

4 RESULT AND DISCUSSION

The intertidal opening of selected coast of this study was very narrow, about 6 to 8 m. The surface of all selected sampling sites was sharp edged. The upper intertidal zone was made of rocks with fine creeks and pools, which help populations of this zone to interchange along with the upcoming tidal water. The sea-floor off all selected sampling sites contains irregular flat rocky bottom, rocky patches and sandy sea-bed. All selected site are mostly steeply declined tidal flat that builds it challenging to access the lower littoral zone.

The middle and lower zone of intertidal area of all study sites have almost one and the same features of substratum and biotic composition. The middle and lower intertidal zones remains under water for most of the time, therefore the faunal compositions do not change considerably with the seasons. Due to abundant pools and puddles, this zone holds water for long time. High intertidal zone or high tide zone is flooded at the time of high tides only. Organisms found in this zone are crabs, anemones, chitons, barnacles and snails. Middle tide zone or mid-littoral zone is covered /uncovered twice in a day. Sponges, barnacles and crabs are the common organisms found in this zone. Lower littoral zone or low intertidal zone is covered with water almost all the time except at the time of extremely low tide. That is the reason why organisms are not well adjusted for longer duration of dryness or to extreme temperatures with compare to other zone. Seaweed, crabs and sea anemone are the common organisms in this region. Overall the intertidal zone is harboured by hard shelled Mollusca, crabs and sea anemone.

When the tide retreats, the upper regions called as supra tidal or splash zone become exposed to air. The organisms found during the course of this study in this region are algae, lichens, barnacles and limpets. They facing problems like dryness, temperature changes and feeding. This area is covered only at the time of storms and extremely high tides and moistened by the spray of the breaking waves. Organisms are exposed to the drying heat of the sun in the summer and to extreme low temperatures in the winter. Just because of these severe conditions, only a few resistant organisms live in this zone. During the winter algae found on the rocks of the supra tidal may be due to moisture of the sea spray from waves and gradually die during the summer may be due to higher temperature. Sometime dryness and residues of sea weeds were very common, which provides good shelter as well as breeding ground to many organisms in intertidal zone.

The sub tidal zone or sub littoral zone is the region below the intertidal zone, which continuously covered under water. This zone is more stable than the intertidal zone. Organisms available in this zone do not dry out as often as organisms available in other zone. They develop more rapidly and better in competition for the same niche. More important nutrients are acquired from the water and they are protected from extreme changes in temperature (Karleskint, 1998; Levinton, 1995).

Entire coast of selected study area has been covered by mainly three classes of the algae i.e., chlorophycea, pheophycea and rhodophycea. Total 22 species were recorded from selected sampling site. From that 12 species of chlorophytes, 6 species of pheophytes and 4 species of rhodophytes were recorded (**Table 4.1**). It is clearly indicated that chlorophycea was the most diverse class from all three recorded class. Among chlorophycea, *Ulva* species was most common, in pheophycea *sargassum*

swartzii and *padina gymnospora* were common and in rhodophyceae *champia indica* was the most common algae was observed in intertidal zone of all selected sampling sites.

Out of overall recorded, 22 species of algae, 5 species distributed all over the coast, which were found at all selected sampling sites, it include two species of sargassum, one species of padina and two species of Ulva (**Table 4.1**).

Faunal macro benthos, observed at intertidal zone of selected sampling sites were mainly six groups, such as Porifera, Arthropod, Mollusca, Echinodermata, Annelida and Cnidaria. As per Morton, 1968 and Menez, 2003 phylum Arthropoda and Mollusca were the most dominant and diverse from above group. In this study, Mollusca were the most dominant and diverse from all recorded phylum at all selected sampling site of this study (**Table 4.4 & 4.5; Figure 4.1 to 4.6**). Among all the class of Mollusca, Gastropod was the most abundant at all selected sampling sites. Most of the found fauna were grazer that utilized the sea weeds resources as their food as well as accommodation. Also the environmental factors were supporting the diversity status Mollusca. All these were responsible to provide good breeding ground to sustain population of species. Total 81 species of Macro benthos (fauna) were recorded from all selected sampling site of this study, which were identified and classified as per latest update of WORMS. 43 species of Mollusca, 17 species of Cnidaria, 11 species of Arthropoda, 6 species from Porifera, 3 and 1 species from Annelida and Echinodermata respectively were recorded from all selected sampling sites of study (**Table 4.2 & 4.3**).

During the study, it was found that *Cellana radiata*, *Onchidium verruculatum*, *Turbo coronatus*, *Turbo intercostalis*, *Trochus radiates*, *Conus miliaris*, *Rhinoclavis sinensis* and *Nerita albicilla* were dominating at all the selected coastlines.

For studies of population ecology three species from above dominant molluscs were selected i.e. *Onchidium verruculatum*, *Cellana radiata*, *Conus miliaris*. Therefore, study of ecology, faunal attributes like Density, Abundance and Frequency of these dominant species were measured (Table 4.6 to 4.17; Figure 4.7 to 4.18).

The sea water quality suggest the normal range of analysed water samples collected from the intertidal zone of selected coastal study area of the south Saurashtra coast of India from the period of December-2014 to November-2015. Analysed water samples shows water quality status of selected site as a base line reference and will be useful for environmental monitoring of coastal sites (Table 4.18 to 4.29; Figure 4.19 to 4.26).

