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DIVERSITY AND DISTRIBUTION OF MOLLUSCA AT VERAVAL COSTAL AREA, GUJARAT, INDIA

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ABSTRACT
Among the eight oceanic states of India, Gujarat, located on the western coast of India, with the shoreline of 1650 km. Diversity and distribution of marine molluscs were studied seasonally along the intertidal zone of Veraval. Veraval is situated at the coast of Saurashtra, Gujrat. The Mollusca fauna represented by 50 species belonging to 16 order and 25 families were collected and documented. Members of families like Cerithiidae, Muricidae and Turbinidae were reported throughout the study. Results showed that main molluscan populace belonged to class Gastropods, some of the maximum abundant species were Anachis terpsichora, Cantharus undosus, Turbo coronetus, Turbo intercostalis and Tibia curta, Cerithium sp., Murex sp., *etc.* Species mentioned above were observed throughout the study. The study of the distribution of marine molluscs was studied using the quadrat method. High species diversity was noted during winter and monsoon in the site studied. Dominated gastropod families Turbinidae, Buccinidae, Muricidae, Columbellidae, Carithiidae were observed during all the seasons. Carithiidae showed the highest density, abundance and frequency ranged from 5.06, 14.3, 66.66% while Buccinidae and Columbellidae showed the lowest density, abundance and frequency ranged from 0.03, 1.0, 3.3% during the study.

INTRODUCTION

The Saurashtra coast, which is the Northern part of the Indian coastline, is categorized by its rocky, sandy, and muddy Intertidal zones, harboring rich and diverse flora and fauna. Marine biodiversity is the diversity of life in the sea; the coastal zone is also gifted with a very wide range of coastal ecosystems like mangroves, coral reefs, seagrasses, salt marshes, dunes, estuaries, lagoons, *etc.* (Vadher, *et al.*, 2014). Rocky shores are the most widespread littoral habitats exposed to waves and, thus, are ecologically very important. Zonation is the vertical banding of the organisms (Vaghela, 2010). The phylum Mollusca is a large assemblage of animals having diverse shapes, sizes, habits and occupies different habitats (Sharma, *et al.*, 2011).

In the geological time scale, mollusks evolved about 600 million years ago and this phylum is a very old monophyletic family, dating from before the Cambrian, and is the second most various of all animal phyla, occurring in many habitat types (Monolisha and Edward, 2015). Malacology is the branch of invertebrate zoology that deals with the learning of the Mollusca. Marine species commonly found in low water enrichment, dynamic, and environments, typical brackish opportunistic water species (Pati, *et al.*, 2015). Often their bodies are protected by a hard exoskeleton, as in the shells of snails and clams or the plates of chitons (Agravat and Raval, 2019). In India, the total number of molluscan species recorded is 3271, which comprises 1900 gastropod species (Appukuttan, 1996). Gastropoda are the largest class of phylum mollusca which have successfully invaded land (Jayashankar, *et al.*, 2015).

Mollusca is the second largest invertebrate phyla with estimated species around 45,000 to 50,000 marines 25,000 terrestrial and 5,000 freshwaters. Marine molluscan diversity of India includes about 3,400 species. Recently, there were about 5,169 mollusks species found in India (Biju Kumar and Ravinesh, 2016) There are 7 classes under Mollusca namely, Aplacophora, Polyplacophora, Monoplacophora, Bivalvia, Gastropoda, Cephalopoda, Scaphopoda. Gastropoda contains snails and slugs of all types and all sizes from microscopic to quite big (Mohanraj, 2013). The diversity of Intertidal area, the mollusks are very effective animal group in relationships of natural adaptation and they are present in almost all habitats reaching from deepest ocean frequencies to the intertidal zone, freshwater and land where they live in a wide range of habitats (Vaghela and Kundu, 2012). The uniting features are seen in the anatomy of the animals, in the nacreous inner shell layer and the rounded, corneous operculum (Hickman and McLEAN, 1990). They collected the molluscan fauna indicates that, the unique diverse habitats transform the species to adaptive in this biogeographical zone and diverse endemism (Kubendran, *et al.*, 2019). Gastropods being herbivores, carnivores, scavengers, and filter feeders play a key role in the mangrove ecosystems; they help in maintaining the functioning and productivity of mangroves (Solanki *et al.*, 2016). The present study focuses on diversity and distribution of marine Mollusca at a selected site of Veraval.

