Benthic macrofauna of Andaman and Nicobar insular margin with emphasis on polychaetes

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Ph. D. Thesis in Marine Biology

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Front Cover Illustration
Background: Coralline sandy sediments with biogenic fractions from Andaman and Nicobar Islands.
Overlay: Polychaete *Palmyreuphrosyne* sp., collected onboard FORV *Sagar Sampada* from the study area.

Certificate

This is to certify that the thesis entitled "**Benthic macrofauna of Andaman and Nicobar insular margin with emphasis on polychaetes**" is an authentic record of the research work carried out by Ms. Aiswarya Gopal (Reg. No.: 3875), under my scientific supervision and guidance in the School of Marine Sciences, Cochin University of Science & Technology, in partial fulfilment of the requirements for award of the degree of Doctor of Philosophy of the Cochin University of Science & Technology and that no part thereof has been presented before for the award of any other degree, diploma or associateship in any University. Further certified that all relevant corrections and modifications suggested during the pre-synopsis seminar and recommended by the Doctoral Committee have been incorporated in the thesis.

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DECLARATION

I hereby declare that the thesis entitled "**Benthic macrofauna of Andaman and Nicobar insular margin with emphasis on polychaetes"** is an authentic record of research work conducted by me under the supervision of Dr. A. V. Saramma, Retd. Professor, Department of Marine Biology, Microbiology and Biochemistry, School of Marine Sciences, Cochin University of Science and Technology, Kochi and no part of it has been presented for any other degree or diploma in any University.

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Aiswarya Gopal

Dedication

To my Family

A gift that lasts forever

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LIST OF ACRONYMS & ABBREVIATIONS

ACE	Abundance Coverage Estimator
AI	Andaman Islands
ANI	Andaman and Nicobar islands
ANOVA	Analysis of Variance
AS	Andaman Sea
BoB	Bay of Bengal
CBD	Convention on Biological Diversity
CCA	Canonical Correspondence Analysis
CMLRE	Centre for Marine Living Resources and Ecology
CoML	Census of Marine Life
CTD	Conductivity, Temperature, Depth Profiler
DO	Dissolved oxygen
EAI	Eastern margin of Andaman Islands
EEZ	Exclusive Economic Zone
FORVSS	Fishery & Oceanographic Research Vessel *Sagar Sampada*
ICE	Incidence Coverage Estimator
IIOE	International Indian Ocean Expedition
IndOBIS	Indian Ocean Biogeographic Information System
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MANOVA	Multivariate Analysis of Variance
MGZ	Median grain size
MPA	Marine Protected Areas

NEAS	North East Bay of Bengal
NEM	North East Monsoon
NI	Nicobar Islands
nMDS	non-metric Multidimensional Scaling
NWBoB	North West Bay of Bengal
OBIS	Ocean Biogeographic Information System
OM	Organic matter
OMZ	Oxygen minimum zone
PERMANOVA	Permutational multivariate analysis of variance
POM	Particulate Organic Matter
PR	Predators
PRIMER	Plymouth Routines in Multivariate Ecological Research
Sal	Salinity
SDF	Surface deposit feeders
SEAS	South East Bay of Bengal
SF	Suspension feeders
SIMPER	Similarity Percentage
SPSS	Statistical Package for the Social Sciences
SSDF	Sub-surface deposit feeders
SST	Sea Surface Temperature
SWBOB	South West Bay of Bengal
Temp	Temperature
UNEP	United Nations Environment Programme
WAI	Western margin of Andaman Islands
WoRMS	World Register of Marine Species

APPENDIX 1

Checklist of polychaete species of the Andaman and Nicobar insular margin (50-200m)

APPENDIX 2

Publications

1. Aiswarya Gopal, Abdul Jaleel K. U., Saramma A. V. & Sanjeevan V. N. (2014). A new species of polychaete, *Pettibonella shompens* sp. nov. (Orbiniidae), from the Nicobar Islands, North Indian Ocean. *Marine Biology Research*, 10:10, 1033-1037.

2. Aiswarya Gopal, Abdul Jaleel K. U., Usha V. Parameswaran & Anil Kumar Vijayan (2015). *Armandia sampadae*, a new species of polychaete (Opheliidae) from Andaman Sea, Northern Indian Ocean. *Journal of the Marine Biological Association of the United Kingdom*, 96(8):1625-1632.

3. Usha V. Parameswaran, Abdul Jaleel K. U., Aiswarya Gopal, Sanjeevan V. N. & Anil Kumar Vijayan (2015). On an unusual shallow occurrence of the deep-sea brittle star *Ophiomyces delata* in the Duncan Passage, Andaman Islands (Northern Indian Ocean). *Marine Biodiversity*, 36(1):151-156.

Chapter I

Introduction

An island is a landmass surrounded by water. The distinction between oceanic and continental islands was first made by Charles Darwin. Oceanic islands lie in deep water, often at considerable distance from a continent, and never having been connected to a continent (Lomolino *et al.*, 2004). Majority of them are volcanic in origin. On the other hand, continental islands lie close to the continent in shallow waters. Approximately 45,000 tropical islands exist in Pacific and Indian Ocean (Arnberger & Arnberger, 2001) and ~250 islands in the Atlantic Ocean. The margin (shelf, slope and rise) surrounding an island is known as insular margin (Pálmason, 1974; Hernández *et al.*, 2009). Oceanic islands are noteworthy in their species diversification and endemism (Margalef, 1980). Tropical oceanic islands are typically surrounded by coral reefs, and are characterised by high spatial heterogeneity and exceptionally high biodiversity (Armenteros *et al.*, 2012). Insular margins consists of extensive soft sediment environments below the coral cover, which can sustain diverse and functionally important benthic assemblages (Snelgrove, 1999; Gray, 2002). Marine sediments which form the substratum for benthic fauna, comprising of rock and soil particles that are transported from land areas to the ocean by wind, rivers, along with the remains of marine organisms, submarine volcanic products, precipitates from seawater etc. The seafloor is the final destination of terrestrial and marine particulate organic matter (POM) which is continuously remineralised so as to replenish the nutrients back to water column, thereby sustaining marine food webs and ecosystems.

Benthic fauna are those organisms which live on, in the sediments or near the seabed. The term ‘benthos’ was coined by the German biologist, Ernst Haeckel in 1891, from the Greek word meaning ‘depths of sea’. Benthos comprises of vast variety of organisms, ranging from microscopic bacteria to large megafauna with diverse in lifestyles and feeding modes (Cowie & Levin 2009). Mare (1942) was the first to classify benthic organisms into hyperbenthos, macrobenthos, meiobenthos and microbenthos. Benthos are generally divided into three functional groups, infauna, epifauna and hyper benthos, representing those organism living within the substratum, on the surface of the substratum and just above it, respectively (Pohle & Thomas 2001). Based on their size, benthic organisms have been divided into four major groups - megafauna (>5cm), macrofauna (5cm-500µm), meiofauna (in between 500µm and 63µm) and microfauna (<63µm) (Mare, 1942; Gray & Elliot, 2009). Macrofauna includes macro invertebrates such as polychaetes, crustaceans (amphipods, isopods, caprellids, decapods), molluscs, echinoderms, nemerteans and echiuroids, while meiofauna are dominated by free-living nematodes and microfauna includes protozoans and other microorganisms. Hessler & Jumars (1974) and Snelgrove (1999) argued for the modification of the size classification of benthos, in order to include species retained in 250-300µm sieves as macrofauna, as smaller sized forms are abundant components in certain ecosystems like the deep-sea and oligotrophic systems. The taxonomically diverse component of benthos is macrofauna (Gage, 2001), which harbour highly diverse fauna at phylum level (Snelgrove, 1998). Benthic-pelagic coupling refers to the continuous exchange of energy, mass, or nutrients between benthic and pelagic realms, through sedimentation of pelagic production, followed either by remineralisation and release of nutrients to the water column or its assimilation into benthic biomass, which is incorporated to the pelagic realm through trophic interactions and periodic release of planktonic larval forms. These coupling processes are crucial for the maintenance of food webs and production in a marine ecosystem (Gray, 1981; Kelly *et al.*, 1985; Graf 1992; Marcus & Boero, 1998; Raffaelli *et al.*, 2003; Quijon *et al.*, 2008; Griffiths *et al.*, 2017).

Macrofauna are among the major contributors of ecosystem functioning in the marine realm (Gray & Elliot, 2009), playing key roles in energy transfer in the marine realm. They form food of commercially important fishes and shell fishes (Parulekar *et al.*, 1980; Heip *et al.*, 1992; Snelgrove, 1999) and are used to estimate the availability of potential food for demersal fishes (Petersen, 1918; Blegvad, 1930; Jones & Slinn, 1956). Macrofauna are functionally diverse (Snelgrove, 1999), and many taxa are able to utilize the pelagic derived organic matter (OM) as food either directly (i.e. deposit feeders and suspension feeders) or indirectly (e.g. predation and scavenging). The sediment ingested by the deposit feeders among macrofauna is egested as faecal pellets, which is easily degraded by microorganisms. The movement, burrowing, tube building, and feeding activities of macrofauna cause the reworking of sediment particles, thereby enhancing pore ventilation, and mixing of OM (Organic matter) to deeper layers of sediments, which makes the OM available for microbial remineralization – a process termed as ‘bioturbation’ (Rhoads & Young, 1970; Pearson & Rosenberg, 1978; Snelgrove & Butman, 1994; Hutchings, 1998; Reise, 2002). Macrofauna and meiofauna enhances inorganic nutrient fluxes by advective fluid flow (Aller & Aller, 1992; Elmgren, 1978). The inorganic nutrient exchange between the sediments and water column by bioturbation varies markedly with the size of the organisms, their density and modes of activity (Griffiths *et al.*, 2017). A majority of benthic invertebrates have a complex life cycle that includes separate planktonic larval and bottom-dwelling juvenile and adult phases (Eckman, 1996; Marcus & Boero, 1998; Carson & Hentschel, 2006; Rees *et al.*, 2009). Benthic invertebrate larvae form an important component in pelagic food chain. The settlement of larvae on the bottom sediments is affected by the local hydrodynamic conditions, food supply, substratum, predation, competition for space etc. which, in turn, determines the spatial and temporal distributions of species in benthic assemblages (Woodin 1991; Qian & Dahms, 2005).

Macrofaunal invertebrates can be used as indicators, due to their predominantly sedentary nature and their ability to respond to environmental stress in several ways (Dean, 2008; Bilyard, 1987). They also play a key role in metabolism of pollutants settling on the seafloor (Snelgrove, 1999), which may accumulate in their tissues, and subsequently be conveyed through the food chain (Snelgorve, 1999; Rees *et al.*, 2009). Benthic ecosystems are affected by anthropogenic (increased input of nutrients, fishing disturbances etc.) and climate change disturbances. These disturbances have significant effect on the environmental and biological parameters (community structure, functional ecology etc.) of the ecosystem (Kirby *et al.*, 2007; Griffiths *et al.*, 2017; Hiddink *et al.*, 2017). Macro invertebrates are also used to study the health of the ecosystem as their distribution is largely depended on the hydrographical conditions, sediment characteristics and food supply (Giangrande *et al.*, 2005). Each species exhibits varying responses to changes in environmental perturbations, which often results in predictable and measurable shifts in abundance and composition at the community level. In oxygen deficient conditions (e.g.

under hypoxic conditions) only opportunistic and well-adapted species are able to establish and thrive (Diaz and Rosenberg, 1995; Abdul Jaleel *et al.*, 2014, 2015).

Despite the importance of benthos in the overall functioning of marine ecosystems, studies on their distribution patterns around Island margins are scarce. Relatively more is known of benthos in and around the islands of the Pacific, when compared to the Atlantic and Indian Oceans. Around the Las Perlas archipelago (Panama) in the tropical eastern Pacific, polychaetes were found to be the dominant component of macrofauna, followed by crustaceans, with much higher species richness in sandy sediments with shell fragments, when compared to the silt and clay sediments (Mair *et al.* 2009). Polychaetes were similarly dominant in the subtidal sediments around Isla del Coco (Costa Rica), with low density but high species richness, which was attributed to several factors like geographic location, ocean currents and sediment heterogeneity (Sibaja-Cordero *et al.*, 2016). In the shallow coastal areas around Oahu, Hawaii (USA), benthic communities exhibited higher density, biomass and species richness in coral rubble environments than soft sandy sediments (McCarthy *et al.*, 1998). Significantly distinct polychaete assemblages were observed in artificial (Sea Tiger & YO257) and natural reefs (100 hole) in Malama Bay, Hawaii (Fukunaga & Bailey-Brock, 2008).

Some studies are published on the benthos in atoll lagoons of French Polynesia. Around Tahiti, macrofaunal density was found to be higher in the fringing reefs, relative to barrier reefs (Frouin & Hutchings, 2001). Macrobenthic communities in the atoll lagoons of the Central Tuamotu Archipelago were found to be characterised by high diversity of echinoderms and molluscs, which was higher in larger lagoons (Adjeroud *et* *al.*, 2000), and the distribution patterns were determined by complex interplay of physical factors like surface area, abundance of pinnacles, submerged reef flats, spillways and degree of hydrodynamic aperture. In the south-west lagoon of New Caledonia, sediment grain size were the key factor influencing benthic community structure in soft-sediment habitats (Chardy *et al.*, 1988). In the atoll lagoon of Uvea (New Caledonia), macrobenthic biomass decreased with increasing depth, and four zones (coastal zone, intermediate zone, back reef zone and deep zone) with distinct assemblages and discrete functional characteristics could be delineated based on the substratum (Garrigue *et al.*, 1998). The benthos of the Great Astrolabe islands (Fiji) have been subjected to some study. Within the lagoon (17-43m), molluscs were found to be the major taxon contributing to standing stock, followed by annelids, which reflected the dominance of suspension feeders (Newell & Clavier 1997). High species richness and endemism is also reported in the reefs around these islands, with high spatial heterogeneity, and sediment characteristics are found to be the key factors structuring the distribution patterns (Schlacher *et al.*, 1998; Mohammed & Coppard 2008).

