

## **Mesozooplankton distribution near an active volcanic island in the Andaman Sea (Barren Island)**

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### **Abstract**

The study addresses the distribution and diversity of mesozooplankton near the active volcano-Barren Island (Andaman Sea) in the context of persistent volcanic signature and warm air pool existing for the last few months. Sampling was done from the stations along the west and east side of the volcano up to a depth of 1,000 m during the inter monsoon (April) of 2006. Existence of feeble warm air pool was noticed around the Island (Atm. Temp. 29°C). Sea surface temperature recorded as 29.9°C on the west and 29.6°C on the east side stations. High mesozooplankton biomass was observed in the study area than the earlier reports. High density and biomass observed in the surface layer decreased significantly to the deeper depths. Lack of correlation was observed between mesozooplankton biomass and density with chl. *a*. Twenty-three mesozooplankton taxa were observed with copepoda as the dominant taxa followed by chaetognatha. The relative abundance of chaetognatha considerably affected the copepod population density in the surface layer. A noticeable feature was the presence of cumaceans, a hyperbenthic fauna in the surface, mixed layer and thermocline layer on the western side station where the volcano discharges in to the sea. The dominant order of copepoda, the calanoida was represented by 52 species belonging to 17 families. The order poecilostomatoida also had a significant contribution. Copepods exhibited a clear difference in their distribution pattern in different depth layers. The families Calanidae and Pontellidae showed a clear dominance in the surface whereas small-sized copepods belonging to the families Clausocalanidae and Paracalanidae were observed as the predominant community in the mixed layer and thermocline layer depth. Families Metridinidae, Augaptilidae and Aetideidae were observed as dominant in deeper layers.

**Keywords :** Mesozooplankton , Copepods , Barren Island , Andaman Sea

## **Introduction**

The Barren Island forms part of Andaman and Nicobar archipelago which extends as a stretch of islands from Myanmar to Sumatra separates Andaman Sea from Bay of Bengal. The Bay of Bengal and western Andaman Sea of the northeastern Indian Ocean are very complex basins, in which the interplay of frequent cyclonic depressions, high precipitation, high sea surface temperature, low surface salinity and density stratification occurs (Rama Raju et al. 1981; Murthy et al. 2000, Shenoj et al. 2002; Pankajakshan et al. 2002; Vinayachandran et al. 2002; Jayu and Prasannakumar 2006). Barren Island, which stands in the midst of the volcanic belt on the edge of the Indian and Burmese tectonic plate, is the only active volcano (area 10 km<sup>2</sup>, Summit elevation 335 m) in the Indian subcontinent. It is located 135 km east of Port Blair in east Andaman Sea. It has shown sustained irruptive activity since shortly after the tsunami 2004, the deadliest disaster in the modern history (Javed and Murty 2005; Walthman 2005; Bandopadhyay et al. 2006). After the earthquake, the volcano has irrupted more than six times and still continues the intermittent activity. True to its name, it is an uninhabited area and has a small population of feral goats, birds, bats and a few rodent species. Scientific investigation from this volcanic island is scanty. The general physicochemical characteristics during an intense activity time from the near shore waters have been reported by Mustafa (1992). Rao et al. (1990) gave a preliminary account on the fauna and flora of this island. At present, there is no study describing the plankton distribution from this region except that of Eashwar et al. (2001) which describes plankton distribution during an inactive phase of the volcano. Recently, Laluraj et al. (2006) reported the persistent volcanic signature and the existence of warm air pool around the Barren Island region. Zooplankton acts as an important interconnecting link between the primary producers and higher consumers of the marine food web. Any changes in the surrounding environment may easily reflect on this community; thus, they perform as indicators of environmental changes. In view of this, the present study examines abundance, community structure and diversity of the mesozooplankton in this area up to a depth of 1,000 m.

## **Materials and methods**

The hydrographic and mesozooplankton samples were collected onboard FORV Sagar Sampada (Cruise No. SS 243) in April 2006. Sampling was carried out from stations on the western (Station 1) and eastern side (Station 2) around 300 m distant from the shoreline of the island (Figs. 1 and 2). Atmospheric temperature was recorded using the ship mounted automatic weather station (AWS, model YSI 44202, accuracy,  $\pm 0.15^{\circ}\text{C}$ ; 10 min interval). Sea-Bird CTD (accuracy  $\pm 0.001^{\circ}\text{C}$ ) was used to

