CHAPTER 1

INTRODUCTION AND REVIEW OF LITERATURE

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1.1 Marine ecology and marine pollution

1.1.1 Marine ecology

Marine ecology is a pattern of relationships between organisms and the sea environment.

The study on field of marine biology is focused on various life forms residing in the sea. It can be categorised into two major spectrums of studies 1. Functional biology and 2. Ecology. Functional biology describes each **step of its lifecycle in detail** as for example reproduction, locomotion, feeding and digestion. Ecology can be defined as **interaction of the organisms** with their physical and biological environment. Word ecology dates from about 1900, but only in the past few decades has the word became part of general science. Ecology was and will remain the discipline that addresses highest and most complex levels of biological organisation. Ecology is not only about species-rich forests, wilderness, or scenic beauty. Major goal of ecology is to scrutinize the distribution and abundance of living things in the physical environment. The literal meaning of of ecology is study of "life at home" with emphasis on the pattern of relationship between organisms and their environment. These patterns in nature are driven by interactions among organisms as well as between organisms and their physical environment. Untill there is crisis, humans tend to take natural goods and services for granted. During the 1970s, almost everyone became concerned about pollution, natural area, population growth, food and energy consumption, and biotic diversity, as indicated by the wide coverage of environmental concern.

The major goal behind carrying out marine ecological analysis is to **perceive entire set of factors that affect abundance and distribution of specific species.** To understand the field of marine biology one has to comprehend fundamental aspects of species and habitat interactions. **This will provide how a particular species dwells in specific habitat.**

1.1.2 Characteristics of marine environment

Ecological features of the marine environment are;

1. The sea covers 70% of the Earth's surface. It is continuous and deep. Temperature, salinity, and depth restrict the free movement of marine organisms.
2. Wind stress created by air temperature differences between poles and equator sets the sea in continuous circulation.
3. The sea is influenced by waves of many kinds and tides produced by the moon and the sun.
4. The sea is salty with an average salinity of 3.5%. Major salts present are chlorides, sulphates, bicarbonates, carbonates, and bromides of sodium, magnesium, calcium, and potassium.
5. Dissolved nutrients are in low concentration that projects out as a significant limiting factor in determining the size of marine populations.

1.1.3 Zonation in the ocean

The sea consists of distinct zones, each exhibiting a specific habitat, as shown in figure 1.1. A continental shelf extends for a distance offshore, beyond which the bottom suddenly drops off as the **continental slope**. Many times, there is a slight **continental rise** before dropping down to a deeper plain. The shallow continental area is the **neritic zone**. The zonal area between high and low tide is the intertidal zone. The open sea region beyond the continental shelf is called an **oceanic zone**. The oceanic zone comprises the **euphotic** and **aphotic** zone based on light penetration.

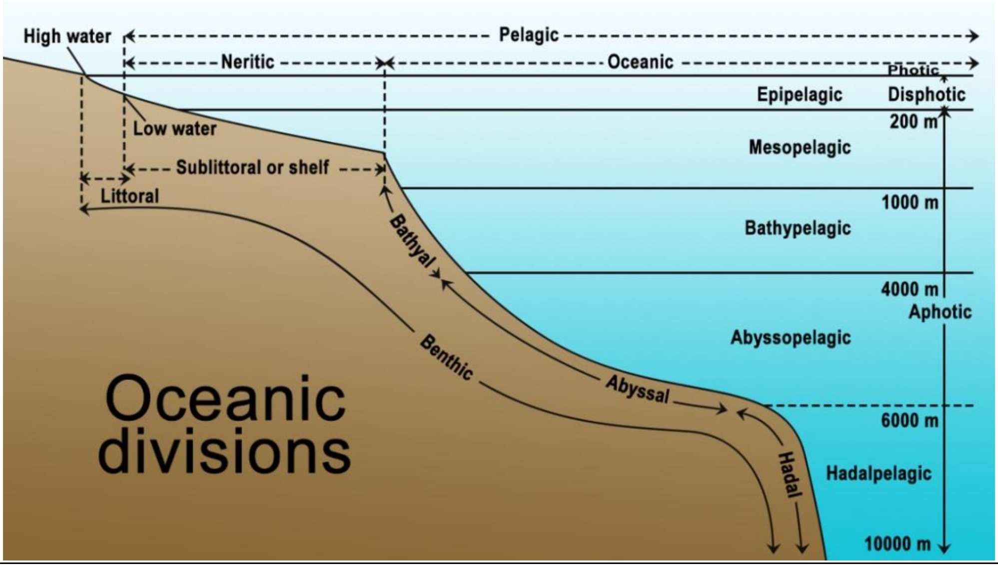

Figure 1.1 Oceanic zonation

It is further divided into an epipelagic zone, mesopelagic, bathypelagic, abyssopelagic, and hadalpelagic, as shown in figure 1.1