4.1 Intertidal Macro Benthos Diversity

All the selected study sites represented various macro benthos species. All the selected sampling sites were surveyed repeatedly and all the species of macro benthos that occurring alongside the complete intertidal area has been identified, recorded and list of species was prepared. The macro benthos identified at all selected study sites is listed in Table 4.1 & 4.2 for flora and fauna respectively. During the course of this study, a total of 103 intertidal macro benthos species recorded. Out of them, 81 species belonging to 50 families and 6 phyla of fauna and 22 species belonging to 3 class of flora were recorded. All scientific nomenclature and taxonomic position of the observed fauna were done as per the latest updates of WoRMS and furnished in

Table 4.2. All species recorded were characterized by six different phyla such as Mollusca, Cnidaria, Arthropoda, Porifera, Annelida and Echinodermata (**Table 4.2**) and three classes of the Algae (**Table 4.1**). Amongst them class, Chlorophyceae from flora and phylum Mollusca from fauna was the most abundant group from the all reported group of intertidal zone of selected sampling sites. At all selected sampling sites total numbers of macro fauna in each phylum are shown in **Figure 4.1**

Amongst the total identified species of intertidal macro fauna at all selected sampling sites, the number of species recorded at each sampling site or each assemblage was 58 species at Navapara, 78 species at Aadri, 60 species at Vadodra dodiya and 72 species at Chorwad (**Table 4.4**). As stated earlier, phylum Mollusca was the most dominated phylum which contributed about 53% with 43 species. The second dominated phylum was Cnidaria which contributed about 21% with 17 species. In Cnidaria 5(6%) species of Coral and 12(15%) species of other than Coral were recorded. Arthropoda was recorded with 11(14%) species followed by Annelida 3(4%) species and Porifera 6 (7%) species and Echinodermata 1 species with 1% contribution in all selected sampling sites (**Table 4.3; Figure 4.1, 4.2**).

Mollusca are the most prominent phylum from all recorded phylum in the intertidal area of selected sampling sites. About 53% contribution with 43 species from 23 families of Mollusca were observed and recorded during the course of this study. Gastropoda was recorded as a dominant class from all recorded class with 23 families consist of 37 species. Other recorded class such as Cephalopoda, Polyplacophora and Bivalvia consist of 4 families with 6 species. In Mollusca, the most plentiful species in all the selected sampling sites were *Onchidium verriculatum*, *Cellana radiata*, *Turbo intercostalis*, *Trochus radiatus*, *Nerita*, *Rhinoclavis sinensis* which all are from

class Gastropoda. The upper intertidal area of selected sampling sites was equally roofed by *Cellana radiata* and juveniles of *Cerithium*. *Chiton* was found in the upper and middle intertidal zone of all selected sites. *Cantharus undosus* and *Cantharus spiralis* were also found in notable number. Amongst the total species recorded of phylum Mollusca, most of were being in upper littoral zone, however in middle littoral zone almost all species were recorded except *Octopus vulgaris* which was recorded only one and two time in a year at Vadodra dodiya and Aadri respectively in lower intertidal zone. Generally Mollusca feed on the algae and due to this reason, at all times associate with intertidal sea weeds. **(Table 4.2 & 4.3; Figure 4.2; Plate 4.1)**

Phylum Porifera contributes total 7% with 6 species from all selected sampling sites, which all are from different family and from three classes. Demospongia is observed as a most divers class from any other class of Porifera from the course of the study period from all sampling sites of study. Some species such as *Halichondria panacea*, *Granita sp* and *Oscareila lobularis* ware recorded at all the selected sampling sites, while *Haliclona tubifera* and *Suberite species* were recorded at Aadri and *Cliona species* was observed at sampling site of Vadodra dodiya only. High Population of sponge found in lower intertidal zones during the course of study. *Halichondria panacea* was the most common and highly diverse species with compare to other species in this group. **(Table 4.2 & 4.3; Figure 4.2; Plate 4.2)**

A total contribution of Cnidaria was 21% with 7 family consist of 17 species were observed and recorded. Among them, 6% contribution of coral with 5 species and 15 % contribution with 12 species in 3 family of other than corals were recorded from intertidal zone of all selected sampling site. Coral species such as *Montipora folisa* and *Goniopora* were observed at all the study sites. Other than coral 5 Species from

Zoanthidae family and 5 species from Actiniidae family were observed and recorded at all selected study sites. Species such as *Zoanthus sociatus*, *Palythoa Matuki*, *Isaurus tuberculatus* and *Actinia equina* species were very common in the intertidal zone of all selected sampling sites during the course of the study. Most of the species of this group were found commonly in the lower and middle intertidal zone and rarely in the upper intertidal zone of selected sampling sites. Species of Zoanthidae were highly observed throughout the course of the study at all the sampling sites, among all the species of coelenterate. **(Table 4.2 & 4.3; Figure 4.2; Plate 4.4)**

The species of phylum Arthropoda was observed in all the selected study sites all over the duration of study. Total recorded species in Arthropoda was 11 which was from 8 families and contributed 14% from all recorded phylum of all selected sampling sites during the course the study. Maximum families of Arthropoda were recorded from class Malacostraca and only two families with one species each were recorded from class Hexanauplia. Arthropoda such as *Amphibalanus amphirite* and hermit crabs like *Clibanarius nathi* and *Clibanarius zebra*, some species of crabs like *Portunus pelagicus*, *Pilumnus vespertilio* and *Pachygrapsus crassipes* etc were recorded commonly at intertidal zone of selected study sites. Arthropoda was recorded at all three littoral zone of the intertidal area. *Clibanarius zebra* and *Clibanarius nathi* were present in all three zones of inter tidal zone. There were appearing in shell of gastropod Mollusca. Diversity of recorded species showed almost comparable design at upper and middle littoral zones at all selected sampling sites of study. **(Table 4.2 & 4.3; Figure 4.2; Plate 4.3)**

