

### 3.1 STUDY AREA

#### 3.1.1 Gujarat coast

Gujarat is located 20° 1' to 24° 7' N and 68° 4' to 74° 4' E in the northwest part of the Indian peninsula. With a total area of 196,024 km<sup>2</sup>, it has the longest coastline of the nation as 1,650 kms. Its Exclusive Economic Zone (EEZ) covers 214,000 km<sup>2</sup>, or 9.9% of the country, while its continental shelf covers 164,200 km<sup>2</sup>, or 35.3% of the country. (Jha, 2009). The substratum includes of the Gujarat coastline vary with percentages ranging from around 28%, 21%, 29%, and 22%, respectively, for sandy beaches, rocky shorelines, muddy flats, and marshy places (Misra and Kundu, 2005). There are variations in the geological features and living biota of different portions of the Gujarat coastline due to their diverse geographical locations. A wide range of ecological and human activities are possible along the Gujarat coast due to its topography, hydrodynamic qualities, and geography, which supports the sustained establishment of a diverse range of marine water flora and fauna. Three primary geographical areas comprise the Gujarat coastline: the Gulf of Khambhat and the Gulf of Kachchh and the Saurashtra coastline.

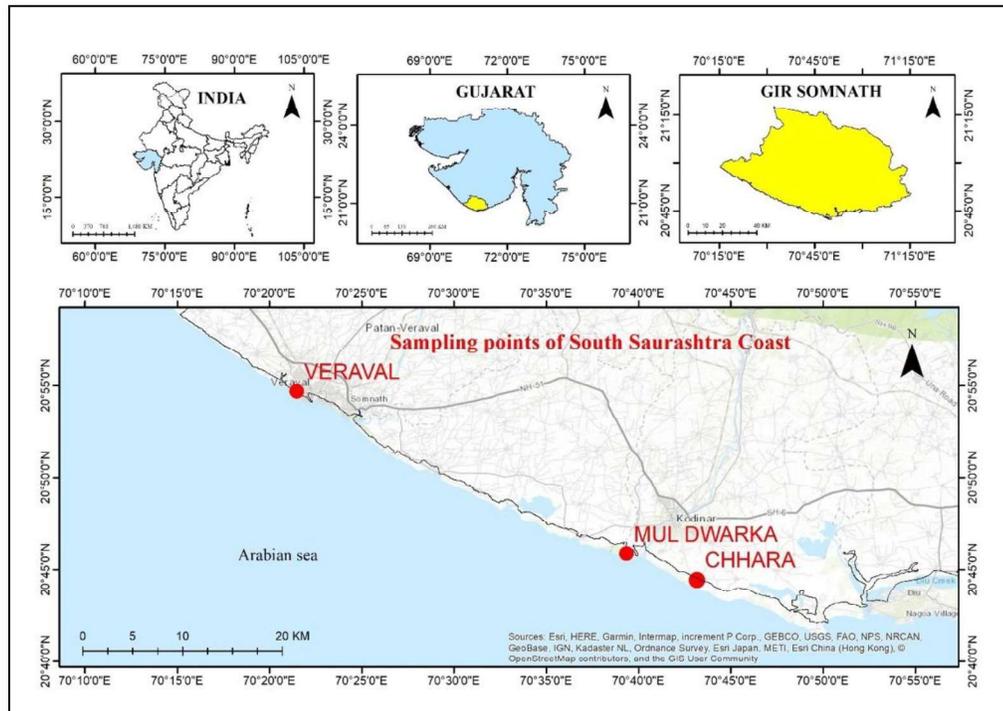
#### 3.1.2 Saurashtra coast

The coast of Saurashtra is around 865 km long and is located on southwestern edge of Gujarat. Based on the geological surveys and remote sensing data reveal unique characteristics produced by tectonic movements and previous sea-level variations. With miliolite deposits spanning from 52 to 235 thousand years, representing various rates of geological uplift, these strandlines give evidence of former sea levels and tectonic uplift (Baskaran, 1987). The coastal regions of Saurashtra are varied, with distinct soil profiles and vegetation found in each of the beaches, dunes, marshes, and cliffs. These environments can be broadly divided into three subcategories: the shore zone, which is directly impacted by waves and tides; the coastal zone, which is distinguished by features that transition from land to sea; and the arid/semi-arid subcoastal plain, which is identified by unique vegetation that has adapted to dry conditions (Rao and Shanware, 1967). This complex terrain offers insights into the region's biological

variety and environmental history in addition to reflecting the dynamic interaction between sea-level variations and geological processes over millennia (Gaur *et. al.*, 2007).