MATERIALS AND METHODS

Study area

The present study was conducted along the South Saurashtra

coast at Veraval 20º54'35.04" N, 70º21'8.56" E, on the western coast of India (Figure 2). Veraval is one of the largest fish landing sites of India situated around 35 kilo meter east of Mangrol, enclosed by a chemical factory, cement factories and fish processing units. The total length of the study area is about three kilo meters (Figure 1). The bedrock of the intertidal zones at Veraval is mostly rocky-sandy with few muddy areas. The diversity and distributional study of mollusk at Veraval coast was carried out from September 2019 to February 2020.

The intertidal zone of site was selected, and all marine molluscs come across were recorded. The molluscs were observed, recorded and identified. Thus, animals under numerous families were noted and checklist was prepared. Wide-ranging photography was done for the identification of animal species with the help of identification keys, literature available in the form of books, reports, research articles and substantial use of internet. Molluscs were identified using standard literatures, *i*.e. Apte (Apte, 1998) and WoRMS.For surveying the distributional data, the particular site was visited for 6 months at regular intervals.

The whole intertidal belt of sample site was divided into 3 vertical zones. The diversity and distribution in the intertidal belt at site were studied during the low tide by quadrat method. Quadrat of 0.25 m^2 was laid along regular interval on the intertidal region. A minimum of thirty quadrates were laid in a criss-cross direction at the inter tidal belt to cover the maximum exposed area. The mollusks of the littoral zone were collected by hand picking.

Among the ecological characteristics, seasonal variations in the population density and abundance of major prominent molluscan species in each sampling stations were calculated (Misra and Misra, 1968).

$$\text{Density} = \frac{\text{Total no.of individuals recorded from the sample plot}}{\text{Total number of sample plot studied}}$$

$$\text{Abundance} = \frac{\text{Total no. of individuals recorded}}{\text{Total no. of sample plot where the individuals occured}}$$

$$\text{Frequency} = \frac{\text{No.os sample plot where the species occured x100}}{\text{Total no.of sample plot where the individuals occured}}$$

RESULTS AND DISCUSSION

The Saurashtra shoreline along the Arabian Sea presented a typical characteristic. The intertidal belt is rocky formed of milio-lite rocks except for some break of sand patches and spray zone is sandy. The intertidal belt of this area is not uniform and contact of this mostly rocky shore is not significantly longer. The bedrock of the intertidal zones at Veraval is mainly rocky-sandy with few muddy areas.

Thus, overall, 50 species belonging to 16 orders and 25 families were recorded. (Table: 1) This shows that there is a great diversity of mollusks observed along the Veraval coast. The checklist was prepared for the diversity found at the coast.

In our study, we found 50 species of molluscs. The distributional data was recorded for 6 months (Table-2). i.e., from post-monsoon to winter season (September 2019 to February 2020). During winter a greater number of molluscs were observed as compared to post-monsoon. A total of 50 species of molluscan consisting of 46 species belonging to class gastropods, 4 species in class Bivalvia, and the rest of class Polyplacophora which were represented (Figure 1). The gastropods, Aplysia oculifera, Astrea stellata, Conus miliaris, Cellana radiate, Cerithium caeruleum, Monodonta australis, Rhinoclavis sinensis, Trochus radiatus, Turbo coronetus, and Turbo intercostalis were dominant at the sampling sites during the study. gastropods were observed with the maximum number. Generally, species composition was similar across the site, with constantly dominating the gastropod fauna and the rest other two classes. The majority population are Turbinidae, Pisaniidae, Muricidae, Columbellidae, Nassariidae, Cerithiidae, Nacellidae, Onchidiidae. In our study we had labelled "other" which includes eighteen species

