SPATIAL AND TEMPORAL VARIATIONS IN POPULATION DYNAMICS OF FEW KEY ROCKY INTERTIDAL MACROFAUNA AT TOURISM INFLUENCED INTERTIDAL SHORELINE

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C E R T I F I C A T E

I have pleasure forwarding this thesis of **Ms. Kavita Joshi** entitled, ―**SPATIAL AND TEMPORAL VARIATIONS IN POPULATION DYNAMICS OF FEW KEY ROCKY INTERTIDAL MACROFAUNA AT TOURISM INFLUENCED INTERTIDAL SHORELINE**", for acceptance of the Degree of **Ph.D.** in **Zoology**.

This thesis contains interpretation of original experimental findings observed by the candidate in the field of Marine Biology and Coastal Ecology.

It is further certified that **Ms. Kavita Joshi** has put in more than five terms of research work in my laboratory.

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CONTENTS

INTRODUCTION

Marine biology is the study of life in the sea. It is, therefore, one of the broadest subdivisions of the natural sciences, for it encompasses all the supplementary disciplines of biology as a whole, merely, restricting the scope of the enquiry to the marine habitat. The marine habitat, together with the plants and animals that occupy the sea, forms part of the entire ecosystem of the earth-so the study of marine life offers a wide-ranging view of life on our planet and the conditions that make such life possible. (Barry fell, 1975).

In terms of marine environment, India has a coastline of about 8000 km, an Exclusive Economic Zone of 2.02 million km^2 adjoining the continental regions and the offshore island and a very wide range of coastal ecosystem such as estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs which are characterized by unique biotic and abiotic properties and processes. The coastal and estuarine habitats have been under tremendous human induced stresses due to their immense economic, recreational and transport services. The population study helps us to understand the regeneration and recruitment patterns of different species and, therefore, is an important conservation tool for sustainable resources. There are 53 coastal districts from the 10 maritime states and 6 union territories including the Andaman Nicobar and Lakshadweep group of island. Nearly 25 percent of the country‘s population resides in these areas. About 340 communities are primarily occupied in marine and coastal fisheries.

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 Indian Ocean region of India includes some of the most diverse and least scientifically known. 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.

For sake of discussions on the coast and its management, it is necessary to distinguish between ‗land-based' and ‗water-based' activities and further classify the land-based activities into coast-dependent, coast-preferring, and coast-independent. Coast-dependent activities are located on the coast because it offers resources that are important to them, such as easily available water, e.g., oil terminals, power plants, ports, fish processing, beach-based reaction, etc. Coast-preferring activities could be located elsewhere but, for various reasons, select the coast as their location, e.g., residential development, and tourism. Coast-independent activities are on the coast for non-specific to the coast, e.g., defense or industry not linked to the coast. Since all three types of activities are now increasingly being located on the coast, the stress on the coast has increased considerably. World's Resources 2000-2001 sound the alarm bell with regard to the state of the state of the world's coastal ecosystems as do various reports of the group of experts on the scientific aspects of marine pollution over the last 20 years (GESAMP, 1990).

Coastal and estuarine systems are among the most threatened by human activities which damage their ecological function and, in particular, their nursery role for many marine species. In this context, the protection these vital ecosystems is a critical issue for the management of fisheries resources. To that aim, functional approaches have to be developed that make it possible to assess habitat suitability and quality. The common sole, *Solea solea* (L.) was selected as an indicator species to identify the features of coastal and estuarine nursery habitats in the Bay of Biscay (France). Coastal and estuarine systems are essential habitats for the renewal of fisheries resources, because they provide nursery grounds for many marine species of the continental shelf (Beck et al., 2001; Able, 2005). Of particular interest are nursery habitats for commercially important flatfishes (Koutsikopoulos et al., 1989; van der Veer et al., 2000). Juvenile growth and survival, hence recruitment into adult populations, are greatly determined by the quality of these nursery habitats (Gibson, 1994; Le Pape et al., 2003a). But over the past decades, these coastal and estuarine nursery grounds are increasingly exposed to anthropogenic impacts (e.g. land reclamation, pollution, eutrophication and introduction of invasive species; Antunes and Santos, 1999; Elliott and Hemingway, 2002; McLusky and Elliott, 2004). This onslaught from human commotion on the coasts is especially perceptible in developing countries with their population increases and population movements towards the coast. Rapid changes are occurring on the African coast of Latin America, from Rio de Janeiro to Sao Paulo in Brazil and along Chilean coasts between Valparaiso and Concepcion, which are becoming large urban areas (Hinrichsen, 1996).

Presently, Indian coastline is facing increasing human pressures e.g., overexploitation of marine resources, dumping if industrial and toxic wastes, oil spills and leaks which have resulted in substantial damage to its ecosystems. The impact of global of global warming-induced sea level rise due to thermal expansion of near-surface ocean water has great significance to India due to its extensive low-lying densely populated coastal zone. Other sectors vulnerable to the climate change include freshwater, industry, agriculture, fisheries, and tourism and human settlements. India has been identified as one amongst 27 countries which are most vulnerable to the impacts of global warming related accelerated sea level rise (UNEP, 1989). The high degree of vulnerability of Indian coasts can be mainly attributes to extensive low-laying coastal area, high population density, frequent occurrence of cyclones and storms, high rate of coastal environmental degradation on account of pollution and non- sustainable development.

Coastal tourism has been seen by many developing countries as the sunshine industry, combining development opportunities with a clean image. Tourism, implies a large-scale movement of leisure-seeking people to a destination –people who have consumption need, both basic and those created by the tourist industry. This consumption, both in terms of quantity and the types of resources it utilizes, and changed relations that it generates in host destination, creates a number of impacts and brings about changes in the social structure of local communities, the norms and standards of the host communities, and the environmental resources that it utilizes (TERI, 2000). Tourism has its own logic as it interacts with local people, institution, and the environment, to alter occupations, landscape, and coastal systems in favors of tourism. It is ‗inherently contradictory in its thrust, for it searches out the untouched and unspoilt only to populate it. With globalization and the rise of the leisure class, both nationally and internationally, tourisms certainly a growth industry. Coastal tourism has, as its central attributes, the triad of sun, sea and sand. Certain seasonality accompanies this form of tourism, given that access to sea and sand is limited in the months of rain. This ‗seasonality' shapes the choices made in the tourism industry.

Society organizes its production and consumption choices depending on the activity that is possible during the period.

Coastal tourism places its own demand on the resources base, especially for fresh drinking water, clean water for swimming, waste disposal sites, vegetation that is attractive to the tourist, and fish. While coastal tourism is highly nature dependent, planners do not realize or sufficiently appreciate this and promote policies that neglect the supporting ecosystem. The societal implications of this phenomenon are serious because tourism can push out other activities, result in change skills of the local population, and affect change in priorities. Coastal ecosystem must be protected not only for the more general functions that they perform in terms of support to human well-being but also because they provide the goods and services required for coast-based activities. The link between population and environment is, how-ever, a non-linear one, and there is need to understand the historical and cultural context to understand the set of social relations that individuals and communities are embedded in when determining the causes of environmental degradation (Aswani, 2002; Gammage et al., 2002; Noronha et al., 2002).

Marine biology covers a great deal, from the microscopic, including plankton and phytoplankton, which can be as small as 0.02 micrometers and are both hugely important as the primary producers of the sea, to the huge cetaceans (whales) which reach up to a reported 33 meters (109 feet) in length. The habitats studied by marine biology include everything from the tiny layers of surface water in which organisms and abiotic items may be trapped in surface tension between the ocean and atmosphere, to the depths of the abyssal trenches, sometimes 10,000 meters or more beneath the surface of the ocean. It studies habitats such as coral reefs, kelp forests, tide pools, muddy, sandy, and rocky bottoms, and the open ocean (pelagic) zone, where solid objects are rare and the surface of the water is the only visible boundary.

The intertidal zone, also known as the littoral zone, in marine aquatic environments is the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide, i.e., the area between tide marks. Organisms in the intertidal zone are adapted to an environment of harsh extremes. Adaptation in the littoral zone is for making use of nutrients supplied in high volume on a regular basis from the sea which is actively moved to the zone by tides. Edges of habitats, in this case land and sea, are themselves often significant ecologies, and the littoral zone is a prime example.

Many intertidal organisms, including *littorina* snails, prevents water loss by having waterproof outer surfaces, pulling completely into their shells, and sealing plate but occupy a home-scar to which they seal the lower edge of their flattened conical shell using a grinding action. They return to this home-scar after each grazing excursion, typically just before emersion. On soft rocks, these scars are quite obvious. Still other organisms, such as the algae *Ulva* and *Porphyra*, are able to rehydrate and recover after periods of severe desiccation. In all probability, the number of species from all groups and all habitats of seas could be of the order of several million but we know only a fraction of that for certain. Even the most recent and most global inventory, the Ocean Biogeographical information system (OBIS), has no more than 40,000 species listed. (Venkataraman, 2005)

Article 7 of the Convention on Biological Diversity directed the identification and monitoring of biodiversity, ecosystems and habitats, species and communities, genomes and genes. In marine, as in terrestrial and freshwater ecosystems, it is well recognized that the biotic and physical attributes of habitats have a major influence on the diversity, distribution, and survival of organisms. Changes in the nature of marine habitats can cause rapid changes in biodiversity composition, including species of commercial interest. Inventory and monitoring of biodiversity are crucial for identifying or clarifying the pressures that impact on ecosystems, the rates at which those pressures are operating, present and likely states of those ecosystems, and the actions or responses needed to mitigate or stop negative pressures. Studies on the distribution and abundance generally sampled through time to detect patterns that could potentially change over short time-scales of days (state of tide, fluctuations in light, temperature, and atmospheric pressure), seasons, years, and decades. Sampling frequency must therefore coincide with whatever variable is being measured. For example, if one is sampling every month, additional sampling should be done within months to demonstrate that variation within a day, between days, and between weeks is less than the variation one is finding among months, seasons, and years; and ideally this procedure should be done at more than one location.

REVIEW OF LITERATURE

The studies on the ecology of the intertidal zones have concerned the consideration of most of the ecologists all over the world, and it has been well predictable that the study of communications and interrelationships between the alive organisms and their environment is a tremendously vigorous and vibrant discipline of science (Reid, 1967). A gradient of environmental situation extends transversely the intertidal zone, due mostly to the intertidal zone, due mainly to the different durations of submergence at each tidal level and therefore sea shore experiences broad and largely volatile variations in temperature, salinity and after defeat (Newell, 1970) which call for a large spectrum, physiological, behavioral adaptations. The 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 communication (Branch, 1976).

Molluscs of the rocky shore reveal ecological succession from high to low water mark, each species being most copious in a convinced horizontal substratum. Amongst these molluscs, the gastropods are characteristically occupant of rocky shores at the intertidal level and as such they are subjected to severe environmental situation (Misra and Kundu, 2005). This circumstances permissible one to correlate, in the field, the division the frequency, variations in abundance and biomass, growth, mortality, reproductive periods and subsistence of phenotypes in different populations of gastropods with relation to complementary and changing environmental conditions (Bacci and Sella, 1970). Intertidal habitats are particularly studied because very different habitats are formed across a shore due to the rise and fall of tides. So, within 10s to 100s of meters, researchers can move from one habitat to another. Animals and plants on intertidal rocky shores have been studied very intensively for the last 30-40 years. The species are generally small, numerous and do not live too long to do experiments (Underwood, 2000). Identification of temporal and spatial scales of variation allows the understanding of the role of these processes (Underwood & Chapman, 1996). Quantifying this variability at different scales is thus a prerequisite to the proposal and test of explanatory models of observed distributional patterns (Underwood, 2000). The spatial patterns in the structure of assemblages on hard substrates have been widely documented from intertidal substrates (e.g. Benedetti-Cecchi, 2001a and references therein). The interaction between biotic and abiotic factors is responsible for the temporal and spatial variability in the species abundance in biological communities (Danielson, 1991). Such changes occur at different scales, along a hierarchy reflecting different processes determining the observed patterns. In the sub tidal, information is still scant and mainly limited to sessile (e.g. Boero & Fresi, 1986) and easily recognizable taxa. Quantitative information on the pattern of distribution of vagile invertebrate assemblages is very poor and limited to few groups. Molluscs have been rarely considered despite their consolidate taxzonomic knowledge and their wide distribution in marine communities. Quantitative information on distribution patterns of molluscan assemblages is mainly focused on soft substrates and coral reefs and derives from studies along Norwegian fjords (Buhl-Mortensen & Hosaeter, T. 1993) and tropical environments (Esqueda et al., 2000). Quantitative studies on molluscan assemblages from hard subtidal substrates are still scant (Milazzo et al., 2000). The main objective of this study is to provide precise information about the composition of Mediterranean molluscan assemblages from hard substrates. The study is also aimed at quantifying possible differences in assemblage structure along a depth gradient and among sites at each of the considered level of the shore. Biodiversity studies now provide abundant evidence that large-scale processes strongly influence both regional, landscape and local diversity at all smaller scales (Ricklefs and Schluter, 1993).

The term ‗biodiversity‘ was introduced in 1986 as a reduction for ―biological diversity” (Takacs, 1996). It ostensive referred to the characteristic of the living world that the new discipline of conservation biology was imaginary to conserve (Sarkar, 2005). With conservation biology, it is interrelated to the group of concepts used to select conservation areas (Sarkar, 2003), in particular, complementarity which will be discussed in some detail later in this note (Sarkar, 2002; Sarkar and Margules, 2002). Ricotta (2005) argues that there is no solitary concept of biodiversity; fairly we must use a put of summary statistics. Mainly conservation biologists seize biodiversity to be a evocative feature of a system. However, biodiversity has sometimes been recognized normality (Callicott et al., 1999; Roebuck and Phifer, 1999) and it has often been imaginary to embody socio-political values (Vermeulen and Koziell, 2002).

In the context of biodiversity and its conservation, we have been using inapt concepts of ecological diversity, inventory-based concepts, referring only to what occur within systems situated at sites, fairly than difference-based concepts; Whittaker (1960) elaborated the applicable distinctions back in 1960. He distinguished is between α-diversity, the diversity inside a site, β-diversity, that between sites, and γ- diversity, or the total diversity of a region, including both α- and β- diversity.

Venkataraman and Wafar, (2005) recorded that a total of 102 species of diatoms belonging to 17 families are known from the east coast, with the largest diversity pertaining to Naviculaceae (21 spp) and Chaetoceraceae and Coscinodiscaceae (11 species each). The dinoflagellate species diversity in the east coast estuaries is relatively small (15 species in 7 families) compared to the west coast estuaries (76 species from 10 families). Marine algae from Indian coasts have been fairly well surveyed since several decades. The latest systematic account (Oza R M et. al., 2000) lists 844 species distributed among 217 genera. The most abundant among them are Rhodophyta (434 species). Followed by Chlorophyta (216 species), Phaeophyta (191 species) and Xanthophyta (3 species). Global estimate of Crustacean species diversity is 150,000 of which 40,000 have been described so far. Of the 2934 species of Crustacea that have been reported (Venkatraman et. al., 1998) so far, marine species (94.85%) contribute maximum to this diversity. In India as many as 139 species of stomatopods, 26 species of lobster and 162 species of hermit crabs have been recorded. Till today, 5070 species of mollusca have been recorded of which, 3370 species are from marine habitats (Subba Rao et. al., 1991, 1998)

Turing now to conservation biology, the field has dissimilar goals at different scales, both geographic and taxonomic, and there is often substantial incongruity about them. However, at larger geographic scales, say beyond 10^3 km^2, it is moderately uncontroversial that a central task of conservation biology, sometimes called arranged conservation planning (Margules and Pressey, 2000; Sarkar, 2004, 2005). There have been many proposed measures of β-diversity (Wilson and Schmida, 1984; Koleff *et al.,* 2003). The one approximately universally used in conservation planning (Justus and Sarkar, 2002) is based on the concept of complementarity. The term ―complementarity" was introduced by Vane-Wright *et al.* (1991). Over the years it has replaced prosperity as the most common measure used to delegate sites for conservation. (Justus and Sarkar

(2000) review the history of the use of complementarity in practical conservation planning until 2000.

The highest overall diversity occurs in the tropical Indo-Western Pacific, a region that includes waters off the coasts of Asia, East Africa, northern Australia, and the Pacific Islands (Reid and Miller, 1989). In the face of uncertain knowledge about the magnitude and location of biodiversity, scientists look for trends or gradients in species richness and patterns of endemism (having a relatively narrow distribution) to determine what areas are most in need of protection. Within this region, some of the highest levels of marine species richness are found off the coasts of the Philippines, Indonesia, and New Guinea. They hope that by focusing conservation efforts on species-rich areas or areas with many threatened and endemic species (hot spots), they can protect much of the flora and fauna that are yet to be discovered. Because only about 7 percent of the oceans have been sampled, the current state of knowledge regarding species distribution and hot spots is poor (Culotta, 1994). Waters surrounding Polynesia, portions of the Indian Ocean and the Red Sea, and the Caribbean contain areas with high levels of reef fish diversity. Coral reef fish make up to one quarter of all known marine fish species (Bryant, 1995).

Of the 1.7 million species cataloged to date, about 250,000 are from marine environments (McAllister, 1995). Although marine ecosystems are probably less diverse than terrestrial environments in terms of total numbers of species, marine ecosystems harbor more varied life forms. Scientists measure this variation in "body architecture" by comparing the range of phyla (major kinds of organisms) found on land and in the sea (Winston, 1998). For example, it is estimated that 32 of the world's 33 animal phyla are found in marine environments-15 exclusively so (Elliott, 1993). The sampling of the deep-sea floor, the least explored region on Earth, has uncovered countless new species. Little is known about the extent of global biodiversity, and even less is known about what species exists in the world's seas. 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 clearest indication of stress in marine populations is evident in the drastically declining stocks of commercial fish species. In 6 of 11 major fishing regions, more than 60 percent of all commercial fish stocks either have been depleted or are being fished to their limits (FAO, 1995). About 25 percent of stocks for which data are available are either depleted or in danger of depletion, while another 44 percent of fish stocks are being fished at their biological limit (Bartley, 1995).

Relatively few attempts to monitor noncommercial marine populations have been carried out globally; as a result, it is difficult to gauge the impact of habitat loss and other human pressures on maritime resources (Culotta, 1994). Because marine species are a part of specific ecosystems, assessing the condition of ecosystems is a useful indicator of threats to species-level diversity. Furthermore, changes in the extent and condition of these habitats are relatively easy to measure; for example, satellite imagery can be used to measure changes in the extent of mangrove area. The decline of critical habitats implies that species dependent on such areas may also be in jeopardy. Although they make up a fraction of the total volume of habitable space available to marine species, coastal ecosystems account for almost one third of all marine biological productivity (the amount of living biomass produced within oceans). Estuarine ecosystems, which include mangroves and sea grass beds, are among the most productive ecosystems of Earth (Costanza et al. 1993). Even though they generally occur in tropical waters where productivity is low, coral reefs contain the highest levels of known diversity among marine species (GBRMPA, 1995).

Coastal and estuarine systems are essential habitats because they provide nursery grounds for many marine species of the continental shelf (Beck et al., 2001; Able, 2005). Of particular interest are nursery habitats for commercially important flatfishes (Koutsikopoulos et al., 1989; van der Veer et al., 2000). Juvenile growth and survival, hence recruitment into adult populations, are greatly determined by the quality of these nursery habitats (Gibson, 1994; Le Pape et al., 2003a). But over the past decades these coastal and estuarine nursery grounds are increasingly exposed to anthropogenic impacts (Antunes and Santos, 1999; Elliott and Hemingway, 2002; McLusky and Elliott, 2004).

Estuaries, mangroves, and other wetlands serve as nursery areas and habitats for significant number of marine species. These habitats are often rich in food, and their shallow waters and vegetation provide shelter from predators. Three fourths of the commercial fish catch in U.S. waters, for example, consists of species dependent on estuaries for part or all of their life cycles (Jennings and Polunin, 1996). No coastal areas include a number of unique habitats, including upwelling and ocean vent communities. Ocean areas with upwelling (regions where nutrient-rich currents come to the surface) are marked by high levels of primary productivity and serve as feeding grounds for many important species. One third of the global marine catch is taken from these areas, including many species that are commercially important. Upwelling, which can shift to new locations, cover about 0.1 percent of the world's ocean surface (Maragos et al., 1996). Ocean vent communities, located around temporary hot springs on the deep-sea floor, are supported by an unusual source of energy. Primary production is based not on photosynthesizing phytoplankton but on bacteria that convert sulfur to energy. Vent communities support tubeworms, sea anemones, mussels, shrimp, and a host of other creatures, many of which appear to be endemic to these ecosystems . Seasonal variability in ocean at mid to high latitudes, the seasonal cycle drives large changes in upper ocean conditions and biological productivity throughout year. Days are shortest, darkest and often stormiest in winter; longest, brightest and often calm in summer. The upper ocean is coldest and least stratified in early spring, warmest and most stratified in early autumn. Inorganic nutrients are often depleted in summer and early autumn. The best growing conditions of the year for most marine organisms are in late spring to early summer, coincident with an annual peak in plankton that occurs while temperature and light are still increasing but before nutrients have become depleted.

Changes in the oceans affect everything from simple processes, to complex processes that might affect biodiversity and the functionining of ecosystems. Changes are also evident at higher trophic levels. (IGBP SCIENCE NO. 5, 2008). Of all marine habitats, coastal ecosystems in general including reefs, mangroves, sea grass beds, and lagoons have been the most heavily affected by human activity. Coastal ecosystems within the highly diverse Indo-Western Pacific region have been severely affected, with likely long-term consequences to marine diversity. For example, 60 to 70 percent of reef areas in Southeast Asia, which straddles the Indo-Western Pacific, were ranked in poor condition in a 1992 assessment conducted by the Australian Institute of Marine Science. Coastal habitats within the Caribbean region, also an area with a high level of biodiversity, are under stress from development, pollution, sedimentation, and dredging (Hinrichsen, 1990). A 1992 U.S. government assessment of Central American coastal areas found that mangrove destruction was a priority issue in five of the seven countries studied. In addition, coastal wetland conversion and degradation were a priority in one country and a significant problem in four others (Foer and Olsen, 1992).

Pillai and Patel (1988) recorded 37 species of hard corals; the Gujarat Environment and education Research Foundation (GEER Foundation) reports 42 hard and 10 soft corals; (Singh et.al., 2006) and the Gujarat's State of Environment Report mentions 44 species of hard corals and 12 species of soft corals. (State of Environment Report; Gujarat; 2005) The age of the reefs varies from 5,240 years at Salaya to about 45,000 years at Okha. Coral colonies grow extremely slowly, at a rate of less than 1 cm to 10 cm every year, growing upwards at a rate varying from a few millimeters to about 3 cm, under amenable conditions.

In general, coral reefs are much less resistant to disturbances (both natural and anthropogenic) than other coastal habitats, and as such, they are particularly vulnerable to a range of human pressures. Coral reefs are located along the coast of 110 tropical countries (WCMC, 1994). In at least 93 of these countries, significant portions of the coral reefs have been degraded or destroyed, primary as a result of pollution; erosion of nearby land areas and subsequent smothering of corals by sediments; mining and dynamiting of corals for building materials; cyanide poisoning (used to stun fish for the aquarium market); and damage from recreational use (WCMC, 1994). Over fishing has affected the coral reef areas bordering at least 80 countries (Jennings and Polunin, 1996). A 1992 assessment of global coral reef condition found that 5 to 10 percent of these habitats have been destroyed. Many coral reef species are important food sources; between 20 and 25 percent of the fish catch in developing countries is taken from coral reef ecosystems (Johnson, 1985). These habitats are unique not only for high numbers of species that seek food and shelter there but also because reefs are the oldest structures in existence created by living creatures, with some approaching 6,000 years in age (Weber, 1993).

Reef biodiversity is highest in the Indo-Western Pacific, which is also thought to have the world's highest overall marine biodiversity. Over half of the world's coral reefs are located within this region. A second reef biodiversity hot spot is located in the tropical Atlantic and includes about 15 percent of the world's total reef area (Jameson et al., 1995b). A study of coral reefs conducted from 1983 to 1991 provides further evidence that these habitats are in trouble. That study found that bleaching occurred within reefs in all tropical oceans of the world during 1983, 1987 and 1991 and that bleaching was correlated with water temperature increases of 1°C or more.

Reefs are created by tiny coral-building animals, which live symbiotically with photosynthesizing algae (the algae provide corals with food and oxygen, and the corals provide nutrients and shelter in exchange). Bleaching occurs when corals expel resident algae in response to stress from pollution, sedimentation, or natural localized warming cycles. Analysis of bleaching patterns in the study suggested that a global pattern of contributed to the bleaching episodes (Bjork et al, 1995). Corals live in waters that are near the upper limit of their temperature tolerance, and so they are especially vulnerable to even small changes in atmospheric temperature resulting from global warming.

The Indian mangroves cover about 4827 km^2, with about 57% of them along the east coast, 23% along the west coast and the remaining 20% in Andaman and Nicobar Island. The mangrove formations are of three types deltaic, backwater-estuarine and insular. The deltaic mangroves occur mainly along the east coast, the backwater-estuarine type along the west coast and the insular in Andaman and Nicobar Islands. (Venkataraman K. and M. Wafar, 2005). Mangroves of India comprise 71 species under 43 genera and 28 families. Of these 65 species are present on the East coast; 38 species on the west coast (Kathiresan, K., and Qasim, S. Z. 2005).

Sponge has an evolutionary history of about 570 million years and so far, 486 species have been described in India (Thomas P A, 1998). In India 212 species of Hydrozoa, 25 species of Scyphozoa, 5 species of Cubozoa and 600 species of Anthozoa have been reported till now. Since all groups of Indian taxonomists, the above figures cannot be taken as final. Except the pioneering works of Annandale (1907, 1915, 1917), Leloup (1934) and Menon (1931) other studies are few and scattered.

The occurrence of live corals along the Saurashtra coast of Gujarat was recorded. Five species of corals, viz, *Gorgonium sp., Polycyathus verrilli, Portis lutea, Tubastrea crater* were recorded from four different places along this coast. A portion of coral patches was randomly scrappeds out from different colonies of each species. The density in terms of numerical abundance of polyp and biomass was expressed per m^2

area of the intertidal zone. All the coral species were identified up to species level by following standard references and published literature (Pillai and Patel, 1988; Allen and Steene, 1999). Raghunathan *et. al.* (2004) reported that the occurrence of live corals on the intertidal region of Dwarka, Veraval, Diu and Mahuva located along the Saurashtra coast. It is also evident that these coelenterate species recorded from Saurashtra coast are commonly found in the Gulf of Kachchh reef environment. The study showed that coral colonies was restricted to rock pools of infra littoral and mid-littoral zone. It enables the species to minimize the desiccation with shorter period of exposure during low tide. The numerical density and biomass of coral polyps were high at Diu. The formation of more coral colonies in this region is significantly correlated with the maximum record of phytoplankton and zooplankton density.

The presence of soft corals and gorgonians was reported by Deshmukhe *et. al.,* (2000). Bhagirathan *et. al.,* (2008) recorded four new species of live octocorals from Veraval waters. The soft corals found were *Litophyton sp.* and *Studeriotes sp.,* the gorgonians were young stage *of Subergorgia suberosa* and *Juncella juncea*. The bottom trawls are designed to tow along the sea floor, on which its operation indiscriminately smashes everything on their way crushing, killing, burying and exposing to predators the benthic fauna. It causes physical and biological damages that are irreversible, extensive and long lasting (Hall, 1999; Kaiser and de Groot, 2000).

Dumping and discharging of pollutants into the sea, oil spills, nutrient and silt-laden runoff from land and rivers, fallout of chemicals carried by the wind from land-based sources and noise from ships and other machinery (which disrupts communication among whales and other species) are some of the major contaminants affecting marine species and ecosystems (Zann, 1994). Contaminant can concentrate in pools, end up on the beach, and cover intertidal rock zones where many organisms live. Oil concentrating in the water after oil spills has been shown to have adverse affects on intertidal communities (Newey 1995). The most immediate effect of high levels of oil on intertidal organisms would be narcosis and the inability of organisms to adhere to there substrate (Newey1995). Roberts (1976) showed that mussels exposed sub-lethal concentrations of oil were able to survive and elute 80-90% after being exposed to clean saltwater. Other organisms such as limpet, periwinkles, topshell, and barnacles do show increased mortality and population declines under increased oil content (Simpson *et. al.,* 1995, Newey and Seed 1995).

Pollution of coastal waters through human activities may drastically alter biodiversity (Thorne-Miller, 1997). Industrial effluents, thermal and fresh water discharges, land reclamation and other anthropogenic effected have caused much damage to coastal diversity all over the world. In the context of the Indian scenario, the large scale destruction of coral reefs in the Gulf of Mannar and Gulf of Kutcchh are well known examples (Qasim *et. al., (*1998), Sen Gupta *et. al.,* (2001). While industrial activities are unavoidable, we are in a situation where we have no clear understanding of the effects that such changes would bring about on the entire ecosystem. Yet another potential threat to coastal biodiversity that looms large is bioinvasion. Introduced species may successfully compete and exclude some local species, may altering the original biodiversity. This has been recently reviewed by Anil *et.al.* The evidence suggests that climate changes affect biodiversity. It is now accepted that the sea is not a permanent buffer, absorbing any amount of climatic or anthropogenic influences. The biodiversity and following ecosystem process can be sternly pretentious for diverse reasons. Numerous concepts and hypotheses that relate to marine biodiversity and ecosystem functioning have now been formulated. However, the validity of these, and their application to dissimilar habitats now have to be examined with care. A assortment of monitoring and experimental tools such as mesocosm manipulation are available to study these effects. Such studies are tremendously imperative if we are to recognize the biodiversity dynamics of our waters prepare prognostic models and formulate policies that will facilitate the sustainable use of the marine ecosystem. (Seshagiri Raghukumar and A.C. Anil, 2003)

Air pollution and runoff and point discharges from the land (and rivers) account for some three fourths of the pollutants entering marine ecosystems. Contaminants affect marine biodiversity in a number of ways. Untreated sewage, oil, heavy metals, and other wastes may be directly toxic to some marine organisms. Their effects may be instantaneous or cumulative. For example, oil has lethal and almost immediate effects on a wide range of marine life-from algae to seabirds- resulting in death through asphyxiation, poisoning, and among mammals and birds, loss of the insulating functions of feathers and fur, causing hypothermia. Eggs and larvae are particularly sensitive to the toxic effects of pollutants, as are organisms living at the ocean surface and on the seabed, where wastes tend to accumulate (Guzman, 1994). Other contaminants such as radioactive waste, pesticides, and other chemicals have cumulative effects, building up within individuals over time, especially within species high on the food chain. Moreover, various contaminants and physical degradation can act together in a cumulative or synergistic fashion.

In marine mud is dominated by deposit feeders. In marine benthos, tentaculate deposit feeding may be the single most important mechanism for both surface and sub surface deposit feeding, including many polychaete families, protobranch bivalve, and many holothurians. Particle collecting by tentacles is widespread and may have important consequences for particle selection (Jumars et al. 1977). The general rule among marine benthic macro invertebrates is a life history of sexual reproduction resulting in larvae that may be dispersed considerable distances before settlement and metamorphosis. Sexes are generally separate. Timing of reproduction usually correlates with seasonal changes in temperature and with lunar cycles, and success of the next generation frequently depends on the availability of food for planktonic larvae (Barnes 1956). The effect of resident infauna on colonizing larvae has been well documented in marine sediment; the adult larvae interactions can be the result of ingestion or burial of the larvae by the adult (Woodin 1976).

Many blooms species produce toxins so-called killer blooms have been linked to die-offs of fish, shellfish, and other species that consume or come into contact with toxic algae or that ingest other consumers of those algae. Human health can also be at risk. A 1987 toxic bloom occurring off the Guatemalan coast, for example, indirectly resulted in the death of 26 people and produced serious illness in 200 other individuals who consumed poisoned seafood (Hughes and Burrows, 1993). Although shall-scale bloom (both toxic and nontoxic) are a naturally occurring phenomenon in most regions, the frequency, magnitude, and toxicity of such events appear to have increased dramatically in recent years (Wilkinson and Buddemeier, 1994). Widespread effects are often noted as a result of sedimentation. Soils eroded from deforested areas and poorly managed agricultural lands often end up at sea, reducing light penetration to sea grass bed, coral, and other communities dependent on the productivity of photo synthesizers living on the sea floor. As sediments settle out, they smother bottom-dwelling organisms and affect filter-feeding species.

In a 1990 report, United Nations marine pollution experts estimated that rivers carry volumes of sediment three times higher than the levels that might be found in undeveloped watersheds, testifying to the magnitude of this problem (UNEP and GESAMP, 1990). Nontoxic solid wastes and marine debris cause significant mortality among marine species. For example, plastic bags, fishing lines, and other debris can entangle seals, seabirds, and other organism, causing slow but sure deaths. Sea turtles and other species, often with fatal consequences, regularly ingest bits of plastic and other man-made materials. Abandoned fishing nets, lobster pots, and other equipment continue to catch fish and other marine creature's years after the gear is discarded or lost (Maragos and Payri, 1997).

A frequently used definition of the coastal zone delimits an area from 200 m below the water level that is the continental shelf, up to 200 m above the water level. The coastal zone comprises only 0.5 % of the volume of the world ocean and 15 % of the world ocean's surface; however, it is critically important for global biogeochemical fluxes. The coastal ocean accounts for about 30% of the oceans primary production, for about 75 – 90 % of the global sink of suspended river load and its associated pollutants, as well as for about 80 % of the global organic matter burial (LOICZ, 1999). About 60% of the world population is living is a stretch less than 60 km from the shoreline; most of the world's largest cities are located at the sea. This area produces food and for a high percentage of the world's population; thus, these areas are exposed to sever pollution and environmental degradation.

A great concern for all countries with a coastline will be to establish ICZM Plans for their coastal space and resources. A major aspect of these activates has to address the man made changes of biogeochemical fluxes from land to sea. An anthropogenic change of biogeochemical element fluxes from land to sea has emerged as one of the leading environmental issues of our time (Howarth et al., 1996). Mclntyre (1968) has reported meiofauna and macro fauna inhabiting the beaches near the Porto Novo on the east coast. Seasonal changes in physico-chemical factors and some biological details of common intertidal populations have been studied at Cochin and Goa beaches (Ansell et.al., 1972; McLusky et. al., 1975). Achuthankutty (1976) studied the sandy beach ecology at Sancolae, Goa. Some of the above workers discussed the physical factors limiting the biological production in the sandy beaches, especially during the monsoon season. Nair (1978) studied the species composition, biomass and available food of the intertidal fauna at Goa and suggested that fluctuation in the production of macro fauna was related to environmental stress and availability of food. Harkantra and Parulekar (1985) studied the ecology of the western coast of India and revealed the presence of 47 macro invertebrates belonging to 32 families.

Fernando (1987) studied the composition and distribution of macro and meiofauna at the marine, gradient and tidal zones in relation to seasons and tide level from the intertidal region of Vellar estuary. Goswami (1992) reported 119 intertidal organisms from Digha coast, West Bengal. Rivonker and Sangodkar (1997) described the benthic production in terms of macrofaunal density, biomass and production along Agatti, Kalpeni and Kavaratti atolls Lakshadweep in relation with physic-chemical parameters.

Macro faunal production of oceans is compared both in terms of community production (total production of all component species) and production to biomass ratios (P: B) of individual species. The biomass of macro fauna is controlled by the amount of organic matter deposited each year and is a function of primary production and depth. In shallower reaches, benthic primary production can be the most important carbon source for the benthos (Strayer and Likens 1986). Deep lakes never have high benthic biomass, while shallow lakes have a wide range of values (Deevey 1941). Similarly the high temperature of tropical lakes reduces the amount of detritus that reaches the bottom and the ratio of benthic to primary production compared to temperate lakes (Morgan et al. 1980). There is a general logarithmic decrease of animal biomass with depth in the ocean (Rowe 1971). In coastal sediments, macro faunal biomass generally falls within 1-16 g dry wt m^{-2} (Mann 1980).

The deep sea floor is also characterized by very low physical energy, very slow sediment accumulation rates and absence of sunlight (Gage and Tyler 1991; Smith and Demopoulos 2003). To the initial surprise of ecologists, deep-sea soft-sediment communities often exhibit very high local species diversity, with 0.25 m^2 of deep-sea mud containing 21-250 macro faunal species (Snelgrove and Smith 2002). Human impacts are occurring, and because of the sensitivity of the deep-sea ecosystem to changes in organic carbon flux, it may be unusually susceptible to global climate change and its cascading effects on oceanic productivity (Hannides and smith 2003). Low and intermediate-level radioactive wastes have also been dumped into the deep-sea (Smith et al. 1988; Thiel et al. 1998). As the human population increased by 1.5-2 billion over the next 20 years (UN [United Nations] 1998), it is likely that increasing pressures will be placed upon the ocean for human waste disposal. Sewage sludge is highly variable in both oxygen demand and the degree of contamination with hydrocarbons and heavy metals. The main potential impacts of sewage sludge disposal are animal burial, clogging of feeding apparatus, increases in turbidity, toxicity from sludge components, and reduction in bottom-water oxygen concentration, and changes in community structure due to organic enrichment (Thiel et al. 1998). In spite of the changes predicted above, deep-sea ecosystems will remain relatively unexpected by human activities in 2025, compared to most of the planet, unprecedented pressure on terrestrial natural resources will have led to significant expansion of human activities in the deep-sea because our knowledge of the deep-sea is so poor. (Adrian G. Glover and Craig R. Smith, 2003)

In the deep sea a shift in emphasis in biodiversity research on macro benthos from the local to the larger scale has become urgent in order to address new observations of biodiversity pattern up to the global scale (Rex et al., 1993; Stuart et al., 2003). High deep sea macro benthic diversity may nit after all is exceptional compared to that of comparable soft-sediment habitats in shallow water (Gray et al., 1997; Gray, 2002).

Meiofauna have evoked considerable interest as potential indicators of anthropogenic perturbation in aquatic ecosystems (Coull and Chandler 1992) as they have several potential advantages over macro fauna, which have traditionally been the component of the benthos examined in pollution monitoring surveys.

The question is what approaches for biodiversity assessment and conservation might prove fruitful? First, complementarily is a central concept for prioritizing areas in systematic conservation planning (Margules & Pressey 2000). It determines the extent to which a new area contributes otherwise unrepresented features (evolutionary characters, species richness and/or restricted range, habitats) to another area or system of areas (Margules & Pressey 2000). Second, following from the above, biodiversity must be disaggregated into its constituent elements, including commonly neglected aspects such as taxonomic distinctness and B-diversity, whose functional role is still unclear. More generally, links between biodiversity and ecosystem services require urgent research attention (Pimm et al. 2001). In the absence of comprehensive assessments, representation of all ecosystems or habitats serves as a proxy for encompassing areas of high species richness and β-diversity. However, different biogeographically regions cannot be compared directly using this approach.

Third, biodiversity needs to be assessed at different spatial scales: point, sample, large area and biogeographical province, the last 3 equating approximately to α, γ and ε diversity as used in earlier literature (Gray 2000). Equally, species-poor systems may need greater conservation effort in order to avoid the loss of essential ecosystem services. Elucidating and prioritizing biodiversity's different facets should help ecologists better define, and organizations better target, high-priority regions for protection (Price, 2002). Various experimental studies confirm these field observations. These have included up shore extensions of species following the creation of artificial run-offs to make the shore wetter (Dayton, 1975) and transplantation experiments where small pieces of rock are chipped off and cemented to the higher shore using cement or resin glues. The latter approach was first used buy Hatton (1938) in France who transplanted barnacle's up shore and showed that younger individuals died quicker than older individuals. Similar experiments have been repeated with barnacles by Foster (1971b). The up shore transplantation protocol has been rightly questioned by Underwood and Denley (1984). Quite subtle sub lethal factors could operate cumulatively towards the upper limits of a species, leading to reduced growth and eventually to death. Connel (1973) quotes a prophetic statement by her : 'On the whole it seems as though the greatest competition has been called into play in the lowest zones, the dry and uncongenial regions of the upper shore being left to the most tolerant forms, which, if left to themselves, are able to growth anywhere on the shore'.

Clear evidence of the importance of biological factors came in a series of classical experiments in which shore organisms were manipulated the field. Experiments by Paine (1969) had considerable international impact, and have since found their way in most general ecology textbooks. The experimental analysis of biologic interactions was made easy because the most dominant species a sessile and permanently attach to the rock surface. Thus, the resource greatest demand on rocky shores is the surface of the rock itself primary space. On a great many shores primary space appears limiting every square centimeter of the rock surface is occupied, especially towards the lower shore levels. This finite resource can only be renewed by the removal or loss of organisms already occupying it through grazing, predation or physical disturbance. This renew process can be easily quantified and the effects of interactions clearly seen.

Connel (1961) studied the zonation of barnacles at Millport on the west coast of Scotland. High on the shore there is a zone *Chthamalus* (called *Chthamalus stellatus* by Connel, this species has sin been split into *Chthamalus stellatus* and *C. mantagui*. Below this species a large faster-growing baarnacle occurs (*Semiba/anus balanoidcs,* then call *Ba/anus balanoides*). Connell found that the larvae of *Chthamalus* could normally settle below their main zone, but when *Chthamalus* we transplanted down shore on rocks they would only survive and grow *Semjmubalanus* were removed. If this was not done, Semibalanus would undercut and crush the *Chthamalus*, excluding them from lower parts the shore by interference competition. Turning his attention to the effects of predation, Connell excluded the dogwhelk *Nucefla la pill* from the lower part of the *Semiba/anus* zone using small, wire mesh cages. This experiment demonstrated that whelk predation normally prevents *Semibalanus* from extending its distribution further down shore, although competition from turf-forming seaweeds and large low-shore species *Fuxus serratus* was also suggested as important and this has subsequently been confirmed (Hawkins, 1983). Simi studies on the high intertidal *Semibalanus glandula* in North America showed that predation by the whelk Thais (now called *Nucella*) *lamellosa* was largely responsible for preventing this barnacle from occupying shore levels (Connell, 1979).

The population diustribution and density of *P. vulgata* in relation to the habitat, affects of wave action and different tidal levels have been studied by Evans (1958), and Southeward (1956). Differences in size of limpets on sheltered and exposed surfaces in relation to wave action have been studied by Southward (1953) whereas in relation to tidal levels has been noticed by Ebling *et al.*, (1962). Distribution and growth studies in keyholke limpet, *Fissurella barbadensis* have been made by Ward (1967). Studies on the population ecology of the limpets *Lottia gigantia* and several species of *Acmaea sp.* Coecisting on an intertidal shore have been carried out by Stimson (1968). Blackmore (1969) has studied the zonal distribution in *P. vulgata*.

Sutherland (1970) has studied the dynamics and energetic of high and low populations of the limpet, *Acmaea scabra*. The relationship between mesolittoral and infralittoral populations of Patella at Mediterranean has been examined by Sella and Bacci, (1971). The niche differences in the intertidal limpets *Acmaea scabra* and *Acmaea digitalis* on the coast of central California have been noticed by Haven (1971). Wallance (1972) discussed the factors affecting the Vertical distribution in the limpet *Acmaea testudinalis*.

Little is known about the distribution and frequency of phenotype and genetic variability of limpets with relation to contrasting and changing environmental conditions, and to geographical variations of the population. The justification for subspecies of the species is found tenuous, as the color variations are numerous and show no constancy with respect to distribution or zonation (Branch, 1975). According to Bacci and Sella (1970), frequency of some characters and phenotypical combinations in *Patella coerulea* are correlated with exposure to wave action or with their apposition in the intertidal zone. Sacchi (1974) have suggested that abiotic factors are related to shell color variation, in particular, to exposure in the case of *Littorina sp.* Pettit, (1973b), suggested that rock color and pattern in association with visual predation are important in the maintenance of certain morph in *Littorina rudius*.

The shell color banding pattern or polymorphism in animals was widely studied during recent years the morphological characters alone have been unsatisfactory in elucidating the polymorphism of a group of a group of animals but also differences in susceptibility to infections have been at the population level even when there are no obvious morphological differences. These lead to the interest in cytological and biochemical characters to establish polymorphism or shell color banding pattern in animals.

Prasad et al. (1984) have studied color banding pattern and their after quinces in a tropical limpet *Cellana radiata* on the Veraval coast of Western India. Malli et al. (1982) made some experiments of the salinity and desiccation tolerances of two limpets *Cellana radiata* and *Siphonaria sipho* of West coast of India.

Going through the literature available on limpet, it is observed that very few studies have been carried out on limpet from Indian Water. Sukumaran and Krishnaswamy (1962) have made some observations on the response of *Cellana radiata* from Madras coast to changes in salinity. Balaparameswara 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. Suryanarayan and Balakrishnan Nair (1976) have studied seasonal variations in biochemical composition of *C. radiata* from south-west coast of India. 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 populatated area at Porbandar, West coast of India. Appukuttan (1977) has documented the fishery of *Trochus* and *Turbo* in the form of shell and meat resources in many part of the world. In India Turbo fishery at Andaman and Nicobar has been described by Rao (1939). Appukuttan (1977) have described the important of *Trochus* and *Turbos* in the shell craft industry. In India, Sarvaiya (1977) has described the distribution of two turbinids, *T. intercostalis* and *T. coronatus* at Okha and nearly islands. Kawalramani and Kadri (1972) and Sarvaiya (1978; 1988) have described the economic importance of *Turbo* sp. From Saurashtra coast as food and craft industry. Similarly, Wells (1981a) have documented commercial *Trochus* fisheries and their status in various countries like New Caledonia, Indonesia, Papua New Guinea, and Australia.

Distribution of gastropod snails in relation to nature of their habitats, availability of food and impact of different physical, environmental and biological factors has been described by several scientists work in on gastropods. From different types of study, it can be concluded that physical factors associated with heights on the shore and periods of emersion during low tide are of many pattern of littoral zonation of groups of species, or as proximate factor causing the upper and or lower limits of distribution of individual species (Underwood and Denley, 1984). The locomotary and clustering (Aggregation) behavior have been studied in different gastropod snails (Patel, 1984). He studied the locomotion rates and shell forms in various gastropods and classified them in various groups showing slow or fast movement. Patel (1984) have studied locomotary behavior in different gastropod snails in relation to tidal rhythm. The littorinids gastropods are ubiquitous in distribution and are found in diverse in intertidal habitats. The population density and size of individual of *Littorina rudis* have been related to the size and availability of crevices (Emson and Faller-Fristsch, 1976) and similar conclusions have been reported for *L. neritocids* (Raffaelli and Huges; 1978).

The snail *Littorina neglecta* is generally restricted in its littoral distribution to the mid and upper zones of the barnacles' belt and a number of factors are thought to operate in restricting the population density at the lower limits.

It has been postulated that a clustering habit is a homoeostatic adaptive mechanism of certain gastropods in tropical waters, to avoid the desiccation. Fisher (1966) added the idea that adhesion to preferable substratum by the snails may also be a factor in clustering behavior. Connel (1961a) noted that dogwhelks *Nucella lepellus* sheltered in crevices during gales on periods of cold water and showed aggregation. On the exposed shores the close relationship between both abundance and size structure of *L. rudis* population and the availabilities of crevices would indicated that these factors, acting singly or in combination are of major importance (Atkinson and Newbury, 1984). The abundance and size characteristics of available crevices may limit numbers in different size groups of mollusks, show influencing local patterns of population structure (Raffaelli and Huges, 1978). In previous studies, the addition of artificial crevices resulted in an eight-fold increase in abundance without any reduction in size specific fecundity in Littorinid Snails (Emson and Faller-Fristsch, 1976*). Littorina nigrolineata* and *Littorina rudis* are found sheltering beneath boulders and their density varies according to the availability of suitable stones beneath which to shelter (Huges, 1980). On the other hand, the gastropod snail *Nucella lapells* is an axceedingly variably species covering a wide range of environmental condition (Ecological niche) to which it's locally adapted. This shows the adaptive capabilities of the snails. While the gastropod *Marula marginalba* are usually in crevices, shallow pools, or in depression at low levels on the shore (Underwood, 1985). Very few species of gastropods such as *Rissoella diaphana Omalogyra atomus* and *Skeneopsis planorbis* are entirely restricted to rocky pools (Emson, 1985).

The difference in physical variables from place to place and time to time will influence the behavior of the interacting organisms, their rates of movement and feeding, and the physiological stresses that might influence the about come of inter-individual encounters (Underwood,1985). According to Underwood (1985), the various influences of the physical environment and complex are generally unpredictable because combinations of physical factors are not linear or simply additive. Denny (1988) suggested that littorinid gastropod snails confirmed to protective microhabitats as they are not capable of withstanding exposure to breaking waves. Menge (1978a) hypothesized that, on exposed shores, wave-stock was restricting the foraging movements of the dog whelks, *Nucell lapillus*, keeping them confined to areas near cracks and crevices, which provided shelter. In littorina *L. acutispira* a high density of snails on exposed shores was related to the protection from wave action afforded by barnacles as opposed to protection from desiccation of high temperatures, while, the Top-shell *Gabbula umbicales* generally inhibits the clumps of mussels (bivalve) and porphyra (Algae) probably because such areas slow to drain and provide protection from wave action and desiccation (Huges, 1980).

The abilities of intertidal gastropod snails to withstand salinities changes are correlated with their level of occurrence on the shore (Young, 1980). The snail *L. rudis* is common in estuaries and other brackish habitats, and it has been shown to be tolerant of a wide range of salinities (Arnold, 1972). This is to be expected in a high shore species which is subject to both concentration and dilatation of sea water at different stages of the tidal cycle and in varying weather condition. Patel (1984) correlated the distribution of two *Cerithium caerleum* and *Clypeomorus moniliferous* from the Saurashtra coast, with their salinities tolerance.

Literature on habitats and distribution of Trouchid and Terbinid gastropods in different countries, and especially in India is very little. The common trochild gastropod, *Gibbula cinenaria* were found beneath the stones inhabitating rocky shore on all Britch coasts (Lewis, 1964). It was restricted to the lower edges of the littoral zone, normally below the level of mean low water neaptides. Trochid and turbinid gastropod snails are mainly restricted to shallow after benthic habitats and are often conspicuous in the intertidal region, where they graze upon detrital film and larger algae (Grange, 1976). Sarvaiya (1977) has described the distribution of two turbinids, *Turbo intercostalis* and *Turbo coronatus* in the rocky intertidal zone at Okha and nearby islands. The influence of reef orientation, degree of exposure to surf, siubstrate type and water depth has been correlated with population density of *Trochus niloticus* (Heslinga Orak and Ngiramengior, 1984). Bour, Loubersae and Rual (1986) have studied biotope of *Trochus niloticus* on Telembia reef (New Calidonia) with the help of Thematic mapping of reefs by processing of simulated SPOT satellite data, and reported inhabitation of these trochid gastropods on colonies of dead coral reefs. However, Hestinga, Orak and Ngiramengior (1984) have never observed *T. niloticus* crawling on or adhering to live corals in nature because of stinging nematocysts present on corals and no growth of filamentous algae on living coral surface. Nayar and Appukuttan (1983) have described the resources of *Trochus nilotichus* and *Turbo marmoratus* in the Andman and Nicobar islands. They have reported the distribution and abundance in the sea around these islands and noticed their distribution at the depth of about 4 to 6 m. on the sea bottom. *Turbo marmoratus* was reported rarely in shallow water and they were more in number only at the depth ranging from 12 to 25 m.

The snails, *Turbo chrysostomus* and *T. argyrostomus* were predominant turbinids inhabitating this reef whereas in the case of *trochids, Trochus pyramids* and *T. lineatus* were the most common sp. These trochids and turbinids were contributed about 96 % of the total population of different animals inhabiting this reef.

Studies on the natural diet are essential for studying population of gastropod mollusks and food resources have been well identified as one of the limiting factors for the distribution of intertidal organisms (Newell, 1976). The distribution and abundance of animals is often correlated with their food, few field experiments have been done to test the validity of such association ship (Mariscal, 1975). It is generally recognized that competition for limited resources of space and food is a wide spread feature influencing the structure of rocky shore communities or at least, modifying the dynamics of some littoral populations (Connell, 1983). In some cases of gastropods the size attained depends on the availability of food (Kiching, 1985). Large *Nucella lapella* with thin shells are found at certain very sheltered sites have abundant food and few of these snails show an indication of thinning of the outer lip.

The abundance and distribution of gastropod mollusks reported in relation to macro algae (Hicks, 1985) indicated that some of them inhibitat at fronds of the algae and on the surface of or within the interstices of complex ramifying holdfasts. The gastropod snail *Littorina littoria* mostly grazes on *Fuxus* sp of algae at lower levels in the intertidal zone (Underwood, 1985). Houbrick (1974) has described the association and distribution of certain cerethiidae gastropod snails in relation of various algae in intertidal zone.

Studies on population dynamics, biomass and growth are very essential in understanding the effects of various factors governing these aspects in different gastropod snails inhabiting the intertidal zone. According to Ramamoorthi and Alagraja (1968) and Patel (1984), the study of growth in any of its different aspects is a problem of great important and comparative study in any group of organisms is a promising field of investigation.

The population densities have been described as one of the factors controlling the growth and biomass in gastropod snails (Prasad, 1984; Patel, 1984). According to Quinno (1988), the growth and biomass of individual gastropods often decline when population densities are high, and thus reduced growth and biomass likely change feature pattern of survival, reproduction or migration.

The shells of many molluscan species have seasonal growth checks (Wilbur and Owen, 1964), and these growth checks have been used to identify the age of individuals in tip-shell *Tegulaa funebralis* by Darby (1964). It was demonstrated the annual nature of visible shell markings in the top-shelkl *Monodonta lineata* and used these to analyze the population are structure. According to Jardine (1985) shell weight is a better weight is a better indicator of age than body weight, which may very seasonally. Observations on the growth rate and longevity of a trochid gastropod, *Trochus niloticus* at the Andaman Island were made by Rao (1939) where he has noted inverse relationship of growth rate and shell diameter, and predicted the life span of this snail to exceed 10 years in the Andaman Island. According to Rao (1939) in *T. niloticus* females grow faster than males and seasons do not seem to have a significant influence on growth. While, Bouchet and Bour (1980) reported the growth of *T. niloticus* attained 12 cm after 10 years at New Calendonia. Sarvaiya (1977) described the growth of two turbinid mollusks, *T. intercostalis* and *T. coronatus* on the bases of their shell size at Okha coast. He noticed the size range of 19 to 35mm in *T. intercostalis* and 18 to 50mm for *T. coronatus.* The distribution, abundance and growth of two turbinid snais, *Turbo chrysostomus* and *T. argyrostomus* inhibiting the Great Barrier Reef (Australia) were described. They observed a close relationship of shall and body weight in above two snails during their growth periods.

