CHAPTER 2 STUDY SITE

LOCATION

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2.1 LOCATION

India, due to its unique location in Southern Asia, is blessed with one of the longest coastline in the world. It is surrounded by open oceanic environment from west, south and eastern sides. Gujarat, located in the western part of the country is bestowed with the coastline of approximately 1650 km in length surrounded by Arabian Sea. Gujarat also possesses unique ecological features along the coastlines being presence of the two Gulfs viz. Gulf of Kachchh (GoK) and the Gulf of Khambhat/Gulf of Cambay (GoC). Gulf of Kachchh has always been an important area of research for the marine biologists as it shows the presence of live corals along with four other places in India. The coastline of Gujarat is differing in substratum features viz., sandy beaches, rocky shores, muddy flats as well as marshy areas having the percentage coverage of approximately 28 %, 21 %, 29% and 22 % respectively (Misra and Kundu, 2005). Extensive limestone deposits are seen to occur in the coastal areas of Gujarat. It is noteworthy that maximum biological diversity is present at the rocky shores where a hard substratum is present as a support system for a number of benthic fauna and flora. The intertidal rocks of Saurashtra shoreline are calcareous sand stone. The rocky portion is generally formed of rocks of miliolite and laterite stone. Due to variation in the geographical locations, parts of the Gujarat coastline show different properties not only with respect to the geological features but also with reference to the living biota. There is wide variation in the abiotic factors affecting the coastal ecosystem. Turbidity due to higher tidal actions has a greater impact on the diversity and distribution of macro fauna (benthos) in the coastal ecosystem (Raghunathan *et al.*, 2003).

2.2 CONSIDERATION FOR CURRENT STUDY

Intertidal zone of the tropics is well known for immense biodiversity since few decades. The rocky shores in the intertidal zones of the tropical regions have been intensively studied for last fifty years by various researchers (Little and Kitching 1996; Connell, 1972; Denny and Wethey, 2001). The intertidal zone has varied topographical features comparatively in a shorter coverage. Due to this variation a number of micro habitats are formed comprising of unique set of organisms specially adapted to that specific niche. This is one of the major reasons these areas are intensely studied (Underwood, 2000). In the intertidal zone, it is not only the twice daily variation in the submergence and emergence but also the seasonal variation that leads to subsequent shifts in the colonizers of the area. The coastal environments, especially the rocky intertidal zones show higher degree of spatial and temporal variation in comparison to the open sea (Dayton, 1971). These environmental variables largely affect the diversity and distribution of the organisms in that particular ecosystem (Chalkia and Pitta, 2003). Apart from the qualitative assessment of the organisms, quantitative analysis of the density and abundance of the organisms help to create a much wider and informative knowledge base. It is a key component in understanding the structural assemblage of the organisms (Dayton, 1971; Sebens, 1985; Underwood *et al.*, 2000). In the earlier stages of research in the field of coastal ecosystems, more stress was given upon variation in the distribution of the existing communities with respect to the elevation profile, the exposure to the waves etc. (Paine 1974, Lewis 1982). However, there are many researchers who have demonstrated other environmental variables such as salinity gradients, sedimentation rates, presence

or absence of other organisms etc. affecting the community structure of the coastal ecosystem (Dayton, 1971; Connell, 1972; Littler and Murray, 1975; Sebens 1982; Ono *et al.*, 2008; Bhadja, 2011) It has also been reported that at some places the density of some of the organisms in the rocky intertidal zone is as high as hundreds of individuals in an area measuring merely $10m^2$ (Underwood and Chapman, 1996). With the higher degree of variability in the physico – chemical status as well as in the biological assemblages the density and diversity is studied intensively at spatial and temporal scales (Kleacher *et al.*, 2001; Misra and Kundu, 2005; Vaghela, 2010). With ongoing research, it has been a well-established fact that the interactions between abiotic and biotic factors play a major role in the community structure with respect to time and space (Danielson, 1991). Once the variation of the community structure and the biological assemblages are understood on spatial and temporal scales, it helps to assess the trend in the variation in the existing community (Underwood and Chapman, 1996; Ferdeghini *et al.*, 2000). The coastal zone in general and the rocky intertidal zone in particular is thus of much importance with a view of ecological assessment.