1.1.4 Beach morphodynamics

Exposed beaches can be divided into three major morphodynamic types depending on wave height, wave period, and sediment grain size- reflective, dissipative, and intermediate (Short, 1996). **Reflective beaches** are characterised by coarse sand, short swash periods, steep slopes, high substrate penetrability, low organic matter, and low sediment water content. **Dissipative beaches** possess fine sand, flat angled sloppy region, subsided substrate penetrability, and high water content. **Intermediate beaches** fall between the two boundaries of reflective and dissipative beaches. It has been studied that species richness, total abundance, and biomass increases from reflective to dissipative beaches (McLachlan and Dorvlo, 2005).

Various hypothetical schemes have been proposed to explain these patterns in macrobenthic communities in coastal regions. Two such adopted hypotheses are **1. (McLachlan, 1990) adapted the autecological hypothesis,** demonstrating that the communities of physically controlled environments such as muddy beaches are structured by the independent responses of individual species to the physical environment and that biological interactions are minimal. **2. Swash Exclusion Hypothesis (SEH) (McLachlan et al., 1993)** proposes that the increasingly harsh swash climate and coarseness of sediments towards the reflective end of the beach morphodynamic spectrum lead to the exclusion of species.

Several studies support the SEH, demonstrating a strong relationship between community parameters and physical factors (e.g., McLachlan, 1990; McLachlan et al., 1993; Jaramillo et al., 2000). The Habitat Harshness Hypothesis (HHH) extends the predictions of the SEH, postulating that the harsh environment of reflective beaches forces organisms to divert more energy towards maintenance, resulting in lower fecundity, growth, mass, and survival. The HHH has been tested for abundance (e.g. McLachlan, 1990; Jaramillo et al., 2000), fecundity, growth, and survival (Brazeiro, 2005; Celentano and Defeo, 2006), burrowing rates (e.g. Nel et al., 1999, 2001), and reproductive strategy (e.g. Delgado and Defeo, 2006, 2007). Most of the beach morphodynamics studies have been done on Dotilla species at the sublittoral zone.

1.1.5 Wave generation and its type

Waves in the ocean are generated by blowing of wind over the surface of ocean. More the power of wind, longer it blows and forms longer fetch and ultimately generating larger waves (Figure 1.2). The strong westerly winds form the world's biggest waves which initially face west, and gets deflected towards equator by Coriolis Effect. Major wave climates are the easterly waves produced by the expansive but optimum velocities towards northeast and southeast directions.

