

Distribution of Gastropods in the Intertidal Environment of South, Middle and North Andaman Islands, India

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Abstract

Andaman and Nicobar Islands, the gastropod diversity is high, due to the majority of shores are rocky. The wet rocky shore promotes algal growth, which is ultimate for feeding ground for gastropod growth and development leading to more diversity. The global warming, anthropogenic activities, industrial and domestic pollution, etc., have accelerated the loss of coastal and marine biodiversity components over the last few decades which has been of great concern. However, except global warming, the other factors were of least concern with reference to Andaman and Nicobar Islands biodiversity due to a pristine environment. Therefore, exploration of biodiversity in these islands is essential to create a baseline data for record and future research. Four locations of south to north Andaman Islands which represented Carbyns Cove from south Andaman, Rangat and Mayabunder from the Middle Andaman and Diglipur from the North Andaman were selected for this study. Gastropoda species were collected for a period of one year in three prevailing seasons of Andaman and Nicobar Islands. They are South West Monsoon (SW monsoon), North East Monsoon (NE Monsoon) and Non Rainy Seasons (NR Seasons). The present study of gastropods distribution in the South, Middle and North Andaman groups of Islands suggested that there are 71 species belonging to 52 genus and 33 families. At any one of the time and any one of the locations, only one occurrence was noticed for 38 species and remaining 33 species were overlapping with respect to stations and seasons. Evaluation of the cluster suggested that Cluster A (NR season in Carbyns Cove) and Cluster B (NE and SW Monsoon in Mayabunder) as a separate entity among the 12 combinations of stations and seasons due to their species representation. It

was also concluded that out of 71 studied species, 3 species were not reported till date in these Island environment and 2 species from any other parts of India.

Keywords

Gastropoda, Abundance, Species Composition, Andaman Sea, Bay of Bengal

1. Introduction

Andaman and Nicobar archipelago located in the central part of the Bay of Bengal consists of 572 islands. Southern tip of this archipelago is located just at 145 NM from the northern side of Indonesia and 750 NM distance from the eastern coast of India. This island is scarcely populated than the mainland India. This pristine environment supports establishment of well diversified coral communities. This archipelago is one among the 12 mega-biodiversities and also one among the 25 hotspots of the rich and highly endangered eco-regions of the world. Among the Asian countries, India is the only one country that has a long record of inventories of coastal and marine biodiversity dating back to at least two centuries.

The research history of malacological studies in India is among the oldest one which was initiated by the Asiatic Society of Bengal during the year 1784 and made a repository in the Indian Museum, Calcutta in the year 1814. Benson published a total of 90 research papers which was mainly concerned land and freshwater mollusks of the Indian subcontinent between 1830-1865 [1]. Till date, 3370 species of marine mollusks have been recorded in India, out of which 1282 species are from Andaman and Nicobar Islands [2]. The majority of mollusks are present in the marine biotopes and they occur from the backwater zone, mangroves, intertidal and shelf in deeper waters. Mollusks have been a favorite candidate for the research in the early days, especially those available on rocky shores and inter-tidal zones as they are plentiful of animal, moderately slow moving and easy to identify [3] [4] [5]. They comprise an important component of intertidal fauna and flora [6].

Among the mollusks, gastropods are more important in the coastal populations' economy, *i.e.* as a shell-craft industry. Over and above, the marine gastropod resources in India consisted of different types of species which are exploited regularly for various purposes like drugs, ornamental purposes as well as for their meat. Andaman and Nicobar Islands, the gastropod diversity are high, due to the majority of shores are rocky. The wet rocky shore promotes algal growth, which is ultimate for feeding ground for gastropod growth and development leading to more diversity. Further, the mangrove environment also provides ideal conditions for the productivity of gastropods [7].

The global warming, anthropogenic activities, industrial and domestic pollution,

etc., have accelerated the loss of coastal and marine biodiversity components over the last few decades which has been of great concern. However, except global warming, the other factors were of least concern with reference to Andaman and Nicobar Islands biodiversity due to a pristine environment. Therefore, exploration of biodiversity in these islands is essential to create a baseline data for record and future research. In this regard, gastropods are a significant indicator of environmental changes, hence, an attempt had been made to understand a comprehensive gastropod diversity by the way of studies on selected locations of the south to north Andaman coast lines.

2. Materials and Methods

2.1. The Study Area

The gastropod diversity of the Andaman Islands was studied in four locations of south to north Andaman Islands which represented Carbyns Cove from south Andaman, Rangat and Mayabunder from the Middle Andaman and Diglipur from the North Andaman (**Figure 1**). The station descriptions are as follows:

2.1.1. Carbyns Cove

This station is located in the south Andaman. This coast has a length of one km out of that, the central part which extends to around 300 m is covered with sand and remaining part are exposed as rock terrain. Near the southern part of the sandy beach environment a freshwater inlet is present through which inflow of rainwater occurs during the monsoon. However, during the high tide the whole beach is submerged with sea water.

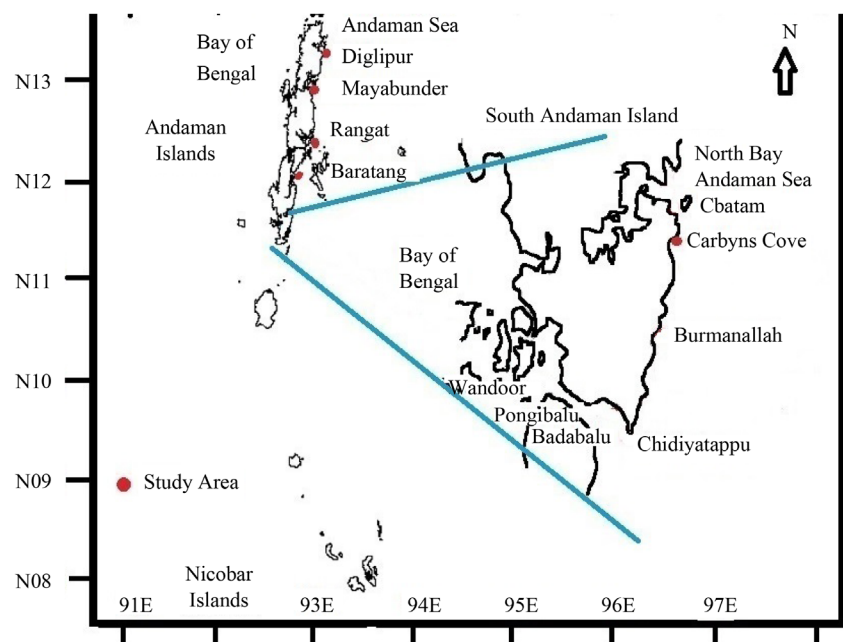


Figure 1. Study area.

2.1.2. Rangat

This location is present in the southern part of Middle Andaman. This area covered a length of one km. This site is covered by rocky outcrops with boulders and pebbles which are in many ways similar to the Carbyns Cove, however, it has a less sandy beach of around 100 m long with a freshwater inlet in south side. However, during the non rainy season this inlet would be blocked with boulders and pebbles while during the rainy season it opens for the freshwater flow.