2.3 STUDY AREA AND STUDY SITES

The Saurashtra coastline was undertaken as the study area for the proposed research of the rocky intertidal zone. It ranges from the southern tip of the gulf of Kachchh to the southern part of the Gujarat coastline along Arabian Sea. Main component of the substratum at Saurashtra Coast is the mileolite lime stone and presence of carbonates which help in the growth of the organisms constructing calcium carbonate exoskeletons (Lele, 1973; Merh and Chamyal, 1993; Bhatt,

2003). The Saurashtra coast has varied features such as sandy beaches, muddy intertidal zones, marshy areas and rocky shores as described previously. Of these, the rocky shores attract many biologists due to higher biodiversity in the intertidal zone. Throughout the Saurashtra coastline many locations are well known for fishing activities and many harbours are also present which provide livelihood to the fisherman community. However, at certain places the industrial complexes are also playing a major role in determining the type of community structure. For the current research, four study sites along the Saurashtra coast were selected ***(Plate 2.1)*** namely Okha, Dwarka, Veraval and Sutrapada from north to south of the Saurashtra coast respectively. The selected locations are situated at Saurashtra coastline off Arabian Sea, which are significantly rocky with irregular patches of sand or mud. The selected shorelines of Dwarka and Okha experience wave actions to a heavy extent. The intertidal zone of Saurashtra coasts is not very wide due to a dynamic wave action. The rocky intertidal zone is with hard substratum having many big tide pools and crevices, whereas, the upper intertidal zone is highly elevated with broad and deep caves because of heavy wave action of splash zone. The intertidal belt is observed to be having variety of topographical features such as tide pools, puddles, crevices, small channels etc. The upper portion of the intertidal belt is generally covered with an admixture of silt and sand mixed with pieces of broken shells. The intertidal belt is intersected by many tide pools and channels. Since the pools are natural ones, the shape and size are not precisely same. The upper intertidal pools have light accumulation of sand settled over the rocky base. All in all, the Saurashtra coast is having quiet diverse geo-

morphological and hydrological features so that the environmental variables differ in a shorter spatial variation.

The following are the major characteristics of the study area:

Sutrapada: **deposition of lime; white layer on the rocky zone near the GHCL factory outlet.**

Veraval: **limestone in upper intertidal area; abundance of barnacles and molluscs on upper intertidal zone.**

Okha: **broader intertidal zone.**

Dwarka: **intermittent presence of tide pools and cliff like area.**

The study areas were located at different geographical locations (Figure 2.1). This leads to varied community structure primarily due to different effects of the abiotic ecological factors, geomorphology and geographical locations.

The details of the study sites are as follows:

2.3.1 OKHA
(Figure 2.2)

Also known as Port Okha (22°28' N; 69°05' E) is located at the mouth of "Gulf of Kachchh" and forms the northernmost part of Saurashtra Coast. The entire zone experiences strong water currents, high sediment load and high turbidity due to the hydrodynamics of the Arabian Sea as well as inputs from Indus river delta. A tertiary formation of rocks had been observed with patchy sand deposition and is characteristic feature of this coast (Lele, 1973, Merh and Chamyal, 1993). This coast is seen to provide the most suitable substratum for the growth of seaweeds and marine benthic fauna due to its vast continental shelf. The intertidal exposure of 300-400m was observed at the intertidal zone for 3–4 hours daily.

2.3.2 DWARKA
(Figure 2.3)

In Saurashtra Coast, Dwarka is situated at 22°14' N; 68° 57' E. Dwarka beach is having a unique topography with a numerous cliffs. Due to the presence of abundant sand at the beaches, sand mining as an anthropogenic activity is also observed at the coast. Intertidal area at Dwarka gets an exposure of approximately 70-80 m exposed during the low tides. The rocky intertidal zone supports the growth and survival of the benthic flora and fauna. The rocky shore of Dwarka is composed of limestone in majority and shows presence of sparse live hard corals along the shoreline. Due to its location near the mouth of GoK, this area is affected

by more tidal influences of the Arabian Sea. The Arabian Sea tide has an open area as well as turbulence of gulf tide impacts together. The mineralogical and petro graphical studies showed the presence of calcareous sandstones forming the intertidal zone (Lele, 1973). A continuous deposition of sediments has taken place since ages. This area is mainly composed of tide pools on one side and flat terrain on other. Creeks are also formed in the entire area due to continuous water movements.