measure the temperature and salinity whereas dissolved oxygen was measured using Winkler's titration method (Grasshoff et al. 1983). For the estimation of chlorophyll (chl.) *a*, 1 l of water was collected from the desired depths using Go-Flo bottle connected to CTD rosette and filtered through GF/F filters (pore size 0.7  $\mu\text{m}$ ), extracted after keeping in 90% acetone for 24 h in the dark and measured using spectrophotometer (Model-UV 1650PC, Shimadzu) before and after acidification (Strickland and Parsons 1972). Mesozooplankton was collected from surface using Bongo Net (mouth area 0.6 m, mesh size 200  $\mu\text{m}$ ) connected with a flow meter (General Oceanics, Model No. 2030) and Multiple Plankton Net (MPN; HYDRO BIOS, mouth area 0.25 m<sup>2</sup>, mesh size 200  $\mu\text{m}$ ) was used for collecting the stratified samples to study the vertical distribution. Five standard depths sampled using MPN are as follows—Surface to Top of Thermocline (TT); Mixed layer (0-TT), TT to Bottom of Thermocline (BT); Thermocline (TTBT), BT–300 m, 300–500 m and 500–1,000 m. The hauling speed of Bongo net was two nautical miles per hour and that of MPN was limited to 1 m/s. Zooplankton biomass was estimated by displacement volume method, and samples were preserved in 4% buffered seawater formalin. Later in the laboratory, the samples sorted out to the possible lowest taxonomic level using standard references (UNESCO 1968; ICES 2000). The species level identification of copepod was done using dissecting microscope (Nikon Smz 645 and Nikon Eclipse E 400) following standard references (Sewell 1929; Kasturirangan 1963; Tanaka 1956). The values were converted to milliliter per unit volume for biomass ( $\text{ml m}^{-3}$ ) and No per unit volume ( $\text{No m}^{-3}$ ) for density. Mesozooplankton taxa and copepod species were averaged from the two stations due to the negligible variations observed between the two stations.

## Results

### Environmental variables

Wind was southwesterly with an average speed of 4.3  $\text{m s}^{-1}$ . Atmospheric temperature was 29°C on the western side and 28.5°C on the eastern side. A feeble warm air pool was noticed around the island. Sea surface temperature recorded as 29.9°C on the west and 29.6°C on the east side station. Sea surface salinity was 32 on the east and 32.4 in the west. The station depth was 1,408 m on the west and 1,512 m on the east side. Mixed layer depth was 19 and 18 m respectively on western and eastern side stations. The vertical distributions of environmental variables were summarized in Table 1. Vertical profile of temperature showed a sharp reduction from surface to bottom, it varied between 30.02°C to 29.16°C in the mixed layer and 9.89°C to 6.54°C in 500–1,000 m depth strata. Salinity showed an increasing pattern from surface to deeper depths in both stations. It varied between 32.08 to 32.56 in the

mixed layer and 32.28 to 35.00 in thermocline to 1,000 m depth. Dissolved oxygen distribution remained almost similar at both stations showed a reduction from surface to deep, and a slight increase in the lowest strata. Values varied from 4.36 to 4.32 ml l<sup>-1</sup> in the mixed layer and 0.55 ml l<sup>-1</sup> to 1.05 ml l<sup>-1</sup> in the deeper depth (500–1,000 m). A strong oxygen reduction was observed in the BT– 300 m (0.42 ml l<sup>-1</sup> to 0.36 ml l<sup>-1</sup>) and in 300–500 m (0.41 ml l<sup>-1</sup> to 0.56 ml l<sup>-1</sup>) depth layers. Surface Chl. *a* was observed as 0.32 and 0.38 mg m<sup>-3</sup> in the surface waters of the western and the eastern sides, and to the deeper strata, it decreased sharply up to a depth of 100 m, and below this depth, the variation was almost negligible (Fig. 3).

#### Mesozooplankton biomass and density

Marginal difference was observed in surface biomass between the western side station (3.87 ml m<sup>-3</sup>) and the eastern side (2.65 ml m<sup>-3</sup>) (Fig. 4). The density at surface was 2,328 and 1,787 No m<sup>-3</sup> on the western and eastern side respectively (Fig. 5). In vertical distribution, biomass and density was high in the mixed layer, which decreased sharply to BT–300 m layer. Below BT–300 m depth the variations were negligible in west (Figs. 4 and 5). Eastern side station also showed similar trend but a slight increase of biomass was observed in the 300–500 m depth.