2.1.3. Mayabunder

This station is located in the northern part of Middle Andaman. The exact location is near the eastern side of the fishery jetty. However, this area largely consists of exposed rocks with boulders and pebbles surrounded by mangrove vegetation.

2.1.4. Diglipur

This study area is located in the northern part of Andaman. The samples were collected at Kalipur beach. Sandy beach precedes an exposed coral basement on the eastern side while the western side has a plain and wider sand cover without any coral basement exposure along with a freshwater inlet. The high tide covers this coral basement along with the upper sandy beach. During the low tide more than a 600 to 700 m wide coral basement with gentle slope would be exposed.

2.2. Methods

All the above stations, once in four months, *i.e.* from August 2013 to August 2014, systematic samples were collected throughout the coastline. The seasons of Andaman considered as a unique one, eight months, having continuous rain and four month considered as the non rainy season. Overall annual rainfall is 3394 mm. The period January to April considered Non Rainy Season (NRS). The month May to August considered as South West Monsoon (SWM) and September to December considered as North East Monsoon (NEM). So, these collections were made at the end of each season, *i.e.* the Second Half of December to First Half of January is representing the end of NE monsoon. The Second Half of the April to First Half of May considered as the end of the Non Rainy season and Second Half of the July to First Half of August represented as the end of the SW monsoon period. The collection of samples was within one square meter transect at two sites in each station by hand picking as mentioned by Arumugam *et al.* [8]. The collected animals were photographed in the field itself for its original colour and then preserved in 10% formalin for further analysis. Identification was carried out using the different authors key such as Pinn [9], Apte [10] [11], Jereb and Roper [12], Ramkrishna and Dey [13], Rao [14], D'Souza [15] and WoRMS [16] based on the colour pattern of the shell, shape, number of whorls, operculum, etc. Then identified gastropods were counted and averaged in two sites of each station and recorded for the diversity and density studies. The data for the gastropods and its diversity were presented in **Table 1**.

Table 1. Percentage Distribution of the Gastropoda Species in Different Locations and Seasons of the Present Studied Samples NER-NE Monsoon Rangat; NRR-Non Rainy Season Rangat; SWR-SW Monsoon Rangat; NEM-NE Monsoon Mayabunder; NRM-Non Rainy Season Mayabunder; SWM-SW Monsoon Mayabunder; NED-NE Monsoon Diglipur; NRD-Non Rainy Season Diglipur; SWR-SW Monsoon Diglipur; NEC-NE Monsoon Carbyns Cove; NRC-Non Rainy Season Carbyns Cove; SWC-SW Monsoon Carbyns Cove.

Species Name	NER 2013	NRR 2014	SWR 2014	NEM 2013	NRM 2014	SWM 2014	NED 2013	NRD 2014	SWD 2014	NEC 2013	NRC 2014	SWC 2014
<i>Trochus radiates</i>	5.32	---	1.53	---	---	2.77	---	---	---	5.00	---	---
<i>Monodonta australis</i>	1.33	---	---	---	---	8.33	---	4.54	4.16	7.50	---	---
<i>Tectus pyramis</i>	---	---	---	---	10.52	---	---	---	4.16	---	---	---
<i>Angaria delphinus</i>	---	---	---	7.14	---	---	---	---	---	---	---	---
<i>Turbo bruneus</i>	2.66	---	---	---	---	2.77	2.85	4.54	12.50	2.50	---	---
<i>Lunella cinerea</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
<i>Turbo sp.</i>	---	---	---	---	---	---	---	---	---	---	33.33	---
<i>Turbonilla felicitata</i>	---	---	---	---	---	---	---	---	---	2.5	---	---
<i>Nerita albicilla</i>	5.33	88.23	10.76	---	5.26	8.33	17.14	13.63	20.83	25.00	---	52.62
<i>Nerita oryzae</i>	1.33	---	7.68	---	36.84	---	2.85	---	8.32	2.50	---	---
<i>Nerita polita</i>	16.00	---	6.15	---	5.26	---	---	9.09	---	---	---	---
<i>Nerita histrio</i>	---	---	---	---	---	---	14.28	---	---	---	---	---
<i>Nerita chamaeleon</i>	---	---	---	---	10.52	5.55	2.85	---	---	---	---	---
<i>Nerita insculpta</i>	---	---	15.38	---	---	---	---	---	---	---	---	---
<i>Nerita costata</i>	---	---	13.84	---	---	---	---	---	---	---	---	15.78
<i>Cellana radiata</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
<i>Cellana sp.</i>	4.00	---	---	---	---	---	---	---	---	---	---	---
<i>Menathais turberosa</i>	4.00	---	3.07	---	---	---	---	---	---	---	---	---
<i>Tylothais virgata</i>	9.33	---	---	7.14	---	---	---	---	---	15	---	---
<i>Menathais intermedia</i>	---	---	---	---	5.26	---	---	---	---	---	---	23.68
<i>Indothais lacera</i>	---	---	---	---	---	---	2.85	---	4.16	---	---	---
<i>Tenguella granulata</i>	---	---	12.3	---	---	---	---	---	---	---	---	---
<i>Vokesimurex tryoni</i>	---	---	---	---	---	---	---	4.54	---	2.50	---	---
<i>Chicoreus brunneus</i>	---	---	1.53	---	---	11.11	---	---	4.16	2.50	---	---
<i>Murex tribulus</i>	2.66	---	---	---	---	---	---	---	---	---	---	---
<i>Semiricinula konkanensis</i>	2.66	---	3.07	---	---	---	---	---	---	---	---	---
<i>Thais sp.</i>	---	---	---	---	---	---	---	---	---	2.50	33.33	---
<i>Morula nodicostata</i>	---	---	---	---	---	---	---	---	20.83	---	---	---
<i>Morula sp.</i>	---	---	1.53	---	---	8.33	---	---	---	---	---	---
<i>Vasum turbinellus</i>	1.33	---	---	---	---	---	---	20.72	---	---	---	---
<i>Clypeomorus bifasciata</i>	4.00	---	---	---	5.26	---	54.27	20.17	---	5.00	33.33	---