### 3.1.3 Sampling sites

Several factors have an impact on the unique marine environment found in the South Saurashtra coastline, especially along the Arabian Sea. The South Saurashtra coast offers a distinctive fusion of marine biodiversity and geological processes, and the region is well known for its abundant marine life in particular. The sites selected for the proposed work are on the south coast of Saurashtra and are characterized by areas of mud or rocky outcrops interspersed with sand (Figure 3.1).



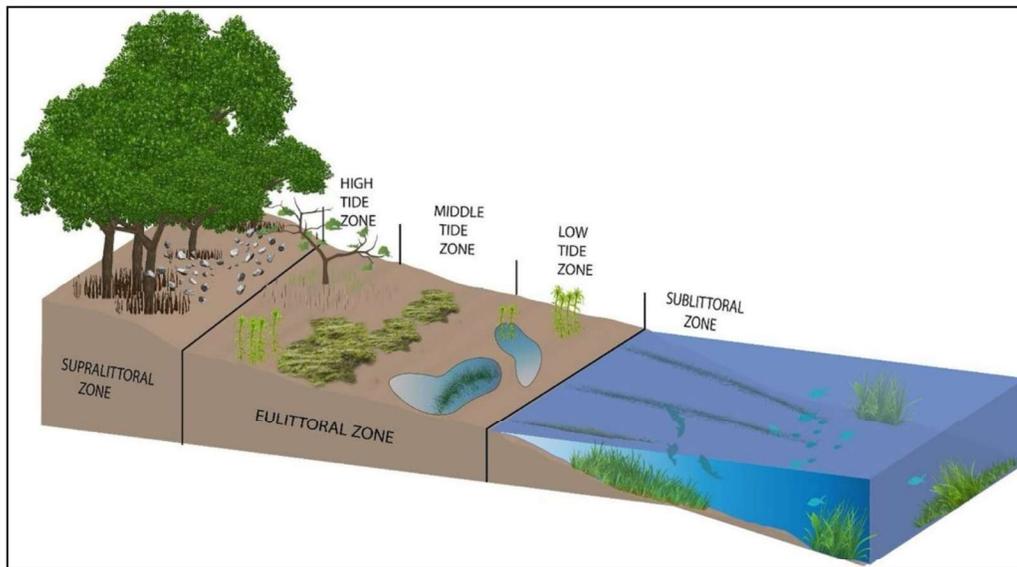
**Figure 3.1:** Location of study sites in Southern Saurashtra coast

### 3.1.4 Zonation patterns

The unique distribution patterns of species along the vertical gradient of rocky coasts are referred to as vertical zonation in the intertidal zone. Several factors, including tide levels, wave exposure, and physiological stressors, affect

these phenomena. Across the vertical gradient from upper supralittoral to upper infralittoral zones, it represents the principal pattern of distribution for littoral assemblages on rocky coasts at the regional level. (Chappuis, 2014).

Research has indicated that distinct species display distinct vertical patterns, referred to as zonation. Adaptations significantly impact the distribution of these species in the rocky intertidal zone (Neill, 2010; Benson, 2002; Seapy, and Littler, 1993; Strachan, *et. al.*, 2015; Chappuis, 2014). Furthermore, studies have shown that the distribution of rocky coast assemblages varies more vertically within the same biogeographical zone. The significance of wave exposure and geomorphological characteristics, as well as physical and environmental variables, in determining the patterns of intertidal zonation in various ecosystems.

