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INSTRUCTIONS FOR AUTHORS

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Andaman and Nicobar Islands which are situated at Latitude 6°- 14° N and Longitude 92°-94° E, consists of 572 green emerald Islands, Islets and rocks; almost all the Island are oriented in the north south direction like an arc and stretch over a length of about 1912 Km. Most of the Islands have originated due to volcanic eruption in the sea and few of them originated by coral reef formation. All the islands are biological and geological paradise having indigenous biota of flora & fauna and geological wonders which are yet to be unearthed. To conduct research in these small and fragile islands, we have a number of scientific organizations who are doing focused research in different areas. However, there is no platform for them to present their research works which have local importance. Andaman Science Association (ASA) was established in 1984 at CARI, Port Blair with an objective to promote research and development in the unique Islands agro-ecosystem. ASA is an unique body that provides platforms for those associated with the management of tropical and islands agriculture, horticulture, fisheries, animal science, oceanographic and marine biological study, disaster management, issues related to science and technology, environment and forest etc. ASA intermittently organizes National and International seminars, conferences, knowledge sharing meets etc.

- S. Dam Roy
President

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Climate of Andaman and Nicobar Islands: Long-term pattern analysis

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Abstract

In recent decades climate change and variability have become major concern for humankind because certain human activities have been identified as significant causes of recent climate change. The present study highlights the changes in rainfall pattern and temperature over these islands from the historical and observational data. Changes in rainy days, post and pre monsoon rainfall are prominently noticed in recent times. Increase in heavy to very heavy rainfall categories (6.5 to 8.8%) was observed as compared to the climatic normal (6.5%). The challenges posed by climate change will have greater impact on Andaman and Nicobar islands by way of erratic rainfall, persistent droughts and high temperature which results in severe water crisis particularly moisture deficit during summer months. This calls for cautious but adaptation centric approach in weather and natural resource management of our Islands. Therefore, agriculture should move towards more water efficient and climate resilient crops.

Keywords: *rainfall, frequency distribution, temperature, long-term average, weather, Bay Island*

Introduction

Since the beginning of the 20th century there have been notable changes in surface temperature, rainfall, evaporation and extreme events as a result of human activities. In this context, climate change has been receiving more attention of scientists, policy makers and common men with different perceptions. The term climate change means "any significant change in the statistical distribution of weather patterns over periods ranging from decades to millions of years". It may be a change in average weather conditions or the distribution of events around that average. Climate change may be limited to a specific region or may occur across the whole Earth. If the weather parameters show year-to-year variations or cyclic trend, it is known as climate variability (IPCC, 2001). The reality of climate change is evident and the likely effects are broadly predicted, although still uncertain with regard to the nature, rate and extent to which such changes will occur. The impact is dominantly felt on agricultural production which will have significant effects on small holder farmers in many parts of the tropics and subtropics, and the resulting reduced food security potentially will increase the risk of hunger and under nutrition (HLPE, 2012).

Globally, there are many studies related to precipitation trend and pattern. Analyses of global precipitation pattern show variations and some notable trends in recent decades. Few studies have shown a rising trend in precipitation over the middle and high latitudes of northern hemisphere. There are also many studies related to precipitation trend and pattern over India (Guhathakurta and Rajeevan 2006; Rajeevan et al., 2008). But, there are only few studies related to rainfall pattern and its variability over Andaman and Nicobar Islands. In addition, the understanding of weather variations and impact of global changes on these islands are very essential due to its geography, unique biodiversity and coexistence of mainstream population with tribals. In view of this, an attempt has been made to study the changes and variations in climatic parameters at various time intervals and its possible impact on the island ecosystem.

Materials and Methods

Assessment of climatic parameters requires reliable data recorded over long period of time. In the present study climatic data pertaining to different stations across the Island were collected from India Meteorological Department, Andaman and Nicobar Administration and Central Island Agricultural Research Institute. The data was verified for consistency and continuity before creating climatic data base. From this data base the changes and trend in annual and seasonal rainfall and rainy days were extracted. Probability analysis was carried out by using RAINSIM to estimate the length of dry spell using historical climatic data pertaining to these Islands. Remote sensing data (IRS P6) was used to derive the land use / land cover of these islands which are verified by field survey and in house information available with Central Island Agricultural Research Institute. A rainy day over a station is considered when it reported more than 2.5 mm rainfall in a day. Sea surface temperature (SST) maps from the NASA JPL–PODAAC site available in HDF format were read using the software binary codes provided with the data and converted to tiff image format. Further processing was done using ERDAS–IMAGINE and ARC–GIS software for display and analysis of the maps. .

Agro-climate of Andaman and Nicobar Islands

The Andaman and Nicobar group of Islands lie in the Bay of Bengal (6-14^0 N lat; 92-94^0 E long) 1200 km east of mainland India. The climate of Andaman and Nicobar Island is typified by tropical conditions with little difference between mean summer and mean winter temperatures. The annual rainfall varies from 2900 to 3100 mm representing perhumid climate. As these islands are situated close to the equator intensive solar radiation is received resulting in high evaporation especially during dry months which far exceeds the rainfall resulting in water deficit condition. The rainfall covers the potential evapotranspiration demands, except for seasonal water deficit of 300-400 mm during the post-monsoon period (January to April). The average relative humidity varies from 68 to 86% and the maximum and minimum temperature is 32°C and 22°C, respectively. The length of growing period is more than 210 days which is long enough to support double cropping and plantation crops grown in the area. The area experiences **Udic** soil moisture and **Isohyperthermic** soil temperature regime. As these islands are topographically undulating, characterized by hills and narrow longitudinal valley there is limited scope for surface water storage.

Results and Discussion

The long-term trend

The long term trend in climatic parameters indicated that these Islands experience hot and humid tropical climate with least variation in maximum and minimum temperatures in major part of the year (Fig. 1). The mean relative humidity in these Islands is 79%, the mean maximum temperature is 30.2° C, and mean minimum temperature is 23.0° C. On an average there has been no significant change in the long-term temperature pattern.

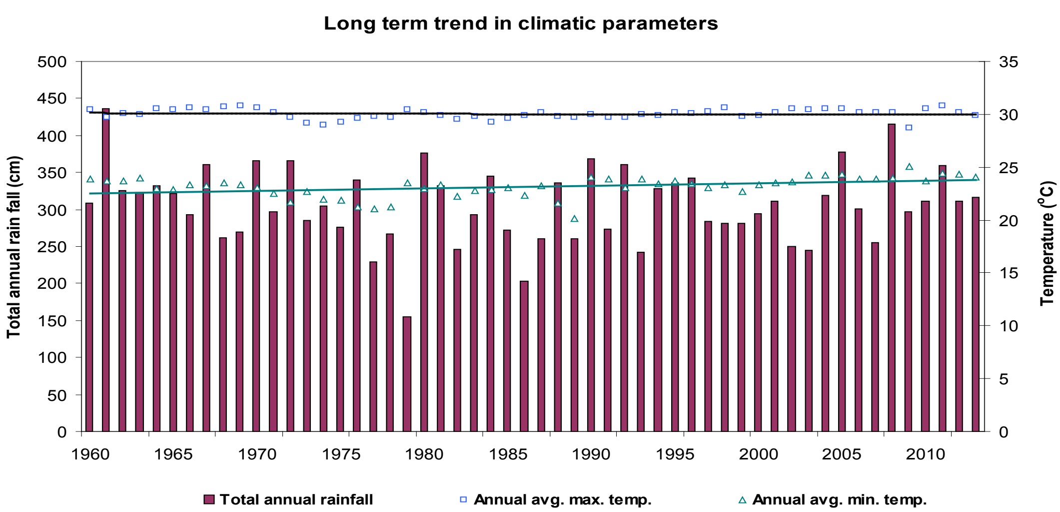


Fig. 1 Long-term trend in climatic parameters over Andaman and Nicobar Islands

These Islands receive annual average rainfall of about 3100 mm with the highest rainfall experienced in 1961 (4362 mm) and the lowest in 1979 (1550 mm). Among the two Island groups, Andaman receives more annual rainfall than Nicobar Islands though it is located in the equatorial belt. About 95 percent of annual rainfall is received during May-December but a deficit of about 610 mm is experienced during January-April when number of rainy days in each month hardly exceeds three. The annual rainfall over Port Blair is the highest (3100 mm) whereas Nancowry receives the lowest annual rainfall (2480 mm).

In season wise distribution, average rainfall is maximum in monsoon and minimum in winter (Fig. 2). On an average this Islands has 136 days of rainy days. The average monsoon seasonal rainfall over Andaman Islands is 173 cm with 73 rainy days, whereas it is 113 cm with 56 rainy days over Nicobar Islands. In contrast during winter season, the average total rainfall over Andaman Islands is only 6 cm with 3 rainy days but it is higher at 17 cm with 9 rainy days over Nicobar Islands.

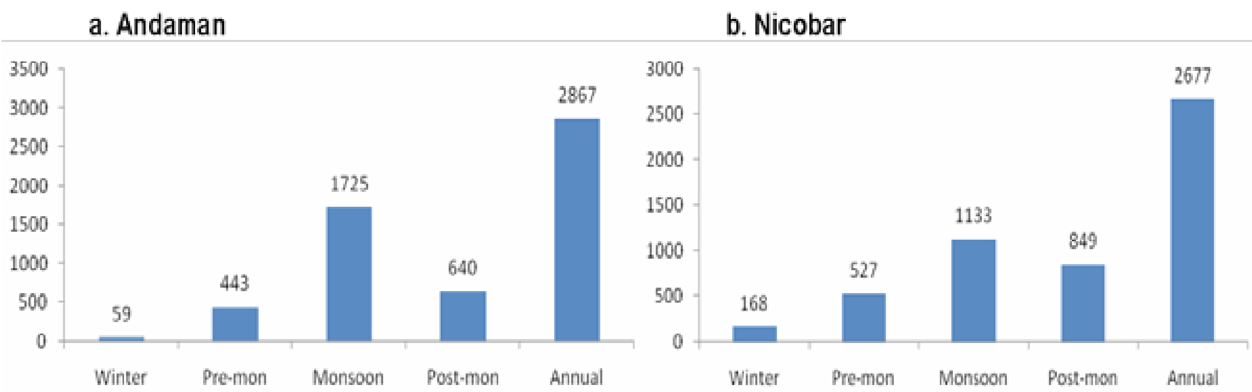


Fig. 2 Annual and seasonal rainfall (mm) in Andaman and Nicobar Islands

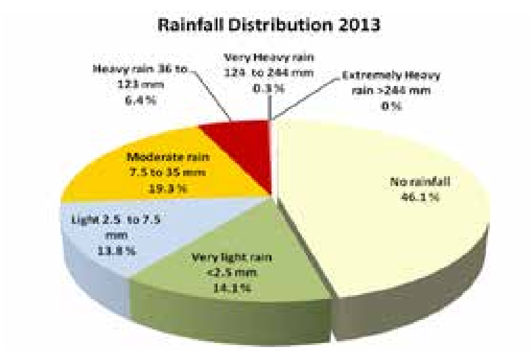
Another important aspect of island rainfall pattern is weekly performance. Historical weekly rainfall for Port Blair was analyzed using RAINSIM software and the weekly probable rainfall was estimated. The results indicated that at normal probability distribution function fitted at 1% level of significance for all except for 24, 36 and 45 standard meteorological weeks. In Andaman and Nicobar Island atleast 60% of the normal rainfall is received with maximum probability however the probability of getting 80% of normal rainfall is between 60-80% chances. Most important feature of the analysis was that the probability of getting rainfall decreases in post monsoon period during which the Island faces moisture stress condition. Though the average rainfall and rainy days are low during dry period, some amount of rainfall is received atleast in 1-2 rainy days. This is very vital for the entire vegetation in Andaman and Nicobar Islands and also provides scope for rainwater harvesting in summer months. Therefore, creation of water harvesting and storage structures for providing supplemental irrigation to crops is very essential for successful agriculture.

Changes in climatic parameters

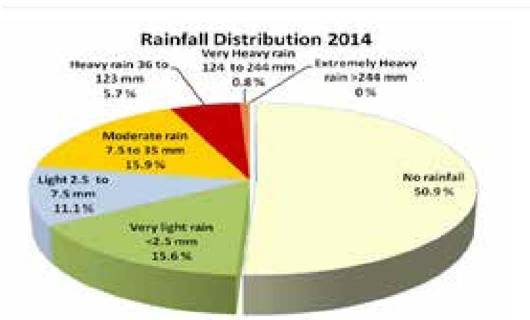
The climate regimes of small islands located in the Indian Ocean are predominantly influenced by the Asian monsoon; the seasonal alternation of atmospheric flow patterns which results in two distinct climatic regimes: the south-west or summer monsoon and the north-east or winter monsoon, with a clear association with ENSO events (Mimura et al., 2007). In response to the global level changes, in recent years, the rainfall pattern and its frequencies of Andaman and Nicobar islands have shown trend which are deviation from the climatic normal. Most of these changes were observed in its seasonal distribution pattern rather than annual mean values which results in extreme events perhaps with large uncertainty.

Analysis of rainfall frequencies of Andaman and Nicobar islands (2013-16) indicated increase in heavy to very heavy rainfall categories which ranged from 6.5 to 8.8% as compared to the climatic normal (6.5%). On the other hand the percentage of total rainless days and total rainfall remains more or less unchanged (Fig. 3). This means that the total number of rainy days remains same but the category of rainfall event has changed. Yet this doesn't explicitly indicate anything on the occurrence of drought or moisture stress whereas flooding is experienced in different months due to increase in heavy rainfall events. The recent experiences of flooding from 2013 to 2016 showed that heavy rainfall is not the phenomena of monsoon season, it also happened even during the post monsoon and premonsoon season as well. Thus the analysis suggested that uncertainty associated with flooding has come down. In other words the predictability of flooding due to heavy rainfall has increased. The major rainfall frequency category is light to moderate rainfall which is the characteristic feature of island climate.

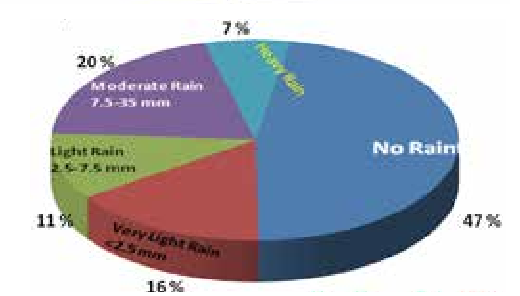
2013



2014



2015



2016

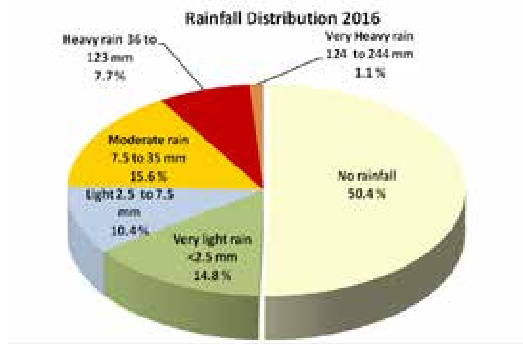


Fig. 3. Frequency distribution of rainfall during 2013-16

Monsoon performance

The performance of monsoon is vital for agricultural growth and food security of our country. Of late, it started reflecting on our overall economy as well. In Andaman and Nicobar Islands the performance of rainfall during monsoon and summer season is equally important, as the entire island is rainfed. The islands receive rainfall from both southwest and northeast monsoon. Since the islands are mostly discrete and the topography, types of vegetation, forestry as also the geographical localizations are varied the rainfall distribution is highly varied and anomalous. These can be quite evident from the rainfall record of the islands. The long period average (LPA) of the annual rainfall of the islands for the period 1949-2005 is 3070 mm which is received in 143 rainy days (Fig. 4). The South-West monsoon (June - September) accounted for 60.8 % of total annual rainfall followed by 22% in North-East monsoon period (October-December). Only 4.8% of the total rainfall is received during summer (January- April) and the rest 12.3% is received during post monsoon season (May). Out of twelve months in a year these islands experience wet condition for 8 months and the remaining 4 month dry condition. During the active monsoon periods, occasionally, a few low-pressure waves originating in the ITCZ move westwards across the southern peninsula without touching Andaman Sea or Western Bay of Bengal. When this happens there is a sudden decrease of rainfall over this island along with intensive solar radiation which favours high evapotranspiration. This creates a break in monsoon consequently stress in the plant system particularly kharif rice due to high evapotranspiration and soil moisture deficit.

During 2016 the Islands received a total annual rainfall of 3542.8 mm which was 97% of the total annual rainfall while only 3% of total rainfall was received during summer season. As compared to 2015 performance it was 14% excess rainfall. While the average of 2011-15 showed that 88% of total annual rainfall was received in monsoon season while 12% was received during summer season. As it is not the cyclic events, therefore, in a decadal scale, this indicated the deviation of monsoon pattern rather than trend. However, the data suggested that the extreme events in the island have increased during this period.

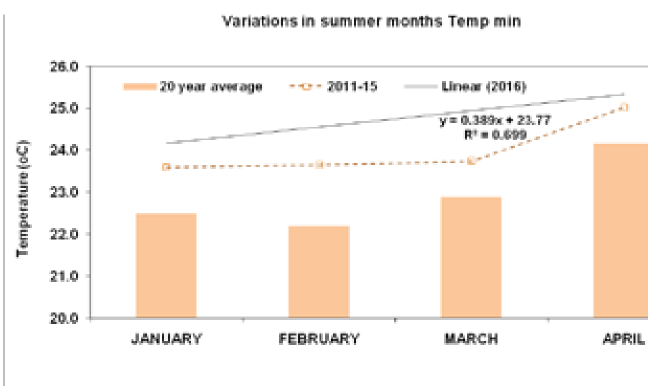


Fig. 4. Variation in monthly rainfall during the monsoon period

The data presented above supports the view that the southwest monsoon is well marked over these islands but the activity of the southwest monsoon is not uniform in time and space during the whole season.

4.3 Temperature pattern

Maximum temperature

The tropical island of Andaman and Nicobar experience hot and humid climate which is strongly influenced by the conditions of the surrounding sea. Further, the sea surface temperature also influences the coastal temperature besides direct effect on the coral reef and the reef biodiversity. Normally summer months maximum temperature ranges fro 28 to 32 °C and beginning from January it starts increasing. It moves up and down around the normal mean but with in -1 °C to +1 °C. However, in recent times the maximum temperature is always above the normal temperature by more than 1 °C. This is in conformity to the IPCC projection of general warming trend in surface air temperature in all small-island regions and seasons (Lal et al., 2002). During January to April, 2011 to 2015 the maximum air temperature was higher compared to the average maximum temperature. Similar trend was observed for 2016 as well. For January and February it was above normal (+2 °C) and during March-April it was appreciably above normal (+3.5 °C). Continuing with the new trend in January 2016 it was markedly above normal (+6.4 °C) temperature. This may be linked with the global warming phenomena or long term cyclical changes. But the aberration has profound effect on the island agriculture and water resources.

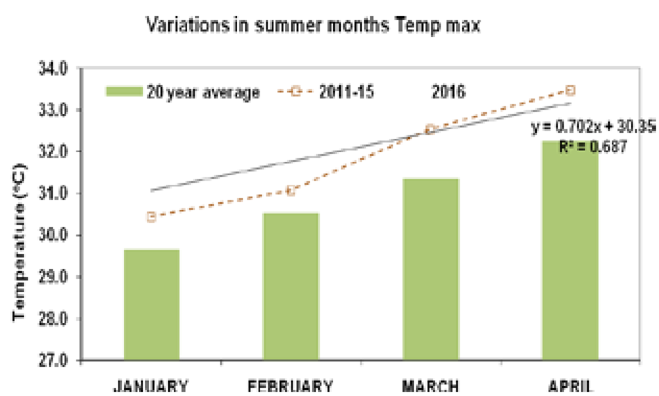


Fig. 9. Variation in summer months maximum temperature

Minimum temperature

The increase in minimum air temperature is very important aspect of global climate change than the maximum temperature. This affects several life processes besides adaptation and survival of plants and animals. The analysis of minimum temperature from 2011 to 2015 showed that during January - February, the increase was markedly above normal while during March - April it was appreciably above normal. In 2016 rapid increase in minimum temperature was observed and it touched severe heat wave condition.

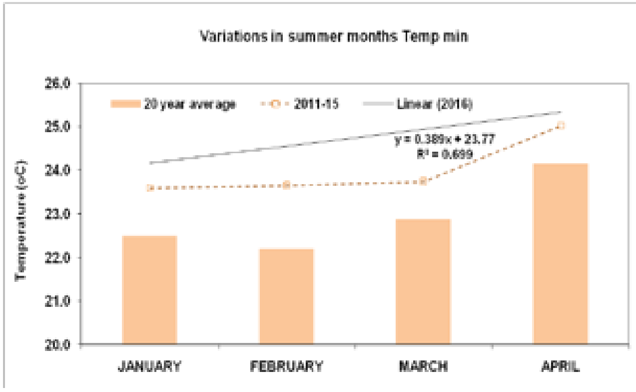


Fig. 10. Variation in summer months minimum temperature

The analysis showed that the percentage of days having very warm maximum or minimum temperatures has increased considerably since the 2011 while the percentage of days with cold temperatures has decreased when compared to the long-term average. In this context it is worth mentioning the projected increase in surface air temperature for all regions of the small islands for the three 30-year periods (2010 to 2039, 2040 to 2069 and 2070 to 2099) relative to the baseline period 1961 to 1990 using coupled atmosphere ocean general circulation models (Ruosteenoja et al., 2003).

Impact on agriculture

Although the interactions of global climate change and crop nutrition are not well understood, it is probable that the net effects of these changes will be negative for agricultural production. This is more pertinent to the island ecosystem of Andaman and Nicobar which is vulnerable to climate change events. Agricultural productivity is sensitive to two broad classes of climate induced effects, one is the direct effects due to changes in temperature, precipitation and carbon dioxide concentrations and the other is the indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases (Mendelsohn, 2014). Drought induced by higher temperatures and altered rainfall distribution would reduce nutrient acquisition, biological nitrogen fixation, and may disrupt nutrient cycling. This may render agriculture unproductive or results in crop failure particularly during post monsoon seasons. On the other hand, more intense precipitation events during monsoon season would reduce crop nutrition by causing short-term root hypoxia, and in the long term by accelerating soil erosion. Increased temperature will reduce soil fertility by increasing soil organic matter decomposition, and may have profound effects on crop nutrition by altering plant phenology (St.Clair and Lynch, 2010). The main effect of climate change on agriculture are, productivity including livestock, in terms of quality and quantity, changes in water use and agricultural inputs, and environmental effects. In general, the negative impacts of climate change on agriculture will far exceed beneficial effects, which would intensify food insecurity.

Adaptation to changes

Averting the challenge posed by changing weather pattern requires that farmers adapt by making changes in farming and land management decisions that reduce the negative consequences associated with changing climate (Jarvis et al., 2011). The adaptation options may include increasing the resilience of existing farming systems, diversification and risk management (Thornton and Herrero 2014). *In situ* water harvesting technologies would help to address the water shortage issue due to changes in rainfall pattern and cope with the El Nino effect. From the viewpoint of immediate adaptation to dry conditions all possible methods have to be used to harvest and store the rainwater as and when it occurs. It can be accomplished by (a) Lined tank for hill top (b) rooftop rainwater harvesting (c) Broad bed furrow system for lowlying areas (d) Check dam for mid hill areas and (b) Ring well downstream of check dam (Velmurugan et al., 2011). The seepage loss from earthen tank is quite high in the hilly areas due to coarse soil texture and porous coral base at lower stratum. Lining of ponds with silpaulin followed by covering with tiles is suitable. In Nicobar group of Islands during dry season water is scare and ground water become saline as a consequence rainwater harvesting is very essential. On an average the roof area of a group house (tuhet) is 300 m^2 and the rainwater falling on the roof is 9,00,000 liters. If we assume 70% collection efficiency then 6,30,000 liters of rainwater is available for collection. This can be effectively used to provide irrigation to crops grown in the homestead garden during dry season and as drinking water for livestock.

Conclusions

The challenges posed by climate change will have greater impact on these islands by way of erratic rainfall, persistent droughts, and high temperature besides changing policy environment within which they operate. This calls for cautious but adaptation centric approach in weather and natural resource management of our Islands. Therefore, agriculture should move towards more water efficient and climate resilient crops. Enhanced efforts are essential for localized harvest and storage of rainwater, recharge of ground water resources in addition to its efficient use for profitable farming system to gear up ourselves for any climate change effects in the future.

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Seaweed resources of South Andaman and their Bioprospecting Potential

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Abstract

Seaweeds are one of the most important components from the marine environment. Their contribution towards ecology and economy is endless. As a result seaweed research is gaining significant attention with a view to augment several growing demands for energy, food, material and medicine in recent years. It is thus paramount to assess the availability of these green resources from the sea around us. In this pretext, an attempt was thus made to assess the seaweed availability along the coast of South Andaman, A & N Islands. The detailed survey of the study area along the south Andaman coast showed the availability of 88 seaweed species comprising 31 from Chlorophyta; 25 from Phaeophyta and 32 from Rhodophyta. All these available species found during the study period were tabulated and a check list was made. From the Andaman Sea prospective, commercial use of all the species are yet to be explored. But some of the species already in commercial use globally were recorded from the south Andaman coast. These include ten *Sargassum* sp.; three *Turbinaria sp.;* five *Caulerpa* sp.; three *Ulva* sp.; seven *Gracilaria* sp.; *Gelidiella acerosa* and *Acanthophora spicifera*. It can be concluded that bioprospecting of seaweed bioresources from the Andaman Sea has high potential and can be sustainably utilised towards food, fodder, organic manure, biofuel, biopolymer, biomedical purposes.

Keywords: *Sea Weed, diversity South Andaman, Checklist, Bioprospecting,*

Introduction

Seaweeds are taxonomically diverse group of marine plants with potential for bioprospecting since time immemorial. Traditionally they are classified as Chlorophyta (green), Phaeophyta (brown) and Rhodophyta (red) based on their pigment constituent pattern and each phylum is represented by extraordinarily diverse group of species. These diverse seaweed resources are being utilised for several purposes globally. Even a good number of seaweeds are projected as a promising future food source and have several other important applications for the human being, including a source of food supplements, feed and fodder, industrial chemicals, organic fertilizers, medicines and as a potential candidate for biofuel production.

The vast Indian coastline of about 7,500 km support very rich seaweed diversity with the presence of about 1,153 species with significant economic importance recorded in Indian waters (Rao and Mantri, 2006). The seaweeds from the Andaman Sea has high species diversity and several works have been carried out on their distribution pattern. Studies by Gopinathan and Panigrahy (1978) reported 55 species of seaweeds from North and South Andaman in which 29 species were from South Andaman. Following Jagtap (1992) reported 66 species from Nicobar group of Islands. Palanisamy (2012) reported that 77 species from South Andaman but mentioned about the availability of 206 species in Andaman and Nicobar Islands, while the estimated number remains above 300 species as reported by the author. On the other hand, some more studies also have been carried out, which gives varying numbers of species distribution such as 27 seaweeds (genus level) from South and Little Andaman (Mohanraju and Tanushree, 2012); 72 species from North and South Andaman Island (Karthick et al., 2013a); 52 species from little Andaman (Karthick et al., 2013b), 7 species of genus *Caulerpa* at Wandoor, South Andaman (Karthik et al., 2013c) and studies by Anuraj et al. (2016) reported 23 species (genus level) from South Andaman.

However, there are several common species among all these reports. But all these studies extending from the year 1978 to 2016 gave a glimpse of varying number of species diversity and are suggestive of the fact that there is a gap in the studies pertaining to the sea weed diversity in the Andaman Sea. The coast of South Andaman has better accessibility and exposed to more anthropogenic activities. It is thus paramount to have a systematic study and assess species diversity in South Andaman with a view to make a checklist of the species for probable bioprospecting in future. In this pretext, attempt was made in enlisting the species available along South Andaman coast covering all seasons of the year in order to prepare a baseline database of seaweeds with their pictorial representation.

Material and Methods

Study Area

The present study was carried out during December 2016 - December 2017 by covering seven sampling stations along the coast of South Andaman (Table – 1).

Table – 1. Location of Sampling Stations along the Coast of South Andaman

S. No.	Sampling Station	Geographic position
1.	Chatham (Sea Shore)	Lat. 11˚68.0735 N; Long. 92˚72.9713 E
2.	Marina Park (Sisostris Bay)	Lat. 11˚66.927 N; Long. 92˚74.9347 E
3.	Carbyns cove (Opp. Hornbill Nest resort)	Lat. 11˚64.7677 N; Long. 92˚75.5828 E
4.	Brookshabad (Quarry)	Lat. 11˚62.785 N; Long. 92˚75.2263 E
5.	Kodiyaghat	Lat. 11˚52.8367 N; Long. 92˚72.3485 E
6.	Chidiyatapu	Lat. 11˚50.1607 N; Long. 92˚70.142 E
7.	Wandoor	Lat. 11˚59.1343 N; Long. 92˚61.2007 E

Seaweed Collection and Identification

The seaweeds were collected from the intertidal region through hand picking along with seawater and collected in a sterile air tight bag. Then the samples were washed properly in running tap water to remove all the epiphytes and sand or debris particles. The cleaned seaweeds were identified for their morphological characters with keys proposed by different authors (Kaliaperumal et al., 1995; Maneveldt et al., 2008; Dhargalkar and Devanand, 2004; Tsiamis et al., 2014; Rath and Adhikary, 2006; Margaret and Charles, 2009; Mary et al., 2012; Baldock, 2104) and also online seaweed database (www.portaltodicovery.og/aday; www.world register of marine species; Macroalgal Herbarium Portal; MACOI - Portuguese Seaweeds Website.htm; www.algaebase.org). The identified specimens were noted and photographed for further studies.

Results and Discussion

Andaman Sea has a unique marine habitat with heterogeneity associated with high degree of biodiversity. As suggested by Satheesh and Wesley (2012), the richness of seaweed resources is due to the intertidal rocky reefs and this is in agreement with the present study, where excellent growth of seaweeds was recorded from intertidal rocky reefs along all sampling stations of the South Andaman coast. During the present study, out of the 88 species studied, 16 reported species of Gopinathan and Panigrahy (1978), 37 reported species of Palanisamy (2012), 40 reported species of Karthick et al. (2013a) and 4 reported species of (Karthick et al., 2013c) were common.