Continued

<i>Clypeomorus petrosa</i>	---	---	---	---	5.26	---	---	13.63	---	2.50	---	---
<i>Cerithium corallium</i>	---	---	---	---	---	---	---	4.16	---	---	---	---
<i>Rhinoclavis vertagus</i>	---	---	---	---	---	---	---	---	---	2.50	---	---
<i>Batillaria multiformis</i>	8.00	---	1.53	---	---	---	---	---	---	---	---	---
<i>Nebularia aurantia</i>	---	---	7.65	---	---	---	---	---	---	---	---	---
<i>Strigatella paupercula</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
<i>Haliotis planata</i>	---	---	---	---	---	---	---	---	---	2.50	---	---
<i>Turritella sp.</i>	---	---	---	---	---	2.77	---	---	---	---	---	---
<i>Nassarius sp.</i>	---	---	3.07	---	---	---	---	---	---	---	---	---
<i>Nassarius coronatus</i>	1.33	---	---	---	5.26	---	---	---	---	---	---	---
<i>Nassarius olivaceus</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
<i>Nassarius pullus</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
<i>Nassarius conoidalis</i>	---	---	---	---	5.26	---	---	---	---	---	---	---
<i>Oliva vidua</i>	---	---	---	---	---	8.33	---	---	---	---	---	---
<i>Oliva sp.</i>	2.66	---	---	---	---	---	---	---	---	---	---	---
<i>Bufo naria rana</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
<i>Bufo naria echinata</i>	4.00	---	---	---	---	---	---	---	---	---	---	---
<i>Bursa granularis</i>	2.66	---	1.53	---	---	---	---	---	---	---	---	---
<i>Gammula vagata</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
<i>Turritatirus craticulatus</i>	---	---	---	---	---	---	---	---	4.16	---	---	---
<i>Latirolagena smaragdulus</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
<i>Scutellastra flexuosa</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
<i>Terebralia paluster</i>	---	---	---	---	---	2.77	---	---	---	---	---	---
<i>Engina mendicaria</i>	1.33	---	---	---	---	---	---	---	8.32	---	---	---
<i>Pollia undosa</i>	5.33	---	---	---	---	---	2.85	---	4.16	---	---	---
<i>Siphonaria sp.1</i>	---	5.88	---	---	---	---	---	---	---	---	---	---
<i>Siphonaria sp.2</i>	---	---	1.53	---	---	2.77	---	---	---	---	---	---
<i>Canarium labiatum</i>	2.66	5.88	---	---	---	---	---	---	---	---	---	---
<i>Gibberulus gibberulus</i>	---	---	---	14.28	---	2.77	---	---	---	---	---	---
<i>Laevistrombus canarium</i>	---	---	---	21.42	---	---	---	---	---	---	---	---
<i>Conus ebraeus</i>	---	---	---	---	---	2.77	---	---	---	---	---	---
<i>Harpa major</i>	1.33	---	1.53	---	---	---	---	---	---	5.00	---	7.89
<i>Semicassis bisulcata</i>	2.66	---	---	---	---	---	---	---	---	---	---	---
<i>Polinices mammilla</i>	1.33	---	---	---	5.26	---	---	---	---	---	---	---
<i>Tanea lineata</i>	---	---	---	7.14	---	11.11	---	---	---	---	---	---
<i>Patelloida saccharina</i>	---	---	---	---	---	---	---	---	---	15.00	---	---
<i>Onchidium sp.</i>	---	---	---	21.42	---	---	---	---	---	---	---	---
<i>Littoraria undulate</i>	---	---	---	21.42	---	13.88	---	---	---	---	---	---
<i>Monetaria moneta</i>	---	---	---	---	---	---	---	9.08	---	---	---	---
<i>Gyrineum natator</i>	---	---	---	---	---	5.55	---	---	---	---	---	---

Further, the data were analysed by Primer 6 software [17] for the different diversity indices and cluster analysis. The cluster analysis was carried out based on the raw data which was converted for resemblance using Bray-Curtis Similarity and then group average was taken as a cluster. The results were provided as a figurative form.

3. Results

Gastropoda species were collected from the coasts of Carbyns Cove, Rangat, Mayabunder and Diglipur for a period of one year in three prevailing seasons of Andaman and Nicobar Islands. They are SW monsoon, NE Monsoon and Non rainy Seasons. The collected samples were identified up to species level and their data were converted into percentages (Table 1). The photographs of these species were provided as Figures A1-A8.

Based on this study, among the four stations, seventy one species belonging to fifty two genus and thirty three families of gastropods were observed. Among the seventy one species, 38 species fell in unique category such that it may be noticed in any one of the stations, in any one of the season, i.e. their appearances/disappearance were not found to be site specific or seasonal specific (Table 2). Among them, 10 species available during the NE monsoon season in the station Rangat followed by SW monsoon season in the station Rangat (08), SW monsoon season in the station Mayabunder (05), NE monsoon season in the station Carbyns Cove (04), NE monsoon in the station Mayabunder, SW monsoon in the station Diglipur, represented 03 species each, Non rainy season of Mayabunder and Diglipur observed 01 species each, NE monsoon for Diglipur and Non rainy season in the station Rangat and Carbyns Cove noticed 01 species respectively, and the SW monsoon season in the station Carbyns Cove represented a total absence of gastropods.

Out of the remaining species, 20 species were observed in two occurrences by the way of any two seasons or any two locations or one season in two locations (Table 3). In these, NE monsoon in the station Rangat represented 09 species. Non Rainy season of Mayabunder (04) and SW monsoon in the station Rangat represented (07) species, followed by SW monsoon Mayabunder (05), Non Rainy season of Diglipur (02), NE monsoon of Diglipur (01), SW monsoon of Diglipur (03), NW monsoon of Carbyns Cove (02), SW monsoon of Carbyns Cove (02) and 1 species in Non rainy season of Rangat and Carbyns Cove were observed.

The species *Tylothais virgata* only observed during the NE monsoon of all the stations except Diglipur. *Clypeomorus bifasciata* species noticed only in the fifty percent of the seasons of the study period (NE Rangat, NRS Mayabunder, NE Diglipur, NRS Diglipur, NE and NRS of Carbyns Cove). *Pollia undosa* species were observed in NE monsoon season of Rangat and Diglipur as well as SW monsoon at Diglipur (Table 4).

Trochus radiates noticed in the NE monsoon of Rangat and Carbyns Cove

Table 2. Percentage of One Time Occurrence of the Gastropoda Species in Different Locations and Seasons of the Present Studied Samples NER-NE Monsoon Rangat; NRR-Non Rainy Season Rangat; SWR-SW Monsoon Rangat; NEM-NE Monsoon Mayabunder; NRM-Non Rainy Season Mayabunder; SWM-SW Monsoon Mayabunder; NED-NE Monsoon Diglipur; NRD-Non Rainy Season Diglipur; SWR-SW Monsoon Diglipur; NEC-NE Monsoon Carbyns Cove; NRC-Non Rainy Season Carbyns Cove; SWC- SW Monsoon Carbyns Cove.

