Marine biology is the study of various life forms residing in the sea. It therefore represents one of the broad divisions of natural sciences. In marine biology, the studies are divided into two broad spectrums like functional biology and ecology. Functional biology is a study of how an organism carries out the functions such as reproduction, locomotion, feeding, digestion etc in the surrounding environment. Ecology, on the other hand, deals with the interaction of the organisms with their physical and biological environment. These interactions determine the distribution and abundance of the species in the habitat. The major objective of science of ecology of the species is to understand the entire set of factors or processes that affect the distribution and abundance of the species. While studying marine biology, one has to understand the basic aspects of habitats without which different aspects of species- habitat-environmental interactions and the ecology of particular species dwelling in the habitat are not understood. So the study of marine life offers a wider view of understanding the environmental conditions in which life thrives well (MacArthur, 1972; Barryfell, 1975; Levinton, 2001).

The marine environment is divided into pelagic and benthic divisions. The pelagic division is divided in to two provinces called neritic province and oceanic province. The neritic province is the form of pelagic area which lies above the continental shelf. The oceanic province range from the edge of the continental shelf to the deepest point of the ocean. The oceanic province is further divided into zones based on the depth. (Fig. 1) (Levinton, 2001).

The meaning of benthic is 'to be on the bottom or on the solid surface'. The benthic division supports various habitats which are mostly associated with the bottom of the ocean. The benthic division is further divided into different zones based on depth of the oceanic floor. The zone that lies between high tide and low tide mark is known as littoral or intertidal zone which covers less than 1% area of benthic environment. Second zone is known as sub littoral zone which lies between 0- 200 meter depth and covers 8% area of benthic environment.

Third zone is known as bathyal zone which lies between 200-2000 meter depth and covers 16% area of benthic environment. Fouth zone is known as abyssal zone which lies between 2000-6000 meter depth and covers 75% area of benthic environment. Fifth zone known as hadal zone starts from 6000 meters and reaches up to the deepest point on the sea floor and covers 1% area of benthic environments (Fig. 1) (Levinton, 2001).

Both the divisions of marine environment support various kinds of habitat and organisms. The organisms living in the marine environment are also classified based on the zone in which they live. The animals dwelling in open waters are commonly known as pelagic animals which are further classified Nektons (the animals which can swim well) and Plankltons (the animals which do not exhibit effective locomotion anddrift with the water current). The organisms residing in the benthic division are commonly known as benthic animals. The diversity of various organisms also varies with the different zones of the oceanic environment. Maximum diversity of the organisms is observed in the littoral, sub littoral, epiplegic and mesoplegic zone. Principally due to the presence of sunlight which drives the physiological activities of various organisms.

Information on species composition and habitat preference of marine invertebrates is the fundamental requirement to understand the presence of difference species in benthic communities, which also provide base line information for successful conservation of the habitat and benthic fauna. Studies on the distribution and diversity of local fauna are of great importance because these studies lead to the best understanding of structure, function and problems of the local animal community (Fransozo et al., 1992; Hebling et al., 1994).

The different divisions of marine environment support varieties of habitats but maximum habitat variations are observed in the littoral and sub littoral zones. The littoral zone supports habitats like mangrove forest, coral reefs, rocky shores, mudflats, sandy shores, estuaries etc. The sub littoral zone supports various marine habitats like sea grass patches, kelp forest, deep sea coral reefs etc. The marine environment supports huge diversity of invertebrates

which are the backbone of marine food web. Maximum diversity of marine invertebrate is observed in the littoral zone.

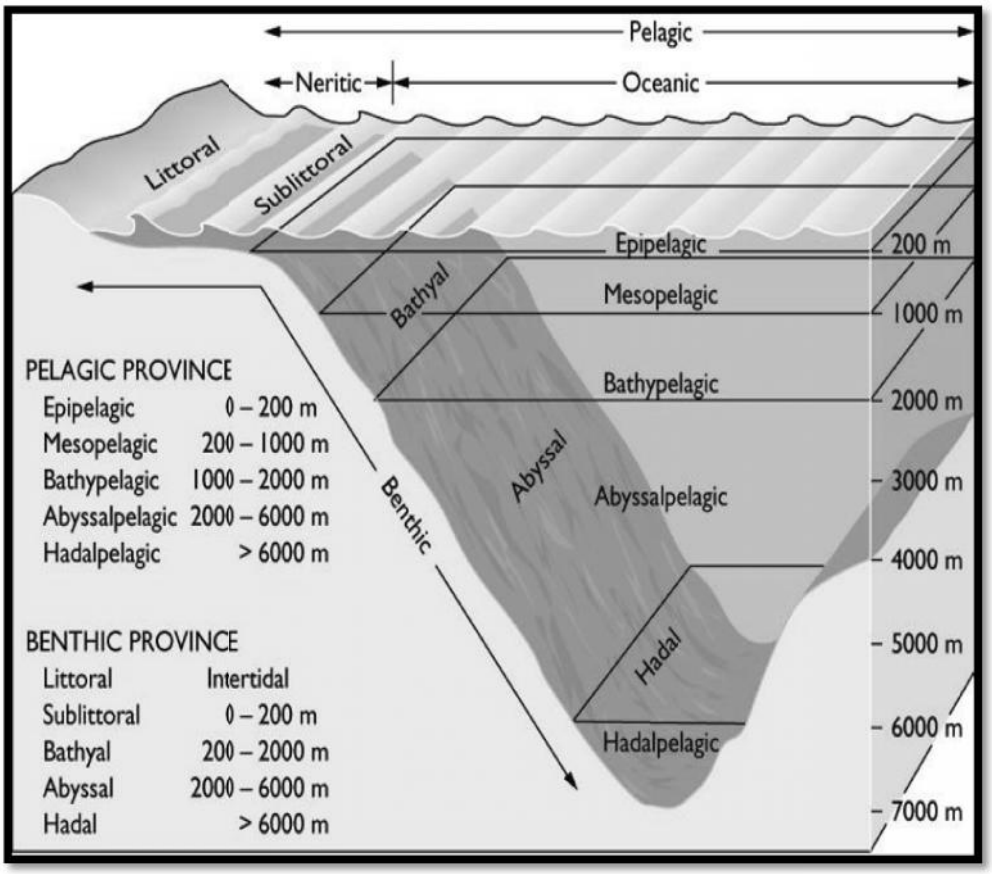

Figure1: Classification of marine environment (Source: www.marine-conservation.org.uk/marine_ecology.html)

Intertidal zone

The marine intertidal zone is the transition from land to sea and in this particular area organisms experience both marine and terrestrial conditions during high tide and low tide, respectively. Organisms living in the intertidal area develop different kind of adaptations since they experience a wide range of physical stresses, including fluctuations in temperature, aerial exposure, salinity, and hydrodynamic forces. The water is available regularly with the tide but the physical property of the water changes with the seasons. The salinity goes down in the monsoon season with the addition of the freshwater while it goes up in the summer because of evaporation of water and deposition of salt (Newell, 1979). The action of waves affects the local diversity of animal because it can dislodge

the residents in the littoral zone. Some microclimates available in the littoral zone are ameliorated by local feature and larger plants such as mangroves. Organisms adapt to the littoral zone is for making use of nutrients supplied in the high volumes on the regular basis by the tides (Newell, 1979; Denny, 1988).