Phylum Annelida was the very low diversity contributed 4% with three species. Class Polychaeta consist of 3 families with one species from each class. Species such as

Neris, *chetopterus chetopterus* and *Serpula vermicularis* were recorded from all sampling site during the course of the study. (Table 4.2 & 4.3; Figure 4.2)

Echinodermata was the lowest diversified and recorded phylum in this study. Only 1 % with one species *brittle star* was recorded at sampling site Aadri of this study. This was recorded only two times from Aadri and both the time it was observed at middle littoral zone of Aadri during the winter. (Table 4.2 & 4.3; Figure 4.2)

4.2 Variations in Macro Faunal Diversity between Assemblage

The outcomes indicated that the total of macro benthos (fauna) species in each phylum identified at Navapara, Aadri, Vadodra dodiya and Chorwad was not the same during the study period. Each assemblage was also differing in its diversity composition.(Table 4.3, 4.4 & 4.5; Figure 4.1) The selected coastal area of Aadri had 72 species out of total recorded 81 species of study, which was the 92 % of total selected species of the study. So, with compare to other selected assemblage it was highest and Navapara was the lowest with 58 species contributed 72 % of total recorded species of the study. Not only in case of total species but selected area of Aadri was dominated in all phyla except Annelida with compare to other selected sampling sites (Table 4.3, 4.4 & 4.5; Figure 4.1). At Aadri contribution of Annelida was low with compare to Chorwad and high with compare to Navapara and Vadodara dodiya. This study point out the clear dominance of the Mollusca in terms of number of species, it was also noted that Mollusca was the extensively distributed macro invertebrates at intertidal zone of the entire study site during the study (Table 4.4 & 4.5; Figure 4.3, 4.4, 4.5 & 4.6). There were not enough differences in the number of individuals at all selected sampling sites, however there were differences in the number of species in different phylum at all the study sites except for phylum

Echinodermata. Only one species of Echinodermata, *brittlestar* was recorded only at Aadri and octopus was also recorded at Aadri which make Aadri little bit unique with compare to other selected sampling sites (**Table 4.4 & 4.5, Figure 4.1**).

The outcomes conclude that, composition of macro faunal species recorded in each group at each assemblage was differing from each other at some point of view and Aadri was the most diverse assemblage from all selected assemblage.

4.3 Variations in Macro Faunal Diversity within Assemblage

Assemblage-1: Navapara

In this assemblage the total 58 faunal species of macro benthos belonging to 37 families and 5 phyla was recorded during course of the study period at Navapara (**Table 4.3 & 4.4**). Phylum Mollusca was the most dominated phylum which contributed about 62% with 36 species in this assemblage. The second dominated phylum was Cnidaria, contributed about 17% with 10 species. In Cnidaria 3(5%) species of Coral and 7(12%) species of other than Coral were recorded. Arthropoda was recorded with 8(14%) species followed by Annelida 1(2%) species and Porifera 3(5%) species contribution in this assemblage. This assemblage is the less diverse than all other selected assemblage (**Table 4.4 & 4.5; Figure 4.1 & 4.3**).

Assemblage-2: Aadri

In this assemblage total 78 species were recorded which consist of 6 phylum with 51 families. Highest species were recorded at Aadri with compare to other selected sampling sites or assemblages (**Table 4.3 & 4.4**). Phylum Mollusca was the most dominated phylum which contributed about 42(54%) species (**Figure 4.4**). In Mollusca most common and abundant class was Gastropoda which consist of the

species such as *Cypraea depressa*, *Cerithium careuleum*, *Conus miliaris*, *Telescopium telescopium*, *Aplysia oculifera*, *Cellana radiata*, *Onchidium verruculatum* and *Turbo intercostalis*. The second dominated phylum was Cnidaria which contributed about 17(21%) species. In Cnidaria 5(6%) species of coral and 12(15%) species of other than coral were recorded. Arthropoda was recorded with 11(14%) species followed by Annelida 2(3%) species, Porifera 5(7%) species and Echinodermata only 1(1%) species. In Echinodermata, *Brittlestar* was recorded only at this assemblage (**Table 4.4 & 4.5; Figure 4.1 & 4.4**).

Assemblage-3: Vadodra dodiya

In this assemblage total 60 species were recorded which consist of 5 phylum with 37 families (**Table 4.3**). In this assemblage phylum Mollusca was the most dominated phylum which contributed about 35(58%) species (**Figure 4.5**). The second dominated phylum was Cnidaria which contributed about 12(20%) species. In Cnidaria 3(5%) species of coral and 9(15%) species of other than coral were recorded. Arthropoda was recorded with 8(13%) species followed by Annelida 1(2%) species and Porifera 4(7%) species (**Table 4.4 & 4.5; Figure 4.1 & 4.5**).

Assemblage-1: Chorwad

This assemblage was the second largest assemblage in terms of diversity. In this assemblage total 72 species were recorded which consist of 5 phylum with 47 families (**Table 4.3**). Just like above all assemblage phylum Mollusca was the most dominated phylum in this assemblage, which contributed about 40(56%) species. The second dominated phylum was Cnidaria which contributed about 15(21%) species. In Cnidaria 4(6%) species of coral and 11(15%) species of other than coral were

recorded. Arthropoda was recorded with 10(14%) species followed by Annelida 3(4%) species and Porifera 4(5%) species (**Table 4.4 & 4.5; Figure 4.1 & 4.6**).