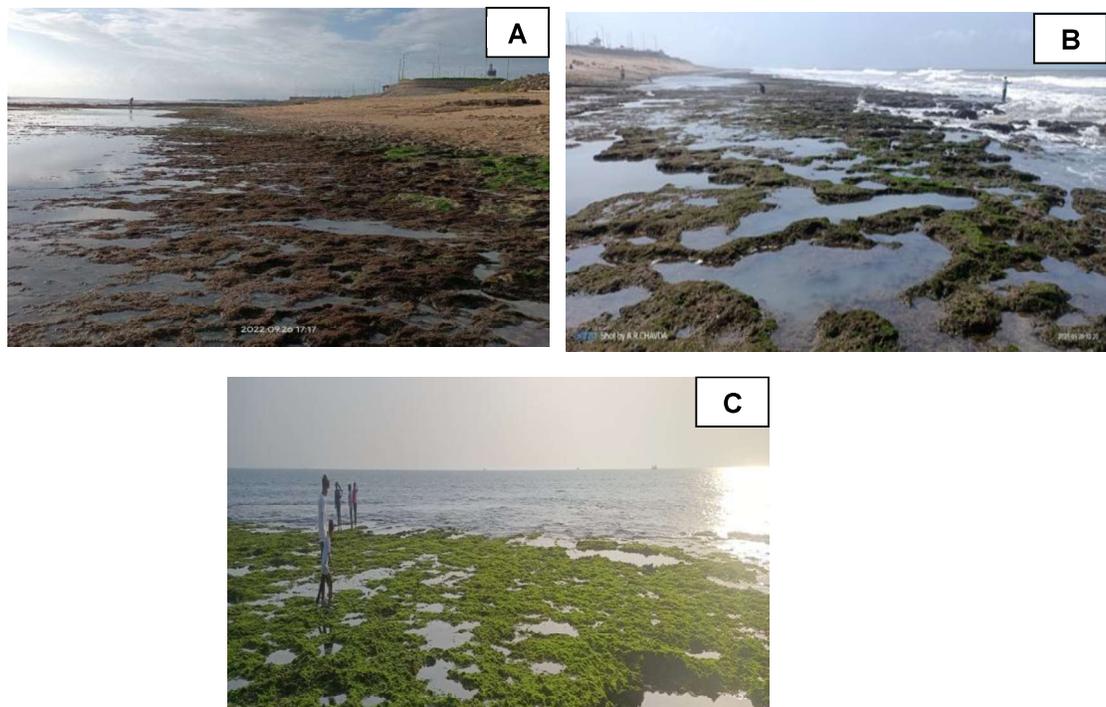


**Figure 3.2:** Diagrammatic representation of Vertical zonation of rocky shore

Littoral zone can be divided into supralittoral, eulittoral and sublittoral zones (Goltenboth *et al.*, 2006). Supralittoral zone (or the upper intertidal zone) is regularly splashed but not submerged, hence also termed as the splash or spray zone. Below the supralittoral zone lies the eulittoral zone (or the middle intertidal zone). Depending on tidal exposure, the eulittoral zone can further be classified into high, middle and low tide zones. With the varying conditions of temperature, light and salinity prevalent in this zone (Figure 3.2).