The pelagic environment is in a continual state of flux. Seasonal, tidal and diurnal changes influence organisms which correspondingly adapt in a variety of ways. The coastal environment is highly variable in space and time when compared to the open-sea environment. The large number of variables influencing species distribution demonstrates the need for intense sampling to reveal controlling mechanisms in the aquatic environment. Although sampling must be designed to evaluate both spatial and temporal variability, it is common practice to study the seasonal variation of plankton sampling at one time in each season and analysing the data for seasonal trends. However, the densities of organisms may vary from one week to the next, sometimes more than from one season to another. The consequences of this for the interpretation of larger temporal patterns are disastrous (Underwood, 1997).

At the intertidal system, different assemblages of intertidal macrofauna occupy different levels of the intertidal zoners, each species showing preference to a particular zones, each species showing preference to a particular zone or level where conditions are most favorable for its survival and growth (Purchon, 1968). Above and below this zone, that particular species occurs in reduced numbers or is absent, because physical conditions are too difficult for its survival, or because it competes less successfully with other species better suited to that environment (Tait 1968; Maragos *et al.,* 1996). Enormous force is transmitted to the shore by the breaking of waves and the destructive impact of the waves poised hazards to the inhabitants of the shore surface. Therefore, the surface inhabitants have great power of adhesion to resist dislodgement (Newell, 1970). Thus, greatest abundance and widest zone of certain biota was reported at the most sheltered point in the intertidal zone where the wave action was minimum (Scully, 1983). Salinity dependent horizontal and vertical distribution of aquatic invertebrates have been reported by many scientists and reviewed by Kinne (1972). It was also reported that abundance and size characteristics of the available crevices in the intertidal area may limit members of molluscs species and show influencing local pattern of population structure (Connell, 1972).

There are many issues for which it is necessary measure the spatial scale at which assemblages of plants and animals differ. For example, it is not possible to understand what processes regulate populations of organisms until one measure how these populations vary in space and change through time. This information is also extremely important in practical issues, such as the development of marine reserves. One needs to understand how animals are distributed through space and whether these patterns vary through time before one can sensibly suggest how large reserves should be and where they should be placed (Underwood & Chapman, 1998).

The Saurashtra region is of special interest not only to sea weed biologists of India, but also those from abroad due to its diverse marine algal flora. However, such studies for Diu island are meager and fragmentary (Sreenivasa Rao *et al.,* 1980). Seventy species of seaweeds were recorded from this coast. Species area relation (Singh *et al.,* 2002) is important in any kind of floristic study. About 397 seaweeds species have been so far recorded from 3216 km stretch of the west coast (Sahoo *et. al.,*2001)

Saurashtra Coastline (India) 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 of the Saurashtra Coast, their ecological attributes with respect to varying environmental conditions. Except for few works on the ecology of certain limpets (Prasad, 1984), turbinids (Malli, 1983) and some cerithids (Patel, 1984), no report has been available on the macro faunal resources of this region (Misra, 2004). This situation required a systematic overall backup study to be acquainted with their present status.

Hermit crabs need gastropod shells for protection, and one means of acquiring them is by exchange of shells with other crabs (Hazlett 1966). Shells can be limiting resources for crabs (Hazlett 1981). The idea that exchanges of shells occur primarily when both crabs gain in resoures value have been termed negotiations (Hazlett 1978). Before the development of the negotiations idea as an alternative model of resource exchange, an earlier study of Hawaiian species (Hazlett 1970) emphasized the aggressive competitive nature of hermit crab interactions.

A wide variety of shell morphological influences have been found to influence choice e.g. identity (Reese 1963, Young 1979), size (Reese 1963, Vance 1972), weight (Reese 1962), degree of damage (Conover 1978) and epibiosis (Jensen 1970). A variety of environmental factors are also considered to influence shell choice, e. g. shell abundance (Resse 1969), habitat tidal height (Bertness 1982) and latitude (Vermeij

1976). The influence of predation and specialized nature of predators on gastropods increases towards the tropics (Vermeij1976, Zipser and Vermeij 1978). Little more is known of shell use by tropical supralittoral species than the preliminary work of Volker (1967) on *Coenobita scalveola*.

The principal area of recent East African hermit crab studies has focused on populations of *Clibanarius laevimanus* in Kenyan mangrove habitats (Gherardi *et al.,* 1991, 1994, Gherardi and Vannini 1992, 1993). Hermit crabs are an extremely abundant, diverse and sometimes locally dominant component of the intertidal macrobenthos of the Quirimba Archipelago, tropical northern Mozambique (Barnes 1997 a, b). There are at least seven genera and sixteen species of hermit crabs found between the subtidal and supralittoral zones within the archipelago. Two of the three supralittoral hermit crab species at Quirimba Island climb trees, a behavioural trait which may influence and be influenced by shell choice (Barnes 1997b). The shell occupied by hermit crabs, principally those of the supralittoral zone, of Quirimba Island is examined in relation to a number of shell characteristics. The diversity of shell utilized across the shore, subtidal to supralittoral zone, is compared to the number of living gastropod species across the shore. Shell use of the supralittoral zone hermit crabs is compared between the three main habitats encompassed. The shells themselves the environmental characteristics of abundance and availability, and physical characteristics of size, architecture, mass, strength, fit and damage were examined. A total of 42 shell identities were used by the hermit crab sample population on Quirimba Island. No individual shell identity was used by all hermit crab species and no individual hermit crab species used all shell identities. The total number of shell identities used by hermit crabs that study area decreased down the shore from around 20 in the supralittoral and upper shore zones to around 5 by the subtidal zone. In contrast the total number of living gastropods and the source of shells increased downshore from six in the supralittoral zone to 29 by the extreme lower shore zone. The wide intertidal zone surrounding Quirimba Island, Mozambique, is populated by an unusually high diversity of local intertidal gastropods. Partly as a result of the use of such mollusks for food by local human inhabitant (Barnes *et al.,* 1998), the hermit crab populations are only shell restricted at certain sizes.

Crabs exchange gastropod shells when the exchange will result in a gain in shell fit for both individuals, and if the non-initiator would not gain in shell fit no exchange occurred. This pattern predominated in the intraspecific interactions of all species studied. The interspecific shell exchanges fell into two quite distinct catrgories. The intregeneric Calcinus interations were very well predicted by the negotiations model. Calcinus species are dominant over Clibanarius species (Hazlett 1970, Bach *et al.,* 1976, Abrams 1981, 1982a, Bertness 1981). In the latter cases, Clibanarius species rarely initiated interations with individuals of Calcinus, but as noninitiators they exchanged shells only when it resulted in a gain in shell fit.

The hermit crabs, *Petrolistshes edwardsii, P. sanfelipensis* and *Hapalogaster cavicaudu* were first time recorded by Brusca (1972) indicating their range extensions into the waters of Gulf of California while Tirmizi and Siddiqui (1979) collected *Paguristes perspicax* for the first time from waters of Karachi, Pakistan reporting their range up to the Northern Arabian Sea.

The information of fossil records of hermit crabs is limited. The fossil record of *Pagurus convexus* was reported by Whetstone and Collins (1982) from the upper cretaceous Eutaw Formation of Alabana, U.S.A. They identified the fossils of above hermit crab species from other pagurines on the basis of longitudinal arrangement of tubercles on the outer surface of the palm.

Most ecological studies have focused completely on the crab-shell interaction, and relatively little work has been done on the crabs as elements of marine ecosystems (Hazlett, 1981). Hermit crabs have successfully exploited most intertidal environments like estuaries, tide pools, rocky areas of exposed coastline (Scully, 1983). They are almost ubiquitous inhabitants of intertidal and subtidal habitats, and often occur in substantial numbers (Reese, 1969; Scully, 1979). In many of the areas that have been studied there are at least two and as many as four sympatric species (Bollay, 1964; Reese, 1969; Vance, 1972a; Medows and Mitchell, 1973; Grant and Ulmer, 1974; Nyblade, 1974; Ameyaw-Akumfi, 1975; Mitchell, 1975; Bach *et al.,* 1976; Fotheringham, 1976a; Kelong, 1977; Bertness, 1980, 1981a, 1981b, 1981c and 1981d).

The evolution of shell-carrying behavior in hermit crabs has been accompanied by a number of morphological modifications of the basic decapods body plan. Among the most striking modifications and the dextral coiling of the abdomen in adult stage, the reduction of the exoskeleton covering the abdomen, and the reduction of the fourth pair of legs. The decree to which most hermit crabs have evolved adaptations associated with shell use makes them extremely vulnerable when they do not inhabit shells (Scully, 1983). Thus, shell-dwelling hermit crabs have no alternative to shell-use, and gastropod shells are a necessary resource for hermit crabs.

Hermit crabs do not investigate shells in a haphazard manner, but rather show a number of stereotyped behavior patterns that are used in shell selection (Scully, 1983). However, hermit crab's entrance into the shell is a complex series of movements of the abdomen and cephalothorasic appendages (Hazlett, 1981). They actively clean out any debris at the aperture for some minutes and may move around on the shell before attempting their initial entrance into it. Further, the whole sequence of shell manipulation and the insertion of appendages into the shell may be repeated a number of times before the animal either breaks contact with the shell or actually moves from one shell to the other. A final factor that has been shown to influence shell preferences in hermit crabs is the presence of organisms on the shell (Hazlett, 1981; Scully, 1983). The considerable number of animals is associated with hermit crabs, and these can be categorized first by location, either inside the shell or on its exterior surface. Some associations have been described more clearly mutualistic (Ross, 1960; 1971, 1975; Conover, 1976). According to Conover (1976), the hermit crab *Pagurus pollicaris* preferred shells occupied by sea anemone *Calliactis tricolor* or by the hydroid *Hydractiona achinata* while *P. longicarpus* selected shells with *H. achinata*. However, both these crabs rejected shells with barnacle *Balanus amphitrite.*

The use of gastropod shells by hermit crabs is probably single most important factor enabling these animals to exploit the intertidal zone, since the shell serves as a microhabitat reducing environmental stress. Therefore, availability of empty gastropod shells may be a basic limiting factor which influences the hermit crab populations in many ways (Yamaguchi, 1978; Provenzao, 1960; Orians and King, 1964; Vance, 1972b; Radinovsky and Henderson, 1974; Kellong, 1976; Spight, 1977; Taylor, 1978, 1981). In an environment when the gastropod shells are scarce, this limitation leads to reduction in the number of hermit crabs (Reese, 1969; Childress, 1972; Ajmalkhan and Natarajan, 1981). Vance (1972a) and Spight (1977) were able to show changes in hermit crab population density with changes in availability of shells. Experimental addition of empty shells to a reef was found to increase the hermit crab population (Vance, 1972a). Availability of gastropod shells to hermit crab *Pagurus pollicaris* was assessed by determining the numbers of unusable shells occurring in characteristic subtidal habitat and suggested that the availability of shells plays a significant role in limiting abundance of at least the larger hermit crabs (Kellogg, 1976). Spight (1977) reported after his 6-year period studies on *Pagurus granosimanus* that changes in the crab population were highly correlated with shell availability. The populations of *Pagurus longicarpus* differed with respect to the physical characteristics of their habitats and the availability of empty gastropod shells. The first population found in an estuary had few empty shells available in the area while population of rock-cobble area had large number of empty gastropod shell available, indicating differences in their densities (Scully, 1979).

Studies on gastropod shell utilization by adult hermit crabs have demonstrated that the choice of a shell can influence crab survivorship (Reese, 1962; Vance, 1972b). Since empty shells are rare, a shell seeking crab apparently has two options: (1) obtain a shell shortly after snail dies and (2) obtain a shell from another crab by 'attacking' the crab (Bertness, 1981d). As long as there are empty shells in the environment (Scully, 1983), and individual may be expected to spend time investigating shells until a critical numbers of negative experiences (no suitable empty shells) is reached; at this point an individual's motivation to initiate shell fights will increase. When shell 'fighting' was first described (Hazlett, 1966), it as assumed that the message communicated by the magnitude and persistence of the initiator's acts was related to parameters of the initiator's size and aggressiveness. Thus a "defender" vacated its shell in response to information about the resource holding potential (Maynard and Parker, 1976) of the "attacking" crab. However, when an initiating crab's shell was artificially increased in weight (Hazlett, 1970), probability of a successful exchange was increased, a phenomena probably due to alteration of the shell-quality message rather than of a message about initiator's resource-holding potential (Hazlett, 1981).

Hazlett (1978) has suggested that the behavior of the non-initiator is the major determining factor in the shell fighting behavior of hermit crab. But, usually the hermit crab that has initiated the shell fight inserts its chelipeds into the non-initiator's shell and then the animal moves its own shell and the shell of the non-initiator is subjected to a unique set of stimuli (Scully, 1983). Shell fighting in hermit crab is an elaborate behavioral sequence in which one hermit crab apparently tries to induce a second individual to exchange shells, and exchanges of shells generally do not occur unless initiator is larger than the non-initiator (Hazlett, 1966, 1970a). An exchange is mutually beneficial or not depends upon a shell sizes and qualities and the sizes of the crabs occupying them. However, little is known about the effectiveness of shell fighting in bringing about shell exchanges in either competitive or mutuality situations (Bertness, 1982). Shell fights have been viewed as aggressive interactions, with the attacking crab fighting to obtain the shell of the depending crab. The possession of an adequate shell by the attacking crab influence the occurrence of these fights (Hazlett, 1970) and of the consequent exchange of shells (Hazlett, 1970; Vance, 1972a). Hazlett(1970a, 1970b) and Wang (1975) have reported that hermit crabs who are inhabiting inadequate shells are likely to initiate, and win shell fights than crabs who are inhabiting adequate shells. However, Vance (1972b) has reported that shell adequacy does not affect the intensity of shell fighting behavior in *Pagurus hirsutisculus*.

The probability that a fitht will result in a shell exchange is influenced by the relative crab sizes, the defender's molt condition, the defender's shell quality, and the attacker's sex (Hazlett, 1966, 1970; Vance, 1972a; Bertness, 1981c). Field experiments on intersspecfic shell fighting between *Clibanarius virenscens* and *Calcinus latens* (Abrams, 1981b) reported that 5 days in sufficient time to observe shell exchanges.

The result that larger animals are more aggressive is consistent with field observations of *Clibanarius vittatus* and other species, although Reese (1962) reported that small females of *Calcinus laevimanus* appeared to be more aggressive. Bertness (1981d) observed that shell fight occur when an individual encounters a smaller crab inhabiting a shell larger than the one inhabited by the larger animal. The effects of molting on dominance relationships are also significant. Hazlett (1966a, 1970b) reported that hermit crabs that had recently molted were likely to be evicted from their shells. In some species the sex of the interacting individuals may influence the result f shell fights (Abrams, 1981a; Bertness, 1981a). They have reported that sex did not appear to be important in determining shell exchange frequencies in *Clibanarius virescens.*

At least two authors have suggested that shell fighting may be a major component of inters specific competition between hermit crabs (Batch *et al.,* 1976; Bertness, 1981a). On the other hand, a broad survey of shell fighting in several intertidal crab communities (Abrams, 1981a) suggested that exploitative competition is generally more important than shell-fighting determine shall supplies. High frequencies of shell exchanges always seemed to be associated with asymmetric relationships in which one member of the species pair is clearly dominant over the other.

Levins has proposed that the degree of niche overlap between two species can be calculated as the summation of interspecific competition interaction value (α) for all the factors of ecological importance to the species. The hermit crabs, *Clibnarius zebra*, *Calcinus laevimanus* and *Calcinus latens* are intertidal inhabitants and overlap in micro distribution to some extent (Hazlett, 1970), and clearly indicate interspecific agonistic interacting. Amongst those species, *Clibanarius zebra* are at a decided disadvantage in shell fights with sympatric *Cacinus species*, and where population densities are nearly equal, the competition against *Clibanarius zebra* in very strong.

Laboratory and field observations on *Clibanarius antillensis, Calcinus libicens* and *C. tricolor* of Florida Keys indicated dominance of *Clibanarius antillensis* in shell fights, while *Calcinus tibicon* dominated *C. tricolor* (Hazlett and Rittschof, 1976). Winston and Jacobson (1978) reported stronger dominance orders inversely correlated with them frequency of aggressive interactions in *Pagurus longicarpus* during laboratory experiments. While, Hazlett (1979) noticed an aggressive order rather than a dominance hierarchy in *Pagurus pollicaris.* On the other hand, Elwood and Glass (1981) reported that duration of fight increased as the potential benefits is increased in *Pagurus bernhardus*.

The interference and exploitative competition abilities of three tropical hermit crab species, *Clibanarius albidigitus*, *Calcinus obscurus* and *Pagurus sp.* In Panama were documented by Bertness (1981). According to him, within each species males were superior competitors to non-ovigerous females, which were better competitor's females. Further, he was able to demonstrate a linear dominance hierarchy with respect to shell fighting among the hermit crab species indicating overall dominance of Calcinus over *Clibanarius* and *Pagurus* species, and *Clibanarius* over *Pagurus* species.

A number of efforts have been made to reconcile the inferred level of competition with the predictions of hiche theory (Hazlett, 1981). Vance (1972a) attempted to identify the factors that allowed the coexistence of the three species of *Pagurus*. His studies indicated that differences in habitat utilization and, to a lesser extent,

Habitat segregation along a littoral gradient can be seen in almost any assemblage of hermit crbs, in which warmer water *Clibanarius* species tend to occur in the supralittoral zone, Calcinus in the middle littoral, and *Pagurus* and *Pagurisstes* species in the lower intertidal or sublittoral zone (Vance, 1972a; Nyblade, 1974; Bach *et al.,* 1976; Abrams, 1980; Hazlett, 1981). Further, differences between species in substrate preference have been described as physical separation of hermit crab populations (Kellogg, 1977). Similarly, Mitchell (1975) showed that there were several differences in the species of gastropod shells utilized, and there were practically no behavioral interaction between the species. However, the current state of knowledge concerning interspecific competition among hermit crabs indicates that they are similar to other taxonomic groups in that a number of factors allow the continued coexistence of species (Scully, 1983). *Clibanarius* species are frequently found in high intertidal zone at low tide, individuals are often exposed to severe conditions (Hazlett, 1981), and individuals of *C. albidigitus* in shell spoecies whose spirals retain more water survived thermal stress significantly better than individuals in other shell species (Bertness, 1981c).

The studies on desiccation on three species of *Pagurus* (Bollay, 1964) and *Porcellana platychelas* (Kensler, 1967) were carried comparing only their survival time and did not consider weight or water loss. Whereas Herried (1969) reported that *Clibanarius vittatus* could survive up to 35 % weight loss during desiccation. On the other hand, Vernberg (1967) noted that *Pagurus longicarpus* maintained at higher temperature survived elevated temperatures better than animals maintained to lower temperatures. Newell (1970) noted that survival upto 50% water loss in *Clibanarius vittatus* may enable this species at withstand the high environmental temperatures (35° C) of the exposed mud flat during a summer day. The desiccation tolerance of three hermit crab species, *Clibanarius vittatus*, *Pagurus pollicaris* and *P. longicarpus* was determined by Young (1980). According to him, *C. vittatus* was the most tolerant of water loss which survived over $1_{1/2}$ times as long as *P. pollicaris* and almost 4 times as long as *P.*

longicarpus. The tolerance to increased water temperature was determined for coexisting species *Pagurus sammuelis, P. hirsutiasculus*, *P. granosimanus* and *P. hemphillis* (Taylor, 1982), indicating significance in tolerance with an increased acclimation of tempoerature in all species, and the tolerances were corresponded with the intertidal zonation of the species. Warburg and Shuchman (1984) studied the thermala response of ahermit crab *Clibanarius erythrops* and reported a a perference of hermit crabs for lower temperatures (12-17° C) and increase in activity up to 20-30° C which was declined at higher temperatures.

The specimens of *Pagurus bernhardus* were exposed to gradual and abrupt salinity fluctuations and changes in haemolymph osmolality, tissue water content and 0_2 consumption were monitored by Shumway (1978). Under sterady state conditions, there was no significant difference between the rates of 0_2 consumption whereas haemolymph osmolality values followed the same pattern of changes as the external medium. Influence of salinity on behavior and oxygen uptake of *P. bernharus* was studied by Davenport *et al.,* (1980). They reported that *P. bernhardus* retreated into their shells when environmental salinity levels fell to 20.5 – 22.5 % sea water, crabs which had retreated into their shells in water 16.5 % or less showed negligible 0_2 uptake whereas those which had retreated while in full sea water showed substantial 0_2 consumption. Recently, wheatly *et al.,* (1984) studied the effects of temperature and water availability on ion and acid-base balance in haemolymph of the land hermit crab *Coenobites clypeatus*.

The models of Kiester and Statkin (1974) predict that population density will change in food availability, and therefore little partitioning of food niches occurs, even among closely related sympatric species (Hazlett, 1979; 1981). Moreover, even competition is avoided by feeding of hermit crabs at different timings of the day (Ameyaw-Akumfi, 1975).

The differences in responses to salinity and temperature by hermit crabs larvae (Roberts, 1968) contributed significantly to the zonation pattern among *Pagurus* species in the northwest intertidal (Nyblade, 1974), and therefore the physiological differences in the abilities of adult (Young 1979, 1980) to withstand environmental extremes correlated with habitat patterns. Both the impact of an individual on its environment and the environment to which animal is exposed, impart upon its movement patterns (Hazlett, 1981). The temporal pattern of daily movements in intertidal hermit crabs is often strongly affected by the tidal regime (Reese, 1969). Among mobile hermit crabs the extent of daily movement ranges from less than half a metre with return to nomatic movements of several hundred metres per day (Hazlett, 1966, 1981). Rebach (1974) and Hazlett (1975) have reported the migrations of adult hermit crabs in few cases.

Association of different animals with hermit crab species has been described by several authors. A considerable number of animals are found associated with hermit crabs and their gastropod shells (Hazlett, 1981) and which can be categorized first by location either inside the shell or on its exterior surface. The interior associates included Nereid worms, amphipods (Taylor, 1979) and porcellanid crabs (Telford and Dexboeck, 1978). The epifauna associated with the gastropod shell exterior hermit crabs the extent of daily movement ranges from less than half a meter with return to nomadic movements of several hundred meters per day (Hazlett, 1966, 1981). Rebach (1974) and Hazlett (1975) have reported the migrations of adult hermit crabs in few cases.

The structural and seasonal migrations of *Clibanarius vittatuo* have been examined by Fourtheringham (1976) for size related or sexual differences. According to him, larger crabs began to leave the shore in early summer while females stayed until late autumn. On the other hand, the smaller crabs returned to the shore atleast 1 month in advance of the large crab. The estuarine population of *Pagurus longicarpus* exhibited seasonal inshore offshore movements without preferring any direction (Rebach, 1978). The relocation and retesting indicated that directionality was not fixed in this particular hermit crab, and therefore, homing was not involved. Several crustaceans, including hermit crab *Pagurus longicarpus,* are capable of using various types of local environmental features, as well as celestial cues, in their seasonal, short range, inshore-off shore movements. In addition to a sun compass, *P. longicarpous* was capable of using the slope of the substrate and some factor of the tidal influx into an estuary to complete an autumnal migration to the deeper waters of day.

Hermit crabs are found in many symbiotic relatioships ranging from parasitism to mutualism (Ross, 1970, 1979; Ross and Zamponi, 1982; Conover, 1976). Some of the symbionts are beneficial and others are detrimental to the crab's welfare. The epibionts benefit from hermit crabs since the activities of the crab keep available to the setting epifauna the only hard surface around (Hazlett, 1981). At the same time, however, the crabs and the epifauna compete for shells since some kind of epifauna eventually make the shell unusable by hermit crabs. Experimentally removal of epibionts from the legs and shell resulted in increased communication efficiency of a hermit crab augurs marshy during agonistic bouts. On the other hand, studies on presence of epibionts and shell utilization in two sympatric hermit crabs, *Calcinus tibicen* and *Pagurus marshi* did not show preference for a type of epibionts on shells (Hazlett, 1984).

The studies on the ecology of the intertidal zones have attracted the attention of most of the ecologists all over the world, and it has been well recognized that the study of interactions and interrelationships between the living organisms and their environment is an extremely active and dynamic discipline of science (Reid, 1967). A gradient of environmental conditions extends across the intertidal zone, due mainly to the different durations of submergence at each tidal level and therefore sea shore experiences wide and largely unpredictable variations in temperature, salinity and water lose (Newell, 1970) which call for a broad spectrum, physiological, behavioral adaptations. The habitats are diverse but compressed into a small area of intertidal zone where upper limits of distribution are usually determined by physical conditions and lower limits by biological interaction (Branch, 1976).

Molluscs of the rocky shore demonstrate ecological succession from high to low water mark, each species being most abundant in a certain horizontal substratum. Amongst these mollusks, the gastropods are typically inhabitant or 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 existence of phenotypes in different populations of gastropods with relation to contrasting and changing environmental conditions (Bacci and Sella, 1970).

Since, the existing literature on the various aspects of intertidal gastropods is very voluminous, the review of literature is restricted only to the gastropods of the family Turbinidae (Turbinids). However, as literature especially on Turbinids is very scanty, the studies on closely related family Trochiodae (Trochids) is also reviewed. Moreover, work on other gastropods with a view to highlight the important findings, is also considered. Appukuttan (1977) has documented the fishery of *Trochus* and *Turbo* in the form of shell and meat resources in many part of the world. In India Turbo fishery at Andaman and Nicobar has been described by Senta (1933) and Rao (1939). Menon (1976). Appukuttan (1977) have described the important of Trochus and Turbos in the shell craft industry. In India, Sarvaiya (1977) has described the distribution of two turbinids, *T. intercostals* and *T. coronatus* at Okha and nearly islands. Kawalramani and Kadri (1972) and Sarvaiya (1978; 1988) have described the economic importance of *Turbo* sp. from Saurashtra coast as a food and craft industry. Similarly, Wells (1981a) have documented commercial Trochus fisheries and their status in various countries like New Calendonia, Indonesia, Papua New Guinea, Australia, Vanuatu, Fiji, and French Polynesia, Philippines and in the Marshall, Mariana, Caroline and Solomon Island.

The existence and development of fishery of different commercially, important gastropods require studies on various aspects of study, distribution of different gastropods in marine environment is of prime importance as it reflects the availability of gastropod resources. Distribution of gastropod snails in relation to nature of their habitats, availability of food and impact of different physical, environmental and biological factors has been described by several scientists working on gastropods. From different types of study, it can be concluded that physical factors associated with heights on the shore and periods of emersion during low tide are of many pattern of littoral zonation of groups of species, or as proximate factor causing the upper and or lower limits of distribution of individual species (Underwood and Denley, 1984).

The locomotary and clustering (Aggregation) behaviour have been studied in different gastropod snails (Moultan, 1962, Patel, 1984). Linsely (1978a) studied the locomotion rates and shell forms in various gastropods and classified them in various groups showing slow or fast movement. Patel (1984) have studied locomotary behavior in different gastropod snails in relation to tidal rhythm. The littorinids gastropods are ubiquitous in distribution and are found in diverse in intertidals habitates. The population density and size of individual of *Littorina rudis* have been related to the size and availability of crevices (Emson and Faller-Fritsch, 1976) and similar conclusions have been reported for *L. neritocids* (Raffaelli and Huges; 1978).

The abilities of intertidal gastropod snails to withstand salinities changes are correlated with their level of occurrence on the shore (Young, 1980). The snail *L. rudis* is common in estuaries and other brackish habitats, and it has been shown to be tolerant of a wide range of salinities (Arnold, 1972; Parsons, 1972). This is to be expected in a high shore species which is subject to both concentration and dilatation of sea water at different stages of the tidal cycle and in varying weather condition. Patel (1984) correlated the distribution of two *Cerithium caerleum* and *Clypeomorus moniliferous* from the Saurashtra coast, with their salinities tolerance.

The snails, *Turbo chrysostomus* and *T. argyrostomus* were predominant turbinids inhabitating this reef whereas in the case of trochids, *Trochus pyramids* and *T. lineatus* were the most common sps. These trochids and turbinids were contributed about 96 % of the total population of different animals inhabiting this reef. Studies on the natural diet are essential for studying population of gastropod mollusks and food resources have been well identified as one of the limiting factors for the distribution of intertidal organisms (Purchon, 1968; Newell, 1976). The distribution and abundance of animals is often correlated with their food, few field experiments have been done to test the validity of such association ship (Mariscal, 1974). It is generally recognized that competition for limited resources of space and food is a wide spread feature influencing the structure of rocky shore communities or at least, modifying the dynamics of some littoral populations (Connell, 1983; Schoener, 1983). In some cases of gastropods the size attained depends on the availability of food (Kiching, 1985). Large *Nucella lapella* with thin shells are found at certain very sheltered sites have abundant food and few of these snails show an indication of thinning of the outer lip.

The abundance and distribution of gastropod mollusks reported in relation to macro algae (Hicks, 1985) indicated that some of them inhibitat at fronds of the algae and on the surface of or within the interstices of complex ramifying holdfasts. The gastropod snail *Littorina littoria* mostly grazes on Fucus sp. of algae at lower levels in the intertidal zone (Underwood, 1985). Houbrick (1974a) has described the association and distribution of certain cerithiid gastropods snails in relation to distribution of various algae in intertidal zone.

Competition for food resources has been proposed as a mechanism of density regulation for many population of marine littoral gastropods (Branch, 1984), and therefore interspecific competition for micro algal food appeared to have regulatory potential for population of *Littorina plena* (Chow, 1989). Further, from experimental studies made by different scientist it is also clear that variations in the intensity of competetion among mobile grazing gastropods can be predicated from knowledge of the density of the grazers and abundance of food resources (Castenhole, 1961).

Trochus and *Turbos* have been described as browsers and graers on algae (Parchon, 1968). The Diet of Turbo *argyrostomus* and T. *setosus* from Micronesia was analyzed, and reported that they mainly feed on filamentous algae.

Hawkins and Hartnoll (1983) classified *Turbo* and *Trochus* feeding by a light brushing action of their redulae. These snail remained cryptic and inactive in coral crevices for most of the day, emerging to feed from soon after sun set until around mid-night. Thus this snail has a total feeding period of 5 hours in summer.

Williams (1964a) investigated the growth and distribution of *Littorina littoria* on a rocky shore to find out the section of the population responsible for the maintenance of the population as a whole. According to Quayle (1951) and Sutherland (1970), higher shore population in certain gastropods indicated faster growth rate. While Russell Hunter and McMohen (1975) studied the population of the gastropod snails *Lacuna pallidula* and *L. vincta*, where growth was faster among females and so the largest snails tended to be females. Population dynamics, growth and reproductive rates have been studied in a gastropod snails *Littorina nigrolineata* by Huges (1980). He observed significant lower growth rates during December to March in the above snails. However, he noticed summer hatchlings growing to a large size than winter hatchling. Similarly, seasonal growth was observed in the snail *Gibbula cineraria* by Jardine (1985) where it occurred between Arial and October, dominating 70mm size group in winter. The difference in the growth pattern of this snail at two sites could be due to either later settlement or slower growth rates on the lower shore. Chow (1989) studied the abundance and standing biomass of a gastropod snail *Littorina plena*, which showed seasonally, and year-to-year growth variations on exposed rocky shores along Northern California coast. These variations were the result of density independent physical factors such as desiccation, wave action and near shore current.

The breeding behavior of the same organism in tropical, subtropical and temperate environments indicates different modes of patterns, as it is generally controlled by endogenous and exogenous environmental factors (Loosan off and Devis 1952, Giese, 1959). The reproductive behaviour in gastropod snails, *Thais lamallasa* was studied by Spight (1974) , where he observed aggregation on snails in small breeding groups. While differences in reproductive behavior were reported between higher shore level and lower shore level gastropod snails by Sutherland (1970). According Jardine (1985) the top-shell Gibbula cinerira in more elevated sites also reached a larger sized and produced larger gonads than those lower down shore. Presumably the larger gonad size of animal of higher site is indicative of greater fecundity.

Seasonility of breeding in the population of different gastropod snails have been reported. According to Grahm (1975) there is a good evidence for seasonality for breeding in snail *Littorina littoria*. Both diurnal and longer time scale fluctuations in spawn output were noticed by him in the same snail. In the case of *Littorina nigrolineata* a continuous breeding with a peak in June was noticed by Huges (1980). The cerithiid gastropod snails *Cerithium cearulum* and *Clypeomorus moniliferous* indicated seasonal variations in their reproductive behavior (Patel, 1984).

Very few studies have been carried out regarding reproductive behaviour of trochid and terbinid gastropod snails. Rao (1937) and Nayar and Appukuttan (1983) reported separate sexes in turbinid snails *Turbo marmabratus*, and noticed spawning during or immediately after the winter season, March-June. The turbinid *Lunella smargda* was observed to spawn at the end of summer when the sea temperate at its maximum (Grange, 1976), and have short spawning seasons of two months. In the same species studies on spawning, fertilization and developmental larval stages were made by Grange (1976). The population recruitment by settlement of planktonic larvae plays an important role in abundance of marine organisms which occupy habitats. Embroys from unstable substrata are reported to significantly larger than those stable ones. Further, in case of *L. rudis*, larger embryos many occur in 'Bolder' population or 'Crevice' population (Huges and Roberts, 1980a). In the case of top-shell *T. niloticus* inhibiting coral reef planktonic larvae apparently settle on the outer reef flat, and juvenile migrate to the reef margin and deeper as they increase in size and age. Thus, from the review of literature, it is revealed that practically very few studies have been done on economically important *Trochus* and *Turbinid* gastropod snails.

In this line, a landmark study on the ecological status of few gastropod molluscs on the South Saurashtra coastline was carried out by Misra (2004) from the very Laboratory.

This study provides in-deapth knowledge about coast characteristics, macrofaunal diversity, macro and micro spatial and temporal variations in the population dynamics of few key species of South Saurashtra coastline. (Misra and Kundu, 2005).

AIMS AND OBJECTIVES

In view of the aforementioned understanding the subject, the aims of the study was to study and prepare a comparative database of the intertidal macro fauna and evaluate the present ecological status of the intertidal area affected by tourism, by measuring population dynamics of few key molluscan and hermit crab species, of the Somnath and Diu coasts, Western coast of India.

Keeping in mind the aforesaid aim, following objectives have been set forth:

- To study the overall coast characteristics of the intertidal habitats at the selected site.
- To study the intertidal assemblage and biological nature of the intertidal areas around the research sites based on the classical vertical zonation.
- To study and prepare a present-day checklist of the intertidal macro fauna of the selected coastline in order to provide a base line data base of the coastal intertidal macro fauna of these coasts.
- To identify the type and degree of tourism related anthropogenic activities and their mode of action in the coastal area under study.
- To estimate the spatial and temporal variations in the population ecology of seven molluscan and two arthropod species of that area in order to understand the present ecological status of the coastline under study in terms of space and time.

HYPOTHESES TESTED

Hypotheses tested in this proposed work were made in Null form and are as follows:

No.	Hypothesis
1	No significant spatial variations will be visible in the general macro faunal diversity between the coastlines of Diu and Somanth.
2	No significant temporal variations will be visible in the general macro faunal diversity between the coastlines of Diu and Somanth.
3	There will be no significant spatial variations in the population density or abundance between the coastlines of Diu and Somanth.
4	There will be no significant temporal variations in the population density or abundance between the coastlines of Diu and Somanth.
5	Spatial distribution of the intertidal organisms will not be responsive against the pressure made on the system by tourism related human activities.

MATERIALS AND METHODS

1. STUDY AREAS:

India has a vast coastline of approximately 7,500 km along the Arabian Sea in the west and the Bay of Bengal in the east. It is a great significance to our country, a nation with an enormous and unique coast line of two oceans, a couple of Gulfs and a bay. Gujarat shares the lion portion of coastline covering around 1600 Km. long shore. Saurashtra region under Kathiawar peninsula occupies a total stretch of 865 Km (Map-1).

The whole Saurashtra coast was surveyed extensively to monitor the coast characteristics, from both physical and biological point of view. Prior to conducting a quantitative survey to macro fauna at station Diu and Somnath, a reconnaissance survey was done to demark the sampling sites. Degree of human interference was the prime object of the pilot visits. After a prolonged survey, these area on the Southern Saurashtra coast was selected namely the Union territory of Diu (20° 42′ N, 71° 01′ E) **(Map-2)** and Somnath (20° 53‘N 70° 24‘E) **(Map-3).** This location was demarcated as two stations for the further reference. The main reason behind the selection was the difference exists between the Somanth and Diu, which were quite high in spite of their same geographical and geological attributes but different level of interferences with the human community. Somnath is a biggest religious place and on other hand Diu is biggest tourist place. It would give a clear indication of the impact of anthropogenic pressure on the marine system keeping all the physico-chemical parameters constant. That‘s why these two stations were selected for the present study. As said earlier, the two locations are not remote to each other, the abiotic parameters; those determine their biological counterpart in the aquatic community does not differ to a considerable level.

Two shores of the Union Territory of Diu (20 ° 42 ′ N, 71° 01′ E) and one of the biggest Hindu religious place Somnath (20° 53‘N, 70° 24‘E) were selected along the South Saurashtra coastline of Arabian Sea for the present investigations. Diu is devoid of any sorts of pollution. And on other hand the population is less, culturally at a bit better position and lack of any industries aggravate the feeble economic condition of the local population. The local community mainly depend on the tourism related opportunities rather than trying their luck in fishing or any other business that claims a lot of financial investment. On the other hand Somnath is located in the Prabhas Kshetra near Veraval on the south-west coast of Saurashtra at the mouth of the river Hiranya or Hiran. It is one of the famous religious and tourist places of Gujarat and India as this is the place of one of the 12 shivalingas of god Shiva. Somnath has a nearly straight coastline revealing a vivid manifestation of marine Aeolian and fluvial process that have resulted in a number of important geomorphic land-forms, such as the near shore zone characterized by formation of recent alluvium deposits, sand-bars, mud-flats and mangrove swamps, oyster beds and sand dunes. The sea floor off Somnath is represented by uneven rocky patches, flat rocky bottom and sandy sea-bed. People of this region depend mostly on fishing and industries. Somnath is on sea shore and many tourists' visits the sea shore along with the temple and most of the industries depend on sea resources i.e. imitation jewelry and the raw material for other artificial decorative hand made products are obtained mostly from sea bed. The most of the industrial wastes and worshipping offerings are dumped in sea shore which is one of the sources of pollution caused by human interference. Sea water receives a huge lump sum of waste products which mostly are hazardous to sea flora and fauna. All these together offer a better environment on the shore. So, the only demarkable point was the human interference to the system and that's why. These two stations were selected.

1.1. The Sampling Sites:

Once the stations were selected, the next step was to select the ‗sampling sites' for the regular surveys. The selection was based broadly on the accessibility of the sites for monthly study. The most important parameter was to find out the locations where the industrial outlets were opening. Another factor that was taken into consideration was the continuity of the substratum. Availability of faunal members and vegetation also played as a factor.

The Diu and Somnath sites were selected on the basis of accessibility to the sites and which are highly hampered by tourism. Keeping this in mind and after an extensive survey of the whole two stations viz. Diu and Somnath were selected.

Somnath sampling site started in the Somnath Triveni and extended up to Vidia. The entire area of the Somnath coastline was divided into three micro sampling sites (A, B and C). The entire site was 2 km long with 20 to 25 m exposed zone. This is the most unproductive site compare to Diu station studied. The site A and B is predominantly sandy with occasional rocky patches distributed at the upper littoral zone only. The rocky portion consists of very sharp edged rocks with large pools. The main problem at this site is that it gets exposed during tides of some definite force. The usual low tide leaves the rocky portion under thick sand mat. At those times, it became totally impossible to trace out any rocky portion. Site C is much rich in flora and fauna compare to other sites.

In Diu station, Jalandhar coast was divided into two sampling site viz. A & B. A was just near the Curcit house. The site A was 1.5 km long with 25 to 40 m wide exposed zone. The site offers a good habitat for the rocky intertidal mollusks. That was the reason behind selecting this micro site. However, the site A has quite a good number of pools and sand patches that sometimes hampered sampling. Another site B was selected as they were closest accessible portion available from the Khukri, a memory about the war in 1971 between India and Pakistan.

Nagoa intertidal region (west of the Nagoa beach) is the second sampling area of Diu station (Plate 1B). Nagoa was divided into two sampling sites viz A and B. Site A was 1 km long with 20 to 25 m. wide exposed zone. The site is rich of flora and fauna it is best known as a tourist resort. The sampling site B is about 0.5 km. long stretch and the spray zone is restricted to high rocks. The area gets exposed about 30 meters offshore during low tide. It is also rich in vegetation and macro faunal diversity. In the pools of rocky beach, the middle zone was absolutely flat. However, the lower zone consists of big boulders. The biggest problem at this site is the high tearing force of water that hampers the vegetation to get stuck into the rocky substratum to that zone.

The common thing in the sites at both the stations was their locations were approachable during all the seasons at the lower tides and the continuity of the intertidal belt was high. In Somnath the rocky portion consists of extremely jagged edged rocks with big pools. The upper littoral and middle littoral zone is somewhat rocky-sandy which is well represented different species of macro fauna. The lower littoral zone was rocky and almost devoid of animals. In this station upper littoral zone and middle littoral zone were gets more exposed as compare to lower littoral zone. At Diu, the upper littoral zone sharply ends up at spray zone. As the rocks are vertical with no slope, so the continuation of spray zone is prominent. But this is not the condition that prevail the entire coast, even at the two site of Diu. So though broadly the intertidal zone of this area is marked as three or four zones, it cannot be distributed into not more than two zones as such if observed from water table and faunal distribution.

1.2. Time Span

The present study was conducted from September 2007 to November 2009. To begin with, the reconnaissance surveys were made in the month of September 2007 onwards. Within few months survey was completed and sampling sites were fixed. After that regular monthly visit to the study sites were commenced and continued for about a year. During this time the intertidal macro faunal diversity was studied. However, the population ecological data were collected from the month of September, 2008. The span of the month wise data collection for population ecology was done from September 2008 to August 2009. The data were collected from the month of August, 2009 After that, till November 2009, visits were made to the sites at an interval of two months with a purpose of generating a data on the available algal species and collection of organisms for association studies and the quadrate data obtained was matched with that of the previous year, thus to check the accuracy of the study. The months were summed up to four seasons viz., winter, summer, monsoon, and post monsoon (September to November).

During the study, all seven micro sites were frequently surveyed at regular intervals during the lowest tides. All intertidal macro fauna observed were recorded properly, identified and classified systematically and a checklist was prepared initially which was verified and confirmed by Zoological Survey of India (ZSI), and other authenticated museums worldwide (through their websites) and by different bulletin boards and online forums in the internet.

2. ZONATION

The intertidal portion of the Arabian sea of this part doesn't show any significant slope while exposed during the lower tides. So, vertical Zonation on these rocks is not possible to mark. Only the upper literal zone could be clearly marked. However, due to same exposure duration, the middle and the lower littoral zones harbored similar type of biota. In the present study, zone wise distribution of the faunal community was not studied. There were certain factors that appeared as major obstruction for this, first, the discontinuity of the intertidal belt. The belt was so irregular broken quite often by seaward rains that except on the upper and the middle zone at a few sites, longitudinal survey was impossible. So the zone wise distribution study ended up with the complete data of only upper littoral zone were the middle and lower littoral zone was presented with an incomplete one. Secondly the pools at the middle littoral zone were too deep to offer any substratum to survey inside these. Again as the bottom part of these pools were open to the sea, so regular thrust of upcoming tidal water made it impossible to survey these. In that case, the zone wise study at middle littoral zone showed a result that reflected quite a different scenario of the area. Thirdly, as mentioned earlier the lower littoral zone ended up with sharp decline to the sub tidal zone and that is too very irregular. So a complete survey at the lower littoral zone was impossible at all the sites except two out of six. Overall, it was the nature of the intertidal zone, which was mainly responsible for exclusion of the idea of studying zone wise distribution patterns of the animals.

3. THE SELECTION OF KEY SPECIES

The key species were selected on the basis of their occurrence in the study area. As these were found to be the most prominent one and their presence throughout the season would ensure the supply of the specimens for laboratory studies, these organisms were selected. More to that, as they were reported to be non migrant (Inter coast), so long selection of these would ensure a long term study on the same aspect. As the study area was purely a rocky one, so filter feeders and other such organisms those are usually selected were not taken into consideration to work with on this belt. A close look to the animals shows that the organisms were selected from all the three zones. So, a detailed study on these could reflect the ecological status of the three zones. For population ecological studies four species of mollusks were selected i.e. *Cellena radiata, Onchidium verruculatum, Cerithium caeruleum,* and *Tibia insulaechorab* were selected in Diu station. While on the other hand in Somnath five species of mollusks i.e. *Onchidium verruculatum, Mancinella bufo, Rhinoclavis sinensis, Conus miliaris, Cerithium caeruleum* and two species of arthropod i.e. *Clibanarius nathi* and *Clibanarius zebra* were selected.

4. SAMPLING METHODS FOLLOWED

4.1. For macrofaunal diversity studies*:*

Prior to conducting a quantitative survey to macro fauna at each sampling site, a reconnaissance survey was done to select the suitable sites to work at. At the first phase of study, survey sites were divided into seven micro sampling locations as mentioned earlier. These sites were surveyed regularly and the organisms encountered were recorded. Extensive photography was employed for the identification of the animal species with the identification keys, literature available in the form of book, journals reports and with extensive use of internet. The complete study was conducted in a ***non-destructive manner in which the organisms were disturbed to the bare minimum, let alone killing any***. Once the organisms were identified, during the successive surveys just the record of the encounter was made. No further collection was done for this purpose. However, whenever any new specimens were encountered, they were photographed and those photos were sent to Zoological survey of India for identification. At all the sites samples were collected from South to North direction along the coast of Arabian Ocean. During the study, all the seven micro sites were frequently surveyed at regular intervals during the lowest tides. As stated earlier, all intertidal macro fauna observed were recorded properly, identified and classified systematically and a checklist was prepared initially which was verified and confirmed by Zoological Survey of India (ZSI), and other authenticated museums worldwide (through their websites) and by different bulletin boards and online forums in the internet.

4.2. Algal diversity:

Intertidal algal diversity was done in a similar fashion like the intertidal macrofauna. Extensive photographic method was employed. However, few algal samples collected during the repeated quadrates study was collected and stored immediately in 10% formalin. They were then brought to the laboratory and washed repeatedly in running tap water. They were then subjected for temporary herbarium preparation.

4.3. For Population Dynamics Studies

4.3.1 Transect

The structural attributes of the intertidal fauna were studied by transect method (Misra, 1968). Belt and foot transect methods were used for generating the data on this study. The main problem in using any other method like belt transect as that all these methods would come out with the result of avoiding a major proportion of the area. The greatest advantage of foot transect method was that it took the maximum available ground into consideration. Quadrate size was determined from the species area curve tried at Diu. Though, Diu has quite a uniform platform and transect method could be used, but lack of man power was a problem to adopt that method. The method used at two stations, i.e., at Somnath and Diu needed to be one and the same.

4.3.2. Movement for sampling

At all the sites, criss-cross direction was followed to cover the maximum exposed area on the intertidal belt. The visits were made at the lowest tides of the months. Sampling used to be started with the start of the low tide and attempts were made to finish seven sites within the stipulated duration of about 4 hours.

4.3.3 Quadrat size and number

Quadrates of 0.25 m^2 were laid while following an oblique direction covering maximum area at almost regular occurrence. Quadrat frequency was determined on the basis of the total length of the sampling site. The classical littoral zone wise belt transect method was not employed since it has been found that the substratum did not encourage the method. At all the seven micro sites of Somnath and Diu, ten quadrats were laid.

5. POPULATION DYNAMICS

Among the attributes, monthly variations in the population density, abundance and frequency of major species in each sampling site were calculated (Misra, 1968). In the present communication, an attempt was made to measure the variation in the population in response to change in seasons and stations. The dominant animals selected for community ecology study showed a very restricted habitat selection along the intertidal belt. That‘s why the total abundance values were taken into consideration (Misra, 1968).

$$\textbf{1. Density} = \frac{\text{Total number of individuals recorded from all the sample plots.}}{\text{Total number of sample plots studied}}$$

$$\textbf{2.Abundance} = \frac{\text{Total number of individuals recorded.}}{\text{Total number of sample plots where the individuals occurred}}$$

$$\textbf{3.Frequency(\%)} = \frac{\text{Number of plots where a species occurred} \quad X \quad 100}{\text{Total number of sample plots where the individuals occurred}}$$

6. TOURISM RELATED ACTIVITIES

All sampling sites of Diu and Somnath were frequently visited in each month for different objectives of the study. During these visits, tourism related human activities were noted by observing the people accumulated in those areas and their activities towards the coastal area as a whole and to the intertidal population of flora and fauna in particular. Since the proper protocol for scientificaly quantification of these human activities was not available, survey observation method was employed to study this parameter as par Misra (2004).

7. COMPUTATION AND STATISTICS

The obtained data were subjected to various statistical tests for the overall acceptability. Besides the general descriptive statistics, more specialized tests for specific purposes were used. The main aim of investigating the population dynamics was to find out whether there was any significant difference in the population of the selected marker species. This was used just as an indicator parameter to monitor the intertidal health on the Southern Saurashtra Coastline. As the result dealt with data of one complete year of two sites and several sampling sites simultaneously, Analysis of Variance (ANOVA) was supposed to be the most handy statistical kit to utilize for judging the difference in the population dynamics at the two station. In the present work therefore, ANOVA was employed to analyze the temporal variations of each species within all micro spatial sampling sites of each station. In order to check the variations of population dynamics indices for each species between the two stations, Paired t-test was employed. As the study area was divided into two stations and the duration into monthly, so it was must to calculate the common statistical parameters. All the statistical parameters were calculated as per Sokal and Rohlf (1969) with the help of POPTOOLS and Microsoft Office Excel 2007 software to maintain the accuracy of the calculation.

RESULTS

The results of the present study show that the rocky intertidal zone of the Somnath and Diu coastline is rich in coast macro fauna and seaweeds. The intertidal belt of Saurashtra coast is totally rocky fashioned of Milliolite rocks except some interruption of sand patches where ever the so called spray zone is sandy. The intertidal opening is generally very narrow measuring about 8 to10 m. however; at some places the opening is about 2m even at the lowest tide of the month. The rocky surface is very much jagged edged with abundant pools and puddles. The clear cut differentiation of the different littoral zonation is not always possible as the slope of the intertidal belt is very less. The upper littoral zone is formed of smooth rocks with many narrow creeks and pools facilitating its dwellers to move along with the upcoming tidal water. The middle littoral and lower littoral zones shares almost one and the same features from the point of view of the types of substratum and existing biotic composition. The faunal composition at the middle and the lower littoral zones do not vary so much with the seasons as the two zones remains submerged for most of the time and contain a very good number of pools and puddles, thus holding water for longer period The lower littoral zone suddenly ends to the sub tidal zone, thus making the migration of the animals from the sub tidal to intertidal zone almost impracticable Inter-faunal competition is quite high as available livable spaces at the different zones are very less. The belt is generally harbored by hard shelled mollusks and hermit crabs. Soft mollusks and crabs are less at convinced areas.

1. THE COAST CHARACTERISTICS

For the present study, seven sampling sites covering two stations Somnath and Diu were selected. The sea-floor off Somnath is represented by irregular rocky patches, flat rocky bottom and sandy sea-bed, the near shore zone characterized by the formation of recent alluvium deposits, sand-bars, mud-flats and mangrove swamps on the other hand Jalandhar and Nagoa were discontinuously sandy and rocky the reason behind this mainly erosion of parent rocks. However, Porbandar shore line constitutes the Porbandar stone and northern belt of Indian coastline is submerged intertidal rocks. While the submerged intertidal rocks of Saurashtra shoreline are Calcareous sand stone. Sites of Diu and Somanth station consist of calcareous stone. Gujarat having the largest coastline in India (1650 km.) has a mostly steeply declined tidal flat that makes it difficult to access the lower littoral zone the sand portion of the coastline mainly consists of lime and shells. Several line ridges are found in the rocks of Diu which are Meleolite and Latarite respectively. Diu is quite undisturbed due to inaccessibility at the rocky portion of the shore line. Substratum of the Somnath contains many pools and cut by numerous creeks allowing the limpets to settle down at their habitat scars.

2. THE VERTICAL ZONATION

The common thing in the sites at both stations was their locations were approachable during all the seasons at the lower tides and the continuity of the on intertidal belt was high. At the Somnath is predominantly sandy-rocky patches distributed at the upper littoral and middle zone. Spray zone is predominantly sandy and merged in upper littoral zone. The rocky portion consists of very sharp edged rocks with slope and large pools. At the Diu station rocks are vertical with no slope, so the existence of spray zone is prominent. But this is not the condition that prevail the entire coast, even at the two sites of Diu. So though broadly the intertidal zone of this area is marked as three or four zones, it cannot be distributed into not more than two zones as such if observed from water table and faunal distribution. An overview of the sampling sites is briefed here.

2.1. Somnath

The sampling site is about 2 km long stretch and the spray zone is long. The rest of intertidal zone is very rocky and irregular patches with much number of pools, which gets exposed about 20 to 25 meters offshore during low tide. The study area comprised rocky out crop, flat rocky sea-bed and sandy patches. Rocky portion consists of very sharp edged rocks **(Plate-2).** The lower littoral zone was rocky and almost devoid of animals except a mollusks, annelids and coelenterates.

