Introduction

In any ecosystem, biotic components are drawn together in tight association as members of complex food chains and food webs. They are also highly diverse, dependent on and specifically adapted to the many and varied environments in which they live as well on the abiotic component, obtained as resources by lithosphere, atmosphere or hydrosphere that sustains the life known as Biosphere. The biosphere is characterized by food chain, food web, productivity, biomass, biogeochemical cycle, community, population, energy flow, ecological pyramids etc. (Odum, 1971).

Among all biospheres on the earth, marine biosphere is the largest one. It is structured by different habitats viz., sea shores, sea bottom, entire pelagic zone and intertidal zone etc. All these create local ecology in particular area; can be maintained by surrounding environment and components of ecosystem. Further, abiotic and biotic component by their inter relationships of local ecosystem control the eco-cycles. All these aspects produce effects on every species dwelling in the habitat in term of biodiversity, population dynamics, and community structure etc.

Marine biodiversity has huge varieties of species due to its vast space expansion. This biosphere is characterized by open sea, defined as pelagic region, which is very deep but life extends up to all the depths. It is denser at the continental slope and coastal margins. Wide ranges of geological, chemical and physical variation produce complex habitat structure, which controls not only the marine ecosystem but world's climate, atmosphere as well major biogeochemical cycles. Thus, the marine realm provides the largest inhabitable space for living organisms, the terrestrial realm on the other hand provides only a limited inhabitable space at surface and of the depth of a few feet at the most in the sub soil, the fresh water realm offers the least habitable space for animals.

Adjoining transit area of marine environment and terrestrial environment is known as littoral zone or intertidal zone. It is the shore line where all the abiotic factors of sea-water and also arial and terrestrial physical extremities interact (Malli *et al*, 1982, Patel, 1984). This area is mainly characterized by wave action, low and high tides. The organisms which are dwelling in any type of intertidal ecosystem either may have sandy, muddy or rocky coast line, to deal with difficult diverse environmental conditions, being both submerged in sea water within tide level and exposed to the air. They have to bear the great physical impact of waves, desiccation, high salinity and sunlight. Moreover, there is a risk of predation, not only from ocean based animals but terrestrial animals and birds as well. They are also affected by anthropogenic activities (Bhadja, 2010, Vaghela, 2010, Vadher, 2014) and pollution, too.

Except substratum base divisions, the biota of the local environment are producing zonation in between the intertidal vertical line (Hobday, 1995; Sibaja-cordero, 2008). Respectively, the super tidal zone or spray zone occurs nearer to the land mass and the animals living in this zone are exposed to the spray caused by the dashing of the tireless waves, it is covered by water only during the time of storms and is frequently eroded by splashing waves and spray of strong winds. High tide zone or upper mid-littoral zone is high saline area in which volume of water is not high enough to sustain the large amount of flora and fauna. Middle tide zone or lower mid-littoral 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 more extreme. Low tide zone or lower littoral zone is only exposed at the point of low tide and for a longer period of time during extremely low tides. This area is teeming with life; the most notable difference with this sub-region to the other three zones is that there is much more marine vegetation, especially seaweeds along

with a great faunal diversity. Organisms in this zone generally are not well adapted to periods of dryness and extreme temperatures.

Among the all types of intertidal zone, the rocky intertidal zone is most interesting zone because depending on its situation, a rocky shore or coastal bank may be in an exposed or sheltered area. Of all seashore habitats, the sheltered rocky shore are probably the best type to study, having varied large numbers of species and often in great abundance, moreover very easy to access and can be quickly surveyed without any destructive methods and without use of the special underwater gears during low tide. Organisms in this area are able to survive the continual cycle of changing tides which may leave them either high and dry or submerged in water for varying lengths of time, at the respective tide level.

