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Distribution and Diversity of Gelatinous Zooplankton from The Coastal Waters of South Andaman

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Abstract

The distribution, abundance and species composition of Gelatinous Zooplankton in relation to various environmental parameters was studied from the coastal waters of South Andaman during September and October 2017. A total of 21 Chaetognaths species and 5 Ctenophora species were recorded in the current survey, which is quite higher than previous studies from this area. Chidiyatapu station displayed a complete absence of ctenophore species. Since these organisms are considered as indicator species of different water masses, it is very important to understand the distribution and diversity of these gelatinous zooplankton from the coastal waters of this area.

Introduction

Gelatinous zooplanktons are fragile animals with delicate often transparent bodies and are easily damaged or destroyed (Lalli & Parsons, 2001). All jellyfish are gelatinous zooplankton, but not all gelatinous zooplankton are jellyfish. The most commonly encountered organisms include ctenophores, medusae, salps and chaetognaths in the coastal waters. However, almost all marine phyla, including Annelida, Mollusca and Arthropoda, comprise gelatinous species, but many of those unusual species live in the open ocean and the deep sea and are less available in the casual ocean observer (Nouvian, 2007). The gelatinous zooplankton has also been called "Gelata". The carnivorous gelatinous zooplankton is defined as scyphomedusae, cubomedusae, siphonophores and ctenophores are important representatives of coastal and marine ecosystems.

Chaetognatha, commonly known as arrow worms is a small phylum consisting of approximately 120 species. They are exclusively marine with small (2-120mm), slender, arrow-like, bilaterally symmetrical bodies with grasping bristles or hooks on each side of the mouth that are used to capture prey with a wide range of distribution in the oceanic, neritic, and even estuarine waters of tropics to the polar oceans and from surface waters to the deep sea. The trunk bears one or two pairs of lateral fins and a terminal, horizontally oriented, tail fin. The body is in a circular cross-section, filled with fluid and usually translucent. Most of them are holoplanktonic forms, dwelling along the water column (0– 1,000 m) during their entire life cycle. A few genera are exclusively benthic (i.e., *Spadella, Paraspadella, Bathyspadella*), and some genera are represented by deep-living forms (i.e., *Hemispadella*, *Heterokrohnia*; Casanova 1986,1996 & 1999). The biomass of Chaetognatha has been estimated as 10-30% of that of copepods in the world oceans (Reeve, 1970); Because of their mass occurrence and predatory mode of life, Chaetognaths play an important role in transferring energy from copepods to higher trophic levels. Hence, the role of Chaetognaths in the marine ecosystem is very important as they mediate the transport of material from the surface to the deep sea and reallocate carbon in the vertical plane, in particular. Paleontological as well as molecular data indicate their very ancient origin (Szaniawski 1982, 2002; Telford & Holland 1993, 1997) but still, their phylogenetic relationships remain under deliberation and their origin is commonly regarded as enigmatic.

Among Chaetognaths, the genus *Sagitta* appears to be the most successful and most highly evolved group with nearly 30 known species. Species of this genus inhabit aninfiniterange of oceanic environments and bathymetric levels. Chaetognaths are also known as excellent indicators of water masses because of their close relationship with certain environmental variables (e.g. salinity, temperature and dissolved oxygen) as well as their species-specific horizontal and vertical distribution (Terazaki, 1999). Chaetognaths are ideal indicators of different physical processes that are active in the marine system (Ulloa *et al*. 2004).

Ctenophores are commonly known as comb jellies. They are exclusively marine, brilliantly luminescent, holoplankton lacking stinging cells and harmless to humans but very detrimental for marine invaded ecosystems. The name Ctenophora is derived from the Greek Word "Cteno" meaning Comb and "Phora" meaning bearer which pertains to the 8 comb rows used for locomotion by the majority of Ctenophore. Ctenophores are known as ambush predators, they use their sticky tentacles or expandable sticky lobes to capture zooplankton. Ctenophores combs propel their movement; the comb rows beat in a regular sequence starting from the aboral end (away from the mouth) thus propelling the ctenophore with its mouth forward. There are about 150-200 described species; most are holopelagic (i.e. they live in the open ocean). Most of these beautiful and exquisite animals are not very well studied because of either difficult to obtain or extremely delicate (or both). The ecology of pelagic Ctenophora has been extensively investigated in recent years. In spite of their fragility, they are now well recognized by marine zoologists as counting significant biomass, especially under blooming conditions (Arai, 2005).