Species from phylum Echinodermata was not recorded from all assemblage except Aadri. This was recorded only two times from Aadri and both the time it was observed at middle littoral zone of Aadri during the winter (**Table 4.3; Figure 4.1 & 4.4**).

4.4 Intertidal Seaweed (algae) Diversity

The sampling sites of this study coast were rich in algal population. The spatial distribution of algae in the selected study area is presented in **table 4.1**. Total 22 intertidal seaweed species recorded throughout the course of study period. From that 12 species of class Chlorophyceae, 6 species of class Pheophyceae and 4 species of Rhodophyceae were identified and recorded in all selected sampling sites of this study. Most of the time the algal species belonging to class Chlorophyceae like *Boergesenia forbesii*, *Caulerpa racemosa* and *Ulva lactuca* were recorded at the intertidal zone of all the selected study sites. *Sargassum swartzii*, *Padina gymnospora*, *Sargassum cinereum* and *cystoseria* from class phaeophyceae were recorded at all selected sampling sites. Other than this *Champia indica* and *Gracilaria corticata* from class Rhodophytes were recorded in all sampling sites. *Sargassum swartzii* was the highly distributed and able to colonize in lower littoral zone of all selected study sites. However, species such as *Cladophora glomerata* and *Stoechospermum marginatum* from class Chlorophyceae were found only at sampling site of Aadri, during the course of the study (**Table 4.1; Plate 4.5**).

4.5 Population Ecology Study

Selected study sites of the Saurashtra coast of this research work were regularly visited at fixed period during the lowest or low tide at day time. It was observed from the baseline study of intertidal macro fauna that group Mollusca was ruled on the selected intertidal belt of the Saurashtra coast. Among the phylum Molluscan, gastropods were record most abundant and found at the entire intertidal zone during the time of study period. During the study, it was found that *Cellana radiata*, *Conus miliaris*, *Onchidium verruculatum*, *Trochus radiatus*, *Turbo intercostalis*, *Turbo coronatus*, *Nerita albicilla* and *Rhinoclavis sinensis*, were dominate at all the study sites.

For population ecological studies three species from above dominant molluscs were selected i.e. *Onchidium verruculatum*, *Cellana radiata*, *Conus miliaris*. Therefore, in this study ecological attributes like Density, Abundance and Frequency of these dominant species were measured.

(1) *Onchidium verruculatum*

Phylum: Mollusca

Class: Gastropoda

Order: Systellommatophora

Family: Siphonariidae: *Onchidium verruculatum*

Distribution: It's a shell-less slug-like marine Mollusca. The size of this species is from 10-70mm long. It has a gill-like papillae scattered over the back and there are eye-like sensory structures on the back.

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

Habitat: It lives in intertidal region, often in sheltered estuaries on rocks, mud, and in mangrove swamps. They also found on limestone cliffs with wide raised intertidal limestone platform.

Status: Fixed in distribution. But stress of different pollution made by human affects its distribution.

Use: Use as food for local community.

Population Ecology:

The species maintained its presents in all selected study site of Suarashtra coastline, throughout the year. The month wise density, abundance and frequency values of upper middle and lower zone of intertidal area of all the study sites are given in **Figure 4.7 to 4.10**

Density

Density of *O. verruculatum* was recorded in intertidal zone of all selected sampling sites throughout the year. During monthly investigations it was observed that highest density of *O. verruculatum* was in middle littoral zone (**Figure 4.7-A**). Average density recorded in Navapara, Aadri, Vadodara Dodiya and Chorwad was 0.24, 0.51, 0.29 and 0.31 no/0.25m² respectively. It was clearly indicated that highest density of *O. verruculatum* was observed at Aadri coast. No density of onchidium was observed in lower littoral zone of Sampling site Navapara and Aadri during summer (March to May) (**Figure 4.7-A & 4.8-A**).

In Navapara highest density was observed during September to November (post Monsoon) in middle and lower littoral zone it was observed for the duration of January and September only. Average density of *Onchidium* in Navapara in Upper, middle and lower littoral zone was 0.15, 0.54 and 0.03 no/0.25 m² respectively (**Table 4.9**).

In Aadri less or no variation observed during December to November. Average density of *Onchidium* in Aadri in Upper, middle and lower littoral zone was 0.36, 1.08 and 0.09 no/0.25 m² respectively which was highest in all selected sampling site (**Table 4.9**).

In Vadodara dodiya and Chorwad Density value of *Onchidium* showed almost similar trend in all the three littoral zones thought the year. Average density of *Onchidium* in Upper, middle and lower littoral zone of Vadodara dodiya and Chorwad ware 0.14, 0.63 and 0.10 and 0.26, 0.58 and 0.09 no/0.25 m² respectively (**Table 4.9**).