2.2. Jalandhar

Jalandhar is a rocky beach positioned at the Southern part of small island Diu. The spray zone is restricted to vertical boulders standing high from the rocky, sandy upper littoral zone. The rest of intertidal zone is totally flat, which gets exposed up to 25 meters and is sharply cut off from the sub tidal zone making the tidal activity very strong **(Plate-5).**

2.3. Nagoa

Nagoa enclosed shallow sandy portion with very limited tidal activity of it is best known as a tourist resort. Each sampling sites were about 1.5 km long stretch and the spray zone is restricted to high rocks which harbors *C. radiata.* Other limpets and juveniles of *T. cornatus* were also found. The gets exposed about 20 meters offshore during low tide. It is also rich in vegetation and macro faunal diversity **(Plate-3).**

3. FAUNAL CHARACTERISTICS

The intertidal macro fauna attribute of the study areas proved to be quite a healthy one. A good number of the different types of molluscan species of the rocky intertidal belt recorded in India were found here. Beside the annual individual, some seasonal species were also found during the extensive survey of the two stations Somnath and Diu. Few non- mollusks species were also recorded. Among the molluscan individuals, some were very prominent and used to show very prominent at different locations. Nine species of this type have been selected as key macro faunal species to measure the overall condition of the shore that is described. Other dominant species were *Nerita albicina, Nerita undata, Monodonta austalis, Trochus hanleyanus, Turbo intercoastalis, T. cornatus etc.* Distribution of the animals varies site wise as well as station wise mainly due to the pattern of the intertidal substratum offered to them. In fact, in each sampling sites, the substratum condition and exposure area were different than other. Thus, the space available for movement and shelter differs markedly with the change of the location. The other most important factor that regulates the distribution is the physical parameters that are external to the system from the biological point of view. One such factor is the tidal force which varies so significantly with the locations that this has become one of the key controlling factors for the spatial distribution of intertidal macro fauna. Monthly survey along the intertidal belt at the lowest tide was done and all the faunal individuals that were encountered were recorded. Detailed description of these sites is briefed herewith.

3.1. Sampling site 1: Somnath

Somnath is a one of the biggest Hindu religious place. The site started at Triveni and extended up to Vidia. The sampling site is about 2 km long stretch and the spray zone is long. These sites are patches of sand and calcareous eruptions. The whole intertidal belt is interspersed with many tide pools, puddles, crevices and small channels and supports a wide verity of flora and fauna that have adopted them in the intertidal environment through evolution. Substratum of the upper zone is forms of sands with numerous patches of stones, *Cellena radiata* and *Rhinoclavis sinensis* is the dominating fauna of this zone. Upper littoral zone is much rocky with lots of sandy patches, in this zone soft body molluscs *Onchidium verruculatum,* annelids and crab species are most abundant. Upper littoral zone is most unproductive zone compare to remaining zones at this site. The intertidal belt covers greater area then that of other places on the Saurashtra coast. *Cerithium caeruleum* and *Tibia sp.* are found more in middle and lower littoral zones. Common shore crabs are also found in upper and middle littoral zone. The vegetation is good in the pools of the middle littoral zone. The lower littoral zone is dominated by the blue green algae. The algal distribution in the all three littoral zones of this site was that the middle littoral zone obtains the best habitat condition followed by lower littoral zone .

3.2. Sampling site 2: Jalandhar

Jalandhar is a rocky beach positioned at the Southern part of the small island Diu. The spray zone is restricted to the vertical boulders standing high from the rocky sandy upper littoral zone. The rest of intertidal zone is totally flat, which gets exposed up to 30 meters and is piercingly cut off from the sub tidal zone making the tidal activity very strong. The area is fully covered by thick seaweeds and harbors comparatively good number and variety of animals. Probably the low desiccation rate and abundant marine algae favors the animals in this region. *Astrea semicostata* is the species that competes with the *Trochus* at this site. The vertical upper littoral zone, better to be termed as the spray zone, is uniformly covered by small sized *cellena radiata* and juveniles of *cerithium caeruleum* and *turbo* were found only at one end of the sampling site. The site has a big fissure right at its centre, allowing the sea water to flow through most of the portion continuously. The vegetation is good in the pools of the middle and lower littoral zone. *Cladophora facicularis* was found in most upper and lower littoral zone.

3.3. Sampling site 3: Nagoa

Nagoa beach is second sampling site of Diu station. It is best known as a tourist resort. The sampling site is about 1.5 km long stretch and the spray zone is restricted to high rocks which harbors *Cellena radiata*. Other limpets and juveniles of *T. cornatus* were also found. The area gets exposed about 20 meter of shore during low tide. It is also rich in vegetation and macro faunal diversity. The middle littoral zone of this sampling site was a place apparently suitable for so many species as there was virtually no difference between the middle and lower littoral zone. *Mancinella bufo* is that competes most toughly with *Turbo intercoastalis* for food and shelter. The Zoanthus population is quite good here. The region is also profusely populated by hermit crabs. In the pools of rocky beach, sea anemones were found. The middle zone was absolutely flat. However, the lower zone consists of big boulders usually covered with *Zooanthus.* At the middle littoral zone, *Ulva* species is the most abundant flora with very little patches. *S.swarzii* was most abundant in middle littoral zone. The biggest problem at this area is the high tearing force of water hampers the vegetation to get stuck into the rocky substratum to that zone.

4. MACROFAUNAL DIVERSITY OF THE INTERTIDAL BELT

The result of the present investigation shows that the rocky intertidal zone of the Diu and Somnath is rich in macro fauna and seaweeds'. Before starting the qualitative survey to meet the objectives of present studies, the intertidal zones have been surveyed and all the species that were occurring along the entire intertidal have been recorded during each month. In all three sampling sites, about 127 species of macro fauna and 36 species of Algae were recorded. The phylum wise distribution of various species recorded at the three sampling sites is given in the table. A ‗+' or ‗- ‗sign against a species in the table indicates presence or absence (not seen till the time of reporting) respectively of that species at the particular sampling site. It has been observed that the major macro faunal population of this zone belongs to phylum coelenterate, Arthropod, Molluscs and Poritera with dominating species like *sea Anemones*, *Zooanthus* etc.

4.1. Sponge

A variety of sponges about 8 species recorded during the entire study period (**Table 1**). Among them, only two were readily identified in the sampling site and were of encrusting types forming flat patches of colorful mats on the rocks, rest were sent to Zoological Society of India, Kolkata for identification. However, large isolated and colonies of upright sponge were also found mostly in lower littoral zones at different sampling site sponge population was too relatively less.

4.2. Coelenterata

In the case of coelenterate few species were recorded in the entire study site. It appears that members of this phylum represented all the sampling sites. It has been found that the discrepancy in species was maximum in lower littoral zone and minimum in upper littoral zone. Among all 9 species of Corals and 6 species of other than coral, which has been recorded during study time, only *Zooanthus* was present in upper littoral zone further its ideal habitat in middle and lower littoral zones. These animals were present in large colonies forming patches on the rocky substratum but not present in sandy potion of the intertidal zone. While, the other species of this phylum like *Sea Anemone*, Brain Coral *Meanrdina, Favia* and other corals were totally absent in upper littoral zone. They were present in middle and lower littoral zone and during the winter months of December and January, occurrence of the number of species in the intertidal belt was low **(Table 2).**

4.3. Platyhalminthes

Among this species of *Ctenophora* and 2 species of *Platyhelminthus* were recorded. Only one species of *Planaria* was recorded in middle littoral zone only during September, November and December. However, it was not all seen in upper and lower littoral zones during the entire study period. It was observed that they live in shallow water and rarely seen in the open **(Table 3).**

4.4. Annelids

Two species of *Nimrtea* and 8 species of phylum Annelida have been recorded during study time. *Naris* was present in sandy portion of the intertidal during September to December. *Sabella sp.* was recorded in middle littoral zone during September and November. Another species *Surpula* was found to be attached with rock and covered with bivalve shell. This animal was present in middle and lower littoral zone, but not encountered with during the winter months of December and January. In both zones, another Annelida *Eurythoe sp*. was also found. This animal was present in upper littoral zone during October and November but not recorded in both zones during December and January **(Table 4).**

4.5. Arthropoda

In all the sampling sites 14 species of Arthropoda have been recorded. The species diversity showed more or less similar pattern at upper littoral and middle littoral zones, and least species diversity observed al lower littoral zone. The barnacle *Balanus* was present in middle and lower littoral zones, was totally absent in lower littoral zone and not seen during December and January. Four species of crabs were recorded in the entire intertidal zones. Among crabs, one species of sand crab *Hippa* was present in sandy portion while, Hermit crabs were present in deserted shell of gastropod mollusks in lower littoral zone. Another two species of crabs was present in crevices at all three zones **(Table 5).**

4.6. Molluscs

Member of the phylum were more numerous than any other phylum or faunal group in the area of study. The group was represented by about 55 species. Among them *Chiton, Cellena, Turbo, Trochus, Nerita* and *littorina* were recorded in upper littoral zone, while , in middle littoral all species were present except *Aplysia* and *Octopus* which were present in lower littoral zone. *Littorina* was present only in spray zone. The lower littoral zone was dominated by *Murex, Baucus, Cyprea* followed by *Aplysia* and *Octopus* during November to January. *Pinktada* was recorded in middle littoral zone during month August only **(Table 6).**

4.7. Echinodermata

Among the phylum Echinodermata, four species have been recorded during the entire study period. The members of this phylum were totally absent in upper littoral zone but abundantly occurred in middle and lower littoral zones. Among them, two species of starfish, one species of Sea Cucumber and species of Brittle star were identified. However, the species diversity of this phylum was comparatively less **(Table 7).**

4.8. Chordata

Three species of Hemichordata and 9 species of Chordata were also observed during the study time. *Balanoglosus, Hadmania* and two species of mullate fish, *Mugil jerdoni, M. Punctata* were also seen along with mudskipper gobies *Boleophthalmas dentatus* and *Periophthalmus dipes* **(Table 8).**

5. INTERTIDAL ASSEMBLAGE:

5.1. Marine algae

The entire intertidal study area has been first thoroughly surveyed to get an idea of the coast characteristics and to make a qualitative assessment of intertidal algae. Throughout the period of the study, seventeen species of Chlorophyceae, five species of Pheophyceae and fourteen species of Rhodophyceae have been recorded, making it a total 36 species observed in the present study. This list shows the mare presence of a species only in the intertidal zone, irrespective of their number and growth. From the above it is clear that the members of Rhodophyceae may be dominating the seaweed flora of this coast. While, number of species belonging to Chlorophycea and Pheophyceae were almost equal. Predominance of Rhodophyceae is a characteristic feature of lower littoral zone.

5.1.1. Chlorophyceae

The present investigation shows that Chlorophyceae, the species maximum diversity was found in lower littoral zone followed by middle littoral zone but minimum in upper littoral zone. For the duration of the winter months of December and January the number of species was found to be high **(Table 9).**

5.1.2. Pheophyceae

The present study showed that very clearly that species diversity was fewer in the post monsoon months August to November but the diversity was highest in December and January winter season in middle and lower littoral zones. It is interesting to note these groups of seaweed in upper littoral zone at the study site were totally absence throughout the year **(Table 10).**

5.1.3. Rhodophyceae

Rhodophyceae showed more or less similar trend like Pheophyceae. The species diversity was low during August to November while, highest was observed during

December and January at the lower littoral zone. This group of seaweed was also totally absent in upper littoral zone at the study site **(Table 11).**

6. POPULATION ECOLOGICAL STUDIES

The animals used for the detailed ecological study at the two stations were selected based on their majority in number, their availability throughout the year, habitat preference covering all the three littoral zones of the rocky intertidal base and to draw s baseline comparison with the time span. The animals were identified at the Zoological Survey of India, Kolkata and the taxonomic details are furnished herewith.

Phylum: Mollusca
- **Class:** Gastropoda
  - **Order:** Archeogastropoda
    - **Family:** Patllidae
      - *Cellena radiata*
  - **Order:** Mesogastropoda
    - **Family:** Cerithidae
      - *Cerethium caeruleum* (Sowerby)
      - *Rhinoclavis sinensis* (Gmelin)
    - **Family:** Strombidae
      - *Tibia insulaechorab*
    - **Family:** Muricidae
      - *Mancinella bufo* (Linnaeus)
    - **Family:** Terebridae
      - *Conus miliaris* (Hwass)
  - **Order:** Systellommatophora
    - **Family:** Siphonariidae
      - *Onchidium verruculatum* (Cuvier)

Phylum: Arthropoda
- **Class:** Malacostraca
  - **Order:** Decapoda :
    - **Family:** Diogenidae
      - *Clibanarius nathi*
      - *Clibanarius zebra*

6.1. Cellena radiata

Description: commonly known as the ridged limpet and its famous for shell colours **(Plate-7).** Found to settle on the walls of the pools and crevices. It is normally very sluggish in nature. Move with the upcoming wave and a true grazer. Fertilization is always external

Occurrence: Found around the globe. Recorded from North coast, Oceania, Japan, Western Australia, Indonesia, Papua New Guinea, New Caledonia, Loyally Island, Solomon Island, Fiji, Tonga, Marquises and Indian subcontinent.
Habitat: this species preferred exposed rocks usually with smoother edge. Found exclusively on the upper littoral zone and spray zone.
Status: Most dominant species on the intertidal belt of Saurashtra coastline. Usually the most common limpet of the Indian subcontinent is the Patella vulgate and *Cellena radiata*, and is spread over the rocky base of the Arabian Sea and Indian Ocean.
Use: Not used in India for any industrial purpose. In China the main use of this is the human consumption. However, export of this species is currently on from the West coast of India.

6.2. *Mancinella bufo*

Description: Shell broad, conical in shape, strongly rainged spot on the shell surface, foot opening wider, thus needs sufficient opening to the settle. Species found here are herbivores. Fertilization is external **(Plate-10).**
Occurrence: Distribution along the Indian Ocean and Arabian Sea.
Habitat: The small to medium size folds and opening of the intertidal belt found in all the three littoral zones. It is predominant species of middle and lower littoral zones.
Status: Stable in distribution. But pressure from the local people and fisherman affect its distribution.
Use: Used as food in some pockets of South Saurashtra coastline. This species is also used in craft industries.

6.3. *Rhinoclavis sinensis*
Description: The shell is narrow, conical shape, strongly raised spotted ridges on the shell, surface foot opening is narrow, thus, can attach itself within a very small area **(Plate-13a).** Prefer pools and walls of the crevices where water accumulates for a longer duration. Fertilization is external.
Occurrence: Mainly found in Indian subcontinent, Japan and other South-East Asian countries.
Habitat: Prefer semi exposed condition. Found on the middle littoral zones.

Status: High and near uniform distribution in Somnath. However, reported from the entire Saurashtra coast.

Use: Mainly used in craft industries.

6.4. *Conus miliaris*

Description: Shell moderately light to heavy in weight. Body whorl with convex side, sculptured with nodules spiral ribs at the base, smooth or weakly grooved above. Shoulder rounded to angulated, coronate. Spire low to medium height, straight or convex in outline; whorl coronate, with spiral grooves. Aperture is generally wider at base. Background color white, with poorly defined spiral bands of pink, grey, white or fawn, overlaid with spiral lines of alternating brown and white **(Plate-11).**

Occurrence: Indo-West Pacific and in Eastern Australia. Animal in nature goes up to 43 mm in length.

Habitat: Intertidal, down to about 10m, feeding on worms. Animal common in the tropics, abundance generally shows a decreasing trend to the end of range.

Status: Stable in distribution. But pressure from the local people and fisher man affects its distribution.

Use: Used as food particle in huge amount in Diu. Also used in craft and ceramic industry.

6.5. Cerethium caeruleum

Description: this is cerethidae is equipped with a very hard, thick shell, foot opening is very small, thus it can attach itself within a very small area. The surface of the shell is very uneven, with strongly raised small and large tubercles prefer polls of the crevices where water accumulates for a longer duration. Fertilization is always external **(Plate-15a).**

Occurrence: Mainly in the Indian subcontinent, Japan and Indonesia.

Habitat: found in the clay surface, prefer semi exposed condition. Found on the upper and lower littoral zones.

Status: this species is very common on Diu coast. However, reported from the entire Saurashtra coast. This species is reported to be comparatively less sensitive to seasonal changes. Quite uniform distribution along the sites around Diu was observed.

Use: Used largely shell in craft.

6.6. Tibia insulaechorab

Description: This is strombidea family is equipped a very hard, thick shell. Dark brown color 4-5 teeth on flayer lip, long siphon, and short straight siphon canal with elegant lines. Fertilization is always external. This species is primary consumers (Plate-13b).

Occurrence: Mainly in Indian Ocean, Andaman and Nicobar island, Malaysia, and Indonesia.

Habitat: Found in rocky, sandy and in the clay surface, prefer semi exposed condition. Found on the middle and lower littoral zones.

Status: Stable in distribution. But pressure from the local people and fisher man affects its distribution.

Use: Commercial use for decoration.

6.7. Onchidium verruculatum

Distribution: The *Onchidium* are shell-less slug-like marine mollusks. They range in size from 10-70mm long. They are usually oval in shape with a hard leathery mantle which ranges from smooth. This species have gill-like papillae scattered over the back and in other species there are eye-like sensory structures on the back. It opens through a pore alongside the posterior opening anus, below the mantle **(Plate-9).**

Occurrence: Mainly in Arabian Sea, red sea, Japan, Andaman and Nicobar island, Indonesia. Australia.

Habitat: *Onchidium* live intertidally, often in sheltered estuaries on rocks, mud, and in mangrove swamps. They are also found on limestone cliffs with wide raised intertidal limestone platform. Found on the upper and middle littoral zone.

Status: Stable in distribution. But pressure from the local people and fisher man affects its distribution.

Use: Use as food for local community and Commercial use.

6.8. ***Clibanarius nathi***

Description: The Hermit crab lives in a very hard, thick molluscan shell. The surface of the shell is very uneven, with strongly raised small and large tubercles **(Plate-25).** Prefer pools and walls of the crevices where water accumulates for a longer duration. Fertilization is always external.

Occurrence: Mainly in the Indian subcontinent, Japan, Indonesia.

Habitat: Rock dweller, but reported to be found in the clayey surface. Prefer semi exposed condition. Found on the upper and middle littoral zones. Usually found in cluster.

Status : Very common in Diu, however, reported from the entire Saurashtra coast. It is comparatively less sensitive to seasonal changes, and quite firm distribution along the study sites.

Use: Used largely as food materials and shells in craft.

6.9. ***Clibanarius zebra***

Description: It is the other species of Hermit crab lives in the molluscan shell for protection from the predators and atmosphere. Legs opening is wider, thus needs sufficient opening to settle **(Plate-24).**

Occurrence: Distributed along the Indian Ocean and Arabian Sea.

Habitat: The small to moderate sized folds and openings of the rocks in the intertidal belt. Found in all the three littoral zones, mainly in upper and middle littoral zones.

Status: Unstable in distribution. Pressure from the local people and fisher man affects its distribution.

Use: Used as food particle in Diu, also used in local handicraft industries.

7. POPULATION ECOLOGY OF KEY SPECIES

In the present investigation selected sampling sites of Somnath and Diu stations were frequently surveyed at regular interval during the lowest tide at day time. During these frequent surveys, intertidal macro fauna recorded systematically classified and checklist was prepared. It was apparent from the checklist that nine species belonging to phylum's Molluscs and Arthropods dominate the selected sites. For population ecological studies four species of mollusks were selected i.e. *Cellena radiata, Onchidium verruculatum, Cerithium caeruleum,* and *Tibia insulaechorab* were selected in Diu station. While on the other hand in Somnath station five species of mollusks i.e. *Onchidium verruculatum, Mancinella bufo, Rhinoclavis sinensis, Conus miliaris, Cerithium caeruleum* and two species of Arthropod i.e. *Clibanarius nathi* and *Clibanarius zebra* were selected. Therefore, for the ecological studies faunal attributes like Density, Abundance and Frequency of these dominant species were measured.

7.1. Cellena radiata

The C*ellena radiata* maintained its presents in both Jalandhar and Nagoa coastline throughout the year. The year wise density, abundance and frequency values in all the sampling sites in Jalandher and Nagoa sites are given in **Figure. 3 and 15** respectively for micro spatial variations therein.

7.1.1. Density

In the Nagoa sampling site, the density value of *Cellena radiata* was high in winter and decreased in pre summer months (February and march), steady during the summer months (April and May) and again increased during the monsoon season (July and August), and post monsoon seasons. The *Cellena radiata* in Nagoa coastline has showed variations on three littoral zones. The species density was high in upper littoral zone during the post monsoon and winter seasons **(Fig. 15a).** The density values were comparatively low in lower littoral zone than upper littoral zone. In lower littoral zone high density value was during in post monsoon and summer months.

The second sampling site was Jalandhar. In the Jalandhar coastline presents more or less similar trend was observed during winter and pre-summer months. High density values were observed in post-monsoon months in upper littoral zone. The density values were comparatively low in lower littoral and middle littoral zone. In middle littoral zone high density values were observed in monsoon and post-monsoon seasons. In lower littoral zone high density values were observed in summer (May) month. As usual the upper littoral zone contents the maximum density of species, with more or less similar density values throughout the year **(Fig. 3a).**

7.1.2. Abundance

In Nagoa sampling site, the abundance values of *Cellena radiata* was high at Nagoa than the Jalandhar shoreline. The abundance values were high in upper littoral zone, at Nagoa site except June and October months (**Fig. 15b).** In Nagoa high abundance values were found in monsoon months. In post-monsoon season more or less similar trend between three littoral zones. Lowest density values were found in lower littoral zone. However, at Jalandhar the abundance value of *Cellena radiata* was found to be more or less similar in all three littoral zones. In the lower littoral zone at Jalandhar the abundance value was low during winter and pre-summer months, however, the lowest abundance value was recorded in winter month (December) **(Fig. 3b).**

7.1.3. Frequency

In Nagoa sampling site, the frequency of *Cellena radiata* was high in winter seasons and decreased in pre-summer month (February). The frequency values were found to be more or less similar at Nagoa, during monsoon season (June-August). Higher frequency values were recorded in upper littoral zone compare to other two littoral zones **(Fig. 15c).** In Jalandhar sampling site for monsoon season the frequency value of *Cellena radiata* showed almost similar trend in upper and middle littoral zone. Highest frequency value during the entire study period was observed at the mid of the post-monsoon season in the upper and middle littoral zone (October). In winter season (December-February) the frequency values showed fluctuations in upper and middle littoral zone **(Fig. 3c).** For lower littoral zone, the values of frequency during the winter months were constant. The frequency value for the summer season in all littoral zones did not follow a particular pattern. Premier frequency value in lower littoral zone was observed in the summer months (April-May) of the study.

7.2. Mancinella bufo

The species maintained its presents in Somnath coastline, throughout the year. The year wise density, abundance and frequency values in all the micro-sampling sites in Somnath station are given in **Fig. 36** for micro-spatial variations therein.

7.2.1. Density

At Somnath sampling sites the highest density value was observed in pre-monsoon month (June) from middle littoral zone and lower littoral zone. In winter season *Mancinella bufo* was found to shift from upper littoral zone to lower littoral zone, that is during the winter months a gradually increase of density value in lower littoral zone and a vice-versa effect was found in upper littoral zone. In the summer season (March-May) the density value for upper littoral zone and middle littoral zone showed fluctuations in its value, but for lower littoral decreased in its value was observed. During the monsoon months (July-August) the density value for upper littoral zone and lower littoral zone showed an increase but for middle littoral zone no significant different was observed **(Fig. 36a).**

7.2.2. Abundance

In Somnath sampling sites the abundance value of *Mancinella bufo* in the winter season showed high abundance value in lower littoral zone than upper littoral zone and middle littoral zone. In summer months the abundance value of this species for middle littoral zone and lower littoral did not showed much variation for a particular month. In monsoon (June-August) highest abundance value was recorded in middle littoral. Lowest abundance value was observed in the upper littoral zone during the pre-summer month **(Fig. 36b).**

7.2.3. Frequency

The maximum frequency value was recorded in the post-monsoon month (October), in lower littoral zone. In post-monsoon season (September-November) in upper littoral zone the values showed increasing pattern. During the winter season frequency value showed decreased in upper littoral while for lower littoral zone values showed an increase, which indicates the species shows a migration to lower littoral zone. In summer season the value of frequency showed increasing effect from upper littoral to lower littoral zone. This mentioned trend was followed through the summer months. In monsoon months (June-August) the value for frequency showed fluctuation in all three littoral zones. Values did not show a particular trend in three littoral zones **(Fig. 36c).**

7.3. Rhinoclavis sinensis

The species maintained its presents in Somnath coastline, throughout the year. The year wise density, abundance and frequency values in all the micro-sampling sites in Somnath station are given in **Fig. 40** for micro-spatial variations therein.

7.3.1. Density

At Somnath sampling sites the high density value of *Rhinoclavis sinensis* was found during winter season (December-February) and pre- summer month (March). During the summer months density values were gradually decreased. During the monsoon months in the end of monsoon month (August) this species showed similar trend between all three littoral zones. On the other hand during the post-monsoon season density values were increased compare to monsoon season. Throughout the year, lowest value was recorded in hot summer month (May) in upper littoral zone **(Fig. 40a).**

7.3.2. Abundance

From the present investigation showed that the species highest abundance values were observed in pre-winter months (October-November). During the winter season values were showed fluctuation pattern in upper littoral zone and middle littoral zone, in lower littoral values were gradually increased. In the summer season abundance value was consequently decreased in upper littoral zone but the abundance value was increased in middle littoral zone. During the hot summer season this species avoids upper littoral zone entirely and possibly migrates to middle littoral zone and lower littoral zone. In monsoon months fluctuating pattern was observed in all littoral zones **(Fig. 40b).**

7.3.3. Frequency

At the Somnath sites high frequency values were observed in middle littoral zone and lower littoral zone during the winter season (December-February) and pre summer months (March-April). Highest frequency value was observed in middle littoral zone in the winter season. In the hot summer month values was minimum in lower littoral zone. During the monsoon months frequency values of this species did not show a particular pattern of all the littoral zones **(Fig. 40c).** Except middle littoral zone frequency values were showed almost uniform pattern in upper littoral zone and lower littoral zone (September-November).

7.4. Conus miliaris

The species maintained its presents in Somnath coastline, throughout the year. The year wise density, abundance and frequency values In all the micro-sampling sites in Somnath station are given in **Fig. 44** for micro-spatial variations therein.

7.4.1. Density

From the present investigation it is quite evident that this species prefers middle littoral zone and lower littoral zones. Present study showed that this species avoids the upper littoral zone. Highest density value of *Conus milliaris* was observed during winter months in lower littoral zone. Moderate to low abundance values were recorded mostly in upper littoral zone, throughout the year **(Fig. 44a).**Minimum value was observed in the upper littoral zone during the pre- summer month (March).

7.4.2. Abundance

Present study showed that the high abundance values were recorded during the mid and end of monsoon months, Highest value was recorded in upper littoral zone. In winter season except the middle littoral zone abundance values were showed fluctuation manner, on the other hand in hot summer months value was almost similar in middle littoral zone. In the monsoon months abundance values were consequently increased in mid of the season than after decreased in the end of the season **(Fig. 44b).**

7.4.3. Frequency

At the Somnath sampling sites high frequency values were observed during the summer and pre-monsoon months in middle littoral zone and lower littoral zone. Highest values were recorded in pre-monsoon month. This investigation was evident that this species migrates to middle littoral and lower littoral zone. Study showed that this species did not found in upper littoral zone some months of the year **(Fig. 44c).**

7.5. Tibia insulaechorab

The *Tibia insulaechoeab* is maintained its presents in both sampling sites throughout the year. The year wise density, abundance and frequency values in all the sampling sites, in Jalandhar and Nagoa are given in **Fig. 12 and 24** respectively for Micro-spatial variations therein.

7.5.1. Density

The both sampling sites *Tibia insulaechorab* was mostly distributed in the lower littoral zone. In comparatively to lower littoral zone least density values were observed in upper and middle littoral zone, this values showed that this species cannot tolerate extreme climatic conditions prevails in to reside in lower littoral zones, having comparatively moderate climatic conditions than the other remaining two littoral zones. At both sites Jalandhar and Nagoa **(Fig. 12a & 24a)** the density values were gradually increased during the successive months of monsoon season (June-August). In the both the Study sites during the post monsoon season the density value for upper littoral zone and middle littoral zones showed fluctuation but for the lower littoral zone the density values showed an increasing trend.

7.5.2. Abundance

In Nagoa sampling sites, during the post monsoon season the abundance value of *Tibia insulaechorab* showed fluctuation in all the littoral zones, but the trend formed due to their fluctuation was same in all the three littoral zones **(Fig. 24b).** During the winter season (December-February) the abundance value for upper littoral zone and middle littoral zone showed a decreasing pattern in the following months, but the values for the lower littoral zone in the winter season did not follow any particular pattern. The minimum values were observed in the upper littoral zone and middle littoral zones during the summer months (March-May). Maximum abundance value was recorded in monsoon months (June-August).

On the other hand in the Jalandhar sampling sites maximum value was observed during front mid of monsoon month (July-August). As compared to upper littoral zone during studied months the species were found more habituated in the middle littoral zone and lower littoral zone. During the post-monsoon season months (September-November) the abundance value showed decline than the monsoon season (June-August). In the following months of the winter season (December-February) the species were found to be shifted from upper littoral zone and distributed in the middle littoral zone and lower littoral zones. So it could be said that in the upper littoral zone the abundance values showed decreased while in middle littoral zones and the lower littoral zone the abundance values were increased. In the peak of the summer season *Tibia insulaechorab* was did not found in the upper littoral zone **(Fig. 12b).**

7.5.3. Frequency

In the both sampling sites highest values were observed in the winter months (December-February). Except the summer months in the Jalandhar sampling sites, in all the seasonal months for the both sampling sites the frequency values showed an increasing trend from upper to lower littoral zone. The frequency value in the post-monsoon season showed a fluctuations but highest frequency value was observed in the lower littoral zone the end of the post-monsoon season (September-November).

In Jalandhar sampling sites during the winter season the frequency value for middle littoral zone showed a decreasing effect in its value **(Fig. 12c).** At the end of the summer season the frequency value for lower littoral zone showed considerable decreased in its value. In Nagoa sampling sites the value for the all the three littoral zones showed a decrease pattern **(Fig. 24c)** throughout the summer season (March-May).

7.6. Cerethium caeruleum

The species maintained its presents in both stations Somnath and Diu coastline, throughout the year. The year wise density, abundance and frequency values in all the micro-sampling sites in Somnath and Diu station are given in **Figs. 9, 21** and **32** for micro-spatial variations therein.

7.6.1. Density

In Nagoa sampling sites maximum density value was recorded in mid of the post-monsoon month. During the winter season density value of *Cerethium caeruleum* was gradually increased in upper littoral zone **(Fig. 21a).** During the summer months high value was observed in lower littoral zone, values were gradually decreased in upper littoral zone. Minimum value was recorded in mid of the hot summer month in upper littoral zone. Values were showed a similar pattern in upper littoral zone during the rainy season (June-August). In Jalandhar sampling maximum value was observed during the winter season in middle littoral zone. Start of summer month uniform distribution was found in all three littoral zones. Minimum value was found in pre-monsoon month in upper littoral zone **(Fig. 9a).**

In Somnath sampling sites, highest density value was recorded in pre-summer month in lower littoral zone. In monsoon season values were showed almost similar trend in upper littoral zone, but fluctuation showed in middle littoral zone and lower littoral zones. The density values were consequently increased during post-monsoon season in middle littoral zone. During the winter season density values were showed fluctuated in all three littoral zones. This species showed seasonal variation throughout the year **(Fig. 32a).**

7.6.2. Abundance

Both sites Nagoa and Jalandhar maximum abundance value was showed during end of the post-monsoon month in upper littoral zone. At Nagoa abundance values were gradually decreased in lower littoral zone (**Fig. 21b**). During start of the summer month same distribution trend was observed in upper littoral zone and middle littoral zone.

During the summer season maximum value was recorded in lower littoral zone. At Jalandhar sampling sites maximum value was observed during the monsoon season in all three littoral zones. In the post-monsoon season values were fluctuation in all three littoral zones **(Fig. 9b).**

At Somnath sampling sites highest abundance value showed during end of the post-monsoon month. During the winter season value was consequently decreased in lower littoral zone. During the hot summer month the abundance values were showed almost similar trend in middle littoral zone and lower littoral zone **(Fig. 32b).**

7.6.3. Frequency

In Nagoa sampling sites during mid of the post-monsoon month frequency value was high in upper littoral zone **(Fig. 21c).** During the winter season minimum frequency value was recorded in upper littoral zone and high value was recorded in lower littoral zone. Lowest frequency value was observed during the hot summer month in lower littoral zone. In Jalandhar sampling sites moderate to high frequency values were observed in lower littoral zone during the post-monsoon season to pre- summer months. In the rainy season minimum values were observed in lower littoral zone **(Fig. 9c).**

In Somnath sampling sites highest frequency value was observed in start of the monsoon month in lower littoral zone. During the post-monsoon season values were fluctuated all three littoral zones. In the winter season values were consequently decreased in upper littoral zone. During the summer months (April-May) values were gradually decreased in all three littoral zones. Moderate values were observed throughout the year **(Fig. 32c).**

7.7. Onchidium verruculatum

The species maintained its presents in both stations Somnath and Diu coastline, throughout the year. The year wise density, abundance and frequency values in all the micro-sampling sites in Somnath and Diu station are given in **Fig. 6, 18 and 28** for micro-spatial variations therein.

7.7.1. Density

In the both sampling sites Nagoa and Jalandhar *Onchidium verruculatum* was did not observed in lower littoral zone throughout the year. In Jalandhar sampling site, highest density values were observed during the winter season in the middle littoral zone **(Fig. 6a).** At the mid month of the summer season the species were not found in the upper littoral zone. In the Nagoa sampling site highest density values were recorded from the upper littoral zone in the pre-winter month. During the winter season (December-February) the density showed fluctuation pattern in the upper and middle littoral zones **(Fig. 18a)** At the Somnath sampling site this species maintained its presence throughout the year. High density values were observed during the winter season. During the monsoon months (June-August) the values gradually decreased in the middle and lower littoral zones. Lowest value was observed from the lower littoral zone at the end of the monsoon month. In the mid of the post monsoon season values showed almost similar trend in all the three littoral zones **(Fig. 28a).**

7.7.2. Abundance

At Nagoa sampling sites the abundance values did not showed a particular pattern throughout the year. Maximum abundance value was recorded during the end of the summer month in the upper littoral zone **(Fig. 18b).** At Jalandhar sampling sites, during the pre-winter and at the onset of the winter month‘s abundance values showed almost similar distribution in the upper and middle littoral zones. Maximum abundance value was recorded during pre-monsoon months in upper littoral zone **(Fig. 6b).**

At Somnath sampling sites, highest abundance value was observed at the end of the monsoon month in the middle littoral zone. In the post monsoon season the abundance value gradually decreased in the upper littoral zone. During the summer months values showed an increase in the lower littoral zone. The abundance values the lower littoral zone was moderate during the year **(Fig. 28b)**

7.7.3. Frequency

In the Nagoa sampling sites, highest value was recorded in the upper littoral zone during the post monsoon months. During the hot summer month the frequency was high in the upper littoral zone. At mid of the winter month frequency values showed uniform pattern in both upper and middle littoral zones **(Fig. 18c).** At Jalandhar sampling sites, highest frequency value was recorded during the winter season (December-February) in the middle littoral zone. The values showed similar distribution during the end of the summer month between upper and middle littoral zones **(Fig. 6c).**

In Somnath sampling sites, the frequency values were consequently increased in the upper and lower littoral zones. In winter season (December-February) values showed almost similar trend in upper and middle littoral zones. Lowest value was recorded during the start of post monsoon month in the lower littoral zone. The frequency value in lower littoral zone was almost moderate during the year **(Fig. 28c).**

7.8. Clibanarius nathi

The species maintained its presents in Somnath coastline, throughout the year. The year wise density, abundance and frequency values in all the micro-sampling sites in Somnath station are given in **Fig. 48** for micro-spatial variations therein.

7.8.1. Density

In the Somnath sampling sites very high density value of *Clibanarius nathi* was recorded during end of the winter months in middle littoral zone. It has been observed from the present investigation that key species a dweller of upper littoral and middle littoral zones. Throughout the year value of density in lower littoral zone was much fluctuation in all the seasons. Upper littoral zone and middle littoral zones showed more or less similar pattern in all the seasons. Minimum value was observed during the post-monsoon season in lower littoral zone **(Fig. 48a).**

7.8.2. Abundance

The maximum abundance values were recorded during the post-monsoon season. Very high abundance value was observed in upper littoral zone and middle littoral zone. This species prefers upper littoral zone and middle littoral zone. Minimum abundance was recorded during post-monsoon season in lower littoral zone. During the winter season values were increased in lower littoral zone, but in upper littoral and middle littoral zone values showed a fluctuation pattern. Values were did not show more changes during the post-monsoon season in upper littoral zone. During the monsoon months high abundance values were showed in middle littoral zone **(Fig. 48b).**

7.8.3. Frequency

The maximum frequency of this species was recorded during end of the winter month (February) in middle littoral zone. Minimum value was recorded during the post-monsoon season in lower littoral zone. Frequency of this species was moderate and did not show much seasonal variations throughout the year **(Fig. 48c).**

7.9. Clibanarius zebra

The species maintained its presents in Somnath coastline, throughout the year. The year wise density, abundance and frequency values in all the micro-sampling sites in Somnath station are given in **Fig. 52** for micro-spatial variations therein.

7.9.1. Density

Present investigation at Somnath sampling sites during the winter season (December-February) density values were showed almost similar trend in upper littoral zone and values were gradually increased in middle littoral zone and lower littoral zone. The density values of this species were showed almost similar pattern in upper littoral zone. During the monsoon months values were consequently increased in upper littoral zone and decreased in middle littoral zone. The maximum density values were recorded mid of the post-monsoon month in middle littoral zone **(Fig. 52a).**

7.9.2. Abundance

In the study sites maximum values were observed during the post-monsoon months. In the winter season except the upper littoral zone, the abundance values were gradually increased in middle littoral and lower littoral zone. During the rainy season values were consequently increased in the middle littoral and lower littoral zone. During the summer months values showed fluctuation pattern in all three littoral zones **(Fig. 52b).**

7.9.3. Frequency

In Somnath sampling sites maximum values showed of this species during the hot summer month in middle littoral zone. The minimum value was observed during end of the monsoon month in lower littoral zone, values were gradually decreased in lower littoral zone. This species showed moderate values in all littoral zones. In the winter season minimum values were observed in lower littoral zone **(Fig. 52c).**

8. TOURISM ACTIVITIES

Somnath and Diu sites were surveyed at regular intervals during low tide in each month from August 2008 to September 2009. In both the cases the coastline was literally abused tremendously by the visiting tourists as well as local resident population as observed in the other Indian places of worship and tourist sites. Mass human defection and urination was the first sign of the human interference noticed as soon as one goes to the coastline. Considering the amount of people visit these places especially the holy place of Somnath (sometimes in lakhs) and the local resident population (fishermen and tourism related tradesmen), the damage caused to the coastline is immense. Dumping of the garbage of all kinds including floral and fruit offerings, waste foodstuffs and plastic bags are the major source of pollution to the shoreline. Tremendous fishing of coastal animals for food and other ornamental and souvenir purpose was noticed. The most dangerous human impact was the harvesting of lush algal species for industrial purpose which leaves the place absolutely bald and thereby causing habitat destruction which takes long time to recover.

8.1. Diu

Diu is a beautiful tiny island lies on the west coast of India with a coastal length of 21 km. This station alternates between lime stone cliffs coves and sandy beaches. Nagoa beach is quite famous for its serene beauty, this beach alternates tourism for swimming and picnic for enjoying, wading in the shallows sun-bathing by sea, water sports and pony riding.

During the study period, tourism related activities like bathing, swimming, water sports, etc. was observed. Along this, a major indirect human interference such as sewage wastes of many resorts, and sugarcane industrial wastes draining off in the sea was also observed. Human interferences were also done by harvesting of molluscan, algal and arthropod species by local population of Nagoa for food, ornamental and industrial purposes. So, this site was used for socio-economic purposes by local population and also by the tourists. It may be possible that due to these interferences many of the ecological or habitat changes occur. On the contrary, Jalandhar site was little safer in terms of human interference because during the study period less human interference was observed compared to that of Nagoa.

8.2. Somnath

Somnath is a Hindu religious and tourist place because of the presence of 12 shivalingas of Lord Shiva. Somnath sea floor is represented by uneven rocky patches, flat rocky bottom and gray- sandy beach. During the study, direct or indirect effect on the coastal ecology of the Somnath site was observed. In this area, human interference was done in the form of fishing for food and ornamental purposes, industrial wastes and worshipping offerings was dumped in this sea shore which definitely caused direct or indirect effects on the coastal ecology of this site.

DISCUSSION

The present investigation was aimed to study the micro-spatial and temporal variations in the population ecology of the some key macrofaunal species at Diu off South Saurashtra coastline. The study involved to contrasting shoreline, Jalandhar having flat and calm shoreline, and Nagoa having steep slope with rough tidal activity. Both sites were further divided into few sampling sites and ecological attributes of eight macro faunal species belonging to phylum- mollusca and arthropoda were measured over a period one year. The study indicates less micro- spatial variations between the sampling sites within each site and also between the sites. This is indicating of almost similar nature of the population ecology based on the climatic conditions of this region. Where ever, micro- spatial variations were found that was due to the difference in the coast characteristic, tidal activity and possibly due to the variations in algal population. These was a clear cut seasonal variation observed in almost all species studied, which was based on the prevailing climating condition of this region.

1.1. COAST CHARACTERISTICS & ZONATION

Survey and literature studied of the intertidal region shows that the intertidal zone can broadly be divided into five different zones:

1. *Supralittoral zone or (Fringe Zone):* The spray zone is just reached by ocean only rare high tides usually during monsoon and winter. Periwinkles live on higher rocks of this zone, where they barely get splashed by the ocean. Limpets and Barnacles are usually found on lower end of this zone.
2. *Upper middle littoral zone or (High tide zone):* The High tide zone is the area which gets flooded during the usual high tide. This zone generally occupied by Limpets specially the Patellids, *Chitons*, members of Trochidae family.
3. *Lower middle littoral zone or (Middle zone):* Middle littoral zone is part of intertidal zone which is most productive among these five with animals of high adaptability. This is the portion which gets exposed during regular low tide. In case

of rocky sandy substratum, this zone, in its pools and puddles, harbors seaweeds and animals, especially most of Gastropods found in the rocky intertidal shore. Arabian Sea being an open sea show high tidal activity and that is the reason this zone is made up of very sharp edged rocks, making the area preferable for the shelled animals.

4. *Infra littoral zone or (Low tide zone):* The low tide zone is portion covered by water. It is exposed to air only during rare low tides. Because of larger submersion period, organisms here do not have to be as adaptive as many of the organisms in higher zones. That is why lots of organisms are found in this zone. Many kinds of seaweeds also grow here, providing shelter for feeding and breeding to many small animals like Crabs small fishes and free swimming marine helminthes. Typically, *Zooanthus*, a coelenterate dominate this area because of optimum light penetration and low turbidity as the substratum is predominantly rocky. But on the negative side of this zone, very high tearing force of the tidal activity does not allow many organisms to settle down at this zone.
5. *Sub tide zone:* The Sub littoral zone is rarely exposed to air, making it hard to excess. The organism cannot withstand much exposure to air and sun. Some of the macrofauna that live in this zone are sponges, sea urchins and sea anemones.

2. FAUNAL DIVERSITY

2.1. Faunal Characteristics:

The intertidal macro faunal attribute of the study areas proved to be quite a healthy one. A good number of the different types of molluscan species of the rocky intertidal belt recorded in India were found here**.** Beside the annual individuals, some seasonal species were also found during the extensive survey of the two stations. Few non-mollusc species were also recorded. A total of 45 species of molluscs were recorded with 12 species of individuals of other phyla. Among the molluscan individuals, some were very prominent and used to show very prominent dominance at different locations. Other dominant species were *Mancinella bufo*, *Nerita albicina*, *N. undata*, *Caerulium caerulum* etc. Distribution of the animals varies site (spatial) wise as well as station wise mainly due to the pattern of the intertidal substratum offered to them. In fact, in each sampling sites, the substratum condition and exposure area were different than others. Thus, the space available for movement and shelter differs markedly with the change of the location. The other most important factor that regulates the distribution is the physical parameters that are external to the system from the biological point of view. One such factor is the tidal force, which varies so significantly with the locations that this has become one of the key controlling factors for the spatial distribution of intertidal macro fauna.

2.1.1. Somnath

This site started behind the Somnath temple and extended up to Vidia. This is the most unproductive site among all the six sites at two stations studied. The site is predominantly sandy with occasional rocky patches distributed at the upper littoral zone only. The rocky portion consists of very sharp edged rocks with large pools. The main problem at this site is that it gets exposed during tides of some definite force. The usual low tide leaves the rocky portion under thick sand mat. At those times, it became totally impossible to trace out any rocky portion. Only an expert person at area can dig out the rock at about four to six inches. During that time, the animals inhabiting that area also get submerged under sand. However, when found open, nothing but *Mancinella bufo* was found. Virtually no vertical zonation could be demarcated at this site due to the lack of uniform exposure at subsequent tides. However, at the end of this portion, about 100 m stretch was very rich in intertidal fauna. This portion is rich in intertidal macrofauna that are mentioned in **Table 1**. The *Chiton* and the *Trochus* species found here were much bigger in size than those of other sites **(Plate-14b).**

2.1.2. Diu

Jalandhar is a rocky beach positioned at the Southern part of the small Island Diu (Plate 1B). The spray zone is restricted to the vertical boulders standing high from the rocky sandy upper littoral zone. The rest of intertidal zone is totally flat, which gets exposed up to 30 meters and is sharply cut off from the subtidal zone making the tidal activity very strong. The area is fully covered by thick seaweeds (algae) and harbors comparatively good number and variety of animals. Probably the low desiccation rate and abundant marine algae favors the animals in this region. *Astrea semicostata* is the species that competes with the *Trochus* at this site. The vertical upper littoral zone, better to be termed as the spray zone, is uniformly covered by small sized *Cellana radiata* and juveniles of *C. caeruleum*. *Turbo* (s) are found only at one end of this sampling site. The site has a big fissure right at its centre, allowing the sea water to flow through most of the portion continuously.

Nagwa (or Nagoa) is second sampling site of Diu station **(Plate-3).** It is best known as a tourist resort. The sampling site is about 1.5 km. long stretch and the spray zone is restricted to high rocks which harbors *C. radiata*. Other limpets and juveniles of *T. cornatus* were also found .The area gets exposed about 30 meters offshore during low tide. It is also rich in vegetation and macrofaunal diversity. The *Zooanthus* population is quite god here. In the pools of rocky beach, Sea anemones were found. The middle zone was absolutely flat. However, the lower zone consists of big boulders usually covered with *Zooanthus* **(Plate-16).** The biggest problem at this site is the high tearing force of water that hampers the vegetation to get stuck into the rocky substratum to that zone.

It is apparent from the results of the present study that higher preponderance of animal species in the lower littoral, as compared to the upper and middle littoral, reflects a better chosen environment by the animals. The marine animals along the intertidal have to protect themselves against high salinity, desiccation and against the predators. This they achieve through taking shelter under the bushy canopy of the seaweeds which grow better on the lower littoral zone (Misra and Kundu, 2005). On the other hand, seaweeds on the upper and middle get desiccated out during the period of emergence. And therefore the animals cannot get shelter at these two littoral levels. Therefore, with the advent of the disappearances of seaweed along the upper and middle littoral, the animal migrates towards the lower littoral as a safer habitat (Misra, 2004, Ramoliya *et al,* 2007).

It is clear that there was greater degree of similarity between the middle and lower littoral levels of the intertidal than upper and middle littoral levels with respect to their biota. During the period of emergence i.e., at low tides, the first part to get emerged is the upper littoral zone and the last emerged is the lower littoral zone. This results in a maximum exposure time of the upper littoral and minimum exposure time of the lower littoral. Different organisms adapted to these environments take shelter at a suitable tidal level. So far as the seaweeds are concerned, these inhabiting the upper littoral get dried out and die first. On the contrary, organisms inhabiting the lower littoral level are the least exposed to the ambient environment and they get here more stable habitat as compared to the upper and middle littoral levels. The intertidal harbors many microhabitats like tide pools, small puddles, crevices, and small channels. Thus, the spore lings of seaweeds germinate, settle and grow at a particular microhabitat. However, all the earlier finding and the present study confirms one important point and that is, maximum seaweed growth occurs during the winter months of December and January when the seawater temperature shows a minimum couple with maximum Dissolved oxygen content (Patel, 2002).

It was observed during the present study that in the case of macrofauna, the sponge population was less because sponge is very delicate and damaged by fishermen and other people. They were seen mainly in middle and lower littoral zone, somewhat present in upper littoral but not in dried area. In case of phylum Coelenterata, it has been found that the variation in species was high in lower littoral zone and minimum was in upper littoral zone almost all cases in all months. This may be due to the fact that lower littoral zone was least exposed zone and upper littoral zone was the maximum exposed one, providing the habitat for only some selected species of this sessile group. During months December and January, the number of species recorded was very less probably due to high density of algae where they could not be visible.

In case of phyla Platyhelminthes, *Planeria* and other related species might be present all time but was in associated with algae and thus, was rarely seen in the open. In case of annelids, very little number of species was recorded. In case of Annelida, *Nereis* was present in sandy portion and due to its nature of burrowing, rarely came out in the open. In case of phylum Arthropoda, the species diversity shows more or less similar pattern at upper and middle littoral zone, and least diversity observed at lower littoral zone. It is possible that the animals of phylum Arthropoda prefers to be in association with intertidal algae at upper and middle littoral zone **(Plate-21a),** especially in the pools and puddles. The Arthropoda feeds on the Algae as well as zooplankton and phytoplankton and thus, vigorous tidal activity of the lower littoral zone might not be a suitable place for them.

Phylum Mollusca showed more or less similar trend like phylum Arthropoda where species diversity was high in upper and middle littoral zones. This trend may be due to the fact that the Mollusca mainly feed on the marine algae and thus, always associated with intertidal seaweeds. During December and January when algal vegetation was very high associated molluscan species also increased because many molluscan species was associated with algae. In the case of Echinodermata species number was less because starfish and brittle star inhabiting deep water. But also present in intertidal zone. On the whole, it appears that in general, this area rich in macrofauna and Algae.

Principal Rocky Intertidal Molluscan Diversity of Veraval and Diu shoreline of the South Saurashtra Coastline off Arabian Sea (Misra, 2004).

Phylum : Mollusca
Class : Gastropoda
Order : Archaeogastropoda
Family : Patelidae
1. *Cellana radiata* (Born)

Family: Trochidae
2. *Euchelus quadricarinatus* (Holten)
3. *Monodonta austalis*
4. *Thalotia*
5. *Astrea semicostata*
6. *Turbo intercoastalis*.
7. *Turbo cornetus*
8. *Trochus hanleyanus*

Family: Neritidae
9. *Nerita albicilla* (Linnaeus)
10. *Nerita undata* (Linnaeus)

Order : Mesogastropoda
Family: Cerithiidae
11. *Cerethium caeruleum* (Sowerby)
12. *Rhinoclavis sinensis* (Gmelin)

Family: Potamididae
13. *Cerithidae sp.* (Juveni & Broken)

Family: Cypraeidae
14. *Cyprinea* sp.

Family: Cyanide:
15. *Cyrinieum natator* (Roeding)

Order : Neogastropoda
Family : Muricidae
16. *Cronia contracta* (Reeve)
17. *Chicoreus brunneus* (Link)
18. *Chicoreus kilburni* (Houart & Pain)
19. *Mancinella bufo* (Linnaeus)
20. *Morula granulota* (Duclos)
21. *Murex* sp.
22. *Purpura panama* (Roeding)
23. *Perpura sp.*

Family : Buccinidae
24. *Cantharus spiralis* (Gray)
25. *Cantharus undata* (Linnaeus)
26. *Engina alveolata* (Kuzber)

Family : Mitridae

27. *Mitra scutulata (*Gmelin)

Family : Olividae

28. *Oliva oliva* (Linnaeus)

Family : Terebridae

29. *Hastula* sp.

30. *Conus miliaris* (Hwass)

Family : Architectonicidae

31. *Architectoniuca laevioata* (Lamarck)

Order : Sasommatophora

Family : Siphonariidae

32. *Siphonaria sipho* (Sowerby)

Order : Systellommatophora

Family : Siphonariidae

33. *Onchidium verruculatum* (Cuvier)

Class: Bivalvia

Order: Archoida

Family: Arcidae

34. *Arca ventricosa* (Lammarck)

35. *Barbatia obliquata* (Gray)

Class: Gastropoda

Order : Mesogastropoda

Family : Strombidae

36. *Tibia* sp.

Family : Cypraeidae

37. *Cypraea grayana schilder*

Family : Janthinidae

38. *Janthina janthina* (Linnaeus)

Order : Neogastropoda

Family : Mitridae

39. *Stringatella scutulata*

Family : Conidae

40. *Conus biliosus* (Roeding)

41. *Conus achatinus* (Gmelin)

Class : Bivalvia

Order : Veneroida

Family : Veneridae

42. *Gafrarium divaricatum* (Gmelin)

It was apparent from the present study that high species diversity occurs on these shores because of the continued reduction of superior competitors and the renewal of the major resource required by the sessile fauna and flora space on the rock surface. Physical processes are also important in freeing space, especially in removing older and larger prey which have escaped predation by virtue of their size, but which often become more vulnerable to dislodgement by waves as they age (Crowe and Underwood, 1999). This effect is often amplified when waves move large objects, such as floating logs. Along many parts of the north-eat Pacific, trees grow down to the edge of the shore, so that a considerable amount of timber is carried onto the shore in breaking waves. Thus weighing many tones make a significant contribution to the provision of space, smashing into mussels and barnacles to leave a bare patch available for colonization by other species (Dayton, 1971). Similar wave action can be exaggerated by pebbles and even large stones being moved around by waves (Shanks and Wright, 1986). Scouring by san or gravel in suspension can also have a major effect on rocky shores. Reefs jutting between stretches of sand are often inundated by sediment which kills all the plants and animals. Ice scour in colder regions can have a similar devastating effect. Unlike predation, this disturbance unselective with regard to species and size of prey removed, but the effect is similar the creation of bare space within the community However they are formed, such spaces will be further enlarged by wave action, particularly in winter, because the individuals immediately adjacent to the cleared area are more susceptible to dislodgement. In the previous examples, consumers increase the diversity of the primary space occupiers by feeding preferentially on the superior competitor. But predators can also lower species diversity. We had shown above how this can happen if the superior competitor al provides secondary space for other species. It can also occur when at high predator densities even the less preferred prey are eaten and only a few unpalatable species are left. A third reason is that the predator may actually prefer to eat the competitive inferiors, not the superiors. In New England, the dominant herbivore over much of the intertidal of sheltered and moderately exposed shores is the sea *Littorina littorea,* which was introduced into the USA in the 19th century In feeding trials, this snail consistently prefers smaller ephemeral seaweeds, such as *Enteromorpha* and *Ulva,* to the tougher fucoids whir can dominate these shores (Lubchenco, 1978). The preferred smaller seaweeds can only thrive in disturbed areas where fucoids hay been dislodged by wave action, or in tide pools which are not colonize by fucoids. Experimental exclusion of *Littorina* from the open shore (non-pool areas) leads to an increase in seaweed diversity, because the smaller species are no longer grazed down. In contrast in tide pools, in the absence of fucoids, the dominant seaweed is the fast-growing *Enteromorpha,* a preferred food of the snail.