It was observed that the representation of seaweeds was dominated mainly by Rhodophytes with 32 species

(36%), followed by Chlorophytes with 31 species (35%) and Phaeophytes with 25 species (29%) of the total recorded species (Fig. 1) along the South Andaman coast during the study period.

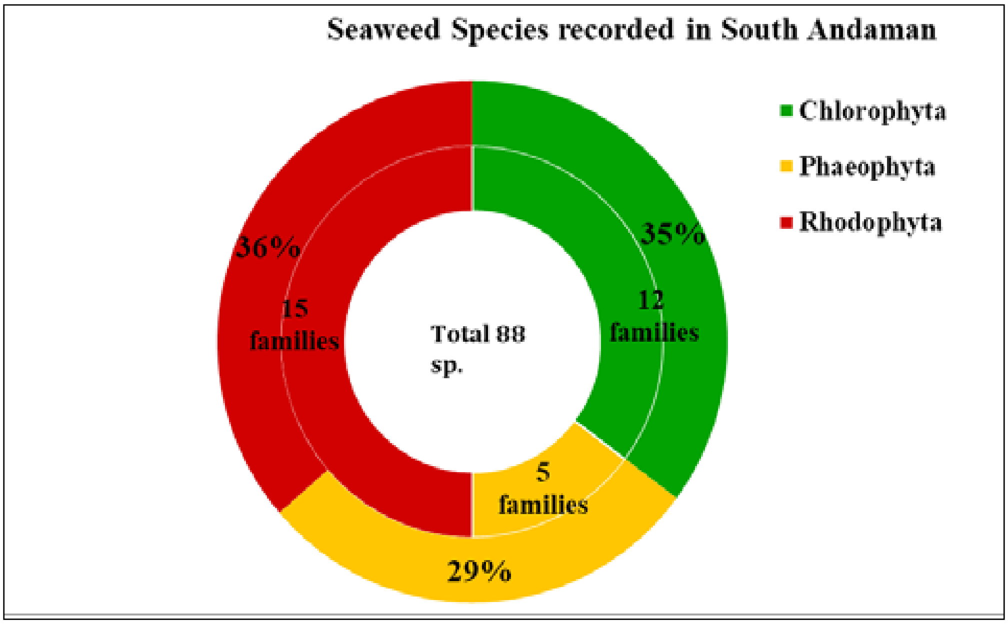

Fig. 1. Total percentage of seaweed species recorded in sampling stations

The 31 species from Chlorophyta (Table – 2) were distributed under 12 families Caulerpaceae, Codiaceae, Halimedaceae, Derbesiaceae, Siphonocladaceae, Boodleaceae, Cladophoraceae, Valoniaceae, Dasycladaceae, Polyphysaceae, Ulvaceae and Ulotrichaceae. The family Caulerpaceae represents total five species *Caulerpa racemosa* (Forsskal) C. Agardh; *Caulerpa serrulata* (Forsskal) C. Agardh; *Caulerpa sertulariodes* (S.G. Gmelin) M. Howe; *Caulerpa taxifolia* (Vahl) C. Agardh and *Caulerpa verticillata* J. Agardh. The Codiaceae family include two species *Codium tomentosum* Stackhouse and *Codium edule* P.C. Silva. The Halimedaceae family include six species *Halimeda opuntia* (Linnaeus) J.V. Lamouroux; *Halimeda tuna* (J. Ellis & Solander) J.V. Lamouroux; *Halimeda macroloba* Decaisne; *Halimeda discoidea* Decaisne; *Halimeda gracilis* Harvey ex J. Agardh and *Halimeda incrassata* (J. Ellis) J.V. Lamouroux. Derbesiaceae family represents only one species *Derbesia marina* (Lyngbye) Solier. Siphonocladaceae family represents three species *Dictyosphaeria versluysii* Weber Bosse; *Dictyosphaeria cavernosa* (Forsskal) Borgesen and *Boergesenia forbesii* (Harvey) Feldmann. Boodleaceae family represents one species *Boodlea composita* (Harvey) F. Brand. Cladophoraceae family represents four species *Chaetomorpha linum* (O.F.Muller) Kutzing; *Cladophora laetevirens* (Dillwyn) Kutzing; *Cladophora columbiana* Collins and *Cladophora sericea* (Hudson) Kutzing. Valoniaceae family represents one species *Valonia utricularis* (Roth) C. Agardh. Dasycladaceae family represents one species *Neomeris annulata* Dickie. Polyphysaceae family represents two species; *Acetabularia acetabulum* (Linnaeus) P.C. Silva and *Acetabularia ceranulata* J.V. Lamouroux. Ulvaceae family was represented by four species; *Ulva reticulata* Forsskal, *Ulva fasciata* Delile, *Ulva lactuca* Linnaeus and *Enteromorpha intestinalis* (Linnaeus) Nees and the Ulotrichaceae family consist of one species *Acrosiphonia arcta* (Dillwyn) Gain.

Table – 2. Seaweed under Chlorophyta along the coast of South Andaman

S.No	Seaweed species	CH	MP	CC	BRB	KG	CHT	WAN
Chlorophytes								
1.	*Caulerpa racemosa* (Forsskal) C. Agardh	+	+	+	+	+	+	+
2.	*Caulerpa serrulata* (Forsskal) C. Agardh	-	+	-	+	-	-	-
3.	*Caulerpa sertulariodes* (S.G.Gmelin) M.Howe	-	+	+	+	-	-	-
4.	*Caulerpa taxifolia* (Vahl) C. Agardh	-	+	+	+	-	-	-
5.	*Caulerpa verticillata* J. Agardh	+	+	+	+	+	+	-
6.	*Codium tomentosum* Stackhouse	+	+	+	+	+	+	+
7.	*Codium edule* P.C.Silva	+	+	+	+	+	+	+
8.	*Halimeda opuntia* (Linnaeus) J.V.Lamouroux	+	+	+	+	+	+	+
9.	*Halimeda tuna* (J.Ellis & Solander) J.V.Lamouroux	-	-	-	-	+	+	+
10.	*Halimeda macroloba* Decaisne	-	-	-	-	+	+	+
11.	*Halimeda discoidea* Decaisne	+	-	-	-	+	+	+
12.	*Halimeda gracilis* Harvey ex J.Agardh	-	-	-	-	+	+	+
13.	*Halimeda incrassata* (J.Ellis) J.V.Lamouroux	+	+	+	+	+	+	+
14.	*Derbesia marina* (Lyngbye) Solier	-	-	+	-	-	-	-
15.	*Dictyosphaeria versluysii* Weber Bosse	+	+	+	+	+	+	+
16.	*Dictyosphaeria cavernosa* (Forsskal) Borgesen	-	-	-	-	+	+	
17.	*Boergesenia forbesii* (Harvey) Feldmann	-	-	-	-	-	-	-
18.	*Boodlea composita* (Harvey) F.Brand	+	-	-	-	-	-	+
19.	*Chaetomorpha linum* (O.F.Muller) Kutzing	-	-	+				
20.	*Cladophora laetevirens* (Dillwyn) Kutzing	+	-	-	-	-	-	-
21.	*Cladophora columbiana* Collins	+	-	-	-	-	-	+
22.	*Cladophora sericea* (Hudson) Kutzing	-	+	+	+	+	+	-
23.	*Valonia utricularis* (Roth) C. Agardh	-	-	-	-	+	+	-
24.	*Neomeris annulata* Dickie	-	-	-	+	+	+	+
25.	*Acetabularia acetabulum* (Linnaeus) P.C.Silva	+	+	+	+	+	+	+

26.	*Acetabularia ceranulata* J.V.Lamouroux	+	+	-	-	-	-	-
27.	*Ulva reticulata* Forsskal	+	+	-	+	-	-	-
28.	*Ulva fasciata* Delile	+	+	-	+	-	-	-
29.	*Ulva lactuca* Linnaeus	+	+	-	+	-	-	-
30.	*Enteromorpha intestinalis* (Linnaeus) Nees	-	-	-	+	-	-	-
31.	*Acrosiphonia arcta* ((Dillwyn) Gain	-	-	+	+	+	+	

NB:CH- Chatam; MP- Marina Park; CC- Carbyns cove; BRB- Brookshabad; KG- Kodiyaghat; CHT- Chidiyatapu; WAN-Wandoor

Similarly, 25 species from Phaeophyta (Table – 3) were represented under five families Dictyotaceae, Sargassaceae, Scytosiphonaceae, Cladostephaceae and Ralfsiaceae. The Dictyotaceae family represents eight species *Padina tetrastromatica* Hauck; *Padina gymnospora* (Kutzing) Sonder; *Padina japonica* Yamada; *Padina pavonica* (Linnaeus) Thivy; *Dictyota acutiloba* J. Agardh; *Dictyota divaricata* J. V. Lamouroux; *Dictyota sandvicensis* Sonder and *Canistrocarpus cervicornis* (Kutzing) De Paula et De Clerck. The Sargassaceae family represents fourteen species *Sargassum wightii* Greville ex J.Agardh; *Sargassum duplicatum* Bory; *Sargassum myriocystum* J. Agardh; *Sargassum echinocarpum* J. Agardh; *Sargassum muticum* (Yendo) Fensholt; *Sargassum filipendula* C. Agardh; *Sargassum tenerrimum* J. Agardh; *Sargassum crassifolium* J. Agardh; *Sargassum oligocystum* Montagne; *Sargassum swartzii* C. Agardh; *Hormophysa triquetra* (C. Agardh) Kutzing; *Turbinaria ornata* (Turner) J. Agardh; *Turbinaria conoides* (J. Agardh) Kutzing and *Turbinaria decurrens* Bory. The family Scytosiphonaceae represented one species *Hydroclathrus clathratus* (C. Agardh) M. Howe. The Cladostephaceae family represents one species *Cladostephus spongiosum* (Hudson) C. Agardh and also the family Ralfsiaceae represented one species *Analipus japonicas* (Harvey) M. J. Wynne.

Table – 3. Seaweed species under Phaeophyta along the coast of South Andaman

S.No.	Seaweed species	CH	MP	CC	BRB	KG	CHT	WAN
Phaeophytes								
1.	*Padina tetrastromatica* Hauck	+	+	+	+	+	+	+
2.	*Padina gymnospora* (Kutzing) Sonder	+	+	+	+	+	+	+
3.	*Padina japonica* Yamada	-	+	+	+	-	-	-
4.	*Padina pavonica* (Linnaeus) Thivy	+	+	+	+	+	+	+
5.	*Dictyota acutiloba* J. Agardh	-	-	-	+	-	-	+
6.	*Dictyota divaricata* J. V. Lamouroux	-	-	-	-	-	-	+
7.	*Dictyota sandvicensis* Sonder	-	-	-	+	-	-	-
8.	*Canistrocarpus cervicornis* (Kutzing) De Paula et De Clerck	+	-	-	+	-	-	-
9.	*Sargassum wightii* Greville ex J. Agardh	+	+	+	+	-	+	+
10.	*Sargassum duplicatum* Bory	-	-	-	-	-	-	+
11.	*Sargassum myriocystum* J. Agardh	-	-	-	+	-	-	-
12.	*Sargassum echinocarpum* J. Agardh	-	-	-	-	-	-	+
13.	*Sargassum muticum* (Yendo) Fensholt	-	-	-	+	-	-	-
14.	*Sargassum filipendula* C. Agardh	+	+	+	+	-	-	+

15.	*Sargassum tenerrimum* J. Agardh	-	-	-	-	-	-	+
16.	*Sargassum crassifolium* J. Agardh	+	+	+	+	-	-	+
17.	*Sargassum oligocystum* Montagne	+	+	+	+	-	-	+
18.	*Sargassum swartzii* C. Agardh	+	+	+	+	-	-	+
19.	*Hormophysa triquetra* (C.Agardh) Kutzing	-	-	-	-	-	-	+
20.	*Turbinaria ornata* (Turner) J. Agardh	-	-	-	-	-	-	+
21.	*Turbinaria conoides* (J.Agardh) Kutzing	-	-	+	-	-	-	-
22.	*Turbinaria decurrens* Bory	-	-	+	-	-	-	+
23.	*Hydroclathrus clathratus* (C.Agardh) M. Howe	+	-	-	-	-	-	+
24.	*Cladostephus spongiosum* (Hudson) C. Agardh	+	-	-	-	-	-	-
25.	*Analipus japonicas* (Harvey) M. J. Wynne	+	-	-	+	+	-	-

NB:CH- Chatam; MP- Marina Park; CC- Carbyns cove; BRB- Brookshabad; KG- Kodiyaghat; CHT- Chidiyatapu; WAN-Wandoor

The Phylum Rhodophyta was represented by 32 species (Table – 4) belonging to fifteen families Rhizophyllidaceae, Endocladiaceae, Gracilariaceae, Rhodomelaceae, Delesseriaceae, Spyridiaceae, Galaxauraceae, Liagoraceae, Scinaiaceae, Halymeniaceae, Corallinaceae, Lithophyllaceae, Gelidiellaceae, Bonnemaisoniaceae and Plocamiaceae. The family Rhizophyllidaceae represents one species *Portieria hornemannii* (Lyngbye) P.C.Silva. Similarly, under the family Endocladiaceae, one species *Endocladia muricata* (Endlicher) J.Agardh was recorded. The family Gracilariaceae represents seven species *Gracilaria pygmaea* Borgesen; *G. tikvahiae* McLachlan; *G. salicornia* (C.Agardh) E.Y.Dawson; *G. crassa* Harvey ex J. Agardh; *G. edulis* (S.G.Gmelin) P. C. Silva; *G. Corticata* Var. *Cylindrica* and *G. coronopifolia* J. Agardh. The family Rhodomelaceae was represented by three species *Acanthophora spicifera* (M. Vahl) Borgesen; *Laurencia majuscule* (Harvey) A. H. S. Lucas and *Laurencia papillosa* (C. Agardh) Greville. Under the family Delesseriaceae one species *Cryptopleura lobulifera* (J. Agardh) Kylin was recorded and also under the Spyridiaceae family, one species *Spyridia filamentosa* (Wulfen) Harvey was recorded. Also, the Galaxauraceae family was represented by four species *Actinotrichia fragilis* (Forsskal) Borgesen; *Galaxaura rugosa* (J. Ellis & Solander) J. V. Lamouroux; *Tricleocarpa cylindrica* (J. Ellis & Solander) Huisman & Borowitzka and *T. fragilis* (Linnaeus) Huisman & R. A. Townsend. The family Liagoraceae was represented by four species *Trichogloea requienii* (Montagne) Kutzing; *Trichogloeopsis pedicellata* (M. Howe) I. A. Abbott & Doty; *Liagora tetrasporifera* Borgesen and *Liagora ceranoides* J. V. Lamouroux. The family Scinaiaceae represented by one species *Scinaia hormoides* Setchell and the family Halymeniaceae also represented two species *Halymenia durvillei* Bory and *H. formosa* Harvey ex Kutzing. Under the Corallinaceae family two species *Hydrolithon gardineri* (Foslie) Verheij and Prudhomme van Reine and *Lithophyllum lichenoides* Philippi were noted and also two species *Amphiroa rigida* J.V. Lamouroux and *A. anceps* (Lamark) Decaisne were recorded under the family Lithophyllaceae. Other families like Gelidiellaceae had one species *Gelidiella acerosa* (Forsskal) Feldmann and Hamel, the family Bonnemaisoniaceae had one species *Asparagopsis taxiformis* (Delile) Trevisan and also the family Plocamiaceae was represented by one species *Plocamium cartilagineum* (Linnaeus) P. S. Dixon.

Table – 4. Seaweed species under Rhodophyta along the coast of South Andaman.

S. No.	Seaweed species	CH	MP	CC	BRB	KG	CHT	WAN
Rhodophytes								
1.	*Portieria homemanni* (Lyngbye) P.C. Silva	-	+	-	+	+	+	-
2.	*Amphiroa anceps* (Lamark) Decaisne	-	+	+	+	-	-	-
3.	*Endocladia muricata* (Endlicher) J. Agardh	+	-	-	-	-	-	-
4.	*Gracilaria pygmaea* Borgesen	-	-	-	-	-	+	-
5.	*Gracilaria tikvahiae* McLachlan	-	-	-	-	-	+	-
6.	*Gracilaria salicornia* (C.Agardh) E. Y. Dawson	+	-	+	+	+	+	-
7.	*Gracilaria crassa* Harvey ex J. Agardh	-	-	-	-	+	-	-
8.	*Gracilaria edulis* (S.G.Gmelin) P. C. Silva	+	+	+	-	+	+	
9.	*Gracilaria corticata* Var. *Cylindrica*	-	-	-	-	+	-	-
10.	*Gracilaria coronopifolia* J. Agardh	+	-	-	+	+	-	-
11.	*Acanthophora spicifera* (M.Vahl) Borgesen	+	+	+	+	+	+	+
12.	*Laurencia majuscule* (Harvey) A. H. S. Lucas	-	+	+	+	-	-	-
13.	*Laurencia papillosa* (C. Agardh) Greville	-	-	-	-	+	+	+
14.	*Cryptopleura lobulifera* (J. Agardh) Kylin	-	-	+	-	-	-	-
15.	*Spyridia filamentosa* (Wulfen) Harvey	+	-	-	-	-	+	-
16.	*Galaxaura rugosa* (J. Ellis & Solander) J. V. Lamouroux	+	-	+	+	+	-	+
17.	*Tricleocarpa cylindrica* (J. Ellis & Solander) Huisman & Borowitzka	+	+	-	+	+	+	+
18.	*Tricleocarpa fragilis* (Linnaeus) Huisman & R. A. Townsend	+	+	+	+	+	+	+
19.	*Trichogloea requienii* (Montagne) Kutzing	-	+	+	+	-	-	-
20.	*Trichogloeopsis pedicellata* (M. Howe) I. A. Abbott & Doty	-	+	+	-	+	-	-
21.	*Liagora tetrasporifera* Borgesen	-	+	-	+	+	-	-
22.	*Liagora ceranoides* J. V. Lamouroux	-	+	+	+	+	-	-
23.	*Scinaia hormoides* Setchell	+	-	-	-	-	-	-

24.	*Halymenia durvillei* Bory	-	+	+	+	-	-	-
25.	*Halymenia formosa* Harvey ex Kutzing	-	-	+	+	-	-	-
26.	*Hydrolithon gardineri* (Foslie) Verheij & Prud'homme van Reine	+	+	+	+	+	+	-
27.	*Lithophyllum lichenoides* Philippi	-	-	+	+	-	-	-
28.	*Amphiroa rigida* J. V. Lamouroux	-	-	+	+	-	-	-
29.	*Gelidiella acerosa* (Forsskal) Feldmann & Hamel	-	+	+	+	+	+	+
30.	*Actinotrichia fragilis* (Forsskal) Borgesen	-	-	+	-	-	-	-
31.	*Asparagopsis taxiformis* (Delile) Trevisan	-	+	-	-	-	-	-
32.	*Plocamium cartilagineum* (Linnaeus) P. S. Dixon	-	+	-	+	+	-	-

NB:CH- Chatam; MP- Marina Park; CC- Carbyns cove; BRB- Brookshabad; KG- Kodiyaghat; CHT- Chidiyatapu; WAN-Wandoor.

The pictorial presentation of all 88 seaweed species representing Chlorophyta, Phaeophyta and Rhodophyta recorded during the study period are depicted in Plate – 1 (A-F). Though commercial importances of all the species are yet to be explored, some of the species are already being utilised globally with high economic value. From the Andaman Sea prospective, these seaweed bioresources also can be sustainably exploited towards food, fodder, organic manure, biofuel, biopolymer and several other applications including extraction of probable bioactive molecules with therapeutic value.

There were several commercially viable species recorded in the present study, which includes 10 species of *Sargassum* i.e. *Sargassum weightii, S. duplicatum, S. myriocystum, S. echinocarpum, S. muticum, S. filipendula, S. tenerrimum, S. crassifolium, S. oligocystum* and *S. swartzii* and three species of *Turbinaria* i.e. *Turbinaria ornata, T. conoides* and *T. decurrens* may be a potential source for the production of alginates from the Andaman Sea. Similarly, the Agar producing species *Gelidiella acerosa* available in the Andaman Sea will also be highly beneficial for commercial utilisation. Simultaneously, some of the edible seaweed species including five species of *Caulerpa* i.e. *Caulerpa racemosa*, *C. serrulata*, *C. sertulariodes*, *C. taxifolia* and *C. verticillate*; three species of *Ulva* i.e. *Ulva reticulata*, *U. fasciata* and *U. lactuca*; seven species of *Gracilaria* i.e. *Gracilaria pygmaea*, *G. tikvahiae*, *G. salicornia*, *G. crassa*, *G. edulis*, *G. corticata, G. coronopifolia* and one species *Acanthophora spicifera* found along the coast of South Andaman can be a potential export oriented seafood product if it is taken up as seaweed culture and processing industry. Apart from this many calcified seaweeds including six species of *Halimeda* i.e. *Halimeda opuntia, Halimeda tuna*, *Halimeda macroloba, Halimeda discoidea, Halimeda gracilis* and *Halimeda incrassate;* two species of *Tricleocarpa i.e., Tricleocarpa fragilis* and *T. cylindrica* recorded from the study area can be used in agricultural practices. Also, the therapeutic application of seaweeds can be a major area of contribution to the health science sector. Some reports from the Andaman Sea suggest that seaweeds also have potential antimicrobial, haemolyitic, antioxidant, antibiofilm, cytotoxic activity (Baskran et al., 2013; Chander et al., 2014; Karthik et al., 2015; Mishra et al., 2016; Deepa et al., 2017; Sivaramakrishnan et al., 2017). One recent study by the authors also suggested that red seaweed, *Tricleocarpa fragilis* from South Andaman possess high concentration of functional constituents (Banu and Mishra 2018a) and its extracts also have antibacterial properties (Banu and Mishra, 2018b).

Plate – 1A. Chlorophytes from the coast of South Andaman

Plate – 1B. Chlorophytes from the Coast of South Andaman.

Plate - 1C. Phaeophytes from the Coast of South Andaman

Plate – 1D. Phaeophytes from the Coast of South Andaman

Plate -1E. Rhodophytes from the coast of South Andaman

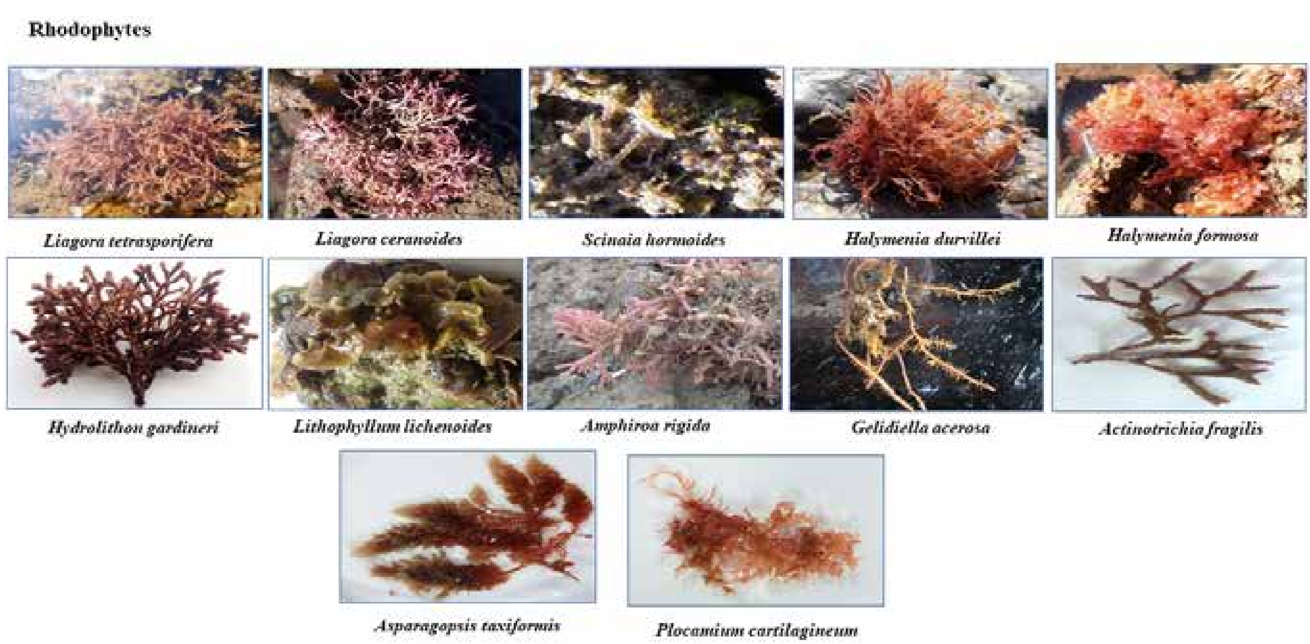

Plate -1F. Rhodophytes from the coast of South Andaman

As enlisted during the study, it is suggested that seaweed potential of South Andaman coast is enormous, but it is yet to be explored and exploited to its fullest capacity. This report provides pictorial presentation of available species composition at South Andaman coast during the study period towards a comprehensive approach for sustainable seaweed resource utilisation and management program.

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A preliminary study on fishing crafts and gears of Mangrove regions of South Andaman

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Abstract

The present study documented the fishing crafts and gears utilized in the eight selected mangrove regions of South Andaman. Total of two fishing crafts traditional and motorized was recorded, of which traditional craft (locally known) dongi, was the most important and commonly operated crafts. The traditional craft over motorized craft was due to the entangled masses of mangrove strands which cause difficulty in operation. Besides, shallow depth and fishing for domestic requirement could be the reason for existence of fewer crafts in this region. Fishing gears recorded in the study area included cast net, gill net, hook and line, scoop net, trap, crab rod, crab net and long lines. There were no seasonal difference of fishing crafts and gears. Comparatively, the cast net was the most frequently used gear.

Keywords: *Fishing Craft; Fishing Gear; Mangrove; Cast Net; South Andaman*

Introduction

Andaman and Nicobar Islands, one of the union territories of India, holds third largest mangrove coverage in India reported being best and most intact in our country (Venkataraman and Wafar, 2005; Mandal and Naskar, 2008). These islands are divided into two groups namely Andaman group and Nicobar group of Islands, occupying 644sq. km and 27 sq. km of mangrove coverage, respectively (FSI, 2009). Furthermore, these islands mangrove areas are one of the richest in the world in terms of quality of vegetation and biodiversity. South Andaman is most populous and urbanized district of this union territory. The dependence of coastal community on this ecosystem is not as that of mainland India and is mainly restricted as a food source rather than livelihood. Mangrove regions are considered as one of the most difficult regions to venture for fishing due to harsh environmental conditions. The absence of tiger, unlike Sunderban, makes the islands mangrove region comparatively safer to venture for fishing. So, the fishing techniques and equipment such as crafts and gears play an important role in mangrove fishing activities. The present study was initiated to understand and document the fishing craft and gear used in the mangrove regions of South Andaman.

Materials and Methods

The present investigation of fishing craft in Mangrove regions of South Andaman was conducted for a period of one year from October 2012 to September 2013. Field visits were made to the Manjeri, Chouldari, Sippighat, Shoal Bay, Carbyns Cove, Beodnabad, Ograbranj and Kadakachang areas in south Andaman district. Each location, the details regarding the crafts operated were collected by personal interviews, discussions, questionnaires and personal observation.

Results and Discussion

Fishing Crafts

Traditional boats are known as dongi and motorized boats were the fishing crafts used by the artisanal fishermen in South Andaman mangrove creeks. Traditional crafts (54 No) were the most important and commonly operated fishing crafts in the study area compared to (30 No) motorized crafts. Traditional crafts were recorded in all study sites, except Beodnabad. while motorized crafts were recorded from Manjeri (5 No), Chouldari (3 No), Sippighat (2 No) and Shoal bay (20 No). Motorized crafts were not recorded from Carbyns Cove, Beodnabad, Ograbranj, and Kadakachang.. Motorized boats were equipped with 1-10 horsepower motors whereas traditional boats were deprived of the motor and were operated using the wooden Oar.

Traditional crafts were constructed of wood; length varied from 4 to 10m, width from 1 to 4m and depth from 1 to 2m and costs about Rs 1 to 3 Lakh INR (Fig. 1). The absence of propeller and small size makes it convenient to move into the mangrove forest and halt conveniently. They are operated manually with a help of two long wooden oars and generally, two persons are required to run the craft, one to operate the craft and other to operate fishing gear.

Motorized crafts (Fig.2) were also constructed of wood, length varied from 7 to 18m, width varies from 1 to 4m, and depth (3 to 4m) and cost about Rs 20,000 to 50,000 INR and are comparatively better than tradition crafts in endurance, capacity, stability and size. However, they are less commonly used than traditional crafts due to the presence of propeller and large size which cause difficulty in operation inside the mangrove forest.

Fishing Gears

Gears are important fishing equipment utilized by fishermen to capture the fishery. The fishing gears recorded in the study area (Table 1 and 2) included cast net, gill net, hook and line, scoop net, trap, crab rod, crab net, and long lines. Among these, cast nets (249 Nos.) dominated followed by crab rod (115 Nos.) and hook and line (68 Nos.), while traps (6 Nos.) and scoop nets (2 No's) were the least. The cast net was the most important fishing gear used in the study area. Only two types of gears were observed in Manjeri (5 Nos.), whereas a maximum number of gears was observed at Shoal Bay (170 Nos.). Traps and scoop nets were the only gear not recorded from Shoal Bay. Fishing gear traps and scoops were only recorded from Chouldari. Cast net, hook, and line and crab rods were recorded in all the stations. Gill nets were recorded mostly in Shoal Bay (15 Nos.) and Sippighat (9 Nos.), however, they were not recorded from Beodnabad and Kadakachang.

Table 1 Number of Fishing Crafts from the Mangrove Habitats

No	Station	Motorized	Traditional
1	Carbyns cove	0	3
2	Beodnabad	0	0
3	Manjeri	5	2
4	Chouldari	3	5
5	Ograbranj	0	2
6	Sippighat	2	10
7	Kadakachang	0	2
8	Shoal Bay	20	30
	Total	**30**	**54**

Carbyns Cove recorded the highest number of cast net (20 Nos.) followed by hook and lines (10 Nos.), Gill net (6 Nos.) and Crab rod (6 Nos). Crab net only 2 Nos., while Traps and scoop nets were not recorded from Carbyns Cove. All the station, cast nets was the most preferred fishing gear followed by Crab rods I In Shoal bay both Crab rod and longlines constituted the second highest number of gear. Seven gears were recorded from Chouldary. Except long lines, which were recorded only from Shoal Bay, all of the fishing gears were recorded from Chouldhary. Highest number (170 No's) of gears were operating in Shoal Bay followed by Sippighat (104 Nos.), Chouldary (79 Nos.), Manjery (61 Nos.), Carbyns Cove (44 Nos.), Ograbranch (34 Nos.) and least in Beodanabad (27 Nos.) and Kadakachand (26 Nos.).