Some species of Ctenophores are introduced into the environment as invasive species. The only comb jelly known to be widespread in the Baltic Sea is the "Sea Gooseberry" *Pleurobrachia pileus* (O.F. Muller, 1776). Temperature has a great influence on the massive occurrence of Ctenophores in surface seawater. Ctenophores hold a special place within the field of evolutionary biology as molecular evidence suggests that they are the sister group to all other metazoans (Dunn et al. 2008). Despite their ecological and evolutionary significance, understanding the taxonomy and phylogeny of the Ctenophora remains poorly understood. Identifying ctenophores can be exceptionally difficult, due to the level of morphological similarity observed between closely related species (and more distantly related larval forms).

Gelatinous zooplankton species are not typically well known, and this is especially true with members of Ctenophora. Though well-represented, in almost all marine pelagic zones they are difficult to capture and difficult to preserve. Furthermore, their taxonomy is poorly resolved, making their identification often difficult (Venkataraman et al. 2015). Also, Jellyfishes (phyla Cnidarian and Ctenophore) have received adequate attention because of their noxious nature which affects the fishery resources.

Andaman and Nicobar Islands is a pristine island ecosystem. Studies on zooplankton distribution have been taken by different researchers to understand the distribution & diversity pattern of zooplankton. Zooplankton comprises diverse phyla in which studies on Chaetognaths & Ctenophorans are very rare. These gelatinous zooplankton occupies a major place in trophic structure as they feed oncarnivore fishes & higher trophic animals. They are also the major organism to determine the health of higher trophic structures. As they are also considered indicator species of different water masses. So it's very relevant to understand the distribution & diversity of these gelatinous zooplankton in the coastal waters of South Andaman.

Materials and Methods

Study area

Andaman and Nicobar Islands comprising 572 islands, located between lat. 6°-14°Nandlong. 92°-94° Einthenorth Indian Ocean have an area of 8293 km^2 with well-known for their biodiversity and fishery potential which makes these islands one of the best biodiversity hotspots in India. Samples were collected during September and October 2017 from three stations viz. Junglighat (St. 1) is located at 11° 39′N and 92º 43′E. Whereas, Bambooflat (St. 2) is located at 11° 42´ N and 92° 43´E and Chidiyatapu (St. 3) is located at 11°31´ N and 92°43´ E.

Junglighat (St. 1)

Junglighat bay is situated near Haddo-harbor and is one of the major fish landing centers in South Andaman. This bay is funnel-shaped and the mouth is three to four times wider than the head end. This lies between 11° 39′ N and 92° 43′ E. The shoreline has been modified due to sea level rise and the tsunami of 2004. Patches of mangroves are present in the head end and right side of the bay. The area is enclosed by hills on all three sides and more fresh water seepage in the industrial region. Mechanized boats with fishing trawls are halting here and releasing oil, plastics, fish discards, and other wastes. Sewage pollution due to human interference is also observed in this area. This station is rich with gelatinous zooplankton.

Bambooflat (St. 2)

Bambooflat is situated in North East part of South Andaman with co-ordinate of 11°42′N and 92°43′E. This station is exposed to anthropogenic activities such as ship transport, jetty, house- hold drainage and hotels outlet. Hence the organic matter of the water is more here. A thermal power station is also situated here which influences the hydro-biological environment more by disturbing the physical parameters of the water. Most of the substratum here is clayey or muddy.

Chidiyatapu (St. 3)

Chidiyatapu is located 30km away from Port Blair. The sampling site, Munda pahad beech is situated on the southern tip of Andaman island which lies between 11°31′ N and 92°43′ E. It is a bay region that connects the Andaman Sea and the Bay of Bengal through the Macpherson strait. This area is the least polluted with fewer anthropogenic activities. Here coral reef is a site for SCUBA diving and snorkeling among tourists as well as the scientific community with small-scale fishery activities are found in this area. Mangroove patches are also found in the study area.