### Site-1 VERAVAL

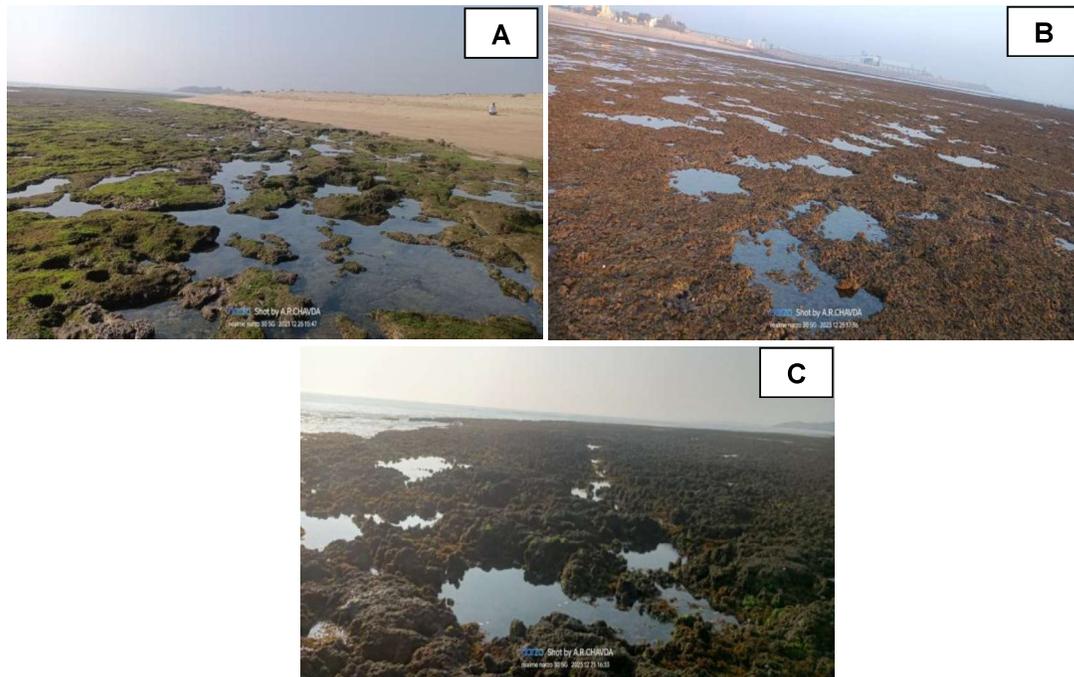
Veraval is located in Gujarat on the southern coast of Saurashtra. Considering one of the major fish landing centres in India, Veraval holds great significance for the commercial fishing industry. It gathers enormous amounts of garbage, including gas, from the port. It also regularly gathers heavy industrial garbage, small-scale fish processing activities, and household sewage waste from the city. At low tide, the intertidal zone's exposed area varies from 30 to 70 meters. Boulders and wide channels break up the rocky shoreline. The shorelines in the upper intertidal zone are sandy. There are deep crevices and tidepools covering the middle and lower intertidal zones. The middle and lower intertidal zone has deep tidepools with large openings. The subtidal zone is reached after a sharp vertical drop from Veraval's lower littoral zone. Numerous structural substratum differences, including Boulders areas, irregular substratum with more tidepools and crevices, areas covered in algae are the characteristics that set this intertidal zone distinct. These variations demonstrate the characteristic assemblage structure of benthic diversity (Figure 3.3).



**Figure 3.3:** Site wise zonation of A) Upper littoral zone B) Middle littoral zone C) Lower littoral zone of Veraval coast

## Site-2 MUL DWARKA

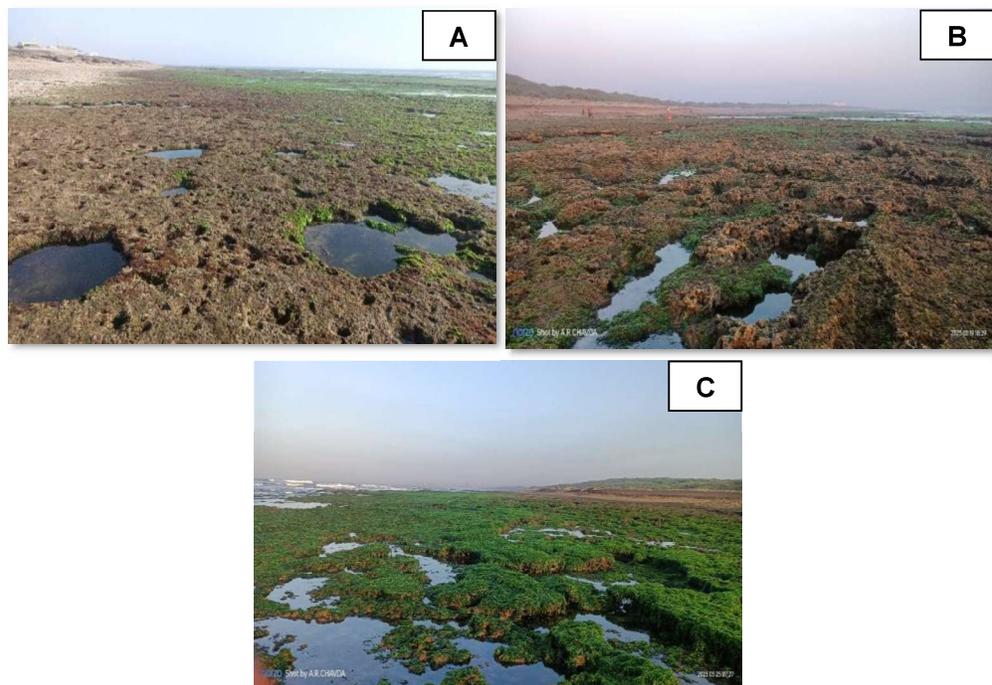
A variety of phenomena have impacted the geomorphology of Mul Dwarka shoreline. According to Rao, 2023 and Sasilatha, 2023, it possesses ancient remnants that date back to the Harappan period, including stone anchors that suggest a thriving marine past and trading channels. Combining emergent and submergent characteristics affected by tectonic processes and variations in sea level, the region displays both erosion and accretion, with progradation along beaches and retreat along cliffs (Sasilatha, 2023). Puddles and flat tidepools appear across the intertidal zone, which is made up of a hard, flat, rocky substratum with cracks. With a modest slope, the spray zone is completely covered with sand. Great shallow tidepools comprise the upper intertidal zone. Wide and shallow tide pools with many of caves and crevices form up the mid-intertidal zone; these tidepools are filled with water during low tide, while deep, medium tidepools protect by lower zone (Figure 3.4).