Table 1: Checklist with order, family and species of mollusc

Order	Class-Gastropod Family	Species
Trochida	Turbinidae	*Astraea stellate* (Roding,1798)
		Lunella coronatus (Gamelan,1791)
		Turbo brunnus (Roding,1798)
		Turbo coronetus (Gmelin,1791)
		Turbo intercostalis (Menke,1846)
		Turbo castanea (Gmelin,1791)
		Monodonta australis (Lamarck, 1822)
	Trochidae	*Trochus hanleyanus* (Krauss,1848)
		Trochus sacellum Rota (Kira, T,1862)
Littorinimorpha	Bursidae	*Bursa granularis* (Roding,1798)
		Tibia curta (Sowerby II,1842)
	Naticidae	*Natica picta* (Recluz,1844)
Neogastropoda	Pisaniidae	*Cantharus spiralis* (Gray,1839)
		Engina zea (Melvill,1893)
	Conidae	*Conus amadis* (Gmelin,1791)
		Conus miliaris (Bruguière,1792)
		Conus mutabilis (Reeve,1844)
	Buccinidae	*Cantharus undosus* (Linnaeus,1758)
	Magilidae	*Purpura persica* (Linnaeus,1758)
	Muricidae	*Morula marginalba* (Blainville,1832)
		Murex brunneus (Link,1807)
		Murex maurus (Broderip & Soweby, 1833)
		Murex palmarosae (Lamarck,1822)
		Murex pomum (Gmelin,1791)
		Murex saulii (Soweby,1841)
		Urosalpinx cinereal (Say,1822)
	Columbellidae	*Anachis terpsichora* (Sowerby II,1822)
		Pyrene flava (Bruguiere,1789)
		Mitrella ocellate (Gmline,1791)
	Mitridae	*Strigatella scutulata* (Gmelin,1791)
	Nassariidae	*Nassarius marginalba* (Blainville,1832)
		Nassarius olivaceus (Bruguière,1789)
Caenogastropoda	Cerithiidae	*Cerethium caeruleum* (Sowerby II,1855)
		Clypeomorus Bifasciata (Sowerby II,1855)
		Rhinoclavis sinensis (Gmelin,1791)
	Potamididae	Telescopium Telescopium (Linnaeus,1758)
Patellogastropoda	Nacellidae	*Cellana karachiesis* (Worth,1930)
		Cellana radiata (Born,1778)
Siphonariida	Siphonariidae	*Siphonaria atra* (sowerby,1824)
Sytellommatophora	Onchidiidae	*Onchidium vericculatum* (*Cuvier*,1830)
Sorbecoconcha	Potamididae	*Tympanotonos fascatus* (Linnaeus,1758)
Cycloneritida	Neritidae	*Nerita(cymostyla) undata* (Linnaeus,1758)
		Theodoxus euxinus (Clessin,1886)
Heterobranchia	Architectonicidae	*Architectonica laevigata* (Lamarck,1816)
Aplysiida	Aplysiidae	*Aplysia dactylomela* (Rang,1816)
Class-Polyplacophora		
Chitonida	Chitonidae	*Chiton granoradiatus* (Leloup,1937)
Class-Bivalvia		
Lucinida	Lucinidae	*Codakia tigerina* (Linnaeus,1758)
Carditida	Carditidae	*Cardita leana* (Dunker,1860)
Cardiida	Donacidae	*Donax obesulus* (Reeva,1854)
Mytilida	Mytilidae	*Modiolus auriculatus* (Krauss,1848)

Figure 1. Veraval coastal area data collection by quadrate method

Figure 2. Map of study site Veraval chowpati, Source: Google map, retrived on 17 May, 2020 (map is not to scale).