The macrofaunal communities of the central Great Barrier Reef (Australia) were found to have distinct species composition in the inner, middle and outer reefs, despite the occurrence of similar sediment characteristics in the middle and outer reefs; and this was attributed to the variability in supply of larvae to these areas by water currents, their settlement (i.e. habitat selection) and differential survival (Riddle, 1988). Around the Lizard Island in the northern part of the Great Barrier Reef, crustacean assemblages were distinct in the coarser and finer sediments of the reef, with higher species richness and evenness in the former (Jones, 1984). Infaunal diversity was high in the Ningaloo Reef (Australia), where half of the assemblages were dominated by rare species and depth and sediment texture played key roles in determining faunal distribution (Przeslawski *et al.*, 2013).

High polychaete abundance and diversity is reported around the Tre, Mieu and Tham Islands (Vietnam) as well as the Natuna Islands (Indonesia), in the South China Sea, with low species recurrence and high evenness (Udalov *et al.*, 2006). In the latter region, sediment texture was found to be an important factor determining distribution. Molluscs were found to be numerically dominant in the islands of the Jakarta Bay (Indonesia), while species richness was significantly higher among the polychaetes (Al Hakim *et al.*, 2010). The influence of the monsoon on macrobenthic communities was evident around the Seribu Islands (Indonesia), where density and diversity was higher in near shore areas during the northwest monsoon, while density was high in the offshore areas during the southeast monsoon (Kastoro *et al.*, 1991). Similarly, in the coral reefs of Karah Island (Malaysia), macrofaunal density was found to be higher in the pre-monsoon season compared to the post-monsoon (Ibrahim *et al.*, 2006), with significant decrease in faunal density from coral covered to non-coralline areas (i.e. distance from shore). A study around the Singapore islands revealed that infaunal macrobenthic communities were influenced by environmental parameters like median particle-size, silt-clay content, salinity and zinc concentrations (Lu, 2005).

In the tropical Atlantic Ocean, distinct macrobenthic communities were observed in the sublittoral and intertidal habitats (tidal flats, reef pools and lagoon) of the Rocas atoll (Brazil), with higher diversity in the reef pools and lagoon; and this is attributed to the physical conditions prevailing in and around the atoll (Netto *et al.*, 1999). An evaluation of long term changes (between 1981-85 and 2003-04) in benthic assemblages of the Gulf of Batabano (Cuba) following a reduction in lobster and finfish catches, revealed a great reduction in species diversity and sea grass coverage associated with fishing disturbances on the seafloor (Arias-Schreiber *et al.*, 2008). Distribution of macro and meiobenthic assemblages of the coral reefs of Punta Frances National Marine Park (Cuba) was strongly influenced by habitat type, with higher density in the coral rubble, relative to sea grass beds, bare sand and algal turf (Ruiz-Abierno & Armenteros, 2016).

In the tropical Indian Ocean, some studies have been carried out on nearshore and intertidal benthic communities around several coral islands. The shallow water (11-62m) benthic communities around Mahe (Seychelles) where distinguished into shallow and deeper assemblages, under the influence of depth and sediment type (Mackie *et al.*, 2005). The oligotrophic sandy sediments of Mahe harboured significantly higher macrobenthic invertebrate diversity when compared to the temperate Irish Sea and the sub-tropical Hong Kong islands. Similar bathymetric zonation (shallow, intermediate and deep) in macrofaunal assemblages were also noted in the shallow water (20-140m) benthos around Reunion Island (Bigot *et al.*, 2006), coupled with bathymetric trends in abundance, biomass and species richness and dominance of polychaetes. Around the Qeshm Island (Iran), polychaetes were found to be dominant among macrofauna, followed by crustaceans (Nassaj *et al.*, 2010). High density and biomass were noted in macro and meiofauna in the deeper insular margin (500-4550m) of Mauritius, with dominance of polychaetes and nematodes, respectively (Ingole *et al.*, 1992). Preliminary investigations at shallow depths (5-40m) in the Palk Strait off Jaffna (Sri Lanka) revealed that depth and proportion of gravel were major factors determining macrofaunal distribution (Dahanayaka *et al.*, 2007).

The Lakshadweep and Andaman & Nicobar archipelagos are the significant oceanic coral islands within the Indian EEZ, while small coral islands are also found closer to mainland like in the Gulf of Kutch and Gulf of Mannar. In sandy beaches of the Lakshadweep islands, meiofauna were found to contribute >50% of total production (i.e. biomass), underlining the importance of smaller sized forms (Ansari *et al.*, 1990). In the sea grass beds of five atolls (Agatti, Kadamat, Bingaram, Kavaratti and Kalpeni) it was found that density of macrofauna was directly correlated to mean macrophytic biomass (Ansari *et al.*, 1991). Around Minicoy island, significant differences were noted in standing stock and species diversity between seagrass beds and mangrove zones (Susan *et al.*, 2014), and this was attributed to variations in factors like salinity, pH, oxygen, clay content and organic content. At intertidal depths, benthic production was found to be higher around Agatti when compared to Kalpeni and Kavaratti islands, with dominance of polychaetes (Rivonker & Sangodkar, 1997). In the small coral islands of the Gulf of Mannar - the Krusadai and Shingle islands, polychaetes and bivalves were dominant among macrofauna, with high species evenness (Magdoom *et al.*, 2009). A few studies have been carried out on macrobenthos around the Andaman and Nicobar Islands, and these are reviewed in detail in Chapter 2. The benthos of continental margins of the Indian Ocean have received some attention in the last decade. Along the upper continental margin (100-1000m) of Western Australia, McCallum *et al.*, (2015) reported significant bathymetric gradients in species richness, with regional variations which were attributed to local oceanographic and productivity regimes.

Several investigations have been carried out on the shelf benthos along the west coast (Kurian, 1953, 1967, 1971; Seshappa, 1953; Damodaran, 1973; Parulekar, 1973; Parulekar & Wagh, 1975; Parulekar *et* *al*., 1976; Harkantra *et al*., 1980; Jayaraj *et al*., 2007, 2008; Joydas & Damodaran, 2009; Smitha, 2011) and east coast (Samuel, 1944; Ganapathi & Rao, 1959; Sokolov & Pasternak, 1964; Radhakrishnan & Ganapathi, 1969; Ansari *et al*., 1977; Rodrigues *et al*., 1982; Harkantra *et al*., 1982; Harkantra & Parulekar, 1987; Raman & Adiseshasai, 1989; Adiseshasai, 1992; Raut *et al*., 1997; Ganesh & Raman, 2007; Vijayakumaran 2003; Rao, 2009; Raja 2010; Kundu *et al*., 2010; Musale & Desai, 2010; Smitha 2011; Manokaran *et al*., 2015) of the Indian peninsula, all of which clearly demonstrate the dominance of polychaetes, followed by crustaceans. Quantitative studies on the benthic production (Parulekar *et al*., 1982) of Indian waters (10-275 m) recorded maximum benthic biomass and production in the shelf, and productivity decreased with increasing depth. Benthic biomass ranged between 0.01 and 6.01gm^{-2}, with mean values of 17.6, 7.3, 5.5, 0.7 gm^{-2}, in the eastern Arabian Sea, Andaman waters, western Bay of Bengal and Lakshadweep waters, and estimated that benthos can support 1.8 million tonnes of potential resources. Ansari *et al*. (1996), recorded benthic production of 0.176-11.8 gCm^{-2}yr^{-1} in the Indian EEZ as a whole.

In the eastern Arabian Sea (EAS) shelf (west coast of India, 10-70m, Quilon-Jamnagar), Harkantra *et al*. (1980), report an average biomass of 11.5 gm^{-2}. Infaunal macrobenthic communities along the EAS from Cape Comorin to Dwaraka, are characterised by high polychaete species diversity and evenness in the shallow depth, and a decrease with increasing depth (Joydas & Damodaran, 2009). Polychaete community composition was distinct in the shallow and deeper areas, with both sediment nature and hydrography forming structuring factors. In the western Bay of Bengal, between the Palk Strait and Paradip (20-1700m) Ansari *et al*., (1977) reported higher density of macrofauna and meiofauna in the shallower region compared to deeper areas, with strong correlation to sediment type. Studies on the macrofauna along the shelf of north eastern Bay of Bengal (Harkantra *et al*., 1982) from Andhra Pradesh to West Bengal revealed that macrobenthic production is comparable with west coast and density of macrofauna decreased with increasing depth. These findings were corroborated by systematic surveys in the shelf (30-200m) between Divi Point and Paradip (north western Bay of Bengal), with high diversity of macro invertebrates (Ganesh & Raman, 2007), which was attributed to salinity, temperature, mean particle diameter and depth. Macrobenthic composition in the shelf regions (30-200m) of the south western Bay of Bengal (Karaikal to Chennai) was also characterised by higher species diversity in the shallow areas, owing to depth-related variations in water pressure and heavy metal concentrations (Manokaran *et al*., 2015).

The impingement of the Oxygen Minimum Zones (OMZs) on the continental margins (between ~150-1000m) of the Arabian Sea and Bay of Bengal (Helly & Levin, 2004), and the resulting impacts on macrobenthos have recieved significant scientific attention in recent years (Ingole *et al*., 2010; Joydas & Damodaran, 2014; Abdul Jaleel *et al*., 2014; Raman *et al*., 2015; Khan *et al*., 2017). All these studies reveal suppressed standing stock of macrofauna and polychaete diversity under OMZ conditions, coupled with low density or absence of other groups like crustaceans, molluscs and echinoderms. Under severe oxygen depleted conditions in shelf edge the northern part of the EAS, macrofauna were altogether absent or else represented only by a few individuals belonging to a few species (Anilkumar, 2017), while in the southern part of the EAS, where OMZ was less intense, faunal densities were high owing to the dominance of opportunistic polychaetes of families Spionidae and Cirratulidae (Abdul Jaleel *et al*., 2014). The dominance of these sedent families is noted in the western Bay of Bengal (Raman *et al.*, 2015; Khan *et al.*, 2017) and other parts of the world ocean also (Levin, 2003). Thus, distinct environmental regimes are now known to exert their influence on standing stock and diversity patterns of benthic fauna in the region.

Biodiversity was first defined by E.O. Wilson (1988) and, subsequently the Convention on Biological Diversity (CBD, 1992) provided the widely accepted definition for the term as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”. The key aspects of biodiversity like structural (diversity of species) and functional elements (physiological processes, predator-prey relationships, trophic webs, competition, resource partitioning etc.) are vital to the maintenance of ecosystem health (Seling *et al.*, 2013; Strong *et al.*, 2015; Cochrane *et al.*, 2016).

Marine ecosystems are structured by the influence of environmental regimes on the organisms, the interactions between organisms, as well as the impacts of organisms and their activities on the environmental conditions (Gray & Elliot, 2009; Cochrane *et al.*, 2016). Marine biodiversity strengthens ecosystem functions, maintains ecological stability (Menge *et al.*, 1999), and enables self-sustenance of the ecosystems (McArthur *et al.*, 2010). In recent decades, anthropogenic pressures on marine systems have led to irreversible changes in environmental settings, leading to biodiversity loss and diminished ecosystem functioning (Magurran & Dornelas, 2010; Hooper *et al.*, 2012; Elliot *et al.*, 2015). The most direct and serious threats to marine biodiversity include over exploitation, pollution and marine litter, damages from fishing gears, habitat destruction and fragmentation, nonnative species invasions and long-term global climate change (Hutchings, 1990; Gray 1997; Snelgrove 1997; Heip 2003; Worm *et al.*, 2006; Halpern *et al.*, 2008; Widdicombe & Somerfield, 2012; Lavers & Bond, 2017). Assessment of impacts of aforementioned anthropogenic disturbances on biodiversity and ecosystem function, as well as natural disturbances such as earthquakes and tsunamis are possible only if the patterns of distribution of species in space-time are well documented, and there is sufficient understanding about the environmental or ecological processes shaping these patterns (Hooper *et al.*, 2012). Such information is essential as baselines for policy makers to assess and frame policies for the conservation of biodiversity (Magurran & Dornelas, 2010; Magurran *et al.*, 2010; Borja *et al.*, 2013).

The Convention on Biological Diversity (CBD), to which India is a signatory, is a multilateral treaty to develop national strategies for conservation of biological diversity, sustainable use of the components of biological diversity, and fair and equitable sharing of the benefits arising out of the utilization of genetic resources. India's National Biodiversity Strategies and Action Plans (NBSAPs) are the principal legal instruments for implementing the CBD policies at the national level. Policy makers, which include lawmakers, scientists, ecologists, and conservationists, usually rely on the taxonomic information for effective decision-making. Taxonomy, which is the science of naming, describing and classifying organisms (CBD, 2007) using morphological, behavioural, genetic and biochemical observations, provides basic understanding about the components of biodiversity. The CBD recognises that there is lack of sufficient taxonomic expertise, taxonomic collections, and field guides, as well as difficulty in accessing existing taxonomic information. This is known as the 'taxonomic impediment', which significantly hampers the implementation of decisions at national as well as international levels. The Global Taxonomy Initiative (GTI) was developed as a measure to address these issues, with the aim of identifying taxonomic needs and priorities, and strengthening of human resources, infrastructure and databases in taxonomy.

The Census of Marine Life (CoML) is an international effort undertaken to document the biological diversity, distribution, and abundance of marine life, which has led to cataloguing of over 30 million species across the tree of life. The data generated through CoML (Census of Marine Life) is disseminated openly as an online geo-referenced database for marine species, the Ocean Biogeographic Information System (OBIS), which is linked to the World Register of Marine Species (WoRMS), Barcode of Life Datasystems, Encyclopedia of Life, and Catalogue of Life. The Indian Ocean Biogeographic Information System (IndOBIS) is one of the seven regional nodes of OBIS, which is responsible for the collection, collation, and dissemination of data about the biodiversity in the Indian Ocean. The Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences, is the recognized nodal centre for IndOBIS.