#### Mesozooplankton composition

A total of 16 taxa were identified from the surface samples. Copepoda was the major group (70.69%) followed by chaetognatha (23%). Other major groups observed were apendicularia (2.70%), gastropoda (1.16%) and euphausiida (1.23%). The rest of the groups together contributing <1% of the total density include foraminifera, radiolaria, siphonophora, heteropoda, cephalopoda, amphipoda, lucifer, salpa, decapoda, fish egg and cumacean. Percentage contribution of dominant groups (at least 1% in any depth layer) was shown in Fig. 6. Twenty-three mesozooplankton taxa were observed from the vertical (MPN) collection. Mixed layer supported maximum number of groups (21) followed by TT–BT (13), BT–300 m (14), 300–500 m (10) and 500–1,000 m (10). Copepoda formed the predominant taxa in all depth layers (79.6–96.94%). An increasing trend was observed for ostracoda from TT–BT to deeper layers. Copepoda, amphipoda, euphausiida, decapoda, hydrozoa, chaetognatha and siphonophora were observed throughout water column while polychaeta, pteropoda, heteropoda, gastropoda and cephalopoda were found only up to 300 m depth. The rest of the groups which shown a scattered distribution include mysids, salps, doliolids, amphioxus, fish eggs and fish larvae. Hyperid

amphipods were observed uniformly distributed in the water column but the *Phronima* sp. was observed only below 300 m. Appendicularia (1.24%), foraminifera (0.61%) and radiolaria (0.45%) were observed only in the mixed layer. A noticeable feature observed was the presence of the cumaceans, a hyperbenthic fauna, in the surface (0.03%), mixed (0.06%) and thermocline (0.1%) layers of the western side station.

#### Copepod community structure

Copepod density showed a sharp decrease from the surface to the deeper layers and it varied from 1,676 to 7 No m<sup>-3</sup> on the western side and 1,215 to 6 No m<sup>-3</sup> on the eastern side stations (Fig. 5). Four representative orders—Calanoida, Cyclopoida, Poecilostomatoida and Harpacticoida—were observed in the surface samples. Calanoids formed the dominant form (86.03%) followed by Poecilostomatoids (11%), Cyclopoids (2%) and Harpacticoids (0.97%). Among the 17 calanoid families observed, members of Calanidae (58%) and Pontellidae (12%) were the dominant in the surface (Table 2). Nineteen species of calanoids belonging to ten families were identified (Table 3). *Undinula vulgaris*, *Cosmocalanus darwini*, *Pontella diogonalis*, *Pontella securifer* were the dominant species observed. Importantly, a reduction in the number of small copepods in the surface, which are usually abundant, was noticed.

In vertical distribution, in addition to the orders observed in the surface sample, order Monstrilloida and Mormonilloida were also noticed and were recorded only in the deeper waters below 300 m depth, though in very small concentrations. Calanoida, Poecilostomatoida and Cyclopoida showed their predominance in the deeper waters also. Harpacticoids were sparsely distributed throughout the water column. Abundance of copepod families varied with depth. Among the order Calanoida, family Paracalanidae (14.5%) and Clausocalanidae (31%) were dominated in the mixed layer and thermocline. The BT-300 m (89%) and 300-500 m (45%) depths showed a clear dominance of the family Metridinidae. The deepest layer (500-1,000 m) was mainly dominated with the families Aetideidae (31%), Scolecitrichidae (28%) and Augaptilidae (17%) (Table 2). A total of 52 calanoid species belonging to 16 families were identified from the surface to 1,000 m depth (Table 3). The mixed layer supported the maximum number of species (29) followed by thermocline (22), BT-300 m (14), 300-500 m (19) and 500-1,000 m (19) depths. Among the calanoids *Clausocalanus arcuicornis*, *C. farrani*, *Calocalanus plumulosus*, *Paracalanus aculeatus*, *Acrocalanus gracilis*, *Eucalanus subcrassus*, *Candacia catula*, *Centropages orisinii*, *Euchaeta concinna* and *Temora discaudata* were the dominant

species in the mixed layer and in thermocline. *Pleuromama indica* dominated in the BT–300 and 300–500 m layers. Species like *Euchirella pulchra*, *Gaetanus miles*, *Euaugaptilus indicus*, *Scaphocalanus* sp, *Pleuromamma xiphias*, *Amalothrix indica*, *Lophothrix frontalis* and *Lophothrix* sp. were abundant below 300 m depth.