The effect of *Littorina* on seaweed diversity in these tide pools depends entirely on snail density. At both high and low densities, diversity is low and only at intermediate densities is diversity high. Under low grazing pressure, *Enteromorpha* dominates and smothers other seaweeds; at high *Littorina* densities, overgrazing occurs. With intermediate levels of grazing, a mosaic of various less competitive species can occur in the gaps left by selective removal of *Enteromorpha.* Lubchenco's work underlines the importance of knowing the food preferences of predators and grazers when interpreting the outcome of exclusion experiments. The intermediate disturbance hypothesis (Caswell, 1978) suggests that at low levels of disturbance, certain competitive species will predominate and hence diversity will be low. At intermediate levels of disturbance, no one species will predominate and diversity will be high. As disturbance increases further, only a few highly tolerant or very opportunistic species will occur. This hypothesis has been tested in elder fields (Sousa, 1979) where stable boulders have a low-diversity community of dominant plants (red turf-forming algae such as *Laurencia s*p., *Gelidium* spp., *Ceramium* spp., *Mastocarpus stellatus*); highly unstable elders have a limited suite of opportunistic ephemeral species *(Ulva, Enteromorpha);* highest diversity occurs on boulders which get turned by storms occasionally, as succession is halted and restarted but proceeds beyond the early pioneer species phase. Patchiness is a fundamental feature of most communities (Pickett and White, 1985) and is easily studied on rocky shores because of their two-dimensional nature. Many shores can be seen as a patchwork or mosaic of species or assemblages on various scales in different phases of succession, from cleared bare rock to complete cover by a dominant species. The dynamics of these patches vary with wave exposure, time of year and patch size. For instance, in Paine's Washington sites, 1-5% of years after initial patch creation. The turnover time for mussel beds in this part of the world ranges from 8 to 35 years, depending on location (Chapman, 2002). The dynamic nature of patchiness has been investigated in detail for smooth limestone ledges on semi-exposed shores on the Isle of Man in the Irish Sea (review Hawkins et *al,* 1992a), where grazing by the limpet *Patella vulgate* is an important structuring agent. Local reductions in limpet density allow clumps of the seaweed *Fucus vesiculosus* to establish, especially on barnacle shells.

The continual sweeping of the *Fucus* fronds over the rock surface dislodges a large proportion of the settling barnacles *Semibalanus balanoides,* and the damper conditions under the plants encourage aggregations of limpets, especially juveniles, as well as the dogwhelk *Nucella IapiIlus,* a predator of barnacles. The clumps of fucoids disappear through loss of insecurely attached plants growing on barnacles and, eventually, ageing. The plants are not replaced locally because of the dense aggregations of grazing limpets and the sweeping action of the fucoids themselves. Once their shelter has disappeared, limpets and dog whelks disperse and in their absence barnacles can now settle successfully. Barnacles settle better in the gaps between fucoids clumps, which also have fewer limpets as these tend to be grouped under the seaweeds. The grazing efficiency of limpets is poor in stands of older barnacles and new escapes of *Fucus* occur in these areas. A patch of *Fucus* lasts about 3-4 years and the community functions as a series of cycling patches, usually out of phase with each other. There are many positive and negative interactions between the various elements in the mosaic, and some species moderate other interactions. Thus, limpets prevent algal growth but fucoid patches encourage the recruitment of juvenile limpets; newly settled barnacles are reduced in number by limpets, but are probably permitted to settle due to the removal of competitively superior ephemeral algae; barnacles reduce limpet foraging efficiency allowing algal escapes; dogwhelks thin-out barnacles, allowing limpets to more effectively reduce algal cover; the sweeping by fucoid fronds reduces barnacle settlement.

3. PLANT – ANIMAL ASSOCIATION

Marine animals take shelter under the seaweeds with bushy morphological canopy to feed and protect themselves from their predators. Added to this, the marine animals, except the sea anemones, corals, sponge are mobile and hence shift from the microhabitat to the other within a territorial range. The association of animals on the bases that the algae provided them protection from extreme high and low temperature and their dislodgement by wave action. Further reason for their algal association may be that they also feed on spores, filaments or detritus matter of these algae as evident by their food content (Misra, 2004).

From the results of the association of different species of fauna with the flora on the upper littoral zone, it is apparent that *Cellana radiata* seldom associated with *Ulva lactuca, Chiton* with *Ulva lactuca* and *Chaetomorpha antennina.* On the other hand, it appears that the Trochus hanleyanus *sp*. did not show any specific affinity to any seaweed species. Thus, it is discernible that this species does not have any specific choice with particular algae and may be using the assemblage as source of food (Dudhatra, 2004). At the middle littoral zone, *Conus miliris* showed affinity with Ulva *lactuca. Planeria* and *Eurythoe* have affinity to association with algae shown In this zone *Trochus hanleyanus* and *Turbo sp.* also present and associated with algae too for feeding and breeding reasons **(Plate-14).** In the lower littoral zone *Chiton peregrinus sp.* associated with *Sargassum swartzii* and *Ulva lactuc, Cyprea sp.*with *Sargassum swartzii*, *Ulva lactuca* and *Gracilaria corticata.* While *Aplysia benedicti associated* with *Sargassum cinctum* and *Ulva lactuca.*

In general, it appears that, all the animal species were well associated with particularly two seaweed species *Ulva lactuca* and *Sargassum cinctum* While, the gastropods *Trochus hanleyanus* and *Monodonta sp.* associated with almost all species of algae.
It is apparent from the results of the present study that higher preponderance of animal species in the lower littoral, as compared to the upper and middle littoral, reflects a better chosen environment by the animals. The marine animals along the intertidal have to protect themselves against high salinity, desiccation and against the predators. This they achieve through taking shelter under the bushy canopy of the seaweeds which grow better on the lower littoral zone (Misra and Kundu, 2005). On the other hand, seaweeds on the upper and middle get desiccated out during the period of emergence. And therefore the animals cannot get shelter at these two littoral levels. Therefore, with the advent of the disappearances of seaweed along the upper and middle littoral the animal migrates towards the lower littoral as a safer habitat (Misra, 2004).

From the present investigation, it was clear that there was greater degree of similarity between the middle and lower littoral levels of the intertidal than upper and middle littoral levels with respect to their biota. During the period of emergence i.e, at low tides, the first part to get emerged is the upper littoral zone and the last emerged is the lower littoral zone. This results in a maximum exposure time of the upper littoral and minimum exposure time of the lower littoral. Different organisms adapted to these environments take shelter at a suitable tidal level. So far as the seaweeds are concerned, these inhabiting the upper littoral get dried out and die first. On the contrary, organisms inhabiting the lower littoral level are the least exposed to the ambient environment and they get here more stable habitat as compared to the upper and middle littoral levels. The intertidal harbors many microhabitats like tide pools, small puddles, crevices, and small channels. Thus, the spore lings of seaweeds germinate, settle and grow at a particular microhabitat. However, all the earlier finding and the present study confirms one important point and that is, maximum seaweed growth occurs during the winter months of December and January when the seawater temperature shows a minimum couple with maximum Dissolved oxygen content (Patel, 2002). It was observed during the present study that in the case of macrofauna, the sponge population was less because sponge is very delicate and damaged by fishermen and other people. They were seen mainly in middle and lower littoral zone, somewhat present in upper littoral but not in dried area.

Variation in species of phylum Coelenterate was high in lower littoral zone and minimum was in upper littoral zone almost all cases in all months. This may be due to the fact that lower littoral zone was least exposed zone and upper littoral zone was the maximum exposed one, providing the habitat for only some selected species of this sessile group. During winter months, the number of species recorded was very less probably due to high density of algae where they could not be visible. In the phyla Platyhelminthes and Annelida, *Planeria* might be present all time but was in associated with algae and thus, was rarely seen. In case of annelids, very little number of species was recorded. *Nereis* was present in sandy portion and due to its nature of burrowing rarely came out.

However, species diversity of phylum Arthropoda shows more or less similar pattern at upper and middle littoral zone, and least sp. diversity observed at lower littoral zone. It is possible that the animals of phylum Arthropoda prefers to be in association with intertidal algae at upper and middle littoral zone, especially in the pools and puddles. The Arthropoda feeds on the Algae as well as zooplankton and phytoplankton and thus, vigorous tidal activity of the lower littoral zone might not be a suitable place for them.

Phylum Mollusca showed more or less similar trend like phylum Arthropoda where species` diversity was high in upper and middle littoral zones. This trend may be due to the fact that the Mollusca mainly feed on the marine algae and thus, always associated with intertidal seaweeds. During December and January when algal vegetation was very high associated molluscan species also increased because many molluscan species was associated with algae. In the case of Echinodermata species number was less because starfish and brittal star inhabiting deep water. But also present in intertidal zone. On the whole, it appears that in general, this area rich in macrofauna and Algae.

4. POPULATION ECOLOGY

Present study involved few contrasting shoreline, Jalandher having flat and calm shoreline, and Nagoa having steep slope with rough tidal activity. Both sites were further divided into few sampling sites and ecological attributes of eight macro faunal species belonging to phylum- mollusca and arthropoda were measured over a period one year. The study indicates less micro- spatial variations between the sampling sites within each site and also between the sites. This is indicating of almost similar nature of the population ecology based on the climatic conditions of this region. Where ever, micro- spatial variations were found that was due to the difference in the coast characteristic, tidal activity and possibly due to the variations in algal population. These was a clear cut seasonal variation observed in almost all species studied, which was based on the prevailing climatic condition of this region.

4.1. Cellena radiata

C. radiata generally inhabits upper littoral zone but also observed in middle and lower littoral zones in lesser numbers (Misra and Kundu, 2005). This animal showed the habitat preference mostly in the pools and puddles up the upper littoral zone during the low tide and feeds on the thick vegetation of Chlorophyceae and Rhodophyceae (Prasad, 1964). In Jalandhar, The density of *C. radiata* was higher in upper littoral zone during monsoon to winter season and was low during the summer season. More or less similar trend was observed in case of abundance and frequency values. The density and frequency values of *C. radiata* were higher in the upper littoral zone and least in lower littoral zone **(Fig. 3).** However, the abundance value did not differ significantly in the vertical zones. The abundance of this species was almost similar in all the three littoral zones, indicating its movement for feeding and other activities (Vaghera, 2008).

In the Nagoa sampling site *C. radiata* showed similar ecological status than that of Jalandhar **(Fig. 15).** The maximum density and frequency was found in the upper littoral zone followed by middle and lower littoral zones. As it appears, there was no significant micro-spatial variations in the distribution on these species where in the site itself (between A and B) and between Jalandhar and Nagoa coasts. The results suggest that both the coasts of Diu can be considered as a continuous shoreline as per the distribution of *C. radiata* is concern (Prasad, 1984).

4.2. Onchidium verruculatum

O. verruculatum showed the typical habitat preference by conspicuously absence from the lower littoral zone. This species being a voracious feeder on algae showed greater density and abundance in middle littoral and lower part of upper littoral zone during monsoon, post-monsoon and winter seasons **(Fig. 6).** These shell less molluscs avoid expose during low tide and normally seen in the large pools in the upper littoral zone in association with green algae during low tide. The temporal variation was obvious during the summer months as it was required to avoid intense heat. The temporal variations in the density values were lesser than the abundance values indication richness of the species was less affected than the evenness. This phenomenon was indicative of the habitat preference and rapid movement to safer places during expose (Vaghera, 2008). In Nagoa sampling site the distribution and other ecological attributes of *O. verruculatum* were similar to that of Jalandhar coast **(Fig. 18).** The result suggested no micro-spatial variation in the density and abundance values of this species. The values of different ecological attributes showed variations in Somnath sampling sites. The density value showed high richness of the species in the upper littoral zone and middle littoral zones throughout the year **(Fig.28).** The temporal variation as such was not evident but the density values decreased in the upper littoral and middle littoral zones but reduced to the level of lower littoral zone. There was not much variation in the abundance of this species. No significant variation in the percent frequency values was also observed **(Fig. 28).**

The results clearly indicate upper and middle littoral zones being the preferred habitats of these species (Vaghera, 2008). There was no significant temporal variation observed but the animals might have moved to the deeper regions to avoid exposer to heat. This reflected the reduced density and abundance values during the summer months. The intertidal zone of Somnath is more flat than that of Diu and covered with rich intertidal vegetation, which is feeding ground for this species. This possibly is the reason for ample abundance of this species in this region (Mishra and Kundu, 2005).

4.3. ***Cerethium caeruleum***

C. caeruleum on the other hand showed temporal variations during summer months **(Fig. 9).** This species was found to be distributed in upper and middle littoral zones and lesser distribution was observed in the lower littoral zones **(Fig. 9).** However, these were not apparent that this animal was not preferential in the habitat selection and live in almost all vertical areas with more or less equal evenness. *C. caeruleum* is a small sized animal which abundantly occur in the shoreline and prefer the substratum which is rich in organic matter (Prasad, 1984). This species is also numerous in numbers which provide food supply for other gastropod eating animals inhabit the intertidal zone. Similar trend was also observed in case of *C. caeruleum* in Nagoa **(Fig. 21).** However, in this case slightly higher density and abundance values were observed in the upper littoral zone than that of the Jalandhar sampling sites. These may be due to the fact that the vertical zonation in Diu sampling site was observed. As the intertidal slop was two high at Nagoa upper and middle littoral zones are limited to few meter all together (Misra, 2004).

In case of Somanth, *C. Caeruleum* no clear cut seasonal variations were observed in any of the sampling sites of A,B and C. habitat preference was not much clear but lower littoral zone was defiantly preferred as these zones are covered with algae at Somanth coast. The result also showed that the distribution of the species was more or less even in this coastline. *C. caeruleum* is abundantly occurring with the seaweed vegetation in the South Saurashtra coastline (Prasad, 1984). As it appears the more flattened slope with the lots of vegetation and reduce tidal activity than Diu made this coastal area favorable for these species.

4.4. Tibia insulaechorab

In case of *T. insulaechorab* which is a typical in habited of middle littoral and lower littoral zones showed temporal variations in there richness **(Fig. 12).** The maximum values were observed during winter months which are possibly most favorable season for their growth and development. The relatively evenness of this species was more or less similar in lower and lower part of middle littoral zones **(Fig. 12).** Frequency values were also high in this region during most of the year. These particular species is normally avoiding exposer during low tide and voracious feeder on marine algae which was present greater abundance in lower part of intertidal zone and sub-tidal zone. The seasonal variations were exactly similar to that of Jalandhar. However, in case of Nagoa the density and abundance values were considering the fact that the available vertical zone was very less in Nagoa (Misra and Kundu, 2005).

The result of statistical analysis showed the micro-spatial variations existed in the case of *O. verruculatum* in middle littoral zone **(Table-12).** As it appears, that there is no significant micro-spatial existed the Jalandhar sampling site for all the species except few cases of *Tibia insulaechorab* were slight significant was observed **(Table-13**). In case of Nagoa, similar observations were made where almost all the species showed no micro-spatial variation (Table-14). Result of one way ANOVA between the mean of density, abundance and frequency values of both Nagoa and Jalandhar sampling sites ratified the results of ‗t-Test' conducted between the micro-spatial sampling sites the Jalandhar and Nagoa respectively **(Table-12).** As it appears, from the results that these two sampling sites are to consider as continuous were coast characteristics, biotic and abiotic variable remained similar (Misra and Kundu, 2005).

4.5. Mancinella bufo

Mancinella bufo is large signed gastropods which are normally seen associated with green algae in the vertical zones. It is a grazer on chlorophycae as a whole and *ulva lactuca* in particular (Misra, 2004). In case of *M. bufo,* no clear cut seasonal variations were observed **(Fig. 36).** This species was present in this coastline in small numbers which is reflected by its reduced density and abundance values. The middle and lower littoral zones were preferred by these species and small number of individuals was found in the deep pools and puddles on association with green algae during the low tide (Gohil, 2007). This species was found to be more prolific in middle and lower littoral zones of this coastline. This may be due to the local migration of this highly motile species from upper littoral zones to avoid excessive heat, desiccation and rough tidal activities especially in the none availability of algal species in the upper littoral zones of Jalandhar sampling during summer and monsoon months (Misra and Kundu, 2005, Gohil, 2007).

4.6. Rhinoclaivs sinensis

R. sinensis prefers lower parts of middle littoral zones and lower littoral zones. This small gastropod species mostly grazes on the pheophycae and rarely seen in the upper littoral and spray zones. In case of *R. sinensis* similar trend that of the *M. bufo* was observed (**Fig. 40).** As it appears, *R. sinensis* competes with *M. bufo* in the middle and lower littoral zones. There by conspicuous by their small numbers (Misra, 2004). Seasonal variations were not evident seems this species remained in the relatively unexposed lower littoral zone. This is certainly indicated that the movement of this species between the vertical zones depends on the availabilities of food (Misra, 2004). The species invades upper littoral zones during the late winter and summer months possibly to avoid the incoming species from upper and middle littoral zones during the summer and monsoon months. It has also possible that by doing so it is taking the advantages of the incrusted brown algae present on upper littoral zones, relatively free of competition.

In case of *R. sinensis*, neither micro-spatial nor the season wise density values showed any significant difference. It gives a clear indication that either the conditions offered to them were adequate or they had acquired resistance to the existing conditions. In almost all cases, the standard deviation value was high. This is due to the fact that the quadrates were laid in a criss-cross fashion, covering all the three zones at a single round. As the animals are restricted to the upper zone only, and a successive upper zone requires at least three sampling in between, it is obvious that the density was supposed to be about 40% of the abundance value even if the distribution was uniform in the upper littoral zone. Substratum on which this species dwell differs from at the two stations from the point of both vertical and horizontal positions. At Veraval, the intertidal belt is in the form of a gradual plane with pools and creeks at about regular interval, whereas at Diu, it is in the form of steep vertical rock with very less number of pools and almost no creeks. This condition did not provide any room to these animals to move along with the upcoming water during high tide. That makes a uniform distribution of the species at Diu as there is no extra benefit to be obtained from the substratum. Being the dweller of the upper littoral zone, rather to the spray zone at Diu, the density is mostly a reflector of the atmospheric physical factors, the degree of tidal harshness. Veraval population showed maximum richness during post monsoon when the temperature and pressure of water is moderate. On the other hand the Diu population reached at its peak during winter as they are protected from being exposed for a longer time to cold water and from the cold air by the large boulders

4.7. Conus milliaris

This large gastropod species is associated with green algae and a prolific grazer on *Ulva lactuca*. Therefore, it migrates from zone to zone for grazing. However the middle and lower littoral zones are most preferable habitat for this species (Underwood, 2000). In case of *C. milliaris* again non definite seasonal variation was observed. The animal was mostly present in the more productive middle and lower littoral zones (Fig. 13). Density values of this species showed a marked reduction during the summer months and again the post-monsoon season when the atmospheric temperature was high in the upper littoral zone. In all three micro-spatial sampling sites, Somnath is essentially flat, rocky out-crop with around 70% sand cover is not a suitable place for the gastropod mollusks (Prasad, 1984). The exposed rocky portion was well represented by patella and Chitons (Gohil, 2007). As this group of animals move with the water current, the seasonal variations in tidal height and force played a role in their distribution (Underwood and Chapman, 1998a). The difference was quite prominent that brought with the change of tidal height during four seasons. It is possible that the distribution at the two stations was regulated by physical factors in a large scale. In spite of having the higher density value at Diu, it also had higher abundance value. This indicates the condition at the upper littoral zone that was quite an unusual habitat for survival. This feature enabled them to survive in a smaller unit on the flat surface with a foot opening of smaller dimension and again the movement was very restricted as there was virtually no chance to move on the high peaked rocks at Nagoa (Prasad, 1984). The value was highest during monsoon which may because of water current and force generated at Diu was unidirectional from upper to lower vertically and the animals moved or being dislodged and accumulated at the pools on the way. During monsoon, water was available at the pools for throughout the day raising the abundance values higher at both Somnath and Diu.

4.8. Clibanarius nathi and ***Clibanarius zebra***

C. nathi, the brown hermit crab normally dwell the upper middle littoral zones. The other hermit crab species studied *Clibanarius zebra* showed slightly different habitat selection than *C. nathi*. It is observed that this species mainly inhabits the lower part of the upper littoral zones. Various ecological attributes did not show clear cut variations between the two littoral zones. *C. zebra* shares the space food with other hermit crab species especially *C. nathi* and in the present investigation successful co-existence of these species was noticed.

In the case of *C. nathi* and *C. zebra* no clear seasonal variations were observed in any of the three vertical zones **(Fig. 48 & 52).** Present study showed irregular pattern of ecological attributes at Somnath. This may be to the fact that micro-spatial variations were also not found between the three sampling sites A, B and C. Desai (1986) reported ecological status of *C. nathi* and *C. zebra* in this coast, studied that the density and abundance of these is totally dependent of the availability of suitable empty gastropod shells, for these hermit crab species.

The result of present investigation showed no significant variation in any of ecological attributes for any of the species studied between the micro-spatial sampling sites A and B **(Table 16).** Similar results were also observed between sites B and C **(Table 17)** and sites A and C (Table 18). The results of t Test is clearly indicating of the oneness of the Somnath coastline. This result was further supported by the ANOVA test between the three micro spatial sampling sites **(Table 15).**

In the Jalandher sampling sites however significant variation was observed in the frequency of the species in the lower littoral zones. This variation is essentially a micro-spatial variation due to the variation in coast characteristic substratum types and other such factors within stretch of coastline. It is possible that local migration towards the upper portion of middle littoral zones in order to find bigger empty gastropod shell as the animal grows (Desai, 1986). Therefore, it can be concluded that the coastal stretch of Somnath can biologically be treated as continuous coastline where ecologically attributes of various key species did not differ significantly. Several species of hermit crabs inhabit rocky and sandy mid-to-low tide areas of intertidal zones and are found skittering about in deserted snail shell (Reid, 1967). Hermit crabs occupy empty gastropod shells to get protection against predation, mechanical damage, and environmental stresses, and thus gastropod shells are very much necessary for hermit crabs as being the most essential factor/resource required for their existence (Ajmal Khan and Natarajan, 1981; 1988; Scully, 1983).

The hermit crabs, inhabiting the intertidal zones at Somnath and Diu mostly belong to the genus *Clibanarius*, comprising *Clibanarius zebra* (Dana), *Clibanarius nathi* (Chopra and Das) and *Clibanarius signatus* (Heller) species. Among these species of the hermit crabs, numerically *Clibanarius zebra* and *Clabanarius nathi* are most abundant. These species, are found inhabiting the soft bottom (Calcarius rocks) or hard bottom (Stony rocks) of intertidal zone with or without algal mats. However, *Clabanaarius zebra* is mostly reported to inhabit the exposed rocks or rocky substrata, which rarely get submerged during low tide exposure, whereas *Clabanarius nathi* present generally on the substratum, which are though get exposed during low tide, but are very closed to the water i.e. on the edges of crevices, pools and puddles. The vertical distribution of these two hermit crab species in the intertidal zone showed their inhabitation from the supra-littoral zone up to 36m inside towards the infra-littoral zone. However, it is interesting to note the *Clabanarius nathi* represented on the exposed rock surface between 14-47 m are of the middle littoral zone.

The distribution of the hermit crabs has been described by several scientists on the basis of their habitat selectivity in the intertidal zone (Reese, 1969; Hazlet, 1981; Scully, 1983), A landmark study has been conducted by Desai (1986) from this very lab on the population ecology and biology of hermit crabs of South Saurashtra coastline long back. They reported the occupancy of the gastropod shells which are available in those particular intertidal habitats. According to Scully (1976 and 1979), *Pagurus longicarpus* may be found in a wide range of habitats including estuaries, tidepools, rocky areas of exposed coast lines and sand flats, and use variety of empty gastropod shells available in these areas. Further, the empty gastropods shells are movable objects in relation to tidal currents (Reese, 1969) and therefore, hermit crabs have been reported to exploit different rocky substratum available throughout the intertidal zone. However, as empty shells are essential for hermit crabs, they occupy whatever the type of shells they get in their specific inhabitat zone. In the case of present hermit crabs, *C.*

nathi and *C. zebra*, their distribution was found to be corrected especially with the vertical distribution of cerithid gastropod snail inhabiting the intertidal zone at Diu (Patel,1984). Moreover, the distribution of these two species of *Clibanarius* was reported to be restricted to mostly supra and mid-littoral zones of the intertidal zone at research site, which conforms the observation made by Vance (1972), Nyblade (1974), Bach et al. (1976) and Abram (1980) that *Clibanarius* sp. tend to occure mostly in higher intertidal level.

Hermit crabs have evolved to the point where they are dependent on a microhabitat as a resource (Provenzano, 1960; Vance,1972; Taylor,198 and 1981), and therefore it is rightly pointed out that non-availability of adequate shells causes heavy mortality of hermit crabs (Fotheringham, 1976). Since the gastropod shells influence the hermit crab populations in many ways, shell selection for them seems to be important criteria (Scully, 1983). The hermit crabs *C. nathi* and *C. zebra* inhabiting the Diu coast mostly occupy the empty gastropod shells of *Cerithium caeruleum*, *C.sinensis*, *Clypeomorus*, *Murex* sp., *Turbo intercoastalis* and *Nucella* sp. At majority of the areas in intertidal zone at Diu, both the present hermit crabs species showed their habitat preferences and indicated segregation of habitat selection to avoid competition for shell selection. Therefore, in such areas where individual species of the two hermit crabs were found to inhabit, *C. nathi* was observed to occupy larger size of gastropod shells available in those areas. Thus, differences between the habitat preferences by the two species of the *Clibanarius* hermit crabs inhabiting Diu coast could be interpreted as an attempt made by hermit crabs towards minimization of competition. However, an overlapping or co-existence between *C. nathi* and *C. zebra* was reported at certain places in the intertidal zone. Studies on distribution and variation in the frequency, abundance and density of various hermit crabs species during different months are very negligible (Ajmal Khan & Natarajan, 1981). The only work on such aspects of hermit crabs inhabiting the Vellar eastuary is of Ajmal Khan and Natarajan (1981), in which the distribution of the different species of hermit crabs during different months has been correlated with the variations in salinity and temperature.

5. IMPACT OF TOURISM RELATED ANTHROPOGENIC PRESSURE

The Arabian Sea along the South Saurashtra coastline is very rich in terms of biodiversity. This coastline has a broad continental shelf thereby extremely rich in intertidal and subtidal flora and fauna, because of its high primary productivity. This area supports some of the rich fishing ground in India. South Saurashtra coastline also contains numerous industrial belt and pilgrim tourist sites; these produce human activities which interfere on the coastal ecosystem. The anthropogenic effects by means of different human activities may affect the coastal belt to an unrecoverable level. Impacts of various human activities in the coastal zone are very complex and difficult to assess. The effects of various activities vary considerably from case to case or type to type not only due to the variety of tourism activities and sources but also due to the specificities of the receiving micro environmental and prevailing hydro morphological conditions (Vaghela et al., 2010). Therefore, overall anthropogenic effects in terms of tourism on the coastal region are a mosaic type composed of different types of inputs and mechanisms (Misra, 2004). As tourism activity has developed dramatically in this region in the recent years which brought about varieties of socio-economical, cultural and ecological changes. In many instances, little considerations have been given to the tourism factors with the consequent influence on the native intertidal population which damaged the intertidal landscapes.

As tourism is one of the most important for social and economic activities the coastal areas dome out to be at the receiving end. The coastal town of Diu is a seasonal tourist centre where people arrive for mostly recreational purpose. The most famous tourist spot is the Nagoa beach which is sandwiched between Jalandhar and Nagoa sampling sites. These tourist beaches actually the sandy extension of Jalandhar coastline, the tourist related activities are concentrated among this beach. Therefore, tourism related disturbances occur in the both the sampling sites by means of picking and fishing of different species for food purpose, harvesting of many molluscan species for handcraft and ornamental purposes, harvesting of many other species is also done for the other purposes and harvesting of marine algae for industrial and for the other uses. As it appears, the harvesting of marine algae for the different industrial purposes was singular most important devastating tourism activity which seriously affects the marine life. It is also noticed that aquatic life is harmed by fishing for fun or increasing in the turbidity from the stirring activity for motor boats or speed boats. In both Jalandhar and Nagoa sampling sites considerable damage has been done by tourist related activities, pollution and fishing harvesting.

On the other hand, Somanth is directly affected by tourism activities. The intertidal area under study is just besides the main center of tourism related human activities. The Somanth temple were massive amount of human activities were noticed. The Somnath sampling site in notoriously use by the visiting human population which freely perform all kinds of notorious human activities in this coast. The most seriously consequent of these tourism related human activities is habitat destruction which adversely and more cormonently affects the coastal ecosystem.

The results of present investigation showed some effects of tourism related human activities on the shore line on Diu and Somnath. As it appears, from the study that Somnath coast is more influenced by the tourism activities than the Diu coast line. This may be due to the fact that Somnath coast is more accessible for the human activities than the Diu coast. Diu is a seasonal tourist centre where the rocky shore line of Nagoa and Jalandhar are devoid of any direct human interference (Vaghera, 2008). Therefore, the tourism activity was not a limited factor for the population ecology of the key intertidal species at Diu. However, the tourist related human interference was indeed a limiting factor for the intertidal population at Somnath (Misra and Kundu, 2005).

The overall results from the both Diu and Somnath sampling sites showed influence of tourism related human activities of the coastal population. Disturbing the local population by unnecessary fishing and the habitat destruction by tourism related activities, possibly cause damage the intertidal macro-faunal population. The most severe anthropogenic impact however, was the harvesting of marine algae when totally destruction of habitat was done. The result of population ecological studies clearly vouch for this kind of tourism related effect.

6. OVERALL ASSESSMENT OF HYPOTHESES TESTED

Discussing the overall assessment of the present study it was observed that, the south Saurashtra coastline is characterized by its rocky, sandy and muddy intertidal zones harboring rich and varied diversity of flora and fauna (Nayar & 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 marine belt. Therefore, it was of utmost importance to make a detailed inventory of the community of the Saurashtra Coast, their ecological attributes with respect to varying environmental conditions. Except for few works from this very lab on the ecology of certain limpets (Prasad, 1984), turbinids (Malli, 1993; Patel, 2002; Misra, 2004) and some cerithids (Patel, 1984; Patel, 2002; Gohil, 2007), no report has been available on the macrofaunal resources of this region. This situation required a systematic overall backup study to be acquainted with their present status.

In the present work, two intertidal rocky shores on the southern Saurashtra coastline (Western India) at Somnath and Diu were selected and a monthly survey of the population dynamics was made in order to understand the seasonal fluctuation in population on the rocky intertidal mollusks in relation to varying anthropogenic pressure. The Union Territory of Diu, a seasonal tourist center, is devoid of industrial and anthropogenic pressure of high magnitude. Therefore, the present study reports the biological nature of the intertidal areas around the two research sites in response to the anthropogenic pressure on the intertidal community keeping almost all physical parameters constant.

Vertical zonation of plants and animals in the intertidal zone is conspicuous feature of all sea shores (Stephenson and Stephenson, 1972). Most early hypotheses about the causation of this zonation emphasized the tide as a primary factor. Connell (1972) reviewed the evidence that not only the physical factors probably set the upper limits of species distribution but, also, that biological interactions with other competitors and natural enemies may affect the lower limit of distributions. Conditions for growth and survival of organisms in either the presence or absence of biological interactions are often better lower than higher on the shore (Connell, 1972; Frank, 1965); Paine, 1969 (herbivore gastropods)). Low on the submersion time is longer, algal production is greater and physical conditions are less harsh.

The orderly replacement of the dominant species along the emersion or immersion gradient is a prominent feature of the rocky intertidal zone. Each species gains a competitive advantage within only a given narrow segment of the gradient and if not suppressed there by predators, it overcomes all other species and dominates the rocky surface wherever the environmental conditions defining this segment prevail (Connell, 1972). Hence, within a given geographical region, the dominance by an intertidal level by a certain species indicates the prevalence of a defined set of the environmental gradient of that level. The domination of a vertical zone of a given site along the shore by a given species will point to the local prevalence of an environmental variable with range of values determined by the acting gradient. It has been suggested that the high species diversity of the tropical communities is an outcome of a subtle ecological segregations which restricts the distribution of each of the coexisting species to an exclusive and narrow range along one and several niche dimensions (Roughgarden, 1988).

As it is suggested that the factors that control the survival of a particular herbivore species is the availability of vegetation and variety of the edible species on the rocky intertidal zone (Hay and Steinberg, 1992). Several of these herbivores strongly affect seaweed community structure and dynamics (Misra, 2004). To avoid, minimize and to tolerate the damage due to herbivores, seaweeds exhibit several adaptations such as decreased attractiveness or tolerance to herbivores (Duffy and Hay, 1990). Among a diverse array of adaptation to reduce the attractiveness, chemical defense is one of the most conspicuous strategies manifested by seaweed species dwelling on the rocky intertidal belts or tropical reef environments where the herbivore pressure is quite high (Hay and Steinberg, 1992; Paul, 1992). So for that aspect, for a survival of a herbivore species, it is important to search out not only the presence of edible species but the species with no or less chemical metabolites with no or very less side effects or if possible to adapt any strategy to get rid of the harmful effect of the toxic chemicals. The differential population dynamics for the key species studied at the two selected stationed mentioned above lead to a search for the controlling forces that determine the distribution of these species on the rocky intertidal shore. Obviously, it is the food availability for the species that should be a key factor. For this purpose, the food habitat was studied for our marker species at both the station to find out whether it could lead to any solution to the problem raised. Again, as one of the two stations is known to offer an adverse condition to its dwellers, so it was aimed to find out any alternative food sources in the disturbed condition by these organisms.

RESULTS OF HYPOTHESES TESTED

Hypotheses tested in this proposed work were made in Null form. The results of the present investigations ratified and tested these hypotheses which are as follows:

No.	Hypothesis Tested	Result
1	No significant spatial variations will be visible in the general macrofaunal diversity between the coastlines of Diu and Somanth.	False
2	No significant temporal variations will be visible in the general macro faunal diversity between the coastlines of Diu and Somanth.	True
3	There will be no significant spatial variations in the population density or abundance between the coastlines of Diu and Somanth.	True
4	There will be no significant temporal variations in the population density or abundance between the coastlines of Diu and Somanth.	True
5	Spatial distribution of the intertidal organisms will not be responsive against the pressure made on the system by tourism related human activities.	False

SUMMARY

1. The present study was undertaken to prepare a comparative database of the intertidal macrofauna and the current status of ecological health of the intertidal area in relation to anthropogenic pressure in terms of tourism activities, by measuring population dynamics of few key molluscan and hermit crab species, of the Somnath and Diu coasts in the Western coast of India. The investigation was to study the biological nature and zonation of the intertidal habitat around the research sites, diversity of the rocky, intertidal macro fauna around the selected locations, to evaluate the ecological status of the intertidal belt of the study sites by steadying the spatial and temporal fluctuation of the population dynamics of few key species of these coasts and to investigate the nature and degree of tourism related anthropogenic pressure and the possible threatening factors to the coastal region.

2. The present investigation reported a data base of intertidal flora and fauna and discussed the habitat type and the response of the dwellers. The study pointed out the existing threats of the interference of the human with the marine system that affect the coastal health. The level and degree of human interference was studied and the effectiveness of these in population distribution was revealed.

3. Present study revealed that this coastal area, being predominantly rocky and rocky-sandy, is markedly dominated by few groups of animals. It was also observed that the slope and the substratum type of the different sites of this area were not uniform and the exposure of the intertidal belt is also not significantly long. Small to moderate sized sand patches studded the continuity of the predominantly rocky shore. Though never given priority, the Southern Coastline of the Saurashtra Peninsula offers a very healthy condition to its dwellers.

4. From present study, it can be inferred that both Somnath and Diu are suitable places for all the species studied since these shores provide ideal intertidal conditions as far as the coast characteristics are concerned. In the intertidal system, different assemblages of intertidal macrofauna occupy different levels of the intertidal zones, each species showing preference to a particular zone or level where conditions were most favorable for its survival and growth. Diu coast is restricted by stiff vertical hillocks making the flat area totally undistinguishable as upper, middle and lower littoral zones. Thus, the animals of the upper and middle littoral zones share same condition. This makes its higher abundance and density values at Diu station.

5. Results of the statistical tests showed that in most of the cases no significant micro-spatial or temporal differences were observed in the population ecology of the species studied. The study also revealed that micro-spatial and temporal variations in the population ecology of few dominant species of this coastline were not significantly different between both stations and also between seasons in some cases. *C. radiata* generally inhabits upper littoral zone but also observed in middle and lower littoral zones in lesser numbers. This animal showed the habitat preference mostly in the pools and puddles up the upper littoral zone during the low tide and feeds on the thick vegetation of Chlorophyceae and Rhodophyceae . The abundance of this species was almost similar in all the three littoral zones, indicating its movement for feeding and other activities. The results suggest that both the coasts of Diu can be considered as a continuous shoreline as per the distribution of *C. radiata* is concern

6. *O. verruculatum* showed the typical habitat preference by conspicuously absence from the lower littoral zone. This species, being a voracious feeder on algae, showed greater density and abundance in middle littoral and lower part of upper littoral zone. The result suggested no micro-spatial variation in the density and abundance values of this species. The density value showed high richness of the species in the upper littoral zone and middle littoral zones at Somnath throughout the year. There was no significant temporal variation

observed but the animals might have moved to the deeper regions to avoid exposure to heat. This reflected the reduced density and abundance values during the summer months. The intertidal zone of Somnath is more flat than that of Diu and covered with rich intertidal vegetation, which is feeding ground for this species. This possibly is the reason for ample abundance of this species in this region

7. *C. caeruleum* showed temporal variations during summer months. This species was found to be distributed in upper and middle littoral zones and lesser distribution was observed in the lower littoral zones. However, these were not apparent that this animal was not preferential in the habitat selection and inhabitat almost all vertical areas with more or less equal evenness. *C. caeruleum* is a small sized animal which abundantly occur in the shoreline and prefer the substratum which is rich in organic matter. However, in this case slightly higher density and abundance values were observed in the upper littoral zone than that of the Jalandhar sampling sites. No clear cut seasonal variations in Somanth were observed in any of the sampling sites of A,B and C. The result also showed that the distribution of the species was more or less even in this coastline.

8. In case of *T. insulaechorab* which is a typical inhabited of middle littoral and lower littoral zones showed temporal variations in the richness. The relative evenness of this species was more or less similar in lower and lower part of middle littoral zone. These particular species is normally avoiding exposure during low tide and voracious feeder on marine algae which was present greater abundance in lower part of intertidal zone and sub-tidal zone. The seasonal variations were exactly similar to that of Jalandhar.

9. *Mancinella bufo* is large signed gastropods which are normally seen associated with green algae in the vertical zones. In case of *M. bufo,* no clear cut seasonal variations were observed which may be due to the local migration of this highly motile species from upper littoral zones to avoid excessive heat, desiccation and

rough tidal activities especially in the none availability of algal species in the upper littoral zones of Jalandhar sampling during summer and monsoon months.

10. *R. sinensis* prefers lower parts of middle littoral zones and lower littoral zones. This small gastropod species mostly grazes on the pheophyceae and rarely seen in the upper littoral and spray zones. Seasonal variations were not evident seems this species remained in the relatively unexposed lower littoral zone. This is certainly indicated that the movement of this species between the vertical zones depends on the availabilities of food. The species invades upper littoral zones during the late winter and summer months possibly to avoid the incoming species from upper and middle littoral zones during the summer and monsoon months. In case of *R. sinensis*, neither micro-spatial nor the season wise density values showed any significant difference. It gives a clear indication that either the conditions offered to them were adequate or they had acquired resistance to the existing conditions.

11. In case of *C. milliaris* again non definite seasonal variation was observed. The animal was mostly present in the more productive middle and lower littoral zones. It is possible that the distribution at the two stations was regulated by physical factors in a large scale. In spite of having the higher density value at Diu, it also had higher abundance value. This indicates the condition at the upper littoral zone that was quite an unusual habitat for survival.

12. In the case of *C. nathi* and *C. zebra* no clear seasonal variations were observed in any of the three vertical zones. *C. nathi*, the brown hermit crab normally dwell the upper middle littoral zones. The other hermit crab species studied *Clibanarius zebra* showed slightly different habitat selection than *C. nathi*. It is observed that this species mainly inhabits the lower part of the upper littoral zones. Various ecological attributes did not show clear cut variations between the two littoral zones. *C. zebra* shares the space food with other hermit crab species especially *C. nathi* and in the present investigation successful co-existence of these species was noticed.

13. South Saurashtra coastline also contains numerous industrial belt and pilgrim tourist sites; these produce human activities which interfere on the coastal ecosystem. The coastal town of Diu is a seasonal tourist centre where people come for mostly recreational purpose. The most famous tourist spot is the Nagoa beach which is sandwiched between Jalandhar and Nagoa sampling sites. Therefore, tourism related disturbances occur in the both the sampling sites by means of picking and fishing of different species for food purpose, harvesting of many molluscan species for handcraft and ornamental purposes, harvesting of many other species is also done for the other purposes and harvesting of marine algae for industrial and for the other uses. As it appears, the harvesting of marine algae for the different industrial purposes was singular most important devastating tourism activity which seriously affects the marine life. It is also noticed that aquatic life is harmed by fishing for fun or increasing in the turbidity from the stirring activity for motor boats or speed boats.

14. Somanth is directly affected by tourism activities. The intertidal area under study is just besides the main center of tourism related human activities. The Somanth temple were massive amount of human activities were noticed. The Somnath sampling site in notoriously use by the visiting human population which freely perform all kinds of notorious human activities in this coast. The most seriously consequent of these tourism related human activities is habitat destruction which adversely and more cormonently affects the coastal ecosystem. As it appears, from the study that Somnath coast is more influenced by the tourism activities than the Diu coast line. This may be due to the fact that Somnath coast is more accessible for the human activities than the Diu coast.

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TABLES AND FIGURES

Table- 1 Faunal Diversity at various sampling sites of Somnath and Diu coasts: **Phylum Poriphera (Sponges)**

Name of Species	Somnath	Jalandhar	Nagoa
Chalena sp.	+	+	+
Chondrilla Sp.	-	+	+
Euspongia sp.	+	+	+
Grantia sp.	-	+	-
Halichondria sp.	+	+	+
Leucosolenia punctata	+	-	+
Microctona prolifera	-	+	+
Oscarella sp.	-	+	+

Table- 2 Faunal Diversity at various sampling sites of Somnath and Diu coasts: **Phylum Coelentarata**

Name of Species	Somnath	Jalandhar	Nagoa
Favia favulus	-	+	+
Goniastraea pectinata	-	-	+
Montipora explanata	-	+	+
Madrepora sp.	-	-	+
Portis lutea	+	+	-
Dendraphyllia	-	+	+
Telia sp.	+	+	+
Obelia sp.	+	+	-
Spongodes sp.	-	+	+
Utricina sp.	+	+	+
Zoanthus sp.	+	+	+

Table- 3 Faunal Diversity at various sampling sites of Somnath and Diu coasts: Phylums **Ctenophora, Platyhelminthes** and **Nimartea.**

Name of Species	Somnath	Jalandhar	Nagoa
Ctenophora			
*Coeloplana sp.**	-	+	+
Platyhelminthes			
*Bipalium marinum**	-	+	-
Nimartea			
Lineus marinus	-	+	+
*Lineus sanuineus**	-	-	+

*Seen only once during entire study period

Table- 4 Faunal Diversity at various sampling sites of Somnath and Diu coasts: Phylum **Annelida.**

Name of Species	Somnath	Jalandhar	Nagoa
Chetopterus chetopterus	+	+	+
Eunice viridis	-	+	-
Glycera iridis	+	+	+
Heteroneris sp.	+	+	+
Neris sp.	+	+	+
Sabella pavonica	+	-	+
Serpula sp.	+	+	-
Terebella sp.	+	+	-

Table- 5 Faunal Diversity at various sampling sites of Somnath and Diu coasts: Phylum **Arthropoda.**

Name of Species	Somnath	Jalandhar	Nagoa
Balanus amphirite	+	+	+
Bopyrus sp.	-	+	-
Carainus maenas	+	+	+
Clibanarius nathi	+	+	+
Clibanarius zebra	+	+	+
Gammarus sp.	-	+	-
Hippa sp.	-	+	+
Lepas sp.	-	-	+
Pagurus longicarpus	+	+	+
Pinaeus monodon	+	+	+
Pinaeus indicus	+	+	+
Palinurus sp.	+	+	-
Scopimera globosa	+	-	+
Squilla sqilla	+	+	+

Table- 6 Faunal Diversity at various sampling sites of Somnath and Diu coasts: Phylum **Mollusca.**

Name of Species	Somnath	Jalandhar	Nagoa
Aeolis sp.	-	+	-
Aplysia oculifera	+	+	+
Arca ventricosa	+	+	-
Astrea semicostata	+	+	-
Barbatia obliquata	+	-	+
Chantharus spiralis	-	-	+
Chantharus undata	-	+	+
Cellena radiata	+	+	+
Cerithium careuleum	+	+	+
Chicoreus brunneus	+	+	-

Chicoreus kilburni	-	+	+
Conus miliaris	+	+	-
Conus biliosus	-	+	-
Conus achatinus	+	-	+
Clypeomorus moniliferus	+	-	+
Cronia constracta	+	+	-
Cyprinea sp.	+	+	+
Chiton sp.	+	+	+
Doris sp.	-	+	-
Euchelus quadricarinatus	-	-	+
Hastula sp	-	+	+
Haliotis sp.	-	+	+
Loritta sp.	+	+	+
Loligo sp.	+	+	-
Mitra scutulata	-	-	+
Monodonta australis	-	+	+
Murex sp.	+	+	+
Morula granulota	-	-	+
Mya arenaria	-	-	+
Mancinnella bufo	+	+	+
Narita undata	+	+	+
Narita albiella	+	+	+
Oliva olive	+	+	+
Octopus vulgaris	+	+	+
Ostrea sp.	+	+	+
Purpura panama	-	+	-
Perna indicus	-	+	+
Perpura sp.	-	+	-
Pinctada sp.	-	+	+
Pecten maximus	-	+	-
Patella vulgate	+	+	+
Rhinoclevis sinensis	+	+	+
Siphonaria siphonaria	+	+	+
Tibia sp.	+	+	-
Thalotia sp.	-	-	+
Turbo coronetus	+	+	+
Turbo intercostalis	+	+	+
Trochus sp.	+	+	+
Teleoscopium teleoscopium	+	-	+
Venus sp.	-	-	+
Xancus pyrum	+	+	+
Zooanthus sp.	+	+	+
Chiton peregrinus	+	+	+
Onchidium verruculatum	+	+	-

Table- 7 Faunal Diversity at various sampling sites of Somnath and Diu coasts: Phylum **Echinodermata.**

Name of Species	Somnath	Jalandhar	Nagoa
Antedon sp.	+	+	+
Anthena sp.	+	+	+
Clymeaster sp.	-	+	+
Echinus sp.	+	+	+
Holothuria sp.	+	+	-
Ophioderma sp.	-	-	+
Pentaceros sp.	+	+	+
Strongylocenttotus sp.	+	+	+

Table- 8 Faunal Diversity at various sampling sites of Somnath and Diu coasts: Phylums **Hemichordata** and **Chordata.**

Name of Species	Somnath	Jalandhar	Nagoa
Hemichordata			
Hadmania indica	+	+	-
*Saccoglossus kowalerkii**	-	-	+
Chordata			
Balone strogylurus	+	+	+
Bolephthalnus boddaerli	+	+	+
Bolephthalmus dentatus	+	+	-
Gobius criatatus	+	+	+
Hemiramphus georgii	+	+	+
Mugil jerdoni	+	+	+
Mugil poicilus	+	+	+
Periphthalmus dipes	+	+	+
Tetradon inermis	+	+	-

*Seen only once

Table- 9 Faunal diversity at various sampling sites of Somnath and Diu coasts: Class **Chlorophyceae**

Name of Species	Somnath	Jalandhar	Nagoa
Enteromorpha compressa	+	+	+
Ulva fasciata	+	+	+
Ulva lactuca	+	+	+
Ulva syenophylla	+	+	-
Acrosiphonia crientas	-	+	+
Chaetomorpha antnnina	-	-	+
Chaetomorpha crystallina	-	+	+
Cladophora crystallina	+	+	+
Boergesenia forbesii	-	+	-
Chamaedoris auriculata	-	-	+
Valonia aegagropila	-	+	+
Bryopsis plumose	+	+	+
Caulerpa racemosa	+	-	+
Caulerpa taxifolia	+	+	-
Halimeda tuna	+	+	-
Codium dwarkness	+	+	+
Codium tomentosum	+	+	+

Table- 10 Algal diversity at various sampling sites of Somnath and Diu coasts: Class **Phaeophyceae.**

Name of Species	Somnath	Jalandhar	Nagoa
Padina gymnospora	+	+	+
Padina tetrastromatica	+	+	-
Sargassum tenerrimum	+	+	+
Sargassum cinctum	+	+	+
Cystoseira indicia	-	-	+

Table- 11 Algal diversity at various sampling sites of Somnath and Diu coasts: Class **Rhodophyceae**

Name of Species	Somnath	Jalandhar	Nagoa
Gelidium pusillum	+	+	+
Gelidium acerosa	-	+	-
Gracilaria corticata	+	+	+
Grateloupia lithophila	-	-	+
Amphiroa anceps	-	+	-
Hypnea valentiae	+	+	-
Hypnea musciformis	+	+	+
Sarconema filiforme	-	-	+
Champia compressa	+	+	+
Centroceras clavulatum	-	+	+
Ceramium rubrum auctorum	-	+	+
Chondria dasyphylla	+	+	-
Laurencia papillosa	+	+	+
Odonthalia veravalensis	-	-	+

Table- 12 Result of the one-way ANOVA of the values of different ecological attributes amongst the sampling sites of Diu station for micro spatial variations of the seven species studied. The t-critical value is 2.81, and * denotes significance at P < 5 %.

SPECIES	LITTORAL ZONES	DENSITY	ABUNDANCE	FREQUENCY
C. radiate	Upper	1.00	0.30	0.79
	Middle	0.82	0.56	1.62
	Lower	1.66	1.37	1.04
O. verruculatum	Upper	1.18	1.71	1.08
	Middle	4.38*	4.65*	3.13*
	Lower	-	-	1.00
C. caeruleum	Upper	0.75	0.82	0.64
	Middle	0.60	0.64	0.07
	Lower	0.16	0.12	0.54
T. insulaechorab	Upper	1.95	0.60	2.77
	Middle	9.34*	1.44	0.35
	Lower	1.76	1.55	0.91

Table- 13 Result of the paired t-test of the the mean values of different ecological attributes of the species studied, in each of the littoral zone, between two sampling sites (A and B) of Jalandhar for micro spatial variations. The t-critical value is 2. 073, and * denotes significance at P < 5 %.

Species	Littoral Zones	Density	Abundance	Frequency
C. radiata	Upper	1.68	0.91	0.80
	Middle	0.13	0.92	0.71
	Lower	0.55	0.25	057
O. verruculatum	Upper	1.49	0.64	0.76
	Middle	1.80	0.30	1.28
	Lower	-	-	1
C. caeruleum	Upper	1.45	1.07	0.88
	Middle	0.90	1.31	0.15
	Lower	0.06	0.41	0.33
T. insulaechorab	Upper	0.63	0.12	1.52
	Middle	5.20*	0.80	0.35
	Lower	0.41	2.97*	0.61

Table- 14 Result of the paired t-test of the mean values of different ecological attributes of the species studied, in each of the littoral zone, between two sampling sites (A and B) of Nagoa for micro spatial variations. The t-critical value is 2. 073, and * denotes significance at P < 5 %.

Species	Littoral Zones	Density	Abundance	Frequency
C. radiate	Upper	0.61	0.19	0.72
	Middle	0.35	0.58	0.48
	Lower	0.11	0.20	0
O. verruculatum	Upper	1.21	1.99	1.55
	Middle	2.95*	3.32*	2.66*
	Lower	-	-	-
C. caeruleum	Upper	0.52	0.84	0.65
	Middle	0.27	0.46	0.14
	Lower	0.58	0.40	1.26
T. insulaechorab	Upper	1.09	0.11	1.16
	Middle	076	1.79	0.88
	Lower	1.83	0.94	1.07

Table- 15 Result of the one-way ANOVA of the values of different ecological attributes amongst the sampling sites of Somnath station for micro spatial variations of the seven species studied. The t-critical value is 3.284, and * denotes significance at P < 5 %.

Species	Littoral Zones	Density	Abundance	Frequency
O. verruculatum	Upper	0.10	0.15	0.09
	Middle	0.86	0.42	1.08
	Lower	0.41	0.03	0.46
C. caeruleum	Upper	0.89	0.39	0.41
	Middle	0.32	0.66	0.25
	Lower	0.09	0.00	0.25
M. bufo	Upper	2.30	2.89	1.32
	Middle	0.39	0.10	2.11
	Lower	0.47	0.06	0.03
R. sinensis	Upper	0.04	0.58	0.32
	Middle	1.07	0.09	1.38
	Lower	0.90	0.10	1.77
C. miliaris	Upper	0.72	0.68	1.76
	Middle	0.45	0.07	0.13
	Lower	3.20	2.32	1.78
C. nathi	Upper	0.27	0.14	0.40
	Middle	0.21	0.65	0.84
	Lower	0.02	0.84	0.03
C. zebra	Upper	0.24	0.90	2.41
	Middle	0.60	0.06	0.16
	Lower	1.38	0.27	0.05

Table- 16 Result of the paired t-test of the mean values of different ecological attributes of seven species studied, in each of the littoral zone, between two sampling sites (A and B) of Somanth for micro spatial variations. The t-critical value is 2.738, and * denotes significance at P < 5 %.