Zonation: patterns and causes

In coastal areas, the intertidal zone is considered as most diverse and productive because with in the area of few meters various kinds of flora and fauna are observed (Underwood, 2000). The intertidal zone has been studied extensively for its biodiversity in past few decades. Vertical zonation is the most important process or phenomena observed on the rocky intertidal area in which from upper to lower intertidal area, different bands or zones containing different biodiversity are observed (Stephenson and Stephenson, 1949; Ellis, 2003). The variation in the distribution and abundance of organisms in different zones of intertidal area has provided basis of so many ecological experiments and such complex patterns of variations have been studied well especially for the organisms of rocky intertidal area. Intertidal distribution pattern, population structure and seasonal variation in abundance have been studied extensively to know the various ecological processes (Myers and McGrath, 1993).

These zones are the biological phenomena which are created by the rise and fall of the tidal waters of the sea. Various scientists working on the ecology of intertidal organism have labelled this stratification of the tides according to the local conditions. Snively (1978) has given a universal scheme for the zonation pattern and divided intertidal area into four different zones *viz.*spray zone, high tide zone, mid tide zone and low tide zone (Fig. 2).

Spray zone (Upper littoral): The highest reaches of the shore where waves splash only during the strongest winter storms at high tides. Otherwise this zone is terrestrial and, except for rain or snow, dry. It is an area influenced mostly by heat, light, wind, and fresh water.

High tide zone (upper mid-littoral): The high tide zone is flooded during high tide only, and is a highly saline environment. The abundance of water is not high

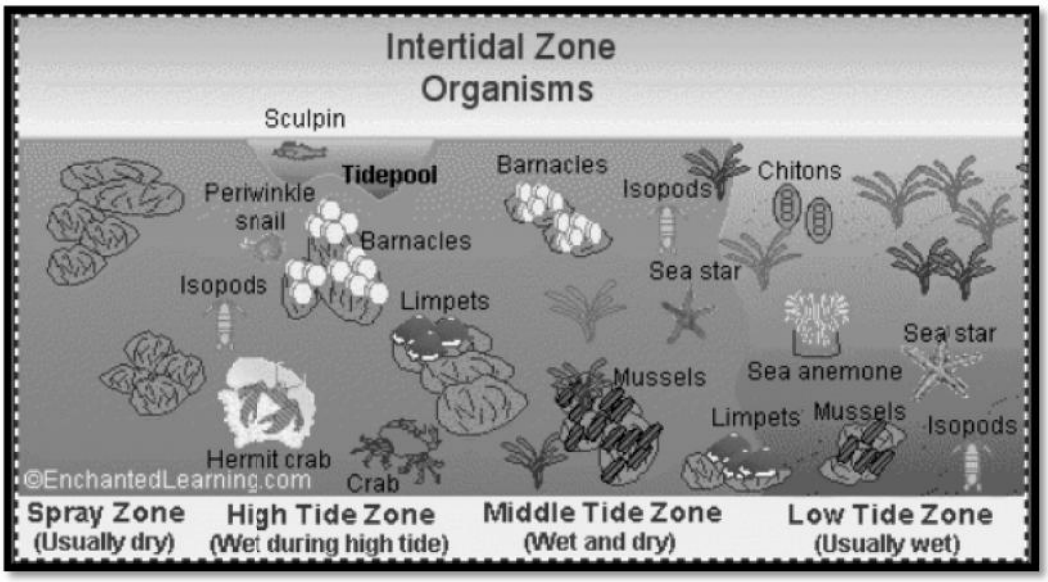

Figure 2: Intertidal zonation pattern (Source: www. Enchantedlerning.com/ Biome / intertidal)

enough to sustain large amounts of vegetation, although some do survive in the high tide zone. The predominant organisms in this sub region are green algae, anemones, chitons, limpets, mussels, snails, whelks, barnacles, isopods, crabs, sea stars, brittle stars and some marine vegetation. Another organism found here is the hermit crab, which because of its portable home in the form of a shell does extremely well as it is sheltered from the high temperature range to an extent and can also carry water with it in its shell. Consequently, there is generally a higher population of hermit crabs to common crabs in the high tide zone. Life is much more abundant here than in the spray.

Middle tide zone (lower mid-littoral): The middle tide zone is submerged and flooded for approximately equal periods of time per tide cycle. Consequently, temperatures are less extreme due to shorter direct exposure to the sun, and therefore, salinity is only marginally higher than ocean levels. However, wave action is generally more extreme than the high tide and spray zones. The middle tide zone also has much higher population of marine vegetation, specifically seaweeds. Organisms are also more complex and often larger in size than those found in the high tide and splash zones. Organisms in this area include barnacles, anemones, chitons, crabs, isopods, limpets, mussels, sea lettuce, sea palms, sea stars, snails, sponges, whelks and green algae. Rock pools also provide a habitat

for small fish, shrimps, krill, sea urchins and zooplankton. Apart from being more populated, life in the middle tide zone is more diversified than the high tide and splash zones.

Low tide zone (lower littoral): This sub region is mostly submerged and is only exposed at the point of low tide and for a longer period of time during extreme low tides. This area is teeming with life; the most notable difference with this subregion to the other three is that there is much more marine vegetation, especially seaweeds. There is also a great biodiversity. Organisms in this zone generally are not well adapted to longer periods of dryness and temperature extremes. Some of the organisms in this area are abalone, anemones, chitons, crabs, hydroids, isopods, limpets, mussels, nudibranchs, sculpin, sea cucumber, sea lettuce, sea palms, sea stars, sea urchins, shrimp, snails, sponges, surf grass, tube worms, whelks, green algae and brown seaweed. Creatures in this area can grow to larger sizes because there is more energy in the localized ecosystem and because marine vegetation can grow to much greater sizes than in the other three intertidal subregionsdue to the better water coverage: the water is shallow enough to allow plenty of light toreach the vegetation to allow substantial photosynthetic activity, and the salinity is atalmost normal levels. This area is also protected from large predators such as large fishbecause of the wave action and the water still being relatively shallow.

Causes of zonation: At a first glance, it was an oblivious assumption that tides are major factors for the creation of different zones in the intertidal area. But the phenomenon is actually very complex and historically, has been subject of controversy. Scientist have rejected tide asthe only factor responsible for the zonation pattern saying that zonation is created due to the air –water inference with various gradients like light penetration below the surface and other factors. On the other hand, Doty (1957) has considered tides as a major factor responsible for zonation, emphasizing that temperature, wind, rains and waves may be important to zonation but only tidal variation match with the biological zonation.

The names of different zones are given for our convenience to understand the complex biological system but actually in nature there are no such boundaries between zones and it varies with time and geography. The intertidal zone is an ecotone, a transition from sea to land, where certain species spend most or all of their time in the transitional habitat (Stephenson and Stephenson, 1949). The variations in the tides and environmental factors have created numerous niches in the intertidal zone. So many species compete with each other for the niche and no two species can live in the same niche for longer period of time. But as there are so many niche created in the intertidal zone, there are often so many species utilizing these niches form upper to lower intertidal zone (Snively, 1978). This is the main reason behind the enormous diversity of organisms in the intertidal zone.