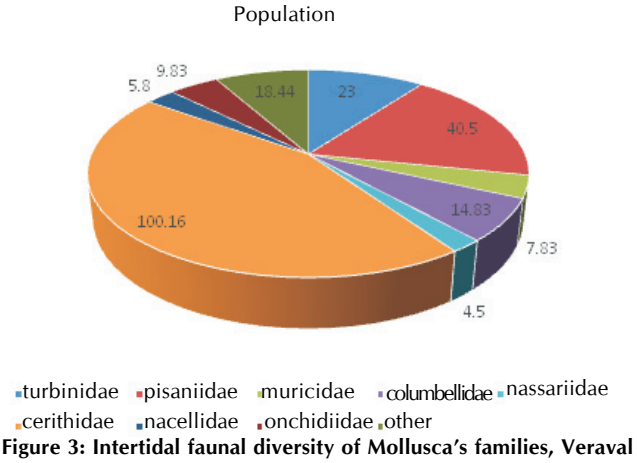


Figure 3: Intertidal faunal diversity of Mollusca's families, Veraval coast

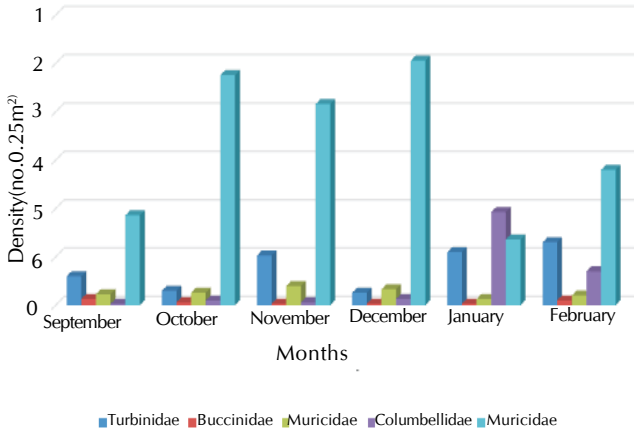


Figure 4. Density of Mollusca's families along the intertidal zone of Veraval.

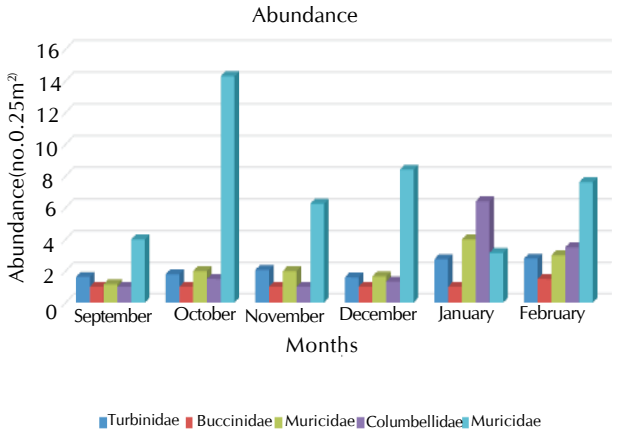


Figure 5. Abundance of Mollusca's families along the intertidal zone of Veraval.

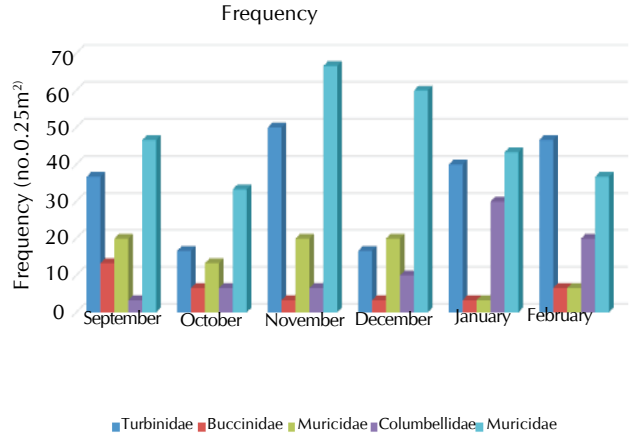


Figure 6. Frequency of Mollusca's families along the intertidal zone of Veraval.

Neritidae, Trochidae, Bursidae, Naticidae, Conidae, Buccinidae, Magilidae, Mitridae, Nassariidae, Potamididae, Siphonariidae, Architectoniadae, Aplysiidae, Chitonidae, Lucinidae, Carditidae, Donacidae, Mytilidae (Figure 3).

Out of 26 families, 5 prominent families were studied for population status. Population characteristics like density, abundance, and frequency were evaluated by standard formula. Family Turbinidae showed highest density during winter (1.3 no/0.25m^2) and lowest during pre-winter (0.26 no/0.25). Family Buccinidae showed highest density during post-monsoon (0.13 no/0.25) and lowest during pre-winter (0.03 no/0.25). Family Muricidae showed highest density during

Table 2: Month wise record of the species (+ or – signs denote presence or absence of species).