Sampling Strategy

Zooplankton nets with a mesh size of 200 µm and a mouth area of 0.2 m² were used for the collection of zooplankton(UNESCO, 1968; Goswami, 2004). The flow meter was fixed at the mouth of the net, horizontal hauling was carried at sub-surface water for 10 minutes at a depth of approximately 1m during the early morning (04:30am) throughout the study period by motorized boat. Collected samples were preserved immediately to avoid autolysis by using 4% formalin, 1-2 ml of glycerine was added to exclude the loss of quality of gelatinous samples due to formalin-induced shrinkage. Physico-chemical parameters of Seawater, such as water temperature, salinity, pH, and Dissolved oxygen were analyzed immediately and recorded throughout the study period from both stations. Laboratory analysis was carried out after 7 days of preservation with glycerine, allowing the specimens to regain their original size and texture. For the observation, sorting and taxonomic identification of specimens Nikon SMZ 1500 model stereoscope were used, and a Nikon camera (Coolpix P6000) was used for taking photographs. The classification and identification of specimens up to the lowest possible taxonomic level was done by using standard identification manuals and keys Conway, (2012), Michel. B. Harding, (1984), Perry R.A. (2003).

Calculation for zooplankton enumeration

A flow meter is a counter, which records the number of revolutions. The flow is fixed in such a way so that it records the actual flow of water passing through the net. The volume of water filtered is expressed in the form of individual per meter cube.

$V = A \times R \times K$

Where,

K = Calibration constant

A = Mouth area of the net

R = Flow meter reading and

V = Volume of water filtered.

Total number of zooplankton specimens/ individuals of all group

$$= \frac{\text{Total counts}}{\text{The volume of water filtered}}$$

Data were expressed in individual per meter cube

Environmental Parameters

Physico-chemical parameters were carried out monthly during the study period. Parameters like surface water temperature, surface water salinity, pH and dissolved oxygen were estimated immediately. The latitude and Longitude of both locations were recorded using GPS (Geographical Positioning System).

1. **Water temperature:** Water temperature was recorded with the help of Hg- thermometer with ±0.1 accuracy. Temperature was expressed in ˚C.
2. **Salinity:** Salinity was measured by placing a drop of water sample over the glassin the refract meter (ATAGO) and the reading was measured in PSU.
3. **pH:** The pH was measured by immersing the pH meter (GENEI) in the water sample and the reading was noted.
4. **Dissolved Oxygen:** Dissolved Oxygen of the water sample was estimated using Winkler's method and the value was recorded in mg/L.

Data Analysis

Most commonly used univariate biodiversity indices d (Marglef'sspeciesrichness,1968), J' (Pielou'sevenness, 1966),and H' diversity index (Shannon-Weiner, 1963) for gelatinous zooplankton ecology were calculated and expressed. In order to know the similarity pattern in space and time of GZP, multivariate analysis was performed on square root transformed based on abundance data. Bray-Curtis similarity was calculated to draw a dendrogram by using PRIMERv6.1(ClarkandGorley,2006).

Result and Discussion

Environmental Parameters

Temperature: The mean water temperature was recorded as 29.67±0.5 and showed no much variation during the study period.

Salinity: The mean salinity during this study was recorded as 29.67±0.52 PSU. The lowest salinity 23 PSU(St. CT) was recorded during the month of Sept' 17 due to high fresh water influx from the adjacent areas during the South west monsoon. Highest salinity 36PSU (St. BB) was observed during the month of Sept'17.

pH: The mean pH during this study was recorded as 7.69±0.35. Lowest pH 7.21(St. JG) was recorded in the month of Sept' 2017. Alkaline pH 8.21(St. CT) was recorded during Oct. 2017.

Dissolved Oxygen: The mean dissolved Oxygen during this study was recorded as 7.69±0.35 mg/L. High value of dissolved Oxygen 6.1 mg/L (St. BB) was recorded in the month of Oct. 2017 and the lowest dissolved Oxygen 3.4 mg/L(St. BB) was recorded during the month of Oct. 2017.