Sl. No.	Species Name	NER 2013	NRR 2014	SWR 2014	NEM 2013	NRM 2014	SWM 2014	NED 2013	NRD 2014	SWD 2014	NEC 2013	NRC 2014	SWC 2014
1	<i>Angaria delphinus</i>	---	---	---	7.14	---	---	---	---	---	---	---	---
2	<i>Lunella cinerea</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
3	<i>Turbo sp.</i>	---	---	---	---	---	---	---	---	---	---	33.33	---
4	<i>Turbonilla felicitia</i>	---	---	---	---	---	---	---	---	2.50	---	---	---
5	<i>Nerita histrio</i>	---	---	---	---	---	14.28	---	---	---	---	---	---
6	<i>Nerita insculpta</i>	---	---	15.38	---	---	---	---	---	---	---	---	---
7	<i>Cellana radiate</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
8	<i>Cellana sp.</i>	4.00	---	---	---	---	---	---	---	---	---	---	---
9	<i>Tenguella granulata</i>	---	---	12.30	---	---	---	---	---	---	---	---	---
10	<i>Murex tribulus</i>	2.66	---	---	---	---	---	---	---	---	---	---	---
11	<i>Morula nodicostata</i>	---	---	---	---	---	---	---	20.83	---	---	---	---
12	<i>Cerithium coralium</i>	---	---	---	---	---	---	---	4.16	---	---	---	---
13	<i>Rhinoclavis vertagus</i>	---	---	---	---	---	---	---	---	2.50	---	---	---
14	<i>Nebularia aurantia</i>	---	---	7.65	---	---	---	---	---	---	---	---	---
15	<i>Strigatella paupercula</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
16	<i>Haliotis planata</i>	---	---	---	---	---	---	---	---	2.50	---	---	---
17	<i>Turritella sp</i>	---	---	---	---	2.77	---	---	---	---	---	---	---
18	<i>Nassarius sp.</i>	---	---	3.07	---	---	---	---	---	---	---	---	---
19	<i>Nassarius olivaceus</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
20	<i>Nassarius pullus</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
21	<i>Nassarius conoidalis</i>	---	---	---	5.26	---	---	---	---	---	---	---	---
22	<i>Oliva vidua</i>	---	---	---	---	8.33	---	---	---	---	---	---	---
23	<i>Oliva sp.</i>	2.66	---	---	---	---	---	---	---	---	---	---	---
24	<i>Bufo naria rana</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
25	<i>Bufo naria echinata</i>	4.00	---	---	---	---	---	---	---	---	---	---	---
26	<i>Gammula vagata</i>	1.33	---	---	---	---	---	---	---	---	---	---	---
27	<i>Turritella craticulatus</i>	---	---	---	---	---	---	---	4.16	---	---	---	---
28	<i>Latirolagena smaragdulus</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
29	<i>Scutellastra flexuosa</i>	---	---	1.53	---	---	---	---	---	---	---	---	---
30	<i>Terebralia paluster</i>	---	---	---	---	2.77	---	---	---	---	---	---	---
31	<i>Siphonaria sp.1</i>	---	5.88	---	---	---	---	---	---	---	---	---	---
32	<i>Laevistrombus canarium</i>	---	---	21.42	---	---	---	---	---	---	---	---	---
33	<i>Conus ebraeus</i>	---	---	---	---	2.77	---	---	---	---	---	---	---
34	<i>Semicassis bisulcata</i>	2.66	---	---	---	---	---	---	---	---	---	---	---
35	<i>Patelloida saccharina</i>	---	---	---	---	---	---	---	---	15.00	---	---	---
36	<i>Onchidium sp.</i>	---	---	21.42	---	---	---	---	---	---	---	---	---
37	<i>Monetaria moneta</i>	---	---	---	---	---	---	9.08	---	---	---	---	---
38	<i>Gyrineum natator</i>	---	---	---	---	5.55	---	---	---	---	---	---	---

Table 3. Percentage of Two Time Occurrence of the Gastropoda Species in Different Locations and Seasons of the Present Studied Samples NER-NE Monsoon Rangat; NRR-Non Rainy Season Rangat; SWR-SW Monsoon Rangat; NEM-NE Monsoon Maya-bunder; NRM-Non Rainy Season Mayabunder; SWM-SW Monsoon Mayabunder; NED-NE Monsoon Diglipur; NRD-Non Rainy Season Diglipur; SWR-SW Monsoon Diglipur; NEC-NE Monsoon Carbyns Cove; NRC-Non Rainy Season Carbyns Cove; SWC-SW Monsoon Carbyns Cove.

Sl. No.	Species Name	NER	NRR	SWR	NEM	NRM	SWM	NED	NRD	SWD	NEC	NRC	SWC
		2013	2014	2014	2013	2014	2014	2013	2014	2014	2013	2014	2014
1	<i>Tectus pyramis</i>	---	---	---	---	10.52	---	---	---	4.16	---	---	---
2	<i>Nerita costata</i>	---	---	13.84	---	---	---	---	---	---	---	---	15.78
3	<i>Menathais turberosa</i>	4.00	---	3.07	---	---	---	---	---	---	---	---	---
4	<i>Menathais intermedia</i>	---	---	---	---	5.26	---	---	---	---	---	---	23.68
5	<i>Indothais lacera</i>	---	---	---	---	---	---	2.85	---	4.16	---	---	---
6	<i>Vokesimurex tryoni</i>	---	---	---	---	---	---	---	4.54	---	2.5	---	---
7	<i>Semiricinula konkanensis</i>	2.66	---	3.07	---	---	---	---	---	---	---	---	---
8	<i>Thais sp.</i>	---	---	---	---	---	---	---	---	---	2.5	33.33	---
9	<i>Morula sp.</i>	---	---	1.53	---	---	8.33	---	---	---	---	---	---
10	<i>Vasum turbinellus</i>	1.33	---	---	---	---	---	---	20.72	---	---	---	---
11	<i>Batillaria multiformis</i>	8.00	---	1.53	---	---	---	---	---	---	---	---	---
12	<i>Bursa granularis</i>	2.66	---	1.53	---	---	---	---	---	---	---	---	---
13	<i>Engina mendicaria</i>	1.33	---	---	---	---	---	---	---	8.32	---	---	---
14	<i>Siphonaria sp.2</i>	---	---	1.53	---	---	2.77	---	---	---	---	---	---
15	<i>Canarium labiatum</i>	2.66	5.88	---	---	---	---	---	---	---	---	---	---
16	<i>Gibberulus gibberulus</i>	---	---	---	14.28	---	2.77	---	---	---	---	---	---
17	<i>Polinices mammilla</i>	1.33	---	---	---	5.26	---	---	---	---	---	---	---
18	<i>Tanea lineata</i>	---	---	---	7.14	---	11.11	---	---	---	---	---	---
18	<i>Littoraria undulate</i>	---	---	---	21.42	---	13.88	---	---	---	---	---	---
20	<i>Nassarius coronatus</i>	1.33	---	---	---	5.26	---	---	---	---	---	---	---

and SW monsoon period in Mayabunder and Rangat. *Chicoreus brunneus* observed in SWM of Rangat, Mayabunder and Diglipur as well as NEM of Carbyns Cove stations. SWM of Mayabunder, NEM of Rangat and Carbyns exhibited *Monodonta australis* species and in Diglipur it had been noticed in Non rainy season and SW monsoon. *Harpa major* species were noticed in NEM and SWM of Rangat and Carbyns Cove (Table 4).

Except NEM in Mayabunder and NRS of Carbyns Cove all the remaining seasons represented by *Nerita albicilla* (Table 4). This is the only species observed in almost all the stations with the majority of the seasons (Table 4).