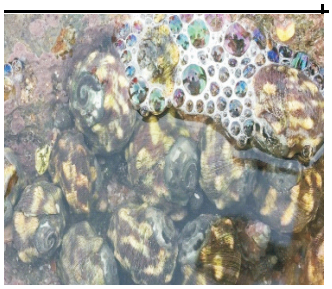
No.	Species	Month					
		Sep	Oct	Nov	Dec	Jan	Feb
1.	*Anachis terpsichora* (Sowerby II,1822)	+	+	+	+	+	+
2.	*Aplysia dactylomela* (Rang,1816)	-	-	-	-	-	+
3.	*Architectonica laevigata* (Lamarck,1816)	-	-	-	-	-	+
4.	*Astraea stellate* (Roding,1798)	+	-	+	+	+	+
5.	*Bursa granularis* (Roding,1798)	-	+	+	-	-	+
6.	*Cantharus spiralis* (Gray,1839)	-	+	+	-	-	+
7	*Cantharus undosus* (Linnaeus,1758)	+	+	+	+	+	+
8	*Cardita leana* (Dunker,1860)	-	+	+	+	+	+
9.	*Cellana karachiesis* (Worth,1930)	-	-	-	-	+	+
10.	*Cellana radiata* (Born,1778)	-	-	-	-	+	+
11.	*Cerethium caeruleum* (Sowerby II,1855)	+	+	+	+	+	+
12.	*Chiton granoradiatus* (Leloup, 1937)	-	+	-	-	+	-
13.	*Clypeomorus Bifasciata* (Sowerby II,1855)	-	+	-	-	+	+
14.	*Codakia tigerina* (Linnaeus,1758)	-	+	+	+	+	+
15.	*Conus acuminatus* (Bruguière,1792)	-	-	+	-	-	-
16.	*Conus miliaris* (Gmelin,1791)	-	-	+	+	-	+
17.	*Conus mutabilis* (Reeve,1844)	+	-	+	-	+	+
18	*Donax obesulus* (Reeva,1854)	-	+	+	+	-	+
19	*Engina zea* (Melvill,1893)	-	+	-	+	+	+
20.	*Lunella coronatus* (Gmelin,1791)	+	+	+	-	+	+
21.	*Mitrella ocellata* (Gmline,1791)	-	-	-	-	-	+
22.	*Modiolus auriculatus* (Krauss,1848)	-	+	+	+	+	+
23.	*Monodonta australis* (Lamarck,1822)	+	+	+	-	-	-
24.	*Morula marginalba* (Blainville,1832)	-	+	-	-	+	+
25.	*Murex brunneus* (Link,1807)	-	+	+	+	+	+
26.	*Murex maurus* (Broderip & Soweby,1833)	+	+	+	+	-	-
27.	*Murex palmarosae* (Lamarck,1822)	+	+	+	+	+	+
28.	*Murex pomum* (Gmelin,1791)	+	+	+	+	-	-
29.	*Murex saulii* (Soweby,1841)	-	+	+	+	-	+
30.	*Nassarius marmoreus* (A. Adamas,1832)	-	+	-	-	-	+
31.	*Nassarius olivaceus* (Bruguière, 1789)	-	+	+	+	+	+
32.	*Natica picta* (Recluz,1844)	-	-	-	-	-	+
33.	*Nerita* (cymostyla) Undata (Linnaeus, 1758)	-	-	+	-	+	-
34.	*Purpura persica* (Linnaeus,1758)	+	-	-	-	-	-
35.	*Pyrene flava* (Bruguière,1789)	-	-	-	-	+	-
36.	*Rhinoclavis sinensis* (Gmelin,1791)	-	+	+	-	-	-
37.	*Siphonaria atra* (sowerby,1824)	-	-	-	-	+	+
38.	*Strigatella scutulata* (Gmelin,1791)	-	-	-	-	+	+
39.	*Telescopium Telescopium* (Linnaeus, 1758)	-	-	-	-	-	+
40.	*Onchidium vericculatum* (Cuvier,1830)	-	+	+	-	-	-
41.	*Theodoxus euxinus* (Clessin,1886)	-	-	-	-	-	+
42.	*Tibia curta* (Sowerby II,1842)	+	+	+	+	-	+
43.	*Trochus hanleyanus* (Krauss,1848)	+	+	-	+	-	+
44	*Trochus sacellum rota* (Kira,1862)	+	+	-	+	-	-
45.	*Turbo brunnus* (Roding,1798)	+	+	+	+	-	+
46.	*Turbo castanea (*Gmelin,1791)	-	-	-	-	-	+
47.	*Turbo coronetus* (Gmelin,1791)	+	+	+	-	+	+
48.	*Turbo intercostalis* (Menke, 1846)	+	+	+	+	+	+
49	*Tympanotonos fascatus* (Linnaeus,1758)	-	+	+	+	+	-
50.	*Urosalpinx cinereal (*Say, 1822)	-	-	-	-	-	+