Among the measures suggested by various organizations to safeguard biodiversity, a broad and important one is the identification of areas like biodiversity hotspots, high biodiversity wilderness areas etc. (Mittermeier *et al*., 1999; Myers *et al*., 2000; Spadling *et al*., 2007; Selig *et al*., 2014). A biodiversity hotspot (Myer, 1988) is a biogeographic region which is a significant reservoir of biodiversity, characterized by high species richness and high degree of rarity as well as endemism, which is threatened by exceptional habitat loss (Margules & Usher, 1981; Possingham & Wilson, 2005; Myers *et al*., 2000). Globally, 35 biodiversity hotspots have been recognized (Williams *et al.*, 2011; Myers *et al.*, 2000), of which 8 to 10 are marine biodiversity hotspots (Marchese, 2015). While these hotspots are spread all over the world, the majority are located in the tropics. The Andaman and Nicobar Islands is one of the terrestrial biodiversity hotspots of the world (Myers *et al.*, 2000), of which Andaman Islands are included in the Indo-Burmese hotspot and Nicobar Islands are included in the Sundaland hotspot. Thus far, the Government of India has declared 105 Marine Protected Areas in the Andaman and Nicobar Islands (Saravanan *et al.*, 2011; Sivakumar *et al.*, 2013). The archipelago is yet to be designated as a marine biodiversity hotspot. The principal reason for this is the dearth of data on species richness, spatial distribution, and percentage of species endemism, and phylogenetic diversity, as well as percentage of habitat loss (Marchese, 2015), which reflects the lack of dedicated scientific effort.

Coral reefs are among the most species rich and diverse ecosystems in the world oceans, which are under the threat of decimation by ocean acidification and warming (Glynn, 1993; Hoegh-Guldberg, 1999; Hughes *et al.*, 2003; Roberts *et al.*, 2002; Marchese, 2015). Destruction of coral reefs has repercussions on reef associated fauna in adjacent areas. The Great Barrier Reef (GBR) is facing massive coral bleaching event, which has led to extreme coral mortality and devastating biodiversity loss (Baird & Marshall, 1998; Berkelmans & Oliver, 1999). Likewise, extensive bleaching events are occurring in the reefs of the Andaman and Nicobar archipelago as well (Brown, 2005; Mondal *et al.*, 2014; Mohanty *et al.*, 2017), with associated biodiversity loss. Andaman and Nicobar Islands are situated on a tectonically active margin (Curray, 2005) and are exceptionally vulnerable to earthquakes and tsunamis. In the year 2004, a 9.1 magnitude earthquake in the Andaman Sea generated a large tsunami, and the ANI was among the worst affected, with widespread destructions of coastlines and reefs

(Ilayaraja & Krishnamurthy, 2010; Prasad *et al*., 2012). Oxygen Minimum Zones (OMZs) have been well reported across the northern Indian Ocean (Helly & Levin, 2004), including the Bay of Bengal (Raman *et al*., 2015; Khan et al., 2017) and Arabian Sea (Joydas & Damodaran, 2014; Abdul Jaleel *et al*., 2014). The impingement of the Bay of Bengal OMZ on the seafloor is known to have immense impact on distribution of benthic macrofauna.

Despite the long history of systematic benthic surveys under Marine Living Resource Programme (MLR) around peninsular India, the Andaman and Nicobar Islands had been overlooked until now. The present study addresses the quantitative aspects of macrobenthos after three decades, and is a pioneer study of polychaete diversity and community structure in the insular margin (50-200m). The data generated through this study can form the baseline for biodiversity assessment and conservation, as well as to assess impacts of natural (e.g. earthquake, tsunamis, OMZs) and anthropogenic (e.g. coral destruction, ocean acidification, global warming, sea level rise, pollution) disturbances.

The study forms a part of the efforts of the Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Science, Government of India, to expand the information on marine benthos in the Indian Exclusive Economic Zone (EEZ).

Objectives of the study

To study

- Standing stock and composition of macrobenthos around Andaman and Nicobar insular margin

- Spatial distribution, community structure and functional diversity of dominant group of macrofauna (polychaetes)
- Influence of environmental factors on distribution of macrofauna and polychaete communities of the region

Outline of the thesis

The thesis is organised in 6 chapters, as given below.

Chapter 1 *Introduction*: This chapter gives general introduction to the benthic realm, the classification of benthos and the importance of benthos in the marine ecosystem. A review of literature on benthos of island margins in the tropical belt of the world oceans is also provided. The major objectives along with relevance of the study are explained.

Chapter 2 *Study area, Sampling design and Analysis*: This chapter provides a detailed picture of the study area, mainly focussing on the oceanographic and geologic settings and previous benthic studies carried out in the region. The sampling methodology adopted for the collection of macrobenthos and near bottom hydrographical parameters are described, along with methods used for analysis of sediment texture and organic matter, macrofaunal standing stock (density and biomass), taxonomic identification of polychaetes etc. Details of statistical tools used for data analysis are explained.

Chapter 3 *Hydrography and Sediment characteristics*: This chapter describes the bathymetric, latitudinal and temporal variation in hydrographic (near bottom water temperature, salinity and

	dissolved oxygen) and sediment characteristics (texture and organic matter) in the study area.
Chapter 4	*Standing stock of macrobenthos*: This chapter elucidates the bathymetric, latitudinal variations in standing stock of macrofauna, along with the influence of hydrographic and sediment parameters on the distribution of macrofauna. Differences in standing stock estimates caused by use of different sieves (mesh sizes) have also been explained. The choice of finer mesh size in an oligotrophic bottom and the importance of small sized organisms are also discussed.
Chapter 5	*Community structure of polychaetes*: This chapter explores the diversity, community structure and functional diversity of polychaetes in the study area along with its bathymetric and latitudinal variations. The environmental parameters structuring the polychaete communities are analysed using univariate and multivariate statistical techniques. The effect of sieve mesh size on the species richness and diversity have also been addressed.
Chapter 6	*Summary and Conclusions*: This chapter summarizes the major findings and conclusions of the study.
References	are listed in the bibliography section.
Appendices	Checklist of polychaete species and Published papers

Chapter II

Study area, Sampling design and Analysis

II. 1. Study area

The Andaman & Nicobar Islands (ANI) are oriented in a north-south arc, between 6° N and 14° N and 92° E to 94° E. The islands are volcanic in origin, located on the Andaman Nicobar Ridge system, at the edge of the Burma plate. The ridge separates the Bay of Bengal from the Andaman Sea. To the east of the Islands lies the Sunda plate, and the boundary between the Burma and Sunda plate is a marginal seafloor spreading center. On the western side of the Islands lies the vast Indian plate, a zone with extensive ongoing subduction. The Island arc is divided into groups by transecting channels, viz. from south to north, (i) Great Channel between Nicobar Islands and Pulao Breweh, off the northern tip of Sumatra (maximum depth 1800m), (ii) Ten Degree Channel between Car Nicobar and Little Andaman Islands (1800m depth) and, (iii) Preparis Channel between the northern side of Andaman Islands and Myanmar (200m depth). These channels, along with a few smaller channels connect the Andaman Sea and Bay of Bengal. To the south, the Andaman Sea is connected to South China Sea through the Malacca Strait (Fig. 2.1).

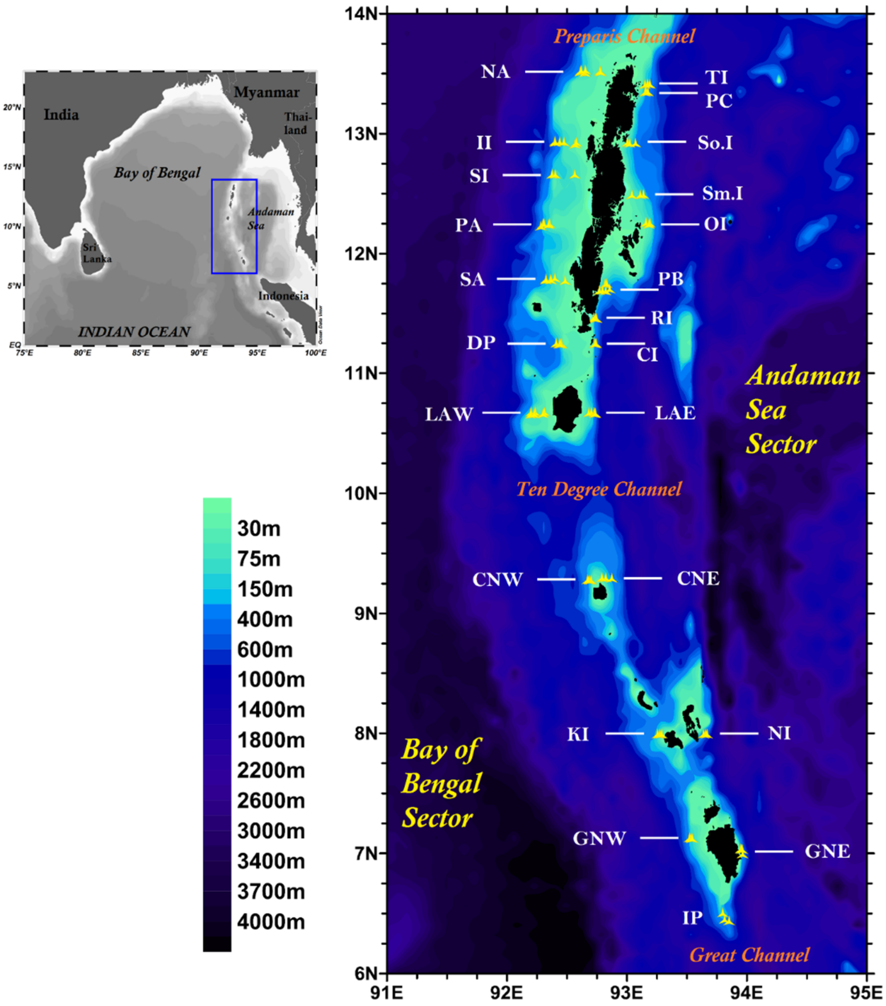


Fig. 2.1. Map of the study area showing sampling sites

The shelf width off the west coast of the ANI is relatively wider than the east (Rao & Kessarkar, 2001; Rao, 2010). Numerous sills as well as underwater volcanic seamounts are located on the eastern side of the Andaman Islands, which are potential sources of internal waves. The Andaman basin lies between the Malay continental margin, the Ayeyarwady delta and the eastern slopes of the Andaman and Nicobar ridge system. The Andaman basin is characterized by complex underwater structures like the Sewell Seamount, the Alocock Rise, the Invisible bank, the Central

Andaman and Nicobar rift valleys, as well as other sea highs and canyons (Rao & Kessarkar, 2001, Fig. 2.2). Barren Island, located to the west of the Andaman Islands, is the only active subaerial volcano in the Andaman basin, while the other sub aerial volcano, Narcondam Island, is dormant.

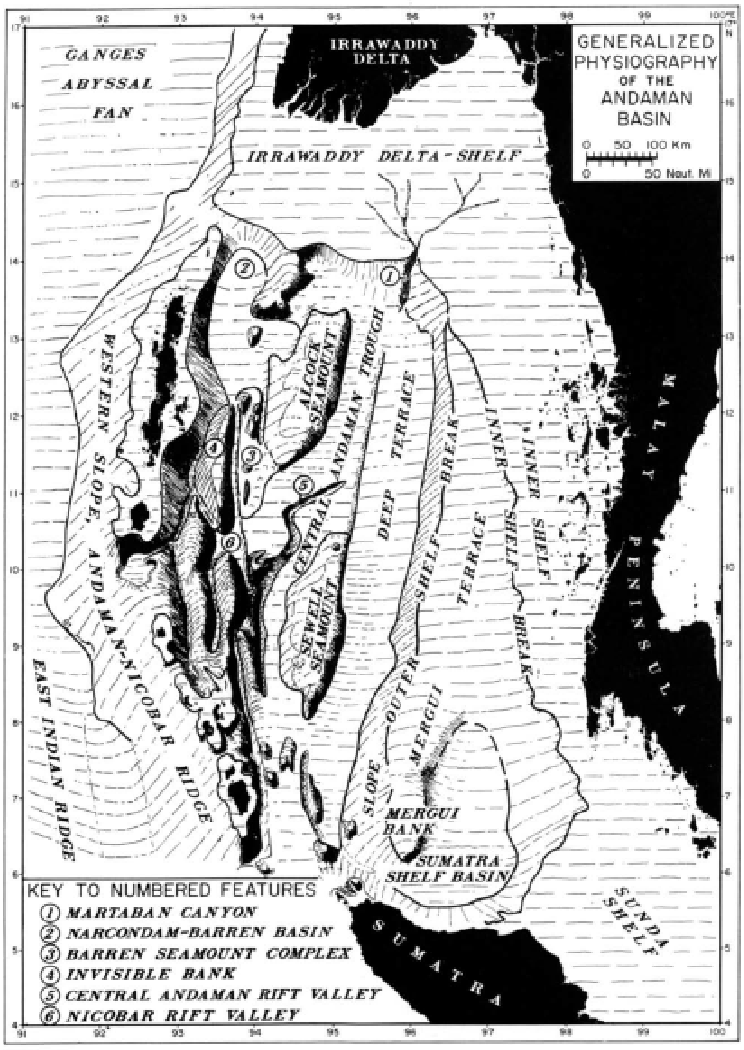


Fig. 2.2. Generalized physiography of the Andaman basin

(Rodolfo, 1969)

The Andaman Sea is a seismically active back arc basin (Rodolfo, 1969) lying above and behind the Sunda subduction zone, where convergence between the overriding Southeast Asian plate and the subducting Australian plate is very oblique. The oblique convergence has led to the formation of a sliver plate between the subduction zone and a complex right-lateral fault system. The subduction of the major plates with respect to one another has resulted in the formation of a deep trench, a back-arc island and basins, and a spreading center. This convergent margin is one of the most prominent tectonic features in the region, marked by the Sunda-Andaman trench, which has resulted from the subduction of the Indo-Australian plates below the Eurasian plate. The ANI, located to the north of the 90° E ridge, are aligned in a north-south direction in an arcuate shape, which separates the Indian and Sunda plates (Curray *et al.* 1979, Dasgupta and Mukhopadhyay 1993, Curray 2005). The tectonic settings in the region has resulted in the development of several thrust and strike-slip faults. Among these, the West Andaman fault (WAF) is the most prominent right-lateral strike-slip fault that has continuity all along the islands. This fault appears to extend from Sumatra in the southwest up to the Burma microplate in the north. Being a seismic activity region, the Andaman region is exposed to physical disturbances like earthquakes and tsunamis (Fig. 2.3).