Desiccation is the main limiting factor for the organism living in spray and high tide zone which is wetted occasionally by splashes of waves during the highest high tides. Many species move to the upper spray zones and live in the crevicesand cracks which provide them protection and food like algae. These animals are adapted to prevent the effect of desiccation (Newell, 1979). Competition for the space becomes limiting factors as organism move towards the lower intertidal zone. Various kinds of competitions can be seen like for food, shelter and exposure. Organisms keep moving in the intertidal zone to find particular niche to live. There is a competition between the species and within the species for resources (Wethey, 1983).Microhabitats can come in a number of forms; crevices, underneath boulders, beneath the canopy of overlying macro algae are a few. Microhabitats can offer protection from drying, predation, light, and heat. Waves bring water for moisture and food in the form of nutrients and plankton, but organisms living along the outer rocky coast both depend on and are at the mercy of pounding surf. The relentless beating by waves during winter storms can dislodge organisms.

Intertidal community: Differences in community structure over geographical space have long been a major concern for ecologists. Though variations in species diversity are perhaps the most striking differences and have certainly received the most attention, other aspects of community structure, including space

utilization patterns, species composition, trophic structure, and body size structure can also vary. Osman and Whitlatch (1978) argued that geographical patterns of species diversity may often be simple artefacts of the shape of the earth and the configuration of the continents and oceans, and therefore other aspects of community structure should be the real focus of geographical ecologists.

A striking character of rocky shore community is that all the resident plants and animals are situated or grouped in different zones, in the mid intertidal zone large congregations of gastropods and hermit crabs are observed in the tide pools filled with water. In the lower intertidal zone, crustaceans and zoanthids form a dominant animal community. Out of all the communities living in the rocky intertidal zone, decapods crustaceans are observed in high numbers and diversity (Fransozo and Negreiros-Fransozo, 1996; Boschi, 2000). The larger and more abundant species are important for human consumption while the incredible variety of small species contribute importantly to the complexity and functioning of tropical ecosystems; for e. g. on rocky shores, crabs are prime predators on molluscs, small crustaceans and other invertebrates, but on the other side, they also provide prey base for fish, decapods and some terrestrial vertebrates. So as a prey and predator they have potential influence on the behaviour, distribution and abundance of their own as well as neighbouring communities.

Brachyuran crabs

Brachyuran crabs belong to order decapoda, infraorder brachyura, the most diverse group of crustaceans alive today (Melo, 1996). The measure of their success is reflected in their colonization of almost every marine and terrestrial habitat. Their distribution range widens down to abyssal ocean depth of 6,000 meters and up to 2,000 meter above mean sea level on mountains. Many of these species have evolved to cope up with frequent higher salinity fluxes seen in the estuaries. Moreover, few of them have adapted themselves to terrestrial habitats and occasionally return to water for breeding and releasing their eggs. The brachyuran crabs exhibit very basic body design in which the abdomen is much

reduced and tucked under the expanded carapace. The first pair of pereiopod is converted into the chelipeds which serves different purposes like feeding, hunting, courtship displays etc. Other four pair of pereiopods are located on the lateral side of the body and commonly known as walking legs. Most of the true crabs are often confused with the hermit crab and porcelain crab which belongs to infra order Anomura. The anomuran crabs have three pair of walking legs which are clearly visible while the fourth pair is very small and tucked under the abdomen (Ng et al., 2008).

Brachyuran crabs are a highly important group of marine decapods and so far total 6,793 species belonging to 1,271 genera and subgenera, 93 families and 38 subfamilies have been reported worldwide (Ng et al., 2008). Due to their great abundance, they are considered as one of the most relevant groups of the marine benthos, both in terms of biomass and community structure. The density of the crabs in mangrove ecosystem can reach up to 80-90 individuals per m^2 (Khan et al., 2005). Many species of crabs are burrowing in nature and with their burrowing activity they frequently alter the sub surface characteristics and drive the nutrient cycling (Pandya, 2011). In mangrove ecosystem, burrowing activity of crabs increase the porosity of the soil which also increase the regeneration of mangrove seedlings (Khan et al., 2005). The bioturbatory processes by crabs affect the physical, chemical and biological processes on the intertidal area which are important for health of an ecosystem. Even a routine activity of burrowing facilitates series of chemical and physical alterations in the original sediment quality. The facilitation of oxygen to the subsurface depth allows microbial diversity and sediment oxic-anoxic zoning. The feeding activity by scraping the upper organic rich layer of the sediments regulates the organic content and the algal covering and on the contrary by-products from gut enriches the sediments with few minerals (Fig. 3).

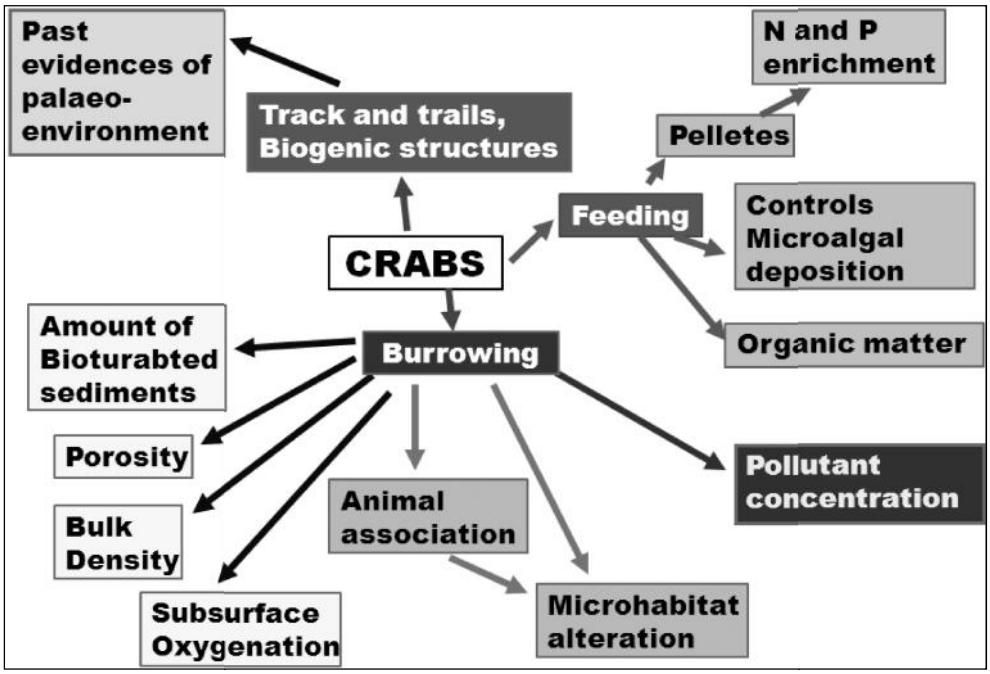

Figure 3: Role of brachyuran crabs in the ecosystem.