Abundance

Highest abundance value was recorded in middle littoral zone, low abundance value was recorded in upper littoral zone and lowest value was recorded in lower littoral zone in all selected study site. At all the sampling sites of this study the abundance values displayed above same pattern all over the year. Average Abundance value observed in Navapara, Aadri, Vadodara dodiya and Chorwad was 1.11, 1.58, 1.34 and 1.28 no/0.25 m² respectively. (**Table 4.7 & 4.9; Figure-4.7-B, 4.8-B, 4.9-B & 4.10-B**)

At Navapara, abundance value was observed almost same and high during September to November (Post Monsoon) and December to February (winter) as compare to

March to August (summer and Monsoon). Highest abundance value 2.6 was recorded in middle littoral zone during September to November (Post Monsoon). In lower littoral zone throughout the year no abundance was observed except in January and September month. Average abundance values observed in Upper Middle and lower littoral zone was 1.04, 2.03 and 0.25 no/0.25m² respectively. As compare to other site average abundance value was observed low at Navapara. (**Table 4.9; Figure 4.7-B**)

At Aadri, highest Abundance value was observed in middle littoral zone and it was between 1.8 to 3.3 no/0.25m² during the course of the study and lowest or no (In summer) abundance was observed in lower littoral zone. Average abundance values observed in Upper, Middle and lower littoral zone was 1.53, 2.39 and 0.83 no/0.25m² respectively (**Table 4.9; Figure 4.8-B**).

At Vadodara dodiya highest abundance values of onchidium was observed in middle littoral zone and it was between 1.8 to 3.5 no/0.25m². In middle littoral zone during monsoon it was observed highest abundance and lowest was in lower littoral zone in summer (Mar-May) and post monsoon (Sep-Nov). Average abundance values observed in Upper, Middle and lower littoral zone was 1.08, 2.15 and 0.79 no/0.25m² respectively (**Table 4.9; Figure 4.9-B**).

At Chorwad highest abundance value of *Onchidium* was observed in middle littoral zone during winter season and lowest was in lower littoral zone during summer and post monsoon. Average abundance values observed in Upper, Middle and lower littoral zone was 1.38, 1.97 and 0.50 no/0.25m² respectively (**Table 4.9; Figure 4.10-B**).

Frequency

Frequency was recorded highest, low and lowest in middle, upper and lower littoral zone respectively in all selected sampling site. Frequency values showed above same pattern all over the year at all selected study sites. Average Frequency observed in Navapara, Aadri, Vadodara Dodiya and Chorwad was 12.78, 24.44, 14.44 and 17.22 %/0.25m² respectively (Table 4.8 & 4.9; Figure 4.7-C, 4.8-C, 4.9-C & 4.10-C).

At Navapara frequency was not observed in lower littoral zone except in January and September during the study time and it was observed highest in post monsoon (September to November). Average frequency was observed in upper, middle and lower littoral zone was 10.83, 25.83 and 1.67 %/0.25m² (Table 4.9; Figure 4.7-C).

At Aadri, highest frequency value was observed in middle littoral zone and it was between 30 to 60 %/0.25m² during the course of the study and lowest or no (In summer) frequency was observed in lower littoral zone. During summer it was observed comparatively low with compare to other season. Average frequency values observed in Upper, Middle and lower littoral zone was 20.83, 45.00 and 7.50 %/0.25m² respectively (Table 4.9; Figure 4.8-C).

At Vadodara Dodiya and Chorwad average frequency observed in middle littoral zone was same 29.17. Average Frequency values observed in upper and lower littoral zone of Vadodara Dodiya and Chorwad were 8.33, 5.83 and 15, 7.50 %/0.25m² respectively. At both the sampling site during summer frequency was observed low as compare to other season (Table 4.9; Figure 4.9-C).

(2) *Conus Miliaris*

Phylum: Mollusca

Class: Gastropoda

Order: Mesogastropoda

Family: Terebridae: *Comus miliaris*

Description: The length of shell is roughly 40-50 mm. Shells are moderately light to heavy in weight. Shape of shell is like Cone, narrowed to flat tip and a well-developed body whorl shaped towards the narrow anterior end. Most common in intertidal zone, but also found deeper on the continental shelf and slope to a depth of approximately 400 m. Living in fresh or muddy-sand bottoms below the rocks. Energetic hunters, equipped by arrow like teeth and a toxic gland which discharges a nerve toxin.

Habitat: Lives in intertidal area, especially in lower intertidal zone, source of food are worms.

Status: Steady in distribution. But stress of different pollution made by human affects its distribution.

Use: Used as food. Also used as a craft and in ceramic industry.

Population Ecology:

The species maintained its presents in all selected sampling sites of Suarashtra coastline, throughout the year. The month wise density, abundance and frequency values of upper, middle and lower intertidal zone of all the selected-sampling sites are given in **Table 4.10, 4.11, 4.12 & Figure 4.15, 4.16, 4.17, 4.18**. There was not a statistically significant change observed between in density, abundance and frequency of all study site

Density

Density of *Conus miliaris* observed high in Lower and low in upper littoral zone at all selected sampling site. Average density of Navapara was recorded 0.24 No/0.25m² and for Aadri, Vadodara Dodiya and Chorwad it was recorded 0.27 No/0.25m². It is clearly indicated that almost same density was observed in all selected sampling site (Table 4.10; Figure 4.15-A, 4.16-A, 4.17-C & 4.18-C).

At Navapara density was observed high in winter and slightly decreased in summer, monsoon and post-monsoon. Highest density was observed in lower littoral zone during summer and lowest was observed in upper littoral zone during post monsoon. Average density observed in upper middle and lower littoral zone was 0.15, 0.23 and 0.35 0.27 No/0.25m² respectively (Table 4.10 & 4.13; Figure 4.15-A)

At Aadri, density was observed high in winter and monsoon and decreased during summer in post monsoon. Same pattern was observed for Vadodara Dodiya and Chorwad also. At Aadri highest density was observed in lower littoral zone during Monsoon and lowest density was observed in upper littoral zone during summer. At Aadri Average density observed in upper middle and lower littoral zone was 0.14, 0.25 and 0.41 No/0.25m² respectively. (Table 4.10 & 4.13; Figure 4.16-A)

At Vadodara Dodiya lowest density was observed in upper littoral zone during summer and highest was observed in lower littoral zone during winter and post monsoon. At Chorwad lowest density was observed in upper littoral zone during summer and post monsoon and highest was observed in lower littoral zone during winter season. Average density observed in upper middle and lower littoral zone was

0.17, 0.24 and 0.40 No/0.25m² at Vadodara Dodiya and 0.18, 0.28 and 0.36 No/0.25m² at Chorwad (**Table 4.10 & 4.13; Figure 4.17-A & 4.18-A**).