A great earthquake of magnitude of 9.0 occurred on 26 December 2004 off the northern tip of Sumatra, Indonesia, and generated a large tsunami which caused large-scale destruction to island ecosystems (Brown, 2005). Most Indian Ocean rim countries were impacted by this Boxing Day tsunami to some extent, with the north eastern margin, including the ANI, being worst effected (Ilayaraja & Krishnamurthy, 2010). The earthquake resulted in the subsidence of coral reefs along the east coast of Middle and South Andaman Islands, while the subsidence rate was even higher at the southern tip of Great Nicobar Island. Along west coast of Andaman the coastline was uplifted, exposing the reef flats.

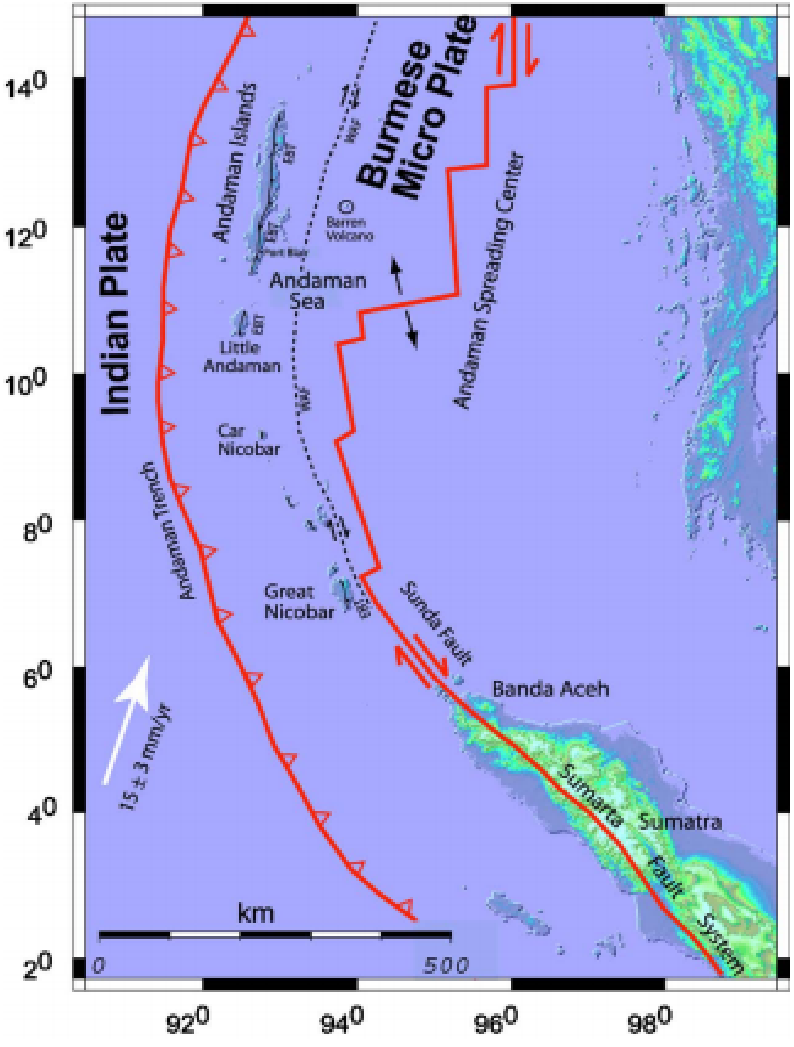


Fig. 2.3. Tectonic map of Andaman and Nicobar islands (Malik et al., 2006)

Fringing reefs dominate all the sites within the Andaman Sea, while the only 'barrier' reef was reported by Sewell (1935) on the west coast of the Andaman Islands (Brown, 2005). In the ANI the reef flats are considerably wide, ranging from 200 to 500 m (UNEP/IUCN, 1988) and coral cover around the Andaman Islands extends up to 50-75m (Mahendra *et al*. 2010; Velloth *et al*., 2014). The uniqueness of the ANI, is that it houses rich biodiversity, with tropical rainforest and coral reefs occurring side-by-side (Rao, 2010). The position of this archipelago, between the Indian subcontinent, Malay Archipelago and Indonesia, which are all repositories of biodiversity, makes it an exceptional biodiversity hotspot. The reef areas and near shore waters of the Andaman and Nicobar Islands are reported to harbour a total of 235 species of scleractinian corals, 111 soft corals, 112 sponges, 188 polychaetes, 411 crustaceans, 1422 molluscs, 425 echinoderms, 750 fishes (Rao *et al*., 2013).

The earliest explorations in the Andaman Sea were carried out during the historic expeditions of the Danish 'Galathea' (1842-46) and 'Dana' (1928-30), Austrian frigate 'Novara' (1857-59) and the German 'Valdivia' (1898-99), during which scattered observations were made on faunal diversity of the region. The first organized oceanographic and marine biological investigations around the ANI were made by the expeditions of the Royal Indian Marine Survey Ship '*Investigator'* (Wood-Mason & Alcock, 1891; Alcock, 1902; Sewell, 1925) & the International Indian Ocean Expedition (IIOE, 1962-1965). Quantitative aspects of bottom fauna around the ANI were first studied by Parulekar & Ansari (1981a). Under the Thai-Danish BIOSHELF project, systematic surveys were carried out in the continental shelf of the eastern Andaman Sea (Thai sector), and the study resulted in the discovery of over 200 new species of polychaetes and crustaceans (Bussarawit *et al*., 2008). Along the continental shelf of the Ayeyarwady, a quantitative study on macrobenthic invertebrates was carried out by Ansari *et al*. (2012). A few scattered works have also been carried out on the benthic fauna and polychaete species in the coral reefs and inshore depths of the ANI (Fauvel, 1953; Tampi & Rangarajan, 1964; Soota *et al.*, 1977; James *et al.*, 1969; Misra & Chakraborty, 1991; Rao, 2010; Rajashekaran & Fernando, 2012; Veeramuthu *et al.*, 2013; Gopal *et al.*, 2014, 2016).

The ANI is subjected to the seasonally reversing Asian monsoon system (Wyrtki, 1973), which strongly influences sediment dispersal in the Andaman Basin. The oceanic flow is predominantly anti-cyclonic during the winter monsoon (Dec-Feb), with the surface currents flowing westwards and pushing riverine discharge from the Ayeyarwady into the eastern Bay of Bengal, while the circulation is cyclonic during the summer monsoon (May-Sep), and since surface flow is towards the east, sediments remain trapped in the Andaman Sea (Wyrtki, 1973; Rodolfo, 1969; Potemra *et al.*, 1991; Ramaswamy *et al.*, 2004; Rao *et al.*, 2005;).

The Andaman Basin is separated from the Bay of Bengal by the Andaman-Nicobar Ridge. The principal sediment source in the Andaman Basin is the Ayeyarwady River, which discharges 265×10^6 metric tons of silty clay annually into the Andaman Sea (Rodolfo, 1969). This river along with the Salweeen, Sittang and Tavoy rivers, delivers more than 360 million tons of sediment a year onto the Ayeyarwady continental shelf in the northern Andaman Sea (Meade 1996), with organic carbon transport of 5.7-8.8 MTCyr^{-1} (Bird *et al.*, 2007). At the mouth of the Ayeyarwady, in the Gulf of Martaban (Myanmar), the sediment is a combination of silt and clay and in the outer shelf it is sandy, while in the transition zone of Gulf of Martaban and Martaban Canyon a mixture of sand, silt and clay dominates. The Gulf of Martaban experiences strong tidal currents which churn the bottom deposits resulting in high suspension of sediments (Ramaswamy *et al.*, 2004). The northern portion of the Martaban Canyon has a steep slope, the tidal currents and gravity flows forms an easy platform for transporting the sediments to Andaman basin (Rao *et al.*, 2005). The Malacca Strait is also a source of sediments to the Andaman Basin, with currents carrying the discharges from Sumatra and the Malay Peninsula. The sediments of Andaman and Nicobar Ridge are composed of coarse coralline detritus and reef foraminifera in the shelf, and silty clay in the slopes (Rodolfo, 1969). Sewell (1925) was first to describe the sediments of Andaman Basin from visual descriptions of dredge hauls. According to Parulekar & Ansari (1981a), beyond ~100m depth, sediments of northern regions were found to be predominantly sandy mud, and in the southern region it was chiefly coralline sand, while sediments of the east coast (Andaman Sea sector) were composed of clay and coralline sand.

The primary productivity of the waters around the ANI was described through IIOE surveys by Kabanova (1964), Qasim (1977), Bhattathiri & Devassy (1981). Ansari & Abidi (1981) reported that region is oligotrophic in nature, with an average primary productivity of 273 $mgCm^{-2}$ and secondary productivity of about 288.8 $mgCm^{-2}$. Bhattathiri (1984) noted that column production was highest during the southwest (summer) monsoon and lowest during pre-monsoon (spring inter monsoon) in the ANI waters. When quantifying seasonal primary production in different sectors of the Indian EEZ, Sarupria & Bhargava (1993) reported productivity of 319.19 $mgCm^{-2}d^{-1}$ during the spring inter monsoon, 586.73 $mgCm^{-2}d^{-1}$ during the summer monsoon, and 440.68 $mgCm^{-2}d^{-1}$ during the winter monsoon in the ANI waters. During the fall inter monsoon, average pelagic primary productivity ranged between 0.1 to 0.24 mg $Cm^{-3}d^{-1}$ (Rashiba, 2010).

The secondary production in ANI waters was 0.84 ml/m^3 (Goswami, 2004). The southern region of the study area recorded higher secondary productivity than northern side (av. 63.263 ml/1000m^3 against 43.44 ml/1000m^3), and the western side (Bay of Bengal sector) was more productive than the eastern (Andaman sea sector) side of the archipelago (60.78 ml/1000 m^3 and 41.96 ml/1000m^3, respectively), (Rashiba, 2010). The average values of secondary production estimated for the entire area of Andaman and Nicobar Islands by Antony *et al.* (1997) was 4.8 gCm^{-2}yr^{-1}. The winter monsoon (October-January) was the most productive season, followed by the spring inter monsoon (February-May). The northernmost part of the study area (12°31'-14°30' N) was found to be more productive (5.62 gCm^{-2}yr^{-1}) than the southernmost region (06°30'-08°30'N) (3.64 gCm^{-2}yr^{-1}).

The benthic production of Andaman & Nicobar waters is known to be very low compared to Arabian Sea and Bay of Bengal, with mean production of 1.27 mg C m^{-2}, and a mean productivity of 1.9 gCm^{-2}yr^{-1} in the shelf region up to 200m (Parulekar *et al.*, 1982), or 0.2-0.7 gCm^{-2}day^{-1} (Goswami, 2004). Around the ANI, only a single study on the quantitative distribution of benthic macrofauna has been carried out onboard RV *Gaveshini* between 11 and 2150m depths (Parulekar & Ansari, 1981a). The shallow regions (<200m) were found to be characterised by coralline sandy sediments, while in the mid depths (200-1000m) texture was sandy mud, and in deeper depths (>1000m) clayey sediment dominated. The density of fauna (<200m) decreased to mid depths (200-1000m), followed by a sharp increase towards higher depths (>1000m). The mean benthic macrofauna biomass was 6 gm^{-2} (0.3-74.4 gm^{-2}) for the entire region. Higher mean biomass was recorded in shallow depths (<200m), with a decline of about 70% towards mid depths (200-1000m), and a marginal increase of 8% towards the deep (1000-2000m), followed by a sudden decrease beyond 2000m. A comparison of macrobenthic biomass along western (Bay of

Bengal) and eastern (Andaman Sea) sectors of the ANI shelf regions (0-200m) revealed that Bay of Bengal sector supported higher biomass than the Andaman Sea sector, while beyond 200m the Andaman Sea sector exhibited higher biomass.

Studies in the Malacca Strait (80-1350m) revealed a higher mean macrofaunal abundance than ANI region with dominance of polychaetes (Parulekar & Ansari, 1981b). Investigations on macrobenthic fauna along west coast of Thailand (eastern Andaman Sea) yielded higher biomass compared to the ANI margin (Chatananthawej & Bussarawit, 1987), while surveys between 20 and 1000m of the Ayeyarwady continental margin provided a comparable abundance and biomass values (Ansari *et al.*, 2012). In the latter region, density and biomass decreased with depth, and standing stock was higher in sandy sediments compared to clay.

II. 2. Sampling design

Systematic stratified sampling was carried out on onboard Fishery and Oceanographic Research Vessel (FORV) *Sagar Sampada* along the insular margin of the Andaman & Nicobar Islands (6° 27’ N to 13° 32’ N latitude and 92° 11’ E to 93° 57’ E longitude, Fig. 2.1, Fig. 2.4), in three depth strata (50m, 100m and 200m), during the north east monsoon of year 2009 and 2011. Cruise SS261 conducted in January 2009 (10.01.09 to 26.01.09), covered 51 sites at aforementioned depths in 17 transects (Table 2.1). Cruise SS292, conducted during November-December 2011 (21.11.11 to 11.12.11), covered 60 sites in 20 transects (Table 2.1). All transects were oriented east-west and perpendicular to the island chain except Indira Point, which was north-south oriented towards the south. Benthic organisms show patchiness in distribution which might be caused by variable patterns in recruitment, disturbances or process existing within the assemblages. Keeping this in consideration, sampling was done in duplicates from each single location during each survey, as spatial replication are a mandatory component of benthic studies (McIntyre & Eleftheriou 2005).

The most suitable equipment for collecting infaunal benthos (quantitative and qualitative studies) is the grab (Smith & McIntyre 1954). A modified Smith-McIntyre grab of bite area $0.2m^2$ was operated for collecting sediments during SS261 while a Smith-McIntyre grab of bite area $0.1m^2$ was used during SS292. A total of 40 sites were sampled during SS261 (17 transects), and 52 sites in 20 transects were sampled during SS292, while grab operations were unsuccessful at many sites (11 sites in SS261 and 8 sites in SS292) due to hard bottom or steep topography. Approximately 100g of sediment samples from each grab were first collected using a scoop, sealed and refrigerated at -20°C for the estimation of organic matter and sediment texture analysis. Test sieves of 500µm and 300µm mesh sizes were used for separating macrobenthos in SS261 and SS292, respectively. Sieving was carried out over a wooden platform under gently running sea water flow. After sieving, the residual sediments with organisms was narcotised with magnesium chloride solution, preserved in 5 to 8% buffered Formalin-Rose Bengal solution and labelled.