The NEM in Rangat, Diglipur and Carbyns Cove as well as NRS in Diglipur and SWM in Mayabunder and Diglipur represented the species *Turbo bruneus*, i.e. all the three seasons in Diglipur this species was present. *Nerita oryzarum* was observed during the period of NEM of Rangat, Diglipur and Carbyns Cove,

Table 4. Percentage of Special Occurrence of the Gastropoda Species in Different Locations and Seasons of the Present Studied Samples NER-NE Monsoon Rangat; NRR-Non Rainy Season Rangat; SWR-SW Monsoon Rangat; NEM-NE Monsoon Mayabunder; NRM-Non Rainy Season Mayabunder; SWM-SW Monsoon Mayabunder; NED-NE Monsoon Diglipur; NRD-Non Rainy Season Diglipur; SWR-SW Monsoon Diglipur; NEC-NE Monsoon Carbyns Cove; NRC-Non Rainy Season Carbyns Cove; SWC-SW Monsoon Carbyns Cove.

Sl. No.	Species Name	NER 2013	NRR 2014	SWR 2014	NEM 2013	NRM 2014	SWM 2014	NED 2013	NRD 2014	SWD 2014	NEC 2013	NRC 2014	SWC 2014
1	<i>Trochus radiates</i>	5.32	---	1.53	---	---	2.77	---	---	---	5.00	---	---
2	<i>Monodonta australis</i>	1.33	---	---	---	---	8.33	---	4.54	4.16	7.50	---	---
3	<i>Angaria delphinus</i>	---	---	---	7.14	---	---	---	---	---	---	---	---
4	<i>Nerita albicilla</i>	5.33	88.23	10.76	---	5.26	8.33	17.14	13.63	20.83	25.00	---	52.62
5	<i>Nerita oryzae</i>	1.33	---	7.68	---	36.84	---	2.85	---	8.32	2.50	---	---
6	<i>Tylothais virgata</i>	9.33	---	---	7.14	---	---	---	---	---	1.50	---	---
7	<i>Chicoreus brunneus</i>	---	---	1.53	---	---	11.11	---	---	4.16	2.50	---	---
8	<i>Clypeomorus bifasciata</i>	4.00	---	---	---	5.26	---	54.27	20.17	---	5.00	33.33	---
9	<i>Pollia undosa</i>	5.33	---	---	---	---	---	2.85	---	4.16	---	---	---
10	<i>Harpa major</i>	1.33	---	1.53	---	---	---	---	---	---	5.00	---	7.89

SWM in Rangat and Diglipur and NRS in Mayabunder (Table 4).

The station Carbyns Cove exhibited a total of nineteen species consist of nine families. Out of nineteen species, single occurrence was noticed in 15 species and dual occurrence noticed for 4 species. A total of 24 families was missing in this station.

The station Rangat reported 42 species from 21 families. Out of 42 species single seasons were noticed for 32 species and dual occurrence noticed in 09 species and one species in all seasons. Twelve families were missing from this station.

The gastropods of 29 species belonging to 17 families were observed at Mayabunder station. Out of these 29 species, single occurrence noticed in 25 species and dual occurrence noticed in four species. There were 16 families missing.

Diglipur station reported 20 species belonging to 10 families in all the seasons. Out of 20 species, 13 species single time reported and two and three time presence noticed respectively 05 and 02 species. In this location 13 families were missing.

The study period represented the highest number of species (60) during the NE monsoon represented than remaining seasons. Next higher number of species (53) noticed in the SW monsoon and lowest numbers noticed in Non rainy season (26).

The results of the studied gastropods in the Primer software and the univariate analysis (Table 5) suggested that highest Margalef's Species Richness Index (6.080) noticed during the NE monsoon period of Rangat (29 species) and the lowest (0.434) noticed during Non Rainy Season at Carbyns Cove and Rangat (3

species). However, the Pielou's Evenness Index represented the maximum of 1.000 for the Carbyns Cove Non Rainy Season samples (3 species) and lowest (0.404) noticed for the Rangat (3 species) Non Rainy Season. The Shannon-Wiener Index represented the maximum (3.067) for the NE monsoon period of Rangat (29 species) and the lowest (0.444) noticed for the Rangat (3 species) Non Rainy Season. The Simpson Diversity Index supports the Shannon-Weiner Index.

The group average of the Cluster plot (**Figure 2**) suggested that three major clusters divided in one independent character and two with sub clusters. The one independent cluster represented the Non Rainy Season of Carbyns Cove (Cluster A). The second cluster with two sub clusters represented NE and SW monsoon periods of Mayabunder (Cluster B-B1, B2). The third cluster (Cluster C) with nine sub clusters has represented by five units of the remaining seasons and stations. The first unit (C-1) has two sub-sub-clusters (C-1-1 and 2) for NRS Rangat and SWM Carbyns Cove. The unit two (C-2) has two sub-sub-clusters represented NEM Diglipur and NRS Diglipur.

The unit 3 (C-3) also has two sub-sub clusters with SWM Diglipur and NEM Carbyns Cove. The unit 4 (C-4) represented only one season that is NRS Mayabunder. The last unit 5 (C-5) has two subdivisions represented NEM and SWM Rangat.

Table 5. Primer 6 Software Univariate Analytical Result. NER-NE Monsoon Rangat; NRR-Non Rainy Season Rangat; SWR-SW Monsoon Rangat; NEM-NE Monsoon Mayabunder; NRM-Non Rainy Season Mayabunder; SWM-SW Monsoon Mayabunder; NED-NE Monsoon Diglipur; NRD-Non Rainy Season Diglipur; SWR-SW Monsoon Diglipur; NEC-NE Monsoon Carbyns Cove; NRC-Non Rainy Season Carbyns Cove; SWC-SW Monsoon Carbyns Cove.

Season	Total Species (S)	Total Individuals (N)– Normalised	Margalef's Species Richness Index (d)	Pielou's Evenness Index (J')	Shannon Wiener Index (H')	Simpson Diversity Index (1 – λ)
NER	29	100	6.0801	0.9109	3.0673	0.9466
NRR	3	100	0.4343	0.4038	0.4437	0.2166
SWR	21	100	4.3429	0.8711	2.6521	0.9184
NEM	7	100	1.3028	0.9424	1.8338	0.8349
NRM	10	100	1.9543	0.8596	1.9794	0.8105
SWM	16	100	3.2572	0.9407	2.6082	0.9259
NED	8	100	1.5200	0.6825	1.4192	0.6578
NRD	9	100	1.7372	0.9330	2.0499	0.8650
SWD	12	100	2.3886	0.9071	2.2542	0.8802
NEC	16	100	3.2572	0.8618	2.3893	0.8826
NRC	3	100	0.4343	1	1.0986	0.6734
SWC	4	100	0.6514	0.8445	1.1708	0.6421