Species	Littoral Zones	Density	Abundance	Frequency
O. verruculatum	Upper	0.47	0.48	0
	Middle	1.18	0.38	1.31
	Lower	0.71	0.24	0.76
C. caeruleum	Upper	0.42	0.74	0.45
	Middle	0.69	0.39	0.75
	Lower	0.07	0.11	0.18
M. bufo	Upper	0.46	0.17	0.39
	Middle	0.21	0.42	0.96
	Lower	0.74	0.03	0.13
R. sinensis	Upper	0.13	0.97	0.17
	Middle	1.22	0.43	1.28
	Lower	0.17	0.45	0.85
C. miliiaris	Upper	1.08	0.23	1.44
	Middle	0.83	0.43	0.34
	Lower	1.54	0.70	1.96
C. nathi	Upper	0.39	0.56	0
	Middle	0.38	0.52	0.84
	Lower	0.25	1.27	0.17
C. zebra	Upper	0.33	1.23	2.38
	Middle	0.57	0	0.51
	Lower	1.44	0.35	0.19

Table- 17 Result of the paired t-test of the mean values of different ecological attributes of seven species studied, in each of the littoral zone, between two sampling sites (B and C) of Somanth for micro spatial variations. The t-critical value is 2.738, and * denotes significance at P < 5 %.

Species	Littoral Zones	Density	Abundance	Frequency
O. verruculatum	Upper	0.31	0.48	0.56
	Middle	0.87	0.54	1.02
	Lower	0.14	0.22	0.20
C. caeruleum	Upper	0.98	0.14	1.07
	Middle	0.57	1.02	0.22
	Lower	0.37	0.04	0.68
M. bufo	Upper	2.23	2.23	1.52
	Middle	0.82	0	1.94
	Lower	0.88	0.28	0.26
R. sinsensis	Upper	0.34	0.50	0.69
	Middle	1.29	0.35	1.59
	Lower	1.29	0.12	1.81
C. milliaris	Upper	0.69	0.92	1.66
	Middle	0.09	0.14	0.15
	Lower	2.44	1.35	1.23
C. nathi	Upper	0.38	0.23	0.80
	Middle	0.73	1.23	1.34
	Lower	0.11	0.32	0.12
C. zebra	Upper	0.66	0.70	1.34
	Middle	1.06	0.30	0.42
	Lower	0.22	0.36	0.14

Table- 18 Result of the paired t-test of the mean values of different ecological attributes of seven species studied, in each of the littoral zone, between two sampling sites (A and C) of Somanth for micro spatial variations. The t-critical value is 2.738, and * denotes significance at P < 5 %.

Species	Littoral Zones	Density	Abundance	Frequency
O. verruculatum	Upper	0.13	0.02	0.34
	Middle	0.38	0.82	0.45
	Lower	0.96	0	0.96
C caeruleum	Upper	1.31	0.75	0.40
	Middle	0.10	0.81	0.46
	Lower	0.32	0.04	0.48
M. bufo	Upper	1.62	2.19	1.17
	Middle	0.66	0.44	1.14
	Lower	0.07	0.29	0.13
R. sinensis	Upper	0.16	0.63	0.76
	Middle	-	0.03	0.21
	Lower	1.03	0.31	1.05
C. milliaris	Upper	057	1.05	0
	Middle	0.89	0.24	0.54
	Lower	1.13	1.93	0.54
C. nathi	Upper	0.69	0.29	0.70
	Middle	0.21	0.58	0.41
	Lower	0.11	1.09	0.25
C. zebra	Upper	0.37	0.71	0.63
	Middle	0.52	0.29	0
	Lower	1.61	0.79	0.30

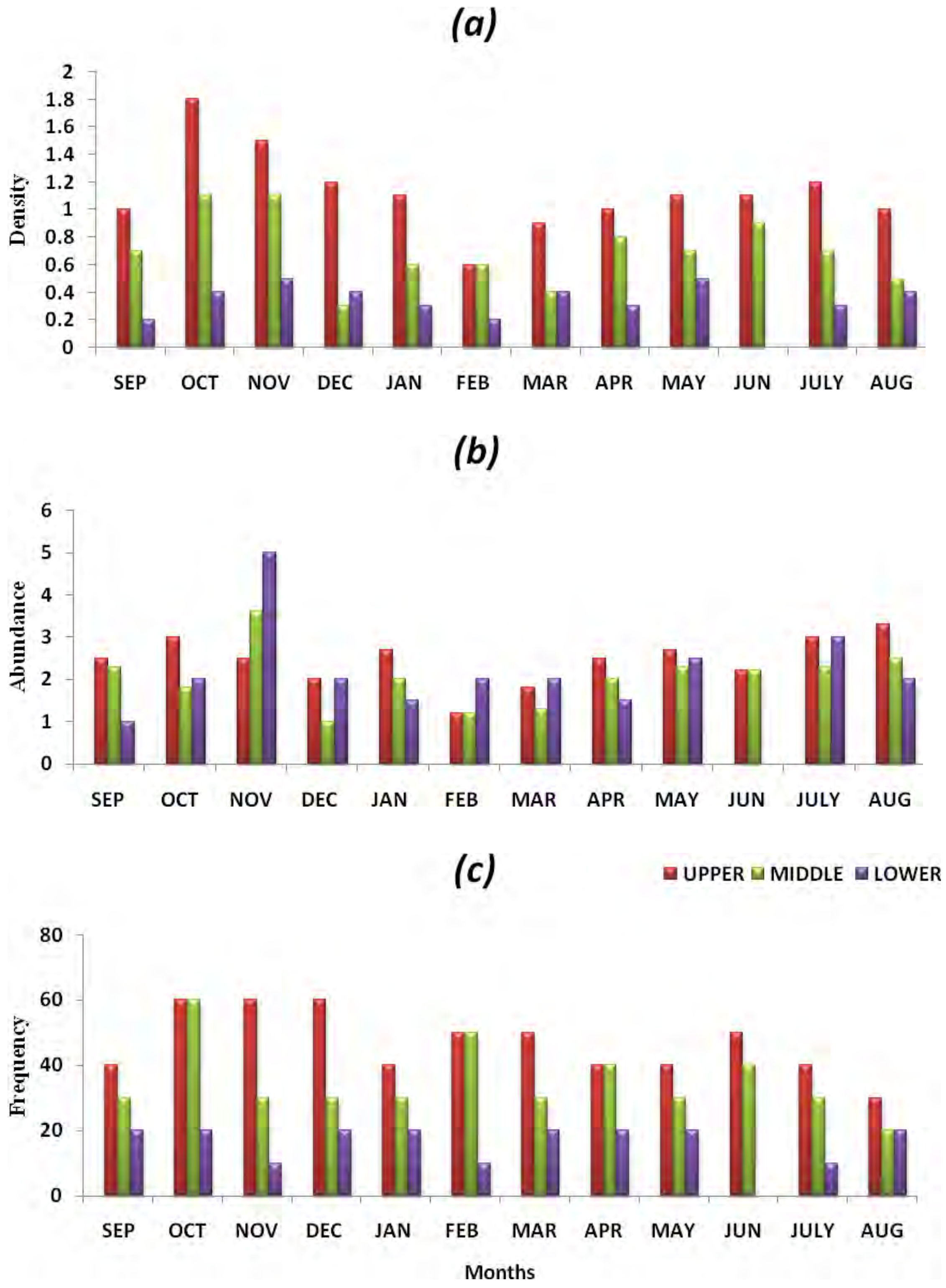

Fig. 1. Monthly variations in various ecological attributes of *Cellena radiata* in different littoral zones at Jalandhar site-A from September 2008 to August 2009.

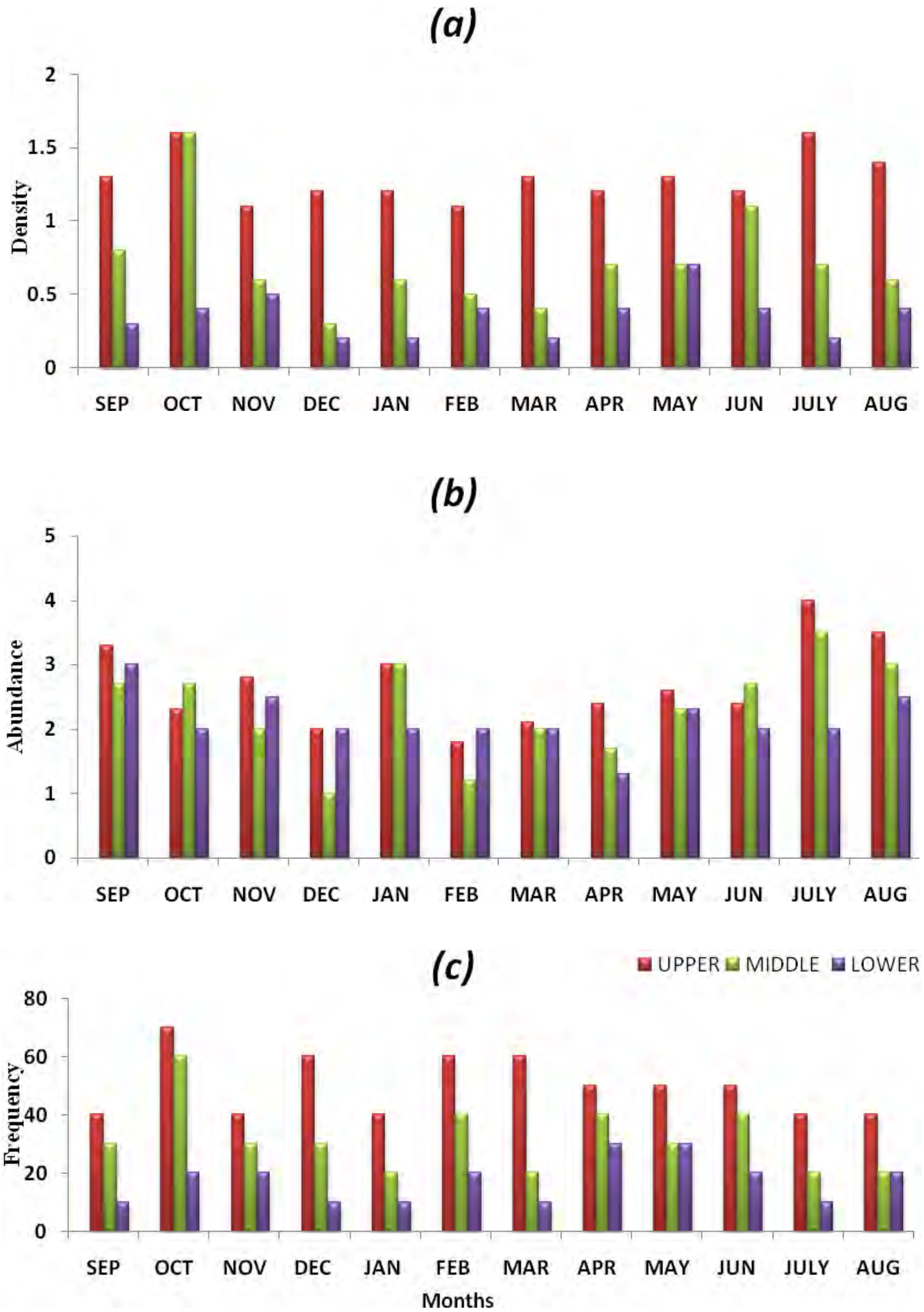

Fig. 2. Monthly variations in various ecological attributes of *Cellena radiata* in different littoral zones at Jalandhar site-B from September 2008 to August 2009

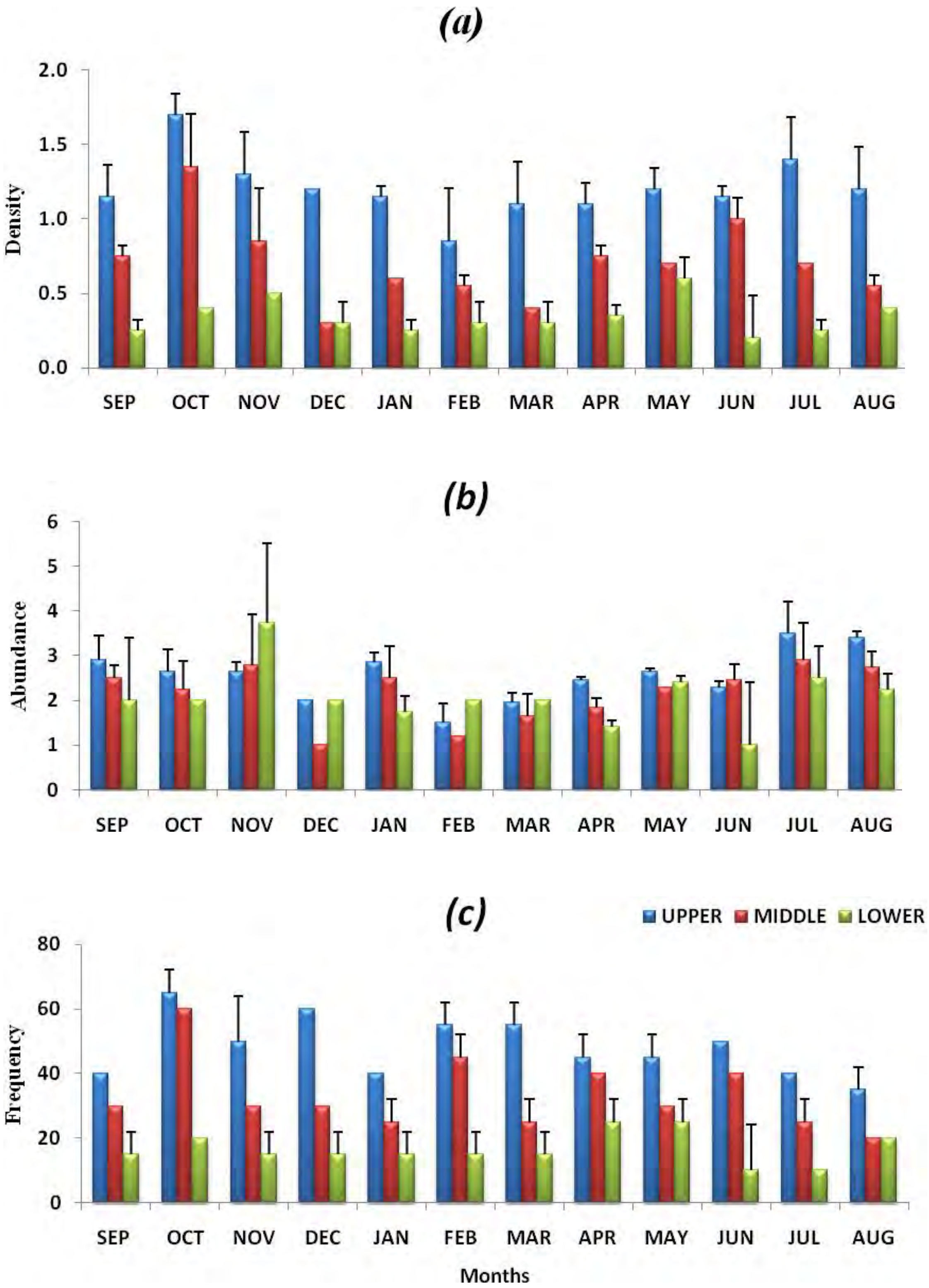

Fig. 3. Monthly variations in various ecological attributes of *Cellena radiata* in different littoral zones at Jalandher site from September 2008 to August 2009. Values revealed mean of two micro spatial sampling sites within Jalandher shoreline, standard bar represents fixed SD.

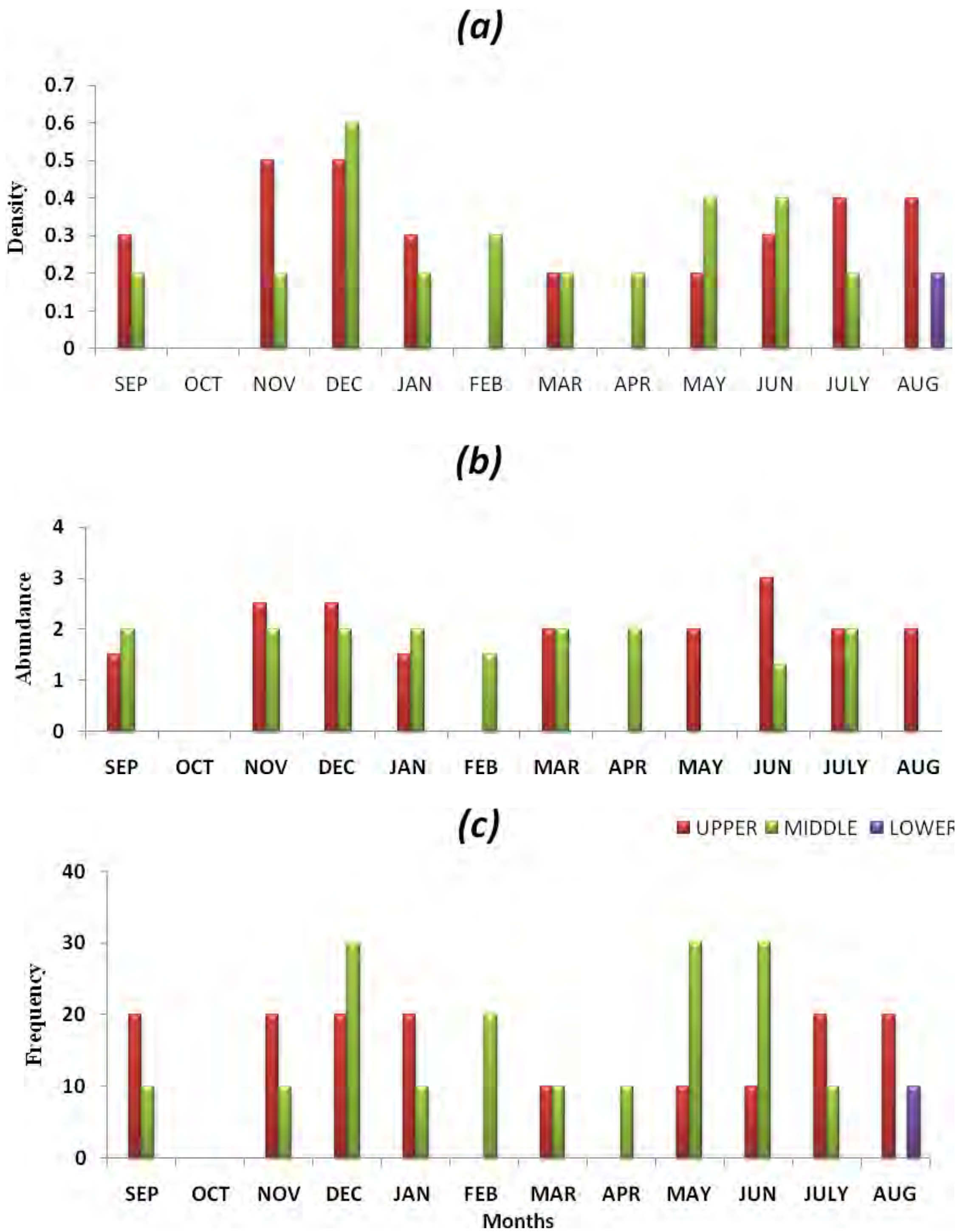

Fig. 4. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Jalandhar Site-A from September 2008 to August 2009.

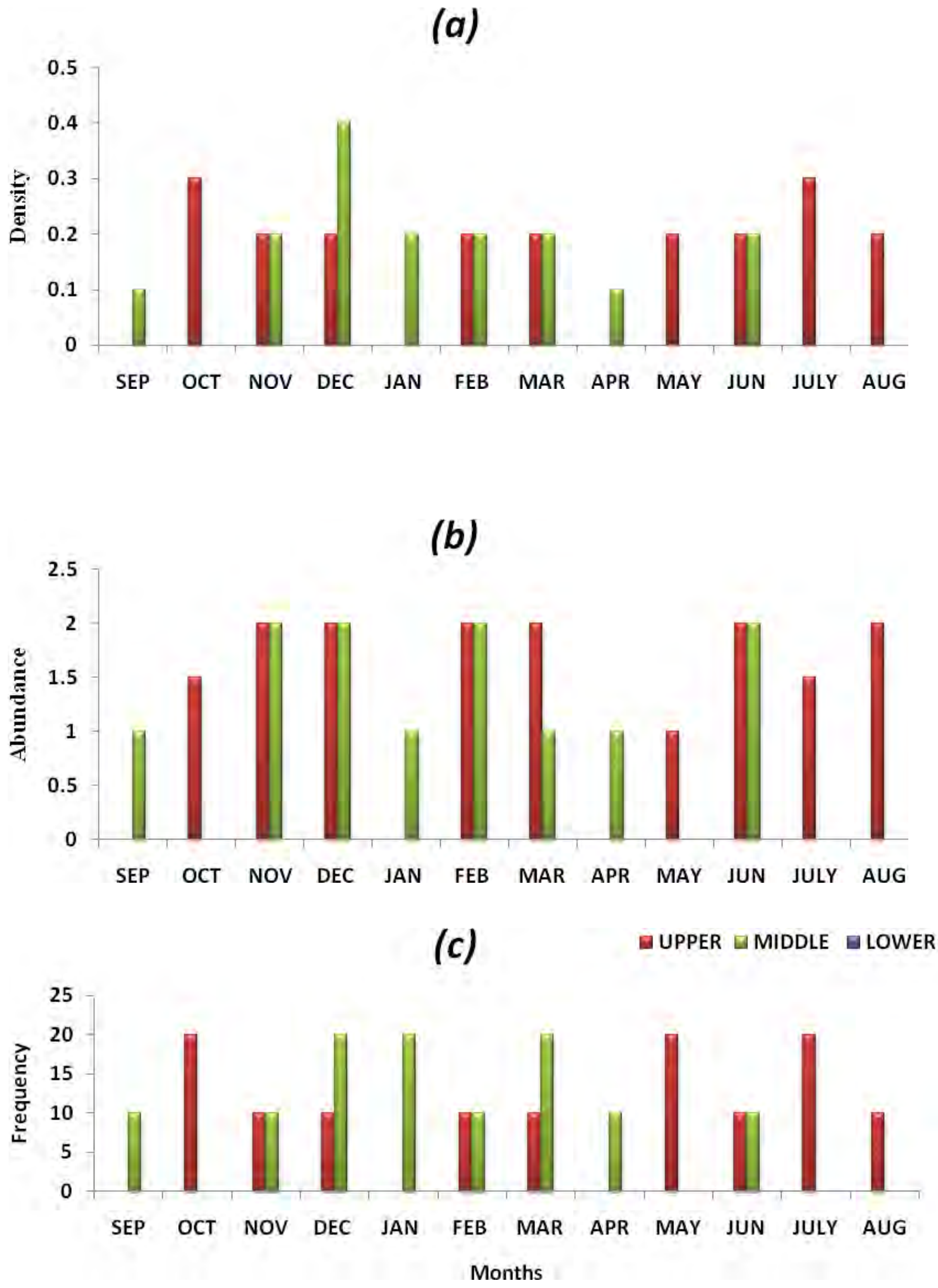

Fig. 5. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Jalandhar site-B from September 2008 to August 2009.

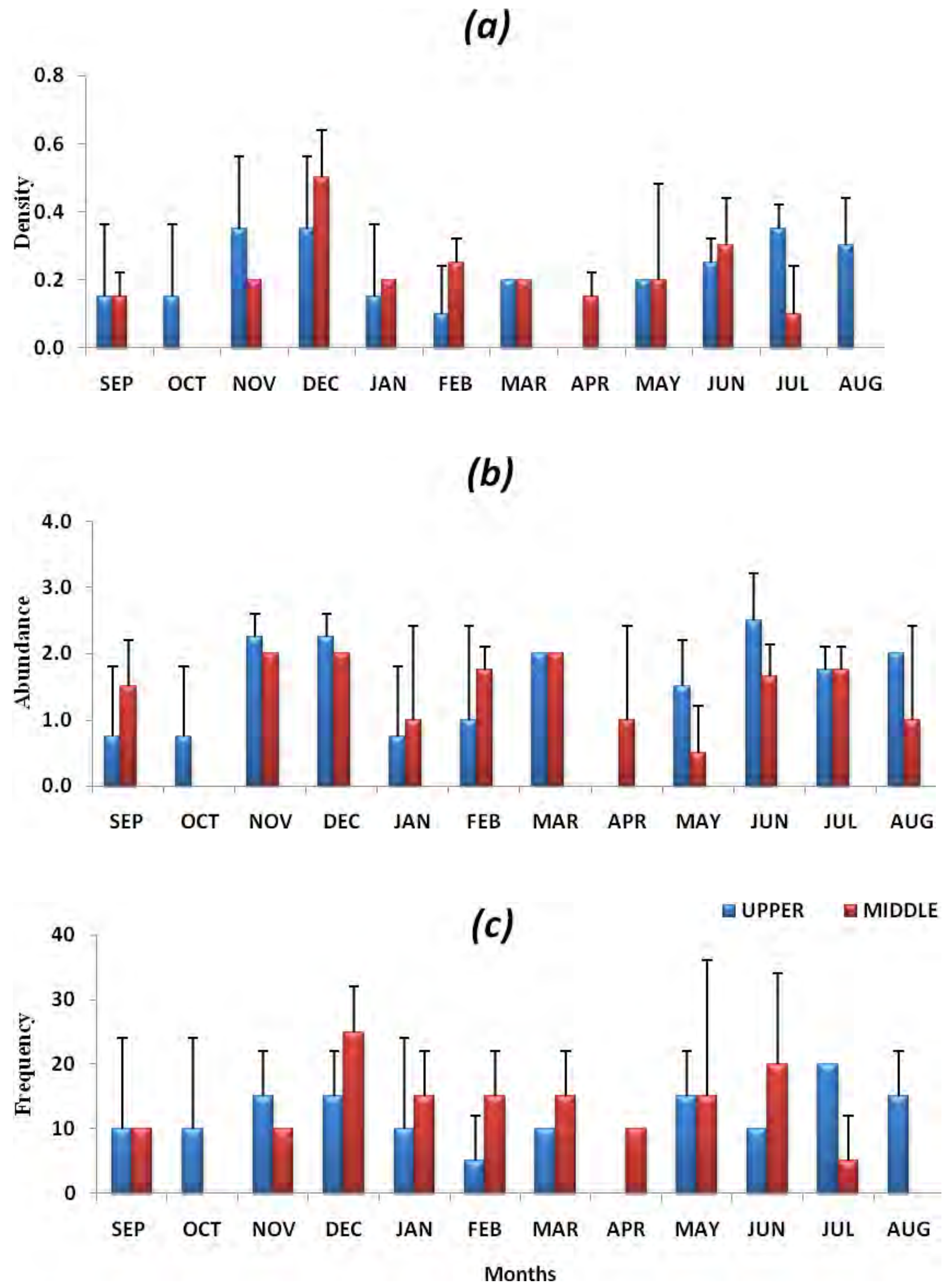

Fig. 6. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Jalandher site from September 2008 to August 2009. Values revealed mean from two micro spatial sampling sites within Jalandher shoreline, standard bar represents fixed SD.

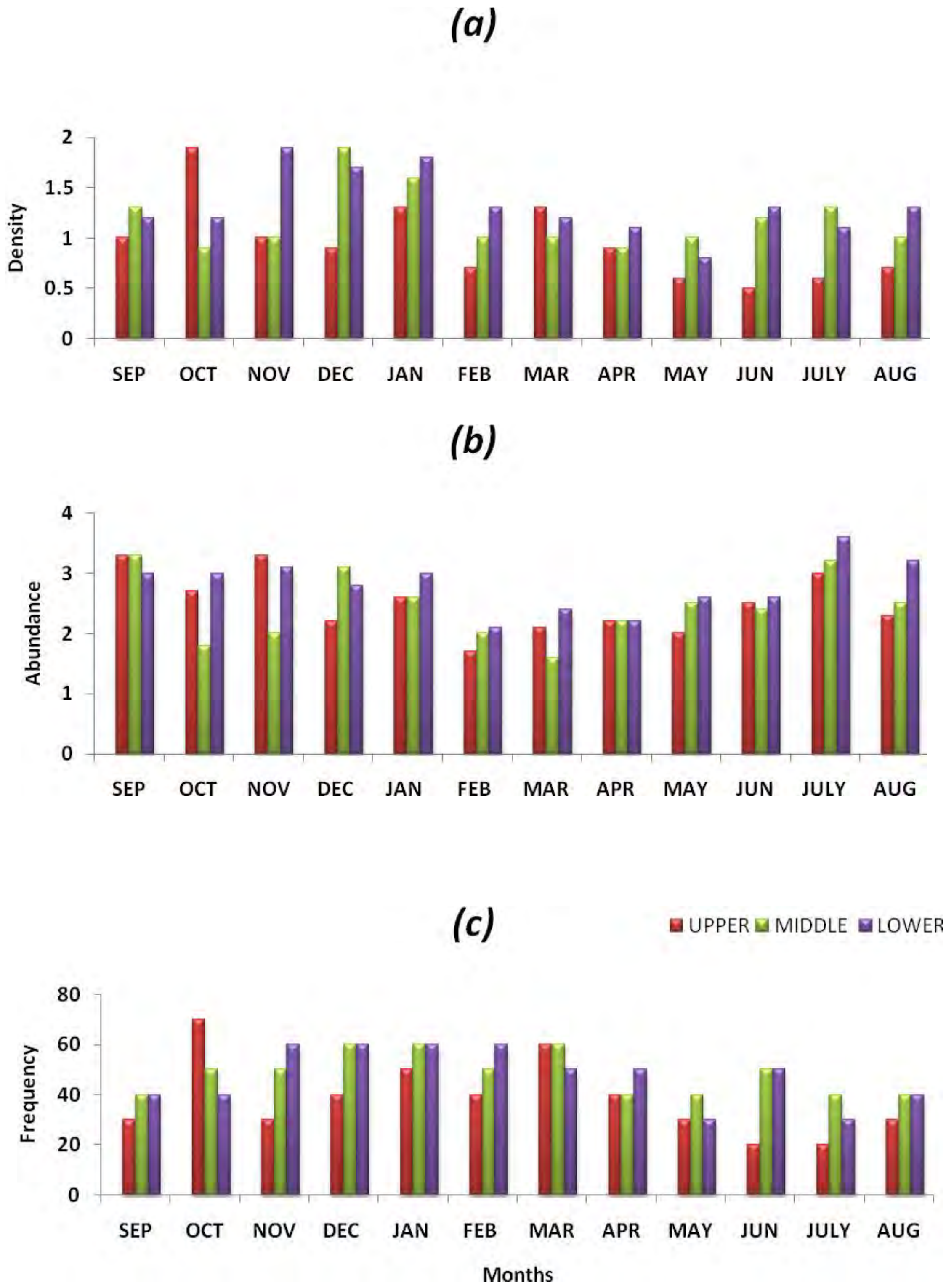

Fig. 7. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Jalandhar site-A from September 2008 to August 2009.

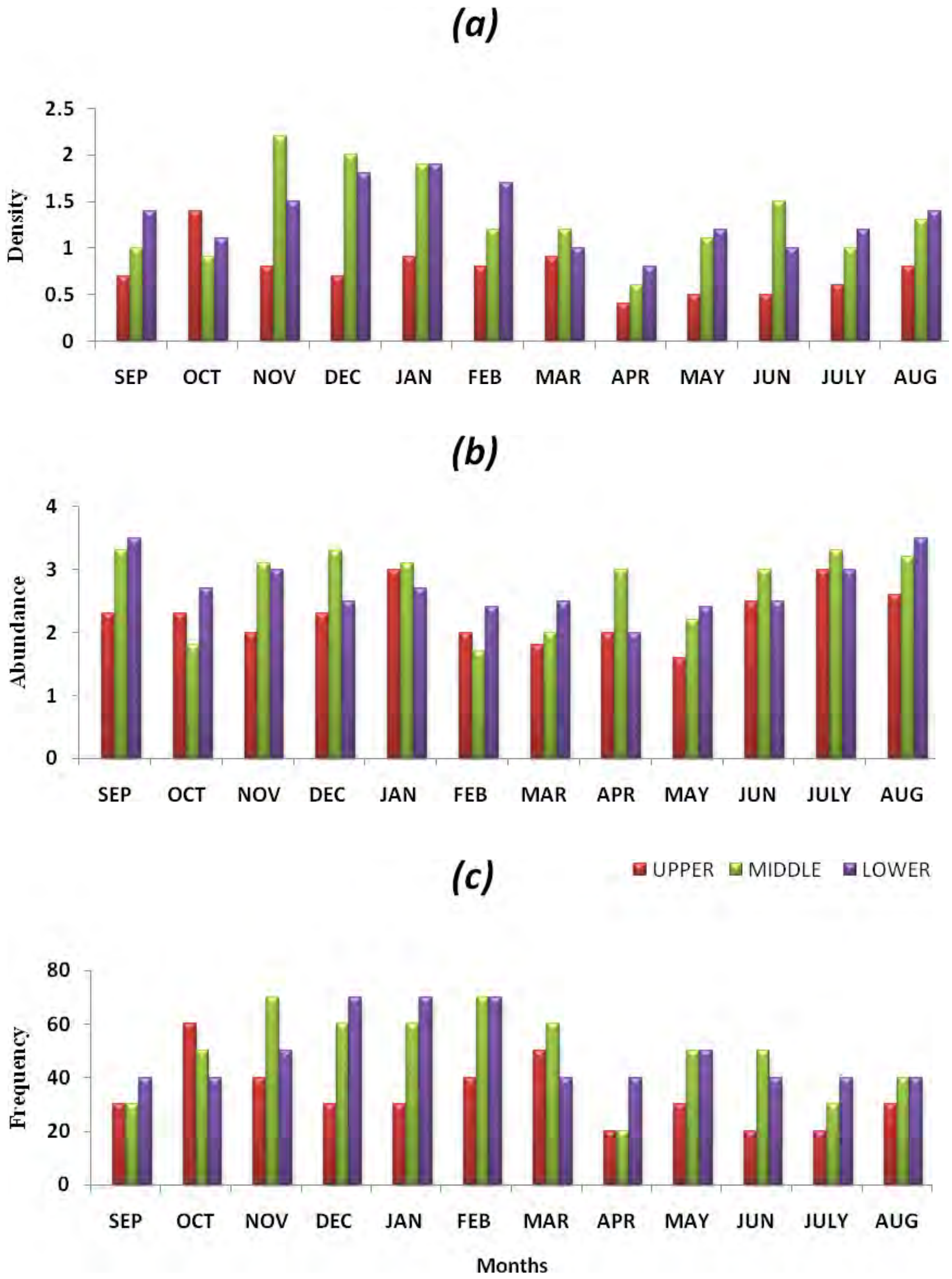

Fig. 8. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Jalandhar site-B from September 2008 to August 2009

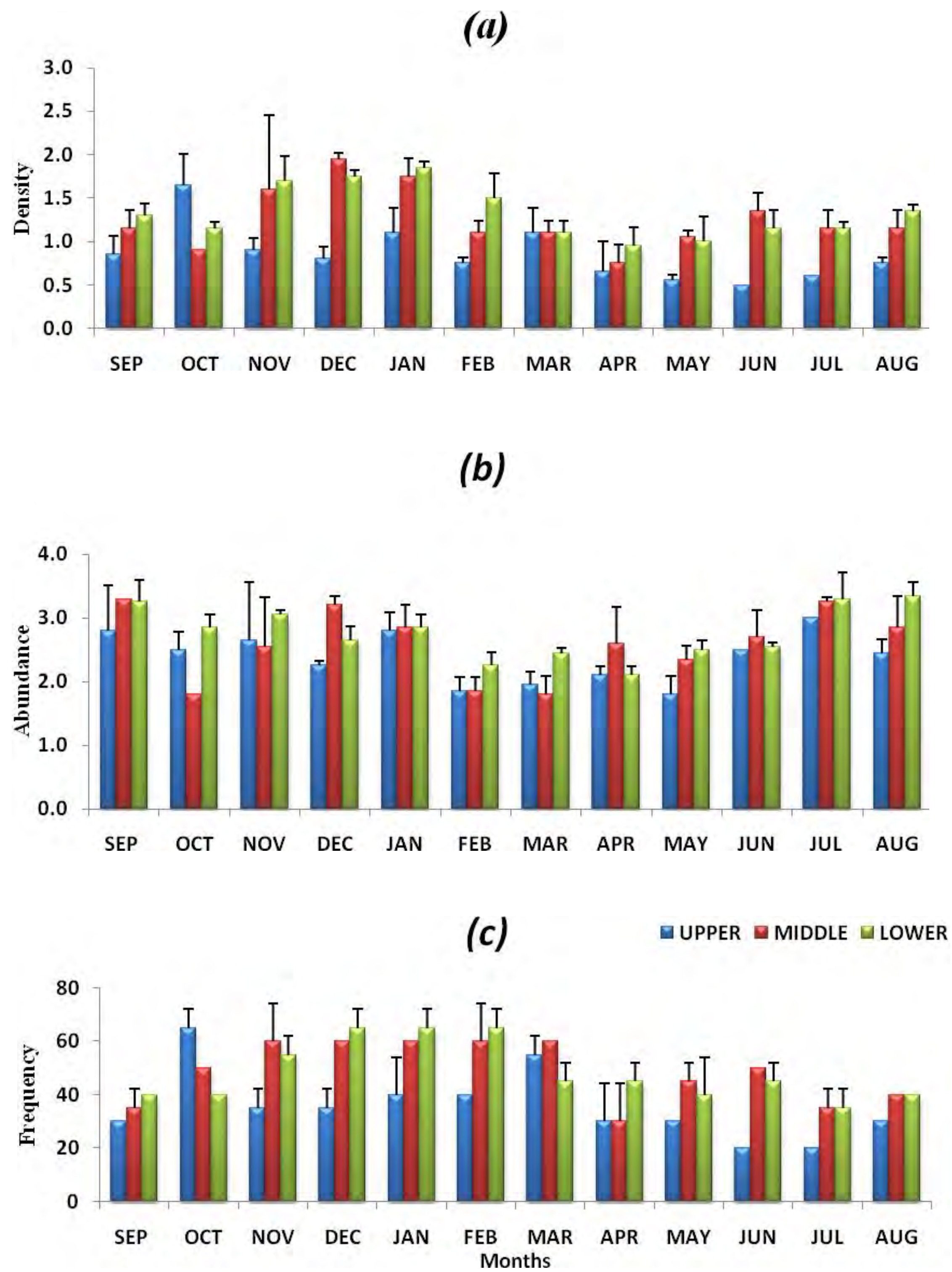

Fig. 9. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Jalandher site from September 2008 to August 2009. Values revealed mean from two micro spatial sampling sites within Jalandher shoreline, standard bar represents fixed SD.

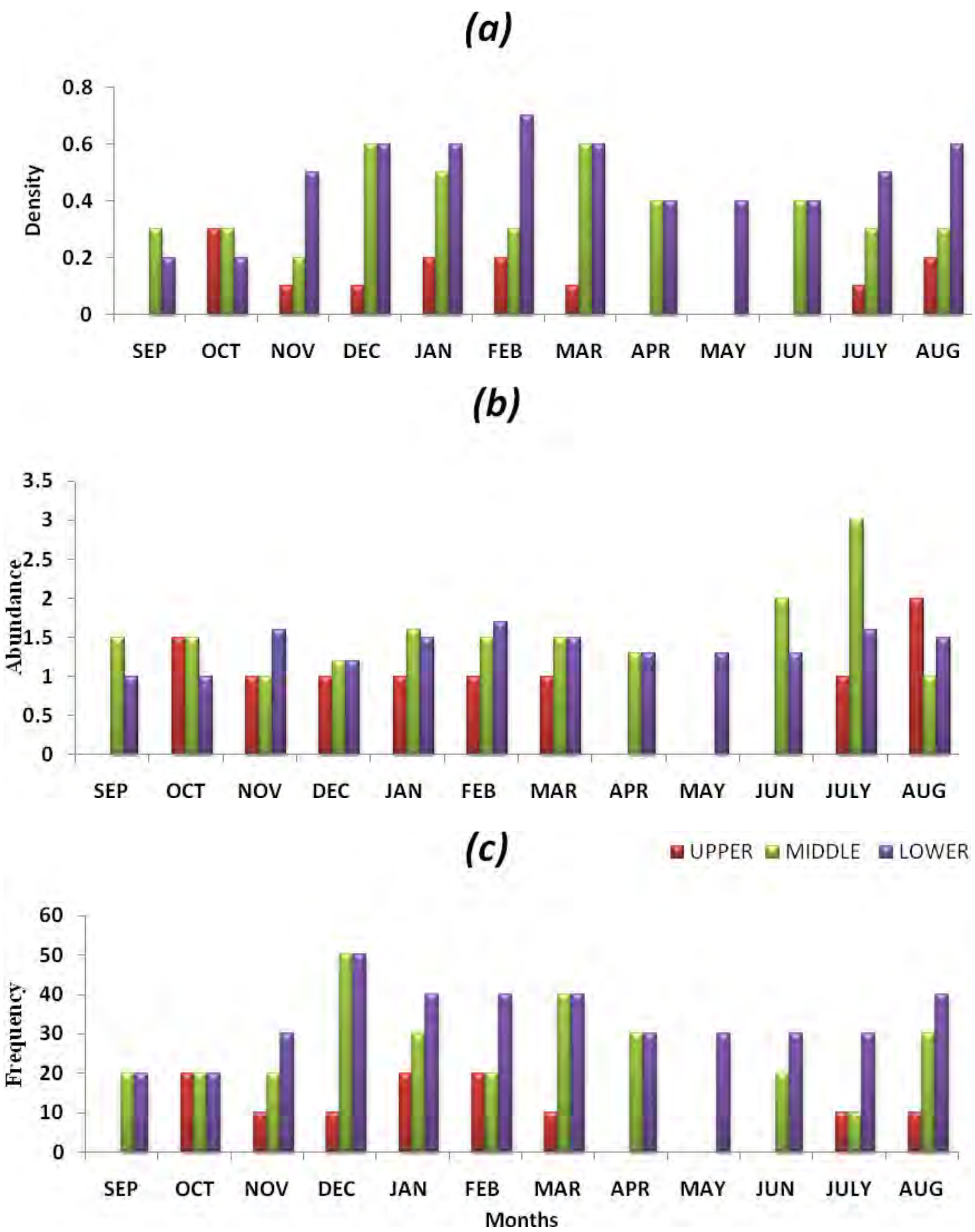

Fig. 10. Monthly variations in various ecological attributes *Tibia insulaechorab* in different littoral zones at Jalandhar site-A from September 2008 to August 2009.

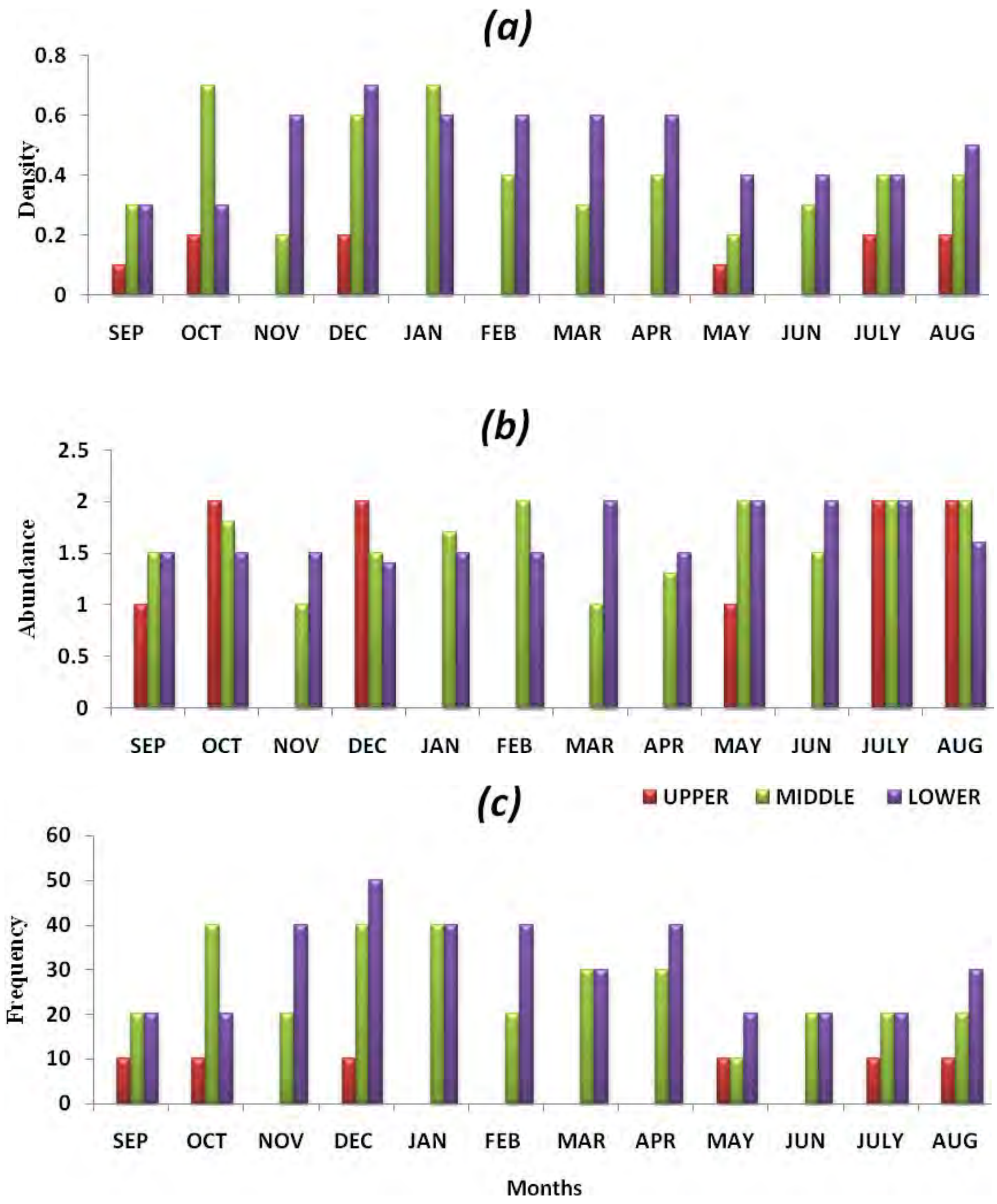

Fig. 11. Monthly variations in various ecological attributes of *Tibia insulaechorab* in different littoral zones at Jalandhar site-B from September 2008 to August 2009

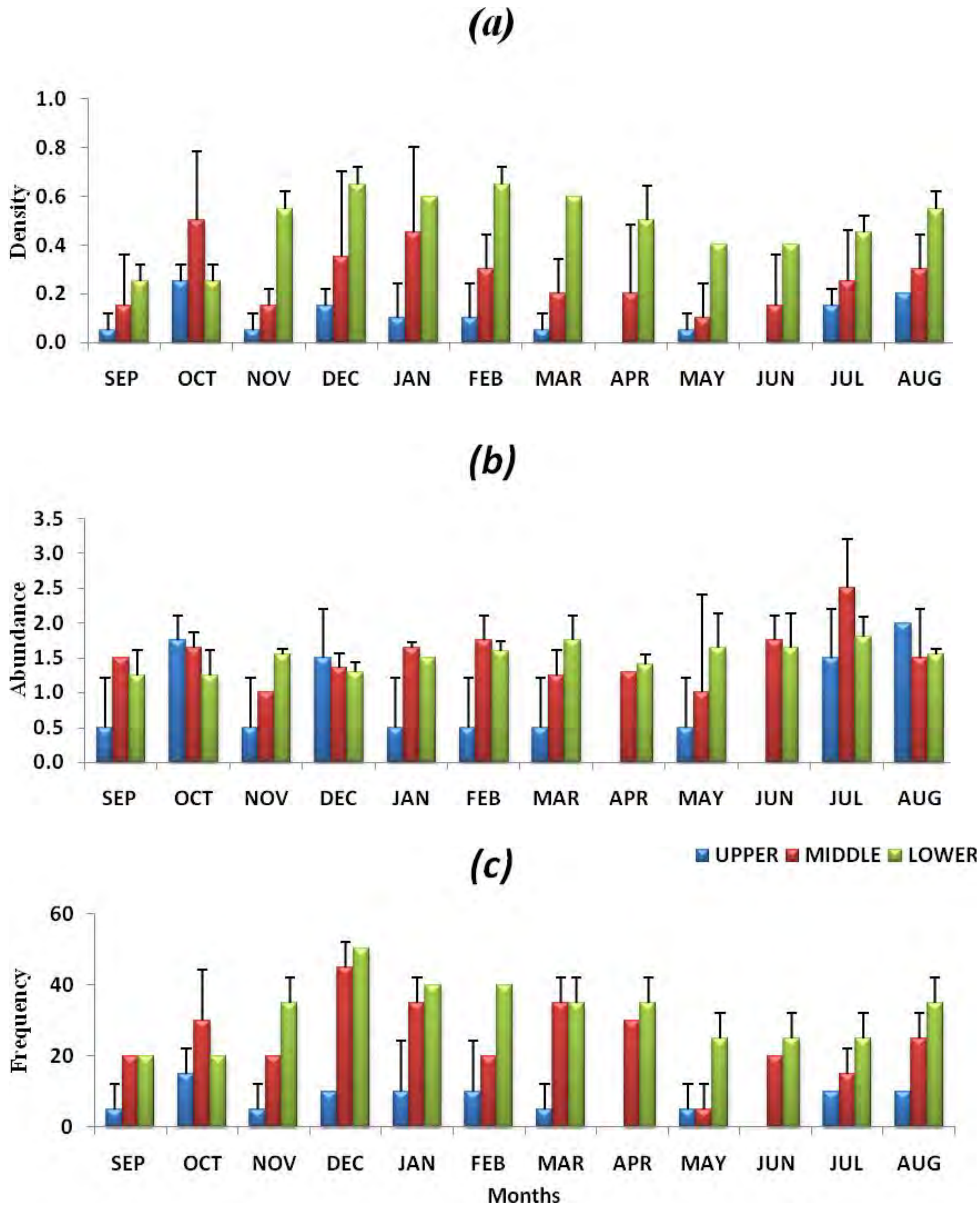

Fig. 12. Monthly variations in various ecological attributes of *Tibia insulaechorab* in different littoral zones at Jalandher site from September 2008 to August 2009. Values revealed mean from two micro spatial sampling sites within Jalandher shoreline, standard bar represents fixed SD.

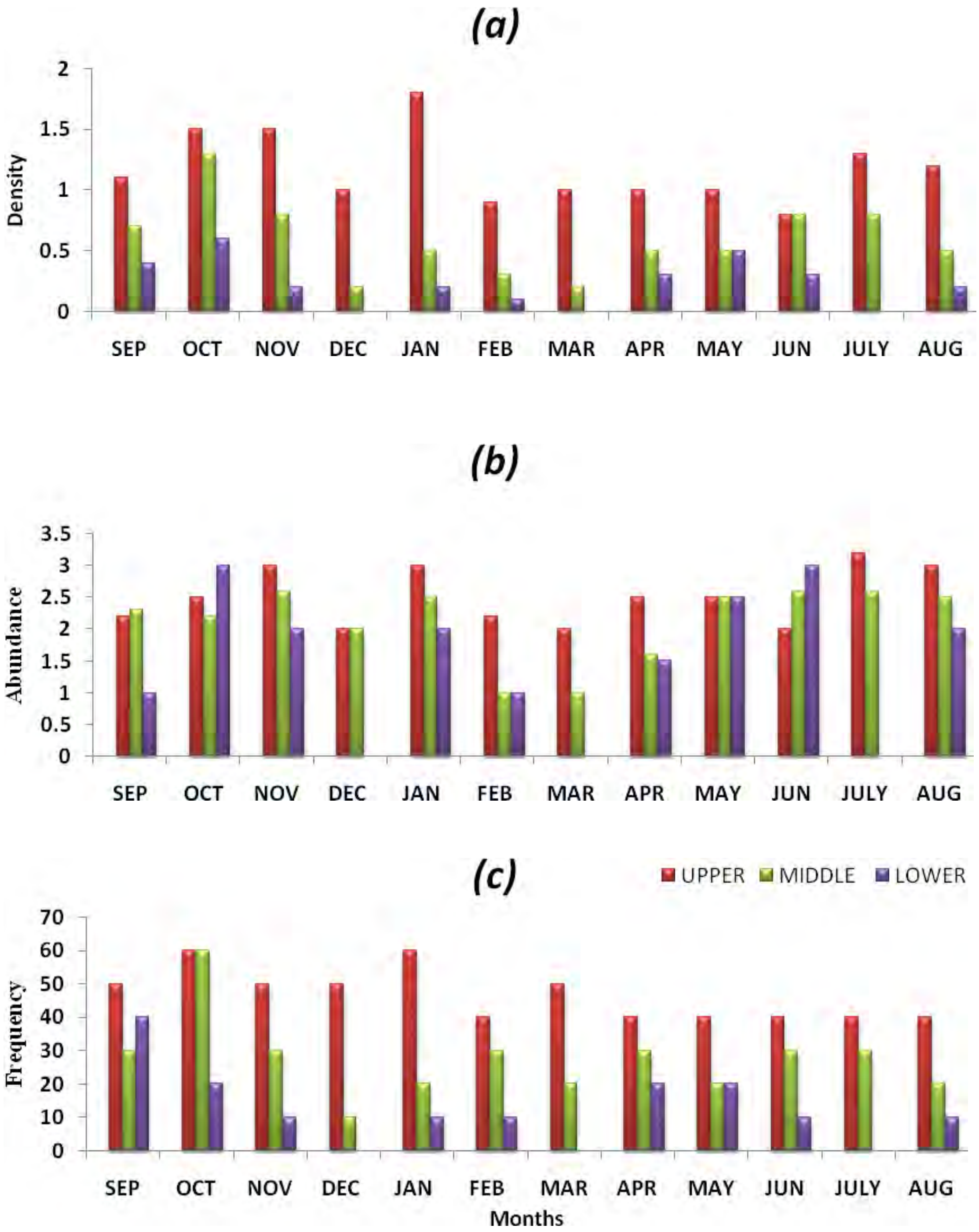

Fig. 13. Monthly variations in various ecological attributes of *Cellena radiata* in different littoral zones at Nagoa site-A from September 2008 to August 2009.