Fig. 2.4. Sampling platform FORV *Sagar Sampada* and sampling gear Smith McIntyre grab

Hydrographic parameters (near bottom temperature, salinity and dissolved oxygen) of sea water were recorded using the on-board CTD (Model SBE 911) at 96 sites across the study area (37 sites in SS261 and 59 sites in SS292), and concurrent manual estimation of dissolved oxygen was carried out using Winkler's method (Strickland and Parsons, 1972).

II. 2. 1. Analysis of sediment samples

In the shore lab, the sediment samples were oven dried (50°C) and 10g of dried samples were accurately weighed, organic matter and salt content was removed and the sediments were dispersed using Sodium hexa-metaphosphate. Subsequently, texture analysis was done using a CILAS 1180 particle size analyser, and data on percentage composition of sand, silt and clay was taken along with median and mean grain size. Samples which were coarser in nature, and therefore not suitable for analysis through the particle size analyser, were subjected to serial sieving (at half Φ intervals), data on sediment texture was extracted using GRADISTAT v8 software and plotted in a ternary diagram to illustrate the percentage of sediment components (sand, silt, clay), following the classification of Sheppard (1954). A ternary diagram is a barycentric plot of three variables which sum to a constant (in this case 100%), graphically depicting the ratios of the three variables as positions in an equilateral triangle. The organic carbon content of the sediment was determined by wet oxidation method (El-Wakeel and Riley, 1975) and then converted into organic matter (Trask, 1939). Organic matter was expressed as percentage of sediment dry weight.

II. 2. 2. Analysis of biological samples

The sediment samples with organisms were sieved again in the shore lab, and sorted to group level (Polychaetes, Crustaceans, Molluscs, Echinoderms and other faunal groups) and were enumerated to generate group abundance data. Wet weight biomass of each group was determined using a high precision electronic balance of ±0.1mg accuracy (Metler Toledo ML204). Density and biomass of macrofaunal groups were expressed as individuals per square meter (ind.m^{-2}) and grams per square meter (gm^{-2}), respectively to quantify the contribution of macrofaunal groups to standing stock. The dominant group of macrofauna, the polychaetes, were identified up to species level.

Misidentification of species due to lack of taxonomic expertise among ecologists have wide implications on the natural-resource management, conservation, sustainable harvesting etc. (Agnarsson & Kuntner 2007; Beerkircher *et al.*, 2009; Shea *et al.*, 2011; Vink *et al.*, 2012). Ecologists are often left to make use of 'bad taxonomy', which are devoid of any supporting information justifying or guaranteeing the correctness of identification of the organisms studied or manipulated (Bortolus, 2008). The most important step to avoid this, is to give clarity on the methods and keys used for identification of species. During the present study, species identification of polychaetes was carried out under a stereo-zoom microscope (Leica S8APO) and compound microscope (Leica DM1000). Photographs of the specimens were taken using Cat Cam 130 Microscope Camera.

The polychaetes from the ANI identified to family and genus level using Fauchald (1977), Rouse & Pleijel (2001) and species identification was done using standard keys (Fauvel, 1953; Day, 1967), taxonomic revisions (Pettibone, 1966; Jumars, 1974; Fauchald, 1974, 1982, 1986; Kudenov & Blake, 1978; Blake & Kudenov, 1978; Maciolek, 1985; Paxton, 1986; Wilson, 1988; Imajima, 1989, 1990, 1991, 1992; Warren *et al.*, 1994;

Boggemann, 2002, 2005; Knight-Jones & Mackie, 2003; Pleijel & Rouse, 2005; Ruta & Pleijel, 2006; Delgado-Blas, 2006; Carrera-Parra, 2006; Yokoyama, 2007; Tovar-Hernandez *et al.*, 2007; Jirkov, 2008; Salazar-Vallejo, 2011; Salazar-Vallejo & Buzhinskaja, 2011; Sirkorski, 2011; Ben-Eliahu & Hove, 2011; Sendall & Salazar-Vallejo, 2013, 2014; Sun *et al.*, 2015), taxonomic publications from the Andaman Sea (Nateewathana & Hylleberg, 1986; Hylleberg & Nateewathana, 1991; Nateewathana & Hylleberg, 1991a, b; Baken, 2002; Boggemann & Eibye-Jacobsen, 2002; Eibye-Jacobsen, 2002; Green, 2002; Fitzhugh, 2002; Holthe, 2002; Lovell, 2002; Sigvaldadóttir 2002; Aungtonya 2007) and other relevant taxonomic publications from other parts of the world. Validity and of status of taxa (species, genera etc.) were checked and updated using the World Register of Marine Species (WoRMS Editorial Board, 2017; Read & Fauchald 2017). In order to understand functional composition of the communities, polychaete species were classified to feeding guilds like predators, surface deposit feeders, sub-surface deposit feeders and suspension feeders based on the classification of Fauchald & Jumars (1979) and Jumars *et al.*, (2015).

II. 2. 3. Data analysis

The sampling sites around the Andaman and Nicobar Islands were plotted using the software SURFER 9. Bar and line graphs, as well as scatter plots were plotted using MS EXCEL 2010. For depicting the range of temperature, salinity, dissolved oxygen, organic matter, macrofaunal abundance, biomass at each depth category in the study area, box-and-whisker plots were drawn using PAST software. Box plots are used for graphical depiction of groups of numerical data based on their quartile ranges, while the lines extending vertically from the boxes (whiskers) indicate variability outside the upper and lower quartiles, and outliers are plotted as individual points.

Spatio-temporal variations in the standing stock, and composition of macrofauna as well as environmental variables were tested using Permutational Multivariate Analysis of Variance (PERMANOVA) in the PERMANOVA+ is an add-on package for PRIMER 6. This method was preferred over the ANOVA and MANOVA procedures, since the latter tests assume normal distribution of data and are to be used only with Euclidean distance measures, while PERMANOVA is permutation-based, and can be used with any similarity (or distance) measure. Pearson's correlation coefficient (r) was used (IBM SPSS 20) to test the strength of relationship between environmental variables, biological parameters, depth and latitude. Pearson correlation coefficient has a value between +1 and −1, where 1 is total positive linear correlation, 0 is no linear correlation, and −1 is total negative linear correlation.

A Principal component analysis (PCA) was employed using PRIMER 6 software on environmental data to detect trends in variation of environmental characteristics across the study area. Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. Since the environmental factors are homogeneous log transformation [log (x+1)] and normalisation was carried out prior to the PCA (Clarke & Warwick 2001). The PCA plot uses the PCs which explain maximum variation in the data as the axes (PC axes), and visualises the ordination of sampled sites around the PC axes so that sites having similar environmental conditions fall close together. The abundance of polychaetes of each feeding guild were superimposed as bubbles onto the environmental PCA, to visualise their preference to environmental conditions.

In order to determine whether the number of species collected over the whole study is adequate to describe the species composition of the area, a species accumulation plot (PRIMER 6) was used. Species accumulation curve depicts the cumulative number of species as a function of sampling effort (Colwell & Coddigton, 1994). The curve rises as the samples are added and concordantly as the species are added, reaching the asymptote or when furthur addition of samples does not add additional species. Several nonparametric species estimators can be employed, which predict the total number of species that can be encountered in a study area when sampling is unlimited (infinite sampling). These estimators operate based on the progression of the actual species accumulation curve, and give in indicator as to the 'true' diversity in an area. In the present study, species accumulation curves were plotted and several estimators like Chaos (1 and 2), Abundance Coverage Estimator (ACE), Incidence Coverage Estimator (ICE) and Jacknife (1 and 2) estimators were also calculated using PRIMER and EstimateS softwares.

Chaos estimators gives importance to the numbers of rare species in the samples. Chaos 1 is the sum of observed number of species plus the ratio of singletons (number of species represented by a single induvidual) and doubletons (numer of observed species represented by 2 induvidulas). Chao 2 is the sum of observed species plus ratio of number of species that occur in one sample only and number of species that occur in two samples. The difference between Chao1 and 2 is that Chao1 uses species abundance data whereas Chao 2 uses species presence/absence data (Magurran, 2004).

$$S_{Chaos1} = S_{obs} + \frac{F_1^2}{2F_2}$$

Where

$S_{obs} =$ *number of species in the sample,*

$F_1 =$ *number of observed species represented by a single individual (singletons), and*

$F_2 =$ *number of observed species represented by exactly two individual (doubletons)*

$$S_{Chaos2} = S_{obs} + \frac{Q_1^2}{2Q_2}$$

Where

$S_{obs} =$ *number of species in the sample*,

$Q_1 =$

number of species that occur in one sample only (unique species),

and

$Q_2 =$ *number of species that occur in exactly two samples.*

The Abundance based Coverage Estimator (ACE) is based on the abundance of species with between 1 and 10 induviduals in a sample, and Incidence based Covergae Estimator (ICE) is calculated based on species found only in ≤10 samples (Magurran, 2004).

$$S_{ACE} = S_{abund} + \frac{S_{rare}}{C_{ACE}} + \frac{F_1}{C_{ACE}}\gamma_{ACE}^2$$

Where

$S_{abund} =$ *number of abundant species (represented by* $>$

10 *individuals)* ,

$S_{rare} =$ *number of rare species (represented by* ≤ 10 *individuals),*

$C_{ACE} = 1 - \frac{F_1}{N_{rare}}$,

$N_{rare} =$ *total number individuals in rare species*,

$F_i =$ *number of species with i individuals*,

$F_1 =$ *number of observed species represented by a single individual (singletons), and*

$\gamma_{ACE}^{2} = max\left\{\frac{S_{rare}}{C_{ACE}} \frac{\sum_{i=1}^{10} i(i-1)F_i}{(N_{rare})(N_{rare}-1)} - 1{,}0\right\},$

$which\ estimates\ the\ coefficient\ of\ variation\ of\ the\ F_i^{'}s.$

$$S_{ICE} = S_{freq} + \frac{S_{infr}}{C_{ICE}} + \frac{Q_1}{C_{ICE}}\gamma_{ICE}^{2}$$

Where

$S_{freq} = number\ of\ common\ species\ (observed\ in > 10\ samples),$

$S_{infr} = number\ of\ infrequent\ species\ (observed\ in \leq 10\ samples,$

$C_{ICE} = 1 - \frac{Q_1}{N_{infr}},$

$N_{infr} = total\ number\ of\ occurrences\ of\ the\ infrequent\ species,$

$Q_j = number\ of\ species\ that\ occur\ in\ j\ samples,$

$Q_1 = number\ of\ unique\ species\ (occuring\ only\ in\ one\ sample),$

$m_{infr} = number\ of\ samples\ with\ at\ least\ one\ infrequent\ species,$

and

$$\gamma_{ICE}^{2} = max\left\{\frac{S_{infr}}{C_{ICE}} \frac{m_{infr}}{(m_{infr}-1)} \frac{\sum_{i=1}^{10} i(i-1)\,F_i}{(N_{infr})^{2}} - 1{,}0\right\}$$

The limitations of Chao estimators is that it provides minimum estimates of richness as they assume homogeneity among samples (Magurran, 2004) and will not be suitable if there are large compositional difference within the dataset. Jacknife estimators (Heltshe & Forrester, 1983) were used to reduce this bias. The Jacknife estimates are a function of the number of species that occur in one and only one quadrat and are affected by quadrat size, sample size and sampling area (Heltshe & Forrester, 1983). The Jacknife 1 (first-order estimator) reduces the bias of the order 1/n and Jacknife 2 (second-order estimator) of the order $1/n^2$.

$$S_{Jack1} = S_{obs} + Q_1\left(\frac{m-1}{m}\right)$$

Where

$S_{obs} = number\ of\ species\ in\ the\ sample,$

$Q_1 = number\ of\ species\ that\ occur\ in\ one\ sample\ only\ (unique\ species)$, and

$m = number\ of\ samples$

$$S_{Jack2} = S_{obs} + \left[\frac{Q_1(2m-3)}{m} - \frac{Q_2(m-2)^2}{m(m-1)}\right]$$

Where

$S_{obs} = number\ of\ species\ in\ the\ sample,$

Q_1

$= number\ of\ species\ that\ occur\ in\ one\ sample\ only\ (unique\ species)$

$Q_2 = number\ of\ species\ that\ occur\ in\ exactly\ two\ samples$, and

$m = number\ of\ samples.$

The traditional measure of biodiversity in ecology is the number of species (Ellingsen, 2002). Diversity indices are tools for assessing the biodiversity and changes in community due to environmental change (McArthur *et al.*, 2009). Whittaker (1960) classified diversity measures into alpha, beta and gamma measures. Alpha (α) diversity measures are those which are used to quantify diversity of at a single site or in a single sample. Beta (β) diversity measures quantify the differences in species composition between sites, and will be high in specialised habitats and where the environmental dissimilarity is more (Harrison *et al.*, 1992). Gamma (γ) diversity is the diversity of an entire landscape. These diversity indices can be used to elucidate the diversity variation in an area, or to elucidate trend in diversity. In the present study, the number of species in a sample (species number, n) was used as a direct alpha measure of diversity. Several other univariate alpha indices (species richness, diversity and evenness) were used to further quantify diversity in each sample. These provided information not only on the species richness (i.e. number of species present in a sample or area), but also take into account the commonness and rarity of species, and their relative abundance. The Margalef's species richness index (d) gives the total number of species per unit area. The Shannon-Weiner diversity index (H'log2), which accounts for the number of species in a sample as well as their relative abundance, was also employed. The Pielou's evenness index (J') was used to measure how evenly individuals are distributed among the species. A graphical method for depicting diversity, the k-dominance curve was plotted using PRIMER 6. It is obtained by plotting cumulative proportional abundance against species rank (Clarke 1990).

$$Margelef's\ richness\ index, d = \frac{(S-1)}{\log N}$$

Where

$S = number\ of\ species\ recorded\ in\ the\ sample$, and

$N = number\ of\ individuals\ in\ the\ sample.$

$$Shannon - Weiner\ Diversity\ index, H' = -\sum p_i \log_2 p_i$$

Where

$p_i = the\ proportion\ of\ individuals\ found\ in\ the\ i^{th}\ species.$

$$Pielou's\ Evenness\ Index,\ J' = \frac{H'}{\log S}$$

The alpha diversity measures given above are based on species abundance and sampling effort. Since the present study uses two grabs and two mesh sizes during the two surveys, the diversity indices, which largely depend on sampling size, could not be compared. So, graphical methods like species accumulation curves were found to be relevant and univariate measures like phylogenetic diversity (Warwick & Clarke, 1995). Phylogenetic diversity indices like taxonomic distinctness measure the phylogenetic distance between pairs of species across a hierarchical taxonomic tree, and they utilize data on presence/absence of species rather than their abundance. So they are well suited to depict biodiversity loss with space or time (Magurran & Dornelas, 2010). Average taxonomic distinctness (Δ+) is the average taxonomic path length between two randomly chosen species along the taxonomic tree (Clarke and Warwick, 2001).

$$\Delta^{+} = \frac{\left[\sum \sum_{i<j} \omega_{ij}\right]}{s(s^{-1})/2}$$

Where

$s = number\ of\ species\ in\ the\ study$, and

$\omega_{ij} = the\ taxonomic\ path\ length\ between\ species\ i\ and\ j.$

A funnel plot was constructed, which depicts the species number of the samples against the taxonomic distinctness (Δ+), and also gives a probability funnel (95%) based on the master taxonomic tree. This measure takes into account the hierarchial taxonomic information of species, in addition to their numbers, and therefore provides additional information on the data.