Review of Literature

International Status

Out of the 1.7 million species cataloged to date, about 250,000 are identified from marine environments (McAllister, 1995). Although marine ecosystems are probably less diverse than terrestrial environments in terms of total numbers of species, a marine ecosystem supports different varieties of life forms. The above mentioned statement was derived from the comparison of variation in "body architecture" by comparing the range of phyla found on land and in the sea.It was estimated that out of 33 animal phyla, 15 phyla exclusively found in marine environment (Elliott, 1993).The sampling of the deep-sea floor, the least explored region on earth, has uncovered countless new species. Some experts believe that deep-water habitats could harbor at least 10 million species (Fenical, 1996). Existing data on species distributions indicate, however, that much of the diversity in the oceans occurs within tropical waters and within near shore habitats.

The inter-tidal coastal areas are complex systems that exhibit widely variable physico-chemical conditions and constant habitat changes that may influence the biotic communities extensively. The hydrodynamics, manipulated by wave action and tidal variations, design the geomorphology of the coast and play pivotal role in determining the complexity of the system and the sediment characteristics. These are probable causes of broad scale community pattern variations spatially and temporally (Stillman and Somero, 2000). The sediment deposition, grain composition and variations on a diurnal, seasonal and annual basis define the micro habitat conditions (Johannesson et. al., 2000). On the inter-tidal area, these variations are noted vertically, horizontally and laterally (Pandya and Vachhrajani, 2010). Depending upon the exposure duration and extent, the salinity gradient makes the conditions of inter-tidal area moderate to harsh longitudinally which influence diversity and distribution of the benthic fauna dwelling in the intertidal area (Moser et al., 2005). The ecosystem component interactions thus contribute to community complexity. The inter-tidal community is therefore, the key target affected by the prevailing harsh

environmental variables. These also describe occurrence of variations in planktonic community and probabilities of larval settlement and juvenile/adult distribution along the inter-tidal length. Tidal variations induce site selection and abundance of brachyuran fauna (Talley and Dayton, 2000).

The studies on ecology of intertidal zone have attracted the scientists all over the world to study the interrelationship of the organisms with their surrounding environment (Reid, 1967). The variations in duration of submergence form a gradient of environmental conditions across the intertidal zone that lead to broad and large volatile variations in temperature and salinity (Newell, 1970). These variations force the organism to develop new adaptations to deal with the situations. The variations in different environmental factors create various kinds of micro habitats and these habitats are diverse but compressed into a small area of intertidal zone where upper limits of division are usually resolute by physical situation and lower limits by biological communications (Branch, 1976). These different habitats are formed across a shore due tidal variations that induce diversified processes. Identification of spatio-temporal variations allows the understanding of the role of these processes (Underwood and Chapman, 1996).Quantifying this variability at different scales is thus a prerequisite to the proposal and test of explanatory models of observed distributional patterns (Danielson, 1991; Underwood, 2000).

The biogeographic ranges of species are determined by a complex set of biological and physical factors which makes it difficult to determine the environmental disturbances. Portner et al., 2006 studied the effect of temperature on physiological performance of intertidal organisms. He revealed results in the form of skewed bell-shaped curve where organisms grow the fastestand have the highest reproductive fitness at the peak of thecurve, and barely survive at the tails of the curve. Rocky intertidal shores, which aredominated by sessile ectotherms, have served as an ideal systemfor studying physiological stress in nature because they havesteep temperature gradients (Davenport and Davenport, 2005; Place et al., 2008).

The coastal areas of temperate and tropical regions are dominated by sandy shores and beaches and they can be classified according to their morph dynamic types and tide range (Short, 1997). Micro tidal beaches can be reflective, intermediate or dissipative in response to increasing wave energy and finer sands. As tide range increases, all beaches tend towards flatter, more dissipative profiles. These changes have a major influence on beach fauna. In general, faunal diversity and abundance increase from micro tidal reflective to macro tidal dissipative types. However, most surveys have covered micro tidal areas and there is limited information on mesotidal regimes and little quantitative data from beaches in the tropics (Jaramillo et al., 1993).

Dahl (1952) proposed a universal scheme of zonation on sandy beaches, who suggested three different zones defined by the fauna dwelling in each zone. The zones were (1) sub terrestrial fringes characterized by the presence of air breathing crustaceans (2) a mid-littoral zone characterized by cirolanid isopods (3) a sub littoral fringes mixed fauna characterized by amphipods. Salyat (1964) has also proposed scheme for zonation of sandy shores based on the tidal variations as described for different zones. Recently, Brown (1983) has revised the zonation scheme on the sandy shore and described only two zones: upper zone inhibited by air breathing animals while lower zone inhabited by water. However, the use of this universal scheme to study the distribution pattern of invertebrate fauna met with only limited success (Raffaelli et al., 1991).The major reason behind the drawback of the universal scheme of zonation on sandy shores was temporal variation in the distribution of invertebrates on the sandy shores. Many invertebrate species living on the sandy shores of temperate region reproduce seasonally and as a consequence the structure of the intertidal community will change seasonally depending on the recruitment and mortality of the dominant species (Shelton and Robertson, 1981; Leber, 1982). As a result, the data collected on the distribution pattern of invertebrates for a shorter period of time does not reflect the same situation in the other period of the year. Because of temporal restrictions of the universal zonation pattern, it has been hardly used for the studies related to the distribution pattern of invertebrates on sandy shores (Shelton and Robertson, 1981; Dexter, 1984)

As compared to the organisms living on the rocky shores, the organisms living on the sandy shore have the opportunity to explore the habitat in third physical dimension which is depth. Because most of the animals living in the sandy shore are burrowing in nature their zonation patterns are not distinct as compared to the animals living on rocky shores (Pearson, 2001). The infauna inhabiting soft-sediment environments can avoid thermal stress by burying themselves into the sediment, and competition does not represent an important restriction because the space is not usually a limiting resource (Lenihan and Micheli, 2001). Since primary production is not a critical process in sandy beaches, these systems receive frequent inputs of nutrients from the phytoplankton in the adjacent water and from particulate organic matter derived from the land and adjacent intertidal habitats (Brown and McLachlan, 1990).

The sandy beaches are mostly dominated by polychaetes, bivalves and crustaceans and the species is usually low as compared to other intertidal habitats. In crustaceans amphipods, isopods and brachyuran crabs are observed dominant on the sandy shores. Species belonging to family ocypodidae are commonly found inhabiting sandy shore in the tropics, especially species of genus *Ocypode,* (commonly known as ghost crabs). Brachyuran crabs *Ocypode ceratophthalma* (Pallas, 1772) is a main inhabitant of tropical sandy shores. The species mostly inhabit upper fringes of the sandy shores and moves to lower zone near the water line for feeding. The species is identified as a biological indicator of anthropogenic pressure on sandy shore (Schlacher et al., 2011). The physicochemical and biological characteristic features of sediment have immense impact on the structure of faunal community of the sandy shore (Jaramillo and McLachlan, 1993). The infauna living in the sediments needs certain kind of characteristic of sediment for survival and they are capable of modifying the sediment characteristic as per their requirement (Lenihan and Micheli, 2001).