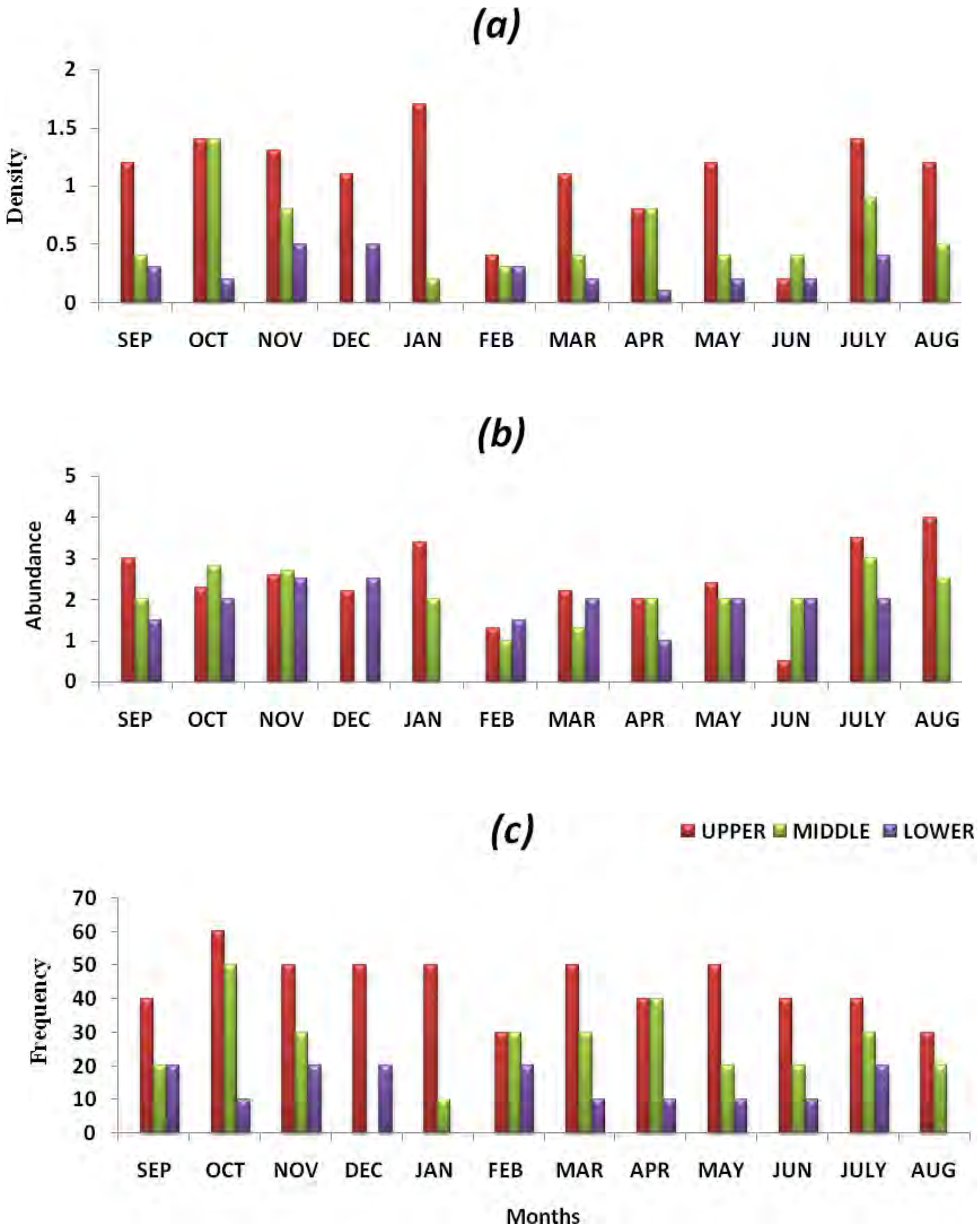

Fig. 14. Monthly variations in various ecological attributes of *Cellena radiata* in different littoral zones at Nagoa site-B from September 2008 to August 2009.

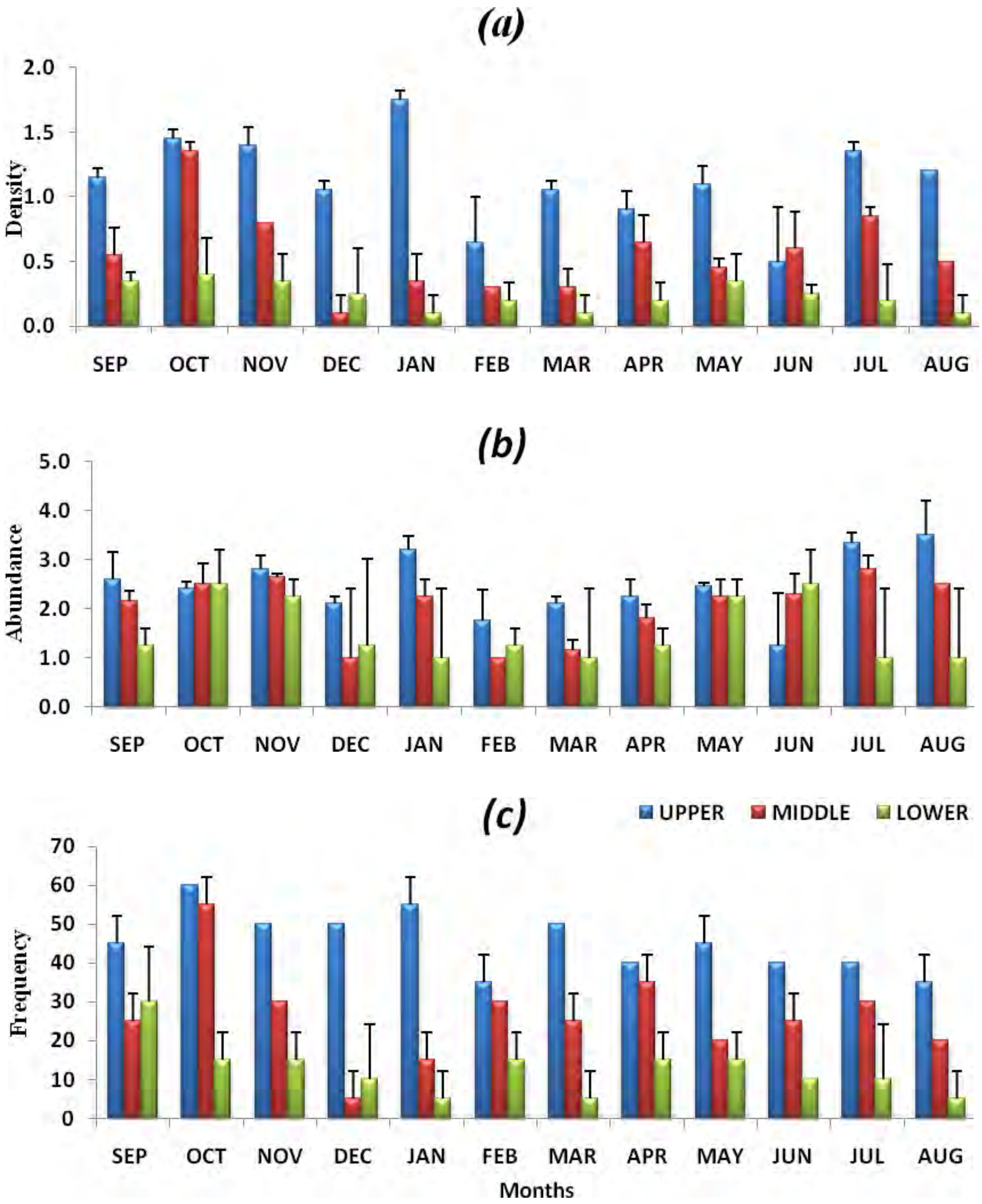

Fig. 15. Monthly variations in various ecological attributes of *Cellena radiata* in different littoral zones at Nagoa site from September 2008 to August 2009. Values revealed mean from two micro spatial sampling sites within Nagoa shoreline, standard bar represents fixed SD.

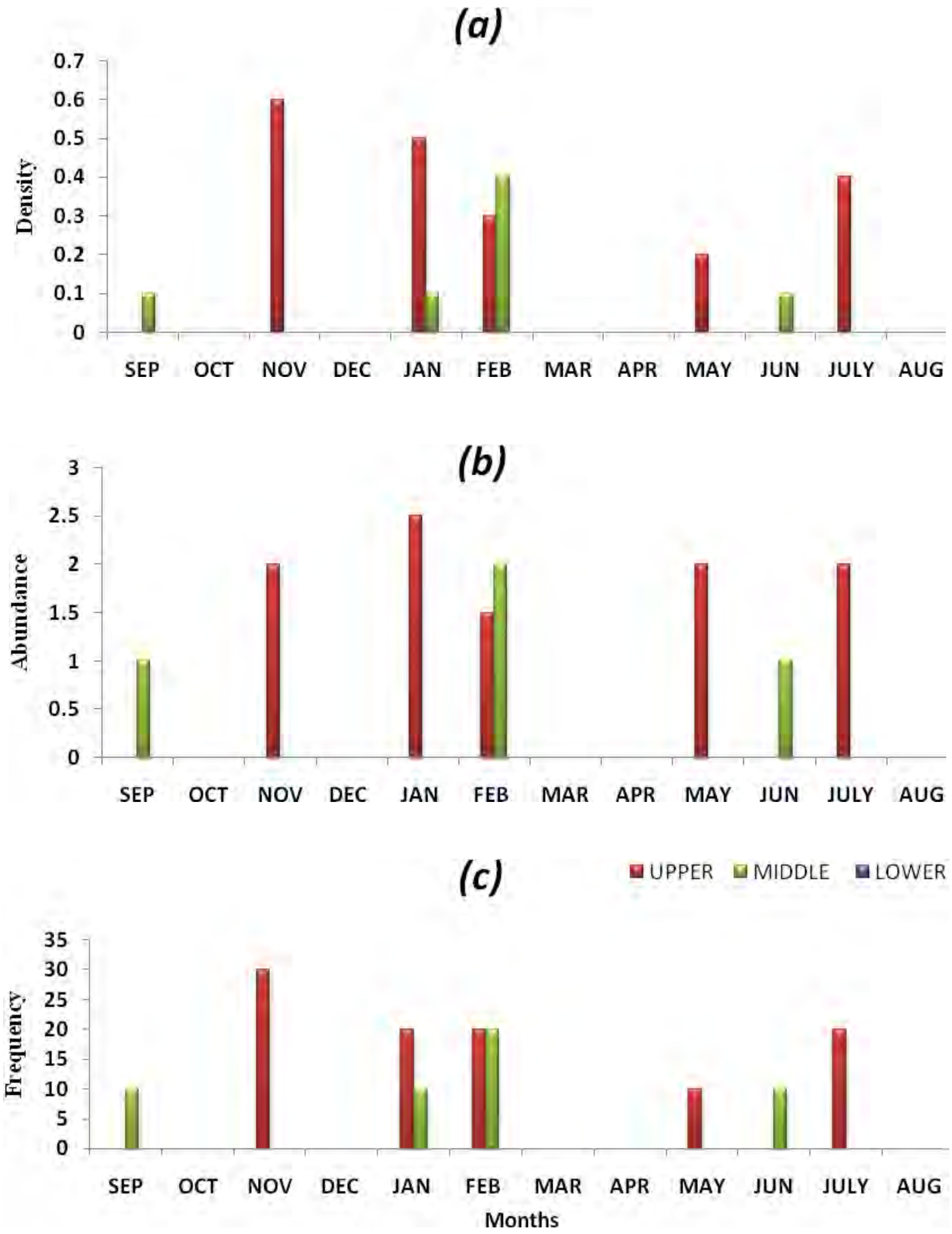

Fig. 16. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Nagoa site-A from September 2008 to August 2009.

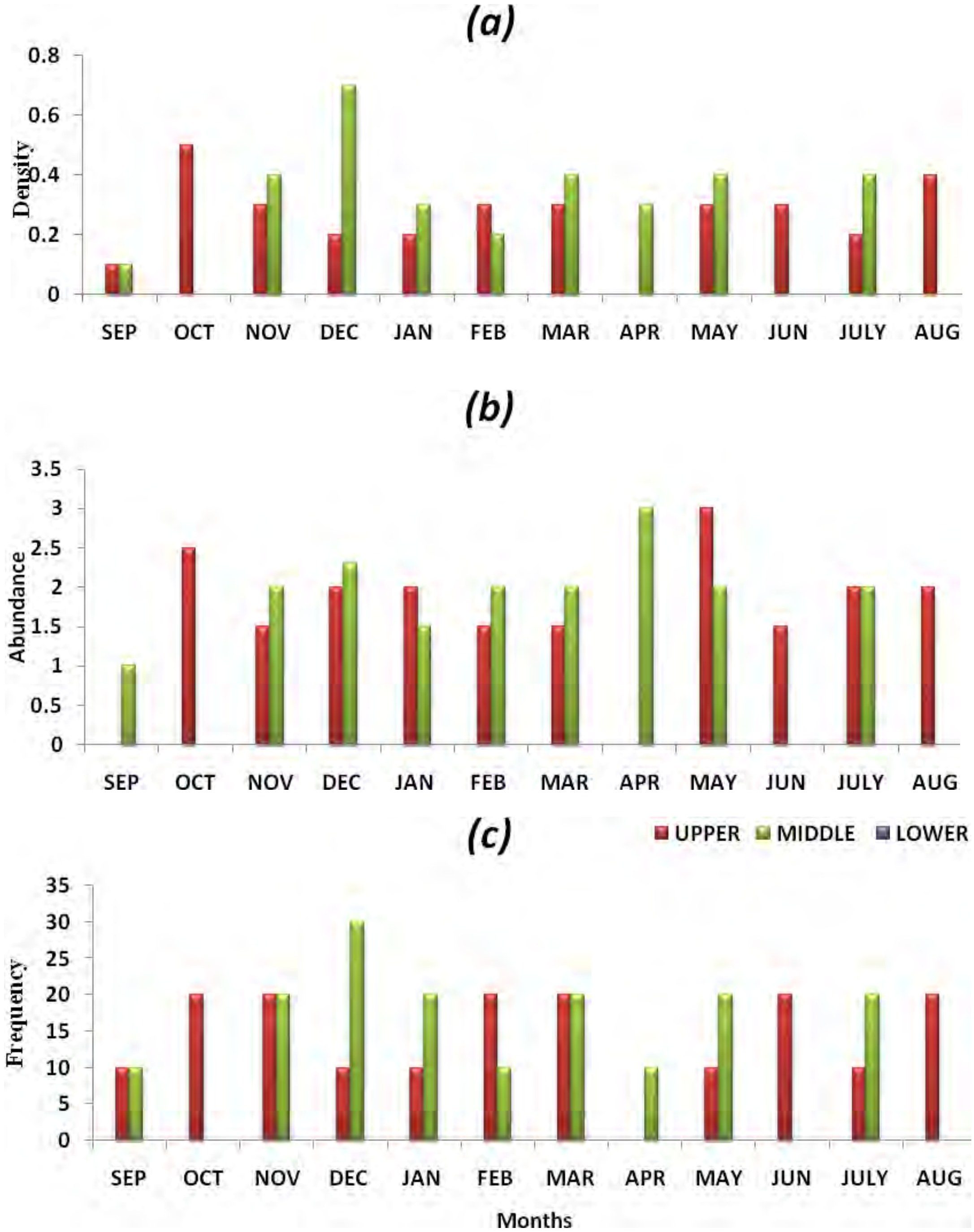

Fig. 17. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Nagoa site-B from September 2008 to August 2009.

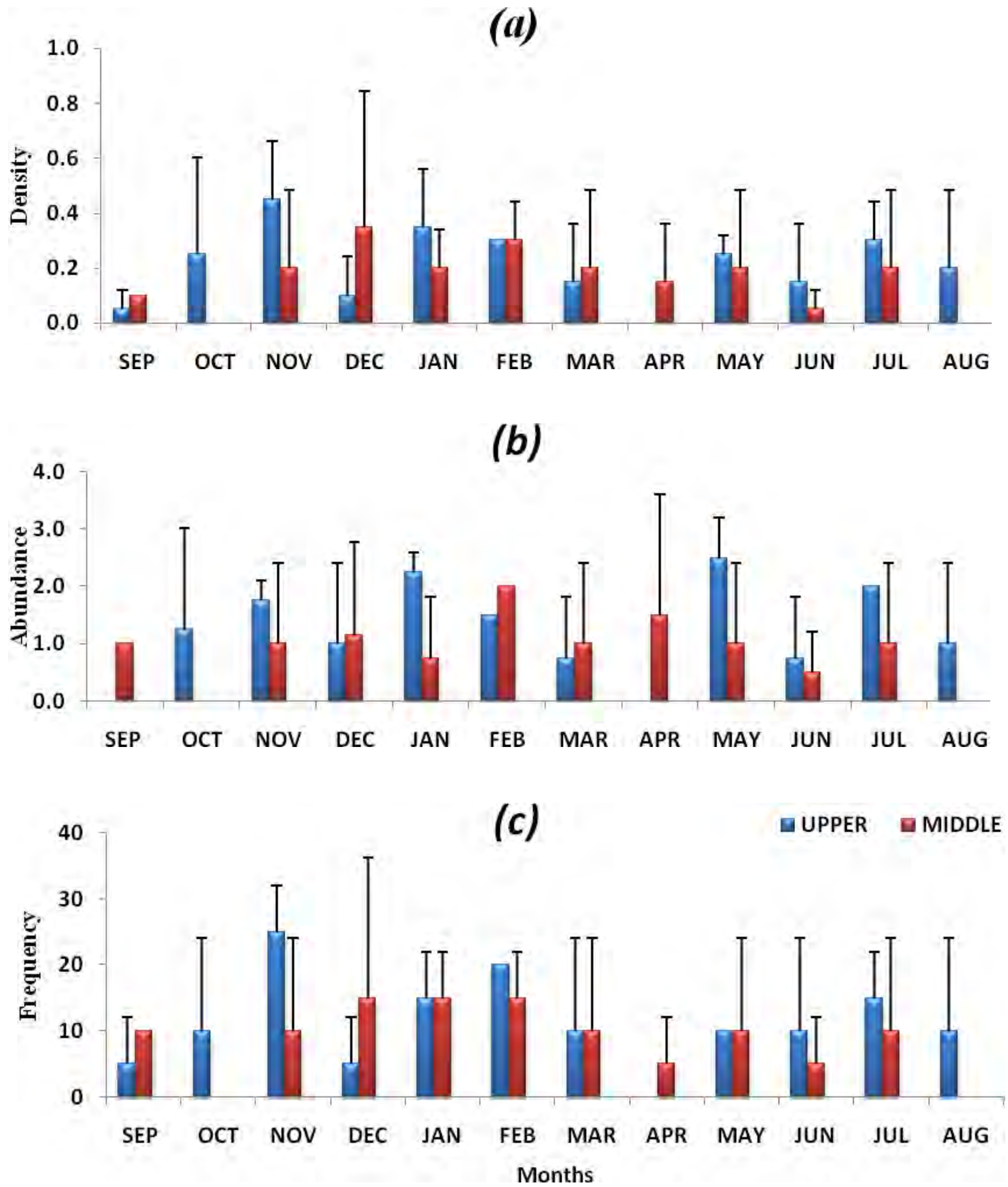

Fig. 18. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Nagoa site from September 2008 to August 2009. Values revealed mean from two micro spatial sampling sites within Nagoa shoreline, standard bar represents fixed SD.

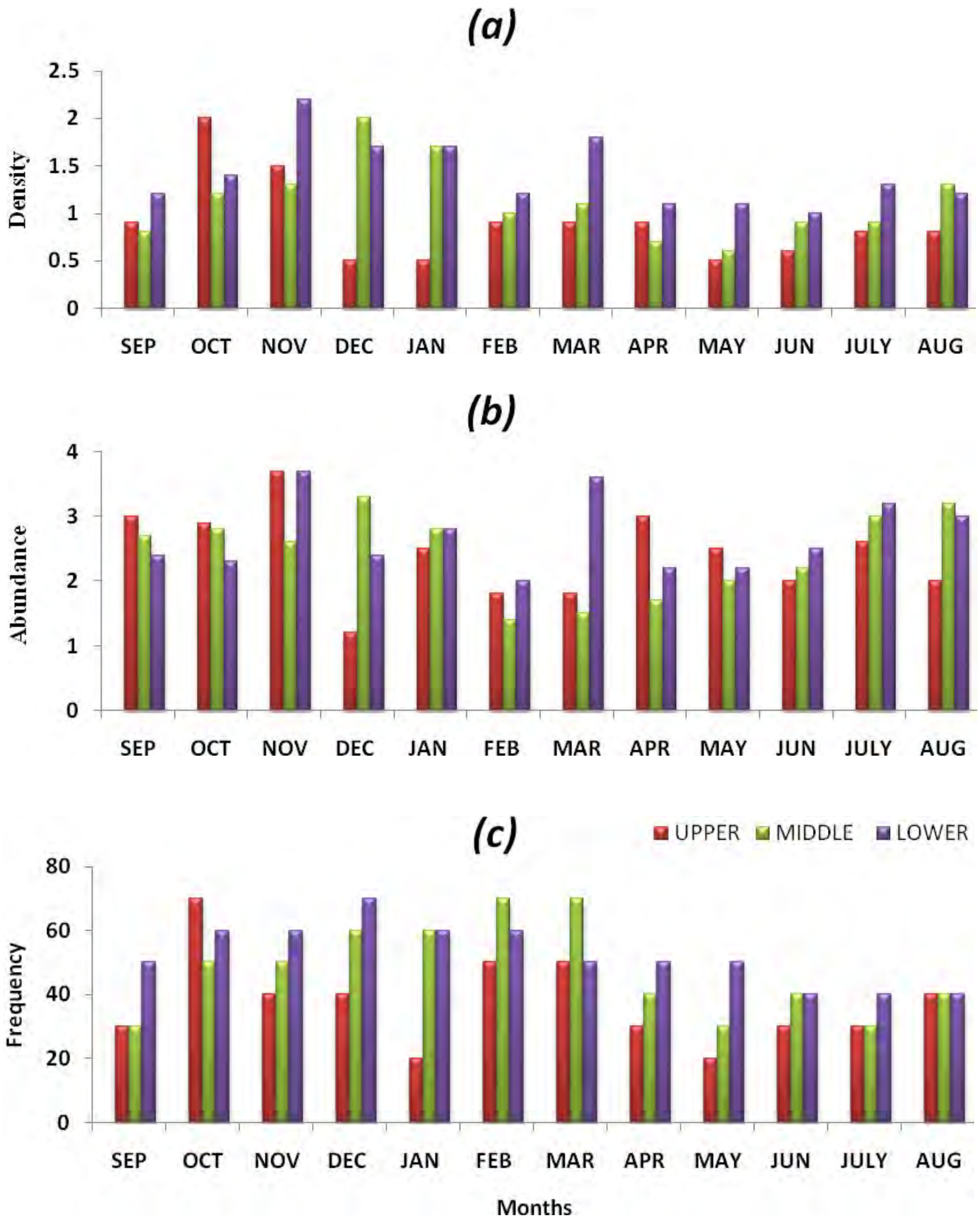

Fig. 19. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Nagoa site-A from September 2008 to August 2009.

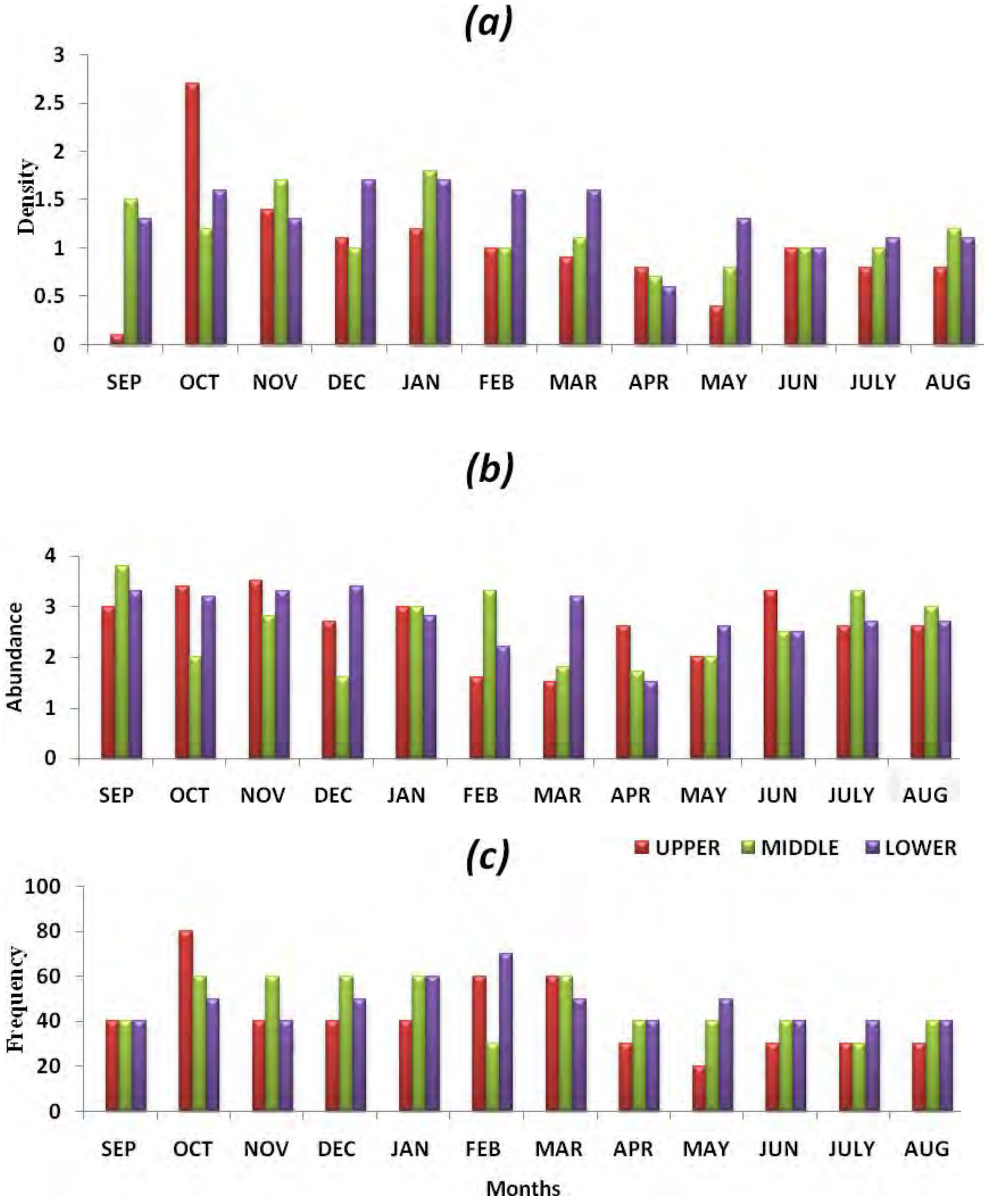

Fig. 20. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Nagoa site-B from September 2008 to August 2009.

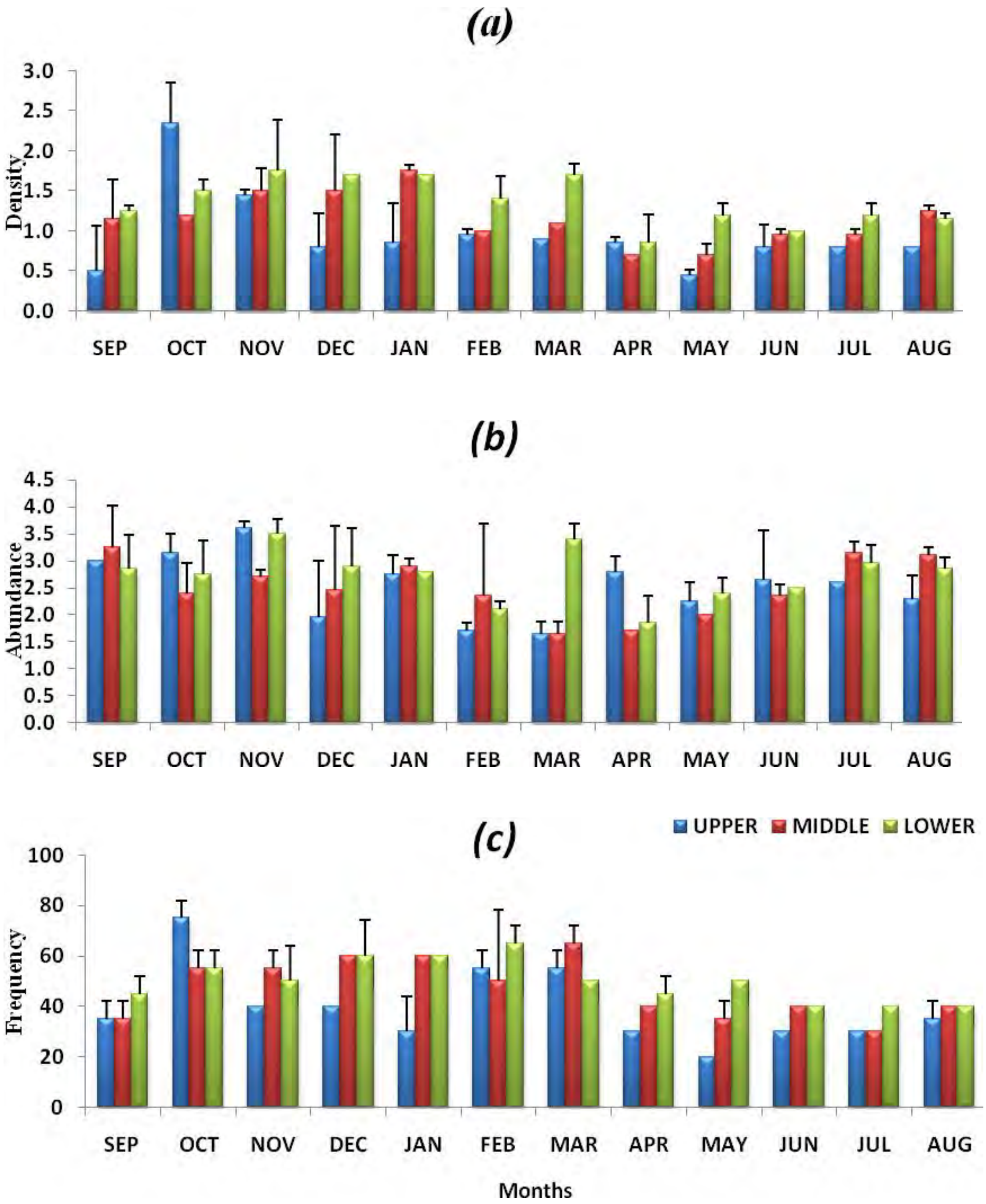

Fig. 21. Monthly variations in various ecological attributes of *Cerithium caeruleum* in different littoral zones at Nagoa site from September 2008 to August 2009. Values revealed mean from two micro spatial sampling sites within Nagoa shoreline, standard bar represents fixed SD.

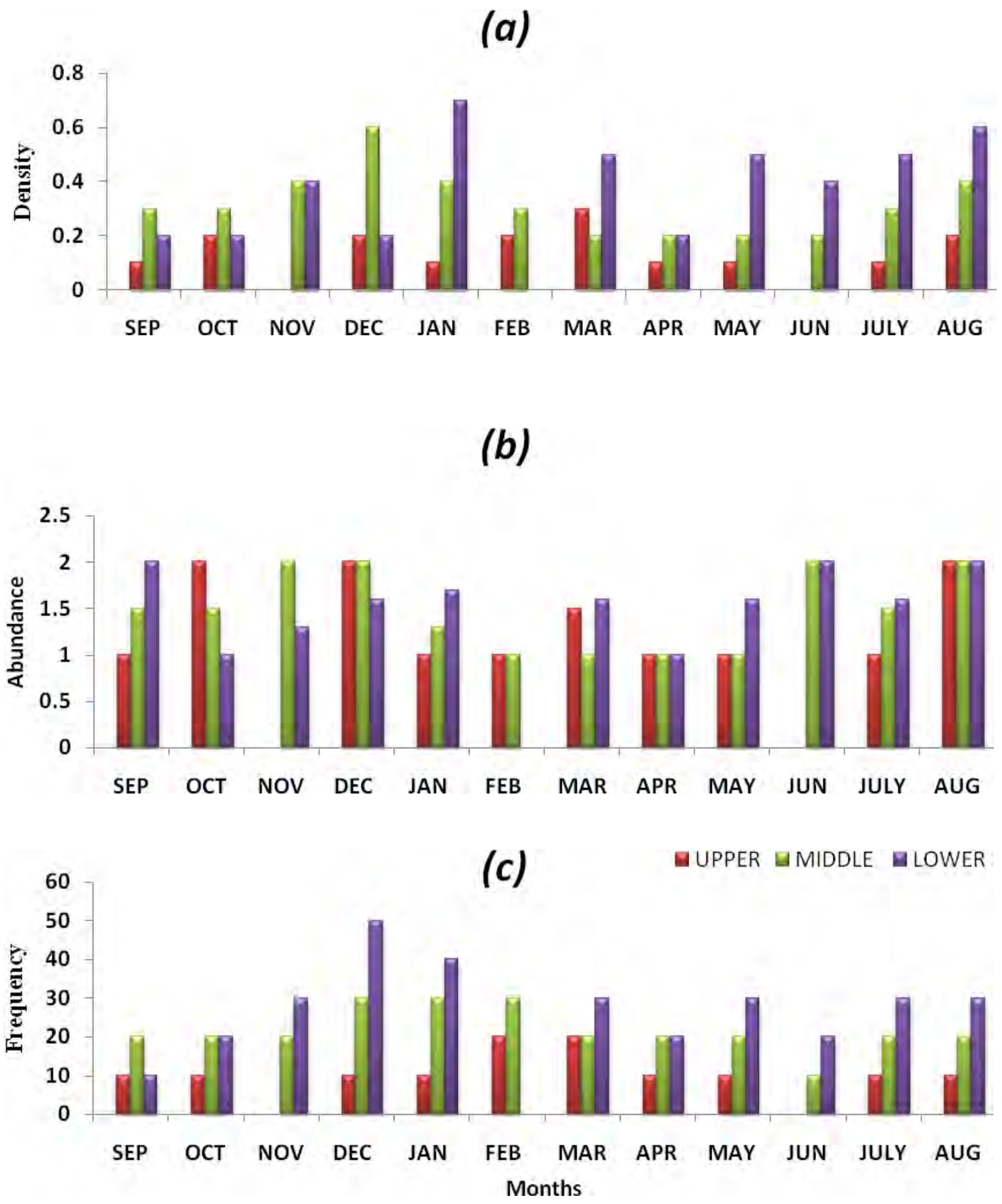

Fig. 22. Monthly variations in various ecological attributes of *Tibia insulaechorab* in different littoral zones at Nagoa site-A from September 2008 to August 2009.

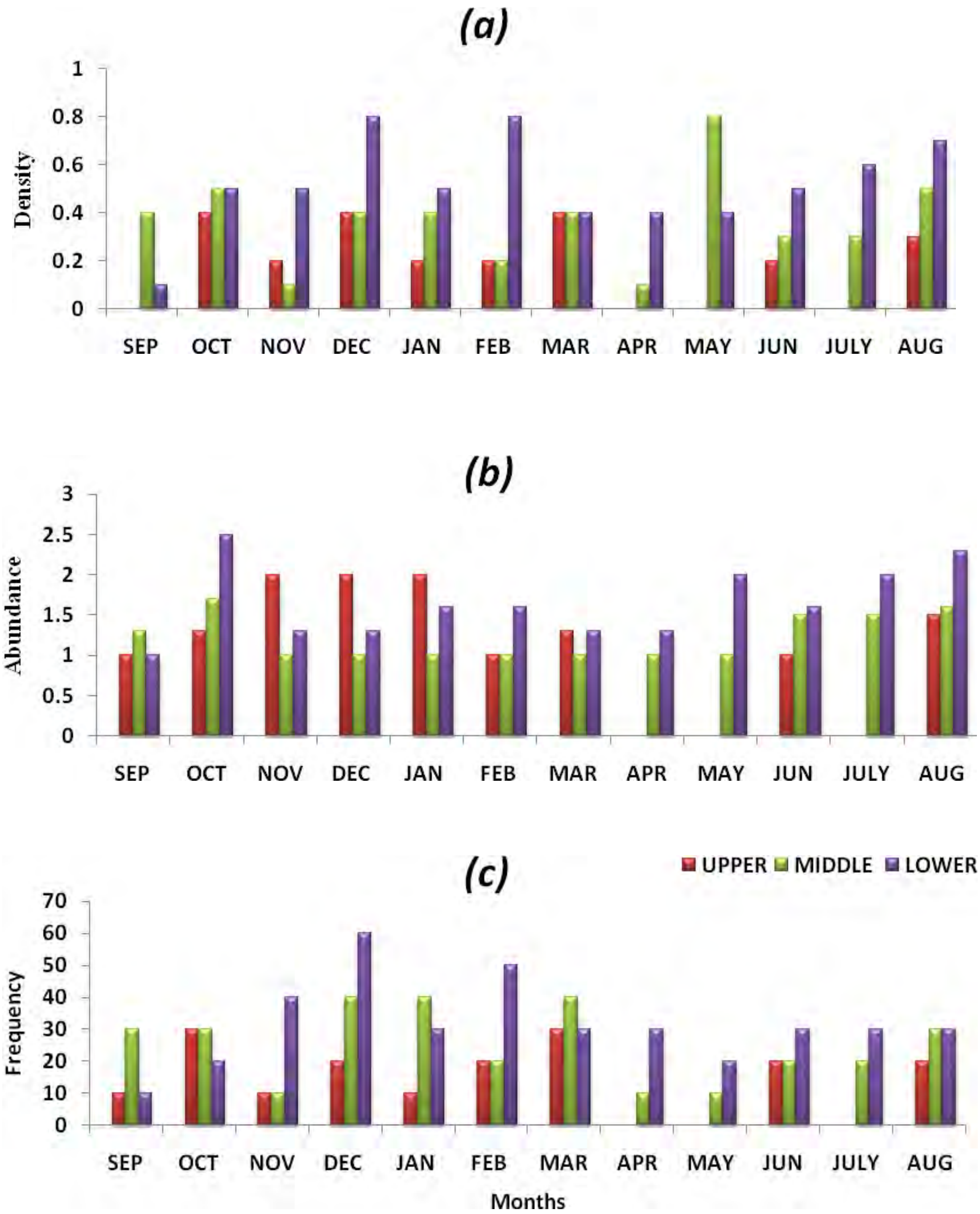

Fig. 23. Monthly variations in various ecological attributes of *Tibia insulaechorab* in different littoral zones at Nagoa site-B from September 2008 to August 2009.

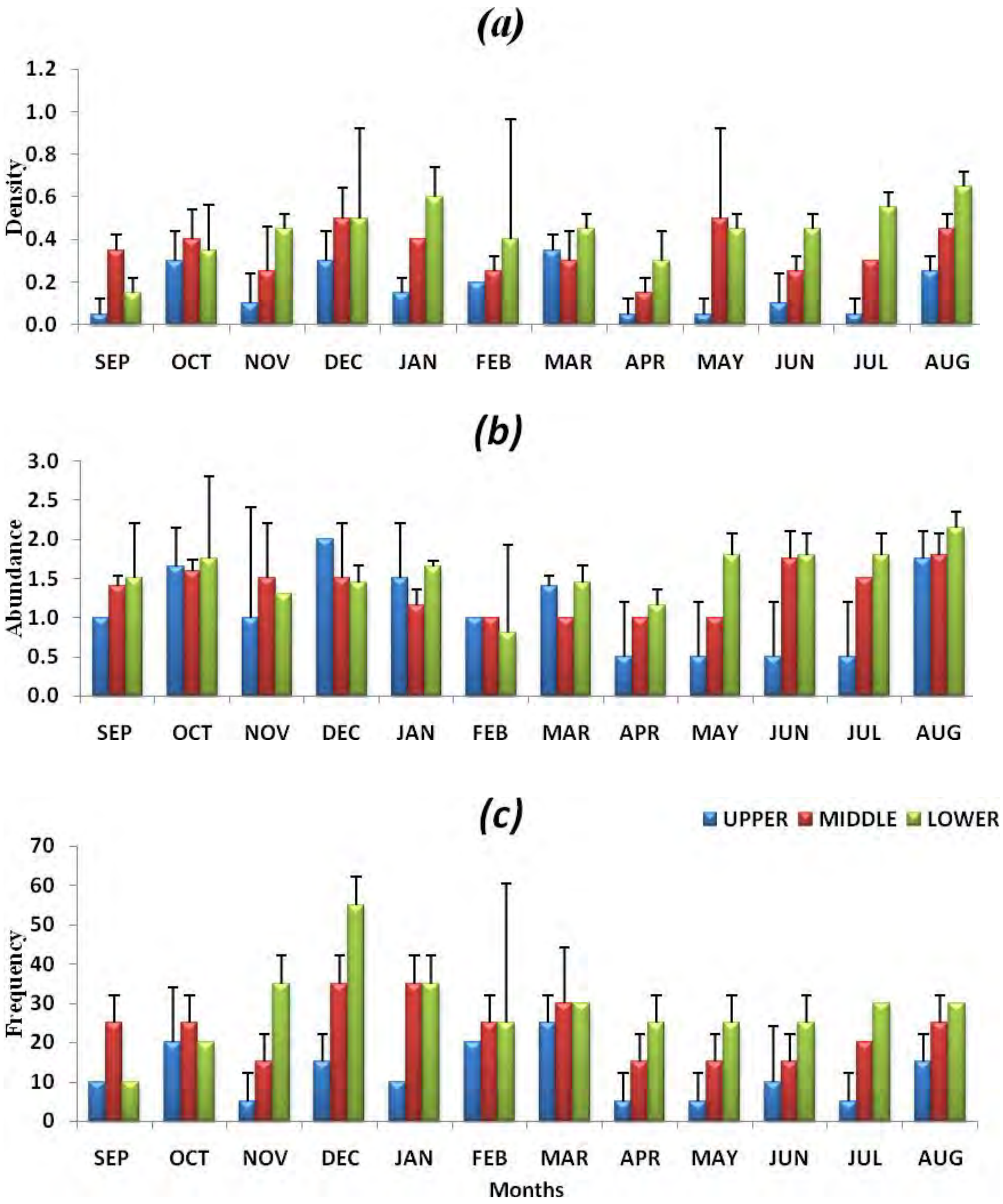

Fig. 24. Monthly variations in various ecological attributes of *Tibia insulaechorab* in different littoral zones at Nagoa site from September 2008 to August 2009. Values revealed mean from two micro spatial sampling sites within Nagoa shoreline, standard bar represents fixed SD.

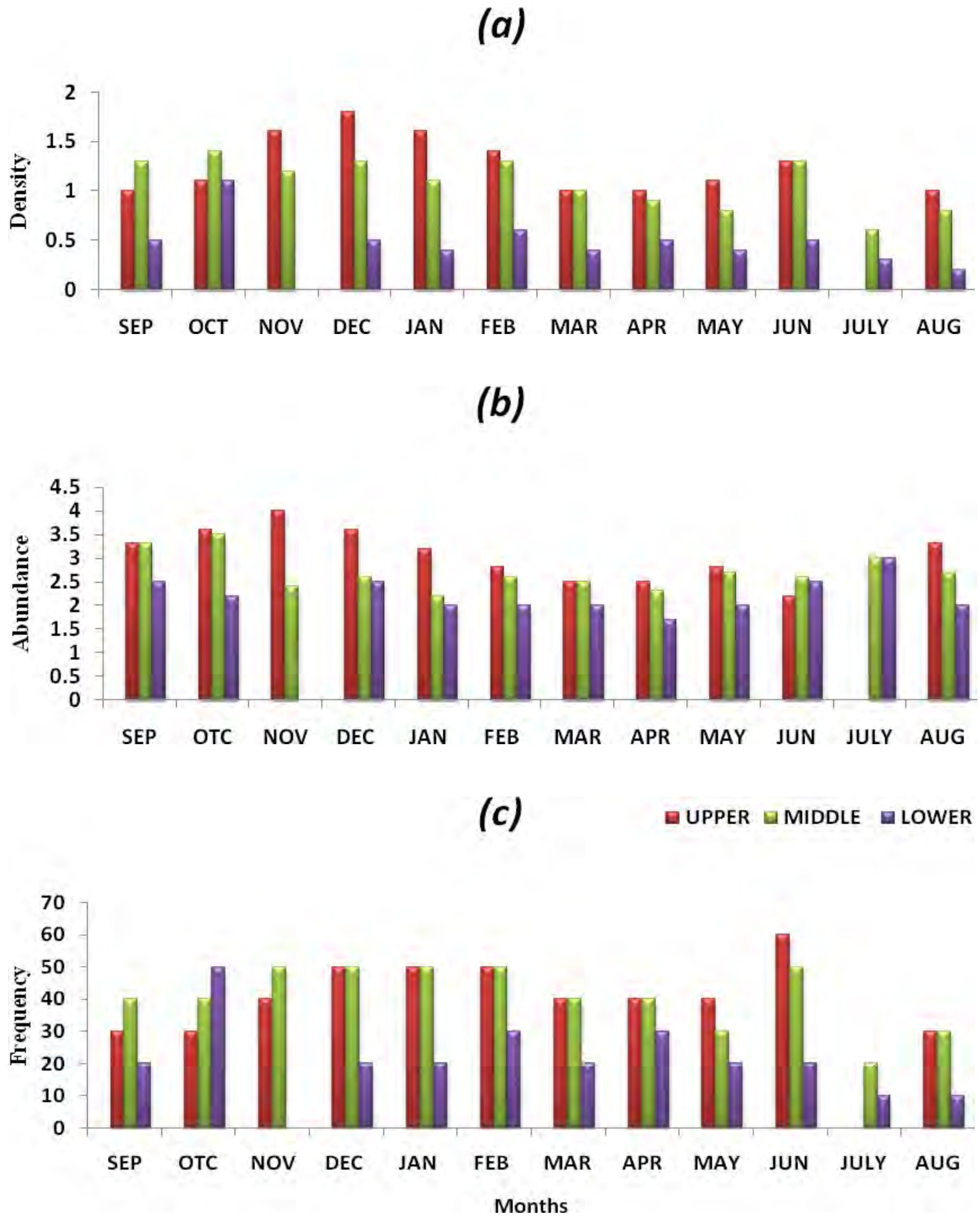

Fig. 25. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Somnath site-A from September 2008 to August 2009.

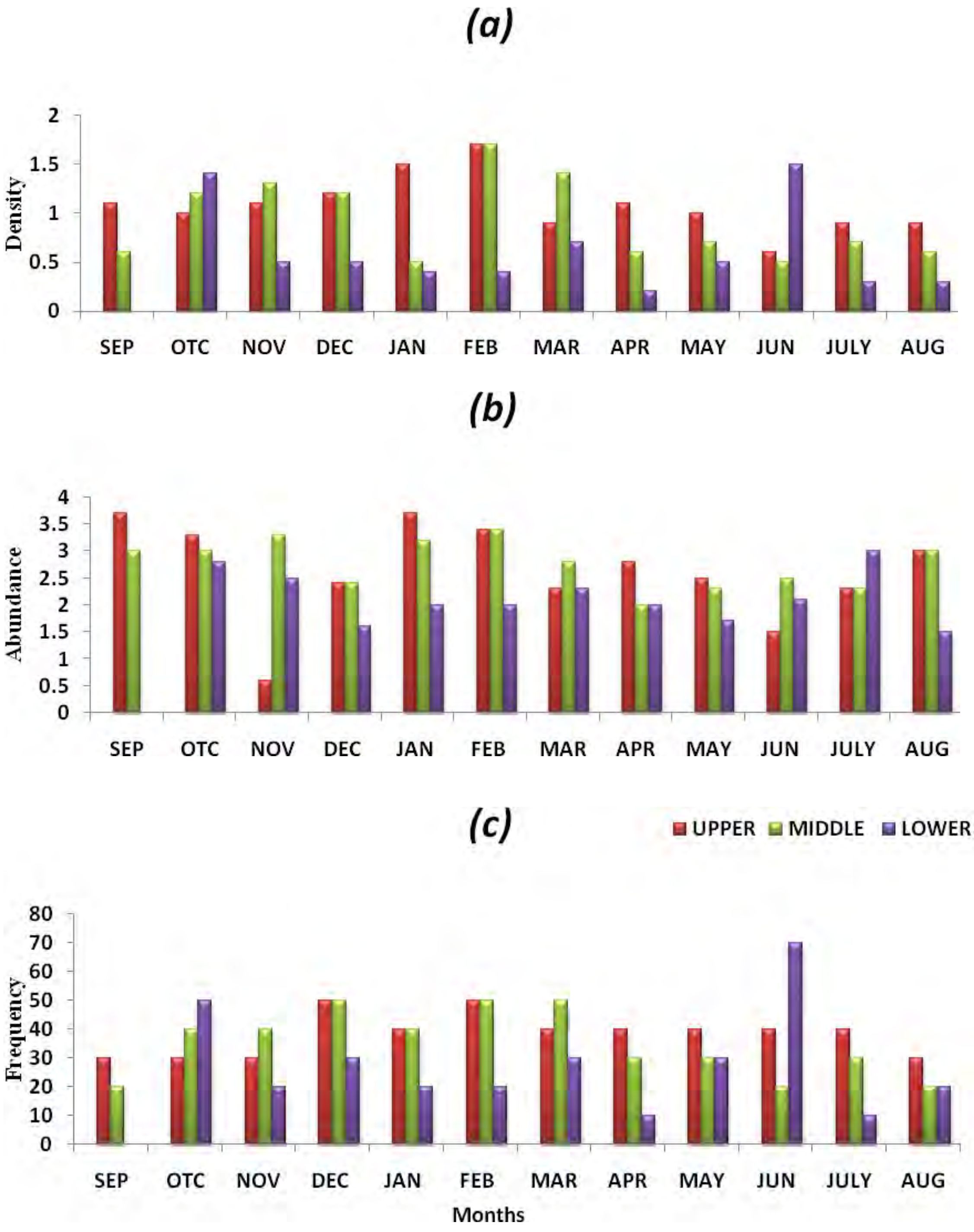

Fig. 26. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Somnath site-B from September 2008 to August 2009.

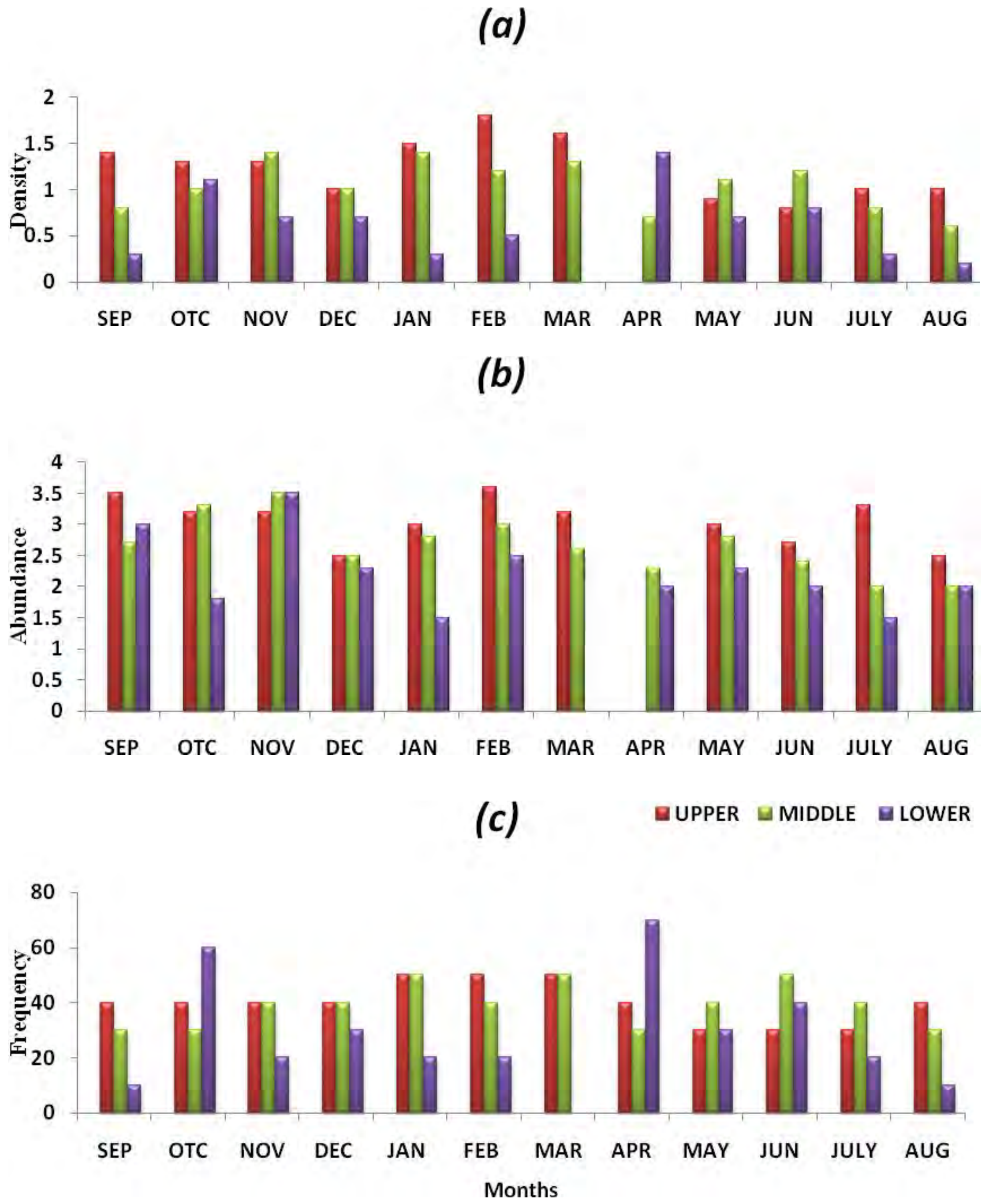

Fig. 27. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Somnath site-C from September 2008 to August 2009.