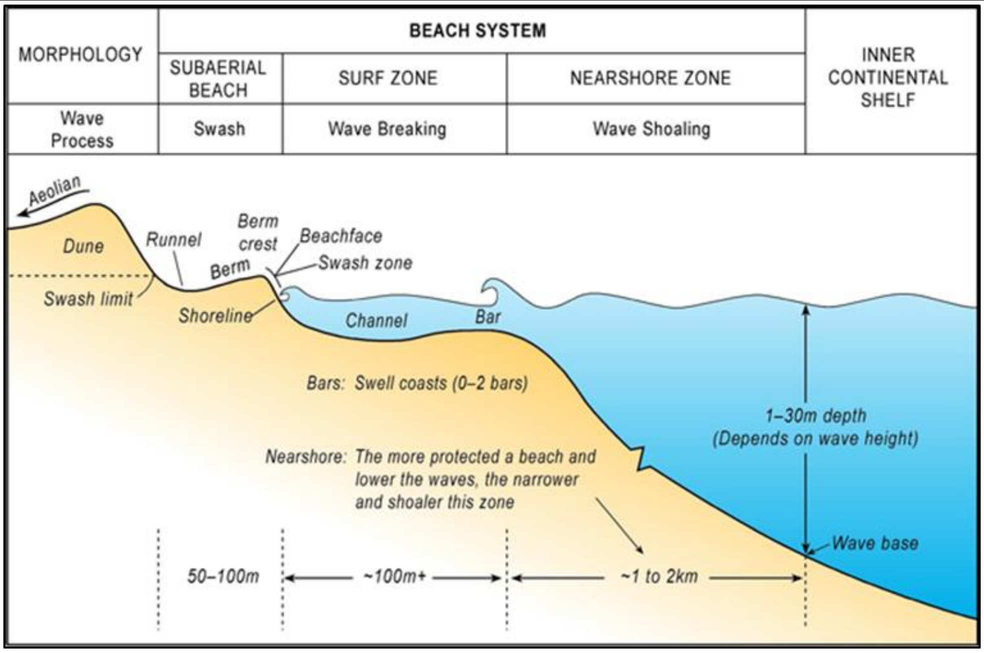

Figure 1.2 Beach systems

Waves are a form of latent energy that can travel from hundreds to thousands of kilometres in the ocean and are released as kinetic energy when they shoal and break. A broad wave spectrum is formed when short, steep, and slow waves topple over each other and ultimately break. These waves, when generated, are called a sea. When the wind drops or heads away from its point of generation, they transform into a swell. A Swell is lower, faster, longer, and uniform in all directions (Figure 1.2).

Waves are characterized by their height (trough to crest), length (crest to crest), and period (time between successive crests) H, L, and T, respectively.

1.1.6 Beach sediment types and sources

The range of beach sediments is from a sand-sized gradient to huge cobbles and boulders. Finer sand beach gradient results in a very low steep of approximately (~1°). At the same time, stacked up cobbles and boulders can form a steep of 20°. Generally, most possess a swash zone gradient between 1–8°. Such beaches carry sediments having fine to the medium sand gradient. In the mid-latitudes, maximum beaches comprise siliceous or quartz sand grains formed most from erosion. Carbonate sediment dominates in the topical beach zones as it possesses a high range of coral reef detritus and shell material. In higher latitude areas weathering produces coarse rocks and gravels. Thus sediments are produced from land areas and reach shoreline with the help of rivers, glaciers, and shoreline erosion. Further, they are carried onshore through waves, tides, and wind. A positive sediment supply produces beach accretion, while when negative beaches erode.

1.1.7 Benthic zone and its characteristics

The benthic zone is the ecological region beginning from the surface of the shore till the bottom of the sea. A negligible amount of sunlight reaches this zone. The sediment layer is crucial for the survival of aquatic life and also helpful in recycling nutrients.

Characteristics of Benthic Zone

1. **Temperature and Pressure**

The benthic zone close to the shoreline is warmer than the area located hundreds of meters deep. This limits biodiversity. Pressure increases with an increase in depth and vice versa.

2. **Light**

Till 200 meters depth light is proper and appropriate known as photic zone. After which light dissipates, this zone is known as the dysphotic zone. Depth after 1000 meters is almost dark, and negligible photosynthesis occurs here.

3. Dissolved oxygen

With increase in depth, dissolved oxygen declines, reaching a minimum mark between a few hundred meters to 1000 meters deep. There is not abundant light to support photosynthesis, so little oxygen is added to the water. Also, oxygen is removed through respiration by organisms present in this zone. Below the minimum oxygen layer, there is often an increase in dissolved oxygen at the greatest depths. As depth increases, water gets colder, and pressure increases, leading to more and more oxygen absorption. Cold, oxygen-rich water goes to the bottom due to its high density, taking the oxygen along with it. The oxygen-rich bottom water spends the thousand years flowing over the seafloor. This water circulation is the source of oxygen for bottom-dwelling (benthic) organisms (Lee et al., 2019).

4. Benthos

The type of zone occupying diverse groups of organisms is known as benthos. They can resist cold temperatures and high pressure. The mode of nutrition is detritivorous. Benthic organism found on the ocean floor is epifauna, while those found at greater depths are known as infauna.

5. Nutrient Flow

The give and take of nutrients between sediments and water columns are regulated by organisms residing in the benthic zone. Microalgae flourish where there is an adequate amount of sunlight. Utilizing carbon dioxide and micronutrients through the process of photosynthesis, an extra polymeric substance known as slime is produced. Slime acts as a source of nutrition to bacteria. Thus the extra polymeric substance plays a crucial role in maintaining the local food web and the sediment structure of a marine ecosystem.

1.1.8 Marine pollution

A combination of toxic chemicals and waste, 80 % of which comes from the land source, is washed or added into the ocean, forming marine pollution.