**Figure 3.4:** Site wise zonation of A) Upper littoral zone B) Middle littoral zone C) Lower littoral zone of Mul Dwarka coast

### Site-3 CHHARA

Chhara is located from 11 km southeast of Kodinar and coast is situated from 1 km from the village. Sea waves that directly contact the area cause damage on a daily basis. There are several pottery and boulders strewn across the space. Brick and pottery sizes imply that the location is from a certain historical era. According to reports, the Chhara archaeological site contains Red Polished Ware from the historical era (IAR, 1957-58). The underwater research off the coast of Chhara was conducted across from the ancient mound. (Sundaresh and Gaur, 2009). The intertidal zone of this site is made up of a hard, sloped elevation, pointy substratum in certain areas, and a flat, rocky substratum with tiny and large depressions interspersed with boulders, puddles, tidepools, and pointer rock (Figure 3.5).



**Figure 3.5:** Site wise zonation of A) Upper littoral zone B) Middle littoral zone C) Lower littoral zone of Chhara coast

#### 3.1.5 Study duration

The proposed study was conducted from February 2021 to September 2023. The preliminary survey of the entire littoral zone of South Saurashtra coast

was conducted at various types of locations, including Velan, Sarkhadi, Chhara, Mul Dwarka, Dhamlej, Sutrapada and Veraval. After the preliminary survey as the main aim of present work was to study the community structure and diversity of rocky tidepools, Veraval, Mul Dwarka, and Chhara were selected based on a variety of ecological characteristics, including rocky substratum type, abundance of tide pools of varying sizes and their relative ease of access, site accessibility, significant tidal exposures, a continuous long intertidal belt, and the availability of various microhabitats. An outline of the zone was created, and the study sites have been divided into the specified littoral zones. Using the enormous exposure of the intertidal area, the study was conducted during low tide.

The whole coastline stretch was examined monthly from February 2021 to September 2023 using visual survey and field observational methods. A preliminary survey with the purpose of selecting a location was carried out during the initial six months. From August of 2021 to September of 2023, the invertebrate macrofaunal diversity of selected tidepools in the littoral zones was investigated. Every field visit included observations of the variety of tidepools, their community structures, and interactions among the communities.

The following methods have been considered for the purpose fulfil the objectives.