The intertidal zone is most productive zone (Underwood, 2000) of all oceanic divisions, of them rocky shore contributing much more because of it is most diverse and populated area. It not only gives good shelter but also it is very much enriched with organic and biotic components (Phifer-rixey, 2008). Organisms which are present in the area provide more advantageous significance by highly availability of food, sufficient amount of light and temperature, constant reshuffling of nutrients and oxygen by waves, hiding and clinging substrate, well established food chain and web, more suitable and stable ecosystem. Also the organisms on rocky substratum are facing number of challenges like more exposure to sunlight and air, varied time of desiccation and aridness, high salinity during long time low tide, competition for food and space, threat to predation during tide out time, and wave forces (Misra and Kundu, 2005). Before all these challenges and problems, the animal possessing number of adaptation as well tolerance capacity, maintains the enhanced abundance of organism at rocky sea shore.

The rocky intertidal area provide strong and solid substratum for growth of wide variety of flora mainly algae and for attachment of many sessile animals. Sessile animals bound to the rocks are many porifera - sponges, colonial hydrozoans, most of anthozoans like corals and sea anemones, bryozoans, number of sedentary forms of fauna inhabiting the rocky shores are a variety of molluscs like limpets, mussels and oysters, Octopus, conchs, Aplysia, barnacles and tunicates. Also abundant are the hermit crab and other crab species, tubiculous polychaetes and others like *Zoanthus* which live in the crevices of hard rocks. Echinoderms, especially sea urchins and star fishes brittle star are found here, simply term as benthos and divided into micro and macro benthic organism. Macro-benthic organisms of rocky shores are ecologically important and they also function as integrators of ecological processes and disturbance over long time scale (Beuchel, *et al*., 2006). Macro-benthos can act as bio-indicator and can be monitored to assess whether their populations are experiencing ecological change as a result of various anthropogenic activities (Ikomi, *et al*., 2005). Macro fauna form vital links within food webs of marine and coastal environments. The community structure and function of these assemblages are therefore likely indicators of the amount and extent of damage caused by man-made impacts within these ecosystems (Gee and Warwick, 1996). The entire rocky shores are often greatly complicated by variation in rock types, rock slope, aspect, intertidal pools, rock pools, cracks and crevices, bounders, small to large cups and integrated water current. Cracks and crevices provide protection from waves and desiccation and will increase species richness of a shore and the abundance of some species. Rock pools provide relatively sheltered microhabitats at all levels on the shore, and support many organisms such as decline algae which could not survive on the open shore surface. Thus the presence of rock pools increases the species richness of the shore (Bhadja, 2010).

India is endowed with a long sea coast and covers more than 7,516.6 km bordering the mainland and the islands with Bay of Bengal in the East, the Indian Ocean on the South and the Arabian Sea on the West (Lok Sabha Secretariat, 2013; Sanilkumar, *et. al*., 2006). It includes Exclusive Economic Zone of 2.02 million km2 adjoining the continental regions and the offshore island and a very wide range of coastal ecosystem such as estuaries, lagoons, mangroves (Shukla, 2015), backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs which are characterized by unique biotic and abiotic properties and processes (Joshi, 2010). At the western south of the Gujarat state, the Saurashtra coast contributes nearly 985 Km. of the total coast line of Gujarat. The intertidal zone of south Saurashtra is composed of sandy, silt or rocky zones. Among these varieties coastal belt of it has comparatively more rocky substratum. It has evenly spread rocky area of long stretch with tide pools, cracks and crevices forming diverse habitat for benthic communities, and also on the coast distribution of flora and fauna may be effluence by controlling factor like abiotic factor and substratum type (Gohil and Kundu, 2012). Saurashtra coast also enrich by several floral species, varied sedentary or sessile and free-living forms of fauna. Usually such habitat has high density of Anthozoans, Molluscs Arthropods and Echinoderms with their specific zonal distribution. Such distribution pattern is attributed to ecological conditions of Saurashtra coast (Pandya, 2014). This coast is predominantly rocky and sandy coast providing best and widest habitat for these group of animals, which was the reason for their high occurrence (Gohil and Kundu,2013) like some Anthozoans (Dave, 2013; Pandya, 2015; Joshi, 2016) limpet species (Vakani *et al*, 2014) crabs (Trivedi, 2015).