Table 1. Environmental parameters (Mean±SD) during the Study period

	JG	BB	CT
Water Temperature (°C)	29.5±0.71	30±0.01	29.5±0.71
pH	7.43±0.32	7.64±0.30	7.995±0.30
Dissoloved Oxygen (mg/L)	4.8±1.84	3.8±0.57	3.55±0.21
Salinity (PSU)	25.5±0.71	33±4.24	28±7.07

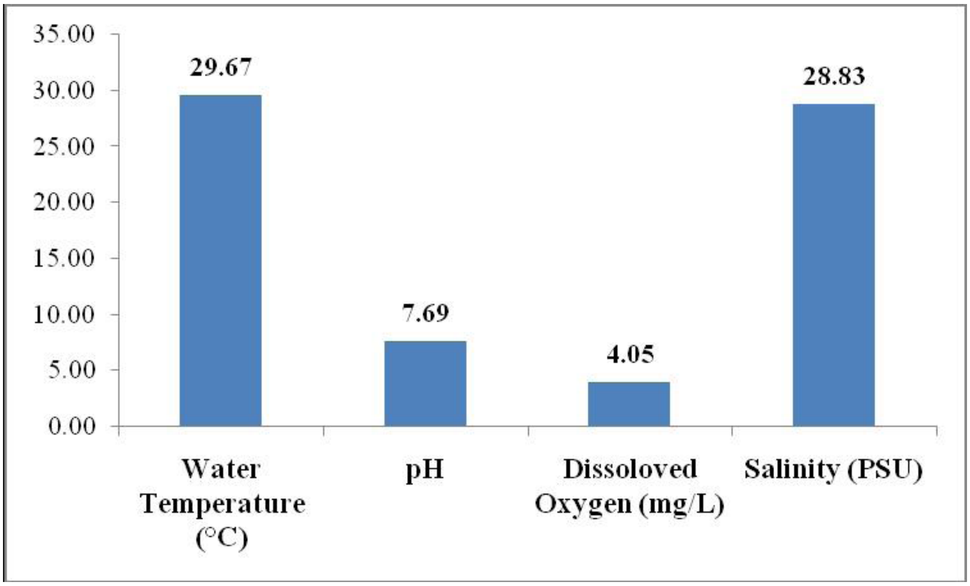

Fig. 2. Water quality parameters (mean±SD)in the study area.

Faunal composition

Species composition of Chaetognaths

During the present study, 21 Chaetognaths species were recorded from a total of 2665 individuals encountered. Junglighat station was recorded with highest number of individuals 0.221 ind./m^3in the month of Oct'17. While Bambooflat station was recorded with the lowest number of individuals 0.0074ind./m^3 in Sept'17 month.Highabundanceof this group was recordedin all the three stations during the month of Oct'17. Among the Chaetognath, *Sagitta* sp. remained the dominant genera comprising 65.29% of all the chaetognath populaltion. The percentage contribution of *Sagitta* sp. was 26.44% followed by *S.maxima*19.25% (Fig.3 and 4). While species like *Sagitta bipunctata, S. bedoti, S. lyra,S. macrocephala, S. megalopthalma, S. nagae, S. neglecta, S. robusta, Krohnitta subtilis* were recorded once during the study period. Some species viz. *Sagitta crassa, S.hexaptera, S.maxima, S.minima, S.heterokrohnia, Krohnitta* sp., *Pterosagitta draco, Spadella sp.*were present in all three stations throughout the study period.