Abundance:

Average Abundance of *Conus miliaris* recorded high in Lower intertidal zone at all selected sampling site except in Navapara (high in middle) and low in upper intertidal zone at all selected sampling site except Chorwad (Low in Middle). Average abundance of Navapara, Aadri, Vadodara Dodiya and Chorwad was 1.08, 1.05, 1.07 and 0.96 No/0.25m² respectively. It is clearly indicated that almost same density was observed in all selected sampling site (**Table 4.11 & 4.13; Figure 4.17-B, 4.18-B, 4.19-B & 4.20-B**).

At Navapara abundance was observed high in upper littoral zone in summer and middle littoral in post monsoon and low at upper littoral zone in post monsoon. It was observed significantly low in upper littoral zone during post monsoon as compare to winter. Average abundance observed in upper, middle and lower littoral zone was 0.92, 1.17 and 1.15 No/0.25m² respectively (**Table 4.11 & 4.13; Figure 4.15-B**).

At Aadri, Vadodara Dodiya and Chorwad there were no seasonal significant change was observed in *Conus miliaris*. At Aadri it was observed low in upper intertidal zone during summer, however high in lower intertidal zone during winter. Average abundance observed in upper, middle and lower littoral zone was 0.83, 1.11 and 1.22 No/0.25m² respectively (**Table 4.11 & 4.13; Figure 4.16-B**).

At Vadodara Dodiya low abundance was observed in upper littoral zone during summer and high abundance was observed in lower littoral zone during summer.

Average abundance observed in upper, middle and lower littoral zone was 0.85, 0.97 and 1.38 respectively. (Table 4.11 & 4.13; Figure 4.17-B)

At Chorwad low abundance was observed in middle littoral zone during summer and high abundance was observed in upper littoral zone during winter. Average abundance observed in upper, middle and lower littoral zone was 1.04, 0.75 and 1.08 respectively (Table 4.11 & 4.13; Figure 4.18-B).

Frequency:

Average Frequency of *Conus miliaris* recorded high in lower, low in middle and lowest in upper littoral zone at all selected sampling sites. Average frequency recorded in Navapara, Aadri, Vadodara Dodiya and Chorwad was 20.56, 22.78, 22.22 and 22.78 %/0.25m² respectively. It shows almost same frequency was recorded in all selected sampling site (Table 4.12 & 4.13; Figure 4.15-C, 4.16-C, 4.17-C & 4.18-C)

At Navapara low frequency was recorded in upper littoral zone during post monsoon and high was recorded in lower littoral zone during summer. Average frequency recorded in upper middle and lower littoral zone was 10.83, 20, and 30.83 %/0.25m² respectively. (Table 4.13; Figure 4.15-C)

At Aadri low frequency recorded upper littoral zone during summer and post monsoon and high density was recorded at lower littoral zone ant monsoon. Average frequency recorded in upper, middle and lower littoral zone was 13.33, 21.67 and 33.33 %/0.25m² respectively (Table 4.13; Figure 4.16-C).

Low frequency was recorded in upper littoral zone during summer in Vadodara Dodiya and summer and post monsoon in Chorwad was recorded however high

frequency was recorded in lower littoral zone during winter and post monsoon at Vadodara Dodiya and during winter in Chorwad. Average frequency recorded at Vadodara Dodiya was 13.33, 22.50 and 30.80 %/0.25m² and at Chorwad 14.17, 24.17 and 30.00 %/0.25m² respectively (Table 4.13; Figure 4.17-B & 4.18-C).

Cellana radiata

Description: *Cellana radiata* is normally well-known for its shell colours. Found to settle on the walls of the pools and crevices. It is habitually very sluggish in nature. Move with the upcoming wave and a true grazer.

Occurrence: It is found around the globe, especially North coast, Oceania, Japan, Western Australia, Indonesia, Papua New Guinea, New Caledonia, Loyally Island, Solomon Island, Fiji, Tonga, Marqueses and Indian subcontinent

Habitat: It preferred uncovered rocks commonly with smoother edge. Found most of the time on the upper littoral zone and spray zone.

Status: Recorded as a most dominant species on the intertidal belt of Saurashtra coastline. Generally the most common limpet of the Indian subcontinent is the *Patella vulgate* and *Cellana radiata*.

Use: In some country used as a food. However, export of this species is currently on from the West coast of India.

The *Cellana radiata* maintained its presents in all selected study area throughout the year. Highest Density, Abundance and frequency ware observed at sampling site Aadri with compare to other selected site Navapara, Veraval and Chorwad (Table

4.17). The month wise density, abundance and frequency values of all the selected sampling sites are given in **Figure 4.11, 4.12, 4.13 & 4.14**).