The study area Mangrol coast is located at south west coast of Gujarat in Saurashtra region, in Junagadh district, at latitude 21^0 06’ N and longitude $70^0$05’ E. Mangrol has a long rocky intertidal zone, which characterized by a flat bed of rocks and presence of small to huge tide pools, water

pools, cups and creaks and crevices. Seasonal variation of seaweeds is observed in the intertidal zone. This long and wide calcareous rocky inter-tidal zone and habitat structure is first exposed to the wave action and breaking waves subject intertidal organisms to large hydrodynamic forces (Denny, 1985), affected by the terrestrial environment during the time of low tide, thus it is also exhibited fluctuations in the ecology of inhabiting fauna. Thus, the entire seashore makes suitable environment for the intertidal fauna as well provide proper shelter to the most of molluscan and other fauna. Moreover, Mangrol is one of the important fishing stations of Gujarat. Marine and coastal fauna were abundant at the Mangrol coast because of comparatively less anthropological activities (Bhadaja, 2010, Vaghela, 2010).

Among all varied coastal fauna of the intertidal zone of the Mangrol, we have emphasized more on Molluscan fauna as comparatively this group is quite varied and dense in this area. Molluscs are among the most ancient of animals on earth today, are also among the most successful of all animals, and are second only to Arthropods in numbers of species representation (Joshi, 2007). It has been classified on the bases of their morphological, anatomical and other salient features. Its abundance is higher at the littoral zones of tropical seas. Out of total population, class Gastropods and class Bivalves constitute 98% and they inhabit in marine environment, freshwater and land, except these two classes, and rest all are exclusively marine inhabitant. Morphologically and structurally molluscs are heterogeneous group of animals with different structural form such as Chiton, Limpets, Slugs, Snails, Clams, Octopus and cattle fishes etc. Majority of the molluscs are more famous by their shell; but in some forms the shell is completely absent, secreting mucus like substances viz., *Onchidium* (Rodregiuz and Rigura, 1992). Molluscans are more adaptive group as well large assemblies of animals, occupying the different and all possible habitats on the earth (Rao, 1993). Geographically molluscan occurs in equatorial, temperate, tropical and even in the

Polar Regions. Even though, they occur in all marine habitats, from upper intertidal to various depths of the oceans, in the water column itself, they occupy a wide variety of habitat types and niches. From the ancient time of India, molluscan attract the human kind for food, medicine, ornaments etc. Even though in Vedic times, Ayurveda utilize the group for preparing Shankh bhasma, Praval bhasma like medicines and also for ingredient of medicines. In modern times, molluscan have most consumptive as well productive values. They are mainly used as food all over the world, utilized as raw material of ornaments and jewelry (Gohil and Kundu, 2013), producers of commercially valuable pearls, raw material for lime stone and cement industries, calcium resources in the poultry feed. They are also potential resources of biomedical components and used for manufacturing drugs and shell craft works.

Especially in intertidal zone of marine environment, the rocky seashore is the more specialized area regarding to the faunal diversity and extreme variation in abiotic factors like high fluctuation in temperature, salinity, pH, water quality etc. is very common and regular features. Thus, the biodiversity and community structure are now recognized to be important determinants of ecosystem functioning. Magarran (2010) also stated that measures of species diversity play a central role in ecology and conservation biology as well Beuchel *et al* (2006) indicated for macro-benthic organisms of rocky shores, is that macro-benthic organism of rocky shores are ecologically important and they also function as integrators of ecological processes and disturbance over long time scale. Macro benthic organism can be act as bio-indicator and monitored to assess whether their populations are experiencing ecological change or environmental variations. Cyclically, all the population dynamics and distribution of inter tidal communities could be as result of the local environmental conditions (George, *et al*., 2009) and the composition, abundance and distribution can be influenced by water quality (George, *et al*., 2010). Differences in physical and chemical

processes are the main causes of variation in intertidal communities, both in time and space (Terlizzi, *et al*., 2002). Physicochemical characteristics are indeed vital water quality parameters for monitoring due to their instability, where significant variations in physico-chemical parameters affect the quality of water resources.

