CHAPTER – 3

STUDY SITES

3.1 LOCATION

India is geographically placed at 28° 36.8' N and 77° 12.5' E in the northern hemisphere of the planet. It is encircled by (i) the Bay of Bengal on the East, (ii) the Arabian Sea on the West, and (iii) the Indian Ocean towards the south. India has one of the longest coastlines of 7516.6 km in the world (SAC, 2012). It is bordered by nine coastal states including Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal and four coastal Union Territories namely, Puducherry, Lakshadweep, Daman & Diu, and Andaman & Nicobar Islands (Panigrahy et al., 2012; Prasad et al., 2002). Among all, Gujarat is situated at 20° 00’ 24°45' N and 68° 00’ 73° 30' E facing the western Arabian sea which approximately covers 1650 km, one-third of the Indian coastline. The coast of Gujarat includes two Gulfs – the Gulf of Kachchh and the Gulf of Khambhat along with the Saurashtra coastline. The Gulf of Kachchh has a shallow depth of roughly 60 m at the entrance to less than 20 m near the head; while the Gulf of Khambhat (Gulf of Cambay) is 190 km wide at the entrance, but rapidly diminishes up to 24 km (Singh, 2012, 2000). The Gujarat coastline covers approximately 28%, 21%, 29%, and 22% varying substratum features for sandy beaches, rocky shores, mud flats and marshy areas respectively (SAC, 2011; GEC, 2012). India's first marine national park is reported in the Gulf of Kachchh which is an important part of Indian ecology. Gujarat coast is also notable for habitat diversity including mangroves, salt marshes, coral reefs, beaches, dunes, estuaries, intertidal mudflats, gulfs, bays, and wetlands. According to Forest Survey of India, Gujarat has the second largest area under mangroves vegetation (FSI, 2015). Around 66 halophyte species belonging to 57 genera were recorded from Gujarat coast. The major portion (around 77%) of mangrove forests of Gujarat is marked by the Gulf of Kachchh which holds an extensive amount of herbs followed by shrubs, trees, climbers and creepers (Rodrigues et al., 2011).
3.2 CONSIDERATION FOR THE CURRENT STUDY

