. farm ponds and encouraging agriculture practices such as Bio Inputs.
Western D/S Zone	Calcareous Sandstone	16 - 32	500-1500	Quantity	Salinity resistant crops; Agriculture practices improvement e. g. Bio inputs;
	Limestone	08 - 30	1500 - 3000	Quantity and water quality	Defunct Bore well Recharge; Recharge wells; Filter Wells;
	Weathered basalt	12 - 20	500 - 2000	Quantity	Groundwater Recharge / Watershed Development;
Eastern D/S Zone	Alluvium/Soft Rock	10-12	<500 - 3000	Seasonal salinity	Groundwater Recharge through injection method; Riverbed recharge through filter wells; Land management activities e.g., Land levelling; Soil moisture and critical irrigation structures e.g., farm ponds and encouraging agriculture practices such as Bio Inputs;
	Weathered basalt	20-25	1500 - 3000	Quantity and seasonal salinity	Groundwater Recharge / Watershed Development.

Further to propose the activities for mitigation, successful technologies and interventions carried out by NGO's, Government program have been evaluated and studied by the project team. A comprehensive list of various technologies for surface water, groundwater and soil moisture conservation have been listed out and a type design has been prepared for respective activities. Table 6.13 shows suggested activities with specific objective while table 6.15 shows zone wise suggested strategies and recommendation for various activities.

Table 6.15. Objective wise Proposed Activity for Land and Water Management

Sr. No.	Objective	Proposed Activity	Unit Cost INR in Lakh /Unit	Remark
1	Surface Water Harvesting	New Structure development	8-10 INR/No	
		Up gradation of Existing Water Harvesting Structures	4-6 INR/No.	
		Link Canal	1.25 INR / RMT	
2	Groundwater Recharge	Artificial Recharge Tube well	8.5 INR/ No.	
		River Bed Recharge pits	6.5 INR/ No.	
		Well Recharge Pit	0.27 INR/Pit	Annexure 3
		Filter Wells	0.5 INR/No.	
		Defunct Bore well Recharge	0.20 INR/Bore	Annexure 4
		Recharge wells	0.20 INR/Well	Annexure 4
3	Soil Moisture Conservation	Farm Bunds	0.33 INR/Ha	Annexure 2
		Land levelling	1.10 INR/Ha	Annexure 2
		Farm ponds	0.80 INR/No.	Annexure 4
		Soil Aquifer Recharge	0.45 INR/ Ha	
4	Agriculture practices	Salinity resistant crops	0.10 INR/Ha	
		Bio inputs	0.05 INR/Ha	

Further to estimate the total investments, based on geo-hydrological characteristics as well as land use and landform pattern a feasible location have been identified to execute proposed activities (Table 6.16) Fig. 6.17 shows feasible zones for respective activities and Table 6.16) shows estimated investment for implementation of the project.

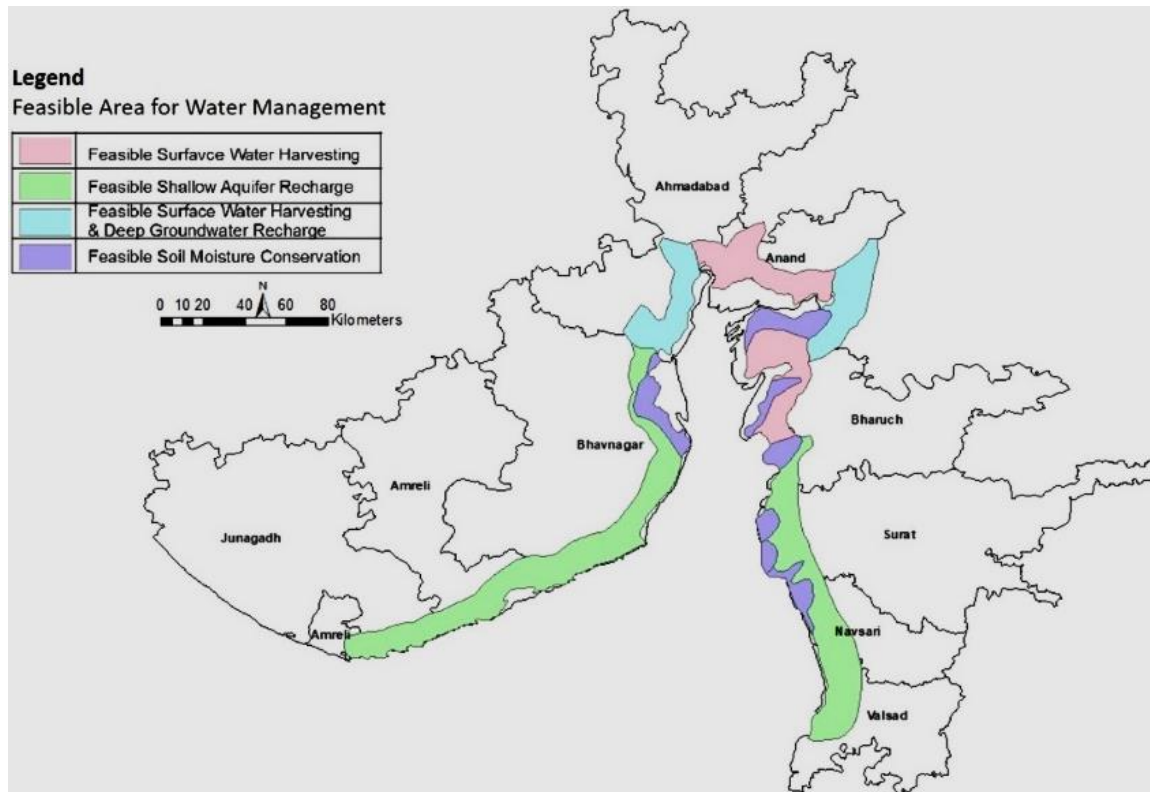


Fig. 6.17 Feasible Zones for Proposed Water Harvesting and Land Management Activities