Density

In all selected sampling sites it was observed that, the density of *Cellana radiata* was high in upper, low in middle and lowest in lower littoral zone. There was no significant seasonal change observed in all selected sampling site in all littoral zone. Average density observed in Navapara, Aadri, Vadodara Dodiya and Chorwad were 0.32, 0.74, 0.36 and 0.49 no/0.25m² respectively. It was clearly indicate that density observed in Aadri was comparatively high (**Table 4.14 & 4.17; Figure 4.11-A, 4.12-A, 4.13-A & 4.14-A**).

At Navapara Density observed between 0.4 to 0.9 no/0.25m² in upper littoral zone, 0.0 to 0.5 no/0.25m² in middle littoral zone and 0.0 to 0.3 no/0.25m² in lower littoral zone. Average density observed upper, middle and lower littoral zone was 0.61, 0.26 and 0.10 no/0.25m² respectively. There was no significant seasonal change observed in density of *Cellana radiata* at Navapara (**Figure 4.11-A**).

At Aadri the species density was observed high in upper littoral zone during the post monsoon. The density values were comparatively low in lower littoral zone than upper littoral zone. In lower littoral zone high density value was observed during post monsoon and summer months. Average density at Aadri observed in upper middle and lower littoral zone was 1.12, 0.91 and 0.20 no/0.25m²(**Figure 4.12-A**).

At the other sampling site was Vadodara Dodiya high density was recorded in summer months in upper littoral zone as well as in intertidal zone. The density values were comparatively low in lower littoral and middle littoral zone and especially

during monsoon at lower littoral zone. Average density observed in upper middle and lower littoral zone was 0.61, 0.33 and 0.14 no/0.25m² (Figure 4.13-A).

At Chorwad the species density was same as all other sampling site, high density observed in upper and low in lower littoral zone. Highest density observed during post-monsoon in upper littoral zone and lowest density was observed in lower littoral zone in monsoon. Average density at observed in upper middle and lower littoral zone was 0.72, 0.56 and 0.18 no/0.25m² respectively (Figure 4.14-A).

Abundance

At all selected sampling sites abundance of *Cellana radiata* was recorded high in Upper littoral zone low in middle littoral zone and lowest in lower littoral zone. There was no significant seasonal change observed in all selected sampling site in all littoral zone. Average abundance observed in Navapara, Aadri, Vadodara Dodiya and Chorwad were 1.12, 1.95, 1.16 and 1.45 no/0.25m² respectively. Highest abundance was recorded in upper littoral zone of Aadri during summer (March-May) and lowest was recorded in lower littoral zone of Navapara and Vadodara Dodiya during Monsoon (June-august) (Table 4.15 & 4.17; Figure 4.11-B, 4.12-B, 4.13-B & 4.14-B).

At Navapara Abundance recorded between 1.2 to 2.3 in upper littoral zone, 0.0 to 1.5 in middle littoral zone and 0.0 to 2.0 no/0.25m² in lower littoral zone. Average abundance observed in upper, middle and lower littoral zone was 1.55, 1.01 and 0.79 no/0.25m² respectively (Table 4.17; Figure 4.11-B)

At Aadri abundance recorded between 1.6 to 2.8 in upper littoral zone, 1.6 to 2.5 in middle littoral zone and 0.0 to 2.0 no/0.25m² in lower littoral zone. Average

abundance recorded in upper, middle and lower littoral zone at Aadri was 2.32, 2.23 and 1.29 no/0.25m² respectively. (Table 4.17; Figure 4.12-B)

At Vadodara Dodiya abundance recorded between 1.0 to 2.0 in upper littoral zone, 0.0 to 1.3 in middle littoral zone and 0.0 to 2.0 no/0.25m² in lower littoral zone. Average abundance recorded in upper zone, middle zone and lower zone at Vadodara Dodiya was 1.47, 1.04 and 0.96 no/0.25m² respectively (Table 4.17; Figure 13-B).

At Chorwad abundance recorded between 1.5 to 2.5 in upper littoral zone, 1.0 to 1.3 in middle littoral zone and 0.0 to 1.5 no/0.25m² in lower littoral zone. Average abundance recorded in upper, middle and lower intertidal zone at Chorwad was 1.75, 1.55 and 1.04 no/0.25m² respectively (Table 4.17; Figure 4.14-B).

Frequency

Frequency of *Cellana radiata* was high in Upper littoral zone low in middle littoral zone and lowest in lower littoral zone in all selected site. There was no significant seasonal change observed in all selected sampling site in all littoral zone. Average frequency recorded in Navapara, Aadri, Vadodara Dodiya and Chorwad was 23.61, 34.72, 26.94 and 31.39 %/0.25m² respectively. Highest Frequency was recorded in upper littoral zone of Aadri and lowest was recorded in lower littoral zone of Navapara. Almost same frequency was recorded in upper littoral zone of Navapara, Vadodara Dodiya and Chorwad (Table 4.16 & 4.17; Figure 4.11-C, 4.12-C, 4.13-C3 & 4.14-C).

At Navapara Frequency was recorded between 30.0 to 60.0 in upper littoral zone, 0.0 to 40.0 in middle littoral zone and 0.0 to 20.0 %/0.25m² in lower littoral zone.

Average frequency recorded in upper, middle and lower littoral zone was 40.0, 23.33 and 7.50 %/0.25m² respectively (**Table 4.17; Figure 4.11-C**).

At Aadri Frequency recorded between 30.0 to 70.0 in upper littoral zone, 30.0 to 50.0 in middle littoral zone and 0.0 to 20.0 %/0.25m² in lower littoral zone. Average frequency recorded in upper, middle and lower littoral zone was 48.33, 40.83 and 15.0 %/0.25m² respectively (**Table 4.17; Figure 4.12-C**).