2.3.3 VERAVAL
(Figure 2.4)

Veraval (20^{o}54' N; 70^{o}21' E) is located at the southern part of the Saurashtra Coast. The total length of shoreline is approximately 3 km. It receives huge amounts of wastes, including oil from the port. It also receives domestic sewage waste as well as heavy industrial effluents and small scale fish processing units from the city on regular basis. The substratum of the Veraval shore is mainly consists of rocky shore with a few sandy patches. The intertidal zone at Veraval varies from 60 to 75 m. The lower littoral zone at Veraval ends up at steep vertical cliff towards sub tidal zone. Predominantly the intertidal belt of this area is not uniform and the exposure of this predominantly rocky shore is not significantly long.

2.3.4 SUTRAPADA
(Figure 2.5)

This site is located at 20°50'N; 70°28'E has a rocky intertidal area extending up to 3 km. This site is the largest of the four study sites. The rest of the coast is sandy.The fishermen colony and fish landing centres are located on the eastern side. Anthropogenic activity is seen more at this site. Sewage is been discharged

near the shoreline and the GHCL factory effluentdischarged is around 500m from the shore. The water current and wind velocity indirectly favours the sediment flow towards the shore.

2.5 SAMPLING AND DATA ANALYSIS

Sampling and data analysis play a critical role in assessment of diversity and distribution of population. In present study, a critical examination of the available literature was carried out precisely to execute the sampling of the species under investigation. Throughout the study period, wet and dry sampling procedures were followed. The subsequent analysis of primary data generated was analyzed by using various mathematical and statistical tools. A detailed account of the same is as follows:

2.5.1 STUDY DURATION

The present study was conducted from January 2012 to May 2014. Extensive coastal survey was conducted prior to the study. Rocky intertidal areas were identified and above mentioned sites were selected for the research work. Delineation of zone was carried out and study area was divided according to the specified littoral zones. Study was carried out during the low tides by taking the advantage of exposure. During each field visit the area was explored for the presence of new variants or associates of key organism. The associated fauna and the ecological characteristics were recorded during each field visit. Major seasonal changes in the occurrence of associated fauna were also studied. The exposed area and the tide pools were studied entirely during low tides. All intertidal macro

fauna observed were recorded properly, identified and classified systematically and a checklist was prepared. The taxonomic identification was confirmed using proper keys.

2.5.2ZONATION OF THE STUDY SITES

Intertidal zones are transitional coastal regions and at different places they are composed of different type of earthen materials. These geological deposits vary in their physical and chemical composition and are largely affected by the cyclic tidal movements. This littoral area is located between the high and low tide marks. Generally a zonal classification is applied to the intertidal area. The intertidal zone had a vertical zonation pattern of organisms. These zones are greatly influenced by height and tidal influence. The rocky intertidal region can be divided into four vertical zones. These four zones are comprising from the highest to the lowest tide marks; the splash zone, the high intertidal zone, the mid-intertidal zone and the low intertidal zone ***(Plate: 2.2)***. Ecologically, the intertidal zone is having a diverse community structure, where the organisms are divided by the vertical distribution of the intertidal zone. Intertidal organisms convey zonation in relation to moving further up the intertidal, and therefore, into more exposed environments. Due to the different zonation patterns, it can harbour different types of organisms.

Horizontal zonation and vertical (perpendicular to the coastline) zonation were done at all four sites and were attributed based on the presence of Zoanthid abundance. The upper most area at Veraval and Sutrapada was covered entirely by the barnacles. At Okha and Dwarka the uppermost zone showed the abundance of the various molluscs with gastropods-cerithrids in majority. Thus three major

zones were identified vertically. Horizontally the areas were demarcated by the presence of the tide pools.

2.5.3 SELECTION OF KEY SPECIES

During the survey period at the study sites, it was observed that Zoanthids were most abundant in the rocky intertidal zone. On referencing, it was observed that the Zoanthids taxonomy is still in chaos. Therefore Zoanthids were selected as key species and other Anthozoans were also studied to generate supplementary data. Zoanthids are known to compete for space with other sedentary Anthozoans and other macro invertebrates.