Table 6.16 Estimated Investment for Proposed Activities

Feasible area for	Area SQKM	Major Activity Proposed	Quantity	Unit	Unit Cost Lakh INR	Estimated Lakh INR
Surface Water Harvesting	1771	One Surface Water Harvesting structure new/Repairer 5 sq km one structure	354	Str.	7	2478.00
Shallow Groundwater Recharge	4529	Defunct Bore Well Recharge	2265	Well	0.20	453.00
		Percolation check dams	566	CD	5.00	2830.00
		Recharge Pits	1132	Pits	0.27	305.64
Surface Water Harvesting Deep Groundwater Recharge	1617	One Surface Water Harvesting structure new/Repair in 50 % of total area and per 5 sq km one structure	162	Str.	7	1134.00
		One ARTW per 3 sq km	539	ARTW	8.5	4581.50
Soil Moisture Conservation Activities	1331	Soil moisture conservation through farm bund and waste weir activities in 30 % of total area	39930	Ha	0.33	13176.90
		Farm Ponds in 10 % area as one pond per 5 Ha	2662	FP	0.8	2129.6
		Soil aquifer recharge in 2 % of total area and one structure per 5 Ha	532.4	Ha	0.45	239.58
Total Estimated Investments (in Lakh)						27328.22
Str. = Structure, CD=Check Dam; ARTW = Artificial Recharge Tube Well; FP = Farm Pond						

6.5.3. Possible Impacts

The groundwater level (Fig. 6.12, 6.13) and groundwater quality maps (Fig. 6.14) prepared for pre monsoon seasons for year 2006 to 2020 have clearly indicated improvements in eastern and western zones of study area while norther zone is having severe groundwater and surface salinity problem. Therefore, this particular zone is the area where Kalpsar Dam's fresh water storage will have possible impact on various aspects. The possible impact in this area can be listed as below

- Due to impounding of fresh water in dam reservoir, major change may take place in land use from one season agriculture to three season agriculture
- Shallow aquifer's salinity ingress ion may reduce and water become brackish first than utilizable quality for agriculture
- Presently the canal is the fresh water source for irrigation but due to improvement in water quality in shallow zone groundwater may be the chief irrigation sources
- Dam will stop the supra tidal water ingress ion in many areas of Dhandhuka, Khambhat, Padra and Hansot blocks, and present saline soil will gradually turn into non saline soil.

In addition to above major impacts, impact on Groundwater salinity ingress ion projection has been estimated without construction of Kalpsar dam. This estimation has been made based on available block level groundwater monitored data of wells located most nearest to the coast line. Most saline block's i.e., Dhandhuka, Khambhat and Hansot analysis has been made for the projection.

The Fig. 6.19 shows the existing trend of groundwater salinization in these areas. As per the pre and post monsoon data records of highly saline wells of these blocks the present trend of dilution of total dissolved solids is shown in Table 6.17. According to hydrograph and data it can be said that groundwater salinity is increasing in Dhandhuka (4950 mg/L) and Khambhat (1570 mg/L) blocks in last 15 years while the salinity has decreased 7410 mg/L in same duration. However, so far projection is concerned the rate by which the salinity has decreased in Hansot is about 494 mg/L per year and if the rate is continue than the groundwater of Hansot block become utilizable i.e., up to 2000 mg/L in the year of 2047 i.e., almost 25 years now. Based on this analysis it may be said that the Kalpsar dam storage may decrease this rate significantly for Hansot block while it can arrest salinity ingress in rest of the saline areas.

Table 6.17 Changes in TDS Concentration (mg/L) in Most Salinity Affected Blocks in Project Areas

Districts		Ahmedabad	Anand	Bharuch
Blocks		Dhandhuka	Khambhat	Hansot
Villages		Fedra	Pandad	Samli
Monitoring Period	Period			
	May_06	39860	11850	35460
	Oct_06	37190	14870	
	May_07	40710	12540	39320
	Oct_07	37270	10490	45490
	May_08	45260	11240	44420
	Oct_08	39450	10880	50210
	May_09	40210	11550	54690
	Oct_09	45920	11200	54150
	May_10	41600	14210	59590
	Oct_10	39530	11130	27710
	May_11	42920	15090	38220
	Oct_11	45140	11130	42870
	May_12	41720	14340	46640
	Oct_12	44550	12330	52260
	May_13	41150	22490	62840
	Oct_13	43310	15200	50210
	May_14	44060	10370	59590
	Oct_14	48080	10680	21570
	May_15	38180	12210	
	Oct_15	44700	14400	47720
	May_16	43370	11390	46970
	Oct_16	38630	12280	41050
	May_17	33980	11740	39550
	Oct_17	44110	10690	42590
	May_18	36020	12850	48020
	Oct_18	34400	11360	32870
	May_19	40270	13160	43200
	Oct_19	40270	12780	53280
	May_20	44800	15130	26190
	Oct_20		13420	28050
Changes		4940	1570	-7410

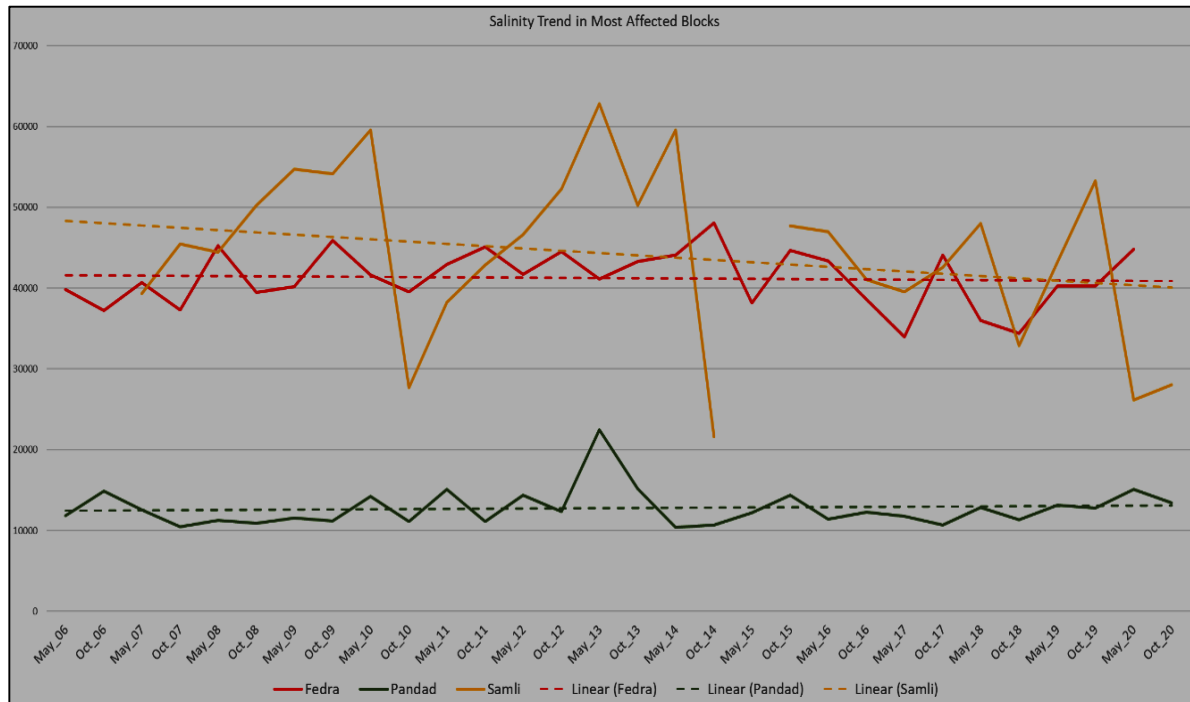


Fig. 6.18. Trend in Total Dissolved Solid Concentration in Groundwater in Most Affected Blocks