## **Discussion**

High zooplankton standing stock was observed during the present study compared to the earlier reports (Madhupratap et al. 1981; Antony et al. 1997; Madhu et al. 2003) from the Andaman and Nicobar region. The air temperature and sea surface temperature during the study period, at intense volcanic eruption period and during an inactive phase of the volcano of Laluraj et al. (2006) clearly shows the varied environment existing in this area. Ash-and-steam plumes from the volcano rising to 1.5–3 km altitude were seen by pilots and in satellite imagery (Venzke et al. 2008). Sorokin et al. (1998) reported the occurrence of increased plankton production in water above the active underwater volcano due to nutrient enrichment. Similarly the present study assumes that observed increased standing stock may be related with the warming and nutrient rich ash discharges from the volcano. According to several studies by Scripps Institution of Oceanography, the initial dissolution of volcanic ash in seawater provides an external nutrient source for primary production in ocean surface waters that may stimulate biological drawdown of CO<sub>2</sub>. Volcanic ash releases large amounts of phosphate, iron, and other macronutrients and bioactive trace metals (Duttamel 2010).

However, there was no correlation observed between mesozooplankton biomass with chl. *a*. It may be related with the active grazing by herbivorous zooplankton (Gasparini and Castel 1999). Abundance of herbivorous copepods in the surface particularly the species *U. vulgaris*, *C. darwini* and appendicularians indicates this. *U. vulgaris* is having a very high grazing rate on phytoplankton (Hwang et al. 1998). In addition to it, predominance small copepods belonging to Paracalanidae and Clausocalanidae in the mixed layers and the thermocline layer also may have considerable role in this waters. Recent studies revealed the significance of small copepods due to their feeding efficiency (Calbet et al. 2000; Satapoomin et al. 2004). The Andaman Sea is reported as oligotrophic and nutrient limited (Qazim and Anzari 1981; Gomes et al. 1992) and as picoplankton dominates both in biomass and the productivity in oligotrophic waters (Platt and Li 1986), the study assumes that besides the traditional food chain a secondary food chain supported through the microbes also may active in these waters.

The high zooplankton standing stock and density observed in the mixed layer showed a reduction in the deeper layers may be related with food availability. Present study observed abundance of carnivorous groups (chaetognaths and pontellid copepods) in the surface layer, whereas small-sized herbivorous/omnivorous copepods (Family Clausocalanidae and Paracalanidae) in the mixed layer. Chaetognaths, an important plankton predator, (Reeve 1980; Feigenbaum and Maris 1984; Ekblad 2008) observed in high abundance indicates active predation might happened in the surface. Copepods are important food items for chaetognaths (Liang and Vega-Pérez 1995), and they play an extremely important role in energy transfer to higher trophic levels (Terazaki 1998; Fulmer and Bollens 2005). It has been found that approximately 10–30% of the copepod biomass is transferred by this pathway through chaetognath biomass (Pierrot-Bults 1996).

The presence of cumaceans, a hyperbenthic fauna, is quite striking, since no reports are so far available from the Indian Ocean describing it as a regular component in the mesozooplankton. They were identified in the surface, mixed and thermocline layers indicating a peculiar variation in the community structure. Low pH and high temperature in some shallow water columns in the immediate vicinity of the Barren Island during its active phase was noticed in the earlier study (Mustafa 1992). However, no such sharp variation in environmental variables was noticed in the water column during the present observation. So, the study supposes that some kind of disturbance happen to the bottom fauna, most probably very close to the island may have resulted the presence of cumaceans in the surface layers even at the midday sampling time.

Eashwar et al. (2001) attributed the unusual pigmentation of the copepods collected from this area as an adaptation to UV radiation. The present study not observed any unusual colouration to the sample or peculiar pigmentation to any of the plankton identified during this period. However, there was a frequent occurrence of blue coloured calanoid copepods (Family Pontellidae) particularly in the surface. This also cannot be considered as a peculiar feature of the study region as they are referred as the typical representatives of neustonic plankters in tropical and subtropical waters (Hering 1965; Heinrich 1960, 1974; Komaki and Morioka 1975). Also meager representation of foraminiferans, radiolarians and gastropods were recorded in contrast to the observation of Eashwar et al. (2001).

Copepods were the dominant taxa similar to the earlier reports of the world oceans including Arabian Sea (Padmavati et al. 1998) and Bay of Bengal (Rakhesh et al. 2006; Fernandes and Ramaiah 2008). The relative abundance of ostracods in thermocline and in deeper waters is assumed to be due to their affinity to the salinity (Stephen and Kunjamma 1996). An increase of biomass in the 300–500 m

depth than BT–300 m layer on the eastern side was due to the occurrence of siphonophores and euphausiids. Among the copepoda, calanoida was the dominant order (Farran 1936; Deevey and Brooks 1977; Madhupratap and Haridas 1990) and their vertical distribution well agrees with the earlier report (Madhupratap et al. 2001). Small-sized copepods (Clausocalanidae, Paracalanidae) were again the predominant community in the mixed layer (Stephen and Kunjamma 1987; Padmavati et al. 1998; Kouwenberg 1994; Cornils et al. 2007). The dominance of *P. indica* in the BT–500 m was noticed and their abundance in the deeper oxygen minimum layer was reported from different regions of Indian Ocean (Saraswathy and Iyer 1986; Goswami et al. 1992; Fernandes and Ramaiah 2008). Comparatively large amphipods, euphausiids and acetes were observed in the deeper layers indicating that deeper waters also sustain comparatively good standing stock by their adaptability to the varying environment.