The main water quality parameters considered for here are temperature, pH, DO, salinity, calcium hardness, sodium hardness, total hardness etc. Such factors are able to modify zonation pattern on an intertidal zone, especially in rocky sea shore. In the lower intertidal zone, the temperature is similar to that of the sea, but higher up the range and rate of change occurs due to exposure of sunlight. Temperature is therefore a more significant factor for littoral organisms than sub littoral organisms. The salinity in marine ecosystem may be affected by a number of factors and fluctuated by evaporation, heavy rainfall, river flood etc. Dissolved oxygen is the basic physiological requirement for nearly all aquatic biota and for the maintenance of balanced populations. Through the water column concentration of the dissolved oxygen can be vary widely with wave action (Bhadja and Vaghela, 2013), tide level, pattern of wind, time of day and biological activities of organism. Its presence is essential to maintain the higher forms of biological life in the marine aquatic environment.

Different functions of an organism such as locomotion, growth and reproduction, are also influence by the various abiotic factors prevailing at the intertidal zone (Newell, 1976). Reproductive behavior and breeding and courtship behavior is greatly controlled by endogenous factors as well as exogenous environmental factor (Giese, 1959) and hence many times the breeding behavior of the some organisms indicates different modes or patterns in tropical, sub-tropical and temperate environments (Underwood, 2000). With the sequencing, the food and food sources also have been recognized as one of the limiting factors for distribution of organisms in intertidal zone (Mariscal,

1974). Each species being most abundant in certain horizontal stratum of intertidal regime, amongst these molluscs are dominant. Of them, the gastropods are typically in habitants of rocky shores at the intertidal level and as such they are subjected to extreme environmental conditions. This situation allowed one to correlate, in the field, the distribution, the frequency, variations in abundance and biomass, growth, mortality, reproductive periods and pattern, existence of phenotypes in different populations of molluscs with relation to contrasting and changing environmental condition. This has also attracted the scientists to study geographical variations of the population under comparable conditions within the prevailing intertidal zone.

Further, the vertical location of a habitat can be defined by examining its physiography, but it actually reflects the position of the habitat along the environmental gradient and thus the vertical location determines a type of key species and their association in each habitat and microhabitat, or belt in the intertidal zone. Hence, within a given geographical region, the dominance of the intertidal level by certain species indicates prevalence of defined set of the environmental gradient at that level (Patel, 1984).

Such variations in environmental conditions of the different zones of intertidal region promoted us to undertake the present investigation with the aim to study the ecology assessment of molluscs, which is the largest group of intertidal organisms, inhabiting the particular area of Saurashtra coast, Gujarat, Western India. Much of the work had been done concern with marine ecology, environmental problems of the Gulf of Kachchh etc. Some contribution on the ecological aspects of flora and fauna of intertidal zone is on record for few sea-weeds and molluscs from Saurashtra coast. However, most of the work has been carried out around Veraval and Dwarka coast or Gulf of Kachchh and other coastal zones were understudied. To fill the gap of biodiversity data and coastal characteristics of Mangrol coastal zone, this work was planned.