At Vadodara Dodiya Frequency was recorded between 20.0 to 60.0 in upper littoral zone, 0.0 to 50.0 in middle littoral zone and 0.0 to 20.0 %/0.25m² in lower littoral zone. Average frequency recorded in upper, middle and lower littoral zone was 41.67, 29.17 and 10.0 %/0.25m² respectively (**Table 4.17; Figure 4.13-C**).

At Chorwad Frequency recorded between 20.0 to 60.0 in upper littoral zone, 20.0 to 50.0 in middle littoral zone and 0.0 to 20.0 %/0.25m² in lower littoral zone. Average frequency recorded in upper, middle and lower littoral zone was 41.67, 36.67 and 15.83 %/0.25m² respectively (**Table 4.17; Figure 4.14-C**).

4.6 Sea Water Analysis

The present study reports that there was no significant variation between all the selected sampling sites of this study. Tidal activities were observed normal possibly because of the nature of the open sites. The water quality of coastal area of Navapara, Aadri, Vadodara Dodiya and Chorwad were almost near to the ideal conditions due to absence or very less significant anthropogenic impacts on this coast. This finding gives the insight into the present day status of the general water quality parameters for selected coastal areas which can be used as a reference for further ecological studies.

Each and every ecosystem is always under control of surrounding environment and medium, further it is supported by number of physic-chemical parameters that are responsible to maintain the cyclic phenomena of particular ecosystem. The present study indicated that all the selected areas are not much influenced by the anthropogenic activities as the water quality parameters were within the normal range for an open sea coastline (Bhadja, and Kundu, 2012). All the selected sites were open and continuous without any kind of barricades so standard tidal activities occurred all along coastline. The results of the different parameters of water quality at all the selected sampling sites are presented in **Table 4.18 to 4.29** and **Figure 4.19 to 4.26**.

Temperature is one of the record key factors in the coastal ecosystem, influencing the physicochemical atmospheres of coastal water (Sundaramanickam, *et al.*, 2008). The variation in different season in the sea water temperature showed almost similar pattern at all selected sampling sites. At all the stations minimum temperature recorded in winter was 21.70°C and thereafter increased in summer up to 25.90 °C. At Navapara, Aadri, Vadodara Dodiya and Chorwad average yearly temperature recorded was 24.21, 24.28, 24.41 and 24.31 °C respectively. It is clearly indicated that there were no change of temperature recorded between all selected sampling sites (**Table 4.22; Figure 4.19**)

The pH values showed less variance between stations as well as months. The range of pH was in between 8.00 to 8.30 during study period. Average yearly pH recorded was 8.20, 8.17, 8.16 and 8.18 at Navapara, Aadri, Vadodara Dodiya and Chorwad respectively. pH values were found to be in their usual range (Naik, *et al.*, 1991) (**Table 4.23; Figure 4.20**).

It was recorded that Total solids were much higher in monsoons with compared to summer and winter. It was in the range of 39.00 to 41.00 g/l during December to May (winter and summer) and 41.00 to 44.44 g/l during June to November (Monsoon and post monsoon). Average TS recorded at Navapara, Aadri, Vadodara Dodiya and Chorwad was 41.35, 41.40, 41.31 and 41.18 g/l respectively. It was clearly indicated that there was no variation in Total Solids (TS) between all selected sampling sites during the course of this study. **(Table 4.24; Figure 4.21)**

Total dissolved solids (TDS) were slightly increased during the study period but no variation recorded between all selected sampling sites. Lower TDS was recorded 37.18 g/l during winter and higher was 44.30 g/l during Monsoon. Average TDS recorded at Navapara, Aadri, Vadodara Dodiya and Chorwad was 40.27, 40.66, 40.63 and 40.98 g/l respectively **(Table 4.25; Figure 4.22)**. Values observed for TS and TDS were within the normal range of coastal seawater of an open sea. (Bhadja and Kundu, 2012).

Salinity is one of the important factor which influences the distribution of organisms. The salinity will be dependent on the rain fall and extent of fresh water inflow (McLusky, 1971). In salinity there was minor variation recorded over the months as compared to other conditions. The range of salinity was recorded between 31.00 ‰ to 35.00 ‰ however, there was no difference recorded in salinity between all selected areas, may be due to topography of sampling sites (open shore). Average salinity recorded at Navapara, Aadri, Vadodara Dodiya and Chorwad was 33.40, 33.18, 33.51 and 33.68 ‰ respectively **(Table 4.26; Figure 4.23)**.

Calcium (Ca^{++}) and Magnesium (Mg^{++}) hardness showed irregular pattern at both the stations for the study period, but it was not statistically significant. Values of Calcium

were between 0.40 to 0.47 g/l and Magnesium were 1.20 to 1.39 g/l (**Table 4.28 & 4.29; Figure 4.25 & 4.26**).

Dissolved oxygen (DO) of water is an important parameter supporting the aquatic life (Paul and Mukherjee, 2006). It is most significant parameter affecting the productivity of aquatic system. The two main sources of DO in seawater are diffusion of oxygen from atmosphere and photosynthetic activity of aquatic flora. The dissolved oxygen values varied between 5.80 to 6.80 mg/l at all selected sampling sites. Average DO recorded at Navapara, Aadri, Vadodara Dodiya and Chorwad was 6.29, 6.24, 6.45 and 6.53 mg/l respectively. It was observed that with increase in salinity the DO level decreased (**Table 4.27; Figure 4.24**) (Pillai, Rajagopal and Varghese, 1979).