To our knowledge, this is the first account on vertical distribution of mesozooplankton from this region while the volcano is active. Despite the comparative dominance of mesozooplankton biomass and the presence of hyperbenthic cumacean, the mesozooplankton distribution near the Barren Island remained quite ordinary. So the present observation assumes that changes in the climate particularly the ash discharges from the volcano may have influenced the surrounding planktonic standing stock and the probable temperature increase of the water column close to the island may have more affected the very near bottom fauna around the island. More studies are needed to understand the composite ecological interactions taking place in such regions.

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**Table 1** Vertical distribution of environmental variables from the western and eastern (in parenthesis) stations

	Surface-TT	TT-BT	BT-300 m	300-500 m	500-1,000 m
Temperature (°C)	30.02-29.16 (29.58-29.43)	29.16-15.03 (29.40-15.40)	15.03-11.31 (14.99-10.99)	11.31-9.89 (10.98-9.58)	9.89-6.54 (9.57-6.71)
Salinity	32.08-32.28 (32.45-32.56)	32.28-34.89 (32.58-34.89)	34.89-35.02 (34.89-35.02)	35.02-35.01 (35.02-35.00)	35.01-34.91 (35.00-34.91)
Dissolved Oxygen (ml l <sup>-1</sup> )	4.36-4.34 (4.32-4.34)	4.34-0.40 (4.35-0.37)	0.40-0.41 (0.36-0.42)	0.41-0.55 (0.42-0.56)	0.55-1.05 (0.55-1.02)

**Table 2** Percentage composition of copepod families observed in different depths

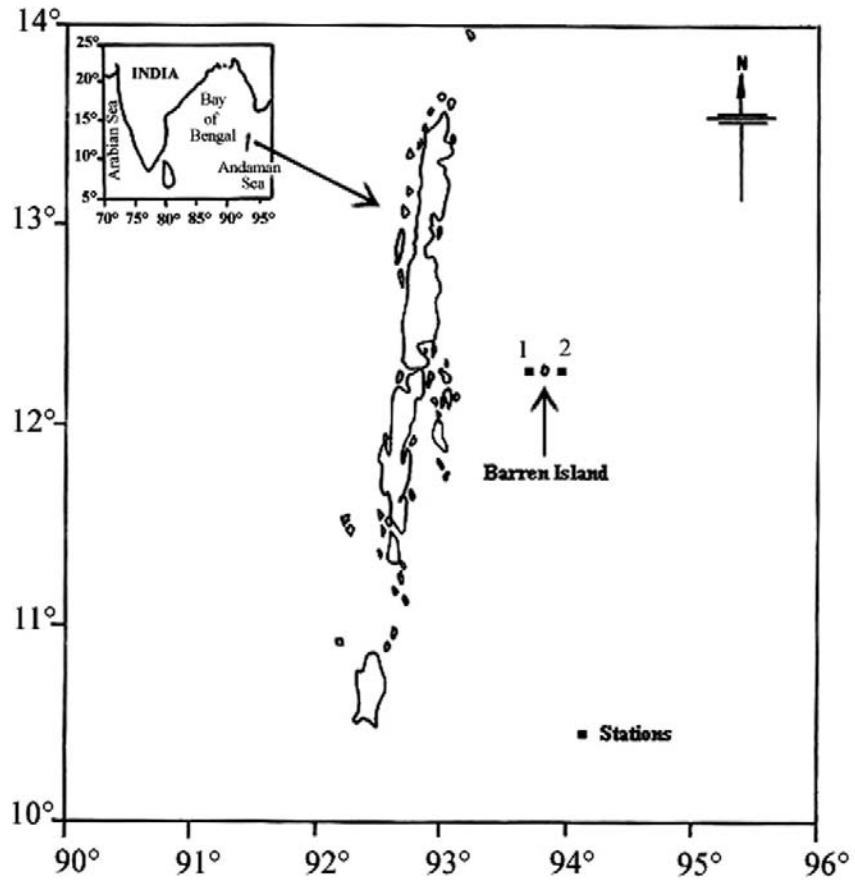
	Surface	0-TT	TT-BT	BT-300 m	300-500 m	500-1,000 m
Calanidae	58	4.5	9	-	-	-
Eucalanidae	6	3	1	-	-	-
Paracalanidae	3	18	11	0.3	1	-
Clausocalanidae	3	39	23	1.5	0.4	0.4
Mecynoceridae	-	2	-	-	-	-
Acartiidae	3	1	0.7	-	-	-
Candaciidae	0.1	2	0.8	0.01	-	-
Centropagidae	0.2	4	3	0.01	-	-
Lucicutiidae	0.03	1	3	0.02	0.46	1
Euchaetidae	0.2	0.3	2	-	-	0.1
Pontellidae	12	1	0.4	-	-	-
Aetideidae	-	4	3	3	21.75	31
Heterorhabdidae	-	-	-	0.7	3	7
Temoridae	0.5	1.3	2	0.02	-	-
Metridinidae	-	1	11	88.73	45.6	9
Scolecitrichidae	-	1	8	1.3	14.5	28
Augaptilidae	-	-	-	-	10	16.6
Oithonidae	2	1.5	1.1	0	0.54	4
Corycaeidae	4	10	8.75	3	-	1
Oncaeidae	7	5	12	1.25	2	1.4
Saphrinidae	0.2	-	-	0.06	-	-
Miracidae	0.67	0.2	-	0	-	-
Clytemnestridae	0.1	0.2	-	0.1	-	-
Agisthidae			0.25			0.2
Monstrilloidae	-	-	-	-	0.25	
Mormonilloidae	-	-	-	-	0.5	0.3