Intertidal zone is the inter phase of all three environmental medium, Lithosphere, Hydrosphere and Atmosphere. Due to its environmental and ecological possessions world of biologist moves toward the most interested realm, subject to fascination (Raffaelli and Hawkins, 1996), it deals with one of the oldest sciences of 17^{th} century – the Ecology. Number of Autecological work of ecology had been done up to 1832 (Vaghela, 2010) but traditional change regarding to the ecology and intertidal zone had only occurred after 1930 (Bensone, 2002). Gislene (1930, 1931) and Colman (1930) first time characterized the physical nature of environment and it's 'Association' (Benson, 2002). Reid (1967) worked on interaction between biotic factors and environment. Effect of abiotic attributes on behavioral and physical adaptation (Newell, 1970) among intertidal area and faunal distribution range proposal to interaction of physical condition was worked out by Branch in 1981. The natural changes show the environmental conditions, and reflect ecological and evolutionary processes. There is an extensive literature relating to spatial patterns such as latitudinal gradients of diversity (Willig *et al*., 2003), species area relationships (Arrhenius, 1921) and range size distributions (Gaston, 1996) while less attention has been paid to temporal patterns of biodiversity (Magurran and Dornelas, 2010).

Intertidal zone is extremely interested area for the most of biological scientist, moreover interrelationship, behavior and communication between living organism and their environment is a vibrant discipline of biological science (Reid, 1967). On the basis of time and space communities at the intertidal zone exhibits more variation in course of biological differentiation as well as physical differentiation (Sousa, 1979, Paine, 1984). The zone is much influence by physical processes viz., wave action (Lewis, 1978) and abiotic factor eg. salinity (Branch, 1976) etc. While

biological processes include organism associations like Predation, competition, settlement etc. (Terlizzi, *et al.,* 2002).

Changing environmental extremities are main characteristics of the intertidal zone which directly deals with distribution of the organism that live in this area (Vakani *et al*., 2014), it may correlate with population dynamics as well reproduction over space and time (Prasad *et al*, 1984). But though extensive attention on the intertidal biodiversity issues may have to required for comparable and meaningful measures (Baran *et. al.,* 2004) and also scarily needed sharp focus (McCabbm, 2000) reason is that functions of ecosystem are in nuclear position for biodiversity and its researches (Tilman, 2000). Days (1998) suggest that intertidal communities are plastic system which constantly changes in special scale as well temporal scale in form of composition and abundance (Menconi *et al*., 1999) of organism.

About 80 % of all marine species occur in the coastal zone (Ray, *et al*., 1999; Arjunan, *et al*., 2010). Now a day biodiversity awareness issues has brought the need for comparable and meaningful measures at many scales into sharp focus (Gray, 1997; McCann, 2000). In particular, factors controlling the biodiversity of an area, and thus ecosystem function, are central to biodiversity research (Tilman, 2000). Generally, it is estimated that diversity is high in benthic coastal areas (Gray, 1997), because of it provides habitat to the living organism. These habitats have important conservation and fundamental values that make them precious of study. In the face of incomplete and uncertain knowledge about the magnitude and location of biodiversity, scientists look for trends or gradients in species richness and patterns of endemism for determine what areas are most in need of protection. Most of ecologist hopes for conservation efforts on species-rich areas or areas with many threatened and endemic species including at the hot spots, they can protect and administrate much of the flora and fauna that are yet to be discovered (Culotta, 1994).

The highest overall diversity occurs in the tropical Indo-Western Pacific region (Reid and Miller, 1989). Within this region, some of the highest levels of marine species richness are found off the coasts of the Philippines, Indonesia and New Guinea. Waters surrounding Polynesia, portions of the Indian Ocean (Wafer, 2011) and the Red Sea, and the Caribbean contain areas with high levels of reef fish diversity. Although marine ecosystems are probably less diverse than terrestrial environments in terms of total numbers of species, marine ecosystems harbour more varied life forms.