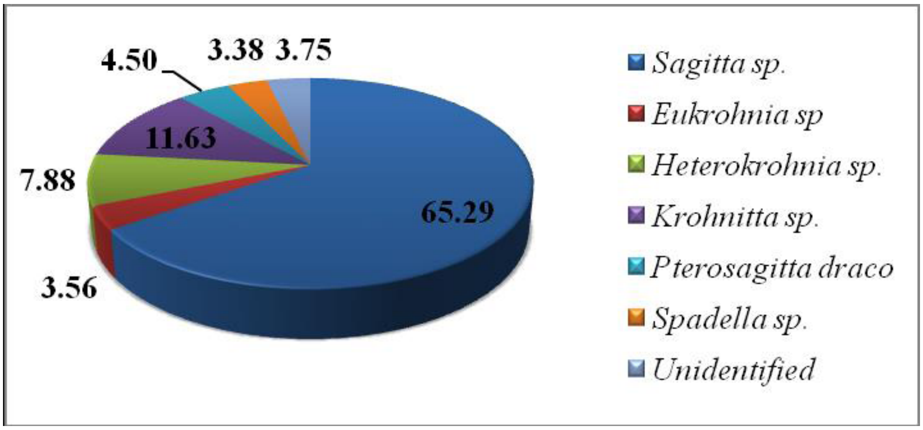

Fig. 3. Overall % composition of Chaetognaths during the study period

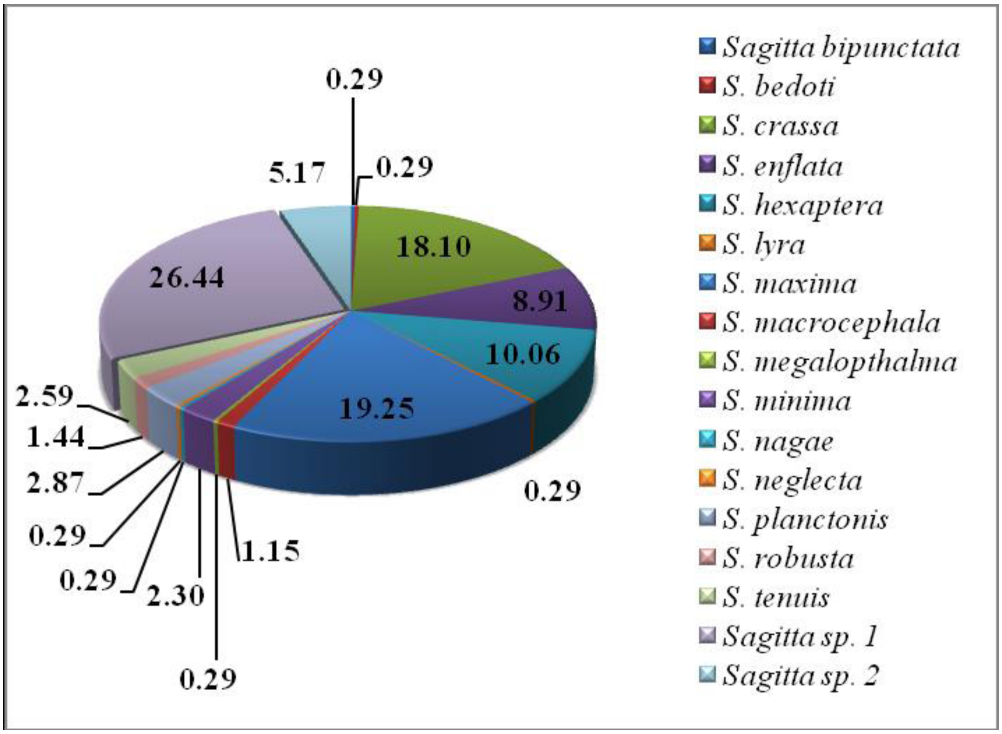

Fig. 4. Overall % composition of *Sagitta*sp. during the study period

Table 2. Overall mean abundance and % composition of Chaetognaths in the study area.

***: Highly present, **: Moderately present, *: Rarely present, -: Absent

Species Name	Mean±SD	%	JG	BB	CT
Sagitta bipunctata	0.17±0.41	0.19	-	-	*
S. bedoti	0.17±0.41	0.19	-	-	*
S. crassa	10.5±9.59	11.82	***	*	**
S. enflata	5.17±5.53	5.82	**	-	**
S. hexaptera	5.83±7.68	6.57	**	*	*
S. lyra	0.17±0.41	0.19	*	-	-
S. maxima	11.17±17.87	12.57	***	**	*
S. macrocephala	0.67±1.63	0.75	*	-	-
S. megalopthalma	0.17±0.41	0.19	-	*	-
S. minima	1.33±1.75	1.50	*	*	*
S. nagae	0.17±0.41	0.19	*	-	-
S. neglecta	0.17±0.41	0.19	*	-	-
S. planctonis	1.67±3.14	1.88	*	*	*

S. robusta	0.83±2.04	0.94	*	-	-
S. tenuis	1.5±3.21	1.69	*	*	-
Sagitta sp. 1	15.33±14.14	17.26	***	**	**
Sagitta sp. 2	3±3.68	3.38	*	*	*
Eukrohnia sp.	3.17±6.34	3.56	*	-	**
*Heterokrohnia*sp.	7±6.63	7.88	**	*	**
Krohnitta pacifica	1.67±3.20	1.88	-	**	-
Krohnitta subtilis	0.17±0.41	0.19	-	-	*
Krohnitta sp.	8.5±8.98	9.57	***	-	**
Pterosagitta draco	4±3.79	4.50	**	*	*
Spadella sp.	3±2.45	3.38	**	*	*
Unidentified	3.33±2.42	3.75	**	*	*
Mean abundance of Chaetognath (ind./m^3)	0.145±0.108				