Annexures

Annexure 1: Well Inventory Format

Well No.		Date		Sample No.	
Village			Taluka		
Location	Longitude	Latitude			
Name of the Owner					Survey No.
Local Name of the Well/Farm/Area					
Use	Drinking Water		Irrigation		Drinking For Cattle
					Abused
Lifting Device		Oil Engine			Electric motor
					Hp
Measurement of "Y" for Discharge in m					

Well / Tube Well Information					
Type of Well	Open /Dug Well	Dug cum Bore Well	Step Well	Bore Well	Virda
Well Detail			Geological Information		
Measurement Point (MP) level	Ground Level	Parapet Level	Rock Type		Thickness m
Height of MP from GL	m				
Total Depth	m				
Diameter	m				
Water level	m				
Casing/Curbing Depth	m				

In Case of DCB, Please give the following informations			
Type of Bore Hole	Horizontal	Inclined	Vertical
Number of Bore Hole			
Depth/Length of Bore Hole			
Year of Bore Hole			
Casing Size inch			
Casing Type	PVC		Cement Pipe
Geological Information			
Rock Type	Thickness m	Status of Water	
		Quality (Fresh, brackish, saline)	Water Zone (Dry/Saturated/Moist)
Terrain Characteristics of the Surrounding area			

Geology	
Geomorphology	
Tectonic Aspects	
Land use Pattern	

Water Utilization Pattern from Well			
<i>Purpose</i>	<i>UserHuman and/or cattle</i>	<i>Unit</i>	
Domestic			Population
			Population
Agriculture	Crop Type	Acre	Season and Duration

Well Behavior or Changes in Water in Different Seasons		
<i>Season</i>	<i>Change in water level (m)</i>	<i>Change in water quality Taste wise</i>
Pre-Monsoon Season		
Post-Monsoon Season		
During Drought Season		
During construction period till today		
Note: Expression of Taste as sweet, brackish, saline		

Well/Bore Well History

Surveyed By: _____ Sign: _____ Date: _____

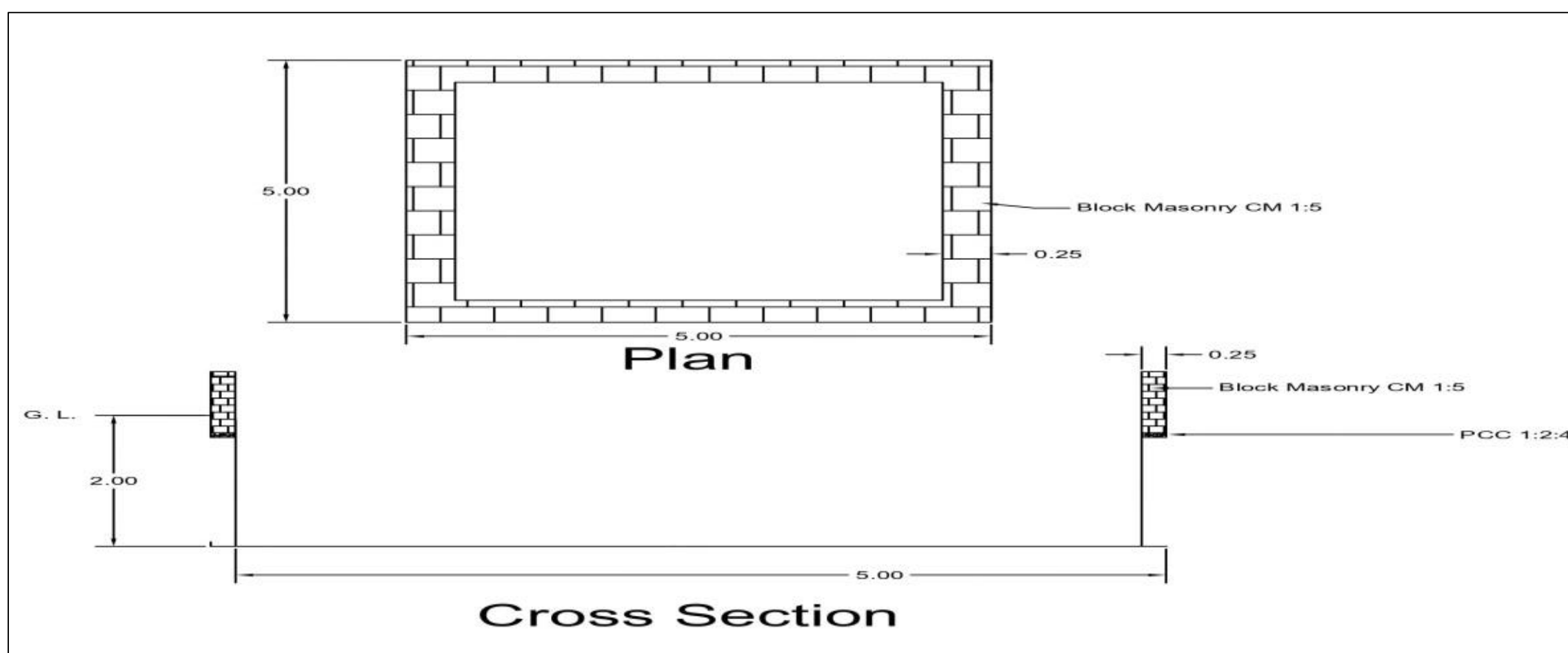
Annexure 2: Unit Cost for Proposed Treatment – Farm Bunding, Farm Waste Weir and Land Levelling