The key species were selected on the basis of their occurrence and abundance in the study area. Zoanthids were found to be more conspicuous and because of their abundance, these organisms were selected. The above organisms were selected from all the three zones viz., upper intertidal zone, mid intertidal zone and low intertidal zone. Therefore, a detailed study on these could reflect the ecological status of the three zones.

2.5.4 SAMPLING PROCEDURE

The intertidal zone of each sampling sites were surveyed regularly on monthly basis and all the macro fauna and flora explored was recorded. Extensive photography was employed for evidence collection and subsequent identification of the animal species with the help of standard literature available. The identification of the animal species was carried out on the basis of their morphological features. The complete study was carried out in a non-destructive

manner to the best possible extent in which the organisms were not disturbed unless and until further investigation was required to collect the sample for ex situ examination. Once the organisms were identified, during the successive surveys just the record of the representative organisms were encountered. However, few algal samples were also collected and stored immediately in polyethylene bags and 10 % formaldehyde for further documentation. The samples were then brought to the laboratory and washed in running tap water, and then subjected for temporary herbarium preparation.

During the study, all sampling sites were frequently surveyed at regular intervals during the low tides. All intertidal macro fauna and algae have been observed and recorded. Later classified systematically for the preparation of subsequent report. Thus animals belonging to various phyla were recorded and a checklist was prepared.

2.5.5. SPECIES IDENTIFICATION AND DIVERSITY STUDY:

Species identification was carried out using standard literature and keys. The individual species were critically examined, the samples were collected and preserved in absolute alcohol and 10% formaldehyde prepared in seawater, before the analysis was carried out. Species identification and further analysis of the individual species were carried out by following ways.

2.5.5.1 MORPHOLOGY

For in situ identification, the morphological features were primarily relied upon. The morphological characteristics of the species taken into consideration for

identification were number of tentacles, colour of tentacles, colour of manubrium, colour of oral disk, presence or absence of dorsal and ventral directive and colour of outer disk. In situ photography was considered as best tool for the colour code generation and comparision with the available keys.

2.5.5.2 HISTOLOGY

Post dehydration in ethanol and clearing with xylene, the samples were embedded in paraffin wax and longitudinal and cross sections were stained with Hematoxylin and Eosin. The size of the sections was 7-10µ.

2.5.5.3 Scanning Electron Microscope (SEM) and Electron Dispersal Spectroscopy (EDS)

SEM and EDS analysis of the zoanthid samples were done to assess the internal structure as well as the sedimentation along with the inorganic components present in organism.

The structural attributes of the intertidal fauna were studied by transect method (Misra, 1968). Belt transect method was used for generating the data on the selected belt and criss-cross direction was followed to cover the maximum exposed area on the intertidal belt. The surveys were made at the lowest tides of the months. Sampling used to be started with the start of the low tide and attempts were made to finish two sites within the stipulated duration of about 4 hours. Quadrates of 0.625 m^2 (0.25 m X 0.25 m) – 1m^2 (1 m X 1 m) were laid down while following an oblique direction covering maximum area at almost regular occurrence. At least 10 quadrates were laid vertically across the complete

intertidal area from upper littoral to lower littoral zone for recording the attributes.

Apart from the quadrate method, Line transects, Belt transects and Photo line intercept transect methods for sampling of Zoanthids were also incorporated in the sampling procedure. At all the sites, random sampling was carried out to cover the maximum exposed area on the intertidal belt.

All the data thus generated was analyzed using various mathematical and statistical tools to assess the diversity and distribution of the Zoanthids. Major analysis was carried out using Non Parametric and Qualitative Analysis and attributes were given to the observations made.