While the above indices give an idea about the quantum of diversity in each sample, they do not take into account the identity of the species or the differences in composition between sites. Such information is incorporated into pairwise dissimilarity measures, which form the basis of multivariate analyses of β diversity (Anderson *et al.* 2011). The Bray-Curtis similarity (PRIMER 6) was calculated using square root transformed species abundance data (Clarke & Warwick, 1994). The Bray-Curtis similarity index and group average linkage were used to produce a non-metric multi-dimensional scaling (nMDS) ordination (Ludwig & Reynolds 1988). The nMDS arranges sites in multidimensional space on the basis of ranked similarities (Bakus, 2007) and aids in directly visualizing the level of similarity of individual sites. The goodness-of-fit statistic, called ‘stress’, is based on the differences between actual distances and their predicted values. In order to identify the polychaete species causing the observed similarity or dissimilarity among the groups or clusters obtained in the nMDS, Similarity Percentage (SIMPER) analysis was done using PRIMER 6 software. The results of the SIMPER quantify the contribution of each species to the observed similarity (or dissimilarity) between samples.

The relationships between the environmental parameters and patterns in species distribution in the study area were examined using the BIOENV procedure (in PRIMER 6). This is a dissimilarity-based and exploratory method to identify subsets of explanatory variables, in this case, Euclidean distance matrix of log-transformed and normalised environmental data, whose similarity matrix correlates maximally with the dissimilarity matrix of the data to be explained (i. e. square root transformed species abundance data). This procedure generally uses Spearman's rank based correlations (Clarke & Ainsworth, 1993). A BVSTEP procedure is a step-wise variant of BIOENV, which operates sequentially with forward and backward stepping phases, and gives the single best set of variables explaining variability in the data. This procedure was employed on the species abundance data (square root transformed, Bray-Curtis similarity) to get a list of species whose abundance (or incidence) determined the observed patterns in the community structure.

A Canonical correspondence analysis (CCA) is a multivariate method for exploring the relationships between two multivariate sets of variables (vectors). The CCA was carried out using PAST software, with a subset of important polychaete species identified using BVSTEP and SIMPER in PRIMER-6, to elucidate the preferences of these species to specific sets of environmental conditions (ter Braak & Smilauer 2002). The

CCA is a linear function of the two sets of variables (abiotic and biotic) so that the correlation between the two functions is maximized (Poore & Mobley 1980, ter Braak & Smilauer 2002). Geometrically, the method looks at the relative positioning of the subjects in the two-dimensional space, the variables with the highest coefficients in each of these linear functions are assumed to define that function and hence the key features relating the two data sets may be assessed from a pair of coefficient vectors (Poore & Mobley 1980). A Monte Carlo permutation test (with forward selection) was used to test the significance of environmental variables explaining the variance of species distribution ($P < 0.05$ level). All data generated through the present study is deposited in FORV Data Centre, CMLRE.

Table 2.1. Location of sampling sites during the cruises of FORV *Sagar Sampada* (SS261 & SS292)

		Transect	Transect Code	Latitude (°N)	Longitude (°E)	Depth (m)
Andaman Islands	Bay of Bengal sector	Little Andaman Island west	LAW	10° 39.672'	92° 11.860'	185
		Little Andaman Island west	LAW	10° 39.972'	92° 13.641'	111
		Little Andaman Island west	LAW	10° 40.115'	92° 18.019'	63
		Duncan Passage	DP	11° 14.855'	92° 27.011'	61
		Duncan Passage	DP	11° 14. 763'	92° 26.149'	160
		Duncan Passage	DP	11° 14.938'	92° 26.395'	94
		South Andaman	SA	11° 47.152	92° 19.555'	208
		South Andaman	SA	11° 47.127'	92° 21.994'	100
		South Andaman	SA	11° 46.866'	92° 29.059'	59
		Spike Island[*]	SI	12° 15.256'	92° 17.982'	203
		Spike Island	SI	12° 15.118'	92° 18.480'	100
		Spike Island	SI	12° 14. 870'	92° 20.776'	48
		Port Andaman[*]	PA	12° 39.928'	92° 22.444'	208
		Port Andaman[*]	PA	12° 39.956'	92° 24.103'	119
		Port Andaman[*]	PA	12° 39.888'	92° 33.899'	68
		Interview Island	II	12° 56.055'	92° 28.442'	101
		Interview Island	II	12° 55.946'	92° 34.593'	50
		Interview Island	II	12° 55.910'	92° 24.139'	224
		North Andaman	NA	13° 31.121'	92° 46.751'	52
		North Andaman	NA	13° 32.080'	92° 39.204'	113
		North Andaman	NA	13° 31.939'	92° 37.063'	219
	Andaman Sea sector	Table Island[*]	TI	13° 24.884'	93° 09.056'	60
		Table Island[*]	TI	13° 25.167'	93° 10.387'	110
		Table Island[*]	TI	13° 24.986'	93° 11.485'	210
		Port Cornwallis[†]	PC	13°21.383'	93°09.506'	116

		Port Cornwallis[#]	PC	13°21.263'	93°10.554'	225
		Sound Island[*]	So.I	12° 55.988'	93° 00.321'	56
		Sound Island[*]	So.I	12° 55.445'	93° 01.446'	109
		Sound Island[*]	So.I	12° 55.645'	93° 04.294'	221
		Smith Island[†]	Sm.I	12° 29.831'	93° 08.301'	189
		Smith Island[*]	Sm.I	12° 29.640'	93° 06.648'	113
		Smith Island[*]	Sm.I	12° 29.743'	93° 02.527'	52
		Outram Island[#]	OI	12° 15.682'	93° 09.466'	69
		Outram Island[†]	OI	12° 15.540'	93° 11.378'	100
		Outram Island[†]	OI	12° 15.044'	93° 14.298'	200
		Port Blair	PB	11° 41.625'	92° 49.450'	248
		Port Blair	PB	11° 41.930'	92° 47.752'	120
		Port Blair[*]	PB	11° 41.841'	92° 46.224'	64
		Rutland Island[†]	RI	11° 27.924'	92° 44.785'	225
		Rutland Island[*]	RI	11° 27.900'	92° 44.195'	95
		Rutland Island[*]	RI	11° 28.038'	92° 43.268'	57
		Cinque Island[#]	CI	11° 15.079'	92° 44.040'	238
		Little Andaman Island east	LAE	10° 40.566'	92° 40.866'	49
		Little Andaman Island east[†]	LAE	10° 40.004'	92° 43.806'	130
		Little Andaman Island east	LAE	10° 40.174'	92° 44.170'	225
Nicobar Islands	**Andaman Sea sector**	Car Nicobar Island East	CNE	9° 17.951'	92° 52.422'	222
		Car Nicobar Island East	CNE	9° 18.175'	92° 49.337'	107
		Car Nicobar Island East	CNE	9° 18.130'	92° 47.490'	55
		Nancowry Island	NI	7° 59.838'	93° 38.293'	58
		Nancowry Island	NI	7° 59.992'	93° 39.213'	102
		Nancowry Island[†]	NI	7° 59.929'	93° 40.050'	195
		Great Nicobar Island east[*]	GNE	7° 00.037'	93° 57.775'	50
		Great Nicobar Island east	GNE	7° 02.667'	93° 56.940'	96
		Great Nicobar Island east	GNE	7° 02.341'	93° 57.637'	230

	Bay of Bengal sector	Indira Point*	IP	6° 27.381'	93° 48.870'	98
		Indira Point*	IP	6° 30.647'	93° 47.810'	65
		Great Nicobar Island west	GNW	7° 07.992'	93° 31.193'	225
		Great Nicobar Island west†	GNW	7° 07.899'	93° 32.000'	99
		Great Nicobar Island west	GNW	7° 07.755'	93° 32.781'	50
		Katchall Island	KI	7° 59.848'	93° 15.295'	200
		Katchall Island	KI	7° 59.844'	93° 16.357'	140
		Katchall Island†	KI	7° 59.885'	93° 17.285'	57
		Car Nicobar Island West	CNW	9° 17.057'	92° 42.040'	48
		Car Nicobar Island West	CNW	9° 16.997'	92° 41.041'	123
		Car Nicobar Island West	CNW	9° 17.158'	92° 40.201'	220

* Grab sampling successful only in SS292
# Grab sampling successful only in SS261
† Grab sampling not successful due to hard bottom, considered only for environmental analysis.

Chapter III

Hydrography and Sediment characteristics

III. 1. *Introduction*

Distribution of benthic fauna is directly or indirectly influenced by the prevailing physical, chemical and biological conditions, which regulate the physiology of organisms and the availability of suitable substrates and food. The major hydrographic parameters affecting distribution of benthic fauna are near bottom dissolved oxygen, temperature and salinity. Marine invertebrates are exposed to a variety of environmental conditions and they respond to these conditions through certain adaptations or by avoiding the habitat (Kinne, 1963; Levinton, 1995). The survival, reproduction, development and growth rates of marine invertebrates are positively correlated with temperature (Kinne, 1963; Palmer 1994; Levinton, 1995; Brockington & Clarke, 2001; O’Conor *et al.*, 2007). The influence of temperature on fundamental biological functions (metabolic rate and growth) vary widely among species, and interspecific variations are manifested through differences in thermal sensitivity (Brown, 2005). For most species living in their mid-temperature tolerance range, an increase in seawater temperature stimulates higher growth, while those living at temperature maxima may become vulnerable to elimination from the habitat (Greenstein & Pandolfi, 2008). Globally, temperature decreases from equator to poles and from near shore to deep-sea which strongly influence the latitudinal distribution of species (Levinton, 1995). While fauna in high latitudes are exposed to wide seasonal fluctuations in temperature and consequently have wider ranges of tolerance, tropical species have low temperature tolerance (Compton *et al*., 2007; Storch *et al*., 2014).Temperature tolerance limits also vary among life stages, with eggs and larvae being more sensitive (Hoegh-Guldberg & Pearse, 1995; Portner & Peck, 2010). The marine realm is witnessing biogeographic and bathymetric range shifts in recent years (Kordas *et al*., 2011), in response to increasing global temperature, which ultimately impacts the biodiversity and ecological functions on a global scale (Yashura & Danovara 2014).

Oceanic islands are vulnerable to environmental changes, as most of them are located in the tropics and surrounded by coral reefs. In recent years, anthropogenic, climate-change induced ocean warming and acidification, pose serious threats to coral reefs and associated organisms. As per the fourth Intergovernmental Panel on Climate Change (IPCC) "Corals are vulnerable to thermal stress and have low adaptive capacity. Increase in sea surface temperature of about 1-3°C resulted in frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals". Coral bleaching (Glynn, 1993) events are being reported with greater frequency in the tropical reefs of the world ocean (e.g. Great Barrier Reefs, Caribbean Reefs, Coral triangle). In the Andaman Sea, average sea surface temperature (SST) is rising by 0.16°C per year and coral bleaching events have been reported (Brown, 2007; Mondal *et al*., 2014). The increasing SST, coral bleaching and reduction in coral cover due to increasing coral mortality have both direct and indirect effects on the sustenance, diversity and function of associated and adjacent fauna.

Most marine invertebrates are euryhaline with high cellular osmotic tolerance or high capacity of osmoregulation, the degree of tolerance to salinity variations shifting during ontogeny. Salinity affects functional and structural responses in invertebrates through changes in osmotic concentrations, relative proportion of solutes, absorption and saturation of dissolved gases, density and viscosity etc. In the tropics, changes in salinity are pronounced in the upper water column, whereas variations are relatively low in bottom waters (Lerman, 1986; Levinton, 1995). Salinity of a water body is influenced by a number of factors including rainfall, evaporation, inflow of river water, eddies, upwelling, currents etc. Salinity in general increases gradually with depth and at times in combination with temperature can cause density driven stratification, which act as barriers for vertical distribution of species. In regions with high salinity gradients, salinity may even form a major factor causing changes in the species composition of a community (Kinne, 1963; Joydas *et al*., 2015). In oceanic islands, the evaporation and rainfall are almost in balance with low riverine input, and the salinity variations are relatively low when compared to continental margins (Goreau *et al*., 2005).