Farm Bund Design Proposed Cost Section Cross Section of Earthen Bund of Farmbund All dimensions are in meters Farm Bund Design Dimensions and Proposed Unit Cost per Running Meter <table><tr><th rowspan="2">Length (M)</th><th colspan="3">Width (M)</th><th rowspan="2">Avg Height (M)</th><th rowspan="2">Qty (Cum)</th><th rowspan="2">Unit Cost INR /CU M</th><th rowspan="2">Total Cost INR</th></tr><tr><th>Top</th><th>Bottom</th><th>Avg</th></tr><tr><td>1.00</td><td>0.5</td><td>2.5</td><td>1.5</td><td>1.00</td><td>1.45</td><td>55.00</td><td>79.75</td></tr><tr><td colspan="7">Therefore, per running meter length Farm bund Cost INR</td><td>80.00</td></tr></table>		Length (M)	Width (M)			Avg Height (M)	Qty (Cum)	Unit Cost INR /CU M	Total Cost INR	Top	Bottom	Avg	1.00	0.5	2.5	1.5	1.00	1.45	55.00	79.75	Therefore, per running meter length Farm bund Cost INR							80.00	Proposed Design Plan of Farmbund Waste Weir Cross Section of Farmbund Waste Weir All Dimensions in Meter	Farm Waster Weir <table><tr><th>Sr. No</th><th colspan="6">Item Descriptions</th><th>Unit Cost</th><th>Total Cost</th></tr><tr><td rowspan="8">1</td><td colspan="6">Foundation Excavation</td><td>INR</td><td>INR</td></tr><tr><td>S.No</td><td>Description</td><td>N0.</td><td>L (M)</td><td>W(M)</td><td>D(M)</td><td>Qty (Cum)</td><td></td></tr><tr><td>1</td><td>Body wall</td><td>1.00</td><td>3.00</td><td>0.45</td><td>0.45</td><td>0.61</td><td></td></tr><tr><td>2</td><td>Abutment</td><td>2.00</td><td>0.60</td><td>0.45</td><td>0.45</td><td>0.24</td><td></td></tr><tr><td>3</td><td>Wing wall U/S</td><td>2.00</td><td>1.00</td><td>0.45</td><td>0.45</td><td>0.41</td><td></td></tr><tr><td>4</td><td>Wing wall D/S</td><td>2.00</td><td>1.00</td><td>0.45</td><td>0.45</td><td>0.41</td><td></td></tr><tr><td>5</td><td>Return Wall</td><td>4.00</td><td>0.45</td><td>0.45</td><td>0.45</td><td>0.36</td><td></td></tr><tr><td colspan="6">Total</td><td>2.03</td><td>148300</td></tr><tr><td rowspan="8">2</td><td colspan="6">Foundation Concrete in C.M. (1:3:6)</td><td></td><td></td></tr><tr><td>Sr. No.</td><td>Description</td><td>N0.</td><td>L (M)</td><td>W(M)</td><td>D(M)</td><td>Qty (Cum)</td><td></td></tr><tr><td>1</td><td>Body wall</td><td>1.00</td><td>3.00</td><td>0.45</td><td>0.10</td><td>0.14</td><td></td></tr><tr><td>2</td><td>Abutment</td><td>2.00</td><td>0.60</td><td>0.45</td><td>0.10</td><td>0.05</td><td></td></tr><tr><td>3</td><td>Wing wall U/S</td><td>2.00</td><td>1.00</td><td>0.45</td><td>0.10</td><td>0.09</td><td></td></tr><tr><td>4</td><td>Wing wall D/S</td><td>2.00</td><td>1.00</td><td>0.45</td><td>0.10</td><td>0.09</td><td></td></tr><tr><td>5</td><td>Return Wall</td><td>4.00</td><td>0.45</td><td>0.45</td><td>0.10</td><td>0.08</td><td></td></tr><tr><td colspan="6">Total</td><td>0.45</td><td>31111400</td></tr><tr><td rowspan="8">3</td><td colspan="6">U.C.R. Masonry in C.M. (1:6)</td><td></td><td></td></tr><tr><td>Sr. No.</td><td>Description</td><td>N0.</td><td>L (M)</td><td>W(M)</td><td>D(M)</td><td>Qty (Cum)</td><td></td></tr><tr><td>1</td><td>Body wall</td><td>1.00</td><td>3.00</td><td>0.45</td><td>0.65</td><td>0.88</td><td></td></tr><tr><td>2</td><td>Abutment</td><td>2.00</td><td>0.60</td><td>0.45</td><td>1.45</td><td>0.78</td><td></td></tr><tr><td>3</td><td>Wing wall U/S</td><td>2.00</td><td>1.00</td><td>0.45</td><td>1.05</td><td>0.95</td><td></td></tr><tr><td>4</td><td>Wing wall D/S</td><td>2.00</td><td>1.00</td><td>0.45</td><td>1.05</td><td>0.95</td><td></td></tr><tr><td>5</td><td>Return Wall</td><td>4.00</td><td>0.45</td><td>0.45</td><td>0.65</td><td>0.53</td><td></td></tr><tr><td colspan="6">Total</td><td>4.08</td><td>296512088</td></tr><tr><td rowspan="4">4</td><td colspan="6">15MM thick cement plaster in C.M. (1:3)</td><td></td><td></td></tr><tr><td>Sr. No.</td><td>Description</td><td>N0.</td><td>L (M)</td><td>W(M)</td><td>D(M)</td><td>Qty (Sqm)</td><td></td></tr><tr><td>1</td><td>Body wall</td><td>1.00</td><td>3.00</td><td>1.05</td><td></td><td>3.15</td><td></td></tr><tr><td>2</td><td>Abutment</td><td>2.00</td><td>0.60</td><td>0.66</td><td></td><td>0.79</td><td></td></tr></table>	Sr. No	Item Descriptions						Unit Cost	Total Cost	1	Foundation Excavation						INR	INR	S.No	Description	N0.	L (M)	W(M)	D(M)	Qty (Cum)		1	Body wall	1.00	3.00	0.45	0.45	0.61		2	Abutment	2.00	0.60	0.45	0.45	0.24		3	Wing wall U/S	2.00	1.00	0.45	0.45	0.41		4	Wing wall D/S	2.00	1.00	0.45	0.45	0.41		5	Return Wall	4.00	0.45	0.45	0.45	0.36		Total						2.03	148300	2	Foundation Concrete in C.M. (1:3:6)								Sr. No.	Description	N0.	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L (M)	W(M)	D(M)	Qty (Sqm)		1	Body wall	1.00	3.00	1.05		3.15		2	Abutment	2.00	0.60	0.66		0.79		Land leveling - One Bigha = 16000 sqm - Maximum slope difference = 0.5 m - Therefore average leveling requires cut and fill = 0.25 m - Therefore net quantity for excavation and filling 8000 sqm x 0.25 m = 2000 cum - Per CUM rate = 55 INR - Therefore per Bigha estimated land levelling cost = 1,10,000
Length (M)	Width (M)			Avg Height (M)	Qty (Cum)					Unit Cost INR /CU M	Total Cost INR																																																																																																																																																																																																																																																																	
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			3	Wing wall U/S	2.00	1.00	1.15		2.30			
			4	Wing wall D/S	2.00	1.00	1.15		2.30			
			5	Return Wall	4.00	0.45	0.75		1.35			
			Total							9.89	136	1345
		5	15MM thick rock soaling in apron									
			Sr. No.	Description	N0.	L (M)	W(M)	D(M)	Qty (Cum)			
			1	Apron	1.00	3.00	1.15	0.15	0.52			
			Total							0.52	557	288
		6	15MM thick pitching in U/S and D/S of Bund									
			Sr. No.	Description	N0.	L (M)	W(M)	D(M)	Qty (Sqm)			
			1	On Bund	4.00	2.50	1.20		12.00			
			Total							12.00	143	1716
		Total										17135
		Therefore Unit Cost for 3 M Long Farm Waste Wier INR										17000