Cast nets were generally used to catch finfish irrespective of size and shape. They varied from 1.5 to 3.5 m in depth; 10 to 20 mm mesh size, stringless and stringed. The nets are spread on the surface of the water with the help a person holding one end of the net tied with rope and retrieved with the help of the rope (Fig. 3). It is operated from the craft in the deeper regions of the creek and without a craft in shallow regions.

Table2: Types and Number of Fishing Gears used in South Andaman Mangrove Ecosystems

Station	Cast net	Gill net	Hook & line	Traps	Scoop net	Crab rod	Crab net	Longlines	Total
Carbyns Cove	20	6	10	0	0	6	2	0	44
Beodnabad	10	0	5	0	0	7	5	0	27
Manjeri	29	5	7	0	0	20	0	0	61
Sippighat	50	9	10	0	0	27	8	0	104
Chouldari	42	5	7	6	2	11	6	0	79
Ograbranj	18	4	4	0	0	8	0	0	34
Kadakachang	15	0	5	0	0	6	0	0	26
Shoal Bay	65	15	20	0	0	30	10	30	170
Total	249	44	68	6	2	115	31	30	545

Figures

1 a)

1 b)

Figure 1 Traditional fishing crafts operated in mangrove habitats of South Andaman

Gill nets were operated in most of the stations but less frequently (Fig.4). The design includes a head rope attached with floaters, foot rope attached with weights generally made of iron or lead and these two ropes connected with mesh. The mesh size varied from 0.1mm to 0.5mm and was generally used to capture fin fishes of various sizes. However Crabs also gets entangled in the net accidentally. These gears were mostly laid vertically across water bodies during the evening and removed next day early in the morning or laid for few hours. These nets were recently banned by Fishery Department because along with the targeted species, juveniles to large size crocodiles also used to get entangled accidentally. However, these nets are still in use.


2 a) 2 b)

Figure 2 Motorized craft fishing crafts operated in mangrove habitats of South Andaman


3a) 3 b)


3 c) 3 d)

Figure 3 Cast nets

Hook and line were the most popular fishing gear among the local community, including small children, as a means of recreation as well as for catching fishery for own personal consumption (Fig. 5). The gear consists of a metal hook is tied at one end of a tread and another end of the rope tied with a stick. Finfishes, mainly of large size, were caught by these gears. Gastropod flesh, small sized shrimps or fingerlings were used as bait.

4 a)

4 b)

Figure 4 Gillnets

5 a)

5 b)

5 c)

Figure 5 Hook & line

Traps (Fig. 6) and scoop (Fig. 7) nets were recorded only from Chouldari in very less number and were used very rarely. Traps are cylindrical nets made of bamboos and are open at both the ends. Scoop nets are made of "oval" shaped wooden or plastic frame to which net is attached. Traps are used for all kind of finfishes and Scoop nets for small sized fishes.

Crab rods are traditional fishing gears made of an iron rod with a hook like a bend at one end and a small wooden handle at the other (Fig. 8). This special gear was exclusively used to capture crab i.e. *Scylla* spp. The gear is held by a handle at one end and the hooked end will be inserted inside the crab holes to pull the crab out. Once the crab is caught, slowly, the rod is retrieved and immediately claws are tied with the twin and stored.

Figure 6 Traps

Figure 7 Scoop nets

Figure 8 Crab rod

a) **b)**

Figure 9 Crab Nets

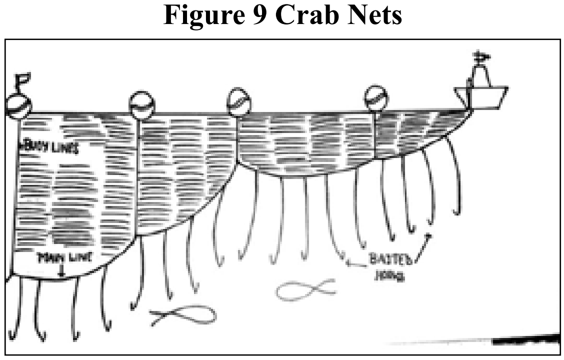

Figure 10: Longlines

Crab net is also a traditional fishing gear, which is made up of roughly square shaped wooden frame, to which net is attached (Fig. 9). The gear is dipped inside the water with one hand and a rope tied with bait is lowered into the water with another hand. As soon as a crab holds the bait with its claws the net will be lifted carefully to avoid escaping of crabs. Generally, crabs of small size were captured with the help of this gear.

Longlines are advanced gears generally operated in the open sea (Fig. 10). During the study, these gears were recorded only in Shoal Bay as these gears require a large area for operation. The long ropes are fitted with numerous hooks all along the line and placed at different depths where one end of the rope will be attached to the weight and other to floats to keep it in position. They were used mainly for large sized fishes and were found to be highly productive gear.

Species Targeted

The existing crafts seem not to have much importance in fishing activities in most of the mangrove regions of South Andaman. The cast net was used generally for all the species of fin fishes irrespective of size. It is of different mesh size, material and length. Hook and line were used for bigger fishes and its usage was less compared to cast net as it was time consuming hence used for recreation. Gill net was generally used for capturing fin fish even though crabs also got caught in this gear accidentally. The gear is laid during the evening time and removed next day early in the morning or for nearly 3 to 9 hours. Traps are used for all kind of fin fishes and hand net is used for small sized resources. Crab rods are exclusively used for single-species (*Scylla* spp.) capture and are a special type of iron rod having a bend at one end similarly crab net is having more or less square shape and is also used for crabs. Shrimps are generally caught by cast nets with smaller mesh size.

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Selected deep sea species taxonomy of gastrapoda and echinodermata, off Andaman and Nicobar Islands

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Abstract

Center for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences (MoES), Kochi conducted FORV Sagar Sampada Cruise 334, Leg II around the Andaman and Nicobar Islands between the time period of 23rd January 2015 and 12th February 2015 and samples were collected from 19 stations situated in 9 transects. Among these 19 stations, dredging operations were carried out for 9 stations and bottom trawl operation was carried out for 3 stations. However, samples brought to on board by only two operation of bottom trawl and three oerations of dredge. Among the collected samples in these operation, the Gastropoda and Echniodermata was studied for it taxonomy and distribution. Seven Gastropoda and five echinodermata were identified from these collected specimens. Two speceimens were identified as *Mammilla melanostoma* and *Granulifusus kiranus*. Four specimens were identified upto the genus level, i.e., Genus *Conus, G*enus *Mitra,* Genus *Gemmula,* Genus *Calliostoma* and specimen able to identified up to family level, i.e. from the Family Terebridae. Among the identified five echinoderms, the two sea star belong to the Genus *Astropecten* and Genus *Tessellaster*. The remaining three brittle star, one each belong to Family Ophiolepididae and Family Ophiomyxidae. The last one belong to Genus *Ophiothrix*. The among these 12 specimens, two gastropoda and Family Opholepididae specimens of echinodermata were observed more than 500m depth. The remaining four echinodermata and five gastropoda observed in less than 500m depth.

Keywords: *Classification, Marine Animals, Gastropoda, Echinodermata*

Introduction

The deep sea constitutes a special habitat by its unique ecological features in the biosphere. The deep sea system is mainly divided into two main regions namely, an upper archibenthic and a lower abyssal benthic. The archibenthic zone extends from the sublittoral zone (200 meters) to about a depth of 800-1100m. The abyssal benthic zone is composed of the entire benthic zone below the archi-benthic zone. All the population below the littoral zone are considered as the deep sea fauna .

The most striking feature of the deep sea system is its changelessness. There is nothing to mark the flight of time. There are no well-defined seasons and remarkably constant conditions prevail day in and day out. These conditions have tremendous influence on the development and existence of organisms. Such habitats with special conditions are subjected to an ecological principle known as "Theinmann's principle". According to this principle, the more isolated and specialized the habitat becomes poor in its diversities, but richer in individuals with astounding peculiarities.

The immense pressure, perpetual darkness, low temperatures and scarcity of food are some of the essential features of the deep-sea systems. These harsh conditions are not favourable to support life. However, deep sea fauna show remarkable adaptations, which enable them to survive the harsh conditions of the deep sea. The weak nature of the skeleton of deep-sea forms is due to the inability to synthesise calcium at lower temperatures that prevail in the ocean depths. The deep–sea molluscs are known for their fragile shells. Deep sea Lamellibranchs and gastropods are very small and they do not reach even a moderate size. Absence of food explains the dwarf nature of deep sea animals. Another remarkable feature of the deep sea forms is the presence of colours. Red colour seems to predominate over the others. Dark violet and brown colours are also common.

Deep sea animals are mainly dependent on the organic matters as a food, dropping like gentle rains from the surface. The ageless uniformity of the deep sea environment has reduced the inter-specific competition to the minimum and hence the deep sea, constitute a sort of refuge for certain archaic forms of life. Some of the echinoderms, particularly the sea urchins, which were thought to be extinct, have been found in the depths. O'Hara and Harding (2015) were stated that the knowledge about diversity exited in the deep sea is inadequate. Even, new species were identified well sampled regions of deep sea also. Further, the findings are also challenged our concept of evolutions.

The phylum Echinodermata, a true ocean realm species, among them few are available under the reduced salinity conditions (Pawson et al., 2009). If habitats are suitable, the echinoderms can form populations of enormous size, and they can dramatically affect the general economy of the benthos (Pawson et al., 2009). There are approximately 6700 living species, and about 13,000 fossil species are known ranging from the lower Palaeozoic (Pawson, et al., 2009). Most sea stars are epibenthic, but numerous species burrow into soft substrates. Some sea star are capable of using their suctorial tube feet to open oysters, clams and scallops (Pawson, et al., 2009). The scavenging and predator habit was observed in the brittle stars also. Some are feed aggregations and suspension feed ans some are capturing prey with their tube feet.

Among the animal kingdom, next to insects, the class Gastropoda exhibnit a vast number of species. The fossil were found from the period late Cambrian onwards. Out of 721 families, 245 familis were available only as a fossil record. (Bouchet et al., 2017). The remaining 476 families having around 80,000 living snails and slug species (Bouchet et al., 2005). Eventhough this class has an extraordinary diversification of habitats, most of these groups studied to intertidal to shallow water environments. The deep sea environment distributions and diversity are less known, that also particularly from the seas of India.

So, the present study is an attempt to understand the deep sea species diversity in large and in particular, Gastropoda and Echinodermata of Bay of Bengal and Andaman Sea.

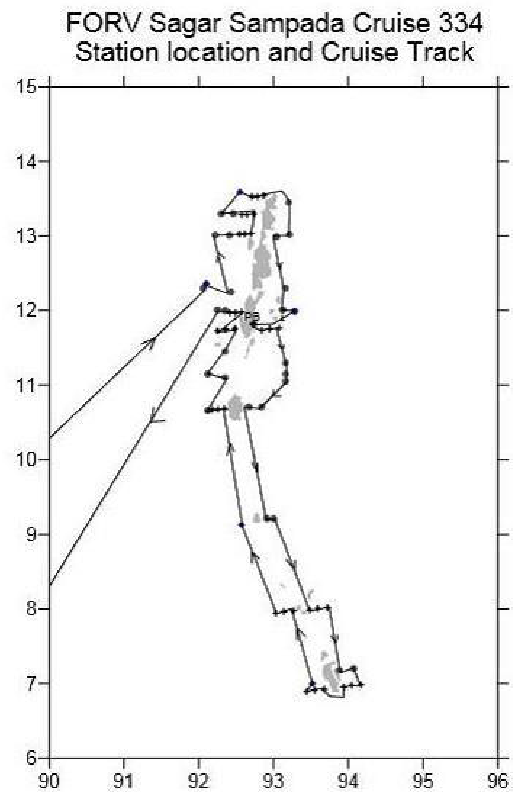

Fig.1. Study Area

Material and Methods

Center for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences (MoES), Kochi conducted FORV Sagar Sampada Cruise 334, Leg II around the Andaman and Nicobar Islands between the time period of 23rd January 2015 and 12th February 2015 with the following objectives such as to study the environment and productivity, marine benthos and assessment of demersal fishery resources. During the cruise, 19 stations were covered along with 9 transects in Bay of Bengal and Andaman Sea. The samples were collected along the Andaman waters between the Latitude 06°17' N to 10°48' N and Longitude 92°11' E to 94°49' E. Even though dredging operations were carried out for 9 stations and bottom trawl was operated at 3 stations, only three dredge stations and two bottom trawl stations provided samples on deck. among the collected samples only gastropoda and echinodermata has been identified and reported in this work (Table 1). The collected biota of the deep sea samples were identified upto the level of Family, Genus and Species, due to limited species number as well not having much elaborate key for this particular species concern.

Table 1. Stations locations and details of operations

Location	Station No.	Lat (N)	Long (E)	Date	Depth (m)	Operation
Off Hut Bay (Bay of Bengal)	2A	10°47'.250"	92°08'.690"	26.01.2015	460	Bottom Trawl
Off Terrsa Island (Bay of Bengal)	4B	09°13'.243"	92°40'.286"	28.01.2015	250	Dredge
Off Car Nicobar (Bay of Bengal)	5B	09°17'.762"	92°54'.542"	28.01.2015	350	Dredge
Off Terrsa Island (Andaman Sea)	7A	08°19'.360"	93°19'.154"	29.01.2015	660	Bottom Trawl
Off Campbell Bay (Indian Ocean)	16B	07°37'.750"	93°24'.030"	03.02.2015	572	Dredge

Results

The samples collected from the deep waters were identified on the following taxonomic character upto Family or Genus or Species Level. The keys used for this work are as follows: Subbarao, 2003; Hadorn et al., 2005; Pomory, 2007; Raghunathan et al., 2013; Gondium et al., 2013; WoRMS, 2018; OBIS, 2018; Shell Catalogue, 2018.

SPECIMEN 1 – MABO P001 (Fig.2)

Systematic Position

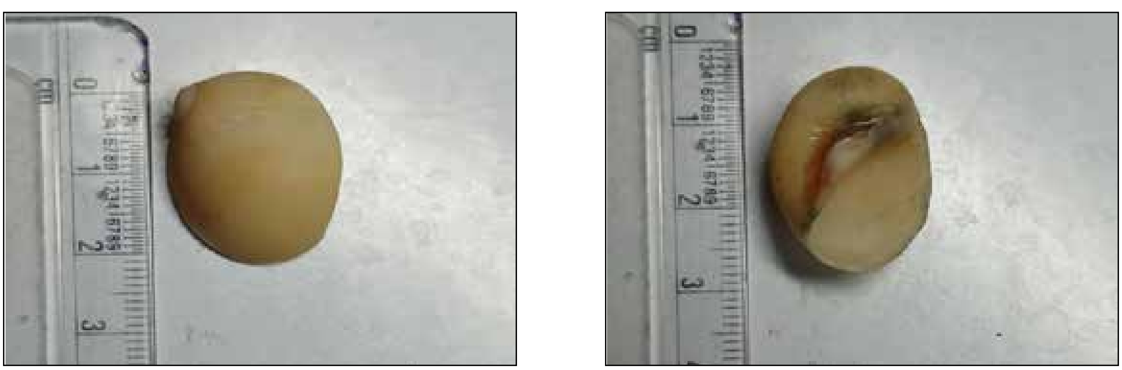

Fig.2 *Mammilla melanostoma*

TAXONOMY

Kingdom: Animalia

Phylum:Mollusca

Class: Gastropoda

Sub-Class: Caenogastropoda

Order: Littorinimorpha

Super Family:Naticoidea

Family: Naticidae

Sub Family: Polinicinae

Genus: *Mammilla* SCHUMACHER, 1817

Species: *Mammilla melanostoma (*GMELIN, 1791)

TYPE LOCALITY – Andaman Sea, Andaman and Nicobar Islands

DEPTH RANGE – Collected from 250 m. – Off Terrasa Island, Bay of Bengal (St.4B)

MEASUREMENT (mm)– Length 23 , aperture length 20, aperture width 12

DESCRIPTION – Shell of medium size, up to 35 mm in length, not thick, pyriformly ovate, spire short with a blunt apex. Aperture large, oblong semilunar, parietal callus folded partly covering the wide and deep umbilicus.

DISTRIBUTION – India- Lakshadweep: Minicoy Island; Tamil Nadu, Pondicherry (common), Andamans (rare). South Africa to Japan and Hawaii.

SPECIMEN 2 - MABO P002 (Fig.3)

Fig.3 *Conus* **sp.**

TAXONOMY

Kingdom: Animalia

Phylum:Mollusca

Class: Gastropoda

Sub-Class: Caenogastropoda

Order: Neogastropoda

Super Family:Conoidea

Family: Conidae

Genus: ***Conus*** **LINNAEUS, 1758**

TYPE LOCALITY - Andaman Sea , Andaman and Nicobar Islands

DEPTH RANGE – Collected from 250 m. Off Terrasa Island, Bay of Bengal (St.4B)

MEASUREMENT (mm) –Total length 36, aperture length 29 , aperture width 3 .

DESCRIPTION – shell of medium length, cone shaped, spire low, aperture long and extending along the whole length of the body whorl, inner and outer lip almost parallel, outer lip is smooth, 5 whorl in spire and 4 suture.

DISTRIBUTION –Andaman and Nicobar Islands, Indo-Pacific, Red Sea.

SPECIMEN 3 – MABO P003 (Fig.4)

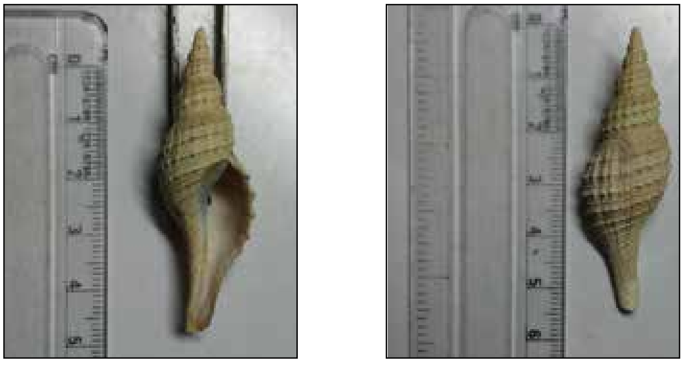

Fig.4 ***Granulifusus kiranus*** **SHUTO 1958**

TAXONOMY

Kingdom: Animalia

Phylum: Mollusca

Class: Gastropoda

Sub-Class: Caenogastropoda

Order: Neogastropoda

Super Family:Buccinoidea

Family: Fasciolariidae

Subfamily: Fusininae

Genus: *Granulifusus* KURODA & HABE 1954

Species: *Granulifusus kiranus* SHUTO 1958

TYPE LOCALITY - Andaman sea, Andaman and Nicobar Islands.

DEPTH RANGE – Collected from 250m –

Off Terrasa Island, Bay of Bengal (St.4B).

MEASUREMENTS (mm) – Length -51, aperture length- 30, aperture width- 9

DESCRIPTION – Shell of medium size, light weight, fusiform, spire slender, consisting of 6 convex whorls, siphonal canal short and broad. Spiral sculpture on upper whorls fine and inconspicuous, axial sculpture usually predominant, close-set and strong. On later whorls the opposite: spiral sculpture predominant, axial sculpture finer.6 distinct suture. Aperture ovate, relatively large, upper end pointed, white. Outer lip convex, slightly crenulated, inside sculptured with fine, close-set internal lirae. Inner lip smooth, slightly glossy, parietal callus thin, extending on parietal wall, attached, underlying spiral sculpture still visible. Siphonal canal short, slightly curved, broad, widely open. Outer side sculptured with fine spiral threads.Operculum typical of genus, reddish-brown.

DISTRIBUTION – Western Pacific, from central Honshu in the north to western Australia in the south.Indonesia and New Caledonia .

SPECIMEN 4 - MABO P004 (Fig.5)

Fig.5 ***Mitra* sp.**

TAXONOMY

Kingdom: Animalia

Phylum: Mollusca

Class: Gastropoda

Sub-Class: Caenogastropoda

Order: Neogastropoda

Super Family: Mitroidea

Family: Mitridae

Subfamily: Mitrinae

Genus: *Mitra* Lamarck ,1798

TYPE LOCALITY – Andaman Sea, Andaman and Nicobar Islands.

DEPTH RANGE - Collected from 572m

Off Great Nicobar, Indian Ocean (St.16B)

MEASUREMENT(mm) – Length -29, aperture length -17, aperture width -5

DESCRIPTION – shell small, spire smaller than aperture, elongately fusiform shell, whorls 5, whorl 13 mm, 5 suture distinct, colour creamy yellow, operculum whitish, outer lip plane, columella contain three columellar folds.

DISTRIBUTION – Andaman Sea

SPECIMEN 5 – MABO P005 (Fig.6)

Fig.6 ***Terebridae***

TAXONOMY –

Kingdom: Animalia

Phylum: Mollusca

Class: Gastropoda

Sub-Class: Caenogastropoda

Order: Neogastropoda

Super Family:Conoidea

Family: Terebridae

TYPE LOCALITY – Andaman sea, Andaman and Nicobar Islands

DEPTH RANGE - Collected from 250 m.

Off Terrasa Island, Bay of Bengal (St.4B).

MEASUREMENT (mm) – Total length 36 , aperture length 10 , aperture width 2

DESCRIPTION – spire contain 21 whorls , 20 distinct suture , pointed spire , aperture small .

DISTRIBUTIONS – Off Terrsa Island, Bay of Bengal (St.4B). In the tropics the majority occur intertidally and in the shallow subtidal, down to about 40 metres. Subtidal species, down to about 350 metres.

SPECIMEN – 6 – MABO P006 (Fig.7)

Fig.7 *Gemmula* **sp.**

TAXONOMY

Kingdom: Animalia

Phylum: Mollusca

Class: Gastropoda

Sub-Class: Caenogastropoda

Order: Neogastropoda

Super Family:Conoidea

Family: Turridae

Genus: *Gemmula* Weinkauff, 1875

TYPE LOCALITY – Andaman Sea, Andaman and Nicobar Islands

DEPTH RANGE - Collected from 572m

Off Great Nicobar, Indian Ocean (St.16B)

MEASUREMENTS (mm) - length-49, aperture -20, aperture width -8.

DESCRIPTION - Shell of medium size upto 50 mm in height, solid, spire high, more than half the total height, body cream in colour, aperture white, aperture straight, columella smooth, 13 whorls in spire, suture 10, outer lip thin, siphonal canal short, sculptured with strong spiral cord with close set gemmules.

DISTRIBUTION - Andaman and Nicobar Islands

SPECIMEN 7 – MABO P007 (Fig.8)

Fig.8 *Calliostoma* **sp.**

TAXONOMY

Kingdom: Animalia

Phylum:Mollusca

Class: Gastropoda

Sub-Class: Caenogastropoda

Order: Trochida

Super Family:Trochoidea

Family: Calliostomatidae

Sub Family: Calliostomatinae

Genus: *Calliostoma* Swainson, 1840

TYPE LOCALITY – Andaman Sea, Andaman and Nicobar Islands

DEPTH RANGE – Collected from 250 m. From shallow water to bathyal depth.

Off Terrasa Island, Bay of Bengal (St.4B)

MEASUREMENTS (mm) – Total length 17, base width 20, aperture width 10

DESCRIPTION – four whorls and four sutures, whorl slightly concave, spiral cords with beads, base of the shell slightly convex with 13 spirals which become gradually finer from the umblicus outward. Aperture situated at the base. Outer lip of aperture thin .

DISTRIBUTION –Andaman and Nicobar Islands

SPECIMEN 8 – MABO P008 (Fig.9)

Fig.9 *Astropecten* **sp.**

TAXONOMY

Kingdom: Animalia

Phylum: Echinodermata

Sub Phylum: Asterozoa

Class: Asteroidea

Super Order: Valvatacea

Order: Paxillosida

Family: Astropectinidae

Genus: ***Astropecten*** **Gray, 1840**

TYPE LOCALITY – Andaman Sea, Andaman and Nicobar Islands

DEPTH RANGE – Collected from 350 m

Off Car Nicobar, Bay of Bengal (St.5B)

MEASUREMENTS – Outer Radius - R= 18 mm, Inner Radius - r = 6 mm

DESCRIPTION - This species have 5 arms. The flattened oral and aboral sides are observed (i.e., carinal plates). The periphery of these plates are larger. The larger supero-marginal and infero-marginal plates appears as block-like. A laerge spine has obsereved in the each infero-marginal plate. Thes spines are projecting horizontally from the upper end and form a peripheral fringe. The three sets of furrow spines are observed.

DISTRIBUTION – Andaman and Nicobar Islands

SPECIMEN 9 - MABO P009 (Fig.10)

Fig.10 *Tessellaster* **sp.**

TAXONOMY

Kingdom: Animalia

Phylum: Echinodermata

Sub Phylum: Asterozoa

Class: Asteroidea

Super Order: Valvatacea

Order: Valvatida

Family: Goniasteridae

Genus: *Tessellaster* H. L. Clark, 1941

TYPE LOCALITY – Andaman Sea, Andaman and Nicobar Islands

DEPTH RANGE – Collected from 460 m.

Off Hut Bay, Bay of Bengal (St.2A)

MEASUREMENT – Outer Radius - R = 14 mm, Inner Radius - r = 4mm

DESCRIPTION – General form stellate with long arms. The disk is large and inflated, and the arms are very long and narrow. The abactinal plates are arranged in a regular series parallel to the carinals. The abactinal surface extends slightly more than half way down the arm and is limited to the carinals and adradials on the arm. The abactinal plates are small and numerous. Abactinal plates completely covered by granules; The plates of the radial areas are low-tabulate and hexagonal. No secondary abactinal plates. Furrow margins of adambulacral plates strongly angular, becoming apophyses distally. No internal radiating ossicles. No super-ambulacral ossicles.

DISTRIBUTION - Andaman and Nicobar Islands

SPECIMEN 10 – MABO P010 (Fig.11, 14)

Fig.11 Ophiomyxidae

TAXONOMY

Kingdom: Animalia

Phylum: Echinodermata

Sub Phylum: Asterozoa

Class: Ophiuroidea

Sub Class: Myophiuroidea

Infra Class: Metothiurida

Super Order: Ophimtegrida

Order: Ophiurida (Ophicanthida)

Sub Order: Ophiodermatina

Family: Ophiomyxidae

TYPE LOCALITY – Andaman Sea , Andaman and Nicobar Islands

DEPTH RANGE – Collected from 460 m.

Off Hut Bay, Bay of Bengal (St.2A)

DESCRIPTION – The thick, naked tegment coverd the pentagonal disk. The elongated internal margins has observed in the radial shield with an enlarged size. Three spines are observed in each lateral arm plate, without dental papillae and one apical papillae on apex of jaw. The jaw exhibited three enlarged oral papillae.

DISTRIBUTION –Andaman and Nicobar Island

SPECIMEN 11 – MABO P011 (Fig.12, 15)

Fig.12 Ophiolepididae

TAXONOMY

Kingdom: Animalia

Phylum: Echinodermata

Sub Phylum: Asterozoa

Class: Ophiuroidea

Sub Class: Myophiuroidea

Infra Class: Metothiurida

Super Order: Ophimtegrida

Order: Amphilepidida

Sub Order: Ophionereidina

Family: Ophiolepididae

TYPE LOCALITY - Andaman Sea, Andaman & Nicobar Islands

DEPTH RANGE - Collected from 660m.

Off Terrsa Island, Andaman Sea (St.07A)

DESCRIPTION – The circular disc has larger cover with im-bricating scales. The scales further surrounded by smaller scales of different shapes and sizes. The primary plate located in the center are rounded. The triangular radial shields separated distally by three large scales. The imbricating scales covered on ventral interradius, which is slightly smaller and narrower than dorsal scales. The long and narrow bursal slits are observed. The oral shields are pentagonal and elongate. The distal margin is convex. The each side of the jaw angle exhibit four to five oral papillae. Fan like dorsal arm plate with triangular shape. The lateral arm plate has 2 spines and one spine is larger than other.

DISTRIBUTION - Andaman and Nicobar, Brazil, Indo –Pacific.

SPECIMEN 12 – MABO P012 (Fig.13, 16)

Fig.13 Ophiothrix sp.

TAXONOMY

Kingdom: Animalia

Phylum: Echinodermata

Sub Phylum: Asterozoa

Class: Ophiuroidea

Sub Class: Myophiuroidea

Infra Class: Metothiurida

Super Order: Ophintegrida

Order: Amphilepidida

Sub Order: Gnathophiurina

Super Family: Ophiactoidae

Family: Ophiotrichidae

Genus: *Ophiothrix* MULLER & TROSCHEL, 1840

TYPE LOCALITY – Andaman Sea , Andaman & Nicobar Islands

DEPTH RANGE – Collected from 250 and 350 m

Off Terrsa Island, Bay of Bengal (St.4B)

Off Car Nicobar, Bay of Bengal (St.5B).

DESCRIPTION – Disc circular, covered by spine and granules.Presence of a clump of dental papillae at the apex of the jaw, oral papillae absent. Disc bearing spines, the arm spine slender, thorny, much longer than the arm segments. Each segment contain 12 spines, radial shield triangular, close to each arm (Fig.16).

DISTRIBUTION – Andaman and Nicobar Island

Discussion

The samples which were collected from deep sea benthic environment were studied to understand the distribution and diversity of organism in the particular environment. Twelve samples were studied in detail for their taxonomic identification and distribution pattern. Out of 12 samples, 7 belong to Phylum Mollusca and 5 to Phylum Echinodermata. The samples were identified up to the levels of Family, Genus and Species depending upon the availability of identifying keys.