**Table 3** Species distribution of copepods in different depths

Species observed	Surface	0-TT	TT-BT	BT-300 m	300-500 m	500-1,000 m
<i>Canthocalanus pauper</i>	√	√	√	-	-	-
<i>Nannocalanus minor</i>	-	√	-	-	-	-
<i>Undinula vulgaris</i>	√	√	√	-	-	-
<i>Cosmocalanus darwini</i>	√	√	√	-	-	-
<i>Eucalanus elongatus</i>	√	√	-	-	-	-
<i>Eucalanus subcrassus</i>	√	√	√	-	-	-
<i>Acrocalanus longicornis</i>	√	-	-	-	-	-
<i>Acrocalanus gracilis</i>	√	√	√	-	-	-
<i>Paracalanus indicus</i>	√	√	-	√	-	-
<i>Paracalanus aculeatus</i>	-	√	√	-	-	-
<i>Delius</i> sp.	√	√	-	-	-	-
<i>Calocalanus pavo</i>	√	√	-	-	-	-
<i>Calocalanus plumulosus</i>	-	√	√	-	√	-
<i>Clausocalanus arcuicornis</i>	√	√	√	√	√	-
<i>Clausocalanus brevipes</i>	-	√	-	-	-	-
<i>Clausocalanus farrani</i>	-	√	√	√	-	-
<i>Clausocalanus</i> sp.	-	-	-	-	-	√
<i>Mecynocera</i> sp.	-	√	-	-	-	-
<i>Acartia amboinensis</i>	√	√	√	-	-	-
<i>Candacia catula</i>	√	√	-	-	-	√
<i>Candacia discaudata</i>	-	-	√	√	-	-
<i>Centropages furcatus</i>	√	√	√	√	-	-
<i>Centropages orsinii</i>	-	√	√	-	-	-
<i>Lucicutia flavicornis</i>	-	√	√	√	√	√
<i>Euchaeta concinna</i>	√	√	-	-	-	-
<i>Euchaeta malayensis</i>	-	-	√	-	-	√
<i>Pontella diogonalis</i>	√	-	-	-	-	-
<i>Pontella securifer</i>	√	-	-	-	-	-
<i>Labidocera acuta</i>	√	-	-	-	-	-
<i>Pontellina plumata</i>	-	√	√	-	-	-
<i>Calanopia minor</i>	-	√	-	-	-	-
<i>Aetideus giesbrechti</i>	-	√	√	√	-	-
<i>Euchirella pulchra</i>	-	-	-	-	√	√
<i>Gaetanus miles</i>	-	-	-	√	√	√
<i>Heterorhabdus spinifrons</i>	-	-	-	-	√	-
<i>Heterorhabdus</i> sp.	-	-	-	√	-	-
<i>Temora discaudata</i>	√	√	√	-	-	√
<i>Pleuromamma indica</i>	-	-	√	√	√	√
<i>Pleuromamma abdominalis</i>	-	-	-	-	√	√
<i>Pleuromamma gracilis</i>	-	-	√	√	√	√
<i>Pleuromamma xiphias</i>	-	-	-	-	√	√
<i>Metridia</i> sp.	-	√	-	√	√	-
<i>Amallothrix indica</i>	-	-	-	-	√	√
<i>Lophothrix frontalis</i>	-	-	-	√	√	√
<i>Lophothrix</i> sp.	-	-	-	-	-	√
<i>Scolecithricella ctenopus</i>	-	√	√	√	-	-
<i>Scaphocalanus echinatus</i>	-	√	-	-	√	-
<i>Scaphocalanus</i> sp.	-	-	-	-	-	√
<i>Euaugaptilus angustus</i>	-	-	-	-	-	√
<i>E.indicus</i>	-	-	-	-	√	√