Annexure 3: Unit Cost for Proposed Treatment –Recharge Pit

Sr. No.	Item	No.	L (M)	W (M)	H/ D (M)	Qty.	Unit	Unit Rate INR	Total Cost INR
1	Item No. 1 : Excavation for Foundation of filter chamber in all type of soil, Hard murrum and soft rock including removing and spreading the excavated stuffs directed with lead up to 90M.	1	5	5	2	50.00	Cum.	126	6300
2	Item No. 2: Providing and laying cement concrete 1:2:4 at bottom (1 Cement: 2 Coarse sand: 4 graded stone aggregates 20 mm nominal size) and curing complete incl cost of formwork but excluding cost of reinforcement	4	5	0.25	0.1	0.50	Cum.	5450	2725
3	Item No. 3: Providing and laying Using CC 1:3:6 block of approved size and cement mortar by mass incl striking out joints, curing, finishing and scaffolding etc. complete. a) IN C.M. 1:5 For all lead and lift.	4	5	0.25	0.75	3.75	Cum.	3216	12060
4	Item No. 4: Cement plaster 20 mm thick rough coat with C.M. 1:3 incl watering curing etc. complete								
	Inside of Protection Wall	4	5		1	20.00	Sqm.		
	Outside of Protection Wall	4	5		1	20.00	Sqm.		
	Total Plaster					40.00	Sqm.	148	5920
Total Cost for Recharge Pit for Shallow Aquifer Recharge									27005
Therefore, Unit Cost for Recharge Pit for Shallow Aquifer Recharge									27000



CHAPTER 7

Proposed Monitoring and Assessment During Construction and Operational Phase

The primary data indicated presence of important species in the region. There are threatened species both in the lower form and higher vertebrates. There are about 27 species falling within the IUCN Red list of Threatened species and Indian Wildlife (Protection) Act 1972 present in the study area (Table 7.1). These species because of their threatened status necessitates special conservation efforts/measures which needs to be executed. The following studies are recommended both during Construction phase and Operational phase, considering the relevance and importance of the species and the habitat in the region

7.1 Studies on Water Quality Monitoring

Regular monitoring of the water quality is important during the construction and operational phase to know the gradual change in the water quality parameters. The water quality is a good indicator of aquatic life as most of the aquatic species have specific niche requirement as per the different water parameters are in concern. So, changes in water quality will directly affect the indicator species and also the biotic community structure. So regular monitoring of the different water quality parameters will give a glimpse of stressors acting on the biotic community and will also help to predict change in community assembly and gradual successional status from marine water to brackish followed by the fresh water environment.

The long-term study on water quality monitoring should be done at select locations along the freshwater and marine water gradient. Within the study both the physical and chemical parameters need to be covered.

Estimated budget: Rs 50,00,000/- Per year.

Table 1: List of Species under IUCN Red list of Threatened Species and Indian Wildlife (Protection) Act 1972

S. No.	Class	Order	Family	Common Name	Scientific Name	IUCN Red list status	IWPA, 1972
1	Reptiles	Crocodylia	Crocodylidae	Mugger	<i>Crocodylus palustris</i>	Vulnerable	Sch I
2	Aves	Accipitriformes	Accipitridae	Black Kite	<i>Milvus migrans</i>	Least Concerned	Sch I
3				Black-winged Kite	<i>Elanus caeruleus</i>	Least Concerned	Sch I
4				Eurasian Marsh Harrier	<i>Circus aeruginosus</i>	Least Concerned	Sch I
5				Greater Spotted Eagle	<i>Clanga clanga</i>	Vulnerable	Sch IV
6				Indian Spotted Eagle	<i>Clanga hastata</i>	Vulnerable	Sch I
7				Montagu's Harrier	<i>Circus pygargus</i>	Least Concerned	Sch I
8				Oriental Honey Buzzard	<i>Pernis ptilorhynchus</i>	Least Concerned	Sch I
9				Pallid Harrier	<i>Circus macrourus</i>	Near Threatened	Sch I
10				Shikra	<i>Accipiter badius</i>	Least Concerned	Sch I
11		Anseriformes	Anatidae	Common Pochard	<i>Aythya ferina</i>	Vulnerable	Sch IV
12		Charadriiformes	Burhinidae	Great Thick-Knee	<i>Esacus recurvirostris</i>	Near Threatened	Sch IV
13			Laridae	River Tern	<i>Sterna aurantia</i>	Vulnerable	Sch IV
14			Scolopacidae	Black-tailed Godwit	<i>Limosa limosa</i>	Near Threatened	Sch IV
15				Eurasian Curlew	<i>Numenius arquata</i>	Near Threatened	Sch IV
16		Ciconiiformes	Ciconiidae	Painted Stork	<i>Mycteria leucocephala</i>	Near Threatened	Sch IV
17				Woolly-necked Stork	<i>Ciconia episcopus</i>	Vulnerable	Sch IV
18		Galliformes	Phasianidae	Indian Peafowl	<i>Pavo cristatus</i>	Least Concerned	Sch I
19		Gruiformes	Gruidae	Sarus Crane	<i>Grus antigone</i>	Vulnerable	Sch IV
20		Pelecaniformes	Pelecanidae	Dalmatian Pelican	<i>Pelecanus crispus</i>	Near Threatened	Sch IV
21			Threskiornithidae	Black-headed Ibis	<i>Threskiornis melancephalus</i>	Near Threatened	Sch IV
22				Eurasian Spoonbill	<i>Platalea leucorodia</i>	Least Concerned	Sch I
23				Red-naped Ibis	<i>Pseudibis papillosa</i>	Near Threatened	Sch IV