The Gujarat coastal zone is distinguished for immense biodiversity as well as an effective perspective on ecology and development. According to Forest Survey of India, Gujarat has 1046 sq km mangroves with 51% muddy area enriched by a diversity of halophytes (FSI, 2013; R. S. Rodrigues et al., 2011). The regions of the Gulf of Kachchh and the Gulf of Khambhat are looked upon for high tides on a routine basis, while the Saurashtra coast is least indented and moderately straight. The Gulf of Kachchh represents distinguished vegetation diversity. It encompasses the marine national park, coral reefs, mudflats, and mangroves diversity, while the Gulf of Khambhat has rocky beaches, marshlands, sandy patches and mudflats with some rocky intertidal zone. The Saurashtra coast is covered by a habitat diversity which includes sandy beaches, numerous spits, bars, marshes and small estuaries predominate (SAC, 2010; Stanely, 2004; GEC, 2012; Singh, 2007). Each habitat comprises unique vegetation, regional climate and environmental variables. Due to a higher diversity of vegetation in the Gulf of Kachchh, and of habitats in Saurashtra coast, these two regions have been chosen for the study. They also become significant in the light of the fact that the Gulf of Kachchh has a high rate of coastal development and a higher impact of natural disasters on the Saurashtra coast because of it facing the Arabian sea directly (SAC, 2012). The various habitats that occur is a reason for the alteration and different amounts of rainfall, its patterns, different climatic condition, soil structures and other environmental variables (SAC, 2010; Prasad et al., 2002; Singh, 2012). Gujarat has maintained a different average annual rainfall for Jamnagar - 600 to 800 mm, Saurashtra - 400 to 800 mm, and Kachchh - less than 400 mm (GEC, 2012; SAC, 2010). The Kachchh region has arid climate conditions and dry soil, while the regions from Jamnagar to Okha and Saurashtra are humid and have dry black soil structures (GEC, 2012). These variables are responsible for the diversity and distribution of biotic components in the coastal ecosystem (GEC, 2012). The coast of Gujarat is assessed for qualitative and quantitative analysis of the density and abundance of environmental components to create wide and detailed knowledge about them (Shah et al., 2005). Previously, the Gujarat coast has been evaluated for mangrove diversity, assessment of edaphic factors,
monitoring and change detection of various classes, coastal vulnerability, salinity, and conservation with the management of different sensitive areas (Bhatt et al., 2009; Hu et al., 2012, 2014; Joseph & Balchand, 2000; Klemas, 2001; Kunte et al., 2003). Moreover, many studies have demonstrated environmental variables such as salinity gradients, sedimentation, a status of microbes and affected parameters for community structure and the ecosystem (Patel et al., 2010; Sims et al., 2013; Yu et al., 2012). The seasonal variability of soil microbes and nutrients were studied in the form of soil enzymes from Sundarban, India (Tripathi et al., 2007). With ongoing research, it has been a well-established fact that the interaction between biotic and abiotic components plays a pivotal role in the community structure with respect to time and space (Hu et al., 2014; Tripathi et al., 2006). Apart from this, coastal halophyte species have been evaluated for traditional medicinal importance (Dagar, 2005). Various medicinal properties such as antioxidant, antidiabetic, anticancer, antimicrobial, anti-inflammatory, anti-hemolytic and so forth were reported from the halophyte species (Chonthida et al., 2013; Dc & Aug, 2016; Kaneria & Chanda, 2013; Medini et al., 2015; Munir et al., 2014; Oueslati et al., 2012; Sudjaroen, 2014). At present, the research has progressed in the direction of ecological study of coastal wetland medicinal plants, their medicinal properties as well as periodical change detection in the habitat area for conservation (Ksouri et al., 2013; Lay, Karsani et al., 2014; Medini et al., 2015; M. J. Rodrigues et al., 2015). Although halophytes have immense importance in the coastal habitats, they are under pressure due to unfavorable environmental conditions, anthropogenic actions, and natural disasters. In 1991, the Government of India (MoEF, 1991) declared the stretch of tidal effects of the coastal area as a Coastal Regulation Zone (CRZ). Under the Integrated Coastal Zone Management program various coastal conservation activities have been initiated. GEER and GEC organization of Gujarat Government has been initiated restoration and management practices of mangrove zones and afforestation using A. marina species. Around 6% mangrove class increased by 2015 and only (GEC, 2009). Along with this some coastal habitats and associated vegetations are also help to protect and conserve the coastal ecology. Though, they are less focused and intensified for the scientific studies. Thus, the study was chosen for the coastal medicinal plant's ecological and medicinal
importance and their properties as well as the interaction of associated environmental parameters from the selected sites of Gujarat’s coastal area (Bassi et al., 2014; Dagar, 2005; Upadhyay et al., 2015).

3.3 STUDY AREA AND STUDY SITE

The Gulf of Kachchh and the Saurashtra coast were undertaken as the study areas for the assessment of their ecological importance. Along with environmental parameters, the main focus of the research is on the antioxidant and alpha-glucosidase properties of halophytes in coastal regions. The Gulf of Kachchh region is divided into two major sites, namely i) Southern Gulf of Kachchh (SGK) and ii) Northern Gulf of Kachchh (NGK). The main components of all the three sites are halophyte species which are helped by the surrounding soil environment for their growth (Ge et al., 2010; Olander & Vitousek, 2000). The Northern Gulf of Kachch (NGK) has limited feature habitats such as sandy beaches, muddy inter-zones, marshland while the Southern Gulf of Kachh (SGK) has high fragile features sites including coastal mangroves, mudflats and salt marshes. The Saurashtra coast (SC) possess salt marshes, sandy beaches, rocky shores and muddy areas near Diu. For the present research, Mundra, Gangeswar beach, Mandvi, Drabudi beach and Kashi beach from the NGK region; Narara, Sikka, Salaya, Dwarka, and Okha from the SGK region, and Veraval, Somnath, Lati, Muldwarka, Tad, and Diu sites from the SC were taken (Fig. 3.1). The coastal wetlands area covers different vegetations like marine algae, phanerogamic and algae of salt marsh, sand dunes slack, vegetation associated with drift-line, shingle beach vegetation, coastal cliffs plant, and coastal mangroves. They are halophyte vegetations which grow under the different saline conditions and have the ability to dilute salt within their succulent leaves or stems. This vegetation helps to stop erosion and run-off of contaminants from the roots of plants and recycles nutrients. Among all vegetation’s, mangrove soil has the waterlogged condition and high salt concentration. The roots of coastal vegetation’s special mangrove plants support binding of the soil and also help in the establishment of microorganisms which further help in stabilizing the area (Alongi, 2002; Cintron et al., 1978; Haoliang et al., 2007; Lugo & Snedaker, 1974).
3.3.1 Northern Gulf of Kachchh