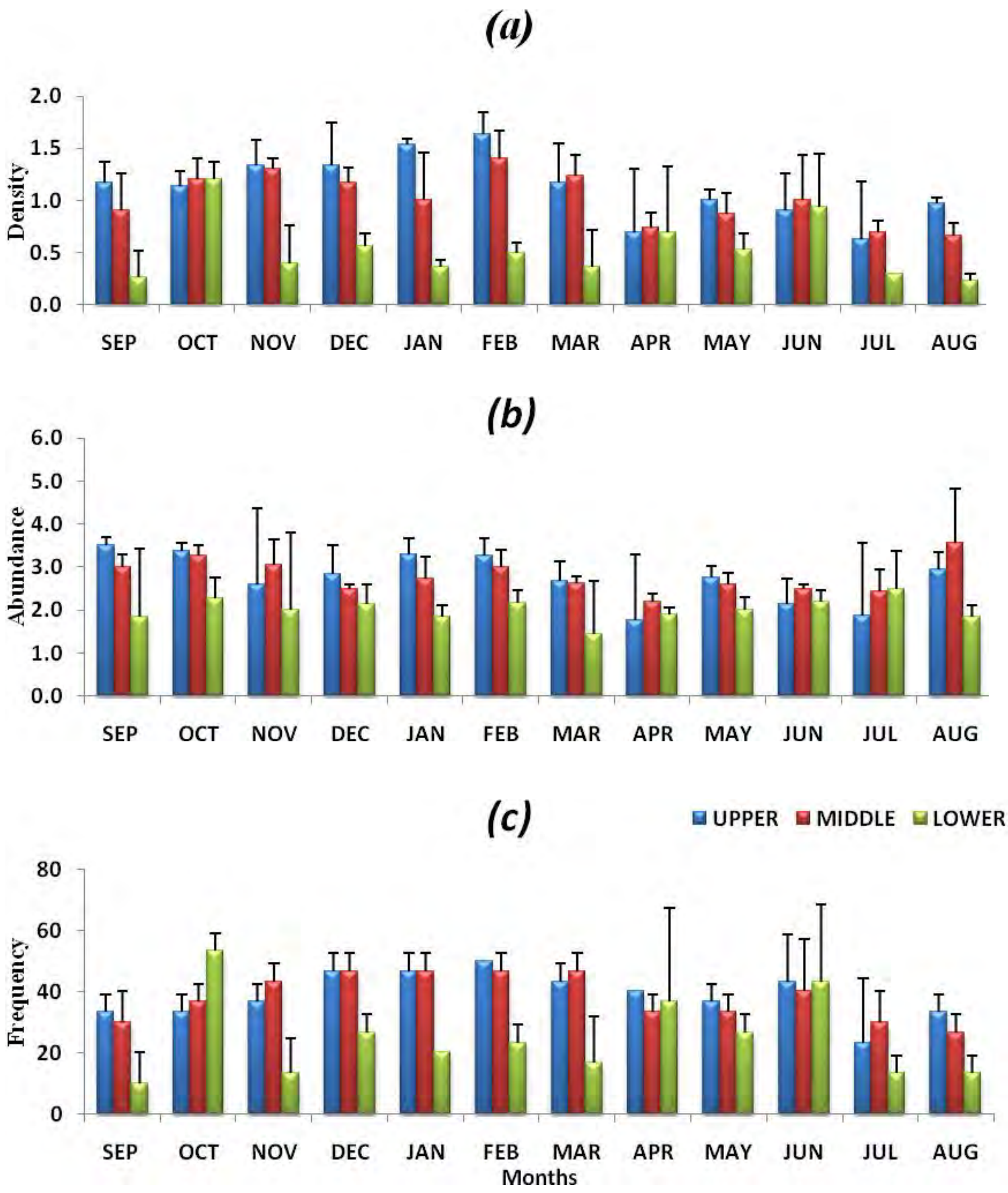

Fig. 28. Monthly variations in various ecological attributes of *Onchidium verruculatum* in different littoral zones at Somnath site from September 2008 to August 2009. Values shows are mean from three micro spatial sampling sites within Somnath shoreline, standard bar represents fixed SD.

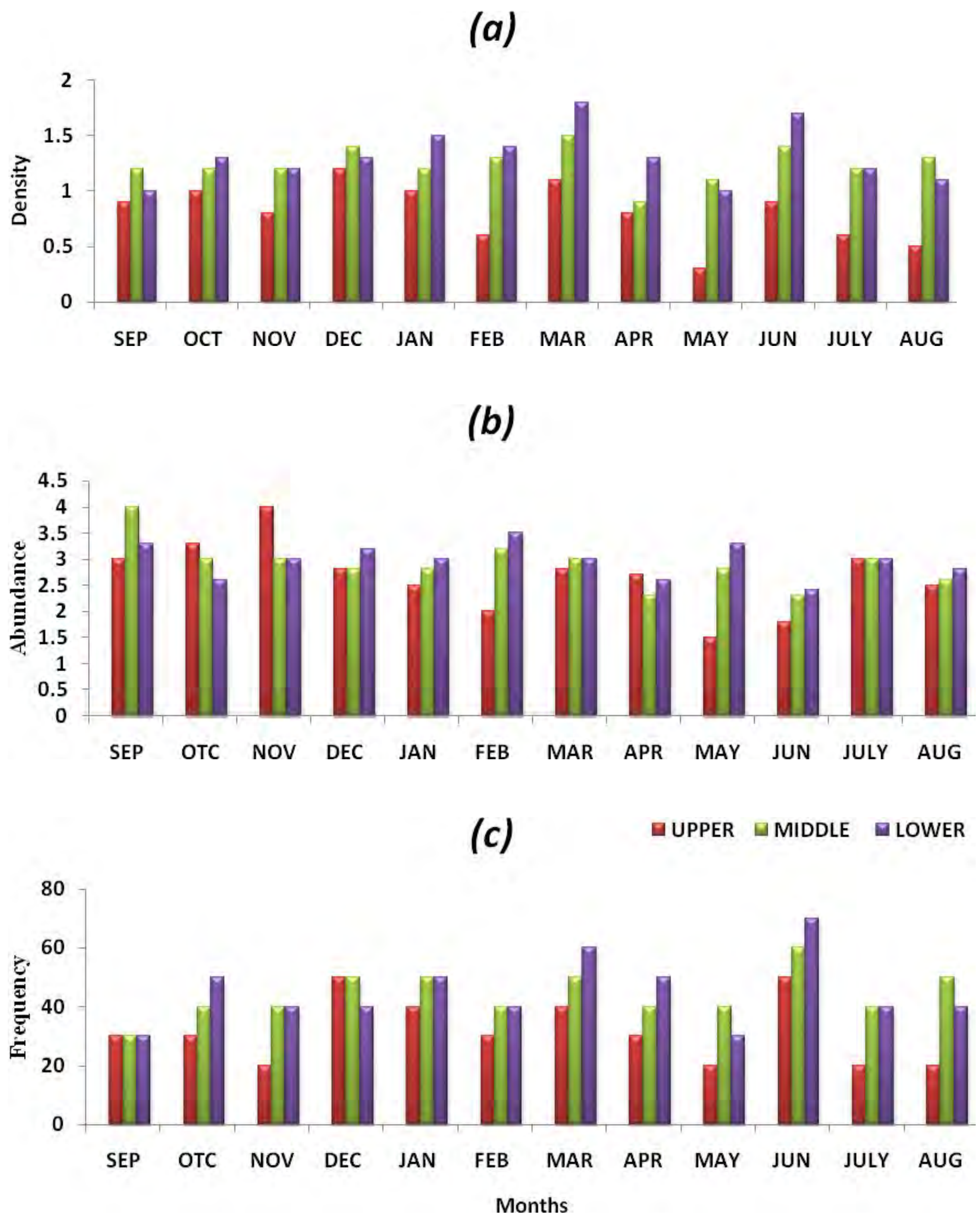

Fig. 29. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Somnath site-A from September 2008 to August 2009.

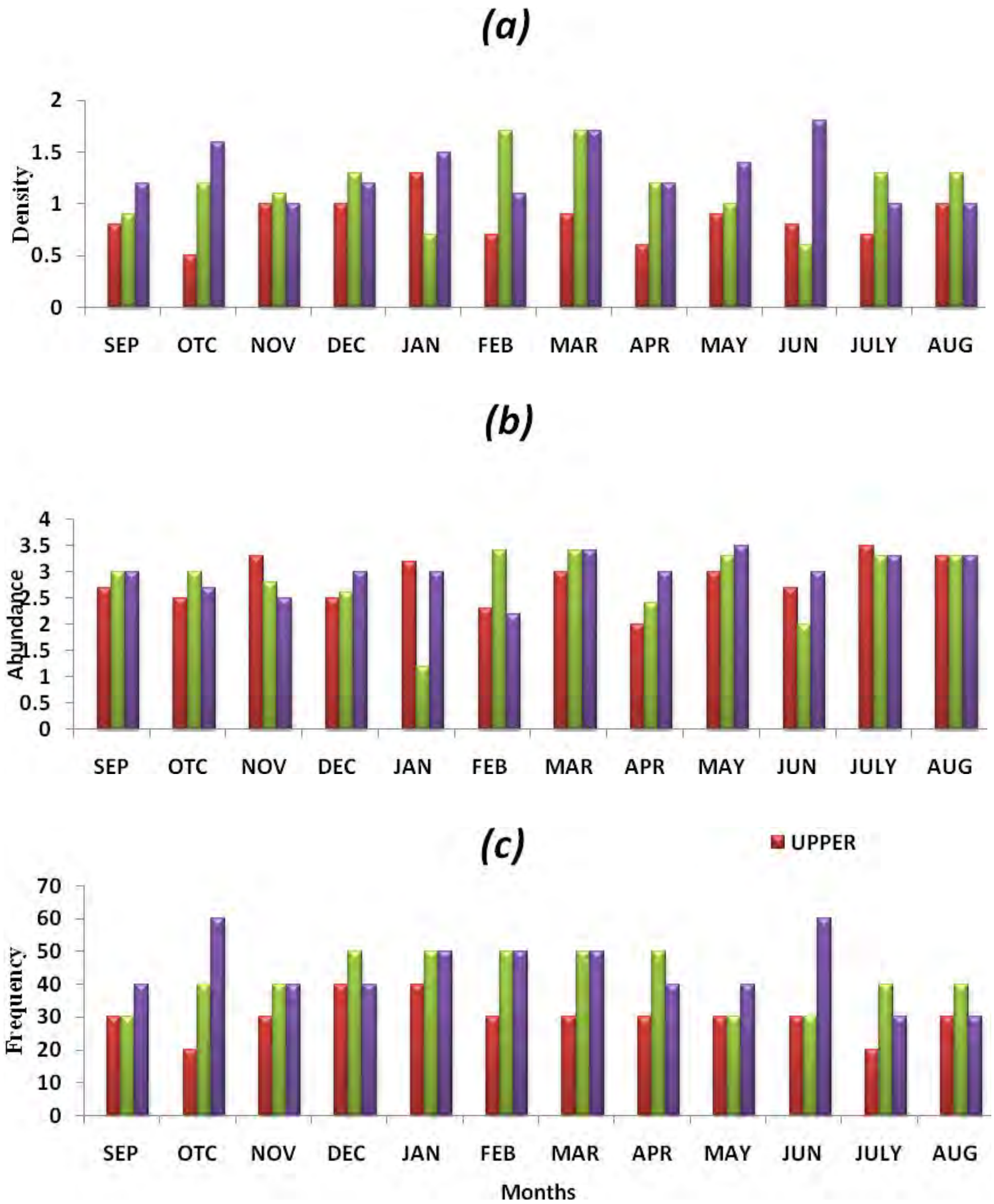

Fig. 30. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Somnath site-B from September 2008 to August 2009.

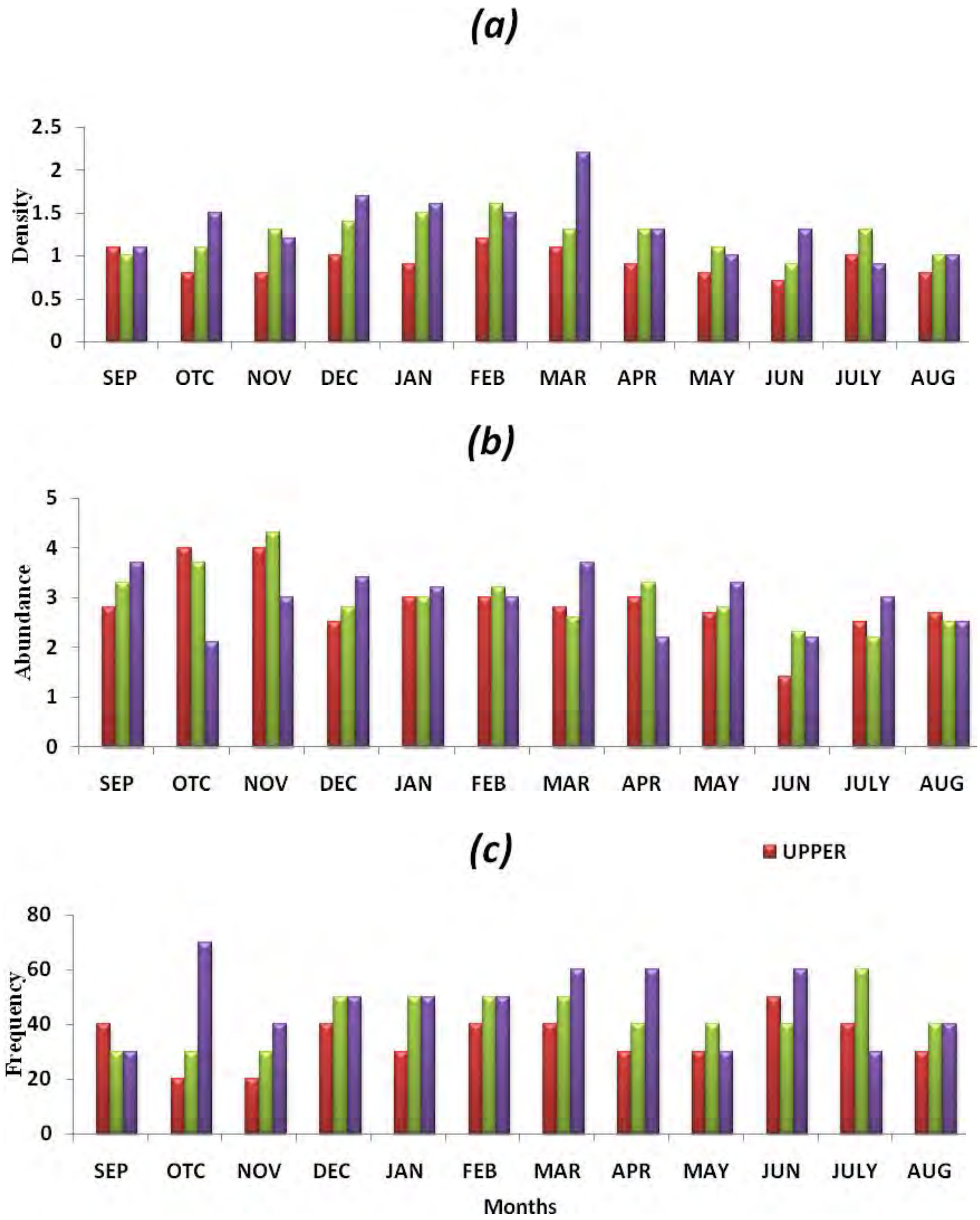

Fig. 31. Monthly variations in various ecological attributes of *Cerethium caeruleum* in different littoral zones at Somnath site-C from September 2008 to August 2009.

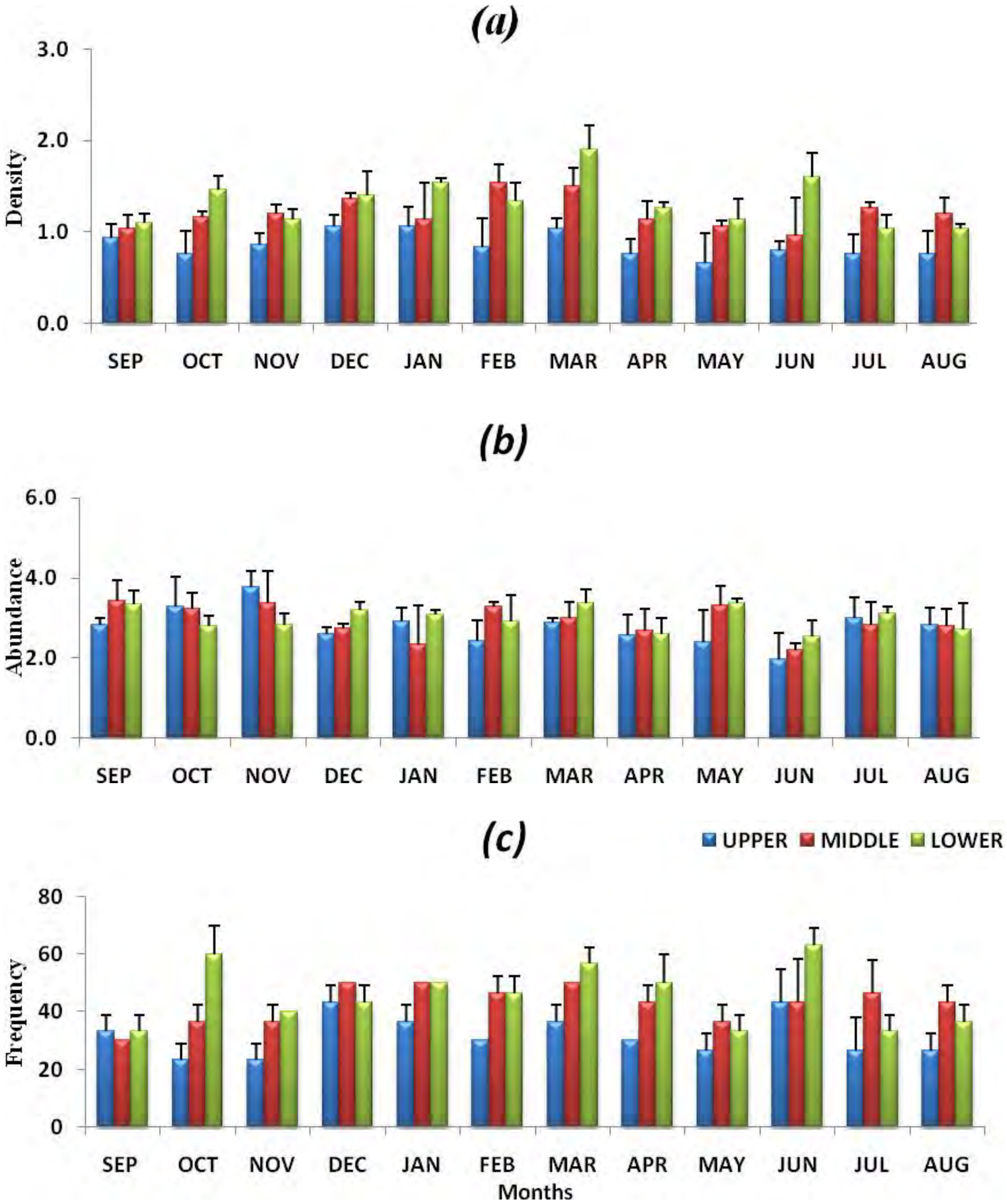

Fig. 32. Monthly variations in various ecological attributes of *Cerithium caeruleum* in different littoral zones at Somnath site from September 2008 to August 2009. Values shows are mean from three micro spatial sampling sites within Somnath shoreline, standard bar represents fixed SD.

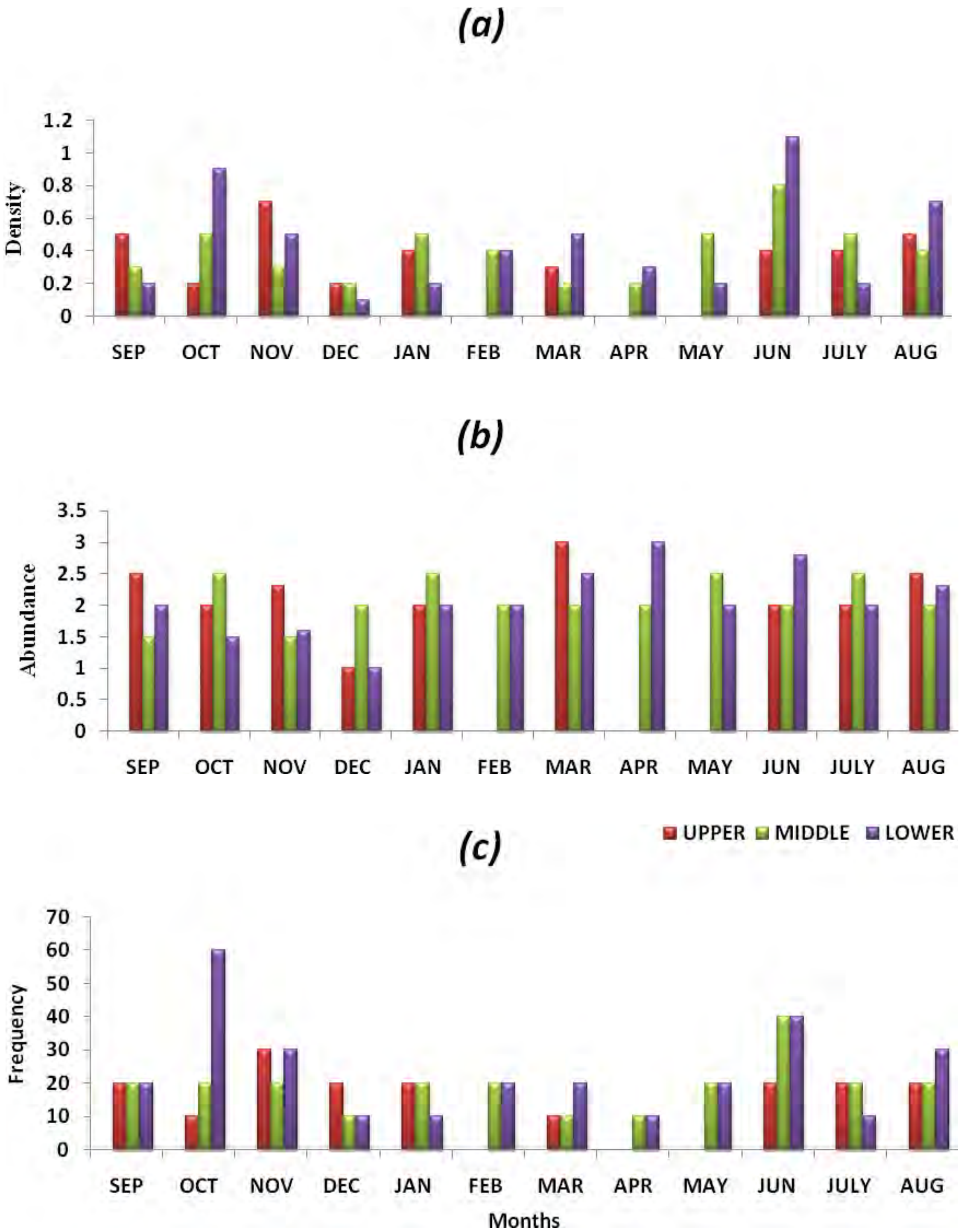

Fig. 33. Monthly variations in various ecological attributes of *Mancinella bufo* in different littoral zones at Somnath site-A from September 2008 to August 2009.

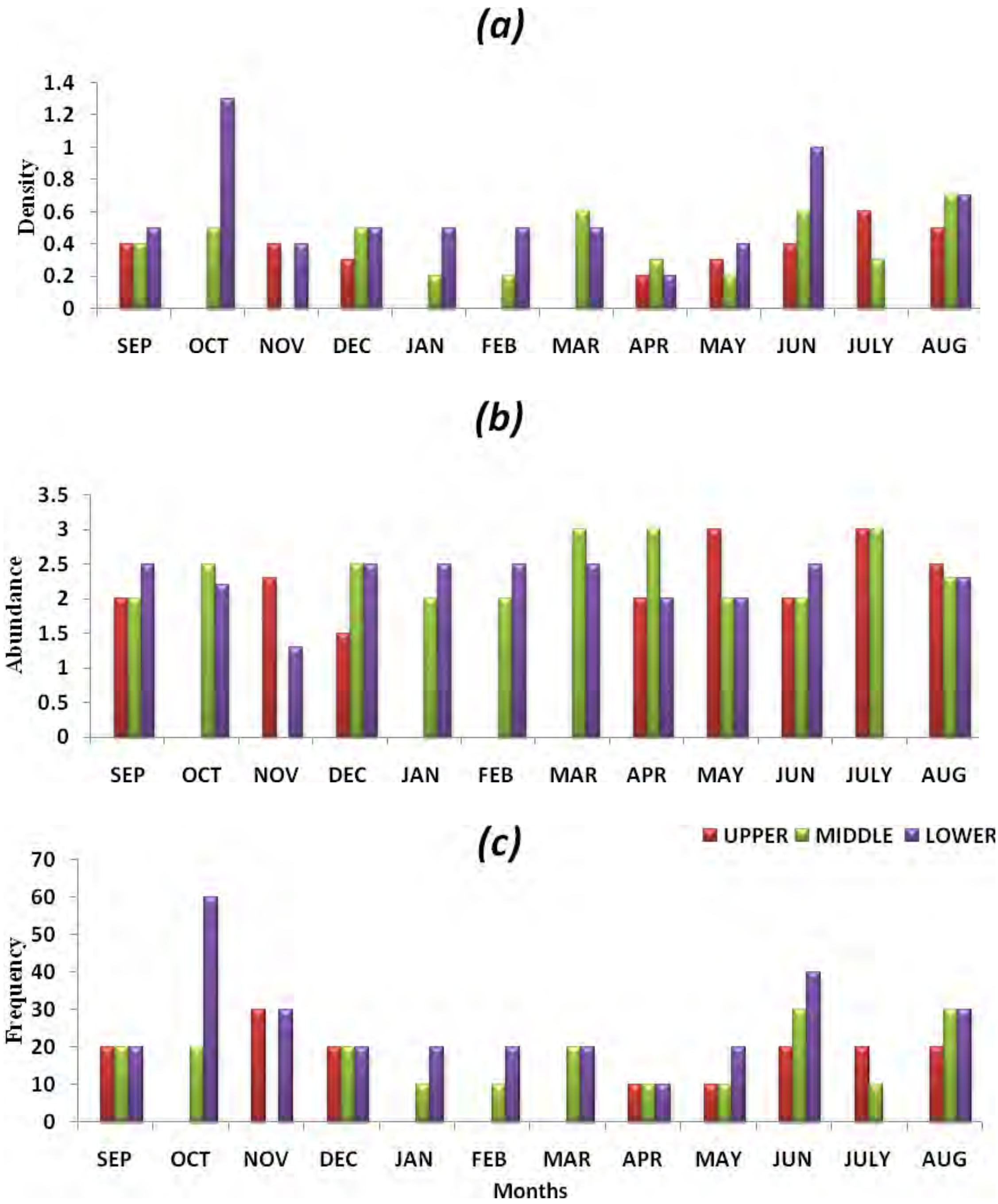

Fig. 34. Monthly variations in various ecological attributes of *Mancinella bufo* in different littoral zones at Somnath site-B from September 2008 to August 2009.

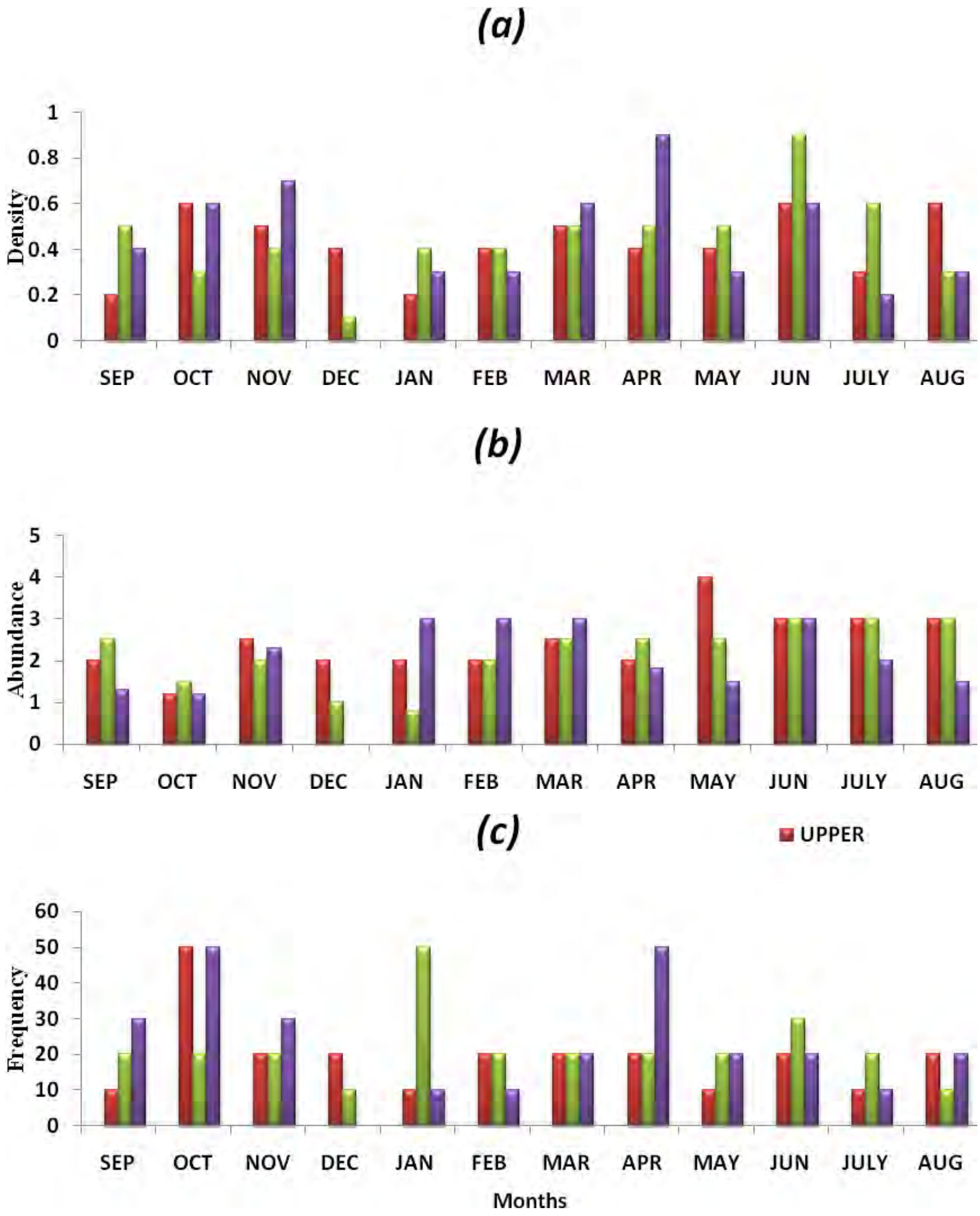

Fig. 35. Monthly variations in various ecological attributes of *Mancinella bufo* in different littoral zones at Somnath site-C from September 2008 to August 2009.

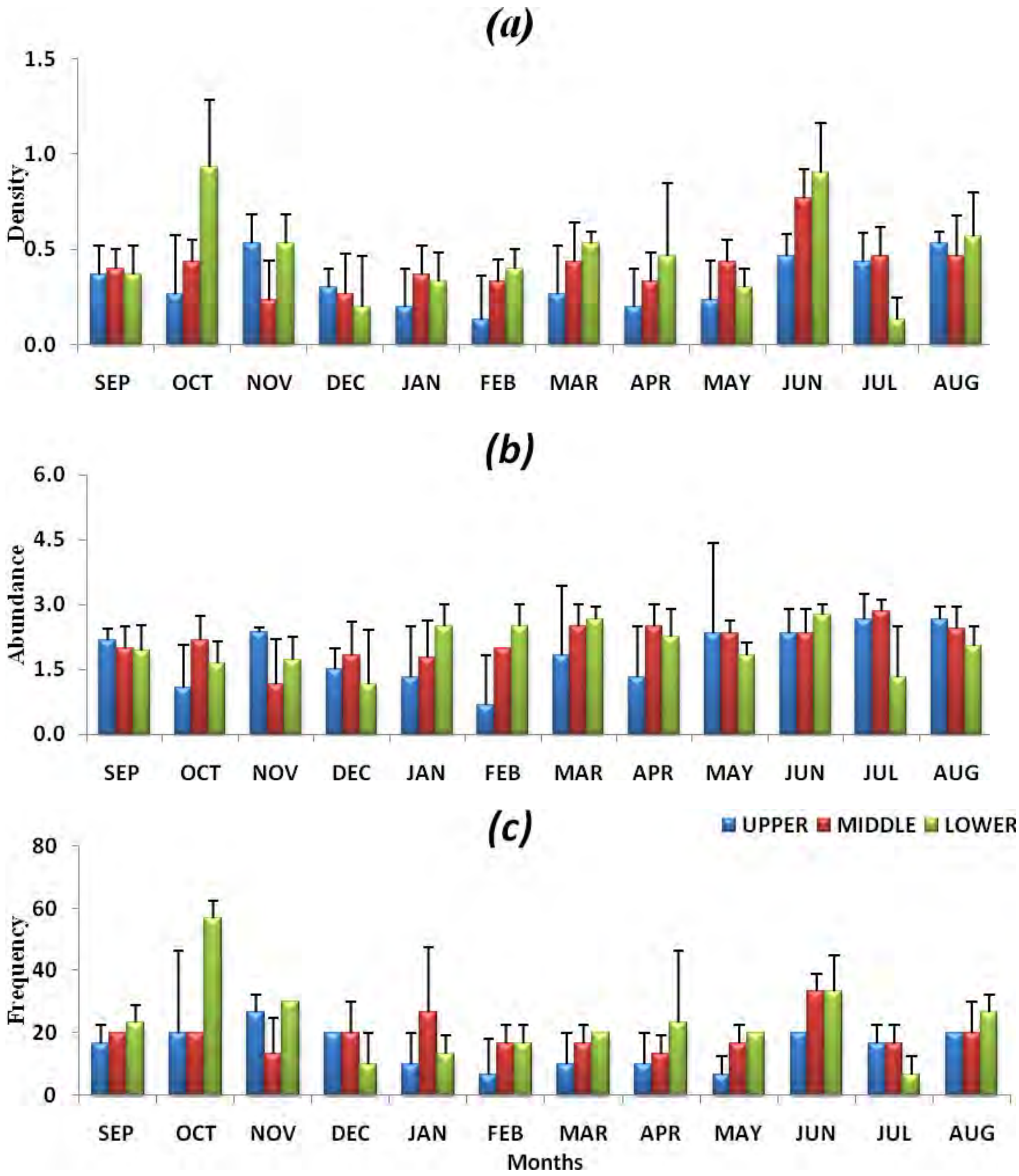

Fig. 36. Monthly variations in various ecological attributes of *Mancinella bufo* in different littoral zones at Somnath site from September 2008 to August 2009. Values shows are mean from three micro spatial sampling sites within Somnath shoreline, standard bar represents fixed SD.

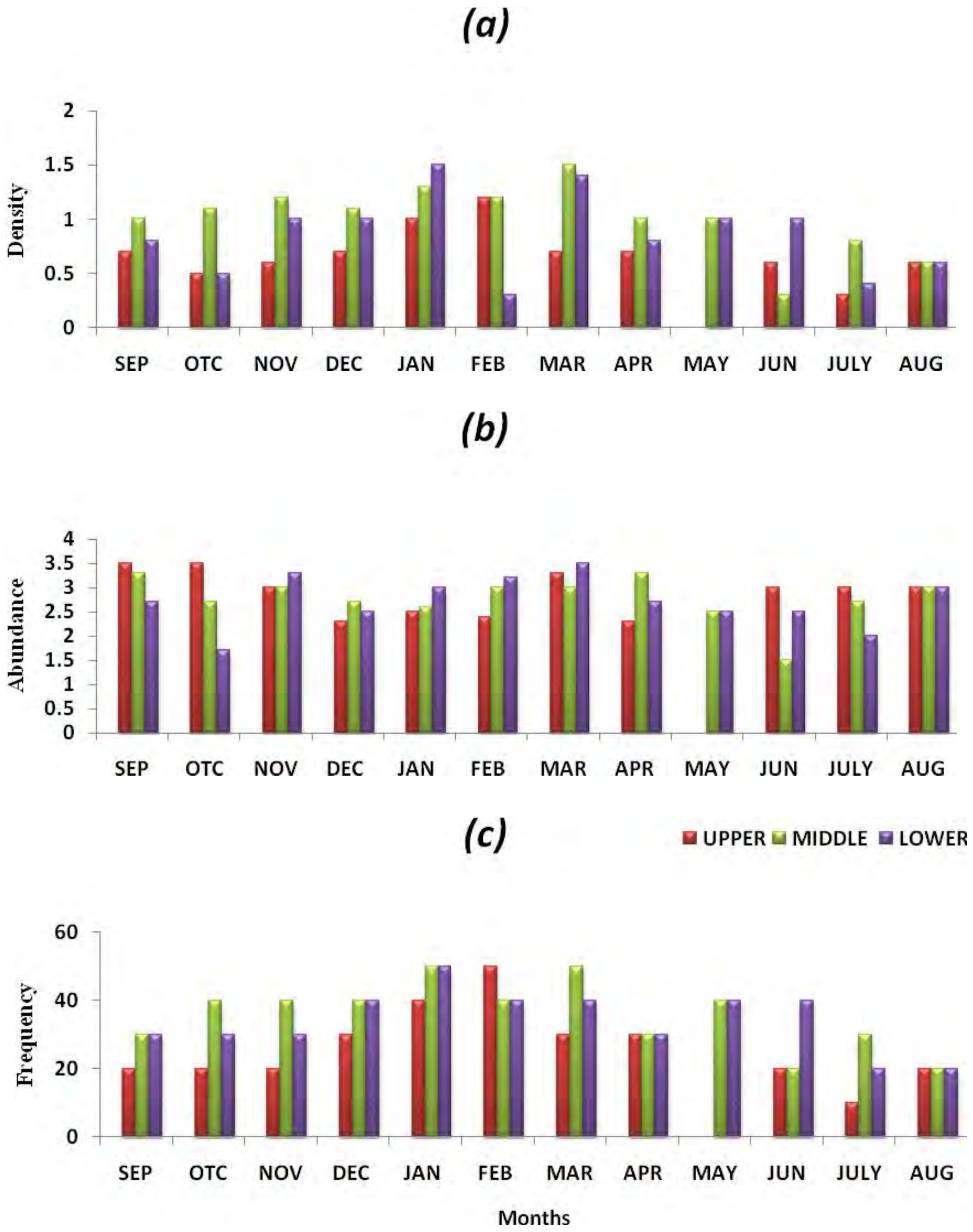

Fig. 37. Monthly variations in various ecological attributes of *Rhinoclavis sinensis* in different littoral zones at Somnath site-A from September 2008 to August 2009.

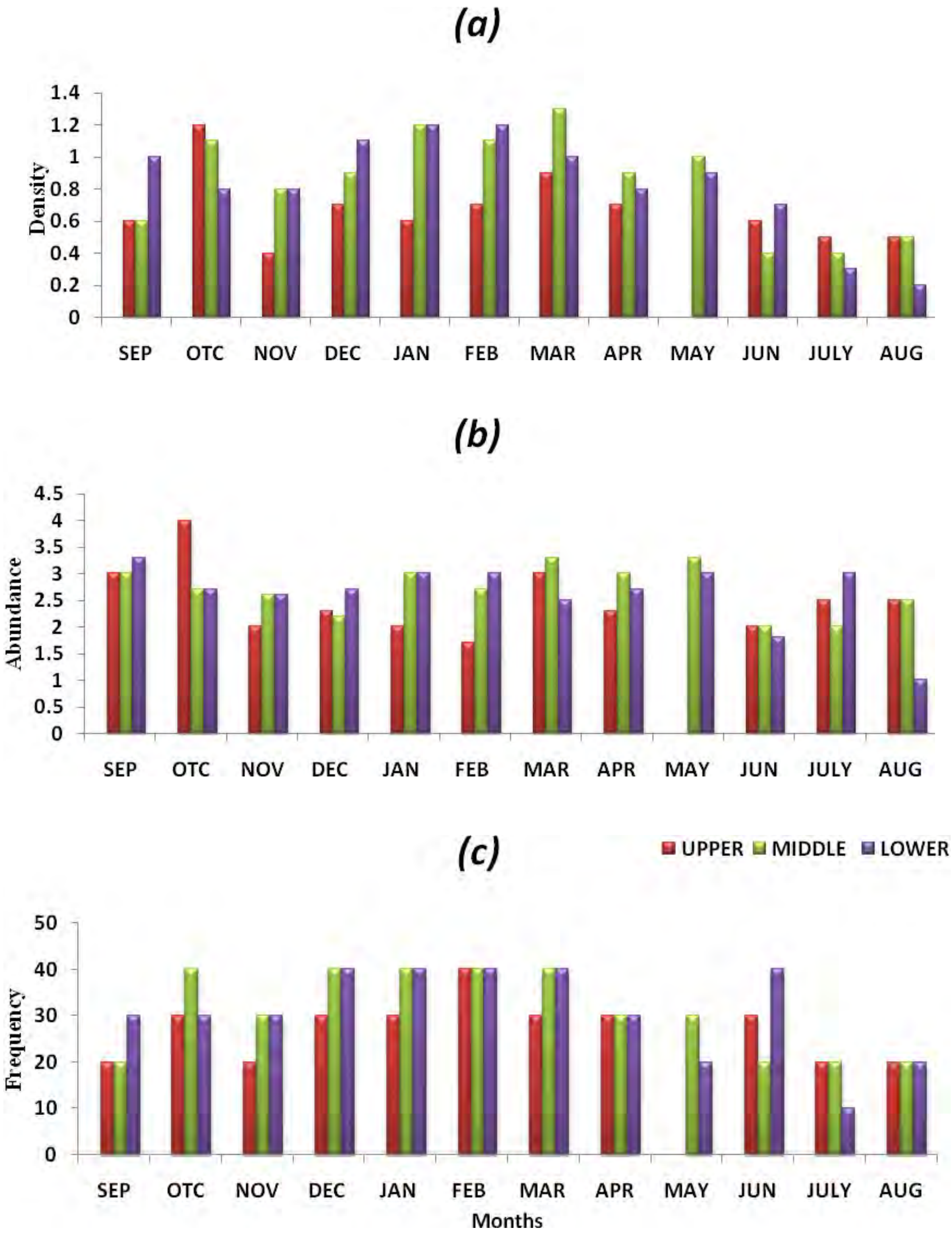

Fig. 38. Monthly variations in various ecological attributes of *Rhinoclavis sinensis* in different littoral zones at Somnath site-B from September 2008 to August 2009.

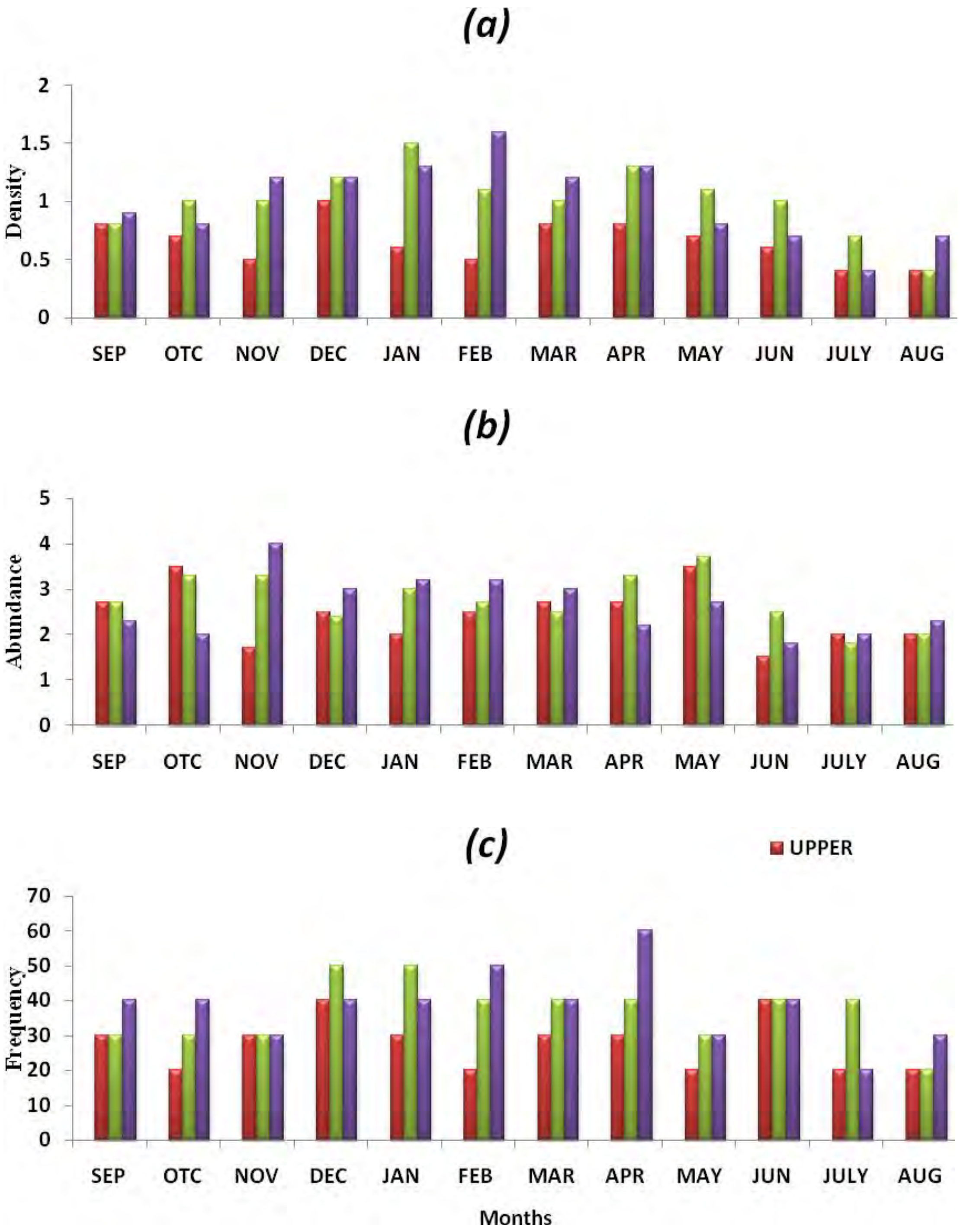

Fig. 39. Monthly variations in various ecological attributes of *Rhinoclavis sinensis* in different littoral zones at Somnath site-C from September 2008 to August 2009.

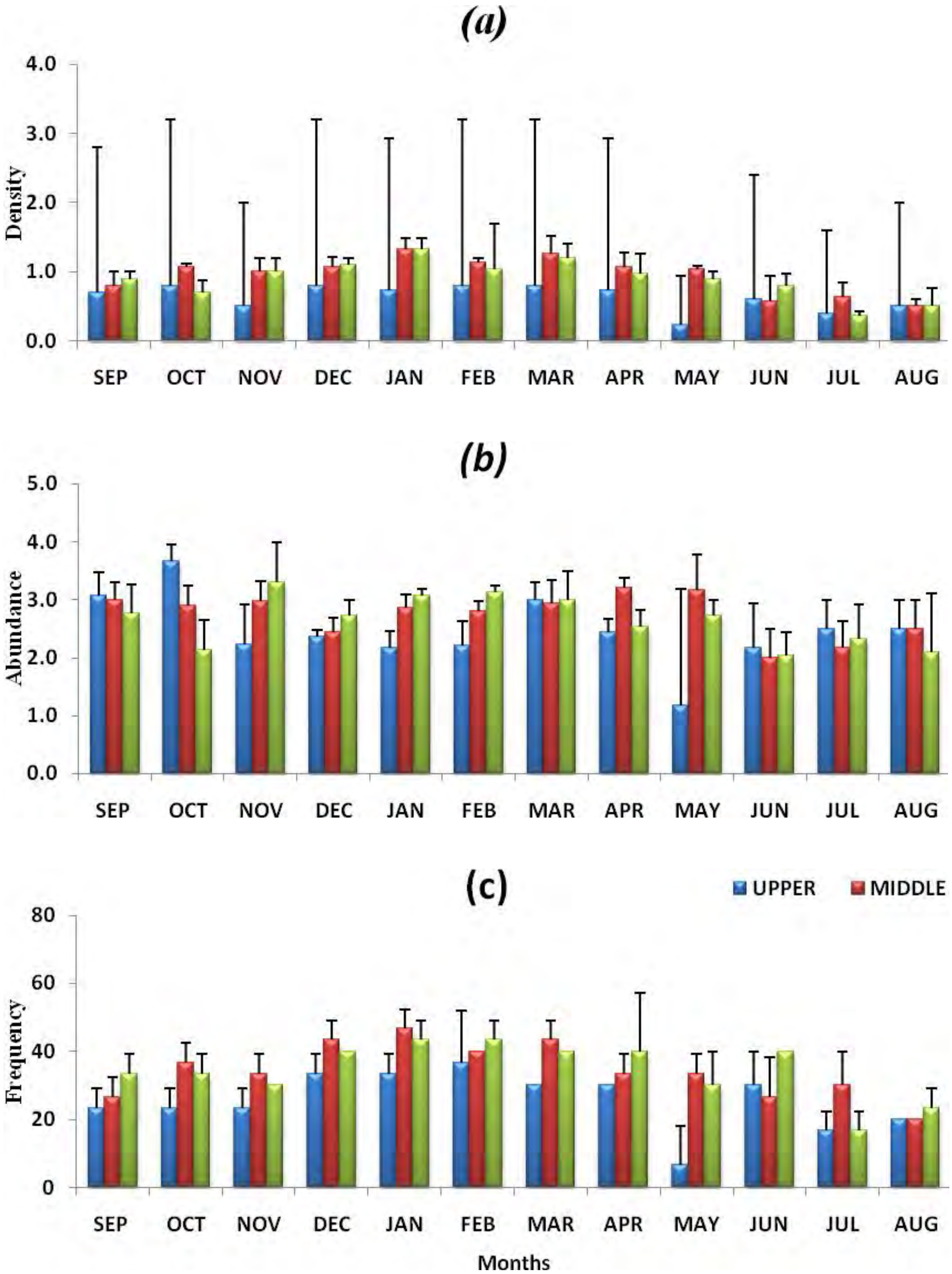

Fig. 40. Monthly variations in various ecological attributes of *Rhinoclavis sinensis* in different littoral zones at Somnath site from September 2008 to August 2009. Values revealed mean from three micro spatial sampling sites within Somnath shoreline, standard bar represents fixed SD.

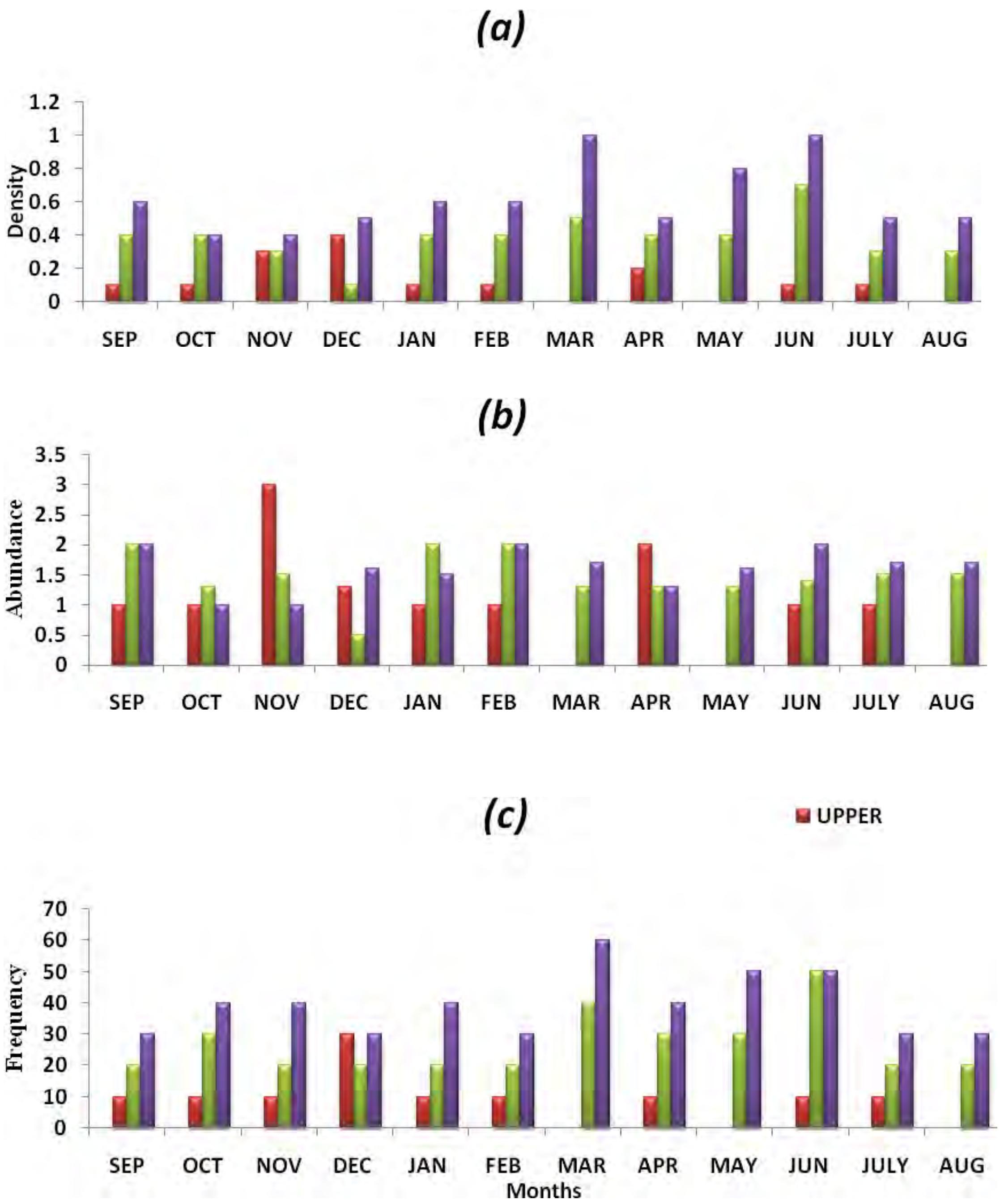

Fig. 41. Monthly variations in various ecological attributes of *Conus milliaris* in different littoral zones at Somnath site-A from September 2008 to August 2009.