Species composition of Ctenophora:

A total of 102 individuals were encountered during the study period and represented by 5 different species. *Pleurobrachia pileus* (86%) was the dominating species with mean abundance of (14.33±21.24) in all three stations followed by *Pleurobrachia* sp.(6.86%). Species such as *P. globossa, Euchlora rubrana* and *Mneomipsis* sp.didn't vary much in the present study. *Pleurobrachia pileus and P. globossa* was recorded at both Junglighat & Bambooflat stations while some species viz. *Euchlora rubra, Mneomipsis* sp. was recorded only from Junglighat station. Notably, Chidiyatapu station didn't have any appearance of any Ctenophore species in the current study.

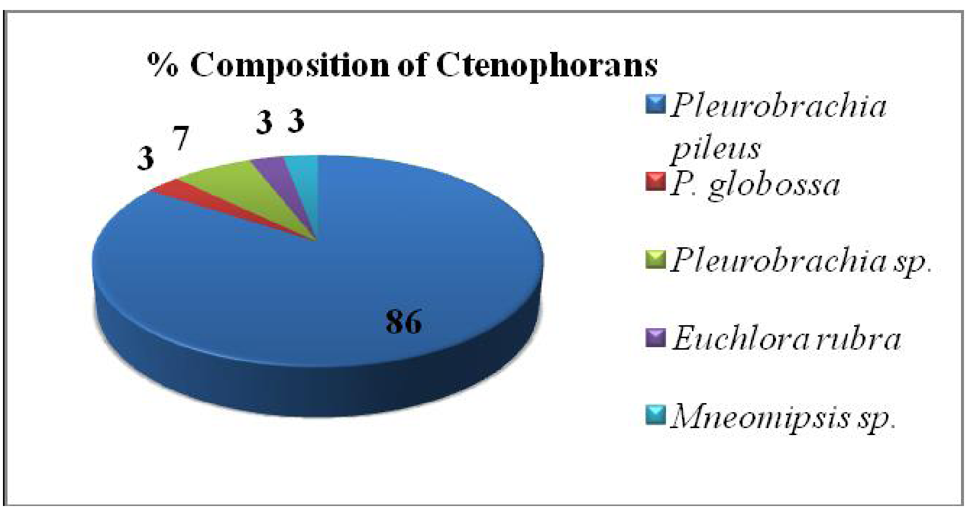

Fig. 4. Overall % composition of Ctenophorans during the study period

Table 3. Mean abundance of Ctenophorans and % composition at three study area

Species Name	Mean±SD	%	JG	BB	CT
Pleurobrachia pileus	14.33±21.24	84.31	***	***	-
P. globossa	0.50±0.76	2.94	*	*	-
Pleurobrachia sp.	1.17±2.61	6.86	*	-	-
Euchlora rubra	0.50±1.12	2.94	*	-	-
Mneomipsis sp.	0.50±1.12	2.94	*	-	-
Mean abundance of Ctenophorans(ind./m^3)	0.01±0.007				

***: Highly present, **: Moderately present, *: Rarely present, -: Absent

Univariate Biodiversity Indices

Chaetognaths

The no. of species (S) and diversity indices in the study area are given in. The no. of species recorded were high at St. 1 (S=14) and St.3 (S=11) compared to St.2 (S=8). Species diversity at St. 1 (H′= 2.31) and St.3 (H′= 2.21)was comparatively higher compared to St.2 (H'=1.64). Relatively high species richness (d=2.08) and low evenness in Chaetognatha species distribution (J= 0.86) at St. 1 could be due to the dominance of few species such as *Sagitta sp., Sagitta maxima* and *Sagitta crassa*.

Table. 5. Univariate diversity indice of Chaetognaths

N: Mean individual (Ind. /m^3).S: Species richness, d: Margalef's Diversity, H': Shannon-Weiner diversity index and J': Pielou's Evenness index (Valued are presented as mean±SD).