Figure 2. 1: Map of the study sites

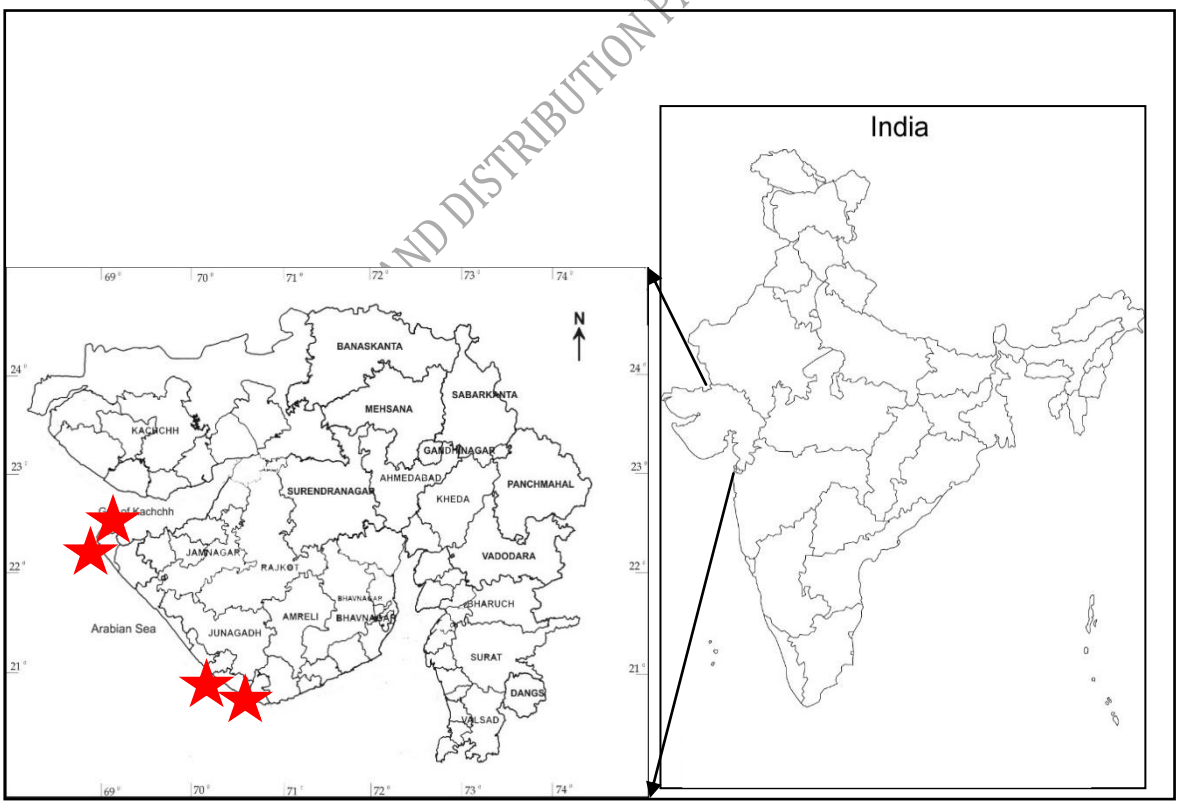


Figure 2. 2: <u>Study area and reef area