The Northern Gulf of Kachchh comprises of marshy, sandy, rocky and muddy habitats. The sites, viz. Mundra, Navinal, Kashi beach, Dhrabudi beach, Mandvi and Gangeshwar coastal area were examined for medicinal halophytes and soil collection. Some potential medicinal halophytes identified at the site were *Suaeda maritima* (L.) Dumort., *Avicennia marina* (Forrsk.) Vierh., *Heliotropium curassavicum* L., *Salvadora persica* Linn, and *Suaeda fruticosa* (L.) -Frossk and collected for further investigation. Among all the species, *A. marina* (Forrsk.) Vierh was found to be abundant at all the sites of the region.

3.3.2 Southern Gulf of Kachchh

The Southern Gulf of Kachchh is enriched with highest vegetation diversity amongst the three sites. It is covered by mangroves, coral reefs, mudflats, and other salt marsh vegetations. For the assessment, the sites of Narara, Sikka, Salaya, Dwarka, and Okha were covered. All sites were found with significant moisture content as well as sufficient nutrient sources. However, the major sites showed the presence of *Suaeda vermiculata* Forrsk.ex J, F.Gmel., *Salvadora persica* Linn., *Limonium stocksii*, (Boiss.), *Suaeda maritima* (L.) Dumort, *Heliotropium curassavicum* L, *Salsola baryosoma*, and *Avicennia marina* (Forrsk.) Vierh. This region’s sites manifested the highest number of halophyte diversity which is categorized under different ecological status.

3.3.3 Saurashtra Coastland

The Saurashtra region contains habitat diversity which majorly includes rocky shores and sandy and marshy areas except for Diu. Union territory Diu contained major muddy, marshy and scrub lands. The sites of Veraval, Somnath, Lati, Muldwarka, Tad, and Diu were assessed and samples of medicinal halophytes and surrounding soil were collected. The halophytes diversity was presented by *Convolvulus microphyllous* Siber ex Spreng, *Salsola baryosoma*, *Heliotropium curassavicum* L, *Avicennia marina* (Forrsk.), and *Suaeda maritima* (L.) Dumort, species.
3.4 SAMPLE SCREENING

Sampling and analysis play a critical role. Here, a significant examination of the available literature was carried out for medicinal properties and traditional importance of halophytes. The species were screened on the basis of literature and listed under GMPB (Gujarat Medicinal Plant Board), NMPB (National Medicinal Plant Board), and IMPD (Indian Medicinal Plant Database). Further, the images of the halophytes studied were displayed in Fig 3.2. (Gurib-Fakim, 2006; GMPB; NMPB; IMPD). The species were prioritized on the basis of research and database records. Among all, the least found and unexplored species were considered for further examination. For the determination of soil quality, composite specimens were developed by mixing soil samples from adjacent sites.

3.5 SPECIES IDENTIFICATION

For individual species identification, various anatomical parts, morphological characters, and habitat structures were examined. In addition, species were identified and authenticated by the botanist, Dr. P. S. Nagar (Assistant Professor, Dept. of Botany, M. S. University, Vadodara). The herbarium specimen for all species was prepared and submitted to Baro Herbarium Centre, Dept. of Botany, M. S. University, Vadodara.
Fig. 3.1 – Sampling sites of Gulf of Kachchh (NGK, SGK) and Saurashtra coastal (SC) region

*Avicennia marina* (Forssk.) Vierh
[Family: Acanthaceae, Common name: Grey Mangrove, Local name: Tavariyan, Tivar). **Identification features**: Generally found as a tree or shrub form up to 3-14 m height, the tree having multiple branches. Stem - smooth light gray bark made up of thin, stiff, brittle flakes. Leaves – thick, ovate-ovate-lance shaped, 5-8 cm long, green glossy upper surface, silvery-white or gray at lower surface, Root – aerial roots, height up to 20 cm and 1 cm diameter, Flower-white to golden yellow, cluster of 3-5, Fruit-large fleshy seed.]