Table 2 Species distribution with reference to stations

Location	Station No.	Identified Fauna	Depth (m)	Operation
Off Hut Bay (Bay of Bengal)	2A	*Tessellaster* Ophiomyxidae	460	Bottom Trawl
Off Terrsa Island (Bay of Bengal)	4B	*Mammilla melanostoma* *Conus* *Granulifusus kiranus* Terebridae *Calliostoma* *Ophiothrix*	250	Dredge
Off Car Nicobar (Bay of Bengal)	5B	*Astropecten* *Ophiothrix*	350	Dredge
Off Terrsa Island (Andaman Sea)	7A	Ophiolepididae	660	Bottom Trawl
Off Campbell Bay (Indian Ocean)	16B	*Mitra* *Gemmula*	572	Dredge

All the 7 samples of Phylum Mollusca belong to Class Gastropoda. Identified gastropods belong to three Orders and seven Families (Table 2). Out of seven gastropoda, one was identified up to the Family level, four up to Genus level and other two up to Species level. The identified three Orders are Littorinimorpha, Neogastropoda and Trochida. The Order Littorinimorpha specimen was identified as Family Naticidae, Genus *Mammilla* and Species *Mammilla melanostoma.* The five specimens belong to Order Neogastropoda. The identified

Families are Conidae, Fasciolariidae, Mitridae, Terebridae and Turridae. Family Conidae specimen was further identified as a Genus *Conus* and named as *Conus* sp. The species from Family Fasciolariidae belong to the genus *Granulifusus* and identified as *Granulifusus kiranus*. The species from Family Mitridae belong to Genus *Mitra* and identified as *Mitra* sp. The other specimen belong to Family Terebridae was unable to identify further. The specimen belong to Family Turridae was identified for the Genus *Gemmula* and named as *Gemmula* sp. The other specimen from the Family Calliostomatidae belong to Genus *Calliostoma* and identified as *Calliostoma* sp.

Among five echinoderms two are sea star and three are brittle star. Two sea stars were identified under the Order Paxillosida and Valvatida belongs to Class Asteroidea. One sea star belong to Family Astropectinidae comes from the Order Paxillosida. The other sea star belong to Family Goniasteridae belong to Order Valvatida. The species from the Family Astropectinidae further identified as Genus *Astropecten* named as as *Astropecten* sp.. The species of the Family Goniasteridae identified as the Genus *Tessellaster* named as *Tessellaster* sp.

Among the three brittle stars, all identified from the Class Ophiuroidea. Under this Class the specimens belongs to Order Ophiacanthida and Amphilepidida. The specimen identified under Order Ophiacanthida from the Family Ophiomyxidae. However, the other two specimens belong to Order Amphilepidida considered under the Families Ophiolepididae and Ophiotrichidae. The speceimen from the Family Ophiolepididae were not identified further. The remaining specimen from the Family Ophiotrichidae identified to the Genus *Ophiothrix* and named as *Ophiothrix* sp.

Two gastropods belong to Genus *Mitra* and Genus *Gemmula* identified in the Station 16.B, have a water depth of 572m, in Indian Ocean region off Great Nicobar Islands. Remining five specimens of identified gastropods from the depth of 250m at off Terrsa Island, at Bay of Bengal (St.4B) waters along with one echinodermata Genus *Ophiothrix*. The St.2A located in off Hut Bay (Bay of Bengal) consists of two echinodermata specimens of Genus *Tessellaster* and Family Ophiomyxidae. The St.5B, located in d Off Car Nicobar (Bay of Bengal) represented two echinodermata viz., Genus *Astropecten* and Genus *Ophiothrix.* The St.7a, deepest studied stations located in Off Terrsa Island (Andaman Sea) has on echinodermata specimen, i.e. Family Ophiolepididae. These distributions suggested that two gastropoda and one echinodermata specimens were able to sustain morethan 500m depth. Remaining nine speceimens able to available in less tha 500m depth. The present study once again confirms the essentiality of a detailed study for understanding deep sea fauna and its distribution in the Andaman Sea region.

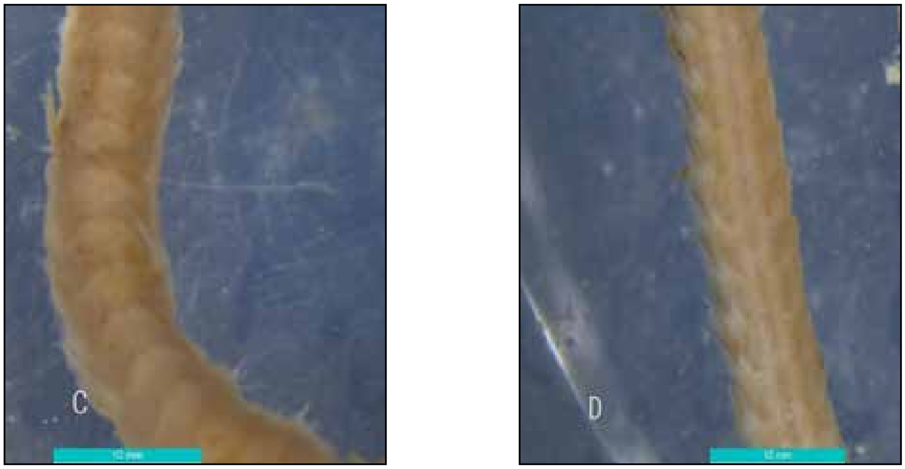

Fig 14 Specimen of Family Ophiomyxidae A; Dorsal view B; Ventral view C; Dorsal view of arm; D. Ventral view of arm.

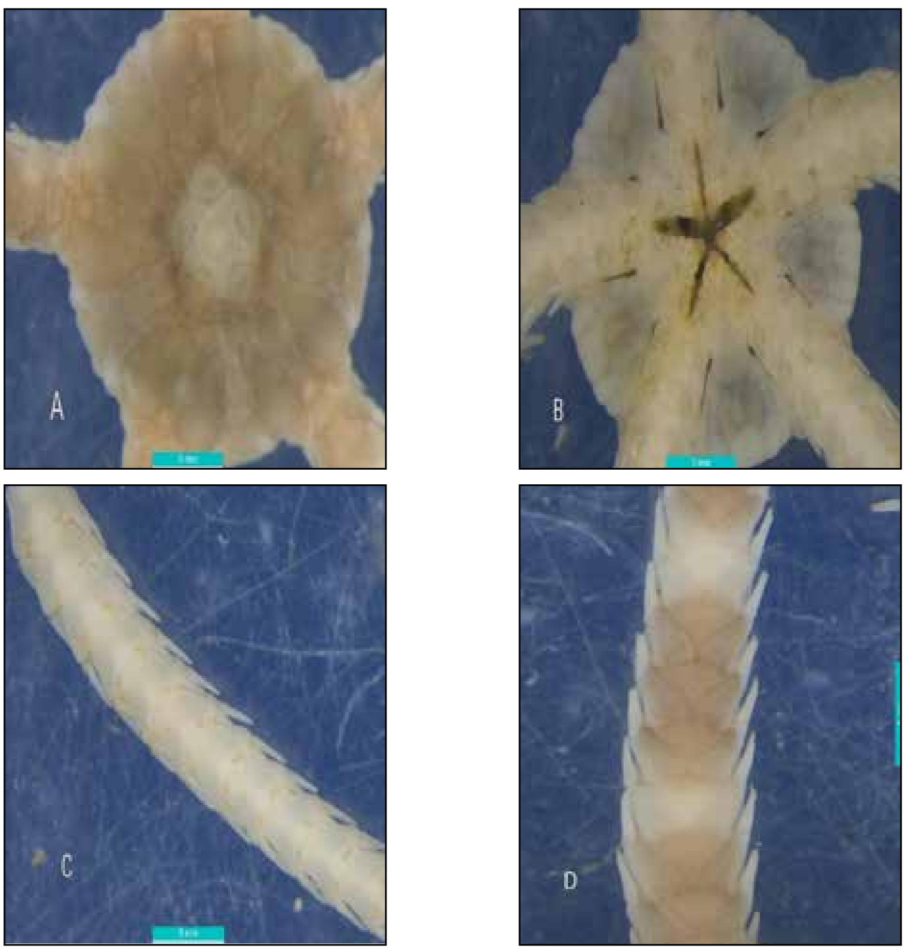

Fig 15.Specimen of the Family Ophiolepididae - A dorsal view; B.Ventral view; C.Ventral view of arm; D. Dorsal view of arm.

Fig 16. Specimen of Genus *Ophiothrix* A. Dorsal view B.Ventral view C. Dorsal view of arm D. Ventral view of arm

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Study on Chiton from the Intertidal Region of South Andaman

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Abstract

Study on chiton was carried out during February 2018, from the intertidal region of South Andaman. A total of 14 species of chiton belonging to 5 genera were identified in the study area. Two species were identified up to the level of Family only and one specimen reported as unidentified. Genera *Acanthopleura* was the most dominant (69%) while *Acanthochitona* and *Mopalia* contributed low (0.3-6.7%) to the total chiton population. Relatively high species richness (d=2.64) and low evenness in chiton species distribution (J= 0.6) at St.2 was found which could be due to the dominance of few species such as *Acanthopleura spiniger, Acanthopleura* sp.2 and *Chiton imitator.* Species composition of Carbyns Cove and Burmanallah were almost same showing 87% similarity, while species composition of Kodiyaghat differed from both the stations.

Keywords: *Polyplacophora, Chiton, Intertidal Region, South Andaman.*

Introduction

Since the Carboniferous period, polyplacophoran molluscs (chitons/ seacradles/ coat-of-mail shells) have persisted with little change in morphology (Sirenko, 2006) with over 900 species worldwide that are exclusively marine and are important intertidal grazers (Dethier and Duggins, 1984; Elahi and Sebens, 2013). Chitons are oval in shape and dorso-ventrally flattened, possessing eight distinctive overlapping shell plates or valves on the dorsal side. These valves are arranged longitudinally surrounded by a muscular girdle ornamented with scales, spicules, bristles or other protuberances (Kaas and Van, 1985), providing protection from wave exposure, predation, and other sources of damages.

Chitons have a large surface area of gills with numerous sensory organs distributed on their girdle and across the upper surface of their valves that helps to respire air by direct diffusion. Among the molluscs, chitons have a unique presence of shell organs called esthetes in the upper layer of valves known as the tegmentum that are modified as shell eyes visible to the naked eye (Leise and Cloney, 1982). The largest Indian chiton *Acanthopleura spiniger* from Andaman and Nicobar Islands was reported by Tikader et al., (1986).

Studies on chitons from the Andaman and Nicobar Islands are inadequate (Tikaderetal., 1986; Rao and Dey, 2000; Dey, 2003) though a rich component of molluscs represent in this little studied ecosystem. Chitons have a unique role and niche as primary consumers of marine plants. Very few literatures are available pertaining to the study of chitons from these waters. This entails the attention of scientific community for conserving the habitat as well as the species biodiversity itself.

Material and Methods

Station 1, Carbyns Cove (CC) -

This sampling site is located between 11º38.428′N to 92º44.652′E. Carbyns Cove has a long stretch of rocky shore with number of tide pools.

Station 2, Burmanallah (BN) -

This sampling site is located between 11º33.228′N and 092º44.866′E. Burmanallah has a long rocky shore stretch with mangroves on one side with diverse biodiversity.

Station 3, Kodiyaghat (KG) -

The sampling site is located between 11º31.733′N and 092º43.415′E. Kodiyaghat has a stretch of muddy and rocky shore with numerous tide pools.

Sample Collection

The study was undertaken during February, 2018. Stations were selected based on the availability of food source, habitat traits and accessibility. Sampling method was based and established on the availability of the organisms in the intertidal zone during low tide. Sample collection was carried out by using a 1m^2 transect (Elftheriou and McIntyre, 2005). Chitons attached on rocks were thwarted by using freshwater and were collected in plastic bags. The use of freshwater allowed the organisms to loosen their grip on the attached substratum as they are marine organisms, thereby making the collection easy. Forceps were also used for the sample collection of chiton. Most of the species were photographed and measured in their natural habitat.

Laboratory Analysis

Chitons were brought to the laboratory for further taxonomic identification and were stored in deep freezer (-5°C). Identification of chiton till the lowest possible taxon level was done following literatures based on Rajagopal and Rao (1974), Subbarao and Dey (1991), Rao and Dey (2000) and Dey (2003). Chitons were defrosted and dissected by using steel blade and forceps. The internal morphology of chiton viz. gills, radula, insertion slits and spicules were observed under microscope (Nikon Trinocular Inverted Microscope). Following the identification, the specimens were preserved in 10% formaldehyde solution (Schwabe, 2006).

Data analysis

One time sampling was conducted to pursue taxonomic classification, so the presence or absence data was used to determine the similarity between the stations by using Primer V6.0 and MS excel.

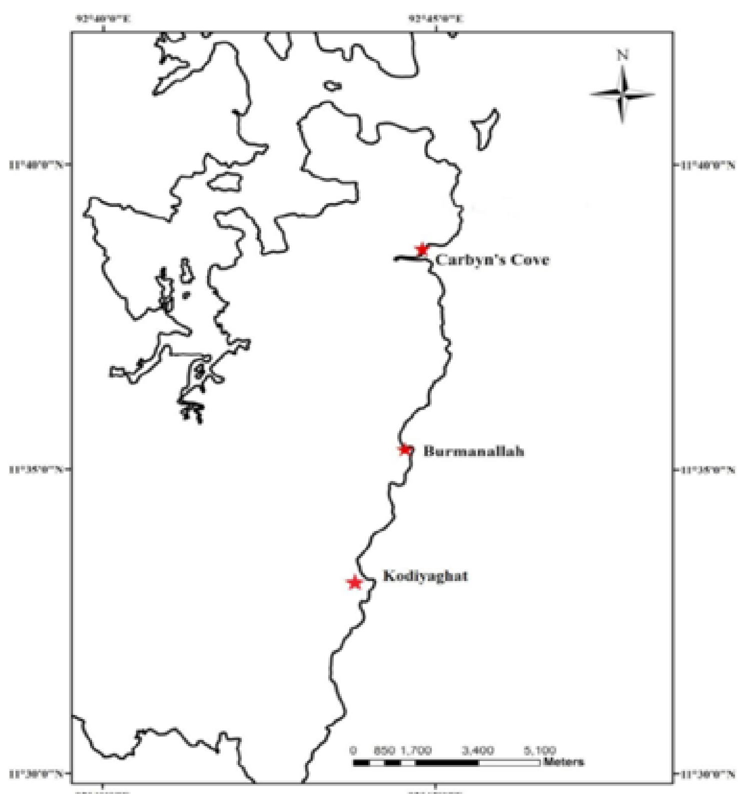

Fig.1. Map showing sampling location

Results

Water temperature varied from (29.3-30 °C) while air temperature (25.7-26 °C) did not show much variation among the stations. Dissolved Oxygen ranged from 4.1mg/L at St.1 to 4.8mg/L at St.2. Maximum salinity of 32.3 PSU was recorded at St.1. pH was maximum (8.4) at St. 1 and minimum (8.2) at St. 2 and St.3 (Fig. 2).

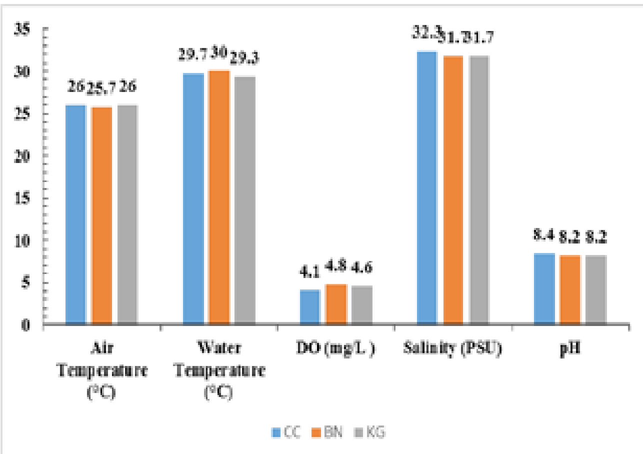

Fig.2 Physico-chemical parameters recorded during the study period

(CC= Carbyns Cove; BN= Burmanallah; KG= Kodiyaghat)

Phylum: Mollusca Cuvier, 1795

Class: Polyplacophora de Blainville, 1816

Order: Chitonida Thiele, 1909

1. *Acanthopleura spiniger* Sowerby, 1840

Collection site - Carbyns Cove, Burmanallah, Kodiyaghat

Preferred habitat - Commonly attached to the rocks in intertidal region

Size - 7-7.2cm

Description - Largest and thorny chiton in the study area, length up to 7-7.2 cm. Girdle with numerous curved spines. Shell large and rounded, with thick and heavy valves.

2. *Acanthopleura* sp. 1

Collection site - Kodiyaghat

Preferred habitat - Intertidal to shallow shore, found active at night during the study period.

Size - 4.5-5.9 cm

Description - Smooth girdle. Girdle milky white. Jugum present on all valves. Gills extending till the foot.

3. *Acanthopleura* sp. 2

Collection site - Carbyns Cove, Kodiyaghat, Burmanallah

Preferred habitat - Rock beds covered with algal patches.

Size - 5.1-6.7 cm

Description - Girdle with numerous curved spines. Shell large and rounded. Jugum absent on the head and tail valves with distinct lateral black lining. Presence of demarcating lines on all valves. Girdle colour- whitish; Valve colour- black or dark green.

4. *Chiton iatricus* Winckworth, 1930

Collection site - Burmanallah, Carbyns Cove

Preferred habitat - Attached to rocks in the intertidal region observed during the period of sampling.

Size - 1.6-2.1 cm

Description - Shell with subdued sculpture with marked ridge separating the lateral areas from the median area, anterior margins of the valves with marked growth lines. Colour reddish brown with dark markings on a yellowish background. Girdle is scaly and smooth.

5. *Chiton imitator* Nierstrasz, 1905

Collection site - Carbyns Cove, Burmanallah

Preferred habitat - Found in the intertidal area, crawling through algae over rocks.

Size - 3.2-3.6 cm

Description - Shell small. Anterior most valve semicircular. The second valve slightly larger than other valves. Posterior most valve slightly depressed.

6. *Chiton* sp.

Collection site - Kodiyaghat, Burmanallah

Preferred habitat - Commonly attached to the rocks in intertidal region. There are numerous species observed in this area

Size - 3.1-3.9 cm

Description - Animals small. Girdle naked and leathery or with well-developed, solid, rounded and closely overlapped scales or spicules.

7. *Acanthochitona* sp. 1

Collection site - Carbyns Cove, Burmanallah

Preferred habitat - Rock surfaces in the intertidal zone

Size - 2-2.2 cm

Description - Jugum present on all valves. Girdle hairy and black in colour. Insertion plate slitted. Tegmentum absent. Valves-light brown and black.

8. *Acanthochitona* sp. 2

Collection site - Burmanallah, Carbyns Cove

Preferred habitat - Found on rock surfaces in the intertidal zone of this area

Size - 2.8-3.4 cm

Description - Jugum absent on the head and tail valve. Girdle hairy and olive green in colour. Presence of spicules. Gills extending till the foot.

9. *Acanthochitona* sp. 3

Collection site - Carbyns Cove

Preferred habitat - Rocks where hydroids are present

Size - 3.5-4.3 cm

Description- - Jugum present on all valves. Girdle spiny and grey in colour. Presence of demarcating lines on the intermediate valves. Head valve slightly bigger than tail valves.

10. *Ischnochiton* sp. 1

Collection site - Kodiyaghat, Burmanallah

Preferred habitat - Attached to the dead shells or other hard substratum

Size - 3.8-4.2 cm

Description - Animal medium in size. Tegmentum of the valves 2-7 usually divided into lateral and central areas by a diagonal rib. Gills are holobranchial.

11. *Ischnochiton* sp. 2

Collection site - Kodiyaghat, Burmanallah

Preferred habitat - Attached near encrusted algae

Size - 4.8-5.6 cm

Description - Girdle hairy and smooth. Jugum absent on head and tail valve. Gills extending to the foot.

12. *Ischnochiton bouryi*

Collection site - Carbyns Cove, Burmanallah, Kodiyaghat

Preferred habitat - Found feeding exclusively on filamentous algae in intertidal rock pools.

Size - 3.6-4.6 cm

Description - All the valves of equal width. Tegmentum grayish brown in colour. Girdle narrow. Gills holobranchial and abanal.

13. *Ischnochiton winckworthi* Leloup, 1936

Collection site - Carbyns Cove, Burmanalla, Kodiyaghat.

Preferred habitat - Around sponges.

Size - 1.8-2.5 cm

Description - Oblongovate and flattened. Dorsal surface of the intermediate valves bearing three distinct bands in the centre. Girdle with closely packed scales.

14. *Mopalia hindsii* Reeve, 1947

Collection site - Kodiyaghat

Preferred habitat - Commonly attached to the rocks in intertidal region.

Size - 4.4 cm

Description - Cross hatched "basket-weave" pattern on plates II-VII. Girdle wide. Plates often solid dark green, brown or nearly black and sometimes bi-coloured with white.

Phylum : Mollusca Cuvier, 1795

Class : Polyplacophorade Blainville, 1816

Order : Lepidopleurida

Family : Leptochitonidae Dall, 1889

15. Leptochitonidae sp. 1

Collection site - Burmanallah, Kodiyaghat

Preferred habitat - Commonly attached to the rocks in intertidal zone

Size - 3.2-3.6 cm

Description - Smooth and hairy girdle. Jugum absent on head and tail valves. Valves brownish to white in colour.

16. Leptochitonidae sp. 2

Collection site - Burmanallah, Kodiyaghat

Preferred habitat - Attached to the rocks in intertidal zone

Size - 1.8-2.1 cm

Description - Smooth and hairy girdle. Jugum irregular. Gills not extending till the foot. Insertion plate grooved. Valves brownish to white in colour. Girdle narrow and absence of tegmentum.

Species Composition of Chiton

Genera *Acanthopleura* was the most dominant (69%) followed by *Ischnochiton* (22%) and *Chiton* (14%). Whereas, the Genus *Acanthochitona* and *Mopalia* were contributed low (0.3-6.7%) percentage to the total population, during the study period.

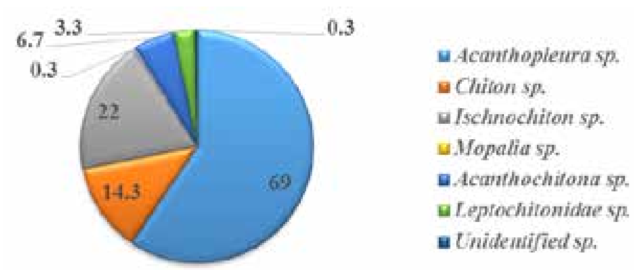

Fig. 3: Percentage composition of major genera of Chiton in the study area

A total of 14 species of Chiton belonging to 5 genera and 2 species were identified till the family level from the study area (Table 1).

Acanthopleura spiniger ranged from 21 ind./m^2 at St.1. to 76 ind./m^2 at St.3 (avg 49.7±2.7) and contributed 42.8% to the total Chiton population in the study area. Only a single individual of *Acanthopleura* sp.1 was recorded at St.3 during the study period. *Acanthopleura* sp. 2 ranged from 11 ind./m^2 at St.1. to 28 ind./m^2 at St.3 (avg. 19.0±8.5) and contributed 16.3% to the total population.

Ischnochiton winckworthi ranged from 1 ind./m^2 at St.2 to 45 ind./m^2 at St.1 (avg. 16.0±2.5) and contributed

13.7% to the total population. The species *Ischnochiton bouryi* exhibited 3-4 ind./m^2 at all the stations (avg. 3±0.5) and contributed 2.5% to the total population. Only 1 ind./m^2 of *Ischnochiton sp.*1 was collected from St.2 and St.3. the species *Ischnochiton* sp. 2 was collected 3-4 ind./m^2 of at St.2 and St.3 in the study area (avg 2.3±2.1) and contributed 2.0% to the total population. The species *Chiton imitator* ranged from 5 ind./m^2 at St.2 to 23 ind./m^2 atSt.2 (avg. 9.3±2.9) and contributed 8.1% to the total population. Species *Chiton iatricus* was recorded 1-2 ind./m^2 at St.1 and St.2. The *Chiton* sp.1 ranged from 1 ind./m^2 at St.2 to 11 ind./m^2 at St.3 (avg. 4.0±6.1) and contributed 3.5% to the total population.

The *Acanthochitona* sp.1 ranged from 2 ind./m^2 at St.1 to 4 ind./m^2 at St.2. The species *Acanthochitona* sp.2 ranged from 1 ind./m^2 at St.2 and 8 ind./m^2 at St.1, while 5 ind./m^2 of *Acanthochitona* sp.3 was recorded at St.1, while only one ind./ m^2 of *Mopalia hindsii* was collected at St.3 in the study area.

Table1: Species Composition of Chiton at St.1, St.2 and St.3 during the study period.

+ : Present; - : Absent

S.No.	Species Composition	St.1	St.2	St.3	%
1.	*Acanthopleura spiniger*	+	+	+	42.82
2.	*Acanthopleura* sp.1	-	-	+	00.29
3.	*Acanthopleura* sp.2	+	+	+	16.38
4.	*Chiton iatricus*	+	+	-	00.86
5.	*Chiton* sp.1	-	+	+	03.45
6.	*Ischnochiton bouryi*	+	+	+	02.59
7.	*I. winckworthi*	+	+	+	13.79
8.	*Ischnochiton* sp.1	-	+	+	00.57
9.	*Ischnochiton* sp.2	-	+	+	02.01
10.	*Mopalia hindsii*	-	-	+	00.29
11.	*Acanthochitona* sp.1	+	-	+	01.72
12.	*Acanthochitona* sp.2	+	+	-	02.59
13.	*Acanthochitona* sp.3	+	-	-	01.44
14.	Leptochitonidae sp.1	-	+	+	01.15
15.	Leptochitonidae sp.2	-	+	+	01.72
16.	Unidentified sp.	-	-	+	00.29

Species diversity of Chiton

The number of species (S) and diversity indices in the study area are given in Fig. 4. Highest number of individuals was recorded at St.3 (N= 134) and the least number of individuals were recorded at St.2 (N=94). The number of species recorded was high at St.2 (S=13) and low at St. 1 (S=9). Relatively high species richness (d=2.64) and low evenness in chiton species distribution (J= 0.6) at St.2 was found.

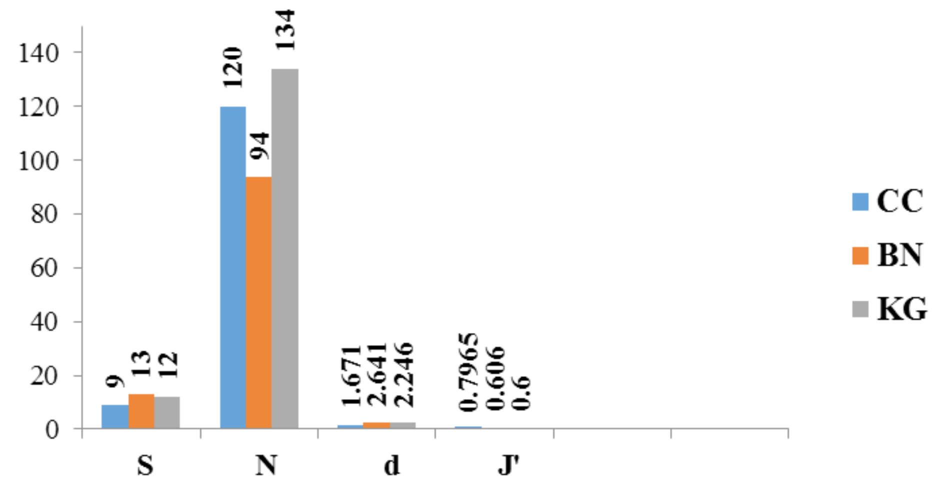

Fig. 4: Diversity indices among the stations in the study area.

(CC= Carbyns Cove; BN= Burmanallah; KG= Kodiyaghat)

luster Analysis of Chiton

From the Bray Curtis similarity, it was observed that the species composition of CC and BN were almost same showing 87% similarity while species composition of KG was different from both the stations. Based on the presence or absence of species data, the study area grouped into 2 major clusters (Fig.5).

The species *C. imitator, Acanthochitona* sp.1 and sp. 2 were common in St.1 and St. 1, 2, and 3 represented *Acanthopleura spiniger*, *Acanthopleura* sp.2, *Ischnochiton bouryi* and *I. winckworthi.* The species *Acanthochitona* sp.3 was observed only in St. 1 and *Acanthopleura* sp.1 and *Mopalia hindsii* were observed only in St. 3.

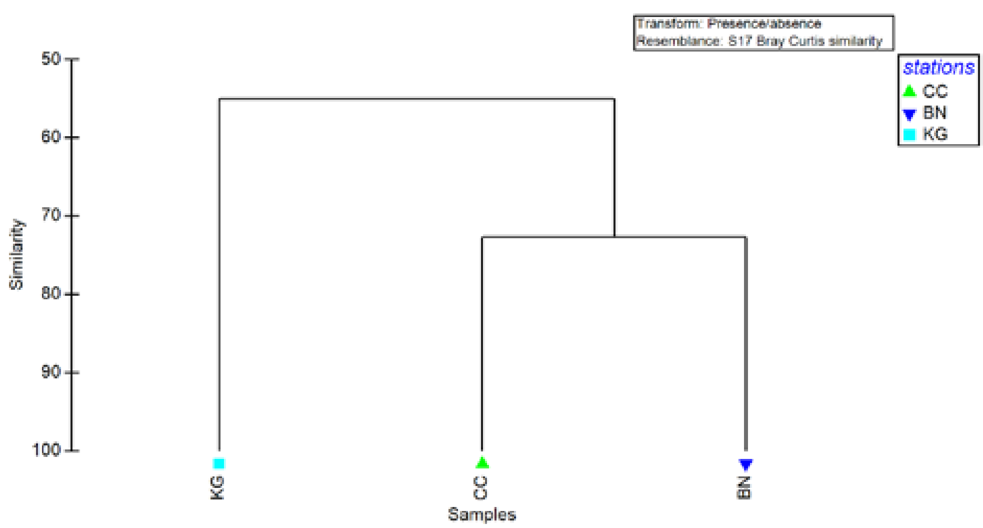

Fig.5. Bray-Curtis Similarity showing the formation of groups between stations in the study area.

CC= Carbyns Cove; BN= Burmanallah; KG= Kodiyaghat

Discussion

A total of 17 species were observed, among them 14 species were confined to the 5 genera in the present study. Two species were identified upto the level of Family and one species were not identified beyond Class. The species *Acanthopleura spiniger* was the most common species found in Kodiyaghat (St.3) and Burmanallah (St.2) followed by *Ischnochiton winckworthi* at Carbyns Cove (St.1). The species of *Acanthopleura spiniger* showed higher abundance in St.3 while St.2 showed higher diversity and abundance of the whole chiton population.