Rocky intertidal habitat may be amongst the first habitat to show the ecological responses to the effect of climate change. Because intertidal environment is combination of habitat space and temperature gradient and changes in this combination can directly affect the species living in the habitat (Somero, 2002). Smith et al., (2006) have studies the distribution pattern of

mussel species *Mytilus californianus* in the rocky shores of pacific coast of North America and found that the climate change has immense impact on mussel bed which consequently affect the rich biodiversity residing in the mussel beds. Paula and Oliveira (1980) have studies the intertidal distribution of brown alga *Sargassum* sp. on the Brazilian coast and found that the distribution pattern of the species is very much affected by the wave action and climatic factors. Es-ton and Bussab (1990) have studied the impact of herbivore sea urchin *Echinometra lucunter* on the intertidal distribution of brown alga and identified that quantity of herbivores can act as limiting factor for the distribution of brown alga on rocky shores.

The complexity of the habitat can be correlated with the characters of brown alga like their structure, chemical composition and surface characteristics. It can also be related with the quantity of epibiont and sediment restrain by the plants. Edgar and Aoki (1993) stated that such algal assemblage provides substratum for sessile animals, refuse to the mesofauna, macrofauna and meo fauna and also food to the herbivores and detritivores. The sessile organisms residing in the algal assemblage of intertidal zone may be benefited by the consumption of the substances released by the alga. According to Montouchet (1979), the vagile invertebrates associated with *Sargassum cymosum* C. Agardh from the coast of São Paulo State, some species use the macroalgae as reproductive sites for the development or growth of a determined larval phase. In the group of macro invertebrates associated with different marine alga, the crustaceans are among the most abundant group (Santos and Correia, 1995). Hiyodo and Fransozo (1994) suggested that communities dominated by *Sargassum* favor the Majidae crabs *Epialtus brasiliensis* Dana and *Acanthonyx petiverii* H. Milne Edwards, most abundant in this habitat.

Gastropods are another major animal community found in the intertidal area. The distribution pattern of various gastropod species in relation to their habitat, availability of food, impact of physical, environmental and biological factors has been studied by several scientists. From different studies it can be concluded that various physiographic strctures of shore and the time period of low tide are the limiting factors of the upper and lower limits of the gasatropod

species (Underwood and Denley, 1984). Emson and Faller-Fristsch (1976) have studied the population density and size of individuals of *Littorina rudies*in relation to the size and availability of the crevices.

It has been hypothesized that the clustering or aggregation of gastropods species in crevices or tide pools reduces the level of desiccation during the low tide. Gastropods also prefer specific site for adhesion which is also the possible reason behind the aggregation of the species (Fisher, 1966). Emson and Faller-Fristsch (1976) have shown in their experiment that addition of artificial crevices in the habitat of the littorinid snail can increase their density many fold without affecting their fecundity. Huges (1980) has proved that availability of suitable habitat can change the distribution pattern of gastropod species at different sites while on the other hand few species of gastropod species can survive in variable environmental conditions. In the intertidal environment, locomotion plays an important factor for the distribution of various mobile organisms.

Linsely (1978) has classified the locomotion of gastropods in different groups and correlated it with their distribution pattern. Patel (1984) has correlated the locomotion of different gastropod snail species with the tidal rhythm. The salinity changes in the intertidal area also affect the distribution pattern of gastropods. Young (1980) has studied the correlation between the salinity tolerance of gastropods and their distribution in different zones of intertidal area. It was observed that the species living in the high shore experience the huge variation in the sea water salinity in different seasons.

The availability of micro habitat and variations in the environmental parameters in the intertidal zone has immense effect on the reproduction and growth of the gastropod species. Williams (1964) stated the faster growth of some gastropod species helps in the maintenance of the population of other carnivore species. Quayle (1951) has correlated the growth of gastropod species distributed in different zones of intertidal area and stated that gastropod species living in the upper intertidal zone shows higher growth rate. Huges (1980) has correlated the season with the growth of the gastropod species *Littorina nigrolineata* and stated that hatchling appeared in December to March show

lower growth rate as compared to hatchling appeared in the winter season. Jardine (1985) has studied the reproductive behavior of gastropod species *Gibbula cinerira* and stated that individuals living in the upper intertidal zone grow in larger size and produce larger gonads as compared to the individuals living in the lower intertidal zone. So it was evident that the breeding behavior of the same organism in tropical, subtropical and temperate environments indicates different modes of patterns, as it is generally controlled byendogenous and exogenous environmental factors (Loosanoff and Devis, 1952; Giese, 1959).

The zoanthids (Hexacorallia: Zoantharia) are an order of benthic cnidarians found worldwide and are particularly common inhabitant of coral reef environment and rocky shores. The group commonly occurs in the intertidal zone still the taxonomy of the group is least studies because of few reasons like lack of confirmed morphological characters, larger intraspecific variation and somewhat cryptic ecology (Reimer et al., 2006). Zoanthids are known to incorporate sand particle into their body structure. Due to this unique character zoanthids are often known as encrusting anemones.

Zoanthids are commonly distributed in most of marine environments of temperate and tropical areas. Their distribution ranges from intertidal area to the depth of 5000 meters and are commonly found in tropical and subtropical seas (Fosså and Nilsen, 1998; Reimer and Miyake, 2009). Fautin (2010) has compiled the list of zoanthid species of the world and recorded around 354 species but the number is likely much less due to inadvertent re descriptions (Burnett et al., 1997). Presently zoanthids are placed in three different families including Zoanthidae, Sphenopidae and Parazoanthidae. The genera like *Palythoa* and *Zoanthus* belonging to family Sphenopidae and Zoanthidae are common benthic taxa found in different coral reefs and rocky shore. Species belonging to these two genera influence the neighboring sessile fauna by covering them or encroaching in their space (Suchneck and Green, 1981).

Zoanthids were studied in details for their population dynamics, dispersal pattern and their impact on coral reefs in Atlantic region (Acosta et al., 2005; Mendonça-Neto et al., 2008) and Caribbean (Sebens, 1982; Karlson, 1983).

Zoanthids have not been studied for their different ecological aspects in Indo Pacific region. In Asia, few studies were done in Japan like; Ono et al., (2003) have conducted a long term monitoring study on coverage of *Zoanthus sansibaricus* in Kogoshima Japan. However the sampling area of the study was very small. Reimer et al., (2007) have studied the distribution pattern of zoanthids in Okinawa, Japan. He stated that *Palythoa tuberculosa* is a common inhabitant of the reef and distributed in wide depth range from intertidal zone to 30 meter while another species *Zoanthus sansibaricus* is distributed only on reef crest.

Brachyuran crabs have been studied extensively for taxonomical and systematic research. So many researchers have compiled list of brachyuran crab of the world at different time periods. The brachyuran crab taxonomy is very confusing and many synonyms are available for different species, so, compilation of valid species was very much needed. Ng et al., (2008) have surveyed through extensive literature published on brachyuran crab diversity from different parts of the world and identified 6,793 valid species belonging to 1,271 genera and subgenera, 93 families and 38 subfamilies worldwide. Brachyuran crabs dwell in all marine habitats and maximum diversity of brachyuran crabs is reported from Western Pacific region where around 2000 species were reported followed by Indo Malaya region where around 1000 species were reported (Ng et al., 2008).