Waste products are added to the ocean in two different manners, first is by the indirect method: anything that is added to rivers like sewage, garbage, fungicides, agricultural wastes, pesticides, and heavy metals ultimately reaches its fate that is the ocean. The second is by the direct method: throwing large containers, net, plastics, discharge of oils and petroleum products. After reaching seawater with constant turbulence oceanic currents, pollutants get scattered. Eventually, its concentration increases in the food chain and in bottom sediment by various physiochemical processes. This causes reduction in species diversity.

Significant effects of marine pollution

1. **Biodiversity loss:** It is the extinction of species that results in loss of biological diversity. It could be temporary or permanent depending on whether a loss is reversible or irreversible. **According to WWF, 39 percentage of marine wildlife has been lost since 1970.**
2. **Water pollution and loss of livelihood for locals:** Dumping illegal waste or oil spill contamination may lead to massive adverse effects on edible fishes and other sea animals. The drop in fish population, and a decrease in tourism, may lead to the loss of livelihood of locals. If they lose any or both of these income sources

financially, their family will not sustain and forced to move.

3. **Toxicity to coral reefs:** Ocean acidification is a reduction in the ocean's pH over an extended period, caused primarily by the uptake of a considerable amount of carbon dioxide from the atmosphere. This creates an area concentrated with acid, which causes bleaching of coral polyps.
4. **Effects on aquatic plants:** As compared to animals, plants cannot relocate to other ocean areas. They are helpless for water pollution. This reduces the population of sea plants

1.2 Biomonitoring tool and its need in the present scenario

Definition of bio monitoring

The utilization of biota to check changes in the environment (Wright et al., 1993, Gerhardt, 2000, Friberg et al., 2011). Biomonitoring relies on organisms to indicate the effect of pressure through their presence/absence and behavior. Common indicator organisms are macroinvertebrates, fish, and algae (Resh, 2008).

1.2.1 Need of Biomonitoring and ecological indicators

As per the taxonomic group utilized, biota can provide several advantages over conventional monitoring approaches. A particular biota has a wide range of ecological requirements /sensitivities, different lifecycle lengths/strategies, and spatial distributions, making it a significant indicator for different anthropogenic pressure. That is why biomonitoring is particularly useful when the pressure or stressors are intermittent or exhibit high temporal variability. Monitoring such pollutants is highly challenging and costly using conventional techniques and may not provide biologically relevant information (Bonada et al., 2006, Friberg et al., 2011).

1.3 Developing a biomonitoring tool

A few considerations and decisions are to be made to develop a bio monitoring tool:

i) In what context will the tool be used? Taking a reference-based approach using observed/expected scores.

ii) At which spatial scale will the tool be applied (e.g., local, regional, national, or international scale)?

iii) Which method will be used to sample the assemblage (e.g., quantitative, qualitative, and sub-sampling)?

(Bonada et al., 2006) defined the **'ideal' biomonitoring tool as based on sound ecological theory, allowing for a prior prediction and assessment of ecological functions across large geographic areas.** The sampling, sorting, and identification process required to use the tool should ideally be low cost and aligned with the other biomonitoring tools and surveys in existence.

In order to link a biological index to a pressure-impact relationship, biotic indices are often developed and tested in specific habitats or eco-regions in an attempt to minimize environmental variation (Zweig and Rabeni, 2001).

1.4 Biomonitoring and ecological theory

The basic principles of biomonitoring are based on ecological theories or concepts (Friberg et al., 2011), like niche theory, the habitat template theory (Southwood, 1977), the environmental filtering hypothesis (Keddy, 1992; Poff, 1997). The general premise of biomonitoring is that organisms have adapted and evolved biological traits like physiological, morphological, behavioral, and life-history strategies to suit a range of optimum environmental conditions in which they can persist (i.e., their fundamental niche) but are also influenced by biotic interactions (i.e., their realized niche). When conditions deviate from these optima, those taxa that are most suited to the new environmental conditions will persist (Menezes et al., 2010). Biomonitoring relies on these organisms to respond to quantifiable and predictable disturbances.