High number of species were observed in St.2 (S= 13) and St.3 (12) where algal patches were abundant. This is indicating that the access to availability of food is the major sourced for high abundance. Furthermore, chiton species at St.2 and St.3 in this study were usually exposed during the low tide in moist areas, signifying the need of O_2 that are utilized by the large surface area of gills allowing them to respire in air by direct diffusion (Eernisse and Reynolds, 1994). The forward growth of the tegmentum in the larger chitons are correlated with the erosion of the superimposed umbo (Leslie and Crozler, 2010). The high chiton assemblage, abundance and species richness at St.3 (N= 134) also tallies to the type of substrata present at the stations i.e., high number of hard rock boulders compared to other stations, which has soft and brittle rocks. The variable pattern of species aggregation on different types of rocks as found in this study has also been carried out in Australia by Liversage and Benkendroff (2013). Relatively high species richness (d=2.64) and low evenness in chiton species distribution (J=0.6) at St.2 was found which could be due to the dominance of few species such as *Acanthopleura spiniger, Acanthopleura* sp.2 and *Chiton imitator* as found in this study has been reported earlier from this area (Tikader et al., 1986).

Out of the 17 species of Chitons observed in this study, *Acanthopluera* sp., especially the larger size ranging from 7.00 - 7.20 cm were found. Bigger sized chitons in the present study had more barnacles attached to its shell valve.

Conclusion

It can be concluded that chitons are an ecologically important species of the intertidal zones of the South Andaman Islands. Hence, a continuous monitoring of chitons from these areas will help in better understanding of the distribution, diversity and ecological role of this mollusk.

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a. *Acanthopleura spiniger*

b. *Acanthopleura* sp. 1

c. *Acanthopleura* sp. 2

d. *Chiton imitator*

e. *Chiton* sp.

f. *Ischnochiton* sp.

g. Spiny girdle of *Acanthopleura spiniger*

h. Radula of *Acanthopleura spiniger*

i. Gills of *Acanthopleura spiniger*

Fig. 6. Photographs of the Chitons recorded in the study area

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Dietary preference of three species of *Periophthalmus* from the mangrove swamp of South Andaman

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Abstract

The dietary preference of three major *Periophthalmus* sp., found along the mangrove swamps of South Andaman coast were studied for gut content analysis by using Point and Frequency of occurrence methods. The analysis of gut content for all the three species of mudskippers revealed that the main food preference were either diatoms or algae, hence linking the relationship of mudskippers as primary consumers feeding directly on the primary producers in the food chain and also their carnivorous mode of feeding on the crustaceans and other polychaetes as a secondary consumers. The interaction of *Periophthalmus* sp., with crabs further streamlines on the ecological niche of mudskipper in the mangrove ecosystem.

Keywords: *Periophthalmus, Dietary Preference, Mangrove Swamp, South Andaman.*

Introduction

Mudskippers are benthic fishes belonging to the family Gobiidae (Order Perciformes). They thrive in the tropical and subtropical waters of wide salinity range inhabiting tidal mudflats, estuaries and mangrove swamps. Mudskipper possess frog- like protruding eyes, torpedo- shaped body, muscular pectoral fins. These special pectoral fins generally help them not only to skip or jump in the muddy swamps of the intertidal zones but also help them to climb upon the mangrove trees for an extent (Clayton, 1993). They are detritus feeders, mainly feeding on insects, benthic diatoms, algae, crustaceans, polychaetes and other small fishes. Unlike other fishes it is an amphibious fish which can survive on terrestrial habitat, as well as in the water. Since it lives in the muddy substratum, the oxygen content and the water percolation is less. It breathes by using gills, mucous membrane in the mouth and throat and through the dense network of blood capillaries in the skin, which holds moisture to survive in such a harsh condition. They usually make burrows of 'J', 'U' and 'V' shapes to lay eggs and escape from predators (Lee et al., 2005; Kim et al., 2011).

Diet of a fish represent an interaction among many ecological components depending on the behavior, habitat, energy flow, food chains and inter/ intra-specific interactions (Chesson, 1983). The study on food habit of the mudskipper also provides valuable information regarding its food preference, the nutrition and relative importance of each food items selected by the fish. The literature review suggested that the study of eco-biology of mudskippers from this area is meager.

Material and Methods

Andaman and Nicobar group of islands located about 1,200 km away from mainland India situated at 6°45′ N to 13°45′ N and 92°10′E to 94°15′ E covers a coastline of 1,962 km and the exclusive economic zone (EEZ) comprising of 0.6 million km^2, which is 30% of the Indian EEZ (Anon, 2008).

Sampling Stations

Station 1 - Carbyns Cove

Carbyns Cove is located at 11^0 38.482′ N and 092^0 44.528′ E. This area is muddy and flourished with mangroves. Mudskippers abundance is high in this region and mostly found on the underside of the resting boats.

Station 2 - Burmanallah

Burmanallah is located at 11^0 33.569′ N and 092^0 43.781′ E. It is basically a rocky beach lined with abundant mangroves where small streams of fresh water join the sea. The abundance of *Rhizophora* sp. in the present sampling site showed high occurrence of mudskippers that were found resting on the network of prop roots.

Station 3 - North Bay

North Bay is located at 11^0 43.112′ N and 092^0 44.626′ E, covering a large patch of coral reefs along with rocky intertidal zone lined by vast area of mangrove vegetation in the muddy base.

Sampling Method

Sampling was carried out in January and February, 2017. Scoop nets (net mouth: 30cm x 30cm; mesh size: 200µm) were operated during low tide. At St. 1 and St. 2, the quiescent mudskippers that were attached on the resting surface were disturbed from the front allowing the fish to somersault backwards into the scoop net that were kept underneath. At St. 3, scoop nets were kept on both sides of tide pools. The tide pools were disturbed, upon which the mobilized fishes were scooped from the tide pool. Cast net (mesh size 1cm) by the fisherman was mainly operated during high tide in all the stations. Due to the mesh size, it captured only the adults and sub adults. Thus, an approximate of 30 adult mudskippers of each species was collected from all the three stations.

Laboratory analysis

All the collected fishes were separated into adults and sub adults in the laboratory. The total length and standard length of all the specimens were measured to the nearest millimeter by using a measuring board. Before the dissection of the specimen, photographs were taken so as to incur accurate pictorial reference for further study. Fish morphometric was analyzed and the specimens were identified up to species level by using identification keys (Murdy, 1989; Rao et al., 2000; Munro, 2000; Larson and Murdy, 2001). Specimens were selected for gut content analysis. Each specimen was weighed before dissection; the dissected stomachs were weighed and then placed in a petri dish and added 1 ml – 2 ml of fresh water for neutralize the formalin to make it working condition. Then, each stomach as slit open and contents were removed by scraping the inner wall of the stomach and weighed. The content was transferred into petri dish along with some distilled water and spread by constant rotating. Analysis of the gut content was done by using a compound microscope (Magnus MLX) and number of dietary components was recorded from each sample.

Data analysis

Two standard qualitative methods was also used to study the gut content analysis of mudskippers, i.e., the Frequency of Occurrence Method (Hynes, 1950; Hyslop, 1980) and Point Method (Swynnerton and Worthinton, 1940). A combination of both these methods was used in this present study, so that one method could nullify the disadvantage of the other.

Results

A total of three species- *Periophthalmus argentilineatus, P. minutes* and *P. kalolo* of mudskippers were identified from study areas.

Systematics

Class - Actinopterygii

Order - Perciformes

Family - Gobiidae

Genus - *Periophthalmus*

Species - *Periophthalmus minutes* Eggert, 1935

Common Name - Minute mudskipper

Location: - Carbyns Cove

Habitat: Marine, brackish, demersal tropical and mangrove swamps and estuaries

Distribution: Western Pacific, Andaman Islands, Thailand, Australia, Indonesia

Fig. 1. *Periophthalmus minutus*

Species description: Fin Formula: D. X- XII, 11-12; A. XI-XII; P. 10-12; Ls. 62-78. Standard length- 4.2 cm, Total length- 5 cm, dorsal spine 10-12, dorsal rays 11-12. Body moderately elongate, compressed; head slightly compressed, profile of snout steep, dermal cup like process each jaws, pelvic fins almost separated, fraenum absent, scales on head and body cycloid, no sensory canals and pores on the head, head and body dark brown, with dusky saddles; first dorsal fin reddish with numerous white spots and white distal margins, second dorsal fin reddish with brown stripes at the middle of fin (Fig.1).

Species - *Periophthalmus argentilineatus* Valenciennes, 1837

Common Name - Barred Mudskipper

Location - North Bay

Habitat: Marine, brackish, demersal tropical and mangrove swamps and estuaries

Distribution: Indo- Pacific, Southern Red sea to South Africa, East to the Marianas and Samoa, North to Ryukyu islands, South to Western Australia and Oceania.

Fig.2. *Periophthalmus argentilineatus*

Species description: Fin Formula: D. XII- XIV, 10-12; A. X, 12; P. 12-14. Standard length- 5.5 cm and Total length- 6cm. The ventral fin lack of fraenum, first dorsal fin margin convex, and both the dorsal fins separated. Body brownish, silvery and white ventrally, numerous white spots on the head and few on the trunk: trunk with narrow silvery bars, first dorsal fin with prominent black infra marginal bands and below white spots. Middle of the second dorsal fin with wide black spots; caudal fin with brownish red spot (Fig.2).

Species - *Periophthalmus kalolo* Lesson, 1831

Common Name - Common mudskipper

Location - Carbyns Cove, Burmanallah and North Bay

Habitat - Marine, brackish, demersal tropical and mangrove swamps and estuaries

Distribution - Indo- Pacific: East Africa to Samoa, Andaman Islands

Fig. 3. *Periophthalmus kalolo*

Species description: Fin Formula: D.XI-XII, 12; A.I, 12; P.12-13; VI; Ls. 72-74. Standard length-6 cm and Total length- 6.5 cm Pelvic fraenum vestigial; First dorsal fin widely separated from second. Body grey; head with numerous white spots antero- ventrally; trunk with black flecks; faint brown saddles dorsally; margins of the dorsal spines white; prominent black stripe infra- marginally, fin with many grey spots all over (Fig.3).

Gut Content Analysis

Frequency of occurrence of all the three species in a single plate depicting that *P. kalolo* gut has highest diatom content (100%) followed by *P.minutus* (84%), but in case of algal fragments *P. minutes* showed the highest (92%) followed by *P. argentilineatus* (80%) [Fig. 4].

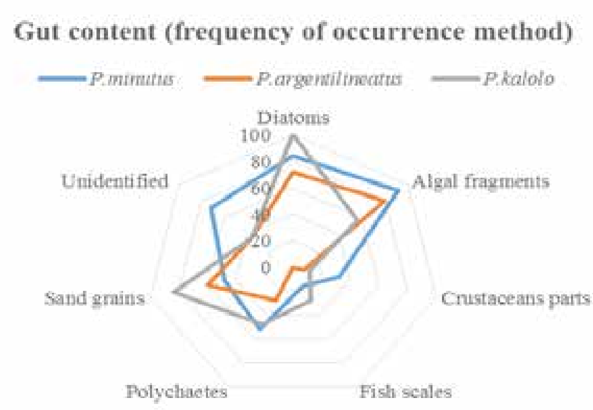

Fig. 4. Gut content of all the three species using Occurrence method

Points gained (using point method) of all the three species in a single plate depicting that *P. minutes* has highest diatom content (69%) followed by *P. kalolo* (23.76%) and *P. argentilineatus* (16.48%) and in case of algal fragments *P. minutes* also showed the highest (81.72%) followed by *P. argentilineatus* (29.8%) and *P. kalolo* (16.04%) [Fig. 5]

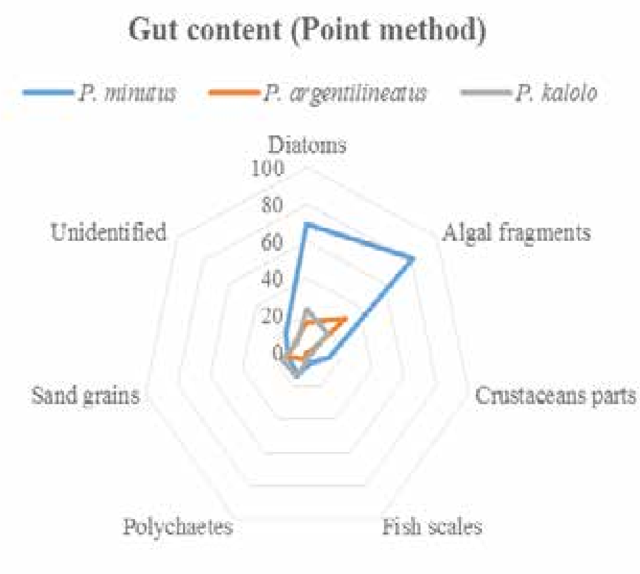

Fig.5. Gut content of all the three species using Point method

Animal association of mudskippers

The rock crab, *Grapsus albolineatus,* when seen resting on the rocky patches or tide pools covered with macro algal mats, the mudskipper were always found to be in the nearby vicinity. The crab upon feeding, tears the thallus into small pieces and feeds on it. On one occasion, while the crab moved away from the feeding site, the mudskipper started to feed on the spilled algal fragments. This type of commensal behavior was observed in St.1 and St.2 during the study period.

The *Uca tetragonon,* which is very common in the mangroves of South Andaman was also observed to have an interesting association with the mudskipper. *Uca* feeds on the humus deposits in the mangrove areas. Once this thick deposit of humus is ploughed and made into small fragments by the slitting activity of the *Uca*, the mudskipper thereby feed upon the detritus.

Discussion

The frequency of occurrence method used in this study revealed that *P. minutes* is an omnivorous fish feeding mainly on algal fragments (92%) conspicuously, followed by diatoms (84%), indicating their primary diet preference relying more over plant materials. The very small percentage of fish scale are found in traces in the gut content indicated its feeding on other small fishes as well. Frequency of occurrence method for *P. argentilineatus* revealed that the preference of algae (80%) and benthic diatoms (72%) as its main food items. Subsequently to the plant components, sand grains were found more in percentage (60%) which might have been consumed while feeding on the detritus. The very interesting fact with this species was that, there were no trace of fish flesh or scales in all of the specimens dissected, indicating that this species might not be feeding upon other fishes. The appendages of crustaceans were only 8% which showed that it can be an alternative or accessory food item as observed in this study has been reported for this species (Clayton, 1993).

P.kalolo diet content was quite different from the other two species. Both the occurrence and point methods of the gut content analysis in this study showed that the main food item of this species was benthic diatoms (100%), followed by sand grains (84%) as accidental food item, revealing that this species of mudskipper is more of a benthic feeder. Algal fragments (56%) was found in the gut content, indicating that *P. kalolo* may come to surface and feed on the algae when the main food source is not available as witnessed in this study has been reported (Polgar and Crosa, 2009).

The association between *Uca tetragonon* and the mudskipper showed that they are commensal. The association between the mudskipper and rock crab was mostly observed during the morning hours (low tide), especially in the tide pools. *Periophthalmus kalolo* was found to have this kind of interaction which was collected at St.3.

Conclusion

Analyzing results channeled to the conclusion that, the mudskippers are omnivores which feeds upon mainly plants components like diatoms and algae, without compromising its carnivorous nature, where small crustaceans and polychaetes were also incorporated as part of their diet. The sand grains and other detritus found in its diet indicate its bottom feeding nature. This study highlights the omnivorous feeding of mudskipper rather than carnivorous as reported earlier elsewhere.

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Biology of *Atule mate* (Cuvier, 1833) with a note on species composition of Carangid landings from South Andaman coast, India

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Abstract

Andaman and Nicobar islands are reported to have 48 species of the family Carangidae under 13 genera. The present study has recorded 18 species under 12 genera. *Atule mate* is an important fishery resource along with the other scads coming under the genus *Selar*. The species is mostly caught and marketed with the scombrid *Rastrelliger* sp., the Indian Mackerel and other carangids mainly *Selar crumenopthalmus* and *Selar boops*. The study has showed that the dominant size group of *A. mate* in the landings was 191-210 mm. The length weight relationship analyses showed isometric growth. The diet composition of *A. mate* mainly consisted of copepods, shrimps, small fish and gastropods which was analysed on the basis of its gut contents. Based on the condition of gut contents, it could be ascertained that it swallows prey as a whole. The mature fishes were found mostly in the length class 231-250 mm, but few female specimens with mature ovaries were also observed in the length classes 170-190 mm and 191-230 mm. The mature specimens were observed to have a low gastrosomatic index. The present study recorded 19 species belonging 13 genera of the family Carangidae in Junglighat fish landing Centre. The species *Caranx ignobilis* (18.9%), *C. melampygus* (18.6%), *Atule mate* (17.8%), *Selar boops* (9.3%), *S. crumenophthalmus* (7.1%), *Carangoides talamparoides* (6.9%) and *C. malabaricus* (5.2%) are the major contributors for the Carangidae fisheries of Andaman waters.

Keywords: *Carangidae, Marine Fish Landings, South Andaman, Atule mate, Fish Biology*

Introduction

Andaman and Nicobar Islands have coastline of 1926 km and the Exclusive Economic Zone around these islands is 6,00,000 sq km forming 28% of the total EEZ area of the country (Rajan et al., 2013). Fish fauna of Andaman and Nicobar consists of an assemblage of about 1463 species spread over all the diverse habitats representing 586 genera belonging to 175 families (Rajan et al., 2013). FisherY is an important food resource as well as livelihood for the Bay islands. Carangids are marine pelagic fishes inhabiting in Atlantic, Indian and Pacific Oceans and include jacks (*Seriola* spp.), pompanos (*Alectis* spp.), trevallies (*Caranx* spp., *Ulua* spp.), runners (*Elegatis* spp.), scads (*Atule* spp., *Selar* spp.) and fast swimming predatory fishes (Froese et al., 2013). Carangids are highly favored food fish among the local community because of its taster meat, high nutritional value and year round availability. A total of 146 species reported so far belonging to 30 genera under the family Carangidae worldwide. Sixty two species were reported from Indian coast which includes 14 major species of commercial importance. The gears used for exploiting carangids are mainly trawl net, gillnets, hook and line, long lines and different types of seine nets. Carangids primarily feed crustaceans, fishes, with an interspecific interactive behaviour with the labrid wrasse *Bodianus rufus*.

The carangid species *Atule mate* commonly known as yellowtail cad ('Topi' locally) inhabit mostly mangroves, coastal bays and coral reefs and are mostly diurnal and most of the time found in schools. These fishes are fast swimmers and their diet mainly consists of small fish, crustaceans and cephalopods. The importance of studying exploited resources of carangids can help the fishery managers to get an overall idea about the changes in their significance, biomass and stock characteristics for better management and sustainable yield. The life history traits of the exploited marine species must be studied to understand the changes happening to the stock due to the commercial exploitation.

There are several studies conducted on the biology of carangids from Indian waters. Length-weight relationship including food and feeding habits of Indian Scad *Decapterus russelli* from the North west coast of India was studied by Jaiswar et al. (1993); reproductive biology of horse mackerel or torpedo scad *Megalaspis cordyla*; preferring planktonic crustaceans and fish juveniles (Sivakami, 1997). There are other studies also on these species except *Atule mate* ((Murty, 1991; Reuben et al., 1992; Sunil and Suryanarayanan, 1994; Moiseeva and Zhuk, 1995; Tamhane, 1996; Raje, 1997; Manojkumar, 2007; Sajina et al., 2010; Jadhav and Mohite, 2013 and Ashwini et al., 2016).

Kingston et al. (1999) had given a general idea on the feeding habits and feeding intensity of *Atule mate* from Gulf of Mannar and shown that the species exhibited two type of feeding pattern in which juveniles mainly fed on crustaceans while the adults fed on fish. It could also found that there are no studies from Andaman waters on the fishery and biology of *A. mate* so far. So, the present study provides preliminary observations on the commercial landings of carangids and biology of *Atule mate* from Andaman waters.

Materials and Methods

Detailed survey of Junglighat fish Landing Centre was conducted following Mini et al. (2005) survey method. Species wise catch composition of family Carangidae recorded during the study. The specimens were photographed, collected and identified following standard identification keys (Fischer and Bianchi, 1984; FAO 1995). The yellowfin scad (*Atule mate*) species was studied for its biology. The details of crafts and gears used for carangid exploitation were recorded along with the geographical details (Latitude/Longitude) and depth (meter) of fishing ground.

The total length (TL) was measured using a digital Vernier calliper with 0.1 cm accuracy and total body weight (BW) was determined by an electronic weighing balance with 0.1 gm accuracy. The length frequency distribution was studied separately for male and female, following the methods of Sivakami et al., (1997) and Khan et al., (1993). The LWRs for species were calculated using the equation: $TW = {}_{a}TL^{b}$ (Le Cren, 1951), where TW is the total body weight (gm), TL is the total length (cm), ***'a'*** is a coefficient related to body form and ***'b'*** is an exponent indicating allometric growth. The parameters '***a***' and '***b***' were estimated by a simple linear regression after logarithmic transformation of weight and length data. Further, the co-efficient of determination (r^2) was calculated.

$$Log\ W = Log\ a + b\ log\ L$$

The gut content was analysed and the stomachs were visually classified as Full, ¾ full, ½ full, ¼ full, Trace and Empty (Kingston et al., 1999) to study feeding intensity. The gastro-somatic index (GaSI) was calculated following the formula:

GaSI = (Fresh weight of the stomach / Total wet weight of fish) X 100.

Stomachs were opened and the contents were separated into major forage categories. Food items were identified to the lowest possible taxon. The number of food items was counted separately and frequency of occurrence was expressed in percentage.

Study the reproductive biology, the gonads were examined while dissecting the fish and the fish was identified as male or female. Maturity stages were identified based on Poojary et al. (2015). The Gonado-Somatic index was estimated based on the following formula:

GSI= (Weight of the gonad / Total wet weight of the fish) x100.

Results

The present study evolved 19 species belonging to 13 genera of the family Carangidae from Junglighat fish landing Centre of Andaman Islands (Fig. 2). The major species contributed to fishery of Carangids were *Caranx ignobilis* (18.9%), *C. melampygus* (18.6%), *Atule mate* (17.8%), *Selar boops* (9.3%), *S. crumenophthalmus* (7.1%), *Carangoides talamparoides* (6.9%) and *C. malabaricus* (5.2%).

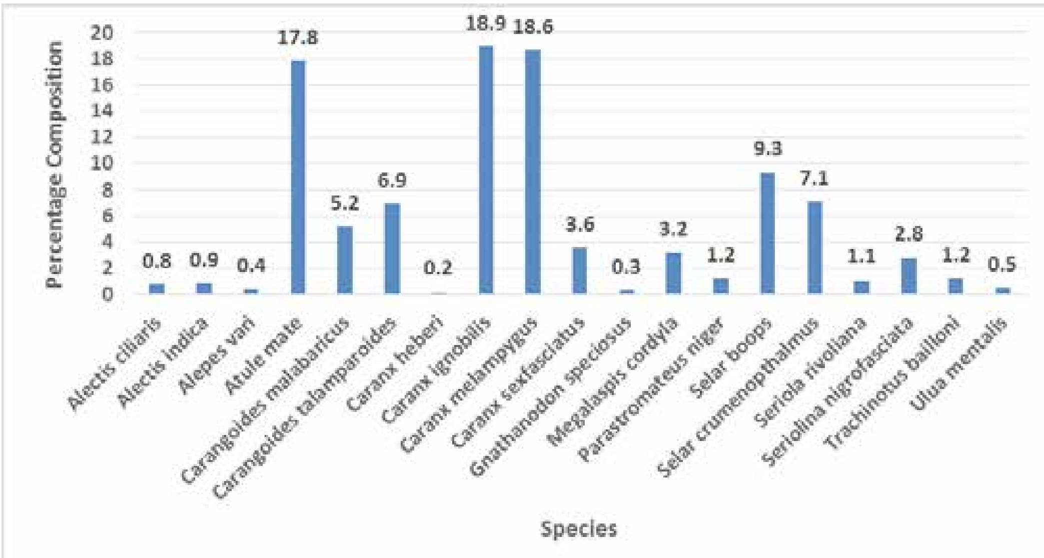
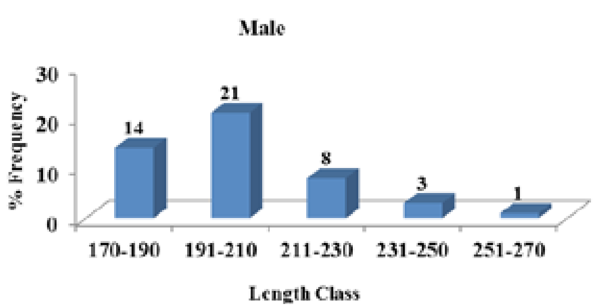


Figure 2. Composition of carangid landings at fish landings centre, Junglighat, Port Blair

The sex ratio observed for the studied species of *Atule mate* was 1 : 0.63 (M:F) significant in the lower length classes (170-190 mm and 191-210 mm) and was found to be insignificant overall as well as in the higher length classes (Table 1). The length frequency distribution analysis of *A. mate* showed that in males, the dominant length class was 191-210 mm followed by the length group 170-190 mm and the length classes 231-250 mm and 251-270 mm were the least (Fig. 3). The dominant length class for the females was also found to 191-210 mm, same as the males, followed by the length class 211-230 mm and the least from 170-190mm and 251-270 mm length classes.



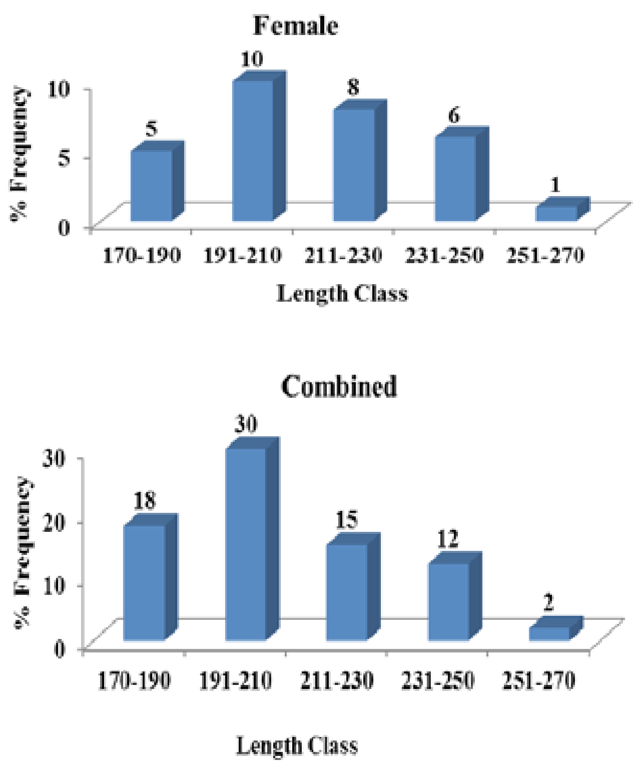


Figure 3: Length frequency distribution of ***Atule mate***

Table 1: Sex Ratio and Chi square analysis of *Atule mate*

Length group	No. of Fish	Males	Females	Ratio	Expected	Chi square	Significance
170-190	19	14	5	1 : 0.36	9.50	**4.26316**	S*
191-210	31	21	10	1: 0.48	15.50	**3.90323**	S*
211-230	16	8	8	1 : 1	8.00	0	NS
231-250	9	3	6	1 : 2	4.50	1	NS
251-270	2	1	1	1 : 1	1.00	0	NS
Overall	77	47	30	1 : 0.64	38.5	3.75	NS

*Significant

The length weight relationship analysis showed positive allometric growth (Fig. 4) for the species with b value more than 3 and the regression value was statistically significant in male, female and combined.

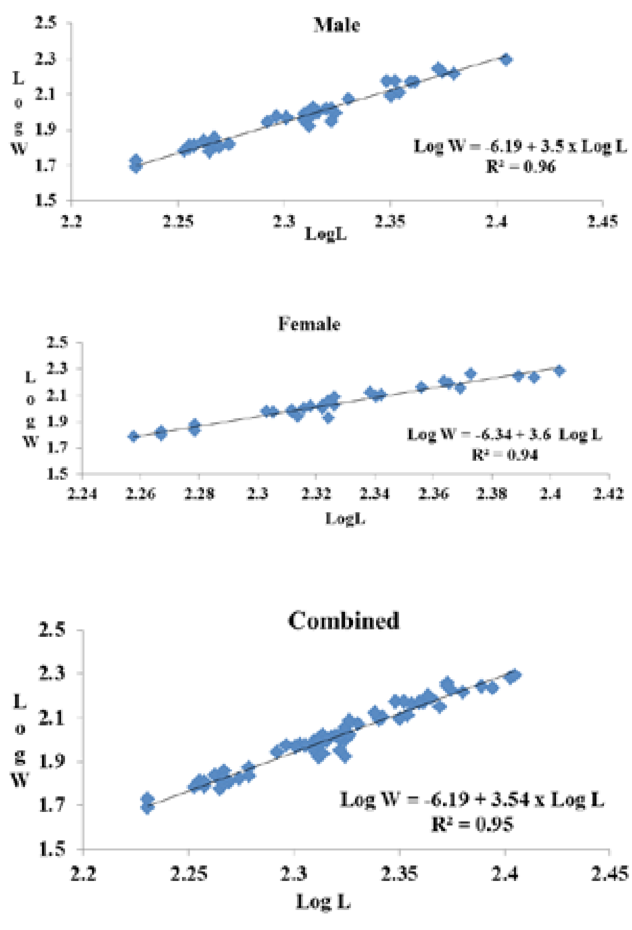


Figure 4: Length weight relationship of *Atule mate* (Male, Female and combined)

The regression equation for *A. mate* obtained is as follows:

Males : Log W = -6.19 + 3.5 x Log L

Females : Log W = -6.34 + 3.6 x Log L

Combined : Log W = -6.19 + 3.54 x Log L

Feeding intensity was observed to be higher for *A. mate* during the study with half (22.66%), full (21.33%) and three-fourth (21.33%) of stomachs (Fig. 5). The average GaSI in the length class 190-210 mm was found to be the highest (2.125), this was followed by the length class 211-230mm (1.701) and 170-190mm (1.606). Interestingly, the higher length classes 231-250 mm (1.247) and 251-270mm (0.968) have shown lowest GaSI (Fig. 6).