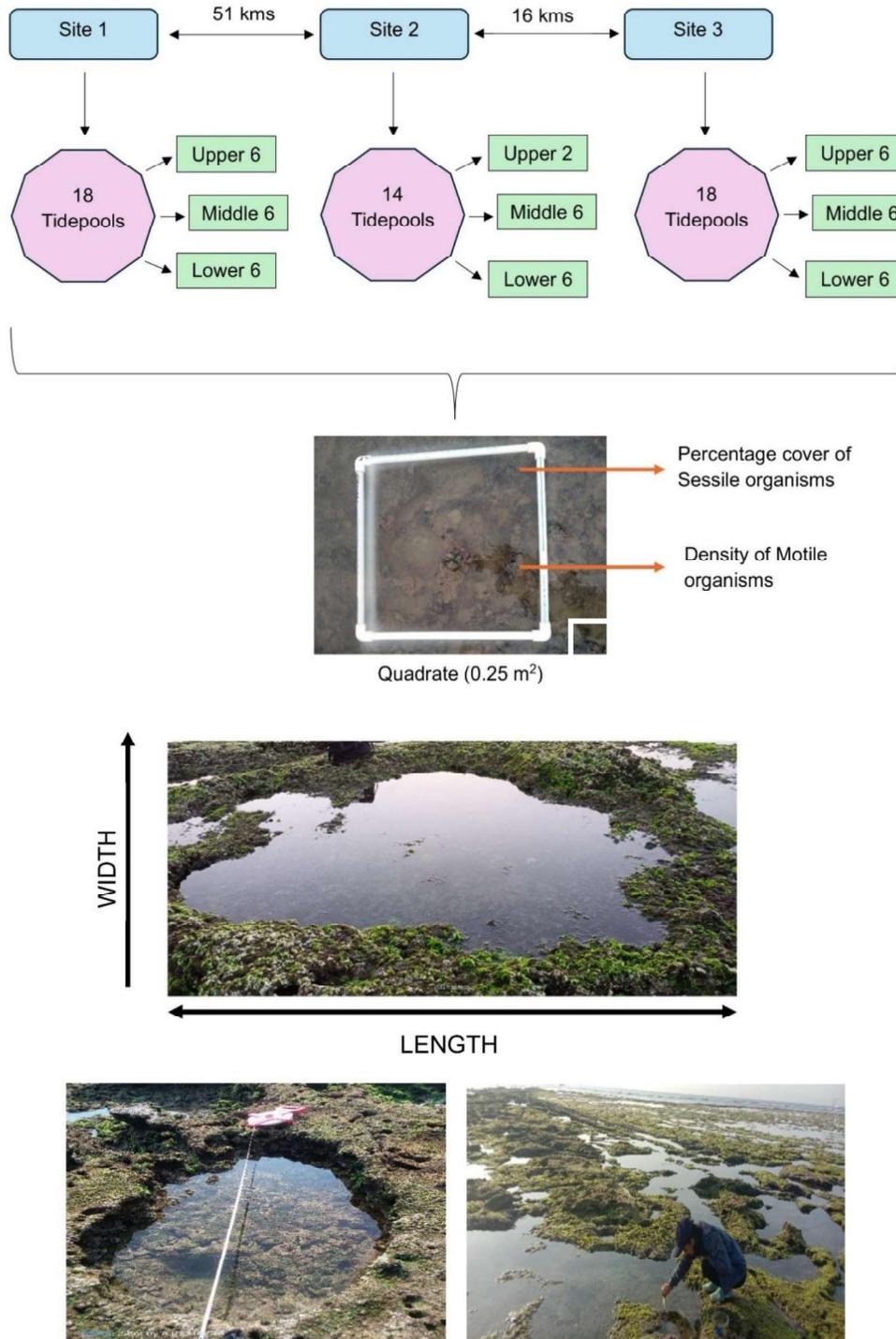
### **3.2 SAMPLING METHOD**

During the low tides of each month regular monthly survey was conducted of littoral zone of each sampling site. A physical visit to the rocky shoreline was undertaken in order to determine the total length of the stretch and to conduct direct observations of the topography of each sampling site, the range of different microhabitat types, exposure levels, and data collection. The purpose of the field survey was to study the structure of the rocky littoral zone and document its physical characteristics.

For the purposes to study the physical structure of tidepools, a measuring ruler was used to record the following physical attributes: length (L), which is the maximum distance across the tidepool's surface; width (W), which is the distance perpendicular to the length axis at the tidepool's midpoint; radius (r), which is the

tidepool's length divided by two; and depth (D). Each tidepool's average depth at water level was calculated by collecting three average random measurements in various locations inside the pool. Additionally, the vertical position and substratum features of each tidepool were noted at each of the study sites that were selected.

Three patches of 200 meters were examined at each sample site based on tidepool range and considering the length of each site. At each patch, six tidepools were selected at random and labelled with knobs. A random quadrat ( $0.25\text{m}^2$ ) sampling method was used to collect the data. There were observations made about the flora and fauna discovered within these quadrats. In each quadrat, the number of individuals that belonged to the motile fauna was specifically specified. Furthermore, for every quadrat, the percentage cover of sedentary fauna was calculated independently. (Figure 3.6).