<i>Euaugaptilus</i> sp.	-	-	-	-	√	-
<i>Augaptilus</i> sp.	-	-	-	-	√	√
<i>Haloptilus acutifrons</i>	-	-	√	-	-	-
<i>Haloptilus ornatus</i>	-	-	-	-	√	-
<i>Haloptilus</i> sp.	-	-	-	-	-	√
<i>Oihona</i> sp	√	√	√	-	√	-
<i>Corycaeus</i>	√	√	√	√	-	-
<i>Oncaea</i>	√	√	√	√	√	√
<i>Sapphirina</i> sp	√	-	-	-	-	-
<i>Macrosetella</i> sp.	√	√	-	-	-	-
<i>Aegisthus mucronatus</i>	-	-	√	-	-	√
<i>Clytemnestra scutellata</i>	√	√	-	√	-	-
<i>Miracia efferata</i>	-	√	-	-	-	-
<i>Mormonilloida</i>	-	-	-	-	√	√
<i>Monstrilloida</i>	-	-	-	-	√	-
<i>Canthocalanus pauper</i>	√	√	√	-	-	-
<i>Nannocalanus minor</i>	-	√	-	-	-	-
<i>Undinula vulgaris</i>	√	√	√	-	-	-
<i>Cosmocalanus darwini</i>	√	√	√	-	-	-