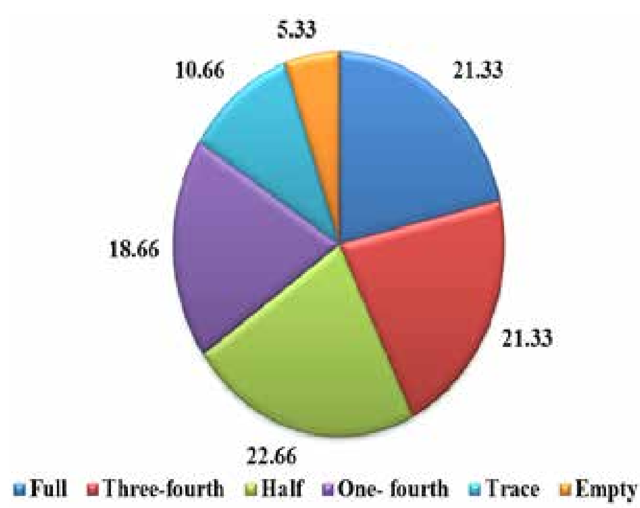


Figure 5: Feeding intensity for *Atule mate*

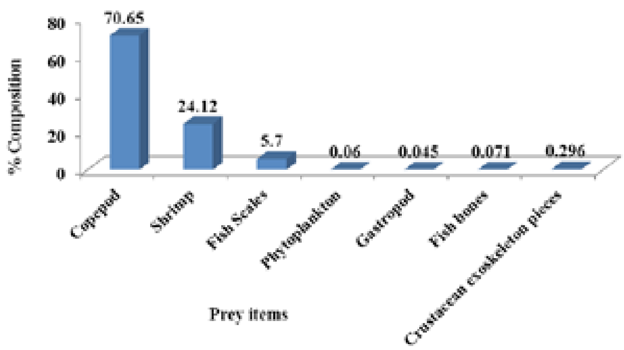


Figure 6: Food Composition of *Atule mate*

The gut content mainly consisted of copepods (70.65%), which were found almost intact with minimal digestion (Fig. 7). Shrimps (24.12%) particularly shrimp larvae, fish scales (5.7%) of large as well as extremely small sizes along with few fish bones and few pieces of crustacean exoskeleton were also found in the gut. The prey items that were found in least quantities were phytoplankton (0.06%) and gastropods (0.045%) the rest was digested completely.

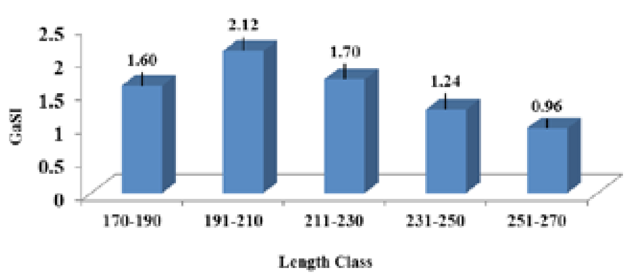


Figure 7: Gastrosomatic Index of *Atule mate*

The GSI was analysed according to the length class. The average GSI was the highest in the length class 231-250 mm (2.84) followed by the length class 251-270 mm (1.166). The first three length classes had the lowest average GSI (Fig. 8), which was 211-210 mm (0.471), 170-190 mm (0.455) and 191-210mm (0.403). The stages of maturity of *Atule mate* were analysed on the basis of length class (Fig. 9). Most of the specimens were immature or maturing in the lower length classes, whereas, mature and ripe stages dominated in the higher length classes. The specimens in ripe stage were only found in the 211-230 mm and 231-250 mm length class in males and females, respectively.

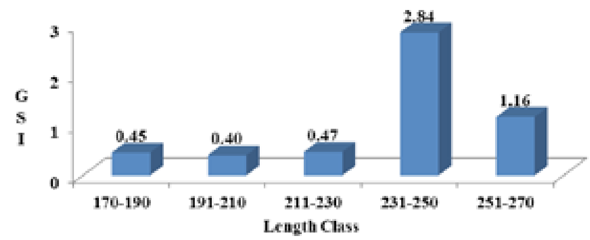


Figure 8: Gonadosomatic Index of *Atule mate*

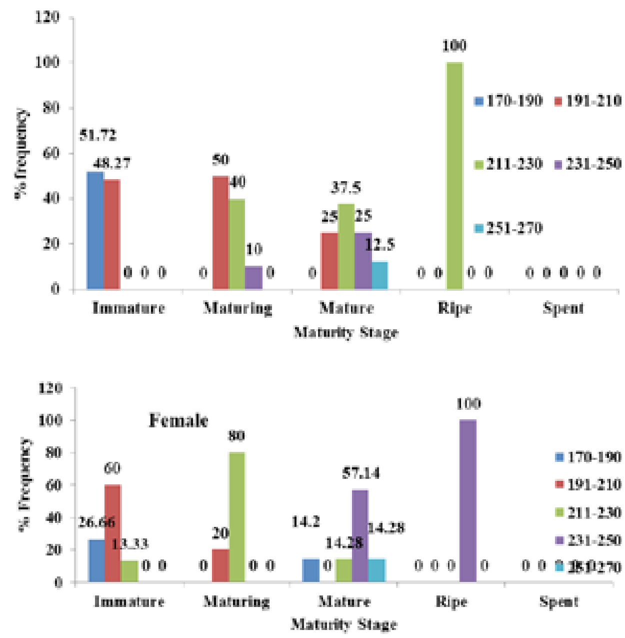


Figure 9: Maturity Stages of *Atule mate*

Discussion

The carangid landings in the Junglighat fish landing centre were mainly dominated by *Caranx ignobilis*, *C. melampygus*, *Atule mate*, *Selar boops*, *S. crumenophthalmus*, *Carangoides talamparoides* and *C. malabaricus.* It was interesting to observe from the present results that most of the carangids contributing to the fishery are medium or small species except *Caranx ignobilis*. This medium to small fishes contributed more to the local consumption. Mustafa (1983) have recorded *Selar* sp., *Decapterus* sp., *Elagatis* sp., *Caranx* sp. and *Megalaspis cordyla* were the major carangid landings in Andaman. *Carangoides malabaricus*, *Decapterus russelli*, *Alepes djedaba*, *Megalaspis cordyla*, *Caranx carangus*, *Selaroides* sp., *Alepes kalla*, *A. djedaba*, *Alectis* sp., *Scombroides* sp., *Elagatis* sp., and *Atule mate* were the most common carangid species contributing to fishery in other maritime states of India (Reuben et al, 1992; CMFRI, 2015).

The fishery of *Atule mate* was found to be dominated by 191-210 mm and male fishes. The length weight relationship have shown a positive allometry and hence showed a normal growth. The food preference of the species showed mainly of carnivory. Kingston et al. (1999) reported that the food preference of *A. mate* changed from crustaceans to fishes when it grows to adult. The present study could not find such variation, but studied fishes preferred a mixed diet. The smaller length group of fishes feed more than the higher length groups. The GaSI was found to be high in the lower length classes and less in the lower length classes which shows an inverse relationship with maturity in fish. While in the previous studies, it was found that the feeding intensity was comparatively less in *Decapterus dayi* and *Megalaspis cordyla* (Sreenivasaan, 1981a, b), *Alectis indicus* (Venkataramanujam and Ramamoorthi, 1983) and *A. mate* (Kingston et al., 1999), in general.

The maturity stages of most of the individuals were exhibited in the higher length classes (231-25-mm) and immature stage in the length class 170-190 mm and 191-230 mm. The absence of spent fishes in the landings and higher percentage of immature fishes could mean that spawning season is mostly towards the end of Pre-Monsoon (Inter-monsoon) season for this species in Andaman waters. Many carangid species from Indian waters show prolonged spawning seasons (Tiews, 1958; Tiews et al., 1975; Sreenivasan, 1981; Raje, 1997; Reuben et al., 1992; Murty, 1991; Manojkumar, 2007).

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Biology of *Gazza achlamys* (Family: Leiognathidae) from Andaman coast

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Abstract

The Family Leiognathidae has 17 species under 4 Genera in Andaman and Nicobar Islands waters. The present study focused on the fishery *Gazza achlamys* from the marine fish landings of South Andaman. *Gazza achlamys* was found to be most dominant fishery resource from this family. The size of the species contributing to the fishery ranged between 110 mm to 165 mm and was dominated by the size group 130-139 mm. Length Weight relationship showed more or less isometric growth. Mature specimens were observed between the lengths of 130-149 mm and it was dominated the fishery. The diet composition of *G. achlamys* mainly consisted of small fishes, worms, shrimps, and crustacean shell pieces. The mature fishes showed low gastro-somatic index. The present study on *G. achlamys* is the basic biology information of this fishery resource from Andaman and Nicobar Islands.

Keywords: *Gazza achlamys, Fishery, Biology, Andaman, Carangidae*

Introduction

Fishes belonging to the family Leiognathidae, are commonly referred to as ponyfishes, slipmouth or silver bellies (James, 1984). There are approximately 53 valid species containing six genera namely *Gazza, Leiognathus*, *Secutor, Photopectoralis, Photoplagios* and *Nuchequula* (Fricke et al., 2020). They are small in size, silver in colour and form large schools, active along open coastlines and in bays where water clarity is low (McFall et al., 1984). They are widely distributed in the coastal waters of subtropical regions (James, 1984). These fishes are generally recognized by their protractible mouth either in direction upward, forward or downward (Woodland et al., 2001; Spark et al., 2005). Ponyfishes are the most commercially important by-catch fishes in most of the fishery industry. They accounted for at least 20.1% of the demersal catch in South East Asia in 1976 (Pauly et al., 1979). Along the Indian coast, the silverbellies are abundant mostly along the south-east coast, especially in the Gulf of Mannar and Palk Bay (Devaraj, 1998, Nair, 2005). Silverbellies typically account around 4% of the total marine fish catch in India (CMFRI, 2019). Silverbellies form major fishery resources in the Indian marine fisheries sector and contribute to an important fishery in the states of Tamil Nadu, Kerala, Andhra Pradesh and Karnataka as well as in Andaman marine fisheries sector.

Members of the genus *Gazza*, with their canine teeth, feed on small fishes and shrimps. The size of the fish mouth type affect the feeding habit of silver bellies (Acharya and Naik, 2016). *Gazza achlamys* species was first time reported from entire Western coast of India in Cochin and Neendakara (Abraham et al., 2011a). There are few works conducted on the leiognathids from various parts of the country (Balan, 1963; Rao, 1967; James and Badrudeen, 1975, 1981; Jones, 1985; Murty, 1983, 1986 a, b, 1990; Jayabalan, 1986, 1988; Murty et al., 2003).

There are no concerted effort on understanding the fishery and biology of fishes from Leiognathidae from Andaman waters other than species documentation (Rajan et al., 2013). The present study gives an insight on the fishery and biology of this important family from this data deficient region.

Material and Methods

The study was conducted based on the marine fishery landings at Junglighat Fish Landing Center, which is the largest and most active fish landing center in South Andaman during the Pre-Monsoon (Inter-monsoon) season during 2018-19. Photographs of Leiognathidae species were taken from the landing center and market during each visit. The specimens were brought to laboratory for further identification as described by the authors James (1984) and Abraham et al., (2011a).

A total of 95 individuals of *Gaza achlamys* (Fig. 1) consisting of 38 males and 57 females were analysed during the present study. Length frequency and the Length Weight relationship of *Gazza achlamys* was studied to understand the size group contributing fishery and its growth pattern (Jayabalan and Bhat, 1997; Sivakami et al., 1998). Total length (L) (From tip of snout to the end of the caudal fin) was measured using digital Vernier caliper with 0.1 cm accuracy and total weight to nearest gram was also measured using an electronic weighing balance with 0.1 g accuracy and recorded. The sex wise and combined length weight relationship was calculated using the equation: **$W={}_aL^b$** (Le Cren et al., 1951; Abdallah., 2002; Krishna et al., 2015).

Figure 1: *Gazza achlamys*

Where W= Total weight (gm), L= Total Length (mm),'a' is an intercept and 'b' is the slope.

The fishes were dissected and stomach was separated and weighed. The dissected stomach was classified visually as empty, trace, ¼ full, ½ full, ¾ full and full (Sivadas and Bhaskaran, 2009) based on the distension to understand the feeding intensity. Contents of the dissected stomach were taken on a watch glass and separated on the basis of size and food items. The same were identified to the lowest taxon possible.

Gastro-somatic index (GaSI) was calculated by using following formula:

GaSI= (Fresh weight of the stomach / Total wet weight of fish) X 100 (Sivadas and Bhaskaran, 2009)

Food items were studied under microscope and identified to record type of food present (Jimmy et al., 2003). The number of food items were counted separately and recorded.

Study the reproductive biology, gonads were examined and sex wise maturity stages and gonado-somatic index were determined (immature, mature, mature, ripe and spent) based on Qasim (1973); Crossland (1977) and Ismen (2003).

Gonado-Somatic Index (GSI) was calculated as follows:

GSI= (Fresh weight of the gonad / Total wet weight of fish) X 100

Results

Length Frequency and Length Weight Relationship

The overall sex ratio observed (females to male) was 1:1.5 for this species, during the study**.** The size contributed to fishery of *G. achlamys* ranged between 110 mm and 169 mm, and 130-139 mm (32.6%) was observed to be dominant (Fig. 2) with 39.5% in males and 28.1% in females. Length frequency for the male, ranged between 110 mm to 159 mm, comparatively lower than the females (110 to 169 mm). The females were more in the higher length classes. Length-weight relationship of *G. achlamys* was studied for combined and also sex wise (males and females separately). The scatter diagram was plotted following regression value and b value calculated presented in Fig. 3. Results have shown that b value for combined (3.4), males (3.1) and females (3.4) are significantly different from the isometric value 3 and indicated positive allometric growth. Also, there were no significant differences among the sexes (ANCOVA, $P>0.05$).

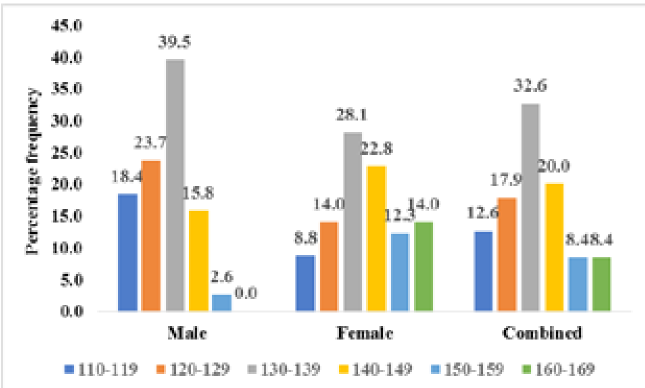

Figure 2. Length frequency of *Gaz*

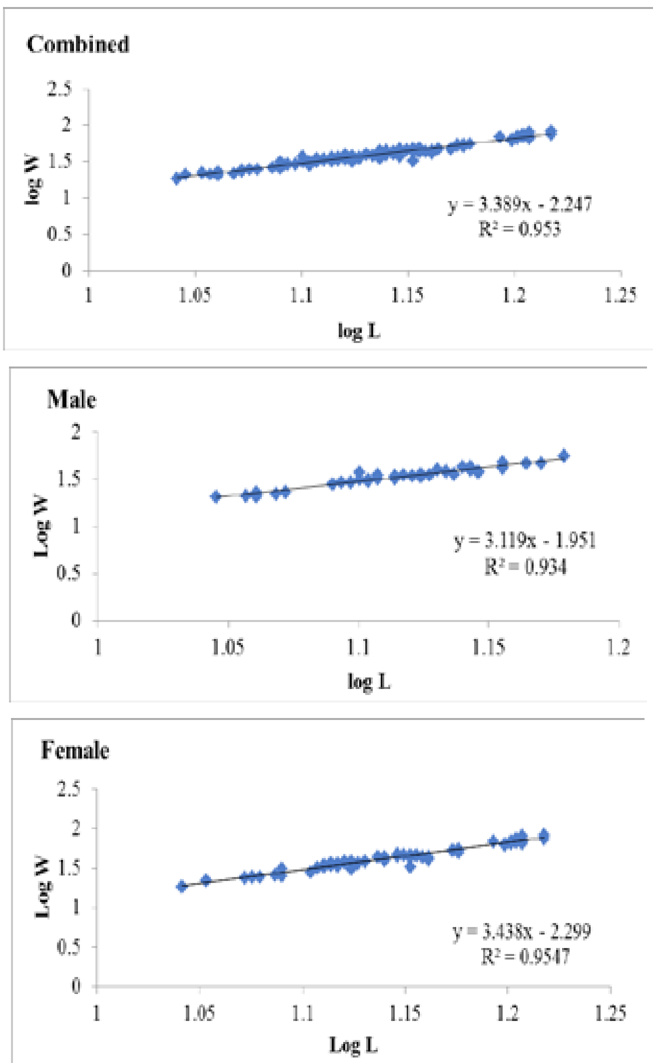

Figure 3: Length weight relationship of *G. achlamys*

The estimated length-weight relationship of G. achlamys is given below:

Length-weight relationship (Pooled) Log W = 3.4 Log L – 2.25

Length-weight relationship (Males) Log W = 3.1 Log L – 1.95

Length-weight relationship (Female) Log W = 3.4 Log L – 2.29

Food and Feeding Habits

The dietary observation on *G. achlamys* revealed average feeding intensity during the period of study and was confirmed from the highest percentage of one-fourth (41.1%) and half (28.4%) filled stomachs (Fig. 4). Feeding intensity was found to be higher in females in comparison to males, where full, half full and three-fourth full stomach were recorded more. The length class analysis showed higher feeding rate in the small sized fishes in length class 110-119 mm (Fig. 5), where more fishes were observed with ½, ¾ and Full stomachs. Less feeding intensity was observed in the average sized fishes (120-149 mm) and average feeding intensity was shown by higher sized individuals (15-169 mm). The length class based gastro somatic index analyses have confirmed the trend in feeding intensity (Fig. 6). The average gastro somatic index in the length class 110-119 mm was found to be the highest (2.5485). This was followed by the average GaSI of length class 160-169 mm which had the average GaSI (2.28). Length class 140-149 mm had the lowest average GaSI that is (1.606). The study showed that the prey composition of *G. achlamys* mainly consisted of fish spines (47.6%) and small fishes (22%). The other prominent food item was worms (20.7%), which were found as a whole with minimum digestion. Shrimps and crustacean exoskeletons pieces were found in trace quantities. Sex wise analyses have shown that female fishes prefer small fishes while males showed more or less equal preference to small fishes and worms (Fig. 7).

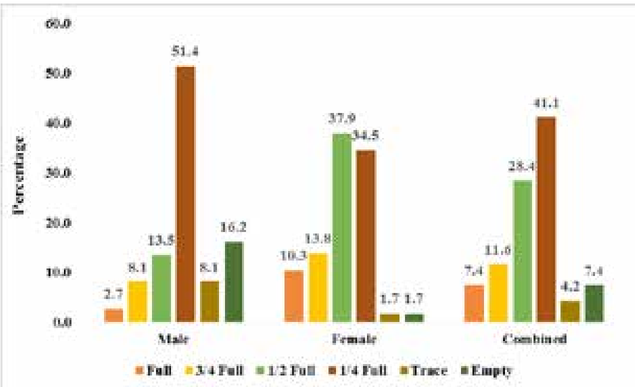

Figure 4: Feeding Intensity of *Gazza achlamys*

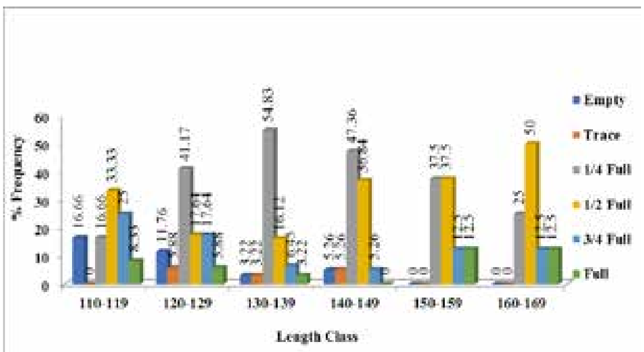

Figure 5: Feeding intensity of *Gazza achlamys* according to length class

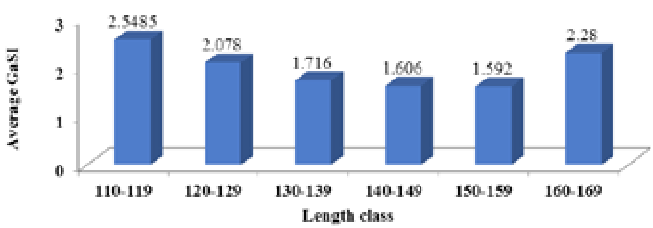

Figure 6: Gastrosomatic Index of *Gazza achlamys*

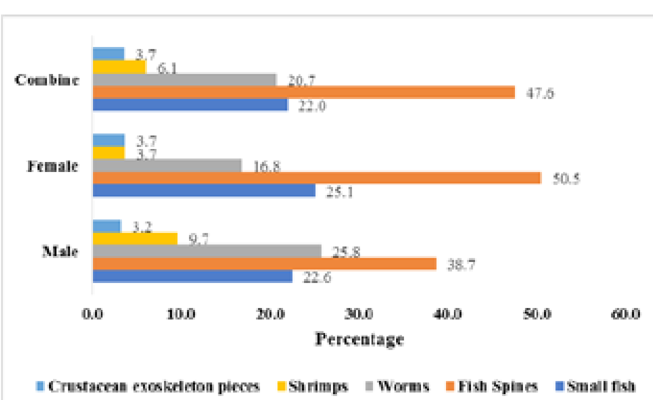

Figure 7: Food composition of *Gazza achlamys*

Reproductive Biology of *Gazza achlamys*

Gonado-somatic index based on length class (Fig. 8) have shown an increasing trend to the higher length groups. The GSI was highest (4.1) in length class 160-169 mm and 110-119mm had the lowest average GSI (0.7). Analyses of maturity stages of *G. achlamys* have shown that the landings is mostly dominated by individuals of maturing stage (Fig. 9) in both males (24.24%) and females (18.94%). Interestingly, the ripe individuals were found only in females and no spent individuals were recorded during the study. This is in accordance with the GSI calculated for the species. Length class based analysis have shown that maturing stage dominated in males with an increase in percentage from the length class 110-119 mm to 13-139mm and decreased (Fig. 10). Mature stages were very less in all length classes and ripe stage absent in males. The females during matured stage dominated in the higher length classes and ripe females were found only in the higher length classes.

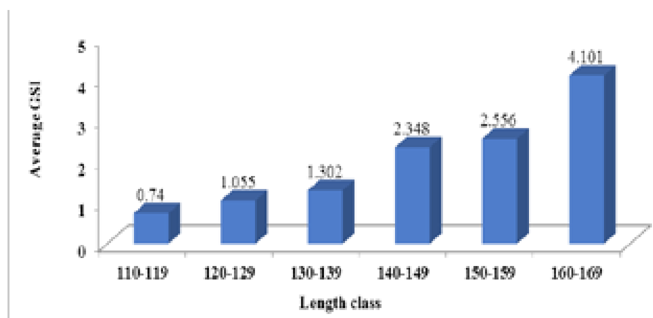

Figure 8: Gonadosomatic Index of *Gazza achlamys*

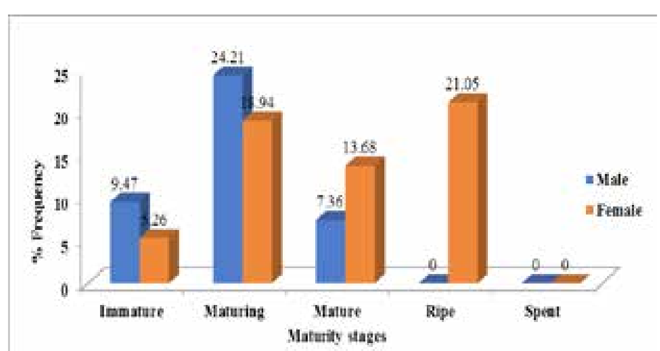

Figure 9: Maturity stages of *Gazza achlamys*

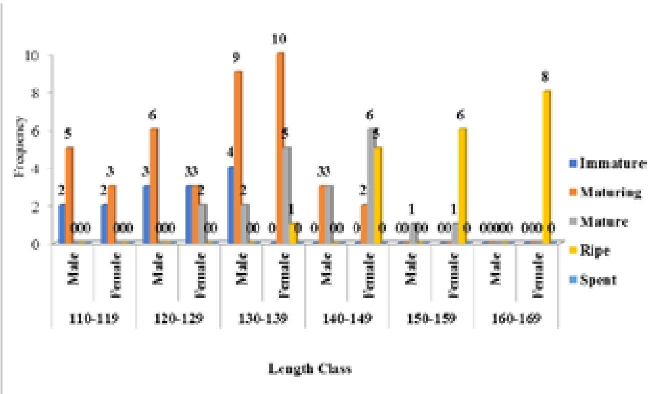

Figure 10: Length class wise maturity stages of *Gazza achlamys*

Discussion

The most dominant length class of *Gazza achlamys* was observed in between 130-139 mm for both the sexes. Length frequency for male ranged between 110-159 mm, which was lower than female 110-169 mm and LWR of this species followed positive allometry growth. Earlier literature (Froese and Pauly, 2019) on biological aspects of *G. achlamys* revealed that maximum length for species were recorded 170 mm and most common length were recorded as 120 mm for males and females. However, the most dominated length from present study showed 130-139 mm which is comparable with earlier recorded data. Studies on other species from the family from south east of Peninsular Malaysia coastal waters (Seah et al., 2009) have shown that the average lengths were comparatively less for *Photoplagios stercorarius* (10.218 cm), *P. bindus* (6.706 cm), *Secutor insidiator* (7.654 cm), *Gazza minuta* (8.802 cm), *Leiognathus fasciatus* (11.127 cm), *L. equilus* (9.385 cm). Jayabalan (1988) recorded 96-105 mm as the most dominating length range of *Gazza minuta* from east coast of India. Previous literature (Froese and Pauly, 2019) also indicated, LWR for *G. achlamys* revealed slightly negative to positive allometry growth with b value was 2.98 (2.80 – 3.16). The results from the present study showed the positive allometry, for which, the b value recorded for pooled (3.39), males (3.11) and females (3.43). Seah et al. (2009) reported 2.211 ± 0.507 for *Gazza minuta*, with a negative allometric growth from southern coast of India.

Leiognathids fed on a variety of food materials, which includes detritus as a major portion with polychaetes, prawns, crabs, fish larvae, copepods, euphausids, ostracods, gastropods, amphipods, etc. (Tiews et al., 1968; James, 1984; Seah et al., 2009). Earlier available literature on feeding habits for *G. achlamys* reported generally feeds on crustaceans, small fishes and polychaetes. The qualitative analysis of food and feeding habit in *G. achlamys* indicated that, the species is carnivorous and the main food included small fishes and worms. This study showed that the fishes from length class 130-139 mm or maturing fishes had highest percentage of ¼ full stomach. Where a lot of stomachs of juveniles and adults were found to be ½ full, ¾ full and completely full compared to other fishes. Hence, juvenile, adult male and female had high feeding intensity. Variation occurred in present study of *G. achlamys* had maximum number of ¼ full stomachs, followed by ½ full stomachs. The gastro somatic index was found to be highest in length class 110-119 mm and then in length class 160-169 mm which coincides with the fact that juvenile and adults had full stomach.

Studies on reproductive biology of *G. minuta* from Indian coast provided by Jayabalan, (1988) revealed maturity stages to determine length at first maturity where it was indicated that males mature between 81 to 116 mm total length while females mature between 91 to 121 mm total length and gonadosomatic index for the species where females were observed higher indices than males. Comparison to present study on maturity stages of *G. achlamys* were found such as immature, maturing, mature and ripe. The present study supports the previous work for the species *G. minuta*, where the length of mature fishes were slightly more but in case of *G. achlamys*, it was found that most of the mature individuals were observed between 140-149 mm total length. Reproductive biology of the selected species of ponyfishes by Seah et al. (2009) showed that the gonads were mono-lobed with maturing and matured oocytes stages and mean value of GSI for *Gazza minuta* was 0.382 ± 0.070. From the present study, the gonadosomatic index observed was more in ripening stages followed by mature as reported by Jayabalan (1988) for *G. minuta*. The present study of *Gazza achlamys* showed the ripe females were maximum in number, followed by maturing females in the month of

January. Based on the report of Jayablan (1986, 1988) *Leiognathus splendens* showed maximum females were immature, whereas maturing and ripe stages were not recorded. This information suggested that the maturation for Leiognathids species were not in the same periods.

Acknowledgements

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Biofuel potential of some seaweed species from the Coast of South Andaman

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Abstract

Fossil fuels have been the major source of energy since industrial revolution began and has become the driving force of global economy. But these fuel resources are in the process of rapid depletion and become a concern in recent years. The CO_2 load due to fossil fuel consumption on the environment and its influence on greenhouse gases brings the disorders which becomes source for climate change. With a view to protect environment, the idea of generating sustainable, cost effective and environment friendly fuels has taken the centre stage and the best source for substituting these fossil fuels is to look into a sustainable source of renewable biofuels. The attention is thus being given towards the marine resources, and seaweeds considered the base for biofuel production, being the most abundant plant with high biomass present in the oceans. The present study, biofuel potential of some seaweeds from the coast of South Andaman is examined. The study was conducted by extracting lipid and converting it to biofuel from 12 species of seaweeds *Acetabularia cranulata, Dictyosphaeria versluysii, Halimeda gracilis, Halimeda opuntia, Padina gymnospora, Padina pavonica, Sargassum weightii, Turbinaria conoides, Galaxaura rugosa, Portieria hornemanni, Trichogloeopsis pedicellata, Trichogloear equienii* representing Chlorophyta, Phaeophyta, and Rhodophyta. The comparative data suggested that seaweeds from South Andaman coast have the potential for use for biofuel production in future.

Keywords: *Seaweed, Biofuel, Energy, Potential,Tropical island*

Introduction

Fossil fuels have been the major source of energy as on date. But it is in the process of exhaustion due to increasing demand and limited stock in the nature. Simultaneously, release of CO_2 due to burning these fossil fuel increases greenhouse gases in the environment and brings lot of environmental disorders and become instrumental in influencing climate change. It is thus essential to look into a sustainable, cost effective and environment friendly fuels. The best alternative is to produce biofuel as source of renewable energy from marine algae as these are most promising bioresources from the marine environment with high biomass and species abundance.