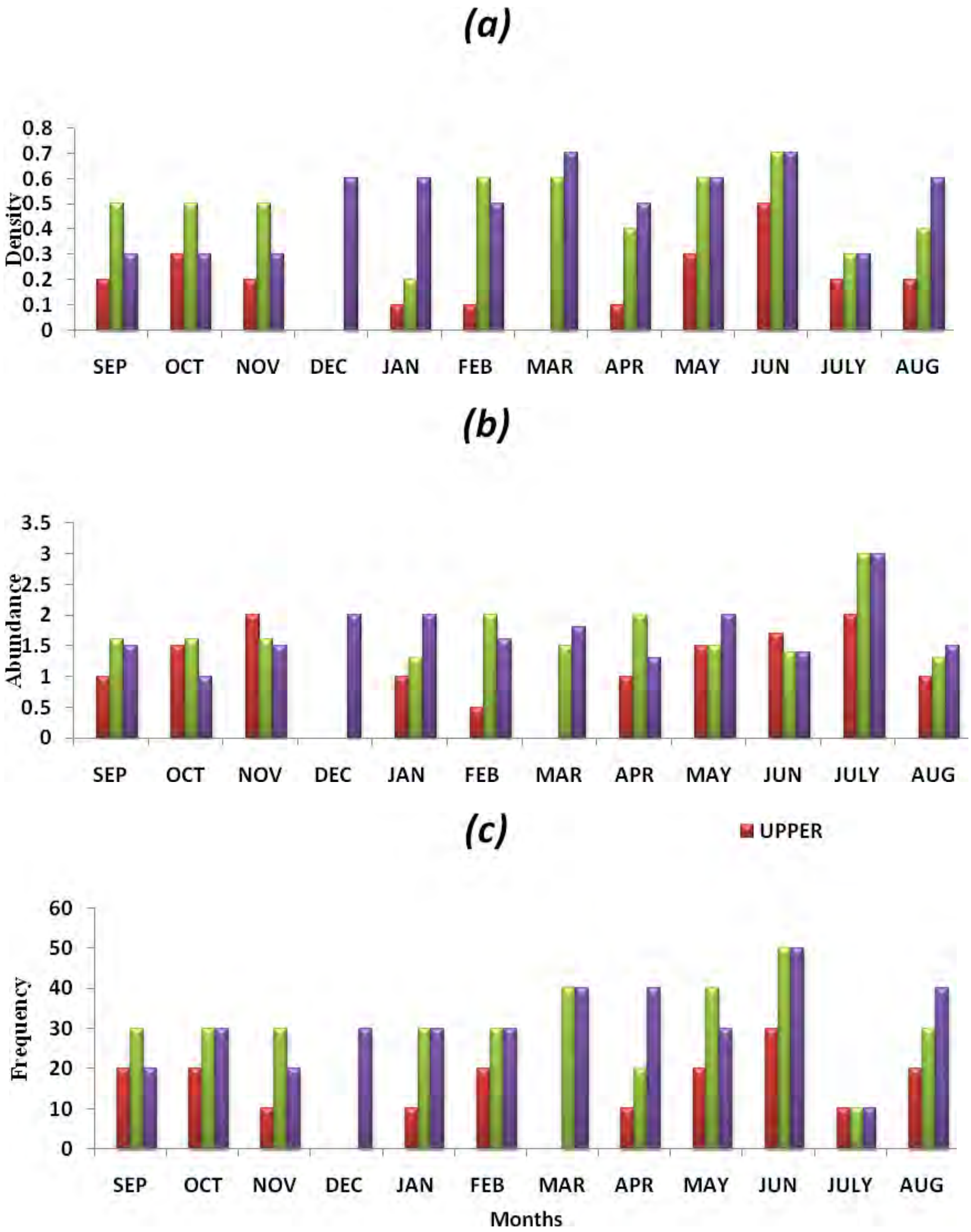

Fig. 42. Monthly variations in various ecological attributes of *Conus milliaris* in different littoral zones at Somnath site-B from September 2008 to August 2009.

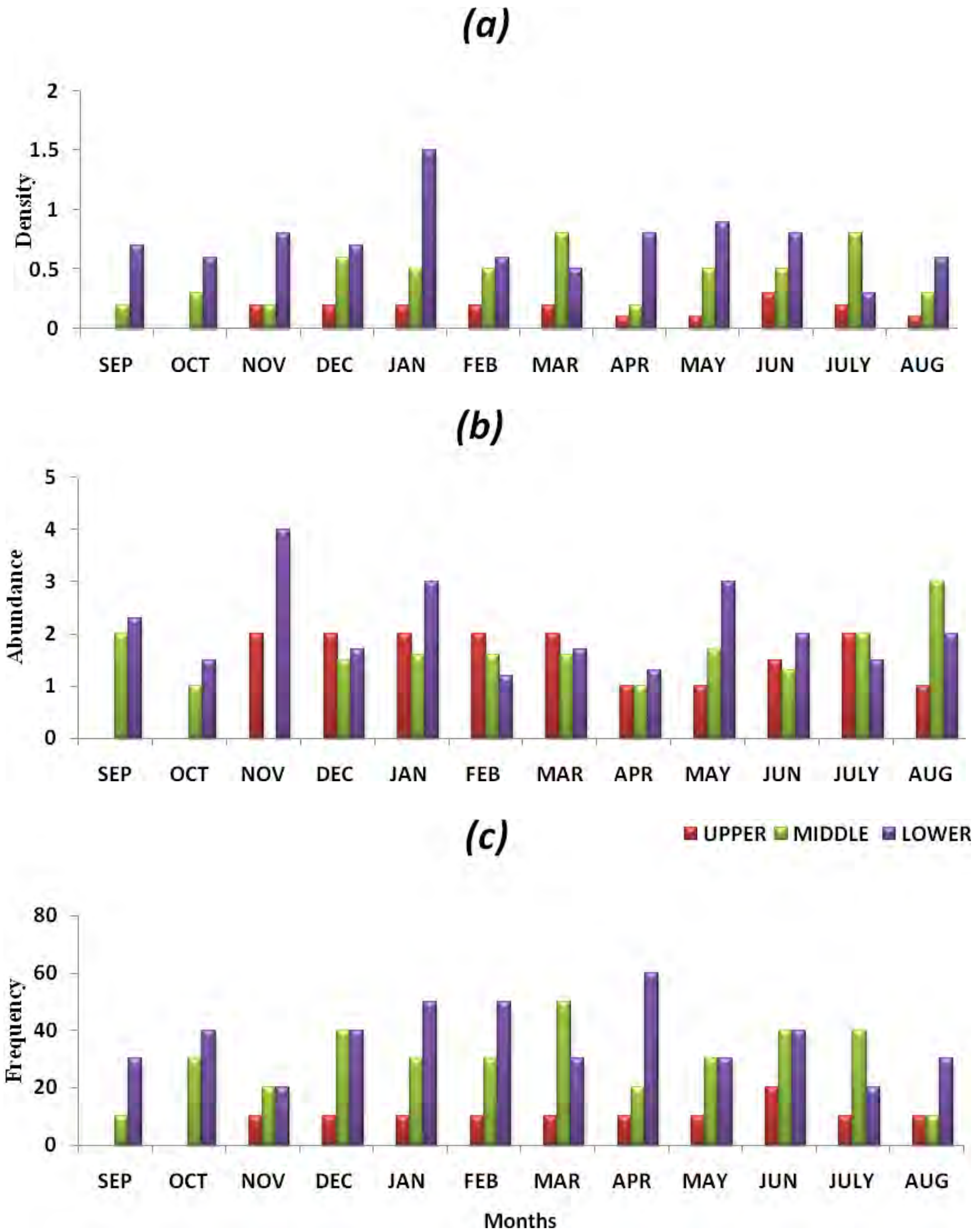

Fig. 43. Monthly variations in various ecological attributes of *Conus milliaris* in different littoral zones at Somnath site-C from September 2008 to August 2009.

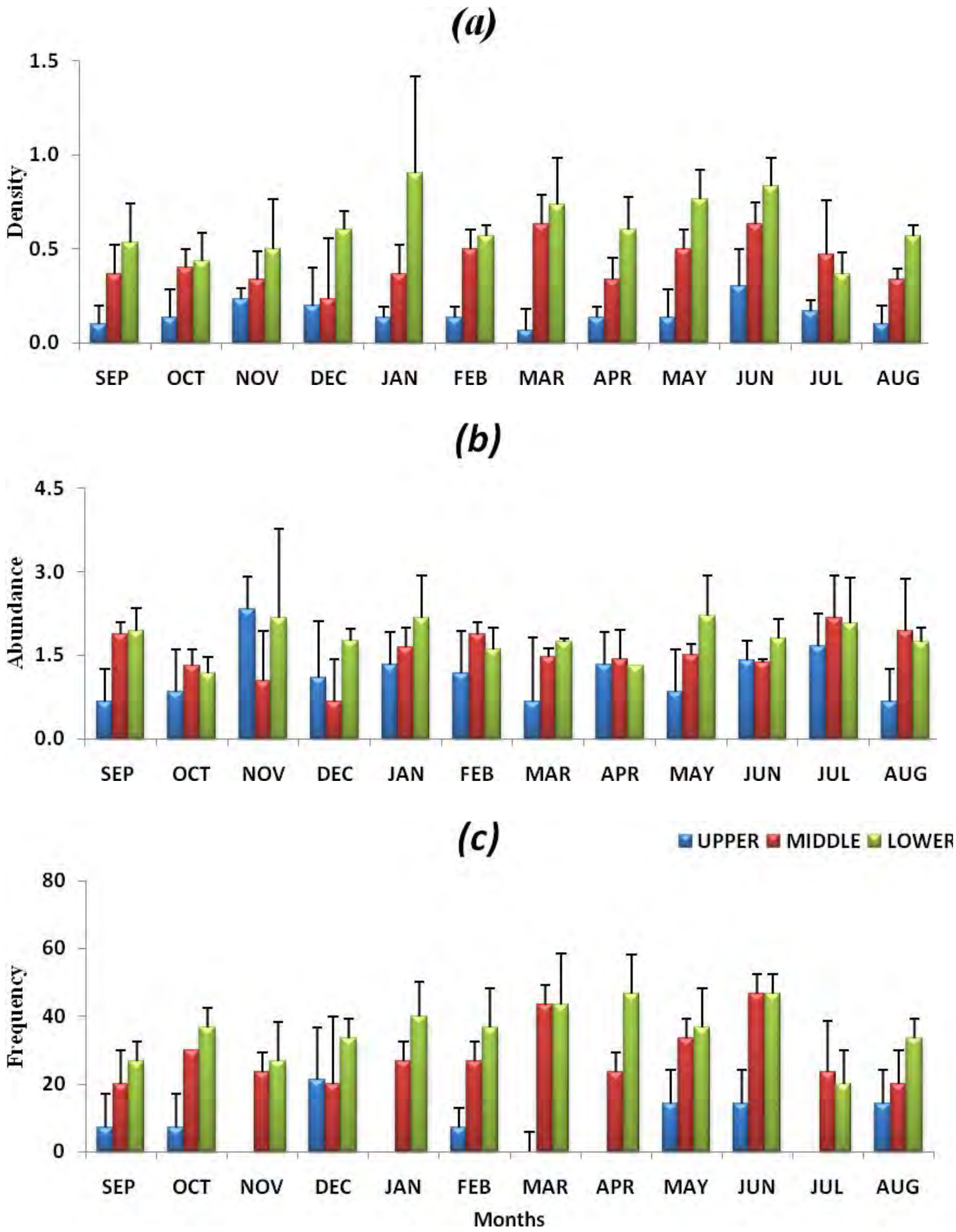

Fig. 44. Monthly variations in various ecological attributes of *Conus milliaris* in different littoral zones at Somnath site from September 2008 to August 2009. Values revealed mean from three micro spatial sampling sites within Somnath shoreline, standard bar represents fixed SD.

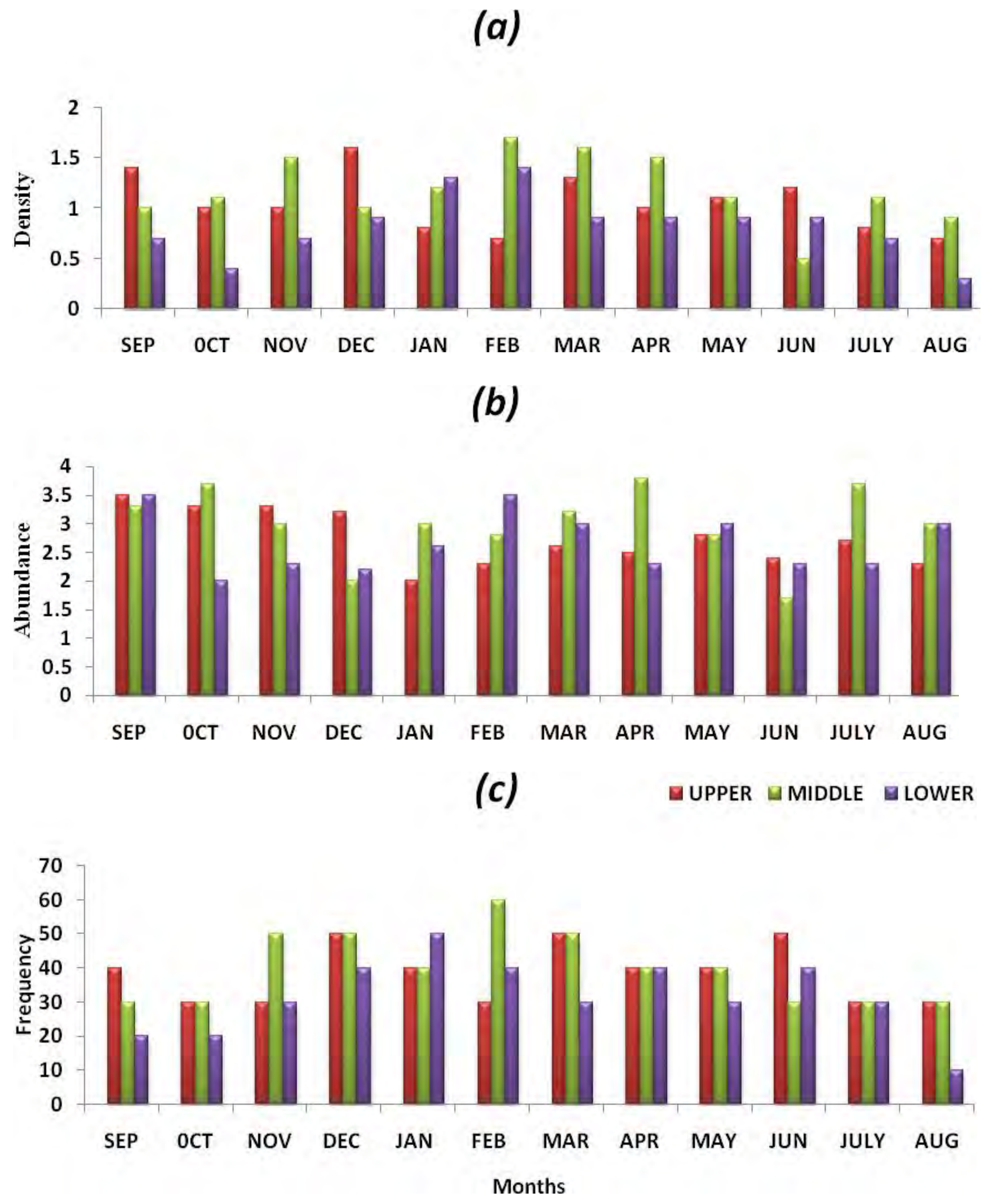

Fig. 45. Monthly variations in various ecological attributes of *Clibanarius nathi* in different littoral zones at Somnath site-A from September 2008 to August 2009.

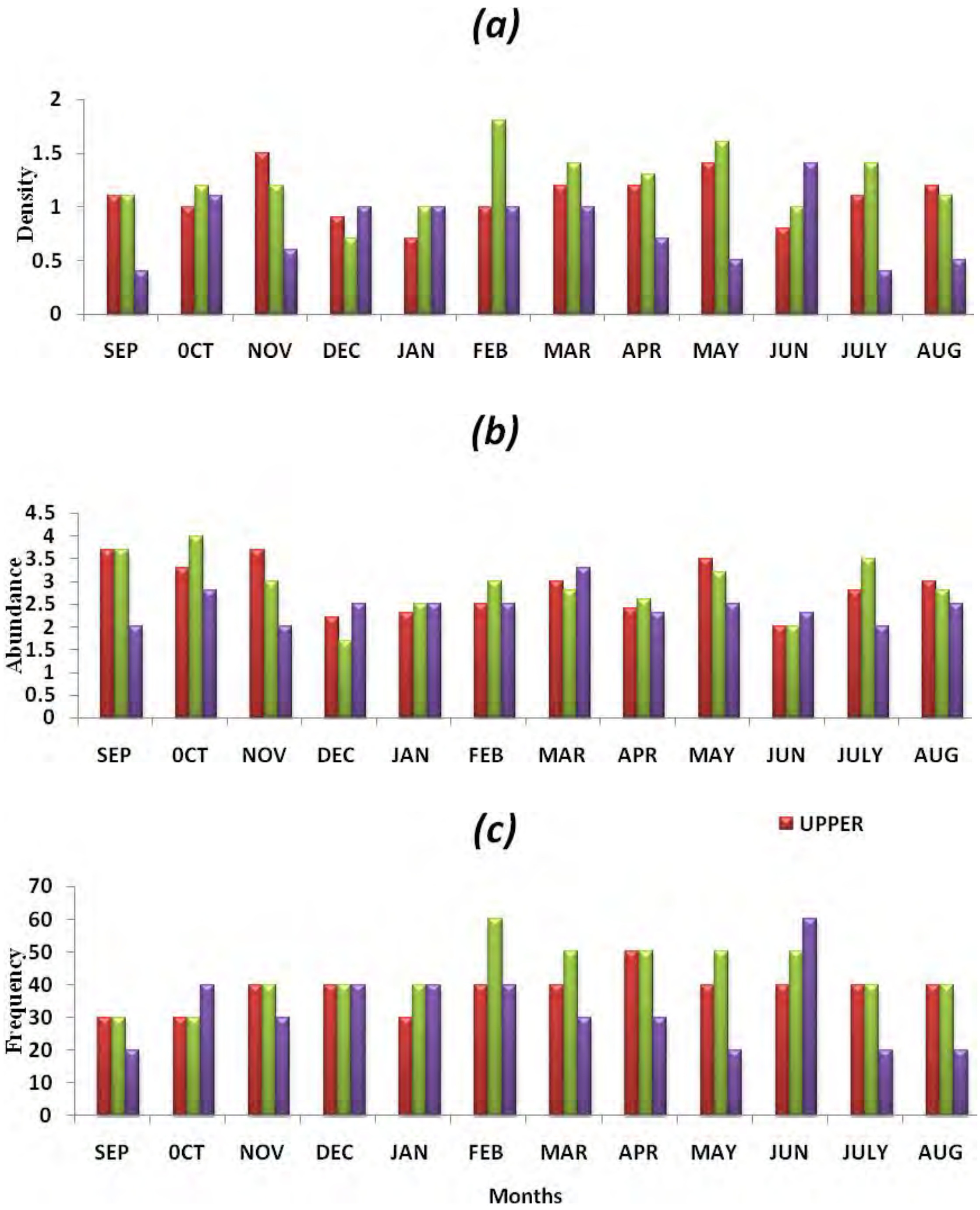

Fig. 46. Monthly variations in various ecological attributes of *Clibanarius nathi* in different littoral zones at Somnath site-B from September 2008 to August 2009.

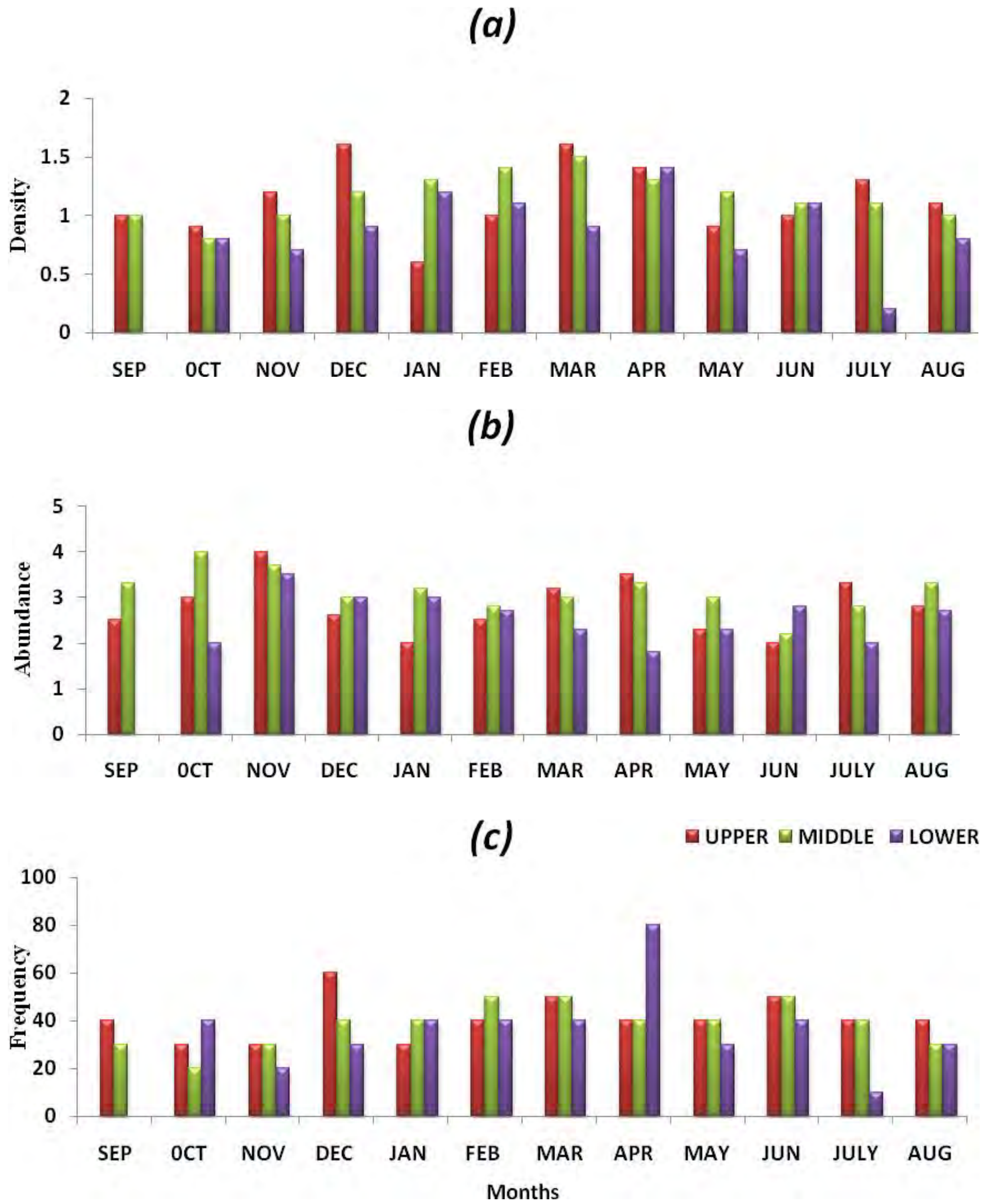

Fig. 47. Monthly variations in various ecological attributes of *Clibanarius nathi* in different littoral zones at Somnath site-C from September 2008 to August 2009.

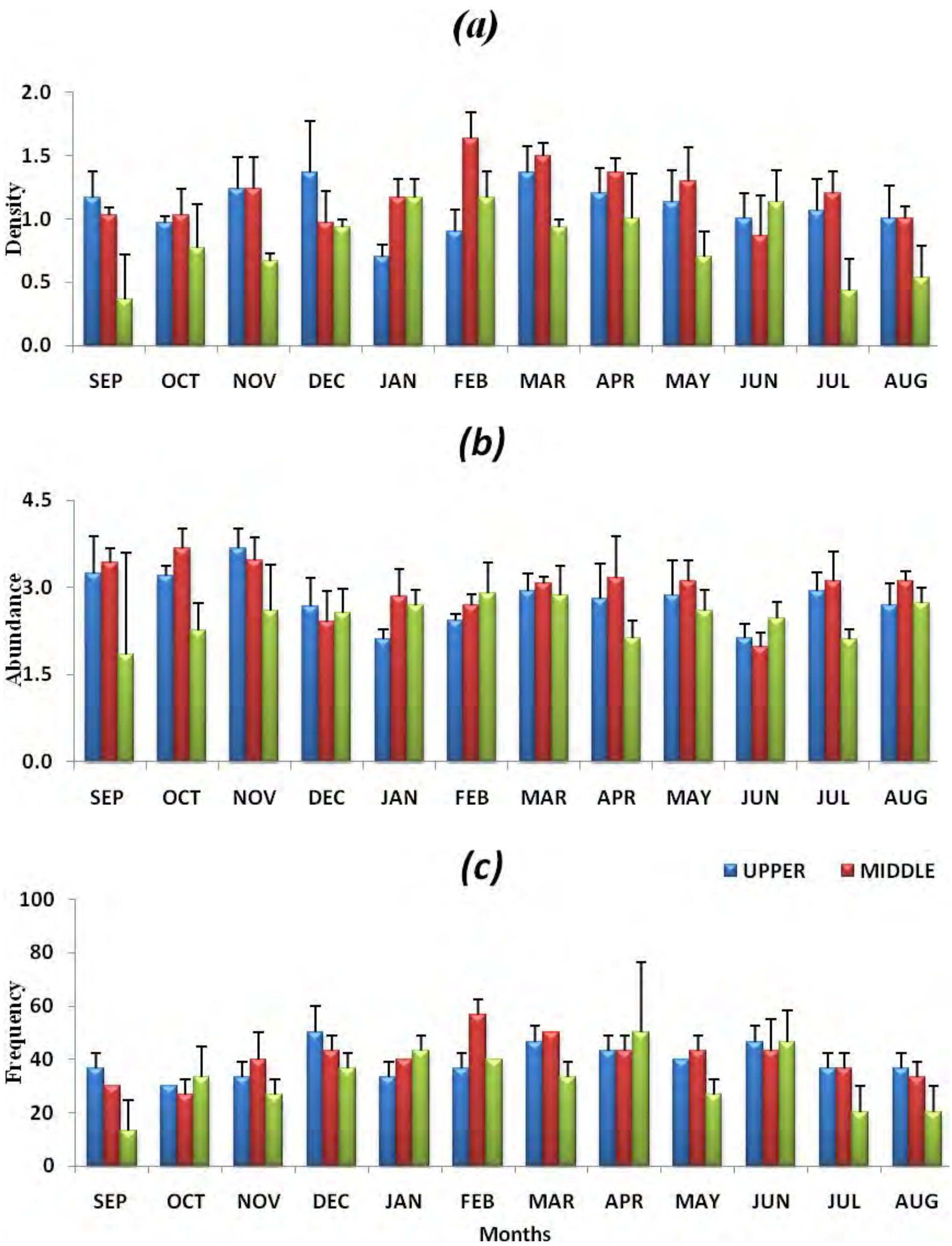

Fig. 48. Monthly variations in various ecological attributes of *Clibanarius nathi* in different littoral zones at Somnath site from September 2008 to August 2009. Values revealed mean from three micro spatial sampling sites within Somnath shoreline, standard bar represents fixed SD.

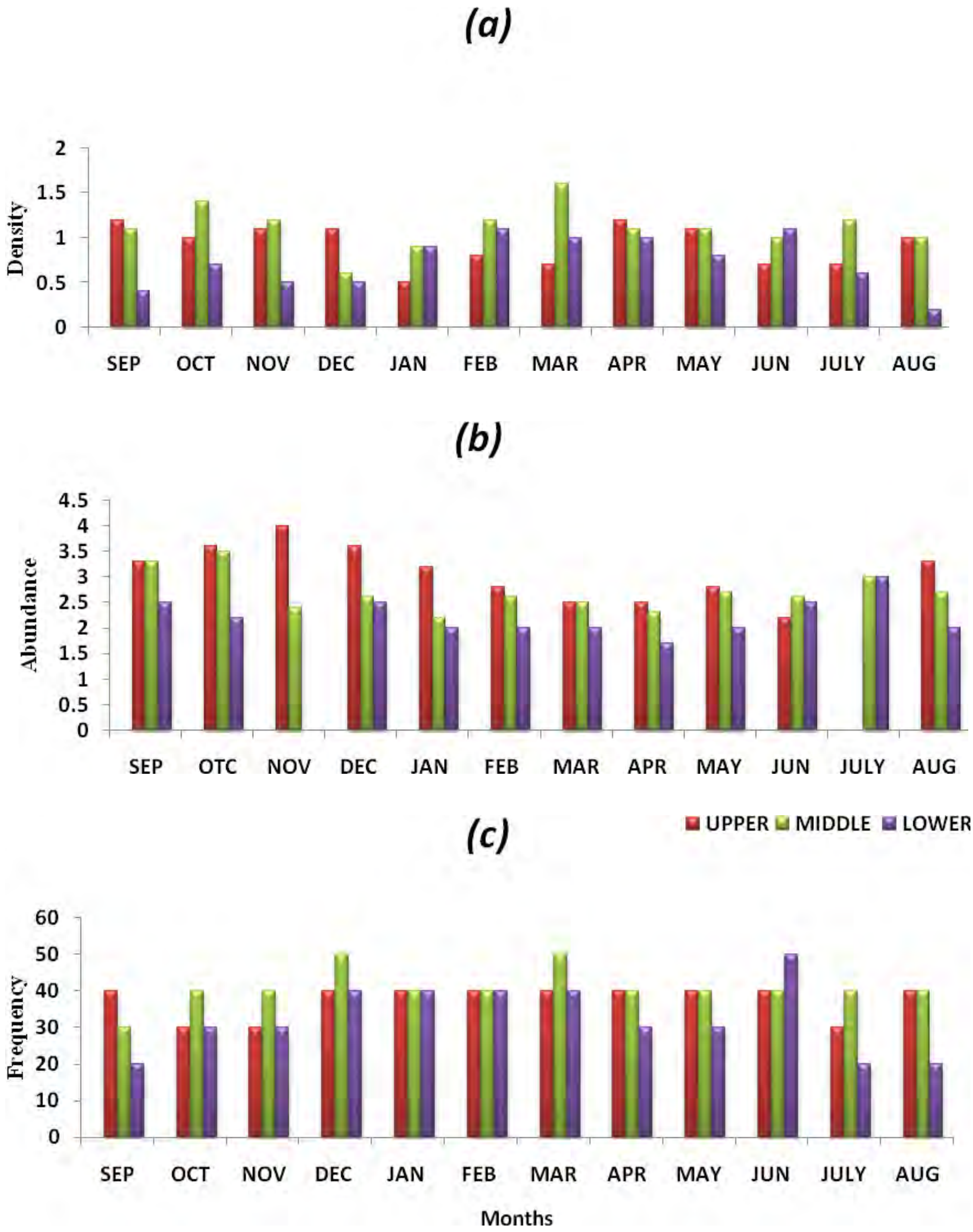

Fig. 49. Monthly variations in various ecological attributes of *Clibanarius zebra* in different littoral zones at Somnath site-A from September 2008 to August 2009.

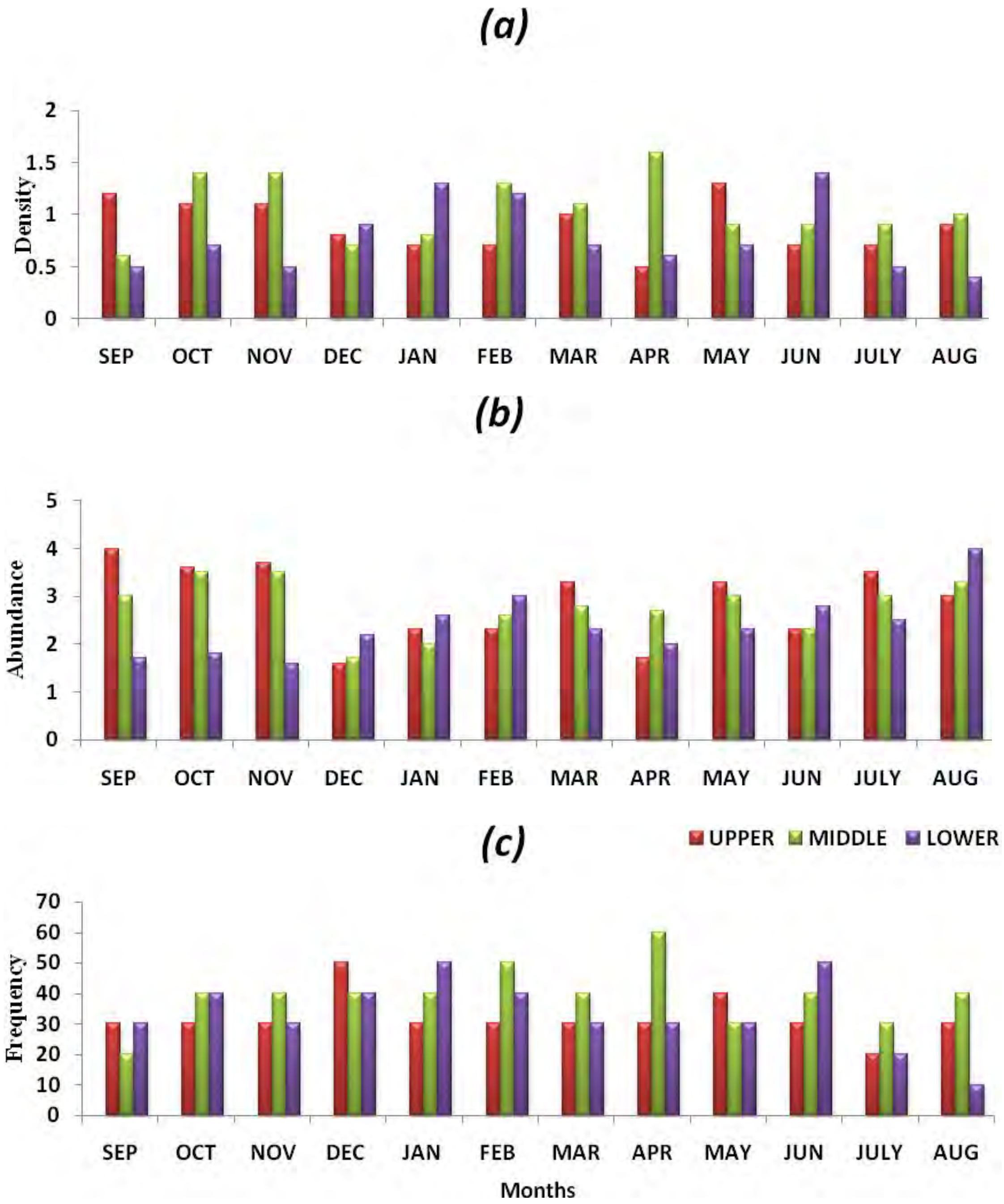

Fig. 50. Monthly variations in various ecological attributes of *Clibanarius zebra* in different littoral zones at Somnath site-B from September 2008 to August 2009.

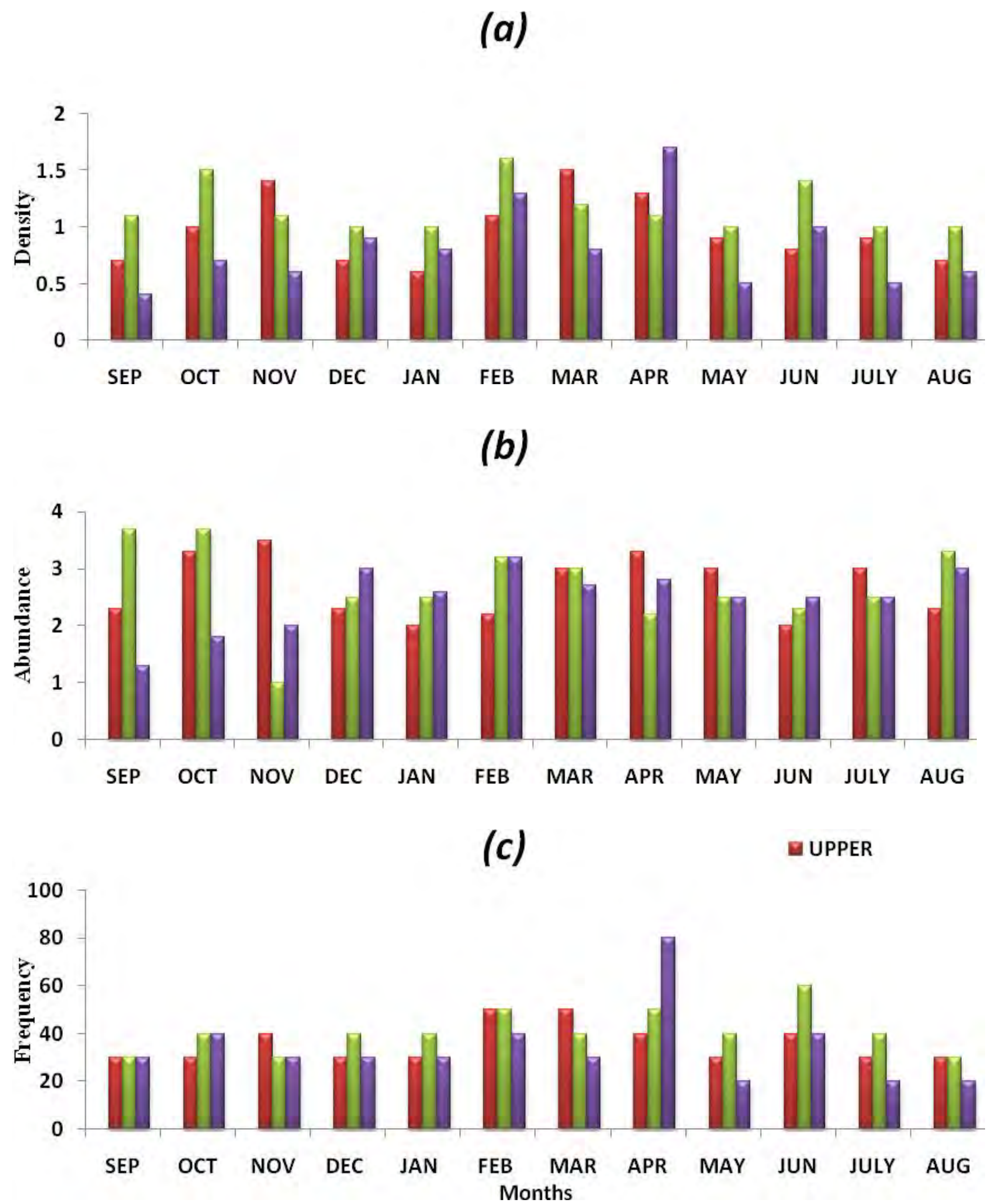

Fig. 51. Monthly variations in various ecological attributes of *Clibanarius zebra* in different littoral zones at Somnath site-C from September 2008 to August 2009.

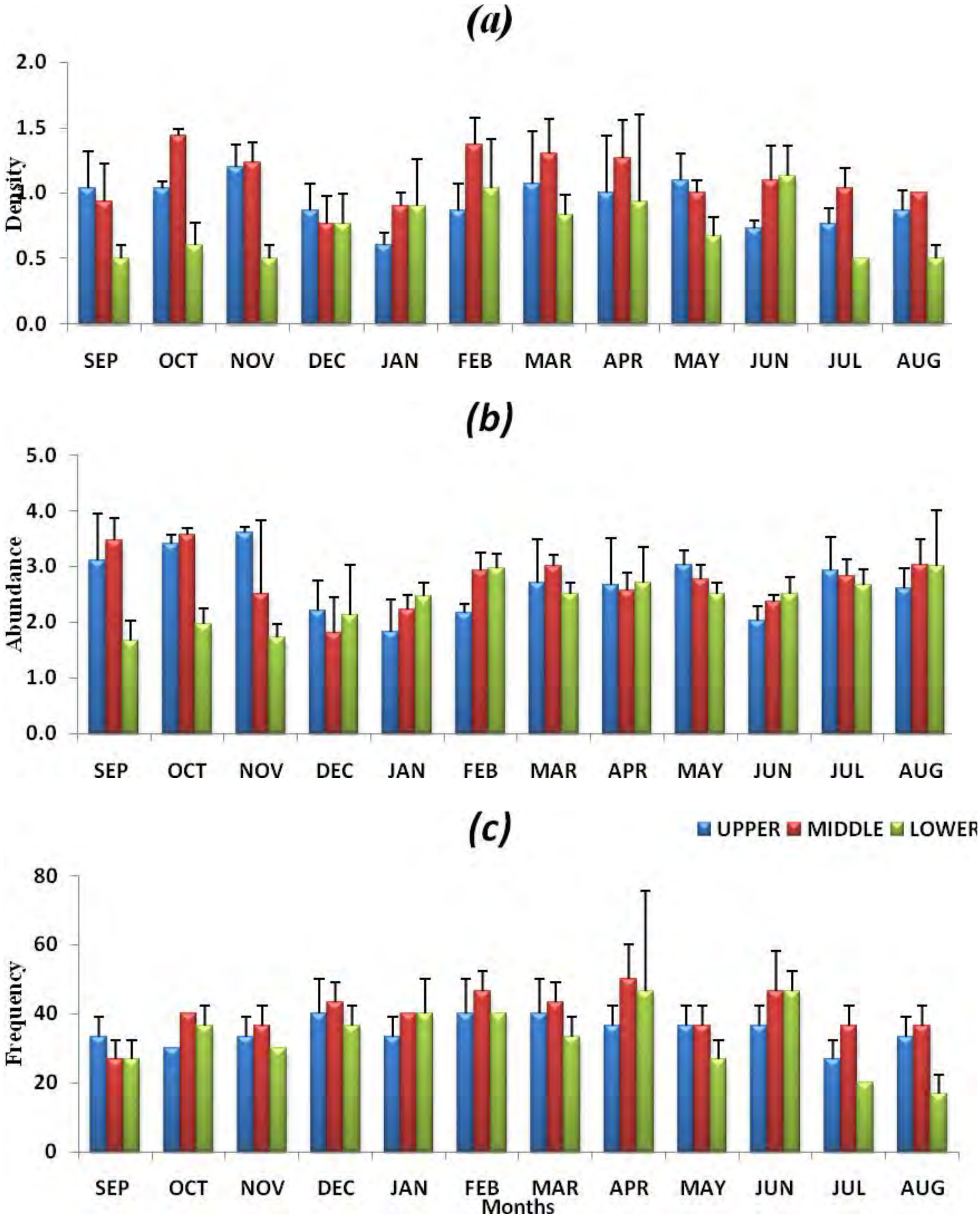

Fig. 52. Monthly variations in various ecological attributes of *Clibanarius zebra* in different littoral zones at Somnath site from September 2008 to August 2009. Values revealed mean from three micro spatial sampling sites within Somnath shoreline, standard bar represents fixed SD.

DESCRIPTION OF PLATES

PLATE NUMBER	DESCRIPTION
Plate-1	Sampling sites of Somnath a) Site A at high tide b) Site A at low tide
Plate-2	Sampling sites of Somnath a) Upper littoral zone of site B b) Upper littoral zone of site C
Plate-3	Sampling site of Nagoa A at low tide
Plate-4	Sampling site of Nagoa B at low tide
Plate-5	Sampling site of Jalandhar A at low tide
Plate-6	Sampling site of Jalandhar B at low tide
Plate-7	*Cellena radiata* in upper and middle littoral zone.
Plate-8	a) Juveniles of *Aplysia oculifera.* b) *Aplysia oculifera* release ink in water.
Plate-9	*Onchidium verruculatum* in upper and middle littoral zones at low tide.
Plate-10	a) *Mancinella bufo* feeding on *Ulva sp.* in middle littoral zone. b) *Mancinella bufo* in upper littoral zone at low tide.
Plate-11	*Conus milliaris* associated with algae.
Plate-12	*Conus milliaris* in middle and lower littoral zones.
Plate-13	a) *Rhinoclavis sinensis* in middle littoral zone. b) *Tibia insulaechorab* in lower littoral zone at low tide.
Plate-14	a) *Turbo intercoastalis* with *Cerethium caeruleum* b) *Trochus hanleyanus* associated with *Ulva sp.*
Plate-15	a) *Cerethium caeruleum* in upper littoral zone. b) *Chicoreus sp.* feeding on green algae.
Plate-16	a) Patch of *Parazooanthus* at low tide. b) Close-up view of *Parazooanthus.*
Plate-17	a) Sea anemone *Metridium* at low tide in middle littoral zone. b) Sea anemone *Metridium* during feeding in middle l. zone.
Plate-18	a*) Neris sp.* coiled with *Trochus sp.* b) *Balanus amphirite* in middle littoral zone at low tide.
Plate-19	a*) Physelia sp.* in upper littoral zone. b)*Cyprinea sp* associated with green, brown algae.
Plate-20	a) A colorful Nudibranch (sea slug). b) *Parazooanthus* colour changing.
Plate-21	a) Sea shore crab feeding on marine algae. b) Red shore crab in a pool.
Plate-22	Common sea shore crab at low tide.
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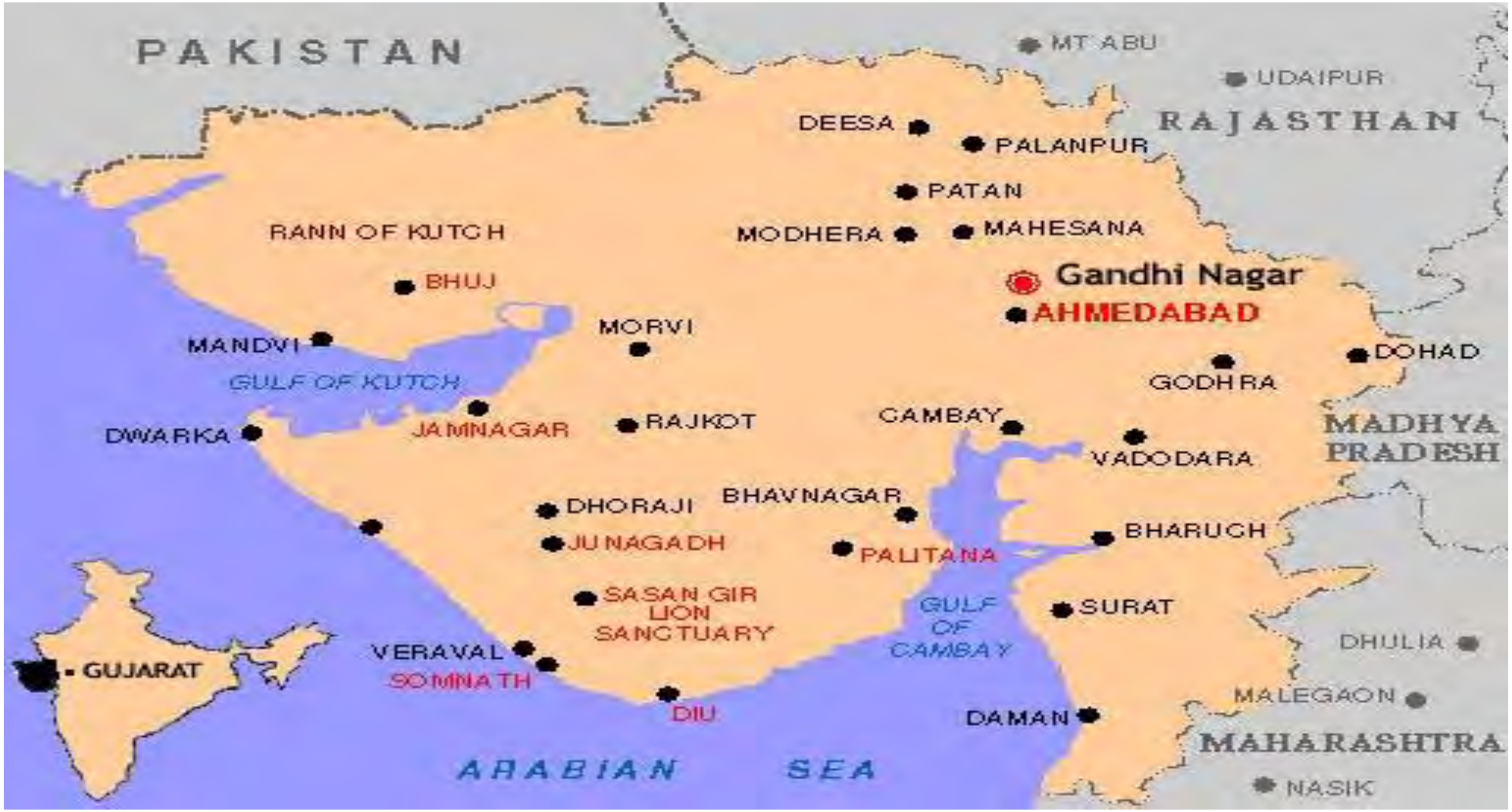
Plate-24	a) *Clibanarius zebra* (Hermit crab) without molluscan shell. b) *Clibanarius zebra* in molluscan shell.
Plate-25	*Clibanarius nathi* (Hermit crab) on rocky upper littoral zone.


PAKISTAN
MT ABU
UDAIPUR
RAJASTHAN
DEESA
PALANPUR
PATAN
RANN OF KUTCH
MODHERA
MAHESANA
Gandhi Nagar
AHMEDABAD
BHUJ
MORVI
MANDVI
GULF OF KUTCH
DOHAD
GODHRA
DWARKA
JAMNAGAR
RAJKOT
CAMBAY
VADODARA
MADHYA PRADESH
DHORAJI
BHAVNAGAR
JUNAGADH
PALITANA
BHARUCH
SASAN GIR LION SANCTUARY
GULF OF CAMBAY
SURAT
DHULIA
VERAVAL
SOMNATH
GUJARAT
MALEGAON
DIU
DAMAN
MAHARASHTRA
ARABIAN SEA
NASIK

Map-1


Tourist Map of Diu
N
Gujarat
Coconut Trees Belt
BUCHARWADA
Coconut Trees Belt
Bird Sanctuary
Bird Sanctuary
GHOGHLA
Ahmedpur Mandvi Beach
VANAKBARA
Agricultural Area Reserve Forest
Salt Pans
Salt Pans
Industrial Zone
St. Paul's Church
Port
Diu Airport
FUDAM
Vanakbara Jetty
Nagoa Beach
NAGOA
Gangeshwar Temple
Jallandhar Beach
Chakratirth Beach
ARABIAN SEA
Map not to Scale
State Boundary
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Map-2


Tank
Cemetery
To Kodinar, Diu & Una
Cold Store
Boatyard
OLD TOWN
Temple
Museum
Bus Stand
Temple of Somnath
Shipwreck
ARABIAN SEA
Legend
Major Road
Other Road
Railway
Important Place
Temple
Hotels

Map-3

PLATE-1

PLATE-2

PLATE-3

PLATE-4

PLATE-5

PLATE-6

PLATE-7

PLATE-8

PLATE-9

PLATE-10

PLATE-11

PLATE-12

PLATE-13

PLATE-14

PLATE-15

PLATE-16

PLATE-17

PLATE-18

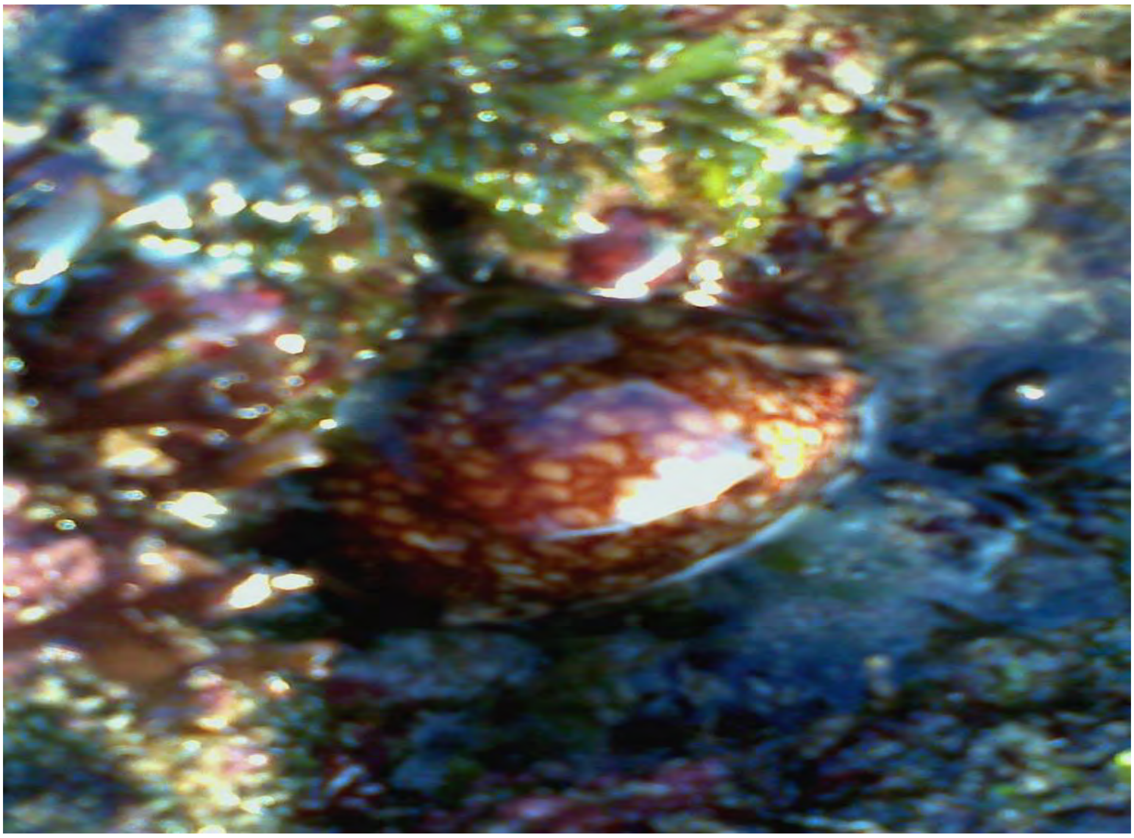

PLATE-19

PLATE-20

PLATE-21

PLATE-22

PLATE-23

PLATE-24

PLATE-25