Dissolved oxygen (DO) in seawater is vital for survival of marine organisms and in general, the oxygen consumption rates of organisms increase with increasing physical and physiological activities (Levinton, 1995). In oceanic islands, coral-associated zooxanthellae liberates substantial amounts of oxygen into the water, which maintain the relatively higher dissolved oxygen (DO) levels in these waters. In general, DO decreases with depth, as a result of decreasing rate of photosynthesis and increasing rate of respiration below the euphotic zone. In the northern Indian Ocean, DO gradually decreases with increasing depth, and perennial oxygen minimum zones (OMZs), with DO <0.5 ml/l are recorded in the Arabian Sea and Bay of Bengal at ~100-1200m depths (Helly & Levin 2004, Abdul Jaleel *et al*., 2014; Raman *et al*., 2015; Khan *et al*., 2017). Beyond this depth, a gradual rise in DO values occurs, due to the prevalence of well oxygenated water masses (e.g. Antarctic bottom water mass). OMZ are formed in areas with high surface productivity, where high sinking rates of organic matter and its degradation leads to depletion of oxygen, in combination with weak circulation (Sarmiento *et al*., 1988). Similar conditions are widely reported in the upper continental margins of Eastern Pacific Ocean, Southeast Atlantic and Andaman Sea (Garg *et al*., 1968; Naqvi *et al*., 1979; Gupta *et al*., 1981; Ansari & Abidi, 1989; Kamykowski & Zentara, 1990; Diaz & Ross, 1995; Levin *et al*., 2000; Gallardo *et al*., 2004; Gooday *et al*., 2009; Hughes *et al*., 2009; Cowie & Levin 2009; Levin *et al*., 2009; Quiroga *et al*., 2009; Zettler *et al*., 2009). In estuarine, coastal and shelf areas, episodic and permanent hypoxic (<2.8 mg O_2/l) conditions are being reported with increasing frequency, as a result of high primary production, stratification, anthropogenic nutrient enrichment, eutrophication and organic degradation (Diaz and Rosenberg, 1995; Rosenberg *et al*., 1991; Pihl *et al*., 1992; Rabalais & Turner, 2001). Hypoxia and anoxia over continental margins and inshore areas negatively impact ecosystems by causing mass mortality of sensitive organisms, altering biodiversity and community structure (Diaz & Rosenberg, 1995; Rabalais & Turner, 2001) and making a way for the dominance of opportunistic, hypoxia tolerant organisms (Wu, 2002; Baustian & Rabalais, 2009).

Soft sediments form a major habitat for benthic biota in the marine environment (Sanders, 1958), providing the physical substratum and also indirectly determining availability of food in the form of prey organisms and organic matter. The distribution patterns of the various sediment constituents (mud, sand, gravel etc.) on the continental margin vary according to hydrodynamic conditions, depth, seasons, wave action, currents and occurrence of river mouths (Nichols, 2009), with fine fractions (mud) most easily dispersed and transported from the source of origin. The energy profile of water flow just above the sediment-water interface determines the size of particle in surficial sediments (Gray & Elliot, 2009). Depth influences the energy profile through wave energy impacting the bottom, and is usually greatest in shallow areas when compared to the deep-sea.

A major source of sediment in oceanic insular margins is derived from coral reefs, is mainly composed of calcium carbonate (Glynn, 1977). Carbonate sediments are formed by the death or destruction of coral reefs through physical, chemical and biological erosion (Dudley, 2003). The physical processes leading to the destruction of coral reefs include temperature variations, increasing ocean pH leading to coral bleaching and death of corals. Mechanical erosion of reef is caused by tsunamis, earthquakes, storms, ENSO events etc. Biological erosion is caused by grazers and borers which vary with area, depth, season, substrate, organisms etc. Besides these, terrigenous sediments are important components in deeper margins of oceanic islands.

Sediment texture plays a key role in regulating the deposition of organic matter on the substratum, which forms the primary food source of many benthic fauna (Gray, 1981; Hedges & Keil, 1995). Besides these, the oxidation of organic matter in coarser sediments is relatively more as the water movements through large pore sizes are higher than fine sediment, and therefore the percentage of deposition will be comparatively less (Mayer, 1994). In the case of fine sediment, the deposition of organic matter on the mineral surfaces of fine sediments is higher, while the availability of organic matter to fauna is relatively low. The restricted water movements through the small pore sizes of fine sediments also reduces the degradation of organic matter. Coarser sediments with large grain size, provide ideal habitats for small-sized interstitial organisms, and also supports larger organisms which prey on them (Gray, 1974; Etter & Grassle, 1992).

Organic matter (OM) in marine sediments originates directly or indirectly from primary production in the water column and also from terrestrial materials brought to oceans through rivers etc. The quantity and preservation of organic matter reaching the bottom is strongly influenced by the supply of OM from the overlying water column, decomposition rate of the organic substances while they are in the water or after they have accumulated in the sediments and movement of the water (e.g. currents) in which the materials are deposited (Trask, 1955; Calvert, 1987; Hedges & Keil, 1995; Zonneveld *et al.*, 2010). The accumulation of OM in sediments in turn depends on the primary settling flux and sedimentation rate (Calvert, 1987). OM reaching the bottom is used up by benthic organisms or degraded by microorganisms or preserved as a layer on sediment. The faecal pellets of deposit feeding benthic organisms are also deposited in the sediments. Oxygen availability is an important factor influencing the degradation of OM in sediments. The sediments under highly productive, low oxygenated waters (e.g. upwelling systems, OMZs, hypoxic & anoxic waters) are characteristically rich in OM (Keil & Cowie, 1999; Levin *et al.*, 2002, Helly & Levin 2004).

Around oceanic islands, the major primary producers are macroalgae and coral-associated zooxanthellae in coastal waters (Rowan, 1998), while the role is taken over by microalgae in offshore waters. Terrigenous nutrient input is relatively low in the oceanic islands, when compared to continental margins, making the waters oligotrophic in nature. In oligotrophic environments, the OM production is low, and most of the OM is used up in the water column itself. The distribution of macrobenthic communities is strongly influenced by sediment texture, sediment grain size, current speed and organic content of the sediment (Gray, 1974). Infaunal organisms, in turn, influence the stability and composition of marine sediments through bioturbation (Kristensen, 1988; Bergen *et al*., 2000). Bioturbation refers to the particle mixing within unconsolidated sediments through the activities (e.g. burrowing, tube construction, feeding, and motility) of benthic fauna that inhabit in the sediment-water interface (Wust, 2011). The ventilation of burrows and tubes by macroinvetrebrates through water pumping causes gaseous exchange, food transport, gamete transport, removal of metabolites etc. (Kristensen, 1988). Bioturbation by macrofauna leads to the mixing of organic matter into deeper layers of sediments, modifies local environmental conditions for microbial activities enhancing the remineralisation of OM (Kristensen, 1988; Aller *et al*., 2001; Reise, 2002; Caradec *et al*., 2004). Benthic fauna thus play a major role in bentho-pelagic coupling by releasing nutrients back to water column, thereby sustaining the balance of the marine realm.

In the present study, data on key environmental factors were collected during north east monsoon in two surveys (SS261, January 2009 & SS292, November-December 2011). The hydrographic parameters (near bottom water temperature, salinity and dissolved oxygen) were collected from 37 sites (17 transects) in SS261 and from 59 sites (20 transects) in SS292. Bottom sediment samples were collected from 40 sites (17 transects) in SS261 and from 52 sites (20 transects) in SS292 to elucidate sediment texture and organic matter content. The variation in these environmental parameters are explored in this chapter using appropriate statistical measures. Latitudinal variations in the hydrographical parameters and sediments characteristics along the Bay of Bengal (BoB) and Andaman Sea (AS) sectors of Andaman and Nicobar Islands (ANI) have been analysed only in SS292, as the number of samples were relatively fewer in the Andaman Sea sector during SS261.

III. 2. *Results*

III. 2. 1. *Hydrography*

III. 2. 1.1. *Bottom water temperature*

During SS261, the near bottom water temperature around Andaman and Nicobar Islands showed significant variations with depth (PERMANOVA F= 499.44, P=0.001) and values ranged from 13.03°C (Interview Island, 200m) to 28.11°C (Spike Island, 50m). In the shallow depths (50m) the temperature values ranged between 27.29°C (west coast of Great Nicobar Island) and 28.11°C (Spike Island) with a mean of 27.65±0.31°C; at the intermediate depth (100m) it ranged from 21.31°C (Katchall Island) to 27.77°C (Interview Island) with a mean of 25.35±1.97°C; at higher depth (200m) between 13.03°C (Interview Island) and 16.31°C (east coast of Little Andaman Island) with a mean of 14.22±0.88°C (Fig. 3.1.a).

During SS292, near bottom water temperature varied markedly with depth (F=676.41, P=0.001) and ranged from 12.79°C (Port Blair, 200m) to 28.35°C (Indira Point, 50m). In the shallow depth (50m) the temperature value ranged between 25.61 °C (Port Blair) and 28.35°C (Indira Point) with a mean of 27.23±0.756°C ; at 100m depth values varied from 18.11°C (east coast of Little Andaman Island) to 23.63°C (South Andaman) with a mean value of 21.22±1.63°C; at 200m depth values ranged from 12.79°C (Port Blair) to 15.50°C (west coast of Great Nicobar Island) with a mean of 13.89±0.79°C (Fig. 3.1.b).

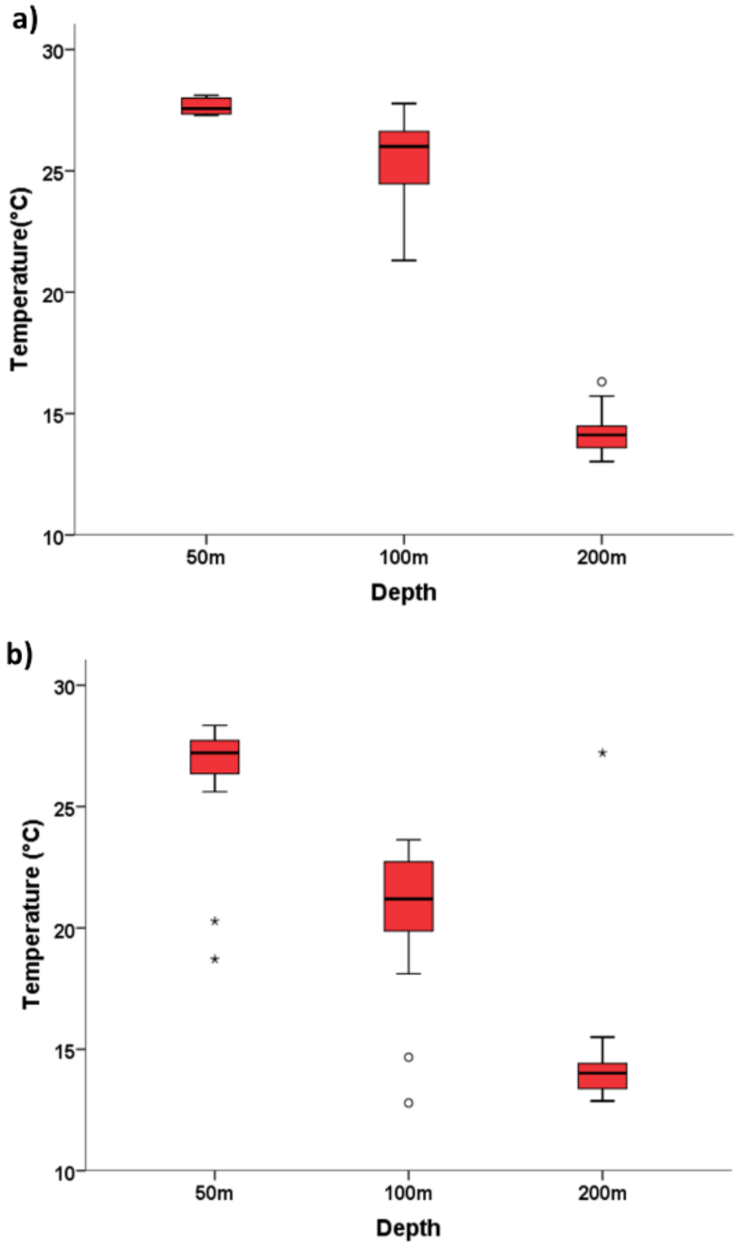


Fig 3. 1. Box-and-whisker plots of temperature for different depth classes during SS261 (a) and SS292 (b)

In the present study, variations in near bottom water temperature between the surveys were not significant (P>0.05). The near bottom temperature decreased significantly with increasing depth (r= -0.972, p <0.01) (Fi. 3.2a, b). Significant latitudinal variations were only observed along the 100m contour in the BoB sector (F=12.678, P=0.029) and 200m contour in the AS sector (F=32.465, P=0.037).

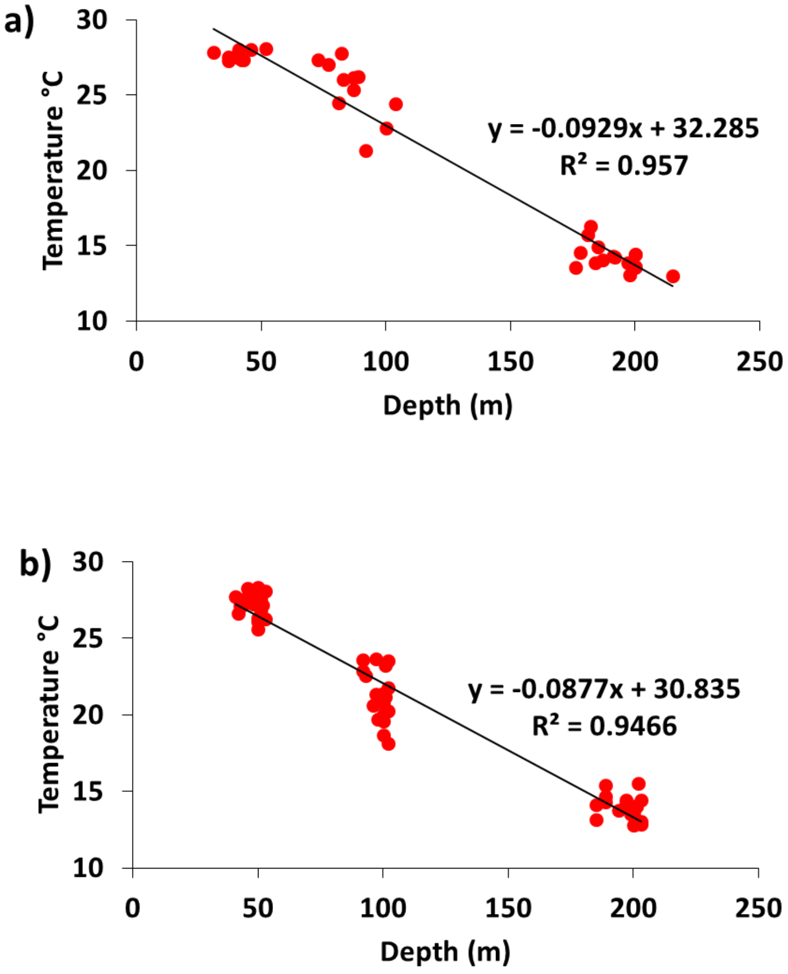


Fig 3. 2. Scatter plot showing relationship between near bottom water temperature and depth during SS261 (a) and SS292 (b)

III. 2.1.2. *Bottom water salinity*

The near bottom water salinity in SS261 siginificantly varied with depth (F=137.56, P=0.001) and ranged between 32.31 (Nancowry Island, 50m) and 34.99 (North Andaman, 200m). Within depth strata, in the shallow depth (50m) the salinity ranged between 32.31 (Duncan Passage) and 33.33 (South Andaman) with a mean of 32.82±0.41; in the intermediate depth (100m) values varied from 33.06 (Outram Island) to 34.46 (Spike Island) with a mean of 33.82±0.43; at higher depth (200m), from 34.82 (Little Andaman Island) to 34.99 (Interview Island) with a mean of 34.93±0.05 (Fig. 3.3a).