studied at different study sites</u>

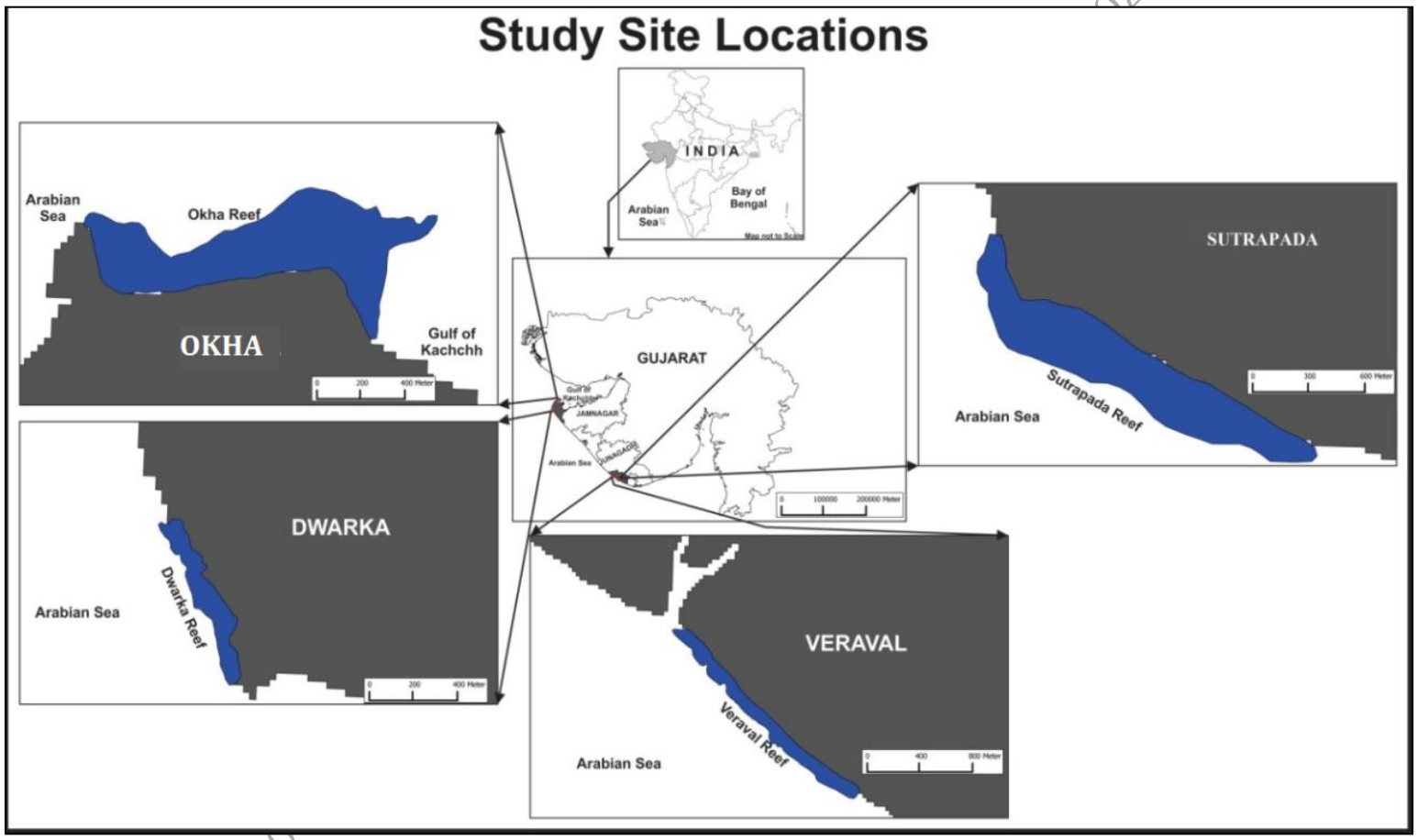
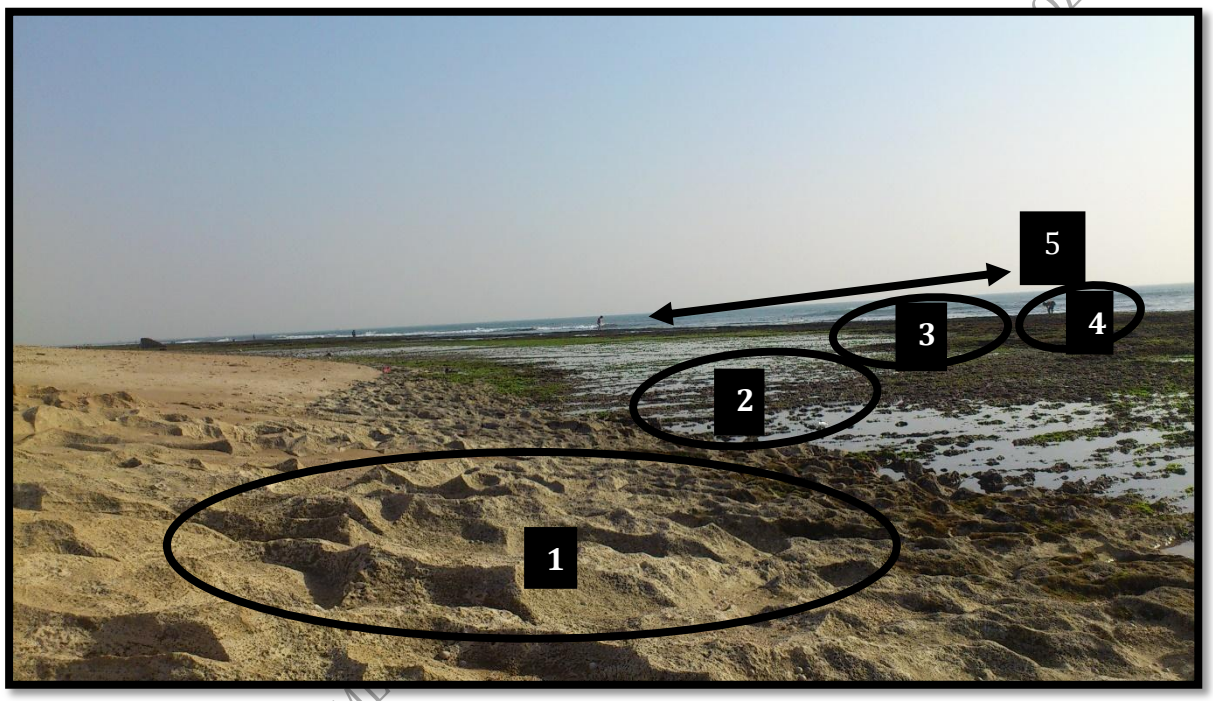