Brachyuran crab diversity varies with the habitat type. Among the different macro fauna canalized in the mangrove forest, brachyuran crabs are one of the most important taxa with regards to number of species and biomass (Golley et al., 1962). So far, 300 species of brachyuran crab were reported worldwide with maximum diversity residing in the mangroves of Indo Malaya region. Two families like Grapsidae and Oypodidae are majorly found in the mangroves and account 80% diversity of crabs (Tan and Ng, 1994). Taxonomy of sub family Sesarminae under family Grapsidae is confusing and phylogenetic relationship of sub family is remained unsolved (Tan and Ng, 1994). Genus *Sesarma* is the largest genus found under sub family Sesarminae which is distributed into 20 sub genera and 125 species (Anger, 1995; Diesel and Horst, 1995). Many researchers have tried to compile the list of mangrove crabs. The

table given below describes the diversity of grapsid and sesarmid crabs associated with mangroves in different parts of the world (Table 1).

Locality	No. of grapsid crab species	No. of sesarmid crab species	References
Northern Pacific	50	11	(Stimpson, 1907)
Malaysia	13	12	(Sasekumar, 1974)
Australia	45	37	(Davie, 1982)
Indo- Malaysian mangrove	26	25	(Jones, 1984)
Malaysian-Singapore Mangroves	51	44	(Tan and Ng,1994)
Hong Kong	31	26	(Lee,1998)

Table 1: Diversity of grapsid and sesarmid crabs in mangroves

Brachyuran crabs belonging to family Xanthidae, Eriphiidae and Pilumnidae are commonly found on the rocky shores and coral reef habitats. Brachyuran crabs occur in high diversity and forms one of the important part of the most diverse reef communities across the world. Serene (1972) has stated that more than 500 species of brachyuran crabs inhabit coral reef and rocky shore environment. Brachyuran crab species belonging to families like Trapeziidae, Tetraliidae, Xanthidae and Cryptochiridae live in symbiosis with several species of corals (Castro et al., 2004).

The crabs select specific substrata for their settlement thus establishing a strong relationship between sediment type and distribution (Bolam, 2003). The burrow formation by crabs facilitates deep oxygenation and sediment upwelling making the upper sediment layer rich in terms of biota (Shih et. al, 2005). Hydrodynamic conditions, resultant beach profile, sediment sorting and variations in sediment characteristics causes gradients on one hand and patchy habitat structure on the other (Attrill and Rundle, 2002) and can be considered as the ultimate cause of broad scale community pattern spatially and temporally.Studies have suggested that such brachyuran faunal communities could be distinguished on the basis of sediment composition (Bolam, 2003). Small-scale textural properties of the grain population may affect stability of

sediment patches and hence the spatial patchiness of the crabs (Peter et al., 2001).

Brachyuran crabs are, therefore, directly associated with the substratum and hence, animal–sediment relationship has become an inevitable aspect of the studies. Several crabs mark their presence by cryptic behavioral patterns, typical burrows; burrowing/feeding/excretory pellets or even by leaving their trail marks (Chakrabarti et al., 2006). These bioturbation activities process the sediments to generate micro-habitat variations, modify micro-topography, sediment chemistry, sediment transport and drainage. Sediment disturbances due to foraging and burrowing activities have impacts on other fauna. The dominant species usually alter recruitment patterns, site selection, survival/mortality of settling larvae, control food availability, predation etc. of other species also and thus regulate the community.

Among various inter-tidal forms, brachyuran crabs are usually the abundant macrofauna actively involved in bioturbatory activities. Additionally, the burrow morphology and substratum preference by brachyurans can provide important information like tidal cycle, high water reaches (Xin et al., 2009), behavioral response, palaeo-subenvironment of the beach (Seike and Nara, 2008) etc. In most of the studies, brachyuran forms are typically correlated with the existing ecological parameters (sediment/water), however, unless the interactions of animals with their habitat are understood, it is difficult to unsheathe their ecological role. Habitat use by shorebirds, major vertebrate predator in inter-tidal areas, is influenced by sediment penetrability, prey density and availability (Botto et. al., 1998).Due to various activities of inter tidal forms, the coastal sediment landscape is in constant flux with disturbance rate dependent on the abundance and activity of the organisms.

National Status

India is amongst the 12 mega biodiversity countries of the world and 25 hot spots of rich and highly endangered eco regions of the world. India has the coastline of 8000 km with an exclusive economic zone of 2.2 million km^2. The coastal areas of the country are endowed with varieties of marine ecosystems

like estuaries, rocky shores, coral reefs, mangroves, lagoons, sandy shores and mudflats which are characterized by unique biotic and abiotic processes. The west coast and east cost of India are different in terms of geo morphology. The west coast if exposed with rocky shores, head land and mudflats while the east coast is mostly endowed with lagoons, marshes, deltas and beaches (Venkataraman and Wafar, 2005). In India, coral reefs are distributed along the east and west coasts at certain places and all the three major coral reef types occur. The mainland of India has two widely separated areas containing reefs: the Gulf of Kachchh in the northwest, which has some of the most northerly reefs in the world, and Palk Bay and Gulf of Mannar in the southeast. There are patches of reef growth on the west coast. The total area of coral reefs in India is estimated at 2,374.9 sq km.

Gujarat being the western proximity of the country harbors a longest coastline which is about 1650 km. The coastline of the state is mainly divided into three coastal areas *viz.* Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. The total coastal area is covered by different kinds of marine habitats which include 29 % of muddy flats followed by 28 % of sandy beaches, 22 % of marshy coast, and 21 % of rocky coast. The first systematic study on the marine biodiversity of Gujarat was carried out by Hornell (1916) who studied the marine fauna occurring in the coastal area of Okha Mandal, part of Gulf of Kachchh. During past decade some studies were carried out on marine biodiversity of Gujarat (Deshmukh et al., 2000). NIO Report (2002) noted that coastal Gujarat, chiefly Gulf of Kachchh, supports 200 species of fishes, 5 species of turtles, 3 species of marine mammals, 70 species of sponges, 200 species of mollusca, 27 species of prawns, 15 species of echinoderm and several species of crabs. Integrated Coastal and Marine Area Management (ICMAM) Report (ICMAM, 2002) cited occurrence of 32 species of gastropods, 31 species of bivalves, 2 species of crustaceans, anthozoa and scaphopoda each and polychaete, sponge and coral species in Gulf of Kachchh.

The molluscan fauna inhabiting Indian waters were studied in detail by several workers in different periods of time. The study on molluscan fauna of Indian subcontinent was initiated by Benson and he has published around 90

papers between the years of 1830 to 1865 describing the ecology and diversity of marine and freshwater mollusca. So far total 5070 species of mollusca hve been recorded from India out of which 3370 species occur in the marine environment (Subba Rao, 1991). The maximum diversity of molluscan is recorded from Andaman Nicobar islands (more than 1000 species) followed by Gulf of Mannar (428 species) and Lakshadweep islands (424 species).