In current trend in investigation of biodiversity, molluscans are used (Linse *et al*, 2006) for investigation of marine biodiversity because they are the bio-indicators (Daka *et al*., 2006) for environment, population dynamics and also are the second most diverse animal group. Among them, gastropods and bivalves are most conspicuous members of the macro benthic fauna (Brown and McLachlan, 1990) of intertidal area (Dexter, 1984). Appukuttan (1996) indicated that India has a total heritage of 3271 species of mollusks belonging to 220 families and 591 genera, including about 1900 species of gastropods, and usually they are found in the water where calcium concentration is more (Tonapi, 1980). These molluscans exhibit their role in aquatic food web as well as in aquatic community structure. More over they are the major class of organisms that resides in the intertidal habitat (Esqueda *et al*., 2000) having the capability and ability to accumulate secretions (may be some times toxic) which are used as bio-indicators for the condition of the intertidal zone (Daka *et al*., 2006; Gomez-Ariza *et al*., 2006). Moreover, gastropods vary morphologically in relation to their surroundings. On the same rocky shore, individuals of the same species may have different morphologies as a result of different microhabitats (DeWolf *et al*., 1997; Britton, 1995). Gastropods also help to curb macro algae growth (Guerry, 2008; Thomas *et al*., 2008) and are an essential part of the diet (Fratini *et al*, 2008, Ghasemi, 2011) of many

molluscan and other carnivorous (Castell and Sweatman, 1997; Burkepile, 2007) because of all these reasons gastropods are of the more well-studied organisms in rocky intertidal habitats.

In India, studies on species diversity are very few Hornell, 1927, Gravely, 1941; Satyamurti, 1956; Appukuttan, 1972, 1980, 1989, 1996; Pinn, 1990; Narashima 1993; Sakthivel and Fernando, 2002. Ramesh *et al* (1996) worked on gastropods and bivalves related to coral-reef and recorded 73 species of molluscan, among them 46 gastropod and 27 bivalves were associated with coral-reef in Palk bay, India. On same coast, at Karaichally Island in Gulf of Mannar, distribution and abundance of Molluscan were studied by Jayabhaskaran *et al*. (1996) regarding to Coral related molluscs. Investigation of ecology of intertidal molluscans on same coast was done by Rao and Sundram (1972). Narsimham (1993) described the importance of shell fishes for the benefits of fisheries.

Intertidal zone of Gujarat state till less explored, but some peculiar investigations were made for diversity and distribution viz., Apte recorded 188 molluscan species at Gujarat coast line. Saurashtra coast of Gujarat was investigated by number of biologist, Prasad & Mansuri, 1982; Patel, 1984, Misra & Kundu, 2005; Gohil and Kundu, 2008; Joshi and Kundu, 2007, Bhadja, 2010, Vaghela, 2010; Dave and Mankodi, 2013 ; Trivedi and Vacchrajani, 2015; Pandya & Mankodi 2014; Vadher and Gadhavi, 2014 etc. particularly at the Mangrol coast, work has been done by, Patel, 1984; Patel, 2002, Raghunathan *et al*, 2003; Bhadja, 2010 and Vaghela, 2010. All these studies were more emphasize population ecology and influence on the intertidal zone and its organisms. , Joshi (2007) recorded 56 molluscan spices at the Chorwad coast; same coast was investigated by Vadher *et al* (2014) and recorded 69 molluscan species.

1.1 Aims and Objectives:

The aim of this work to is document coastal characteristics, biodiversity of the study area and population study with reference to environmental conditions of few key species for Mangrol coast of Saurashtra coastline, Gujarat.

The objectives set for of the study are:

- To assess the ecology of the intertidal zone of Mangrol.
- To study physicochemical factors of the littoral zone
- To study the molluscan diversity and distribution pattern.
- To demonstrate population dynamics of key species.

1.2 Flow of thesis:

This thesis embodies the ecology of the littoral zone of Mangrol coast. The documentation is based on classical chapter format. The first chapter comprises of general introduction to the topic of centre, aspects of study site, basic review of literature pertaining to biodiversity, mollusca and population studies. The aim and objectives are listed at the end. The second chapter deals with employed methodology for data acquisition, parametric studies and statistical applications. The results derived from the observations made are represented as tables, graphs, Figures and photographs etc. and duly supported with justifiable discussions. The thesis finally encompasses nut shell summary for ascertain complete coverage of all the aspects. The literature reviewed is documented in the form of bibliography.