Location	S	N	d	J'	H'(loge)
JG	14.5±0.70	727.5±378.30	2.08±0.28	0.86±0.02	2.31±0.03
BB	8±7.07	212.5±236.8	1.2727±1.05	0.9135±0.07	1.64±0.811
CT	11.5±3.53	392.5±286.3	1.865±0.866	0.91675±0.014	2.21±0.25

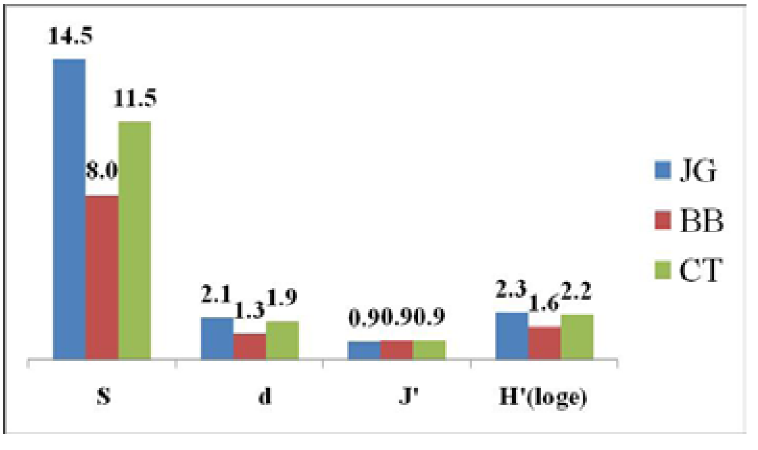

Fig.5. Univariate diversity indices of Chaetognath at different locations

(S-Number of Specie S, d-Marglef's species richness, J'-Pielou's eveness and H'- Shannon-Weiner diversity index).

Ctenophora

The no. of species (S) and diversity indices in the study area are given in Table 6. The no. of species recorded was high at St. 2 (S=16) and very low at St.3 (S=0.1). Relatively high species richness (d=0.94) and high evenness in Ctenophora species distribution (J'= 0.50) was observed at St. 1

Table 6. Univariate diversity indices (mean) of Ctenophora

N: Mean individual (Ind. /m^3) S: Species richness, d: Margalef's Diversity, and J': Pielou's Evenness index (Valued are presented as mean±SD).

Location	S	N	d	J'
JG	2.5±3.54	34.50±48.79	0.94±0.67	0.50±0.35
BB	16.5±23.33	16.5±23.33	0.286±0.20	0.1±0.01
CT	0.1±0.01	0.1±0.01	0.1±0.01	0.1±0.01

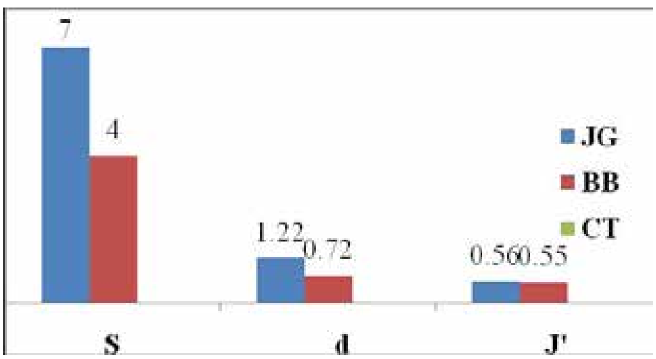

Fig.6. Diversity indices of Ctenophora at different locations

(S-Number of Specie S, d-Margief's species richness, J'-Pielou's eveness and H'- Shannon-Weiner diversity index).

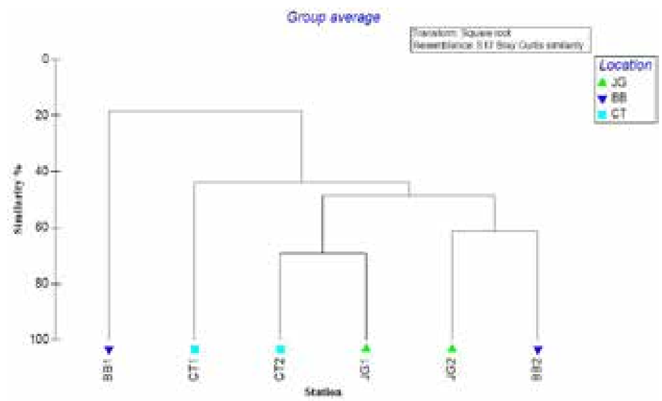

Fig.7 . Dendrogram showing Bray-Curtis similarity of Chaetognaths in the formation of clusters between stations in the study area.