1.5 Crustacea: Brachyura: Dotillidae as a biomonitoring tool

1.5.1 Crustaceans and their significance

Crustaceans form most diverse group of arthropods present in a vast array of habitats. Many species occur primarily in aquatic habitats, but some are adapted to live on land. Crustaceans show significant variations in anatomical structure than any group of arthropods. The majority are marine or, less commonly, inhabitants of inland aquatic habitats with a few terrestrial exceptions. Crustaceans comprise an essential portion of the benthic biomass in many lakes and streams. Some species are abundant in the littoral zone and throughout the oxygenated deeper water, where they feed on bacteria and fungi or live algae. These benthic consumers recycle nutrients that sustain high levels of microbial productivity.

1.5.2 Present biological diversity of crustacean

Total 808 brachyuran crab species belonging to 62 families have been reported from Indian waters, out of which 226 species are reported from the west coast of India while 461 species are reported from the east coast of India (Dev, 2013). The table 1.1 shows the crustacean diversity at GOKh.

Table 1.1 Crustacean diversity in GOKh. (IS: Isopods, AM: Amphipods, BA: Barnacle, AN: Anomuran crabs, BR: Brachyuran crabs, PS: Prawns and shrimps, LB: Lobsters, ST: Stomatopods) (Trivedi et al., 2015)

Area	Taxonomic Division	IS	AM	BA	AN	BR	PS	LB	ST	Total
GOKh	Species	1	1	2	6	113	30	3	1	157
	Genus	1	1	2	2	65	12	3	1	87
	Family	1	1	1	2	27	5	3	1	41

In 2015 Trivedi et al. compiled a checklist of 157 species of crustaceans belonging to 87 genera and 41 families of Gujarat. The highest diversity was recorded in the Gulf Of Kachchh (138 species), followed by Saurashtra (76 species) and (GOKh) (37 species). The checklist of brachyuran crabs consists of 6,793 species, 1271 genera and subgenera, 93 families, and 38 superfamilies worldwide (Ng et al., 2008). A checklist of the brachyuran crabs of the world is presented for the first time. Over 10,500 names are treated, including 6,793 valid species and subspecies (1,907 primary synonyms), 1,271 genera and subgenera (393 primary synonyms), 93 families, and 38 superfamilies.

1.5.3 Brachyuran crabs and its significance

Crabs with short tails fall under infra-order Brachyuran. It possesses the highest number of crabs. They have five pairs of walking legs. The first pair is modified to have large claws to capture food and show a defence mechanism. Brachyuran crabs belonging to diverse families have relatable significance in many different ways (Lee, 1997; Gillikin et al., 2001; Hartnoll et al., 2002). A significant food source for juvenile fishes is crab larvae, thus helping shore fisheries. Dromasardeola (Crab plover), common raccoon, fishes, and many invertebrates have crab as their primary food requirement (Seys et al., 1995; Skov et al., 2002; Litulo, 2005a; 2005b). Crab burrows alter the topography and sediment grain size and play a significant role in aerating the entire region, making it more microbiologically rich (Ridd, 1996).

Removing crabs from any area drastically reduces sulfides and ammonium concentrations, making sediment less fertile for productive and vegetative growth (Smith et al., 1991). The deposit feeders (family Ocypodidae) are an evident resident of intertidal areas of mudflats along the tropical coastline regions. The majority of macro-faunal biomass at the intertidal area is constituted because of them (Montague, 1980).

Fiddler crabs are a significant link to higher trophic levels in an intertidal and shallow water food web, as they convert intertidal organic matter into smaller-sized particles for many predators, both terrestrial (shorebirds) and aquatic (marine crustaceans and fishes), as shown in figure 1.3. The direct conversion of detritus to biomass may be the sole source of energy transfer to the carnivore population (Nicholas and Moshiri, 1974).