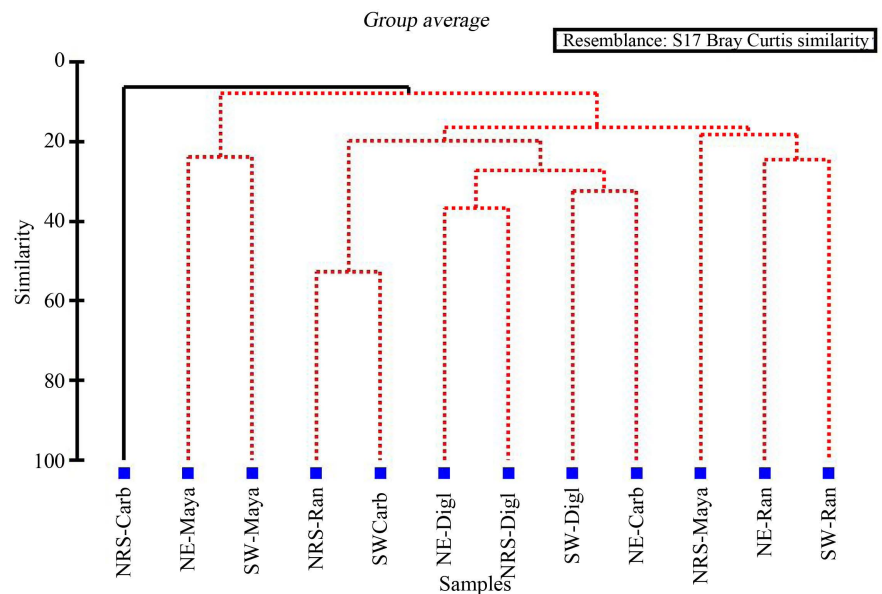


Figure 2. Cluster dendrogram for the studied gastropoda distribution.

4. Discussion

Based on the above results it was inferred that the station Rangat was highly enriched with gastropod species when comparing all the four stations followed by Mayabunder, Diglipur and Carbyns Cove stations. However, based on the occurrence of the species, it was noted that the stations Rangat and Carbyns Cove may be similar in environmental condition than the remaining two stations. Similarly, NE and SW monsoon plays a major role in the diversity and distribution of species in Rangat stations than in the Non rainy season. Mayabunder and Diglipur stations exhibited less diversity and distribution in NE monsoon than SW monsoon.

However, the Non Rainy Season shows diversity and distribution in between the above rainy seasons. Carbyns Cove represented SWM and NRS less favorable for diversity and distribution than NEM period.

Out of seventy one species studied, 10 species identified only upto genus level. The remaining 61 species, 57 species already reported in Andaman and Nicobar Islands by Rao (2003). The species *Nerita oryzae* was reported by Ragunathan and Venkatraman [18] and the other three species *Turbonilla felicitia*, *Vokesimurex tryoni* and *Batillaria multiformis* were not reported in these Islands.

The west coast of India in Raigad District, Maharashtra exhibited 14 species occurrence from the studies of Kade and Mane [19]. Haragi *et al.* [20] reported 7 species at the Karwar coast of Karnataka. Seven species of Charwad coast (Gujarat) reported by Vadher *et al.* [21]. Goa coast exhibited seven species of occurrence [6]. Elaiyaraja *et al.* [22] reported four similar species in the study from Palk Bay region. Chelladurai *et al.* [23], reported one studied species from the Gulf of Mannar, Tamil Nadu region. Sakhivel and Fernando [24] studied five species in the present study from Mudasal Odai and Nagapatnam coastal regions.

Arumugam *et al.* [8] reported eighteen species of the present study in the Great Nicobar Coastal environment. Priyankadevi *et al.* [25] reported 12 species of the present study in Avis Island and Karmatang beach of Mayabunder.

The station Rangat, Mayabunder, Diglipur and Carbyns Cove represented 42, 29, 20 and 19 species among the studied species. This suggested that Rangat station has an exposure of rocky outcrop which may provide a better niche for larger diversity of gastropod species. Even though Carbyns Cove also has the similar exposure because of little areal exposure during the low tide time may be reduced the population of this species. The studied Mayabunder location may have rocky and mangrove exposure support the presence of *Littoraria undulata* exclusively in this location and have next in concentration of diversity. Diglipur station was covered with coralline exposure than the rock exposure has fallen in between the Carbyns Cove and Mayabunder diversity status. Chelladurai *et al.* [23], and Elaiyaraja *et al.* [22], reported that the coralline outcrop has more amount of diversity during the non rainy season also proved in this study location where the similar outcrop exposed, *i.e.* the station Diglipur which exhibited comparatively equal or more diversity during the non rainy season than in the monsoon period.

These studies well follow the existing inference from the world wide study pattern of the gastropoda. As reported by the Sanpanich *et al.* [26] and Suresh *et al.* [27], *Littoraria undulata* only occurred in the rocky outcrop with mangrove environment. Ramadoss [28], Tan and Clements [29], Arumugam *et al.* [8], Haragi *et al.* [20], Khade and Mane [19], Sorensen [30], Miloslavich *et al.* [31] and David [6] was reported rocky outcrop species were also present in this study area also in the same environment. Bhadja [32], David [6] and Vadher *et al.* [21], reported that diversity is more in the period of monsoon than in non rainy seasons of rocky outcrop environment also supported in this present study that the station Rangat exposed to 40 species during the monsoon (SW and NE) period. Yaninek [33] reported that *Conus ebraeus*, more abundant in the higher intertidal zone than in the outer zone, which also true in the present study.

The results of univariate analysis based on Margalef's Species Richness Index, Pielou's Evenness Index, Shannon-Wiener Index and Simpson Diversity Index supported each other for the distribution of gastropods in the study locations for all the seasons. The cluster analysis also grouped the unique character of occurrences with reference to locations and seasons. While comparing these clusters, it was noted that that the individual clusters Cluster A and Cluster B has no similar species between them, but it shared similarities of the species with C1 and C2 clusters. The cluster B represented single common species (*Nerita albicilla*). Cluster C, among all the sub clusters (5 Nos.), the cluster four and five have three common species *Nerita albicilla*, *Nerita oryzaeum* and *Nerita polita*. The sub cluster three, four and five showing two common species *Nerita albicilla* and *Nerita oryzaeum* and three and four exhibited two common species *Nerita albicilla* and *Turbo brunneus*. However, the cluster two and five exhibited one

common species are *Nerita albicilla*. Turbo species exclusively in Cluster A among the three available species and Cluster B exhibited twelve species exclusively among the 20 available species. Total forty nine species exclusively found in Cluster C among 59 which can be divided into five sub clusters.

5. Conclusion

The present study of gastropods distribution in the South, Middle and North Andaman groups of Islands suggested that there are 71 species belonging to 52 genus and 33 families. At any one of the time and any one of the locations, only one occurrence was noticed for 38 species and remaining 33 species were overlapping with respect to stations and seasons. *Nerita albicilla* observed at all the stations with the majority of the seasons except NEM of Mayabunder and NRS of Carbyns Cove. *Turbo* species exclusively in Cluster A among the three available species and Cluster B exhibited twelve species exclusively among the 20 available species. Total forty nine species exclusively found in Cluster C among 59 which can be divided into five sub clusters. This study also concluded that three species (*Turbonilla felicitata*, *Vokesimurex tryoni* and *Batillaria multiformis*) were new to the Andaman Islands and among them two species (*Vokesimurex tryoni* and *Batillaria multiformis*) were not recorded any part of India.