The molluscan fauna is studied less for the various ecological aspects like distribution pattern, population ecology etc. The benthic molluscan fauna has been studied in detail for the distribution pattern in different mangroves and estuarine regions of India. Ansari et al., (1986) have studied the spatio temporal variation of benthic macrofauna of Zuari estuary of Goa state, India. They have stated that seasonal variation in water quality parameters affects the distribution pattern of macro fauna in estuarine region. Chakraborthy et al., (1992) have studied the zonation pattern of various macrofauna in mangrove habitat of Sagar island of Sundarbans. Kashinathan and Sanmugham (1986) have studied tha distribution pattern of macrofuna in different zones of Pichavaram mangroves. Sukumaran and Krishnaswamy (1962) have correlated the changes in the sea water salinity with respect to the density of *Cellana radiata* at Madras coast of Tamilnadu. Rao and Ganapati (1971) have carried out investigations on hermophroditism, radula fraction and shell length, distribution, population density and resistance to temperature, salinity and desiccation in *V. radiata* from Visakhapatanam waters on East coast of India.

Saurashtra Coastline of Gujarat state is characterized by its rocky, sandy and muddy intertidal zones harboring rich and varied diversity of flora and fauna (Nayar and Appukuttan, 1983). The substratum is mainly formed of rocks of miliolite and laterite stone providing altogether a different habitat to the intertidal population (Sarvaiya, 1977). Rapid industrialization and consequent pollution on the Saurashtra coastline has resulted into deterioration of the community on the Saurashtra Coast. Except for few works on the ecology of certain limpets (Prasad, 1984), turbinids (Malli, 1983) and some cerithids (Patel, 1984), no report is available on the macro faunal resources of this region (Misra, 2004).

Samantaray (1979) has made some observations on reproduction and population of *C. radiata* of Veraval coast. Prasad and Mansuri (1982) have reported the density of *Cellana radiata* in the polluted area at Porbandar, West coast of India. Sarvaiya (1977) has described the distribution of two turbinids, *T. intercostalis* and *T. coronatus* at Okha and nearly islands. Kundu and Mishra (2005) have studied the intertidal distribution of key gastropod species along the Saurashtra coast of Gujarat. They have stated that the intertidal distribution pattern of gastropod species is highly influenced by the geomorphology of the area, structure of intertidal zone and seasonal variation in the water quality parameters.Trivedi et al., (2013) have studied the shell preference behaviour in hermit crab *Cllibanarius zebra.* They stated that the shell preference behaviour of particular species is highly influenced by the availability of various gastropod species in the intertidal area.

Venkatraman and Wafar (2005) have listed occurrence of 218 species of corals under 60 genera and 15 families. Amongst the four major reefs of India, maximum diversity of corals is reported from Andaman Nicobar islands while minimum diversity is reported from Gulf of Kachchh. Zoanthids are group of anthozoans which form integral part of coral reef environment. The zoanthid fauna of Indian waters is poorly studied and scanty information is available on the diversity and distribution pattern of particular group. Hornell (1916) in his document on the marine fauna ofOkha mandal of Gujarat state mentioned the presence of few zoanthid species along the coastal region of Okha. Hornell (1916) has also reported presence of *Palythoa tuberculosa* for the first time from India. After that no studies have been done on the zoanthids of Gujarat state till Bhattji et al., (2010) reported presence of *Palythoa* sp. from the coastal areas of Dwarka. In the recent study, Pandya and Mankodi (2012) have identified presence of four species like *Pallythoa tuberculosa, Pallythoa mutuki, Zoanthus sansibaricus* and *Zoanthus vietnamensis*. They also stated that *P. mutuki* is occurring in high densities in the lower intertidal zone.

Venkataraman and Wafar (2005) had compiled a checklist of marine biodiversity of India and stated that more than 13000 species of flora and fauna are occurring in the Indian marine waters. In case of faunal diversity, maximum

diversity is recorded for crustacean (3377 species). The species diversity of various crustacean fauna is listed in the table given bellow (Table 2).

Taxa	Number of species
Copepoda	1925+
Ostocoda	120+
Branchiura	5+
Cirripeds	104
Mysidacea	75
Cumacea	30
Tanidacea	1+
Isopoda	33+
Amphipoda	139+
Euphasacea	23+
Macrura	55+
Brachyura	705+
Anomura	162

Table 2: Marine crustacean fauna of India (Venkatraman and wafar, 2005)

The studied related to the brachyuran crab fauna of India has glorius history but the all the work is carried out in selected patches of coastal areas of India (Fig. 4). The studies on brachyuran crab fauna was initiated by Fabricius (1775, 1793) who has recorded brachyuran crab species like *Philyra globosus, Philyra craniollaris* and *Matuta Victor* from Malabar coast of western region of India. The brachyuran crab fauna of eastern coast of India has been studied by different researchers in different time frames. In the past, Henderson(1893) initiated studies on the brachyuran crabs of eastern coast of India. Alcock (1898) has also studied that cracinological material available in the Indian Museum and also carried out sampling of several species of brachyuran crabs from various parts of India. Although his focus was mainly on the east coast of India.

On the eastern coast of India, the sites studied extensively for the brachyuran crab studies include Andaman Nicobar Island, Gulf of Mannar and Chilka lake (Gravely, 1927; Sankarankutty, 1969; Jeyabaskaran et al., 2000; Dev Roy and Nadi, 2012 and Kumaralingam et al., 2012). Alcock and Anderson (1894, 1899) during their survey by H. M. S. "Investigator" have surveyed several stations in Bay of Bengal, near Andaman Nicobar Island and in the Arabian Sea.

They have described several new species and new records of brachyuran crabs using the samples collected during their survey. Kemp (1917, 1919) has also studied the brachyuran crab material available in the Indian Museum which was mostly collected from Andaman Nicobar Islands, West Bengal Coast, Orissa, Andhra pradesh and Tamilnadu and described several new species of brachyuran crabs. The mangrove habitat available on the eastern coast of India was also studied in detail for the brachyuran crab fauna (Seturamlingam and Khan, 1991).

The brachyuran crab fauna of western coast of India is studied less as compare to the eastern coast. After the work of Fabricius (1775); H. Millne Edwards (1852) has reported six more species of brachyuran crabs from Malabar and Bombay coast. Nobili (1903) has recorded five species of brachyuran crabs from Bombay coast.Pillai (1951) studied the brachyuran crab fauna of Travancore along the western coast of India and reported many species of brachyuran crabs from the area. Chhapgar (1957a, b) has extensively studied the brachyuran crab fauna of Bombay state and reported 93 species of brachyuran crabs including two new species of crabs. Tikedar (1965) has studied the marine fauna of Devgadh coast of Maharshtra and reported few species of brachyuran crabs. Ummerkutty and Deb, (1972) studied the brachyuran crab fauna of Maysore coastal area. Several new species of brachyuran crab have also been described from west coast of India like Sankarankutty (1969, 1975) has reported two new species of brachyuran crab belonging to genus *Xenophthlmus* and *Hexapus* respectively. Suseelan (1972) has also described *Ixainermis* based on the material collected from the western coast of India. Vogel (1983) has redescribed a species *Dotillamalabarica* from the coastal areas of Kerala. Dev Roy (2013) has compiled the list of brachyuran cab species occurring on the western coast of India and reported 226 species belonging to 130 genera and 39 species. In this paper, maximum diversity is reported from Kerala (93 species) followed by Maharashtra (92 species); Gujarat (66 species); Karnataka (53 species) and Goa (51 species).