24	Mammals	Cetartiodactyla	Delphinidae	Indian Ocean humpback dolphin	<i>Sousa plumbea</i>	Endangered	-
25		Carnivora	Felidae	Jungle Cat	<i>Felis chaus</i>	Least Concerned	Sch II part II
26		Carnivora	Canidae	Indian/Golden Jackal	<i>Canis aureus</i>	Least Concerned	Sch II part I
27		Primates	Cercopithacidae	Indian Gray Langur	<i>Semnopithecus entellus</i>	Least Concerned	Sch II

7.2 Monitoring the Marine Biota

Long-term monitoring the marine biota throughout all the season will be helpful to ascertain and establish the baseline community structure and then to assess the shift in community assemblage with periodical change in water quality. Thus, a dedicated survey of the marine biodiversity assemblage needs to be started as soon as the construction phase of the project started. During the construction phase both nektons and benthos will possibly be affected. Some of the species will sustain and some of them will perish. The identification of threshold level indicator taxa will be very much important, as they will shape the future community and effectively take part in the ecosystem functioning. Biomarkers or indicator species also can be identified through this process.

The study should be long term and covering both the construction phase and operational phase. Seasonal monitoring is recommended.

Proposed Budget: Rs. 30,00,000/- per year.

7.3. Socio-economic Studies: Studies to be undertaken to ensure proper rehabilitation and resettlement of the fishing communities mostly the *Pagadias*. Proper training has to be given to them for aquaculture and the level of acceptance of new technology within the community. Some of the implementation projects helpful for *Pagadiya* community is given in section 7.10. within the sub heading of Implementation projects. The detailed socio-economic studies for generation of baseline for all fishing community members to be generated to know where, when and how much assistance is needed for better socio-economic development of the community to start different implementation projects. The same study to be repeated after 3-5 year to know the status of the fishing community.

Proposed Budget: For creating the base line data Rs. 10,00,000/- for a period of 6 months.

7.4. Experimental Study to Control the Algal Bloom

Increase in population of cyanophyceae and chlorophyceae members especially the filamentous forms result in growth of algal mat which is detrimental for the aquatic life. There are various techniques to remove the algal bloom like (1) Mechanical control

involves the use of filters, pumps, and barriers (e.g., curtains, floating booms) to remove or exclude blooms from impacted waters. 2) Physical, chemical (Copper sulfate, Buffered alum and/or calcium compounds are sometimes added to bind up phosphorus and make it unavailable for algal use) and biological control (pathogens that can kill algal blooms) measures have been used in freshwater systems for small and large-scale control of algal blooms due to their significant public health, economic, and ecosystem impacts (Chorus and Bartram, 1999). 3) Artificial mixing can be an effective measure to establish a shift in the phytoplankton composition from cyanobacteria to green algae and diatoms (Petra *et.al.*, 2015) in the short term and in lakes with an open connection to eutrophic rivers, artificial mixing could be a good solution to prevent nuisance blooms of cyanobacteria.

Artificial Mixing has been used in several lakes to improve water quality. Preconditions for successful applications are as follows: (1) mixing rate should be sufficiently high to entrain the cyanobacteria in the turbulent flow, (2) the mixing should be deep enough to sufficiently limit light availability and (3) the distribution of aerators or mechanical mixers should be designed in a way that a sufficiently large part of the lake participates in the artificially induced turbulent flow (given the bathymetry of the lake).

Mixing can lead to a higher nutrient concentration in deep stratified lakes due to nutrient-rich hypolimnetic waters. Deep mixing will reduce the light dose as experienced by phytoplankton and will increase the amount of suspended matter in the water column. Reduced light exposure will lead to decreased growth of cyanobacteria and algae. Decreased stability of the water column will benefit diatoms and green algae, but will be disadvantageous for buoyant cyanobacteria. Due to the increased oxygen concentrations that are generally the result of mixing, the conditions for fish and zooplankton may improve. More zooplankton generates higher grazing of algae and will decrease the net growth rate of diatoms and algae

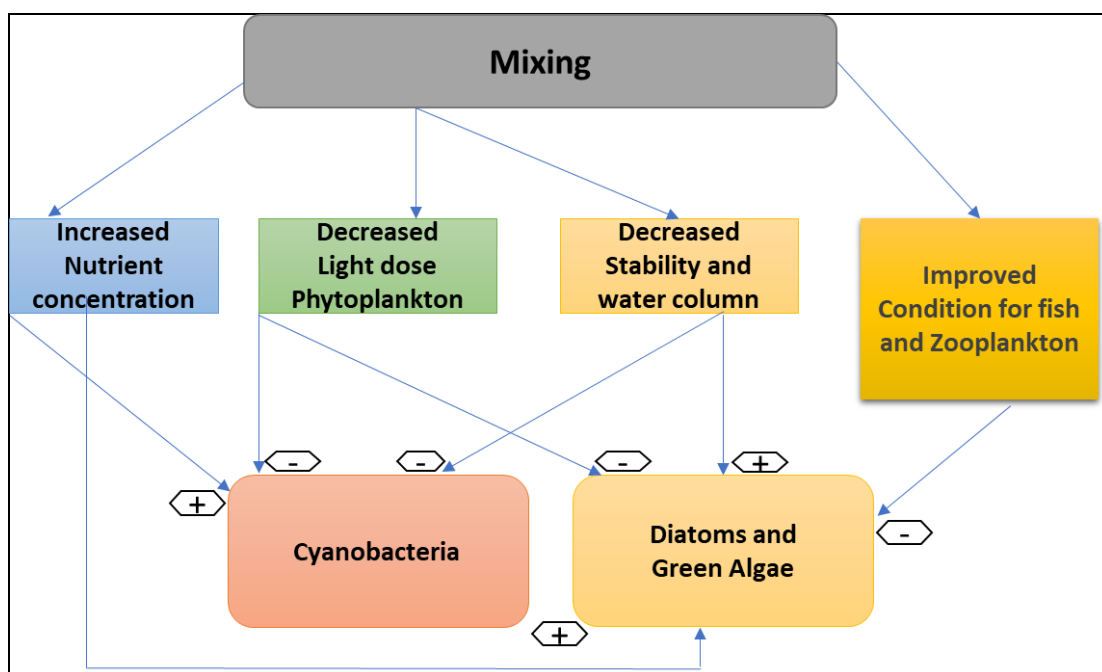


Fig 7.1. Diagram showing the general effects of artificial mixing on algae and cyanobacteria (after Shapiro 1979).