Plate 2. 1: A generalized diagram of intertidal zonation

[Zone 1: Splash zone, Zone 2: supra littoral zone, Zone 3: infra littoral zone, Zone 4: sub littoral zone, Zone 5: Open Sea]



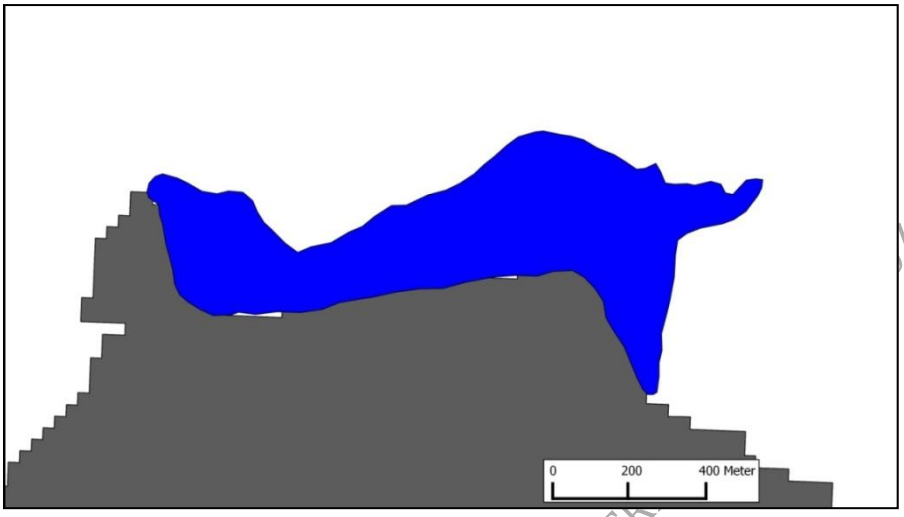


Figure 2. 3: Study site at Okha (intertidal zone shown in blue)