Recent years, attempts are being made to develop suitable technology for extracting biofuel from biological sources (Antizer and Turrion, 2008). The biomass is said to be the largest energy resources available in the world and seaweeds may be considered as one of the most important components in this regard. Also, these biofuels are mainly renewable, sustainable, biodegradable and carbon neutral source of energy, so that, it encourages green industries, agricultural and automobile trade (Xu and Li, 2016; Su et al., 2015). The production of biofuel has undergone several stages of development and in recent times, the production of biofuel includes extraction from marine algae (Aitken and Ladislao, 2012). The conversion of brown macroalgae *Padina tetrastromatica* biomass to liquid biofuel through trans-esterification method was reported by Ashok et al., (2017). The idea of biofuel from macroalgae is due to its biochemical constituents to produce energy generating fuel, which can replace the current trend of fossil fuel-based powers (Hughes et al., 2012).

Many algae constitute several types of lipids that can substitute petroleum derived fuels (Lee and Lee, 2012). Apart from its high lipid content, seaweeds also possess carbohydrate that can also be converted to different form of biofuel. Again, the algal cellulose content is heavier with less lignin content signifying that the biomass can pave way for the biofuel production. Different processes are used to achieve different type of biofuel such as biodiesel, bioethanol (Wargacki et al., 2012), bio-hydrogen, biogas, methane (Ghosh et al., 1981; Chynowethet al., 2001). The most significant aspect of algal biofuel is that it directly converts the biomass into biofuel and it can be cultivated with any less desirable source of water; in saline, brackish, polluted waters (Knothe, 2006; Meher et al., 2006).

The seaweeds comprise largest biomass in the marine environment, so, it is the most suitable candidate for biofuel extraction. The Andaman Sea exhibit a high seaweed resource with estimated representation of about 300 species (Palanisamy, 2012) and have the potential for commercial use (Gopinathan and Panigrahy, 1983; Banu et al., 2018; Banu and Mishra, 2019). Also, along the coast of South Andaman, the species diversity is very high and all these species can be assessed for their potential towards commercial use including biofuel, food, manure and medicinal value, etc. With this backdrop, present study was attempted to assess the biofuel potential of some seaweeds from the coast of South Andaman, Andaman and Nicobar Islands. The basic objective of this study has to examine the lipid content of some of the abundant seaweed species and convert them to biofuel, along with their analysis towards the production of biofuel.

Material and Methods

Study Area

The seaweed samples were collected from six locations along the coast of South Andaman namely, Brookshabad Quarry (Lat. 11°.38'N, Long. 92°.44'E), Burmanallah (Lat. 11°.34'N,Long. 92°.44'E), Chatham (Lat. 11°.68'N, Long. 92°.72'E), Kodiyaghat (Lat. 11°.35'N, Long. 92°.42'E), Marina Park (Lat. 11°.40'N, Long. 92°.45'E) and Mazhar Pahar (Lat. 11°.45'N, Long. 92°.44'E). All these locations were endowed with luxuriantly growing seaweed species. The sampling duration was from December, 2018 to March, 2019, i.e., during non-rainy season of Andaman.

Collection of Seaweeds

The present study, 12 seaweed species belonging to three Phyla with four representative species from each such as Chlorophyta (*Acetabularia cranulata, Dictyosphaeria versluysii, Halimeda gracilis* and *Halimeda opuntia);* Phaeophyta (*Padina gymnospora, Padina pavonica, Sargassum weightii* and *Turbinaria conoides);* Rhodophyta (*Galaxaura rugosa, Portieria hornemanni, Trichogloeopsis pedicellata* and *Trichogloea requienii*) were selected randomly (Plate - 1).




Acetabularia cranulata Dictyosphaeriaversluysii Halimedagracilis Halimeda opuntia




Padina gymnospora Padina pavonicaSargassum weightii Turbinaria conoides

Galaxaura rugosa Portieriahornemanni Trichogloearequienii Trichogloeopsispedicellata

Plate - 1. Seaweed species from Chlorophyta; Phaeophyta and Rhodophyta in the present study

The seaweed samples of the respective species were collected by hand picking from the sampling areas and washed with seawater at the sampling site to remove debris and sand. Samples were brought to the laboratory in an ice box and washed thoroughly under tap water to remove any associated epiphytes. The cleaned seaweed samples were shade dried for a week and then powdered using electronic blender. The powdered samples were packed in air tight container respectively and stored at 4°C for further analysis.

The lipid was extracted by taking 10gm of seaweed powder in a 250 ml conical flask and 100ml of chloroform methanol solution (2:1) was added to this. The flask with sample mixture was shaken vigorously for two minutes and then kept at ambient temperature for 24 hours in sealed condition. Latter, the mixture was filtered (Whatman No.1 filter paper) and the filtrate was mixed with 0.8% Sodium Chloride (NaCl) solution. At this, the solution mixture got separated into two different layers i.e. the upper hydrophilic layer with water and methanol, where bottom hydrophobic layer was of lipid and chloroform. This solution was then transferred to a separating flask and kept undisturbed for five minutes to allow the two phases to separate properly. The lower bottom phase containing lipid was eluted out carefully into a pre-weighed empty beaker and the lipid from the chloroform was collected by evaporating the chloroform. The weight of the total lipid (gm) was calculated by subtracting the weight of the pre-weighed empty beaker from the beaker with the lipid [Total Lipid (gm) = Weight of beaker with lipid content – Weight of empty beaker].

Conversion of Lipid to Biodiesel

For conversion of lipid to biodiesel (biofuel), 10 ml of 0.5% Sodium methoxide (CH_3NaO) solution was added to the beaker with extracted lipid and the solution was kept in the water bath at 60°C for 4 to 5 hours with frequent shaking for trans-esterification. Then 8ml of hexane was added to the beaker with sample and allowed to stand for 20 minutes. After formation of two distinct layers, the upper layer was identified as a biodiesel with hexane and bottom layer was glycerine. The upper layer was separated with micropipette and transferred into a pre-weighed blank test tube and biodiesel was collected by evaporating the hexane. The biodiesel concentration was calculated by subtracting the pre-weighed blank test tube weight from the test tube with biodiesel and total conversion rate (%) from lipid to biofuel was estimated.

Results

Lipid Profile

The lipid content of all the twelve studied species was estimated per 100 gm of dry seaweed biomass. As depicted in Fig. 1, the lipid content was found to be highest in the red seaweed *Trichogloeopsis pedicellata* with a concentration of 2.67gm followed by brown seaweed *Turbinaria conoides* (2.5gm). But other brown seaweed *Padina gymnospora*, *Padina pavonica* and *Sargassum weightii* also had lipid concentration of 1.52, 1.43 and 1.15 gm, respectively. Similarly, lowest concentration (0.34 gm) was obtained in the case of green seaweed *Halimeda gracilis*.

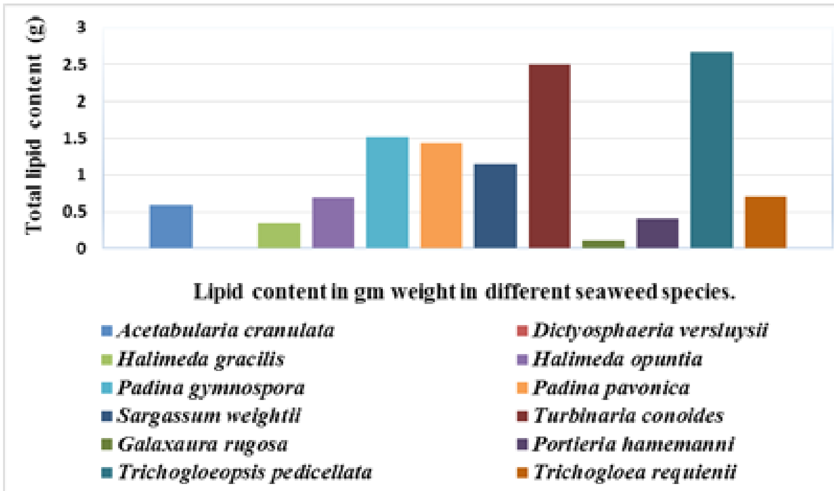

Fig. 1. Total Lipid content (g) in twelve seaweed species from South Andaman coast

However, overall lipid content of all twelve species studied in the present investigation suggested that the brown seaweed species had higher concentration followed by red seaweed and the least is green seaweed species (Fig.2).

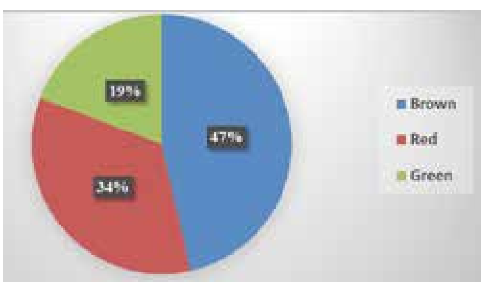

Fig. 2. Lipid content (%) of seaweed species under different Phylum from the Coast of South Andaman

Biofuel (Biodiesel) Production

The conversion percentage of biofuel (biodiesel) production from lipid of twelve different species of seaweeds is given in Table - 1. As depicted in Fig.3, it is revealed that the maximum yield of biofuel was produced from *Turbinaria conoides* with 0.69/100g of biodiesel followed by *Halimeda opuntia* and *Trichogloea requienii* with 0.52 gm and 0.46 gm, respectively. The minimum amount was recorded in *Portieria hornemanni* with 0.09gm. Whereas, amount of biofuel production capacity is same (0.34g) in case of *Acetabularia cranulata* and *Padina pavonica*.

Table - 1. Lipid and Biofuel production rate from different seaweed species from the coast of South Andaman

Species	Lipid/100g	Biofuel /100g	Conversion Rate (%)
Acetabulariacranulata	0.58	0.34	58.62
Dictyosphaeriaversluysii	1.12	0.20	17.85
Halimedagracilis	0.34	0.27	79.41
Halimedaopuntia	0.69	0.52	75.36
Padinagymnospora	1.52	0.19	12.50
Padinapavonica	1.43	0.34	23.77
Sargassum weightii	1.15	0.21	18.26
Turbinariaconoides	2.50	0.69	27.60
Galaxaurarugosa	1.10	0.30	27.27
Portieriahornemanni	0.41	0.09	21.95
Trichogloeopsispedicellata	2.67	0.12	4.49
Trichogloearequienii	0.70	0.46	65.71

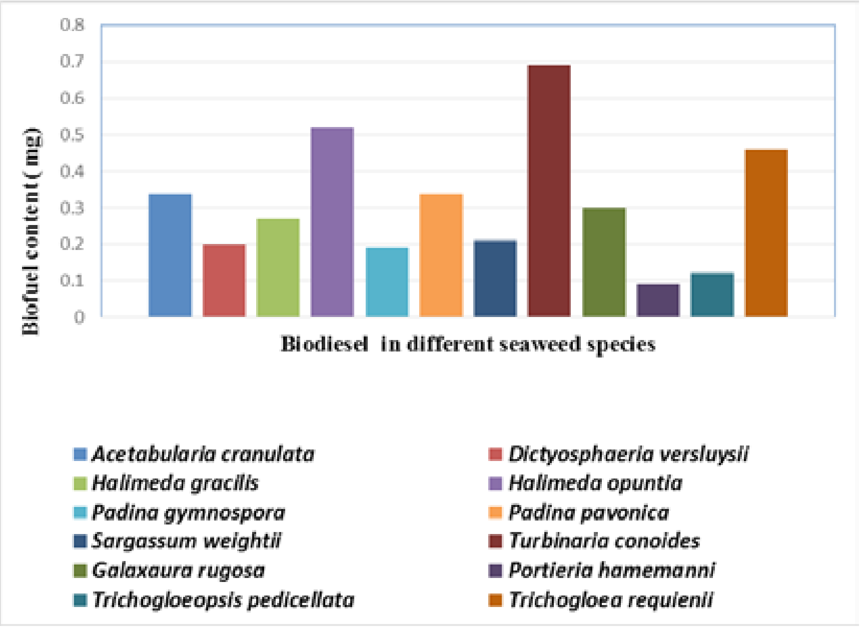

Fig. 3.Biofuel concentrations in different seaweeds

The comparative production capability among the three Phyla of seaweeds suggests that brown algae had the highest production value of 38% followed by green algae with 36% and the least is red algae with 26% in terms of biofuel production rate (Fig. 4).

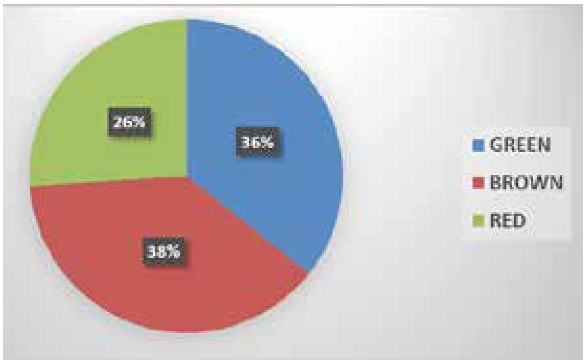

Fig. 4. Percentage of biofuel content in the seaweeds under three Phyla from South Andaman coast

Biofuel Conversion

The conversion of lipid to biofuel in all 12 seaweed species in the present study resulted in varying degree of biofuel production (Table - 1). In terms of percentage conversion maximum biofuel production rate was obtained in *Halimeda gracilis* (79.41%) followed by *Halimeda opuntia* (75.36%) and *Trichogloea requienii* (65.71%) respectively and minimum percentage of conversion was recorded in *Trichogloeopsis pedicellata* i.e. 4.49% (Fig.5).

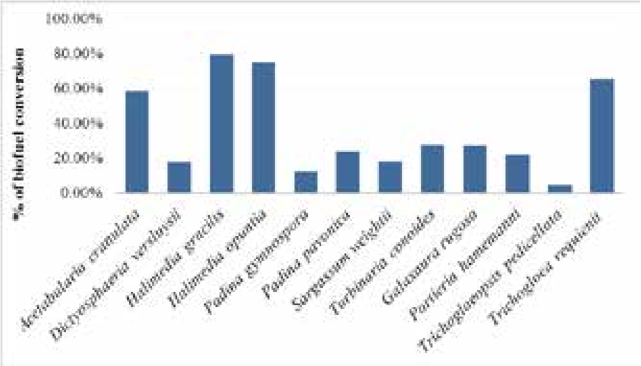

Fig. 5.Conversion percentageof lipid to biofuel in different seaweeds

Discussion

The biofuel potential of some seaweed, from the coast of South Andaman was investigated and potential seaweed species like *Turbinaria conoides*, *Halimeda opuntia* and *Trichogloea requienii* were recorded from the coast of South Andaman. There is no earlier report pertaining to biofuel potential of sea weeds from Andaman Sea, India. The present study was an attempt to assess the potential and probable utilisation of the sea weed resources in this respect.

Some studies estimated that red seaweed *Gracilaria verrucosa* could provide highest biofuel yield (Mohapatra and Padhi, 2018). But in the present investigation biofuel potential in terms of lipid content and yield percentage was found to be high in brown sea weed *Turbinaria conoides* followed by green seaweed *Halimeda opuntia* and red seaweed *Trichogloea requienii,* respectively. Also, the brown seaweeds had overall high yield percentage in comparison to red seaweeds. Ashok et al. (2017) reported about 7.8% biofuel production from *Padina tetrasporomatica*. Whereas, in the case of *P. gymnospora* and *P. pavonica,* rate of biofuel production was found to be 0.19% and 0.34%, respectively, in the present study. However, the present study suggested that the biofuel production in four brown seaweeds within a range of 0.19-0.69%, which is in agreement with earlier study by Xu et al. (2014).

Lipid profiling of seaweeds suggested that this will be a source for biofuel production (Anuradha *et al*., 2015). Sivaramakrishnan et al., (2017) reported that lipid content of four seaweeds *Halimeda macroloba, Halimeda tuna, Enteromorpha* sp. and *Acetabularia acetabulum* from Andaman Sea lies in the range of 0.69 - 3.22% with a maximum in *A. acetabulum* and minimum in *H. tuna.* This study showed that lipid content in12 species was found within a range of 0.34 - 2.67% with maximum in red seaweed *Trichogloeopsis pedicellata* and minimum in green seaweed *H. gracilis*. The earlier study, the total lipid content in *Sargassum weightii* from the cost of Mandapam (SE Bay of Bengal) was reported to be 2.33% (Manivannan et al., 2008), which is higher in comparison to the present study from the coast of South Andaman Sea, where it was 1.15%. This variation may be attributed to local conditions. Similarly, in case of *Galaxa urarugosa* lipid content was 1.46 g (Nunes et al., 2017). Whereas, in this species, lipid content was 1.10g with 27.27% conversion rate to biofuel found in the present study. On the basis of the percentage of lipid content it was presumed that the conversion rate to biofuel for the two red seaweed species *Trichogloeopsis pedicellata* and *Portieria hornemanni* will be highest and lowest, respectively. But the higher conversation rate was recorded in green seaweeds in biofuel content (58.62 – 79.41%), though they had lowest lipid content (0.34 – 1.12%). But in overall, brown seaweeds had the highest biofuel content (0.19 – 0.69%). The variation in the lipid and biofuel can differ even in same species seasonally, location wise and temperature of seaweed growth (Renaud and Luong-Van, 2006; Nelson et al., 2002). As per the study though biofuel production was higher in brown seaweed *Turbinaria conoides*, the conversion of lipid to biodiesel was found to be higher in green seaweed *H. gracilis, H. opuntia* and red seaweed *Trichogloea requienii* suggesting that these species have significant potential for biodiesel production. Again, the benefits offered by seaweed based biofuel are numerous without any negative environmental impact and it can be obtained from the biomass, which is available in plenty and can be produced in Andaman Sea. The study suggested that seaweeds of Andaman Sea can be an instrumental for possible biofuel production. Emphasis may thus be given to explore potential seaweeds from the Andaman Sea. Also, with the emphasis given by development of blue economy algal fuel production especially from seaweeds will be highly beneficial.

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A review of macro plastic pollution in marine environment

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Abstract

Despite its vital importance, we are currently treating our ocean like an enormous dump particularly for plastic wastes. We have collected global level information, compiled data from national level studies and included regional studies pertaining to Andaman and Nicobar islands. More than 320 million tons of plastics are produced globally each year, and for this reason, the introduction of plastic waste into the marine environment is a global concern, causing direct and indirect impacts on ecosystems, marine fauna, and local economies. This review discusses the marine pollution by macro plastics (> 0.5 cm dia) encompassing (i) types of plastic commonly found in the oceans; (i) the global distribution of marine plastic debris in the world's oceans; (ii) threats to wildlife and the environment; and (iii) international / regional agreements and initiatives to prevent and combat plastic debris in the world's oceans.

Keywords : *Plastic pollution, Large debris, Entanglement, Ingestion, Regulation*

Introduction

Marine litter is defined as "any waste, discarded or lost material, resulting from human activities, that has made it into the marine environment, including material found on beaches or material that is floating or has sunk at sea" (Cheshire et al., 2009). The marine debris is a menace to the environment. In a survey conducted from the Arctic to the Antarctic, 20-80% of the debris items collected from 30 islands were anthropogenic debris (Barnes, 2002).It is known to affect about 693 species, out of which 17% are listed in the IUCN Red List (Gall and Thompson, 2015). The fauna and flora existed in the marine habitats are affected severly by human introduced debris from the plastic compounds (Critchell and Lambrechts, 2016).

The characters of the plastics such as lightweight, durable, high thermal and electrical inulation properties, strong and inexpensive causes serious environmental threat (Ryan et al., 2009, Thompson et al., 2009a, Thompson et al., 2009b; Koushal et al., 2014). Due to their efficiency and performance, there is a gradual increase in the usage of plastic (Andrady and Neal, 2009). The plastic industry is one of the largest and fastest-growing manufacturing industries in the world (Vegter et al., 2014) with about 260 million tons of plastic usage annually (Thompson et al., 2009a). Daily life of a human being entangled with plastic in one form or other and in worldwide, almost a million plastic bags consumed per hour (Andrady and Neal, 2009; Koushal et al., 2014). The data in the year 2018 suggestd that 360 million tons of plastic were produced globally with half of it as single-use plastic (Dharmamony, 2018). Asia contributed to 51% of global plastic production in 2018 with China topping the list with 108 million tons (Plastics Europe, 2019). The polyethylene and polypropylene composition plastic are commonly used (Worm et al., 2017). The global production of polyethylene was 140 million tons per year (Sivan, 2011).

Plastic in Marine Environment

Plastic pollution or littering is one of the biggest environmental challenges humans face today (Dharmamony, 2018). It accounts for the major portion of marine litter worldwide (Derraik, 2002; Moore, 2008; Kaladharan et al., 2017; Dharmamony, 2018) and single-use plastic provide a significant contribution to it (Xanthos and Walker, 2017). As reported by Jambeck et al., (2015), based on the year 2010 data, 192 countries were produced 275 million tons of plastics and 4.8 to 12 million metric tons entering in to the ocean as a debris (Fig. 1). Based on several studies on the persistence, size, composition and effect on the environment, there are two categories of plastics viz, '**macroplastics**' (larger plastic materials greater than 0.5 centimeters in diameter) and **microplastics** (smaller particles less than 0.5 centimeters).

Fig. 1. Plastic debris in marine environment

Coastal and marine environments act as an ultimate sink of plastic debris (Vennila et al., 2014). It is predicted that by 2050, there will be more plastic in oceans than fishes unless we find a solution for single-use plastics (Dharmamony, 2018). The commercial production of plastic commenced during the year 1950's from then to till date, the debris of the plastic omnipresent in every environment of earth, including atmosphere (Gall and Thompson, 2015; Barnes et al., 2009; Vennila et al., 2014). Coastal currents, wind direction, and tidal patterns as well as the size, weight, and density of plastic influence the distribution of plastic pollutants across the oceans (Cundell, 1974; Browne et al., 2010; Eriksen et al., 2014). Merchant ships dispose of significant amounts of litter wastes including plastic, into the sea (Horsman, 1982). During the years 2007 to 2013, 24 marine expeditions found that 4291 items of fishing buoys and 1116 foamed polystyrene under the most heavy (58.3%) floating plastic debris (Eriksen et al., 2014).

The summary of studies on plastaics in marine are (Fig. 2),

- The vast majority – 82 million tonnes of macroplastics and 40 million tonnes of microplastics – is washed up, buried or resurfaced along the world's shorelines.
- Much of the macroplastics in our shorelines is from the past 15 years, but still a significant amount is older suggesting it can persist for several decades without breaking down.
- In coastal regions most macroplastics (79%) are recent – less than 5 years old.
- In offshore environments, older microplastics have had longer to accumulate than in coastal regions. There macroplastics from several decades ago – even as far back as the 1950s and 1960s – persist.
- Most microplastics (three-quarters) in offshore environments are from the 1990s and earlier, suggesting it can take several decades for plastics to break down.

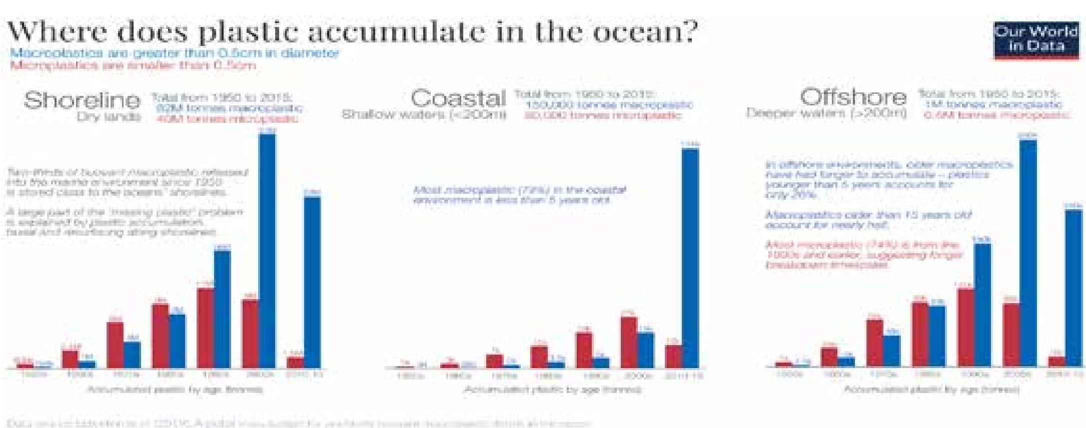

Fig. 2. Marine plastics – source and accumulation (Ref: Lebreton et al., 2019)

Each polymer differs in its time of degradation (Palmisano and Pettigrew, 1992). The degradation of plastic in the ocean is a slow process due to its cooling capacity (Dharani et al., 2003) and complete degradation of plastic might take even hundreds of years (Moore, 2008). They either float on the sea or sink to the bottom and stay for years or even decades (Laist, 1987). The plastic can temporarily break into fragments, which can increase the concentration of microplastic (Thompson et al., 2009b; Browne et al., 2010; Eriksen et al., 2014; Koushal et al., 2014; Vegter et al., 2014), their wider dispersal and their impacts in the environment (Palmisano and Pettigrew, 1992; Engler, 2012).

Impacts and Threats to Marine Life

The accumulation of plastic debris through different environment can impact adversely on marine systems (Ryan, 2015). A large number of marine animals affected by entanglement or ingestion of plastic debris, i.e., over 260 species viz. zooplanktons, fishes, seabirds, sea turtles, corals, crustaceans, bivalves, mammals, etc. (Laist, 1987; Laist, 1997; Derraik, 2002; Dharani et al., 2003; Moore, 2008; Todd et al., 2010; de Stephanis et al., 2013; Cozar et al., 2014) (Fig. 3). As reported by Hall et al. (2015), the Great Barrier Reef Scleractinian corals *Dipsastrea pallida* showed the ingestion of microplastics. Later, Allen et al. (2017) found that the chemosensory cues are the driving force responsible for the feeding of plastics by Scleractinian corals, as a part of his experiment on plastic ingestion by *Astrangia poculata*. The seabirds, especially young and immature birds are more often vulnerable to plastic pollution as they normally ingest floating plastic mistaking for food (Moore, 2008; Thompson et al., 2009b; Van Franeker and Law, 2015). As predicted by Wilcox et al., (2015) during the year 2050, 95% of humans and 99% of all seabird species will have ingested plastic.

The larger surface area of plastics can undergo biofouling and host a wide size range of organisms, which can aid as a dispersion tool, especially for invader species (Derraik, 2002; Reisser et al., 2014; Cozar et al., 2014; Gall and Thompson, 2015). Plastic contains and absorbs hydrophobic organic pollutants (or plasticizers) like PCB, phthalates and bisphenol A (Carpenter and Smith, 1972; Dharani et al., 2003; Oehlmann et al., 2009; Teuten et al., 2009; Thompson et al., 2009a; Koushal et al., 2014; Jayasiri et al., 2015). PCB ranging up to 5 parts per million are being absorbed from the surrounding seawater by plastic (Cundell, 1974). The absorption and adsorption, release of toxic elements like antimony, cadmium, chromium, lead, tin, etc., can contaminate the marine waters and sediment (Nakashima et al., 2012). Further, these absorbed and adsorbed chemical also make more complex mixture of chemical pollutants on marine environment (Rochman, 2015). The contaminants from plastic pose a threat to the animals that ingest them (Derraik, 2002; Teuten et al., 2007; Teuten et al., 2009) as they can bioaccumulate and transfer up the food chain (Engler, 2012; Vennila et al., 2014). The organic pollutants can cause damage to the reproductive system, hormone functioning, thyroid functioning, carcinogenic effects and can even cause genetic aberrations (Oehlmann et al., 2009; Koushal et al., 2014).

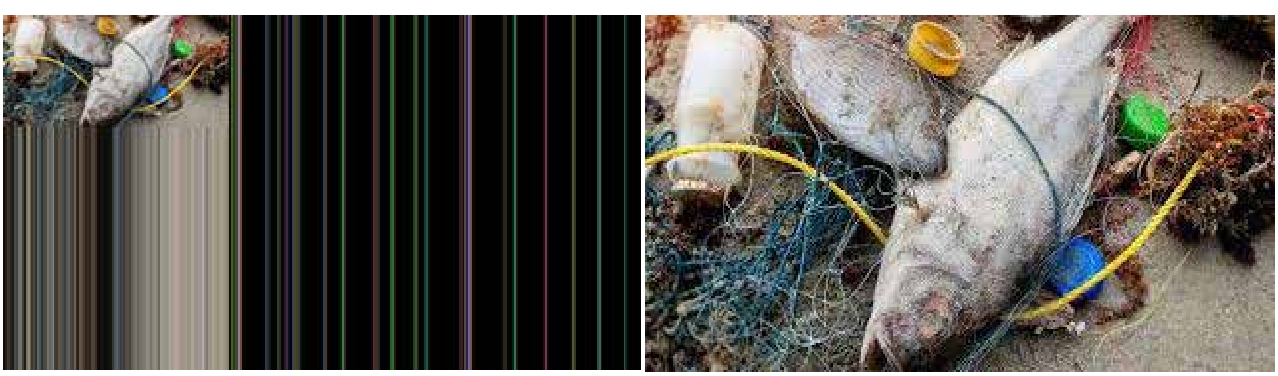

Fig. 3 Effect of plastics on marine life (entanglement)

Global Scenario

The Carpenter and Smith (1972) work on plastic in the marine environment was considered as a pioneering work. This study found out that the Sargasso Sea surface had 3500 pieces and 290gm per square kilometer plastic. Scott (1972) found that the ocean currents transported seaborne plastic pollutants of foreign origin to isolated stretches of the shoreline in Scotland. Velander and Mocogni (1999) compared ten sampling methods for estimating beach litter and found a huge amount of litter accumulation near the vegetation line across all the stations. A review of 13 different sampling protocols used across the world to survey marine litter was made by Cheshire et al. (2009) and they provided a set of standard methodologies and datasheets for marine litter sampling and monitoring. Ryan et al. (2009) reviewed methods used for sampling beach surveys and boat surveys for plastic litter estimation and suggested to use a 50m wide belt for beach litter sampling. The floating plastic debris was sampled using the Neuston surface nets to estimate its concentration (Carpenter and Smith, 1972; Cozar et al., 2014; Eriksen et al., 2014; Van Franeker and Law, 2015). ATR FT-IR (Attenuated Total Reflectance Fourier Transform-Infrared Spectroscopy) technique has been used for identifying the polymer composition of plastic marine debris (Jung et al., 2018). Comparision of data on plastics, the number and mass of plastic debris items are considered significant (Ryan et al., 2009).