Estimated Cost: The study will be of five-year duration and the total cost will be Rs. 10,000,000/- for five years (Rs 20,00,000/- per year)

7.5. Ecological Monitoring and Conservation of the Mugger (*Crocodylus palustris*) in and around the Kalpasar Project Area

Mugger is the most adaptive species and it is envisaged that with the dam enclosure and decline in salinity regimes, the species will proliferate and expand its territory. The exposed soft mudflats will provide suitable habitat for nesting. Along with the increase in the mugger population increase in human wildlife conflict with the coastal population residing will increase. The proposed projects intend to provide water for agriculture and the irrigation area will increase in the new areas which are now under the influence of tides. Thus, it is important to undertake the proposed study with the following objectives

Objectives:

- (1) Status and population estimation survey of the Mugger in the study area
- (2) To study Behavioural patterns of Mugger and using it to suggest guidelines for locals to minimise Human-Mugger face off/conflicts.

(3) Survey on Human-Mugger Conflict in different rivers and lakes within a 10 km buffer zone of the Kalpasar Dam.

(4) Undertake Mugger conservation and awareness through local people's participation in the villages under the influence of the proposed dam

Time duration: 2 years estimated tentative cost Rs 25,00,000/=

7.6. Investigating the Status and Distribution of Endangered Raptors within 10 km Buffer of the Kalpasar Site

The study region falls within the pathway of the Asian Flyway and there are reports of presence of raptors in the region. Further, with the change in the ecosystem and expansion of the terrestrial vegetation along with agriculture there is possibility of increase in raptor population and number of raptors wintering is likely to increase.

Objectives: The objectives of the proposed study include

- (1) Status survey of raptors in and around the Kalpasar Dam area
- (2) Study on the feeding habits and hunting success of raptors across the study area
- (3) Record incidence of nesting of raptors
- (4) Outline strategies for the conservation of endangered raptors

Time duration: 2 years estimated tentative cost Rs 25,00,000/=

7.7. A Study on The Status and Distribution of Indian Ocean Humpback Dolphin (*Sousa plumbea*) in and around the Kalpasar Dam Project.

Indian Ocean humpback dolphin is the only marine mammal reported in the area. The threatened status of the Indian Ocean humpback dolphin is endangered as per IUCN Red List and therefore further studies and conservation of the species is essential.

Objectives: the objectives of the study include

- (1) Status and abundance of the Indian Ocean humpback dolphin in and around the Kalpasar Dam area.
- (2) Find out trend for the species population pre and post the Kalpasar dam construction phase.
- (3) Record incidence of the species mortality due to fish by-catch, etc.
- (4) Outline strategies for the conservation of the dolphin species

- (5) Developing a cost-efficient and reliable technology to monitor dolphin and other marine mammal population in highly turbid waters of Gulf of Khambhat.

Time duration: 2 years estimated tentative cost Rs 50,00,000/=

7.8. Diversity, Status, And Distribution of Migratory Avifauna in And Around the Kalpasar Dam Project

In July 2022, a flamingo tagged at Mumbai was spotted in the Gulf of Khambhat and therefore the area needs thorough investigation on the avifaunal species visiting the area throughout the year. The region lies in the route of the Central Asian flyway and therefore is important to undertake a detailed study for one complete year of observations on the birds visiting the area which will include the coastal area, intertidal mud flats and wetlands within 10 Km of the tidal line. Some of these wetlands are used by the birds for roosting and breeding purposes. This will help to design the conservation measures and steps to be taken during the implementation phase.

Objectives:

- (1) Assess distribution, composition and movement of migratory birds (inward and outward migration) in the area with respect to the Central Asian Flyway.
- (2) Identification of suitable habitats for the migratory birds in the area.
- (3) Identification and evaluation of potential threats on migratory avifauna, with a focus on critical species and habitats.
- (4) Suggest mitigation measures to avoid risk impacts on the migratory avifauna.

Time duration: 2 years estimated tentative cost Rs 50,00,000/=

7.9. Study on Indian smooth-coated Otter in Central and South Gujarat and predicting the potential effect of Geo-hydrological changes occurring due to Kalpasar project

There is small population of Smooth Indian Otter reported from Hansot region of Bharuch district. With the availability of food in form of fish and aquaculture will attract Smooth Indian Otter into the proposed dam. Smooth Indian Otter is categorised as Vulnerable on IUCN Red List and therefore it is essential to undertake a study based on the following objectives.

- (1) Estimating population and abundance of Smooth-coated otter in Central and South Gujarat

- (2) Modelling based distribution study of Smooth coated Otter in the freshwater and estuarine areas
- (3) Identification of threats impacting Smooth-coated otter across the study area.
- (4) Suggest conservation measures to avoid risk on the species.

Time duration: 2 years estimated tentative cost Rs 35,00,000/=

7.10. Assess the Temporal and Spatial LULC Dynamics of the Past and to Predict the Future in and around Kalpasar Area Using Landsat Images and LCM (Land Change Modeler)

The proposed dam will result in changes in the land use pattern and hydrogeological regimes. The mudflats that receive tidal waters will remain exposed and form new landform. The decline in salinity in the aquifer will result in expansion in agriculture area and from one crop to three crop in a year. These changes will greatly influence the land use and therefore the present study has to be undertaken with the following objectives.