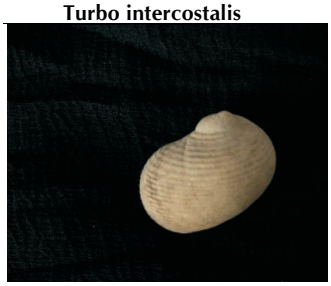
pre-winter (0.4 no/0.25) and lowest during winter (0.13 no/0.25). Family Columbellidae showed highest density during winter (1.93 no/0.25) and lowest during post-monsoon (0.03 no/0.25). Family Carithiidae showed highest density during early winter (5.06 no/0.25) and lowest during winter (1.36 no/0.25) (Figure 4). Family Turbinidae showed highest abundance during winter (2.78 no/0.25) and lowest during pre-winter (1.6 no/0.25). Family Buccinidae showed highest abundance during winter (1.5 no/0.25) and in rest of the season value were observed all most same values (1.0 no/0.25). Family


Turbo intercostalis


Turbo brunnus

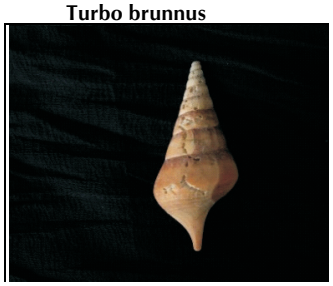

Astraea stellate


Turbo brunnus

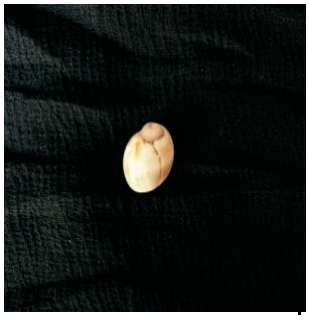

Nerita (cymostyla) undta


Trochus hanleyanus

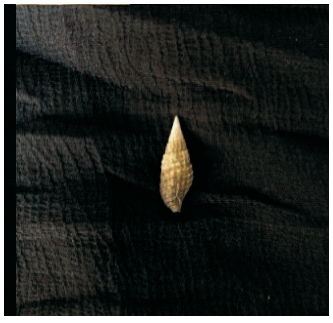

Trochus sacellum rota


Bursa granularis

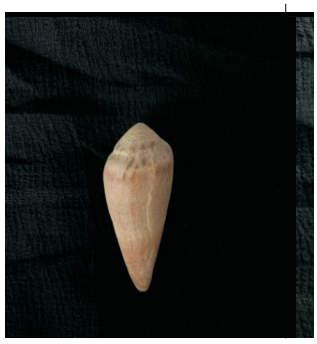

Bursa granularis


Natica picta


Cantharus spiralis


Engina zea


Conus amadis

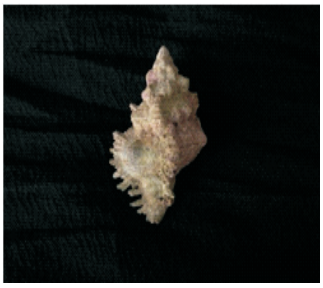

Conus mutabilis


Cantharus undosus


Purpura persica

Muricidae showed highest abundance during winter (4.0 no/0.25) and lowest during post-monsoon (1.16 no/0.25). Family Columbellidae showed highest abundance during winter (6.4 no/0.25) and lowest during pre-winter (1.0 no/0.25). Family Carithiidae showed highest abundance during post-monsoon (14.3 no/0.25) and lowest during winter (3.15 no/0.25) (Figure 5). Family Turbinidae showed highest frequency during pre-winter (50%) and lowest during post-monsoon (16.66%). Family Buccinidae showed highest frequency during post-monsoon (13.33%) and lowest during winter (3.3%). Family Muricidae showed highest frequency during pre-winter (20%) and lowest during winter (3.3%). Family Columbellidae showed highest frequency during winter (30%) and lowest during post-monsoon (3.3%). Family Carithiidae showed highest frequency during pre-winter (66.66%) and lowest during post-monsoon (33.33%) (Figure 6).