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Appendix



Figure A1. 1. *Trochus radiatus* (lateral view); 1a. *Trochus radiatus* (apertural view); 2. *Monodonta australis* (lateral view); 2a. *Monodonta australis* (apertural view); 3. *Tectus pyramis* (lateral view); 3a. *Tectus pyramis* (apertural view); 4. *Angaria delphinus* (lateral view); 4a. *Angaria delphinus* (apertural view); 5. *Turbo brunneus* (lateral view); 5a. *Turbo brunneus* (apertural view); 6. *Lunella cinerea* (lateral view); 6a. *Lunella cinerea* (apertural view); 7. *Turbo* sp. (lateral view); 7a. *Turbo* sp. (apertural view); 8. *Turbonilla felicitata* (lateral view); 8a. *Turbonilla felicitata* (apertural view).

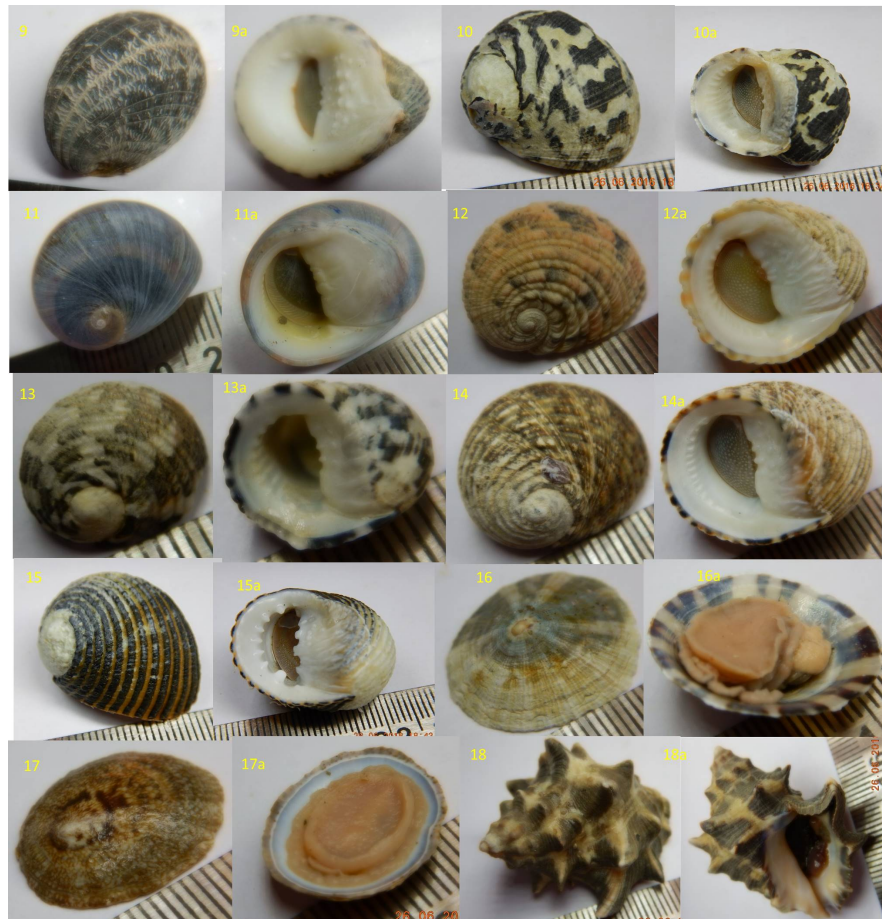


Figure A2. 9. *Nerita albicilla* (lateral view); 9a. *Nerita albicilla* (apertural view); 10. *Nerita oryzae* (lateral view); 10a. *Nerita oryzae* (apertural view); 11. *Nerita polita* (lateral view); 11a. *Nerita polita* (apertural view). 12. *Nerita histrio* (lateral view); 12a. *Nerita histrio* (apertural view); 13. *Nerita chamaeleon* (lateral view); 13a. *Nerita chamaeleon* (apertural view); 14. *Nerita insculpta* (lateral view); 14a. *Nerita insculpta* (apertural view); 15. *Nerita costata* (lateral view); 15a. *Nerita costata* (apertural view); 16. *Cellana radiata* (lateral view); 16a. *Cellana radiata* (apertural view); 17. *Cellana sp.* (lateral view); 17a. *Cellana sp.* (apertural view); 18. *Menathais tuberosa* (lateral view); 18a. *Menathais tuberosa* (apertural view).



Figure A3. 19. *Tylothais virgata* (lateral view); 19a. *Tylothais virgata* (apertural view); 20. *Menathais intermedia* (lateral view); 20a. *Menathais intermedia* (apertural view). 21. *Indothais lacera* (lateral view); 21a. *Indothais lacera* (apertural view); 22. *Tenguella granulata* (lateral view); 22a. *Tenguella granulata* (aperture); 23. *Vokesimurex tryoni* (lateral view); 23a. *Vokesimurex tryoni* (apertural view); 24. *Chicoreus brunneus* (lateral view); 24a. *Chicoreus brunneus* (apertural view); 25. *Murex tribulus* (lateral view); 25a. *Murex tribulus* (apertural view); 26. *Semiricinula konkanensis* (lateral view); 26a. *Semiricinula konkanensis* (apertural view); 27. *Thais* sp. (lateral view); 27a. *Thais* sp. (Apertural view); 28. *Morula nodicostata* (lateral view); 28a. *Morula nodicostata* (apertural view).