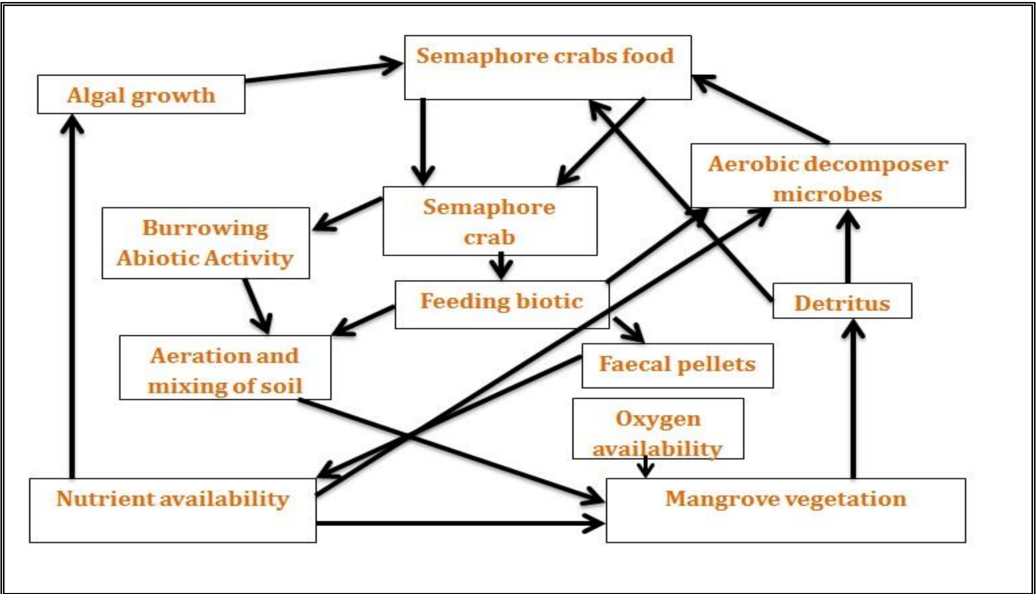

Figure 1.3 Importance of semaphore crabs and its biotic/abiotic inter-linkage

1.5.4 Crustaceans as bioindicator

Crustaceans are more often used as bioindicators in many aquatic systems as they are distributed in different habitats, including marine terrestrial and freshwater environments. Features like reproduction strategies play a crucial role in data interpretation. Within crustaceans, crabs are considered the significant bioindicator biological system, with the hepatopancreas appearing as primary a bioaccumulator organ. Research indicates that exposure to metal ions may result in nervous, respiratory, and reproductive system effects on animals and humans. Studies indicate that the amount of these elements in crustaceans for human consumption crosses limits established by international organizations regarding seafood metal contents as daily, weekly, or monthly intake limits set for humans, which indicates higher consumer health risks. Metals that are potentially toxic in the aquatic environment originated from natural and anthropogenic sources that can be easily quantified through the analysis of crustaceans. These elements are primarily deposited in the sediment followed by water dissolution in ecosystems, potentially contaminating resident biota. Among several aquatic animals, crustaceans are considered excellent bioindicators, as they live in close contact with contaminated sediment. Among the main toxic elements to animal and human health are aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and silver (de Almeida et al., 2021).

1.5.5 Crabs as bioindicators:

The use of particular organisms as biomonitoring of trace metal bioavailability in coastal waters allows outlining comparison between space and time, providing significant ecotoxicological integrated measures of the selected metal within the study system. Bio indicators have an essential role in assessing the bioavailability of toxic trace metals in the Argentina estuarine systems and complement the chemical measurements (Beltrame et al., 2010).

Crustaceans are the second largest group of organisms and the fourth most diverse group, with their distribution ranging from 6000 meters below sea level to 2000 meters above sea level.

Crabs are very significant species of tropical benthic communities. More giant crabs are essential for human consumption. Small species contribute significantly to the complexity and functioning of tropical ecosystems. Rocky shore crabs are prime predators on molluscs, small crustaceans, and other invertebrates, but they also provide a prey base for fish, decapods, and some terrestrial vertebrates. Most are omnivorous and possess a broad spectrum of food preferences, eventually structuring the ecosystem. They feed on dead and decayed organisms, thus contributing to the breakdown of organic matter and accelerating mineralization. This creates an essential link between benthic and pelagic organisms. **The intertidal distribution of brachyuran crabs can potentially influence the behavior, distribution, and abundance of their own and neighbouring communities (Szaniawska, 2018).** Thus crabs can play a crucial role if established as bioindicators.

1.6 Study area- Kamboi, Gulf of Khambhat (GOKh)

1.6.1 Physical structure of GOKh

The Gulf of Khambhat, situated between Saurashtra peninsula and the mainland Gujarat, is known for its extreme tides and variation in average heights (Figure 1.4). It is 70 km wide at its mouth and about 18 km wide at the extreme end near lower estuarine region of Mahisagar River. The mudflats of Kamboi, located on the upper reaches of the Gulf, were selected as sampling area. The climate of this area is tropical and the annual water temperature varies from 25 to 39^{O}C.