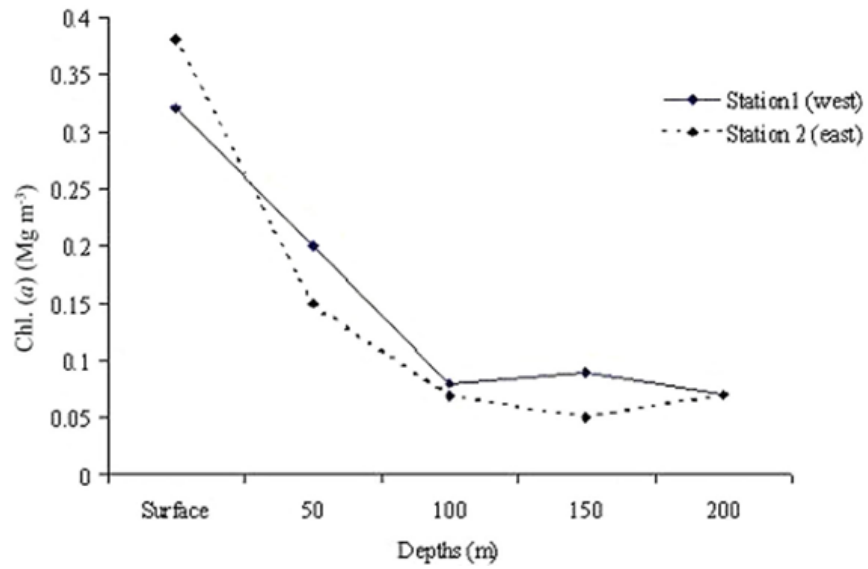




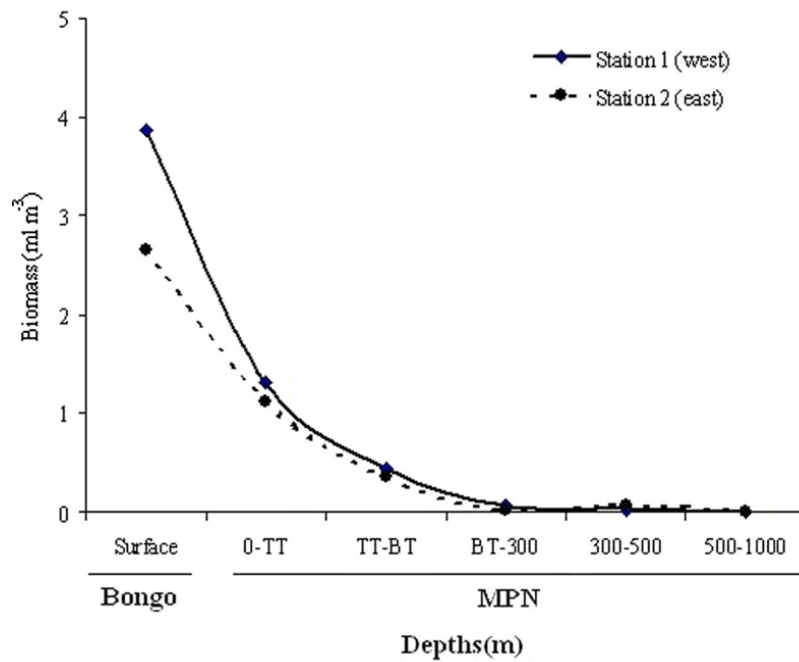
**Fig. 1** Station locations



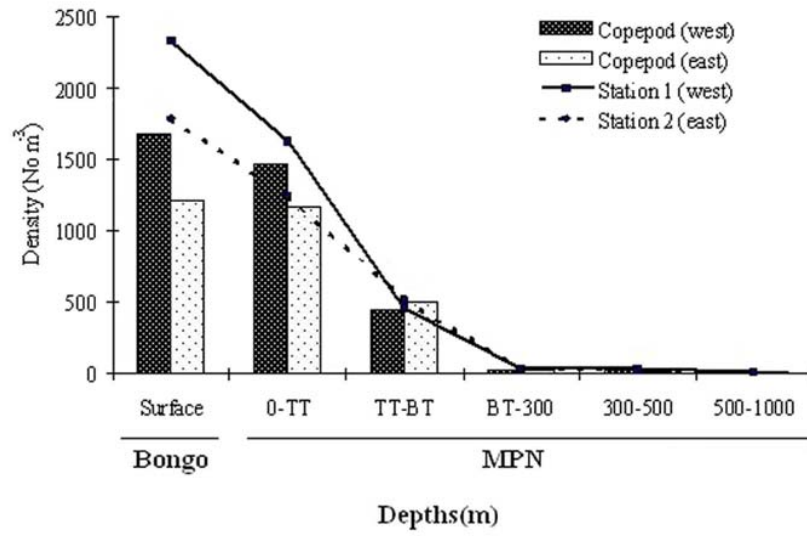
**Fig.2** Barren Island and its active volcanic vent-view from western side  
(Photograph taken from *FORV Sager Sampada* on 04/04/2006)



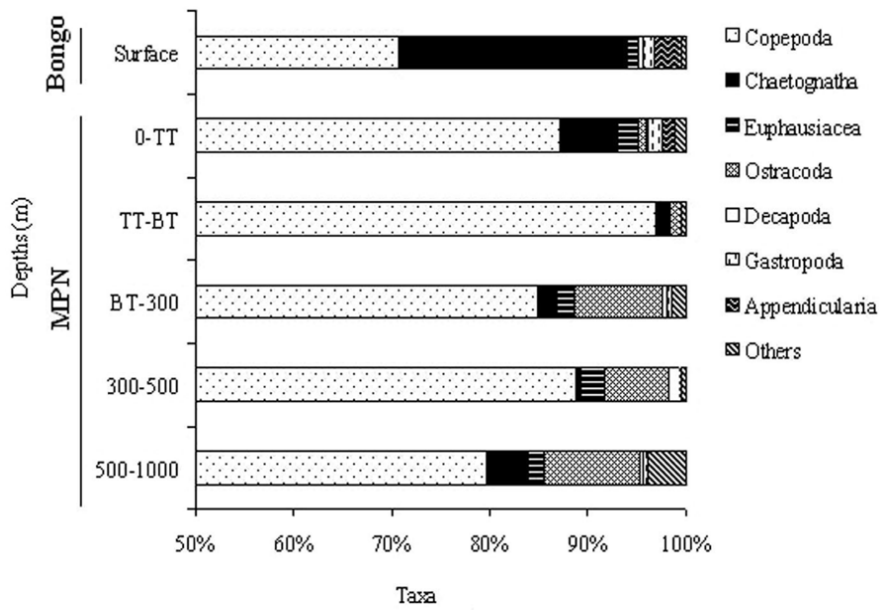
**Fig. 3** Chlorophyll *a* distribution in different depths



**Fig. 4** Biomass distribution in different depths



**Fig. 5** Total density (*lines*) and copepod density (*bars*) in different depths



**Fig. 6** Percentage contribution of dominant groups in different depths