![Salvadora perisca L.](image)

[Family: Salvadoraceae, Common name: Grey Mangrove, Local name: meswak (Hindi), Piludi (Gujarati). **Identification features**: Small tree or shrub with a crooked trunk, seldom more than one foot, Bark - root bark light brown and inner surface is white, Leaves – almost circular oblong-elliptic, light to dark green, fleshy, wartlike glandular dots and dense, sharp tipped, base broad, entire margin, opposite pairs, Flower – very small greenish to yellow, Fruit – spherical, fleshy 5-10 mm, single seeded green, turn pink to purple red and semi transparent when mature.]
**Suaeda maritima** (L.) Dumort.

[Family: Chenopodiaceae, Common name: Seaside Indian Saltwort, Local name: Alur (Hindi), Moras (Gujarati). **Identification features:** Sea-Blite annual herb grows at seashores, in the salt marsh, mud, sand, below tideline. Stem - light green or pale yellow stem, Leaves – fleshy, semi-cylindrical, 1-2 mm wide, Flower – tiny, 1-2 mm, it occurs 1-3 together in axis of upper leaves, no petals.]

**Heliptropium curassavicum** L.

[Family: Boraginaceae, Common name: Seaside/Salt Heliotrope, Local name: **Identification features:** growing about 25 cm long, ascending fleshy perennial herb, Leaves – fleshy, glaucous, blue-green to yellowish gray-green, narrow, obovate, 4 cm long, Shoot – sprawling clumps emerging from a perennial taproot, spread from lateral root, Flower – born has coiled branches,
dull while waxy with yellow throat but turned blue or maroon tinged on maturity. Generally found in high tidal marsh and often in silty or sandy sediment.]

*Salsola imbricata* Forssk.

*Family: Amaranthaceae, Common name: Salsola baryosma Identification features:* a herb with large much branched, pale-hoary, branches filiform, crowded, slender, beset with linear leaves, Leaves: minute, fleshy, subglobose, Flower: tiny cylindrical spike, Fruit: perianth, bracteoles, silvery white, oblong, wings symmetrical.]

*Limonium stocksii* Kuntze.

*Family: Plumbaginaceae, Common name: Sea Lavender, Identification features:* upright plant with dandelion like leaves that grows to 16 inches tall and 12 inches across, Flower: cluster of small white flower, bloom at the ends
of stems in summer and early fall, bright in colour flat flower, stem: green stick, grown in well-drained soil, static will tolerate heat and drought as well as salt spray.]

*Convolvulus microphyllus* Siber ex Spern.

[Family: Convolvulaceae, Common name: Shankh Pushpi  
Identification features: A prostrate, spreading, perennial herb, generally found in a rocky or sandy ground xerophytic condition. Stem: ascending or prostrate, 10-40 cm long, densely velvety with appressed to spreading hair, Leaves: stalkless, linear to oblong lanceshaped or inverted lanceshaped, pointed/blunt tip, velvety to hairy, Flower: carried on stalks up to 2-3 cm long, bracts are linear to lanceshaped, flower stalk up to 3 mm long, sepals are lanceshaped, long-pointed, 4-8 mm long, 2 outer longer hairy, white or pale pink, 1-1.3 cm long, midpetaline areas velvety, Seed-dark brown.]

*Suaeda vermiculata* Forssk Ex J.F.Gmel. (*S. fruticosa*)
Family: Amaranthaceae, Common name: Shubby sea blight, Identification features: Shrub halophytes, found in arid and semiarid flats, upright growing up to 3 m height, much branched, prostrate, climbing or straggling. Stem: rough, week and thin, Leaves: succulent, smaller ones being long and narrow while the larger ones are elliptical, Flower: grow in a clusters, fruit: small seed, black shining, slight flattened, drop-shaped.]

Fig. 3.2 Collected Plant Samples From the Three Different Sites