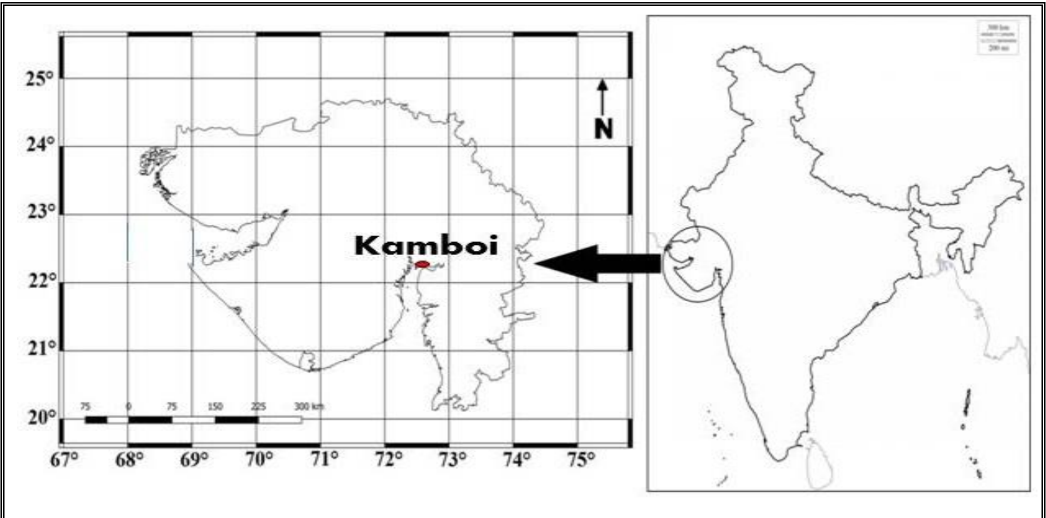

Figure 1.4 Field area, Kamboi, GOKh, Gujarat

The Gulf of Khambhat is also known by its other name as the Gulf of Cambay. It forms a bay structure on the Arabian Sea. Major rivers that pass through Gujarat are Narmada, Tapi, Mahi, and Sabarmati that form major estuaries in the Gulf. It cleaves the Kathiawar Peninsula from the south-eastern part of

Gujarat. The Gulf of Khambhat stretches 200 km with a width of 20 km on the northern side and 70 km on the southern side.
The declination range of the Gulf is from 18 to 27 m with an average depth of 20 m. Though depth at shoreline area (Head portion of Gulf) is 5 m which is very much shallow. ; The tides are semi-diurnal type, with large diurnal inequality and varying amplitude, which decrease from north to south. The coastline of Gujarat experiences the highest high tides all over the Indian coast because the Tropic of Cancer almost passes through it.
The mean tidal height at Mahuva Bandar is 4.7, which uplifts to 6.5 m at Gopnath Point and at Bhavnagar is 10.2 m. As a result of huge tide heights in the upper Gulf, it possesses large inter-tidal expanses of 1.5 to 5 km, which is the widest along the entire Indian coast. The geometry and hydrodynamics of the Gulf cause high convulsion of water during the tidal cycle forming a prominent increase in TS (Total Solids) and SS (Suspended Solids) at a lower estuarine region of Mahi River. Sediments nurture the growth of benthic fauna (Vachhrajani and Pandya, 2009).
The Gulf of Khambhat emerges from south to north of the Arabian Sea on the western side of Gujarat, India. It is located approximately between 20°30' to 22°20' N latitude and 71°45' to 72°53' E longitude. It possesses its extreme ends in the northern face between the mouths of Mahi and Sabarmati, having a width of 5 km. It has its widest end open at the southernmost end at Gopnath. It acquires a length of 115 km. It covers an extent of about 3120 km^2 which mainly covers mudflat areas with rocky areas patches and a total volume of 62400 million m^3. Rarely sandy patches are also seen intermittently.
The highest rocky shore beaches are from Mahuva to Gopnath, and it reduces from Ghogha to Bhavnagar. Many rivers like

Narmada, Tapi, Mahi, and Sabarmati discharge their water in the Gulf. Estuaries are formed from all major rivers carrying a heavy load of suspended sediments into the Gulf. A medium-sized delta is present near Shetrunji between Gopnath and Ghogha. The ecosystems of the Gulf comprising mangroves, estuaries, creeks, and vast intertidal mudflats have abundant biodiversity and a number of endemic flora and fauna.