Marine debris of different locations of the world was studied extensively. 72% of debris collected from Hawaiian archipelago were plastic particles and their concentration was found to be higher towards the high tide line (McDermid and McMullen, 2004). The samples collected from the strandline of Tamar estuary, NE Atlantic, Polyethylene and Polypropylene (Browne et al., 2010) were the dominant polymers. McIlgorm et al. (2011) estimated $1.26 billion annual damage to the marine industry in the Asia-Pacific region due to marine debris during the 2008 term. Nakashima et al. (2012) collected about 974 plastic samples (26.5 kgs) from Ookushi Beach, Nagasaki, Japan using random quadrat (2m x 2m) sampling. The Spanish marine waters were studied for plastic pollution by Cozar et al. (2014). The convergence zone of each of the five large subtropical gyres accumated 7,359 plastic items (Malaspina 2010), and a minimum of 5.25 trillion floating plastic particles weighing about 268,940 tons (Eriksen et al., 2014). Walther et al. (2018) found a total of 9,04,302 items weighing 1,31,358.3 kg from Taiwan coast in the 12-year period from 2004 to 2016, out of which 90% was plastic. A questionere was prepared with a set of 16 priority questions, as suggested by 26 researchers from around the world, to address the plastic pollution by future researchers (Vegter et al., 2014).

Lebreton et al. (2012) found that the plastic debris accumulated larger level in Northern hemisphere and lesse in Southern hemisphere, based on the transport, distribution, and accumulation of floating marine debris. Potemra (2012) also compared and suggested a few ocean models to study the drifting marine debris. Critchell and Lambrechts (2016) evolved based on the different marine debris study models, quantity of debris, the rate at which plastics sink, resuspension of beached plastics and their source location, the degradation of macroplastics into microplastics at sea and their processes.

Indian Scenario

Indian Ocean coast concern, out of 20 countries, 10 countries are releasing waste into the oceans (Veerasingam et al., 2017). India uses about 15 million tons of plastic annually (Dharmamony, 2018). Plastic shopping bags are one of the main sources of plastic wastes in India (Koushal et al., 2014). In 2002, Legislation was passed to ban <20 μm thick plastic bags, followed by <50 μm thick bags in the year 2005 (Xanthos and Walker, 2017). Indian coastal region, Odisha coast showed the lowest beach litter (0.31 g/m^2) and highest in Goa coast (205.75 g/m^2) (Kaladharan et al., 2017).

Sridhar et al. (2009) collected five samples each from hind dune and mid dune across the beaches in Karnataka and found 22 types of plastic debris (Low-Density Polyethylene and Polystyrene were common). Ganesapandian et al., (2011) quantified the marine litter of Gulf of Mannar along top wet strandline parallel to the beach and found that plastic accounted for 48% of total litter. Kaladharan et al., (2012) collected data on plastic debris from 32 beaches and trawl grounds of eight coastal centers of India gravimetrically along line transects in beaches and from trawling vessels after each haul. Jayasiri et al., (2013) collected samples from the high-tide mark on the beach shore and found an average of 7.49 g and 68.83 items of plastics per square meter from four recreational beaches of Mumbai. The mean concentration of polycyclic aromatic hydrocarbons (9,202.30 ± 114.89 ng g^{-1}) as well as the median concentrations of polychlorinated biphenyls (37.08 ng g^{-1}) and organochlorine pesticides (104.90 ng g^{-1}) in the plastic pellets from Mumbai coast were also significantly high, indicating oil pollution in the Mumbai coastal region as the petrogenic sources (petroleum hydrocarbons) were predominant over pyrogenic sources (Jayasiri et al., 2014; Jayasiri et al., 2015). A mature female specimen of Bigeye Thresher Shark *Alopias superciliosus* collected from Cochin Fisheries Harbor, Kerala, during a gillnet operation at a depth of 200m off Ratnagiri coast, was reported to ingest transparent plastic cover (Diana Benjamin et al., 2014). A total of 44.89% of marine debris accumulated in vegetation line of Marina beach, Chennai (Arunkumar et al., 2016). Around 8.8 million tons of plastic debris dumbed in the ocean by 254 beaches of India, in every year (Kaladharan et al.,, 2017). Nallathanni Island, Gulf of Mannar, coral reef regions shows that plastic debris are the major component of the deposits (Krishnakumar et al., 2018).

Sridhar et al., (2009) identified food-based litter as a major source of plastic pollution in India, while Ganesapandian et al., (2011) report fishery as the major source of plastic litter, followed by tourism. Household items, bottles, and plastic covers are major plastic litter observed on Nallathanni island, Gulf of Mannar (Krishnakumar et al., 2018).

Sampling strategies varied greatly among the researchers. 1m^2 quadrat along 100m line transect was used for collection by Sridhar et al. (2009) and Kaladharan et al. (2012) while 50cm^2 quadrat was preferred by Jayasiri et al. (2013). Ganesapandian et al. (2011) used a wider area of 100m^{2}for collecting samples. Kaladharan et al. (2017) collected triplicate rope quadrat samples of 10m^{2}with 100m intervals.

Andaman and Nicobar Archipelago

The study on plastic debris in Andaman and Nicobar Islands was initiated by Dharani et al. (2003), assessing the magnitude and impacts of marine debris along the coasts of Nancowry and Great Nicobar, with a huge amount of plastic litter originating from adjacent countries. Their finding was later supported by Das et al. (2016) and Sahu and Baskar (2019) with the **majority of debris recorded were originating from adjacent countries like Thailand, Malaysia, Indonesia, Myanmar, China, Cuba, etc., and not of Indian origin**. Mohan and Dhivya (2013) studied on the six-year trend (2003-2008) of plastic waste distribution on Sunset Bay, Colinpure, Port Blair, and found a 400% increase. This study further reported that shoreline/recreational-related debris and ocean/waterway-related debris were highest in Andaman, while smoking-related debris was minimal. Seetharaman et al., (2015) compared the impact of city effluents on water and oysters (*Crassostrea rivularis*) using a polluted area [Phoenix Bay Jetty] and an unpolluted area with least human interference [North Wandoor] and found poor water quality parameters in waters of the polluted area with the high microbial load.

Kaladharan et al., (2017) reported Andaman as extremely littered region in their study where 47% of total debris collected from Andaman was plastic, which included single-use sachets and carrier bags, soft drinks bottles, sachets of edible oils, beverages, detergents, toothpaste, cases of cosmetics, ice cream containers, PET bottles, etc. Sahu and Baskar (2019) collected plastic litter bottles from 5 beaches of Great Nicobar Island and found that 97.8% of bottles were of foreign origin from the countries like Malaysia (40.5%), Indonesia (23.9%) and Thailand (16.3%). Over and above, they also found the debris contribution from the countries like Singapore, Philippines, Vietnam, India, Myanmar, China, and Japan. They identified a continuous increment of litter on beaches and mangroves of the Andaman Islands. Dharani et al., (2003), Das et al., (2016) and Sahu and Baskar, (2019) reported sea-based debris as a major source of litter in Great Nicobar.

Preventive Measures and Recommendations

Like the problem, finding a solution is also a multifaceted process. Beach cleanups are proposed by most of the literature (Dharani et al., 2003; Moore, 2008; McIlgorm et al., 2010; Vegter et al., 2014) but litter cleanup operation is expensive and is having practical difficulties. It is true that good, quality data can help to plan better management strategies as well as help in updating global and national datasets (Cheshire et al., 2009). However, in India, the existing literatures suggested that continuous monitoring of the marine debris is lacking, which lead to deficient data base for the effective action for preventing measures.

It is essential to reduce the plastic waste by the way of curb the single-use plastics (Jambeck et al., 2015). Switch to eco-friendly, biodegradable alternatives that contain no toxic chemicals and which breaks down easily in the environment without any negative impacts (Dharmamony, 2018). Recycling of waste food into biopolymers (which use renewable biomass instead of oil) can reduce the use of non-biodegradable plastic (Thompson et al., 2009b). Establish the incentive system to reduce the use of plastic along with high tax for plastic materials inturn increase the cost of plastic materials are advised. Further, more recyclable packaging should be encouraged (Kaladharan et al., 2017). Deposit-Refund schemes and Take-back schemes are implemented in several countries to promote the returning of plastic waste and can prevent it from getting dumped in the environment. Devices to capture plastic debris like debris booms and litter traps on storm water drains can prevent plastics from reaching to the rivers and oceans (Moore, 2008; McIlgorm et al., 2010).

Fishery related debris act as a major source of plastic related to entanglement. Finding new technologies to decrease the potential for gear loss can aid in reducing the problem (Laist, 1997). The universal 3 'R's: Reduce, Reuse, Recycle, remains a widely advocated solution to reduce the plastic waste and additionally, a 4^{th} and 5^{th} 'R' viz. Recover and Redesign are also proposed (Thompson et al., 2009b; Engler, 2012; Koushal et al., 2014; Kaladharan et al., 2017). Encourage to use the plastic debris as a recycle materials for the fishery products and advise the fishing community to collect the debris to the shore during their operations (Dharani et al., 2003). Controlling the use of disposable single-use plastics, plastic straws, and plastic beverage bottles are also advocated (Dharmamony, 2018). Suggested for the integrated waste management systems for waste collection, disposal, and treatment methods (Worm et al., 2017). The attitude of giving importance to short-term economic gain over the protection of the environment should change in Asian regions (Todd et al., 2010).

Littering is primarily a behavioral issue (Andrady and Neal, 2009). The simplest and effective solution for plastic problem is thus managing the discard behavior in humans (Cheshire et al., 2009). Only education can bring change to their littering behavior (Derraik, 2002; Vennila et al., 2014). Educate the community for the environmental consequences of marine debris which produce a significant difference (Arunkumar et al., 2016). But the message needs to be built on accurate scientific information and should be brought to the public and decision-makers through traditional as well as social media, conferences, press, websites, and advertising (Vegter et al., 2014). It also essential to reduce the production of plastic (Ryan, 2015). Global cooperation is recommended and a new innovative strategy needs to be conceived to address this global issue.

The incineration of plastic shouldn't be practiced as it releases metal-corroding and air-polluting fumes and chemicals (Cundell, 1974). However, as reported by Balasubramanian (2010), who identified and isolated fifteen bacteria by enrichment technique from the Gulf of Mannar, which include two bacteria (*Pseudomonas* sp. and *Arthrobacter* sp.) with a potential of degrading High-Density Polyethylene (HDPE) in in-vitro condition. This methodology should not stop at the laboratory level and scaleup is needed for largescale use in the sustainable environmental activities. In summary, the general steps to manage the marine plastic problems are,

- Reduce our plastic dependency
- Increased producer responsibility
- Increase fees and taxes on polluting plastics
- Increased waste management where the problem is greatest

- Implementation of the zero vision for ocean plastic
- Increased mapping, surveillance and research
- Stop the flow of plastic waste into the sea
- Increased funds and co-operation for clean-up

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Study on microplastics in the gut content of selective fin and shell fishes

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Abstract

Microplastics are the smaller size of the original or disintegrated plastic. These plastics are available in the aquatic column in large which became a concern with reference to health issues. So, it is essential to understand what extent these microplastics are consumed by the high order animals and its bioaccumulation. In this study an attempt was made to understand the same by the way of commercially important fin fish and shell fish samples. The gut content was estimated for the availability of microplastics and the exerted data was interpreted to understand the microplastics consumption and its distribution in this marine ecosystem. Statistically it stated that 50% of the studied mackerel specimens were found containing microplastics of which 33% contained high amounts of microplastics and 36% of the shrimp specimen contained microplastics but in lesser concentration. Moreover, no correlation was found with reference to feeding intensity and availability of microplastics in the gut content. Further studies are essential to correlate and understand the impact of fishing gears and other land based anthropogenic activities.

Keywords: *plastics, environmental impact, wild life, fish, gut content*

Introduction

The microplastics are classified as primary and secondary microplastics based on their origin. The primary microplastics mainly originated from the manufacture of plastics, pharmaceuticals and cosmetic products as pellets or granules. The secondary microplastics are the plastic products that degraded and converted in to smaller size as pellet or granule or fibre or filament.

Since these microplastics are also concentrated in the soil, it will accumulate in the pore spaces of the soil and reduce the water percolation capacity in turn, reducing the recharge of the ground water, nutrient recycle in the soil and thermal profile of the soil. If the same available in the water column, due to its less dense nature, it will float in the system and develop turbidity in the water column. Hence, it affects light passing capacity in the water column. The consumption of these suspended particles by marine biota leads to bioaccumulation in the food web and hazard to the higher animals. Over and above, these microplastics also absorb toxic elements on its surface and also lead to concentration of potential harmful elements in the biota.

So, it is essential to understand to what extent these microplastics are consumed by the high order animals and are concentrated in it system by its bioaccumulation. These higher order animals will be consumed by the humans, which lead to harmful effects. The studies on these aspects, with reference to fishes, are very minimal, that also in India very few studies are available. So, an attempt was made to understand the same.

The existing literature states that Cole et al., (2011) reviewed the literature and discussed about the properties, nomenclature and sources of micro plastics and its routes to enter the marine environment. Further, this article also discussed about the analytical methods and the spatial and temporal trends of abundance in different environments. Andrady (2011) discussed the microplastics ability to concentrate organic pollutants in the marine environment and its impact on the biota. Browne et al., (2013) reported worm's consumption of microplastics and its toxicological effects. Zhao et al., (2014) studied the Yangtze estuary in east China Sea and established that rivers were transport larger amount of microplastics to the sea.

The different methods for analysing and reporting technique on microplastics were established by Masura et al., (2015). Anderson et al., (2016) reviewed the Canadian aquatic ecosystems for the presence of microplastics, especially Arctic regions. The global modelling was developed for the microplastics quantification till 2050 by Seigfried et al., (2017). MSPGB (2018), Loder and Gerdts, (2019) and Vollerstein (2019) discussed the different methodology for the study of microplastics in different environments. The microplastics concentration was analysed for captive grey seals (*Halichoerus grypus*) and Atlantic mackerel (*Scombers combrus*) for its abundance in their digestive tracks (Nelms et al., 2018). Carlos de Sa et al., (2018) compared the marine faunal microplastics ingestion and its adverse effect. Malakar et al., (2019) reported plastic pen occurrence in the guts of yellow fin tuna *Thunnus albacores*. Indian marine waters do not show any significant dedicated research on the marine biota with reference to microplastics.

Material and Methods

Selection of Species

Two species which are normally consumed by the population of Andaman and Nicobar Islands were selected. The feeding behaviours of the fishes are also considered for the selection of commercialy important species. Accordingly, the fin fish species *Rastreilleger kanagurta* and shell fish *Metapenaeus monoceros* were selected for this study.

Collection of Samples

Freshly caught specimens of both the species were bought from the Junglighat landing centre, Port Blair on the 28th January, 2019. The details like the fishing ground, time of collection and the craft and gear used were recorded. Both the species were collected from Diglipur coast and the effort was made during the day and night. The craft was mechanised dhinghi and the purse seine net was used as a gear.

Storage of the Samples

The iced specimens of both the species were collected from the craft in icebox and brought to the laboratory and stored in 10% formaldehyde. Care was taken to ensure that all the specimens were completely submerged in the formaldehyde. The formaldehyde was changed as and when, it became excessively turbid due to its preservation process.

Dissecting the Samples

Prior to dissection, the specimens were placed in distilled water for few hours, to flush the formaldehyde and reduce its vapours. After that, the gender was identified as well the basic biometric such as length and weight were measured. Latter, the dissection was made to remove the gut content. The gut weight also measured. However, the shrimp gut was not weighed due to its small size. Once the above formalities were over, the contents of guts were collected in a vial with 10% formaldehyde for the preservation.

Observation under Microscope

The collected gut contents were placed in a petri dish and the clumps were gently broken down using a forceps and a needle. A jet of distilled water was used to further separate the clumps of organic matter into smaller masses. These contents were then viewed under the stereo-binocular microscope.

Identifying and Isolating the Microplastics

Microplastics were quite prominent and easily identifiable when considered the following points:

- Microplastics are almost always brilliantly coloured unless they are transparent. This makes them highly visible. The colour of the most microplastics will not fade hence this was an easy task.
- The shapes of the microplastics need to be kept in mind, i.e., granules, film, sheets, fibre or filaments. Microplastics, which are usually used in cosmetics and air blasting media will always have a regular shape usually spherical in nature.
- To confirm whether the object is truly a microplastics it was pressed with needle. If it breaks easily, then it was considered non plastics and if comparatively strong then it was identified as microplastics.

The identified microplastics can then be extracted using a suitable micropipette and placed in a smaller vial along with small amounts of distilled water to facilitate its removal, when it is needed for further confirmation and counting.

Results and Discussion

The studied fin and shell fish specimens revealed the following results. It was observed that 24 out of 48 mackerel specimen (Table 1) contained microplastics. Out of this, 8 specimens contained microplastics in excessive amounts (greater than 4 nos.). The shrimp specimens (Table 2) represented 16 out of 45 microplastics in their digestive tracts.

Statistically it stated that 50% of the studied mackerel specimens were found containing microplastics of which 33% contained high amounts of microplastics and 36% of the shrimp specimen contained microplastics but in lesser concentration.

Table 1. The results of the gut content analysis of the *Rastreilleger kanagurta* species

+ Presence, 4 or less than 4 Nos. of microplastics and organisms

++ More than 4 Nos. of microplastics and organisms; * Absent

Sample No.	Status of Gut	Microplastics	Organisms identified in the Gut
F1	Fresh	+ +	**++copepods**
F2	Digested	++	**++None identifiable**
F3	Digested	+	**++None identifiable**
F4	Semi digested	*	**Copepods**
F5	Semi digested	*	**Copepods**
F6	Semi digested	+	**+ copepods ,unknown-4 ,**
F7	Semi digested	*	**ND**
F8	Semi digested	*	**ND**
F9	Semi digested	+	**+ copepods , jelly ball**
F10	Semi digested	*	**ND**
F11	Semi digested	*	**ND**
F12	Undigested	*	**ND**
F13	Digested	+	+
F14	Semi digested	*	**ND**
F15	Semi digested	*	**ND**
F16	Large, sparse	++	**++ copepods**
F17	Digested	+	**++ copepods**
F18	Digested	*	**++ copepods**
F19	Semi digested	*	**++ copepods , unknown-2**
F20	Semi digested	*	**++ copepods**
F21	Undigested	++	**ND**
F22	Digested	++	**++ copepods , 1 worm, 2 jelly balls**
F23	Semi digested	++	**++Copepods , worms**
F24	Semi digested	++	**++1 worm,**
F25	Digested	+	+
F26	Semi digested	+	**Unknown -1**

F27	Semi digested	*	**ND**
F28	Semi digested	+	**+Copepods,**
F29	Semi digested	*	**ND**
F30	Digested	*	**ND**
F31	Semi digested	*	**ND**
F32	Semi digested	*	**ND**
F33	Semi digested	+	+
F34	Semi digested	*	**ND**
F35	Semi digested	*	**ND**
F36	Semi digested	+	**+copepods**
F37	Digested	*	**ND**
F38	Digested	*	**Copepods**
F39	Semi digested	*	**ND**
F40	Semi digested	*	**ND**
F41	Digested	+	**+ copepods**
F42	Digested	+	**Copepods , unknown -3**
F43	Digested	++	**+ copepods**
F44	Digested	+	**ND**
F45	Digested	*	**ND**
F46	Digested	+	**+ copepods**
F47	Digested	+	**ND**
F48	Semi digested	+	**+ copepods**

Table 2. The results of the Gut content analysis of the *Metapenaeus monoceros* species. + Presence; ND- Absence

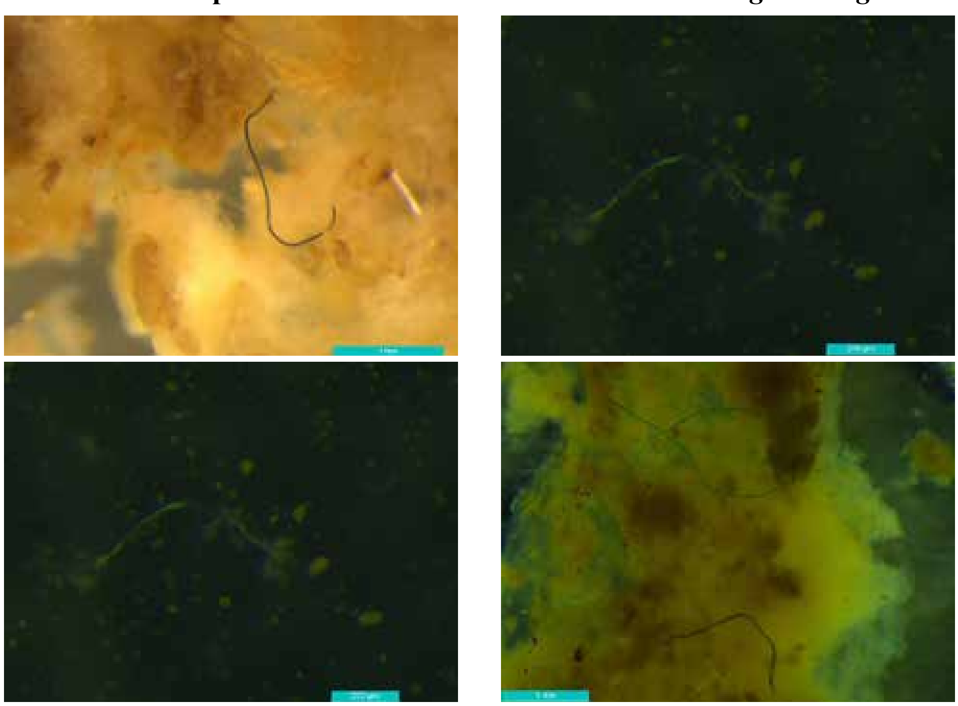
Sample No.	Microplastics	Sample No.	Microplastics
P1	**ND**	P24	**ND**
P2	**ND**	P25	+
P3	+	P26	**ND**
P4	**ND**	P27	+
P5	**ND**	P28	**ND**
P6	+	P29	+
P7	**ND**	P30	+
P8	**ND**	P31	**ND**
P9	+	P32	**ND**
P10	**ND**	P33	+
P11	**ND**	P34	**ND**
P12	**ND**	P35	**ND**
P13	**ND**	P36	+

P14	+	P37	+
P15	+	P38	**ND**
P16	**ND**	P39	**ND**
P17	**ND**	P40	**ND**
P18	+	P41	**ND**
P19	+	P42	**ND**
P20	**ND**	P43	**ND**
P21	**ND**	P44	+
P22	**ND**	P45	+
P23	**ND**		

The study revealed that the size of the microplastics available in mackerel *Rastreilleger kanagurta* specimen's gut content was larger, i.e., 1000µm to 2000µm in size (Fig.1). However, the microplastics in gut content of *Metapenaeus monoceros* was around 500µm size. This may be related to their feeding behaviour as well as due to the availability of microplastics, i.e., the mackerel moves in the pelagic waters and consume these plastic, so it may be in larger in size. Whereas, the shrimp *Metapenaeus monoceros* are mainly detritus feeders and mostly available in the bottom of the ocean, so, the settlement of fibres to the bottom may be less or disintegrated before its settlement to the smaller fractions.

Further, it may also infer that the selecting feeding habit of shrimp will reduce the intake of microplastics. When the content of mackerel specimen analysed, the F2 specimen exhibited the granular form of microplastics and the remaining forms are in fibre or lines (Plate 1 and 2). This shape also imparts greater buoyancy to the microplastics, which in turn must have been in suspension for longer time period and provide more opportunity to be fed by the pelagic fishes.

Plate 1. Microplastics observed from the Gut of *Rastreilleger kanagurta*



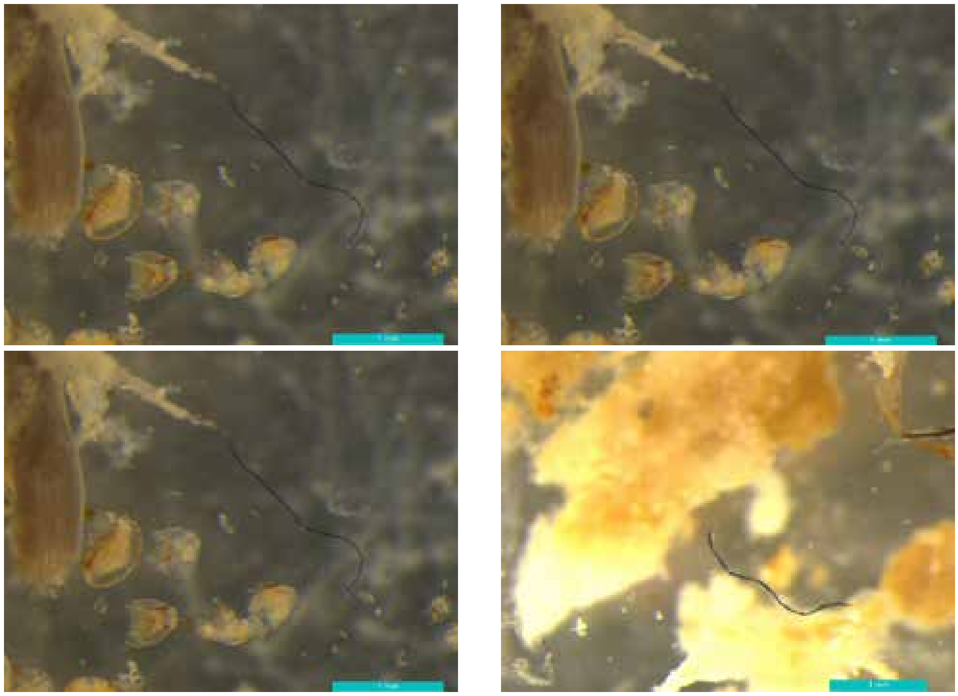
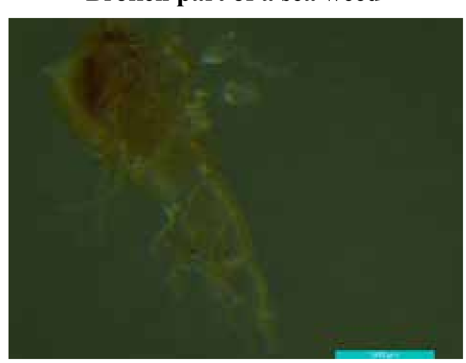


Plate 2. Plankton content from the gut of *Rastreilleger kanagurta*

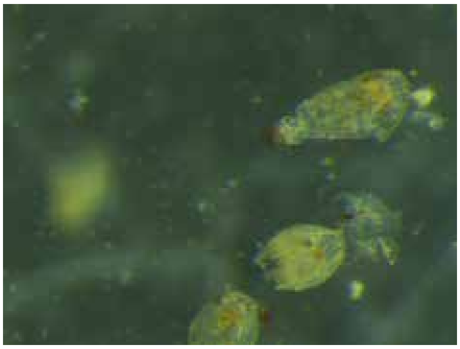
Veliger larvae

Broken part of a sea weed

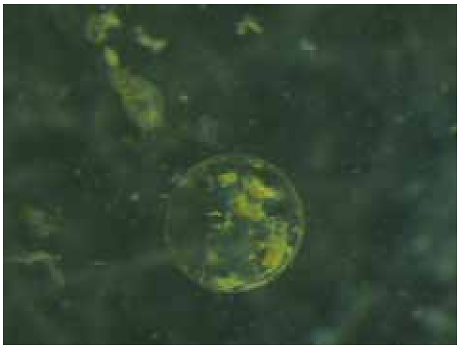
Round worm



Exoskeleton of a shrimp



Copepod exoskeletons



Digestive Particles

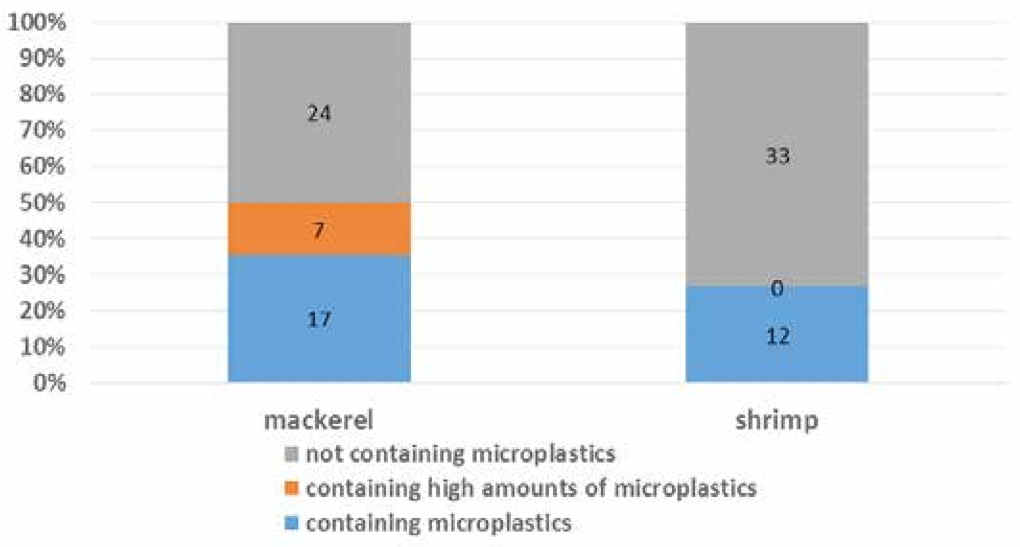


Fig.1 Percentage break-up of the micro plastic abundance in the analysed fish and shrimp specimen

The prevalence of fibres as microplastics in the gut content of the fish indicated that this may be due to the fishing activities, which may have been originated from the disintegration of fishing gears such as fishing nets, long line wires and related activities. The colour of the microplastics which was observed during this study was blue. This colour also support that the origin of this plastic may be fishing related activities. Addition to that, the microplastics of transparent, green, brown and red colours were also encountered during this study.

Further, no correlation was found with reference to feeding intensity and availability of microplastics through the gut content analysis suggested that this may be due to the accidental entry to this gut content and not intentional. However, the amount of availability in the gut content inferred that this fishing ground infested with good amount of microplastics concentration floating in the pelagic waters and also deposited in the sediment.

Conclusion

The two species such as *Rastreilleger kanagurta* and *Metapenaeus monoceros*, respectively, representing fin and shell fish of pelagic and benthic community gut content stated that 50% of the studied mackerel specimens were containing microplastics of which 33% were exhibit high amounts. The shrimp specimen contain 36% of the microplastics but in lesser concentration. There were no correlation was found with reference to feeding intensity and availability of microplastics through the gut content analysis suggested that this may be due to the accidental entry to this gut content and not intentional. A systematic study is essential to understand bioaccumulation of the same to the humans.

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