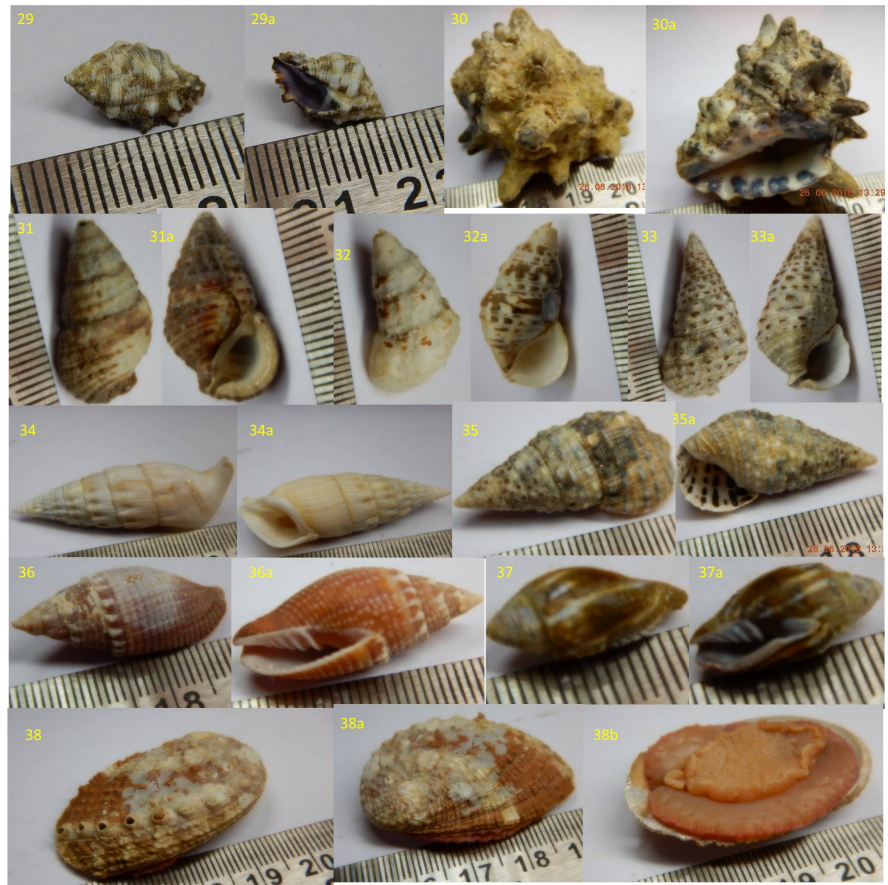


Figure A4. 29. *Morula* sp. (lateral view); 29a. *Morula* sp. (apertural view); 30. *Vasum turbinellus* (lateral view); 30. *Vasum turbinellus* (aperture view); 31. *Clypeomorus bifasciata* (lateral view); 31a. *Clypeomorus bifasciata* (ventral view); 32. *Clypeomorus petrosa* (lateral view); 32a. *Clypeomorus petrosa* (apertural view); 33. *Certhium coralium* (lateral view); 33a. *Certhium coralium* (apertural view); 34. *Rhinochoclis vertagus* (lateral view); 34a. *Rhinochoclis vertagus* (lateral view); 35. *Batillaria multiformis* (lateral view); 35a. *Batillaria multiformis* (apertural view); 36. *Nebularia aurantia* (lateral view); 36a. *Nebularia aurantia* (apertural view); 37. *Strigatella paupercula* (lateral view); 37a. *Strigatella paupercula* (apertural view); 38. *Haliotis planata* (lateral view); 38a. *Haliotis planata* (ventral view); 38b. *Haliotis planata* (apertural view).



Figure A5. 39. *Turritella* sp. (lateral view); 39a. *Turritella* sp. (apertural view); 40. *Nassarius* sp. (lateral view); 40a. *Nassarius* sp. (apertural view); 41. *Nassarius coronatus* (lateral view); 41a. *Nassarius coronatus* (aperture view); 42. *Nassarius olivaceus* (lateral view); 42a. *Nassarius olivaceus* (apertural view); 43. *Nassarius pullus* (lateral view); 43a. *Nassarius pullus* (apertural view); 44. *Nassarius conoidalis* (lateral view); 44a. *Nassarius conoidalis* (apertural view); 45. *Oliva vidua* (lateral view); 45a. *Oliva vidua* (apertural view); 46. *Oliva* sp. (lateral view); 46a. *Oliva* sp (apertural view); 47. *Bufo naria rana* (lateral view); 47a. *Bufo naria rana* (apertural view); 48. *Bufo naria echinata* (lateral view); 48a. *Bufo naria echinata* (apertural view).



Figure A6. 49. *Bursa granularis* (lateral view); 49a. *Bursa granularis* (apertural view); 50. *Gammula vagata* (lateral view); 50a. *Gammula vagata* (apertural view); 51. *Turrilatirus craticulatus* (lateral view); 51a. *Turrilatirus craticulatus* (apertural view); 52. *Latirolagena smaragdulus* (lateral view); 52a. *Latirolagena smaragdulus* (apertural view); 53. *Scutellastra flexuosa* (lateral view); 53a. *Scutellastra flexuosa* (lateral view); 54. *Terebralia paluster* (lateral view); 54a. *Terebralia paluster* (apertural view); 55. *Engina mendicaria* (lateral view); 55a. *Engina mendicaria* view); 57. *Siphonaria* sp1. (lateral view); 57a. *Siphonaria* sp1. (apertural view). 58. *Siphonaria* sp2. (lateral view); 58a. *Siphonaria* sp2. (apertural view); 59. *Canarium labiatum* (lateral view); 59a. *Canarium labiatum* (apertural view); 60. *Gibberulus gibberulus* (lateral view); 60a. *Gibberulus gibberulus* (apertural view).



Figure A7. 61. *Laevistrombus canarium* (lateral view); 61a. *Laevistrombus canarium* (apertural view); 62. *Conus ebraeus* (lateral view); 62a. *Conus ebraeus* (apertural view); 63. *Harpa major* (lateral view); 63a. *Harpa major* (apertural view); 64. *Semicassis bisulcata* (lateral view); 64a. *Semicassis bisulcata* (apertural view); 65. *Polinices mammilla* (lateral view); 65a. *Polinices mammilla* (apertural view); 66. *Tanea lineata* (lateral view); 66a. *Tanea lineata* (apertural view); 67. *Patelloida saccharina* (lateral view); 67a. *Patelloida saccharina* (apertural view); 68. *Onchidium* sp. (lateral view); 68a. *Onchidium* sp. (apertural view).

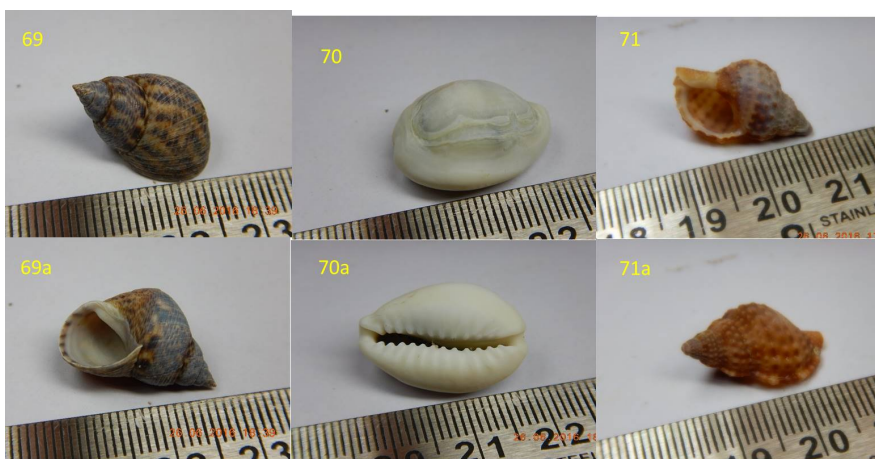


Figure A8. 69. *Littoraria undulata* (lateral view); 69a. *Littoraria undulata* (apertural view); 70. *Monetaria moneta* (lateral view); 70a. *Monetaria moneta* (apertural view); 71. *Gyrineum natator* (lateral view); 71a. *Gyrineum natator* (apertural view).