Average rainfall in the Gulf eastern side is 800mm and on the western side is 600mm in a period from June to September. The relative humidity ranges from 65% to 86% giving rise to semi-arid to sub-humid atmospheric conditions. Annual temperature range from 8.4 °C to 43.7 °C is observed, minimum in the month of January and maximum in the month of May.

1.6.2 Discharge of industrial effluents in Gulf

A large amount of fertilizer and allied chemical industries are established near the coastal area of the Gulf generating great importance for its study basically near Bharuch and Hajira and thermal power station at Dhuvaran. The oil pipeline near Ubharat, between Dahej and Gogha, is also the recently proposed tidal power station in the Gulf of Khambhat. The geomorphic processes of erosion, sediment transport, deposition, and the extent and condition of tidal wetlands greatly influence these industrial and commercial activities. Industrial activities are extremely dependent on geomorphic processes of erosion, deposition, the extent and condition of tidal actions, and sediment transport.

Once extremely flourishing ports at Khambhat, Bharuch, and Surat leading to complete abandonment is a result of constantly high filing rates of suspended sediments by the ocean. It has also affected the recreational activities at the sea resorts of Dumas and Ubharat. The suspended sediments may carry absorbed chemicals dumped by the chemical industries and affect the marine ecosystem. The study of suspended sediments facilitates observing the dynamic relationship that persists between sediment input, transport, and deposition. It was perceived that during and immediately after the monsoon season, because of strong water currents, a temporary suspension was formed, thus increasing the concentration of sediments throughout the Gulf. On the contrary, during the winter, the concentration of sediments decreases considerably because, during this phase, currents are not too strong, so it settles at the highest rate. The Ebb and flow of oceanic water impart a key role in the movement of the suspended sediments.

Flocking of suspended particulate matter is densely concentrated in coastal areas as compared to the central area of the Gulf. Thus depositional activity is more than eroding activity. Their concentration is exceptionally high on the mainland side than on the Saurashtra side, as water is shallow on the mainland side (Nayak and Sahai, 1983a). During the ebb period, the central part of the Gulf contains an appreciable amount of suspended sediments, while the coastal region contains less sediment. During the 'slack period, i.e., between the ebb and flood tide, the deeper central portion is seen to be free of suspended sediments. This probably indicates a period of settling of the sediment at the Gulf.

1.6.3 Ebb and Flow of tides and wind speed

The Arabian Sea is known for its high-shore currents, which rise due to strong wind currents. The average speed of the wind is 3 to 4 knots that dominate the flow, which is directly proportional to the ebb and flow tides. The maximum velocities of 6 knots associated with high wave energy occur during mid-tide (Unnikrishnan et al., 1999). With the transition in seasons, the flow also adjusts accordingly. The turnover residence times are quite short because of its shallow depth, large tidal amplitude, and strong tidal current. With a physical funnel-shaped structure of the Gulf and partially enclosed nature at the head, the tidal height increases tremendously upstream. After the Bay of Fundy on Newfoundland coast of Canada (17 m) second highest tide recorded is at Bhavnagar, reaching up to a height of 12.5 m.

The Gulf is known for its extreme tides and variations in the heights of the tides. It is 70Km wide and 131 km long. It lies between the Saurashtra peninsula and mainland Gujarat. The Gulf is inverted funnel-shaped and occupies 3120km^2 of area. The Gulf merges into the shallow estuaries of the Mahisagar and Sabarmati rivers through Khambhat Channel. Apart from Sabarmati Mahisagar, the other major rivers joining the eastern shore of the Gulf include Dhadhar, Narmada, and Tapi. Westward cover to Gulf is of minor seasonal rivers such as Utavali, Malesari, Shetrunji River, and Dhantarvadi that join the Gulf.

1.7 Aim and objectives

1. To study the population ecology of *Ilyoplax sayajiraoi*

(I) Population size and sex ratio

(II) Distribution pattern

(III) Zonation concerning changes in sediment characteristics

2. Burrow morphology of *Ilyoplax sayajiraoi* and sediment analysis

(I) Seasonal variations in burrow morphology

(II) Distribution of burrows in different tidal zones

3. Insitu effect of chemical pollutants on the behavioral ecology of *Ilyoplax sayajiraoi.*

(I) Normal behavioral analysis (Foraging, Feeding, Popping, Droving, Cheliped waving, Territorial)

(II) Comparative study of above objective (I) and in-situ chemically driven behavioral studies

(III) Establishing *Ilyoplax sayajiraoi* as a bio-indicator