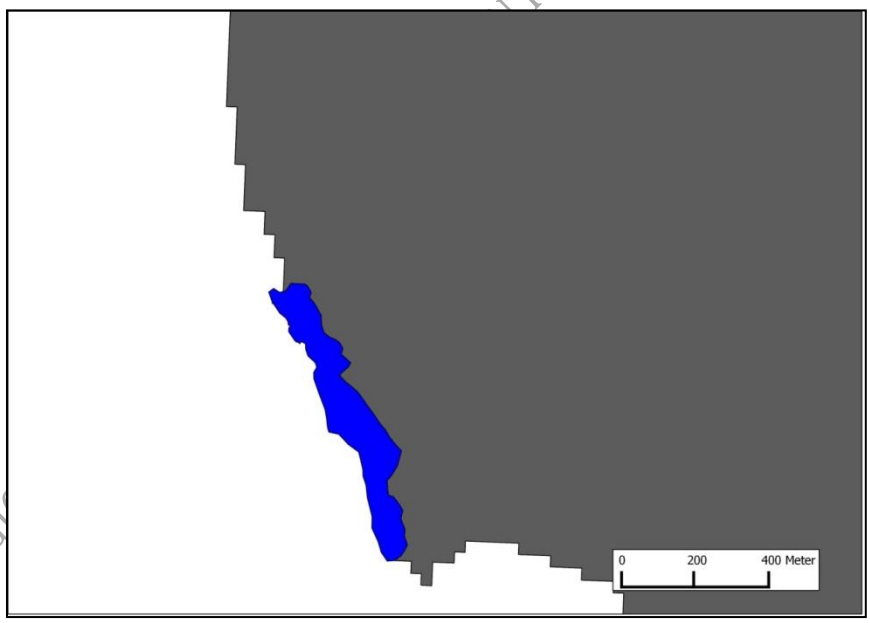


Figure 2. 4: Study site at Dwarka (intertidal zone shown in blue)

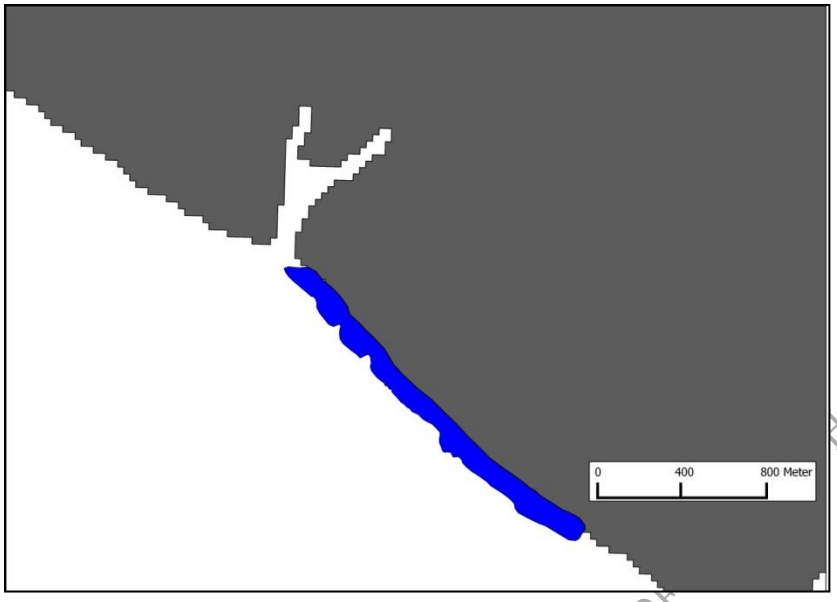


Figure 2. 5: Study site at Veraval (intertidal zone shown in blue)

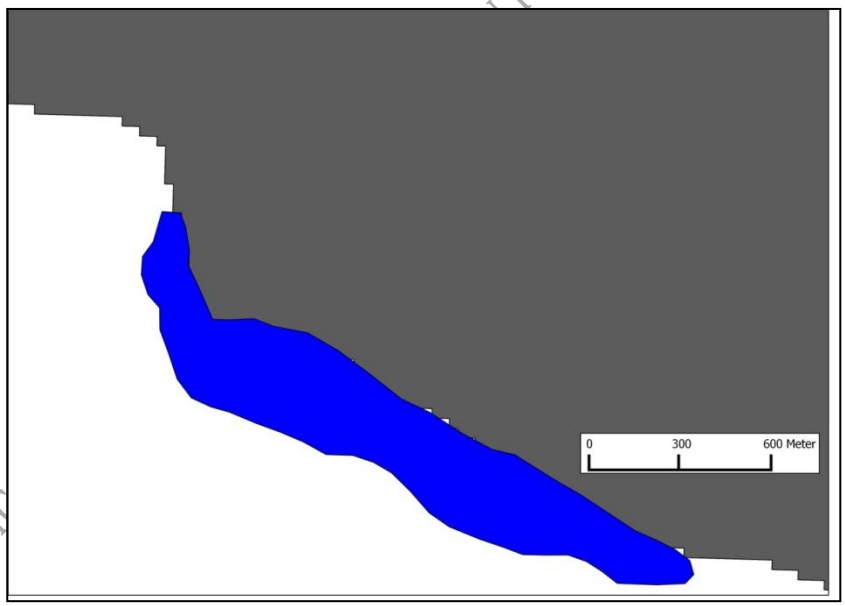


Figure 2. 6 Study site at Sutrapada (intertidal zone shown in blue)