The coastal areas of Gujarat state support rich marine biodiversity. The coastal areas were studies for various kinds' marine fauna but as compared to other fauna the brachyuran crab fauna of the state is least studied. Hornell

(1916) has reported the presence of few crab species in the coastal areas of Okhamandal. First comprehensive work on brachyuran crabs of Gujarat state was carried out By Chhapgar (1957a, b; 1958; 1969) in different parts of Gujarat. He has reported 42 species of brachyuran crabs from different sites like Okha, Kodinar, Umarsadi, Kollak and Udwada. Chhapagar (1955) has also described two new species of brachyuran crabs like *Pseudograpsus intermedius* Chhapgar, 1955 belonging to family Grapsidae and *Leptodius euglyptus qudrispinosus* (= *Macromedaeus quinquedentatus*) form the coastal areas of Okha. Chandi (1969; 1973) has also worked on brachyuran crab fauna of Gulf of Kachchh and added few more crabs to the existing list of brachyuran crabs of Gujarat. Chhapgar and Mundkar (1995) have also reported *Euxanthus exsculptus* from Gujarat. Chhapgar et al.,(2004) have also added few brachyuran crab species recorded from Mandavi of Gulf of Kachchh. Recently Pandya (2011) has worked on the brachyuran crab fauna of Mahi estuary of Gulf of Khambhat and identified 11 species of brachyuran crabs. Trivedi and Vachhrajani (2012) have worked on mangrove crab diversity in some selected sites in Gulf of Kachchh and identified 19 species of brachyuran crabs.

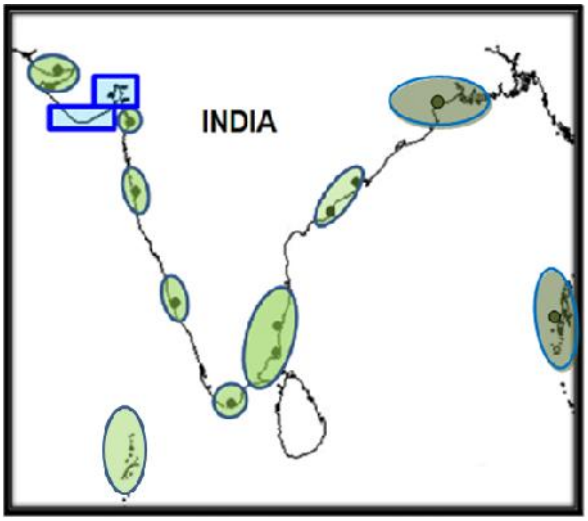

Figure 4: Distribution of brachyuran crabs studies in India. The boxes indicates less studied areas in Gujarat

The distribution pattern of brachyuran crabs dwelling in different marine habitat on the coastal areas of India is not studied in detail. In the past few studies on the distribution pattern of brachyuran crabs was studied in the

mangrove habitat. Joel et al., (1985) have identified 29 species of bracvhyuran crabs and studied their distribution pattern in Chilka Lake. Chakaraborty and Choudhury (1992) have studied the distribution pattern of mangrove crab species on Virgin Island of Sunderbans. The Pichavaram mangrove situated in the coastal areas of Tamilnadu has been studied extensively for the diversity and distribution pattern of mangrove crabs (Ravichandran et al., 2001).

Khan et al., (2005) have compared the diversity and distribution pattern of brachyuran crabs in natural mangroves and planted mangroves. Bandekar et al., (2011) have studied the distribution pattern of mangrove crabs in Karwar mangroves of Karnataka. Dev Roy and Das (2000) have studied the distribution pattern of brachyuran crabs in the mangroves of Andaman and Nicobar islands. The distribution pattern of brachyuran crabs in the rocky shore habitat or coral reefs habitat is not studied in detail on the coastal areas of India. Kumaralingam et al., (2012) have studied the distribution pattern of brachyuran crabs in different coral reef habitats of Andaman and Nicobar islands.

The distribution and habitat preference of different brachyuran crab species with relation to the various environmental factors is not studied well on the coastal areas of India. In the past, Silas and Sankarankutty (1965) have studied the ecology of shore crabs occurring on the coastal areas of Palk Bay. They have studied ecology of *Scopimera proxima* in which they tested the effect of environmental factors and occurrence on other crabs species on the distribution pattern of the studied species. Pandya and Vachhrajani (2010) have studied the distribution pattern of brachyuran crab *Macrophthalmus depressus* in the mudflat habitat of Mahi estuary of Gulf of Khambhat. They have correlated the burrow density of the species in the different zone with the sediment texture and abiotic parameters.

The ghost crab *Ocypode ceratophthalma* is commonly occurring species on the sandy shores of Indian subcontinent still the species is studied very less for different ecological aspects. Chakrabarti (1981) has studied the burrow architecture pattern of *O. ceratophthalma* on the eastern coast of India. He identified presence of different shapes in the structure of burrow. He stated the

shape and architecture of the burrow depends on the sediment type and texture. He also studied the temperature variation in different type of burrow and stated the temperature plays an important role in the architecture of the burrow. Recently Dubey et al., (2013) have studied the burrow architecture of *Ocypode macrocera*. He also identified presence of different shapes in the burrow architecture of the species. He checked the variation in air temperature and burrow temperature and found significant correlation. The sandy shores of western coast of India are different in terms of sediment texture and climatic conditions as compare to the sandy shores of eastern coast of India. No studies have been carried out for the burrow morphology of sandy shore inhabiting brachyuran crab species.

Origin of the work

Gujarat is a maritime state which has longest coastline in the country. The coastal areas of the state are divided into three major regions viz. Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. The coastal area of these three regions supports various kinds of marine habitats like mangroves, coral reefs, rocky shores, sandy shores and mud flats. These habitats were studied extensively for the biodiversity of various marine fauna. Amongst the various fauna studied, the brachyuran crab fauna is not studied in detail.

During the literature survey on the brachyuran crab fauna of Gujarat, it was observed that most of the studies were carried out in the marine habitat available in the Gulf of Kachchh (Chhapagar, 1957a, b; Chandi, 1973; Trivedi and Vachhrajani, 2012). Chhapagar (1957a, b) has mostly explored the coastal areas of Okha (Gulf of Kachchh), Kodinar (Saurashtra coast), Umarsadi, Kolak and Udwada (Gulf of Kahmbhat) to study the brachyuran crab fauna. Recently Pandya (2010) has studied the brachyuran crab fauna of Mahi estuary of Gulf of Khambhat while Shukla et al., (2013) have studied the brachyuran crab fauna of mangrove habitat of Gulf of Khambhat.

In the context of above mentioned studies the coastal areas of Saurashtra coast are not studied in detail for brachyuran crab fauna. The study of spatio temporal variation of brachyuran crab fauna dwelling in various marine habitats

is also not studied. The habitat preference is the most important factors thataffect the distribution pattern of the local brachyuran crab fauna. Pandya and vachhrajani (2010) have studied the habitat preference of *Macrophthalmus depressus* in mud flat habitat of Gulf of Khambhat. Such kind of studies are not carried out for the sandy shore and rocky shore brachyuran crab fauna of Saurashtra coast.

Objectives of the study

I. Study of intertidal zonation pattern and animal community structure
II. Study of diversity of brachyuran crabs – a taxonomical approach
III. Study of distribution and habitat preference of brachyuran crabs
IV. Study of burrow architecture of *Ocypodeceratophthalma*