Objectives:

- (1) Analysis of land use/ land cover changes from early 1990 to 2020 (1990, 2000, 2010, 2020)
- (2) Analysis of LULC transition changes (2030 and 2050) and probabilities using the MLPNN (Multi-Layer Perceptron neural networks) and CA-Markov (CAMCM) chain model
- (3) Analysis of geo-hydrological changes and its probable impact on land use due to changes from marine water to fresh water system

Time duration: 2 years estimated tentative cost Rs 50,00,000/=

7.11. Implementation Projects

To enhance the livelihood options of the displaced fishermen community out of which majority of them are *pagadiya* is a major task. In the following section optional livelihood mechanism is outlined which could be effective for the upliftment of the local community.

7.11.1. Sea Ranching Programme in the Proposed Study Site to Develop the Fish Production for the Upliftment of the *Pagadiya* Fisher Communities.

Sea ranching can be defined as: “Releasing juvenile specimens of species of fishery importance raised or reared in hatcheries and nurseries into the sea for subsequent harvest at the adult stage or manipulating fishery habitat to improve growth of the wild

stocks". Sea ranching essentially capitalizes on existing favourable features of a marine area and combines the natural attributes of the sea environment of the region with various levels of technology. The released animals exploit the resources for food and other requirements of life, and can be caught when marketable. The sea ranching technique involves (1) brood stock development, (2) breeding, (3) larval rearing on large scale, (4) nursery rearing, (5) release of seed at suitable sites and (6) monitoring of the released and natural stocks to assess the impact.

Time period:

Yearly two times, depends on the stock availability of the species present in hatchery or nursery rearing organisms of different hatchery, and especially post monsoon season ideally for Sea ranching programme.

Implementing Agency

S. No	Agency with Hatchery Technology	Species
1	CMFRI, Mandapam, Tamil Nadu	Cobia, Pompano
2	CMFRI, Visakhapatnam, Andhra Pradesh	Grouper, Pompano
3	RGCA (MPEDA), Pozhiyoor, Kerala	Seabass, Cobia, Pompano
4	RGCA (MPEDA), Sirkali, Tamilnadu	Seabass, Mud crab
5	CIBA, Chennai, Tamil Nadu	Seabass

The potential for sea ranching programme remains largely unexplored. Five important species can be experimentally taken in Khambhat for sea ranching depends on the salinity changes happen in due courses of time.

(1). Mud Crab Crablets, (*Scylla serrta*)

(2). Tiger prawn.PL, (*Penaeus monodon*).

(3). Seabass fingerlings (*Lates calcarifer*).

(4). Pampano fingerlings (*Trachinotus blochii*)/Curry meen fingerlings, (*Etroplus suratensis*)

(5). Milk fish fingerlings, (*Chanos chonos*)

The economy of the Sea Ranching exercise is given in table 1.

Table 1: Economic Cost for Sea Ranching at Khambhat Bay

S. No	Sea Ranching Species	Unit Price In./ Rs	Total Nos	Amount In Lakhs	Hatchery
1.	Seabass, 3.5 cm size, <i>Lates calcarifer</i>	Rs. 15/piece	100000	17.0	RGCA
2.	Milk fish 3.5 cm, <i>Chanos chanos</i>	Rs.8/piece	100000	8.0	CIBA
3.	Curry meen 3.5 cm, <i>Etroplus suratensis</i>	Rs. 8/piece	100000	8.0	CIBA
4.	Crab 2.5cm, <i>Scylla serrta</i>	Rs.20/piece	100000	20.0	RGCA
5.	Post larvae Prawn	Rs.1.0/piece	200000	2.0	Private Hatchery

The hatchery-produced seed needs to be grown to a proper size before releasing into the nature. Careful acclimatization to the new environment is necessary before any such release. Also, probable predators of the species have to be kept away using net enclosures wherever possible. In order to increase survival of the introduced stocks in the wild, artificial habitats have to be created, coastal areas have to be improved, and mangrove forestation has to be encouraged.

7.11.2. Small Scale Cage Culture in Brackish Water (Post Construction)

In Gulf of Khambhat and nearby area is suitable for practising aquaculture activity such as pen culture, cage culture, Mussel culture and Seaweed culture after the post construction of Dam and it is explained below -

Farming in Pens

Inexpensive pen structures for farming the milkfish are constructed in shallow natural creeks, swamps, lagoons, lakes and bays, ranging in depth from 1 to 3 m. The bottom in pen culture sites should be of firm clay or mud so that poles and posts can be driven sufficiently deep to make them support the pen structure. Traditionally pens are made up of wooden planks, split bamboo etc. But in recent times, nets materials made of synthetic materials such as nylon, polypropylene, polythene etc are used commonly. A part of the vertical net barrier is buried inside the mud or ground with the aid of a

footrope and small weights, secured to a chain link between concrete sinkers. At the upper level, floats are provided. Fingerlings stocked in usually feed upon the natural food in the lagoon or lake and no artificial food is provided.

7.11.3. Mussel Culture:

Backwater mussel culture is a low investment activity opens immense potential for resource and employment generation among coastal communities especially women and youth. It can stimulate a healthy socio-economic development in the area. Better post-harvest technologies can develop attractive value-added products. Green mussel is widely distributed and found extensively around Kollam, Alapuzha, Kozhikode, Kannur and Kasargod in Kerala and in small beds in Chilka lake, Visakhapatnam, Kakinada, Chennai, Pondicherry, Caddalore, Mangalore, Karwar, Goa, Ratnagiri and in Gulf of Kutch.

7.11.4. Seaweed Cultivation

The bamboo raft system is the preferred method for all industrially valuable Indian seaweeds. Advantages include: raft located in sub-surface seawater column providing adequate sunlight exposure; rafts are easily handled and relocated to suitable locations free from epiphytes and grazing; and bottom nets minimize herbivore grazing of algae. Materials for making rafts (e.g. bamboo, anchor stones, polypropylene rope, etc.) are commonly available close to the farm areas. *Kappaphycus alvarezii* raft size is 3×3 m; 500 rafts would occupy 1 hectare. The raft size typically used for *Gelidiella acerosa*, *Gracilaria edulis* and *Gracilaria dura* cultivation is 2×2 whereby 1000 rafts can fill 1 ha.

Monoline culture method: The rope which is used for tying is 7mm main rope and for loop 1mm rope two bouy is tie in between the line. Maximum 3-4 kg of seaweed will seed during the seeding

This activity could be taken on pilot scale at suitable places. The activities can be done with technical support of different agencies of Indian Council of Agricultural Research (ICAR) and agencies like CMFRI, RGCA, CIBA, etc.

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