Multivariate Analysis: Faunal assemblages

Bray-Curtis similarity was calculated on the square root transformed abundance data of Chaetognaths. Cluster dendrogram shows two distinct assemblage patterns in the study area Specimen at Chatam and Bambooflat assembled and showed 70% similarity while the chaetognatha species at Janglighat and Bamboo flat showed 60% similarity. While for Ctenophora Bray-Curtis didn't show any distinct assemblage may be due to their least occurrence of ctenophore species during the study period.

Dissucssion

Chaetognaths

Chaetognaths were represented by 21 different species belonging to 5 families i.e. Spadillidae, Eukrohniidae, Sagittidae, Pterosagittidae, Krohnittidae and represented by *Sagitta bipunctata, S. bedoti, S. crassa, S. enflata, S. hexaptera, S. lyra, S. maxima, S. macrocephala,S. megalopthalma, S. minima, S. nagae, S. neglecta, S. planctonis, S. robusta, S. tenuis, Eukrohnia spp., Heterokrohnia spp., Krohnita pacifica, K.subtilis, Pterosagitta draco* and *Spadella spp.* which is high as compared to a previous report (Saneen &Padmavati 2017). The reason for the high species diversity in the present study could be due to the eutrophic nature and abundance of copepods inthe coastal waters of South Andaman & alsothe lack of detailed information, particularly on Chaetognaths in this region. Species like *S.bedfordii, S.pulchra, S.ferox, S,zetesios, S. decipiens, S.regularis* and *S.pacifica* which are already reported from Indian coastal waters were not found during the present study. It could be due to the geographic barrier, endemic to the Arabian Sea &Rodriguez Triple Junction (Rao and Ganapati 1958; Bieri 1959).

Some deep water species like *S.maxima* & *S. planctonis* are also encountered during this study with the second highest abundance in the entire sample. This kind of variation could be due to their cosmopolitan nature. Seas around the Andaman and Nicobar Islands and central and northern parts of the Bay of Bengal also have to be thoroughly explored and studied well for the chaetognath fauna. *S. tenuis* was reported during this study from 2 stations (JG & BB) and the occurrence of this species in the Indian Ocean is uncertain but a common species in the Atlantic Ocean was reported from Trivandrum Coast by Menon(1945) *S.enflata* & *Pterosagitta draco* the most abundant species of West coast of India (Nair, 1993; Balamurugan, 2011) recorded in significant numbers in this study.

St.BB (St.2) showed a very low diversity of chaetognath during Sept'17. The reason for this could be high grazing pressure by the higher trophic organisms i.e. fishes that are generally found more abundant in this area. All three stations showed a higher number of species abundance during Oct'17 month. St.JG (St.1) showed the highest species abundance in the entire study period may be because of the highly eutrophicated water and the influx of sewage waste from the fisher folk dwelling there and also a major fish landing center

Ctenophora

A total of 5 ctenophora species were reported during the study period and belonged to 3 different genera. St. JG (St.1) showed highest species diversity could be due to the occurrence of periodic algal blooms followed by high abundance of copepods in this area (Karthik et al. 2012). While St. CT (St.3) showed complete ctenophores during the study period. This could be due to climatic effects such as the tsunami occurred during December 2004 this area has been affected by the high incursion of seawater into the shoreline and influenced the ecosystem of this area. Similar observation was also reported earlier from this area (Saneen &Padmavati 2017). Population dynamics of various gelatinous zooplankton taxa varied according to the change in physic-chemical factors, eutrophication, trophic cascading, overfishing as found in this study has been reported earlier (Purcell 2005).

Summary and Conclusion

The sheltered coral reef ecosystem of Andaman Sea promotes speciation & endemism, of various gelatinous zooplankton taxa. The present study gives an account on species composition and seasonal change in the abundance of Chaetognaths & Ctenophora from the coastal waters of South Andaman during September-October 2017. A total of 21 Chaetognaths species and 5 Ctenophora species were recorded which is quite higher than previous studies from this area. Chidiyatapu station showed a complete absence of ctenophore species. This kind of restrictions could be due to limited period sampling in this study. A detailed monitoring would be able to demonstrate the population dynamics of these gelatinous zooplankton over long time scale with a valuable information regarding the oceanic currents may be able to resolve the mysterious realmof these gelatinous zooplankton in this area.

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