**Figure 3.6:** Flow chart of the methodology employed in the study

A comprehensive understanding of the variety and distribution of species within the tidepool ecosystem is made possible by this data collecting technique. The collected data will be analysed further to reveal more about the ecological dynamics of this area. Measure the species richness, abundance, community composition, and distribution patterns within tidepool communities using this approach. Samples of seaweed have been collected from the field and transported to the laboratory to create herbarium sheets.

Direct observational techniques were used to thoroughly evaluate the dynamics of species interactions within the selected tidepools of each sampling site for the purpose to conduct a studies of community interactions within the tidepools. The observational method made it possible to collect comprehensive data and detailed information on interactions between different species. The aim of the studies was to identify the fundamental processes influencing community dynamics and ecosystem resilience in intertidal environments by systematically and rigorously documenting these interactions.

For the purpose to record the physical characteristics of the rocky littoral zone and the species inhabiting there, field surveys included in situ photography and videography of live specimens. Visual records that may be analysed and compared in later research are provided by photographic documentation.

A GPS device was used to record the locations of the field observations. During the field visits, the tide tables were obtained from <https://www.tide-forecast.com>. Field notebooks, data sheets, or digital devices have been used to properly document field observations, measurements and sample data with the aim to facilitate further data analysis.

The identification of species was carried out on the bases of morphological and molecular analysis. Using available identification keys, literature available in the form of books, monograph, journals, reports and other sources. All the invertebrate macrofauna were identified up to lowest taxonomic level as possible. Every intertidal macrofauna was accurately documented and subsequently categorized in a systematic method. As a result, a checklist of organisms classified into different phyla was created.

### 3.3 DATA ANALYSIS

#### 3.3.1 Biodiversity Indices

A diversity index is a metric that expresses the number of different kinds, or species, that exist within a community. These indexes provide statistical representations of biodiversity in terms of evenness, dominance, and richness, among other aspects. In ecology, species are often varieties that are studied when diversity indexes are employed, although they can also be other categories like genera, families, functional types or haplotypes. Individual animals are often the entity of interest, and the number of individuals, biomass, or coverage are a few examples of measures that can be used to quantify abundance.

Many different indices of diversity are used by scientists, but we discuss the widely used.

##### 1. Shannon-Weiner Index

The Shannon-Weiner Diversity Index, initially proposed by Claude Shannon in 1948, is another popular diversity index that also takes into consideration species richness and evenness. An alternative name for it is Shannon's Diversity Index. The idea of uncertainty is connected to the index. For example, if there is minimal diversity in a community, we can identify an organism with a high degree of certainty or low degree of uncertainty. We are less confident about the species we will select (low certainty or high uncertainty) in a highly varied community if we select an organism at random.

$$D = \sum_{i=1}^S p_i * \ln p_i$$

When S is the species richness, ln is the natural logarithm, and p<sub>i</sub> is the percentage of individuals in species i.

H has a value between 0 and H<sub>max</sub>. Each community's H<sub>max</sub> varies and is influenced by the species richness. (Note: The symbol H' stands for Shannon-Weiner).

##### 2. Evenness Index

The term "species evenness" describes equitability or how evenly the distribution of the number of individuals in a given ecosystem. Pielou's evenness index (Pielou 1966) may be used to indicate the evenness of a community.

$$J = \frac{H}{H_{max}}$$

J has a value between 0 and 1. Elevated values signify increased evenness levels. J = 1 at maximum evenness.

In a community, species dominance, the antithesis of diversity can be measured using J and D. If the community is dominated by one or a few species, the J value is low.

### 3. Berger parker index

In ecological studies, dominance is measured using the Berger-Parker Index. It measures the proportion of the most abundant species in a sample compared to all of the individuals in the sample. Lower diversity is reflected in a higher Berger-Parker Index, which denotes more dominance by a single species.

When analysing species dominance in a sample, ecologists may use the Berger-Parker Index as a useful tool. The analysis's findings indicate periods of high and low biodiversity, which indicate variations in the environment during the course of several months. Investigating the variables affecting these differences, such as environment conditions or human activity, may require more research.

$$d = N_{max} / N$$

where  $N_{max}$  is the number of individuals in the most abundant species, and N is the total number of individuals in the sample.