It is belonging to the family Muricidae, which is the second-largest family in the Neogastropoda with about 600 species recent species (Morris, 1980). The Intertidal zone of Kathiawar peninsular shoreline shows a great deal of biotic diversity in the aquatic environment. There is total of 40 species of Mollusca were recorded (Poriya and Kundu, 2014). The Veraval spring represented a solid development of seaweeds and rock bedrock as attachment site which supports a probable potential site for the progresses of mollusks. The straight up spring bare the richness Cerithium Spp., Chiton granoradiatus, Patella (Cellana) radiate, Rhinoclavis sinensis, Siphonria laciniosa, Turbo (Marmarostoma) intercostalis (Dave and


Murex palamrosae


Murex brunneus

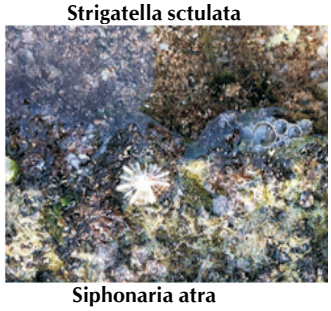

Anachis terpsichora


Strigatella sctulata


Cerethium caeruleum


Rhinoclavis sinensis


Cellana radiata


Siphonaria atra


Onchidium vericcula

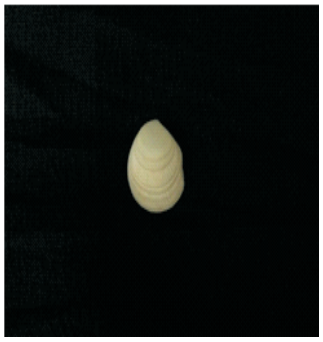

Tympanotonos fascatus

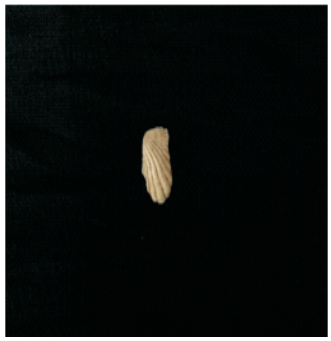

Theodoxus euxinus

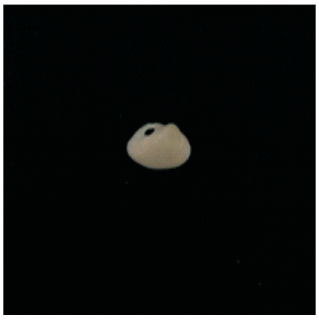

Architectonica laevigata

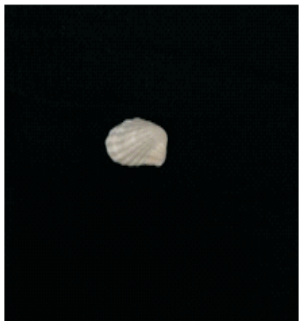

Apiysia dactylomela


Chitan granoradiatus


Codakia tigerina


Cardita leana


Donax obesulus


Modiolus auriculatus

Chudasama, 2018). The Highest species diversity of this group was recorded at Veraval during winter (Bhadja *et al*., 2014). The 44 species in 17 families of gastropod molluscs were recorded from the intertidal zone of Alang ship breaking yard of Gujarat state, India. Species of few families like Cerithiidae, Muricidae, Nassaridae, Onchididae and Trochidaewere observed common during all the seasons (Baxi *et al*., 2017). Total 22 species belonging to 14 families were recorded from Veraval coast. The distributional data from Veraval coast showed variation as per the season (Agravat and Raval, 2019). The 44 species of gastropoda, 23 species of bivalves and 3 species of cephalopods are noted at Andhra Pradesh coast (Monolisha *et al*., 2014). Total 60 species of gastropods belonging to 38 genera, 25 familiesand 8 orders were recorded from Uran coast. In present study, gastropods belonging to order Archaeogastropoda, Caenogastropoda, Chitonida,

Cycloneritimorpha, Littorinimorpha, Neogastropoda, Nudibranchia and Patellogastropoda were recorded (Pawar *et al*., 2017). The substratum of the Veraval coast is mainly rocky with a few sandy patches that supports the molluscs diversity. Among 5 selected dominant families, Turbinidae, Buccinidae, Muricidae, Columbellidae, Carithiidae were mostly associated with green algae.

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