The near bottom water salinity in the SS292 significantly varied (F=170.78, P=0.001) with depth and ranged from 32.73 (Rutland Island) to 34.99 (Port Andaman). The salinity values varied between 32.73 (Rutland Island) and 34.26 (Spike Island) at 50m depth strata with a mean of 33.49±0.39; at 100m depth strata, values from 34.17 (Nancowry Island) to 34.79 (Indira Point) with a mean of 34.51±0.15; and at 200m depth strata value ranged between 34.84 (Table Island) and 34.99 (Port Andaman) with a mean of 34.93±0.04 (Fig.3.3b).

Variations in near bottom water salinity between surveys were not significant at all depth categories (P>0.05). Salinity showed a progressive increase with increasing depth (r=0.864, p=<0.01) (Fig. 3.4a, b). In each depth category, latitudinal variations in salinity were significant only in the higher depth (200m) within BoB sector (F=14.363, P=0.038) and AS sector (F=15.325, P=0.035).

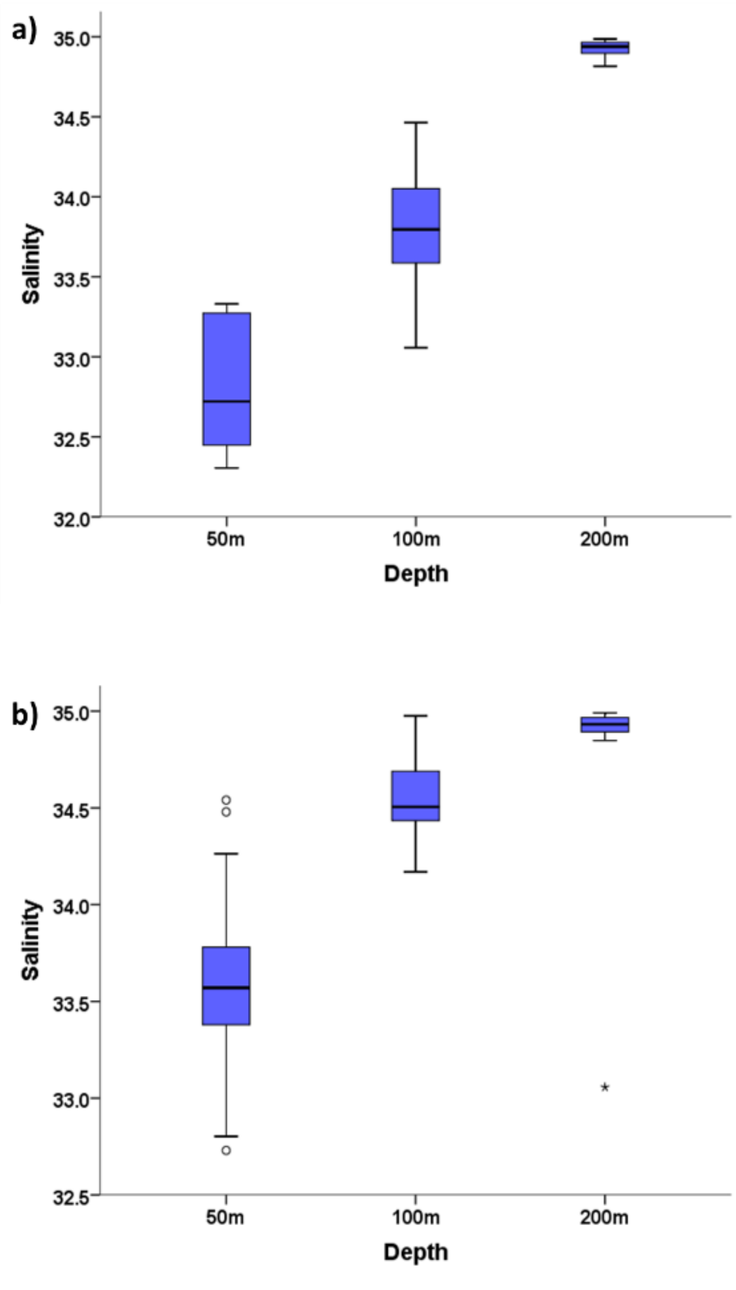
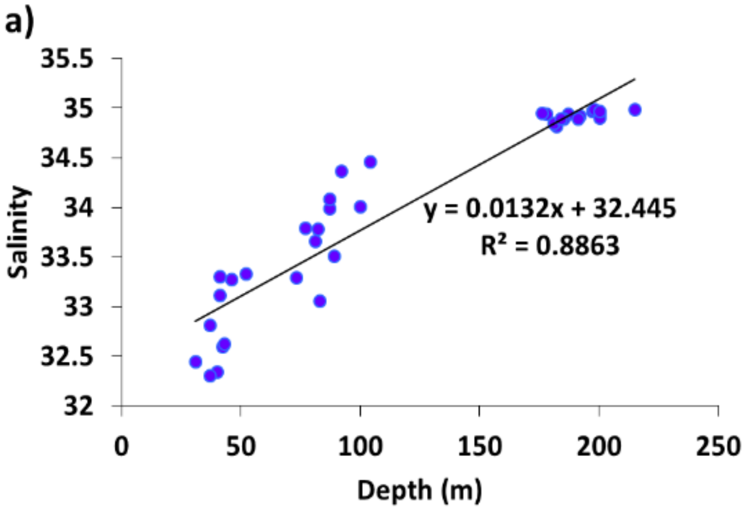


Fig 3. 3. Box-and-whisker plots of salinity for different depth classes during SS261 (a) and SS292 (b)



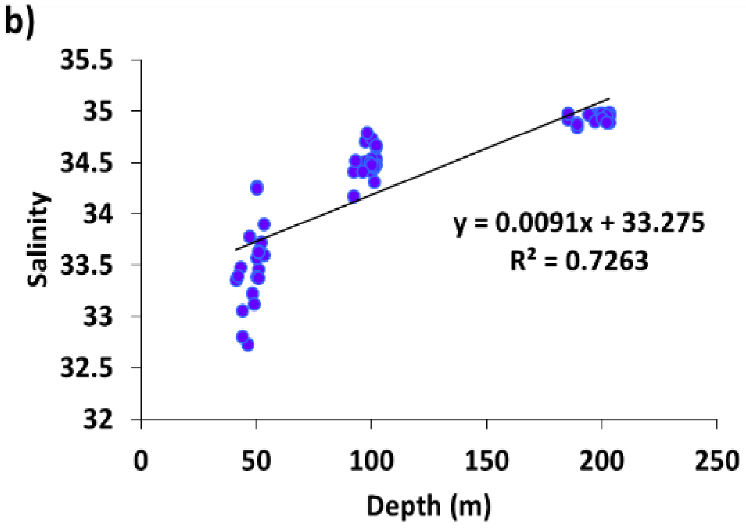


Fig 3. 4. Scatter plot showing relationship between near bottom water salinity and depth during SS261 (a) and SS292 (b)

III. 2.1.3. *Bottom water dissolved oxygen*

The near bottom water DO, during SS261 varied between 0.14 ml l^{-1} (Interview Island) and 4.22 ml l^{-1} (Nancowry Island) with significant variations among depth categories (F=269.54, P=0.001). Along the depth classes, at 50m depth category, the values ranged from 3.77 ml l^{-1} (west coast of Great Nicobar Island) to 4.22 ml l^{-1} (Nancowry Island) with mean of 4.03±0.17 ml l^{-1}; at 100m depth category, 1.39 ml l^{-1} (Spike Island) to 3.43 ml l^{-1} (west coast of Car Nicobar Island) with a mean of 2.61±0.68 ml l^{-1}; at 200m depth category, from 0.14 ml l^{-1} (Interview Island) to 0.71 ml l^{-1} (Katchall Island) with a mean of 0.45±0.19ml l^{-1} (Fig. 3.5a).

The DO in SS292 showed a significant decrease with depth (F=183.62, P=0.001) and DO varied between 0.18 ml l^{-1} (South Andaman) to 3.98 ml l^{-1} (Rutland Island). At 50m depth category, the dissolved oxygen values ranged from 1.84 ml l^{-1} (Spike Island) to 3.98 ml l^{-1} (Rutland Island) with a mean of 3.29±0.59 ml l^{-1}; at 100m depth category, from 0.22 ml l^{-1} (North Andaman) to 2.07 ml l^{-1} (west coast of Great Nicobar Island) with a mean of 1.06±0.51 ml l^{-1}; at 200m depth category, from 0.18 ml l^{-1} (South Andaman) to 0.72 ml l^{-1} (west coast of Great Nicobar Island) with mean of 0.39±0.17 ml l^{-1} (Fig. 3.5b). In each depth category, latitudinal variations in DO were noticeable especially in the higher depths within BoB sector (F=31.413, P=0.032, 200m) and AS sector (F=17.093, P=0.004, 100m; F=135.29 P=0.036, 200m). Dissolved oxygen showed a significant decreasing trend with increasing latitude at all depth strata in the BoB sector (50m: r= -0.668, p=0.035; 100m: r= -0.917, p=<0.001; 200m: r= -0.856, p=0.002) whereas in AS sector it was evident only in the 200m contour (r= -0.790, p=0.011).

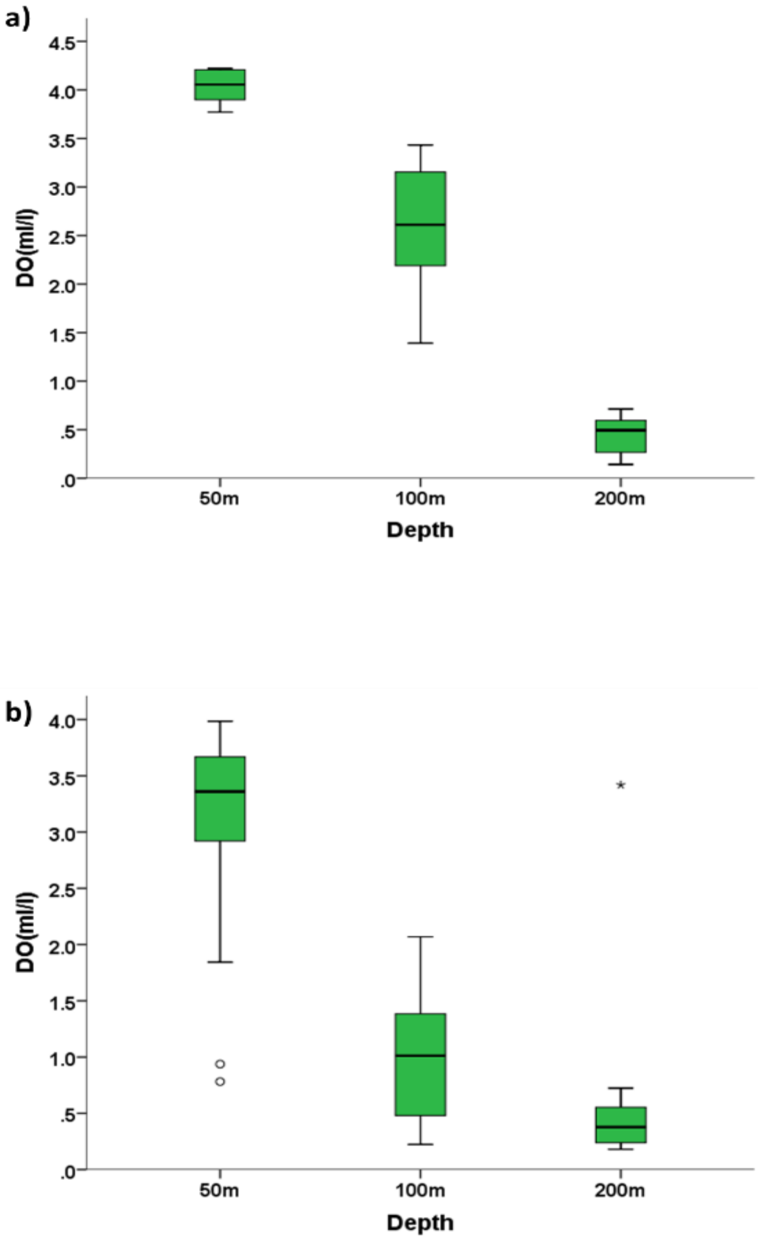


Fig 3. 5. Box-and-whisker plots of dissolved oxygen (DO) for different depth classes during SS261 (a) and SS292 (b)

Variations in near bottom water DO between the surveys were not significant at all depth categories (P>0.05). Dissolved oxygen showed a negative correlation (r= -0.872, p<0.01) with depth showing a sharp decline with increasing depth (Fig. 3.6a, b). In the 100m depth contour, the oxygen minimum conditions were encountered north of 12°N in the BoB sector (Fig. 3.7a, b).

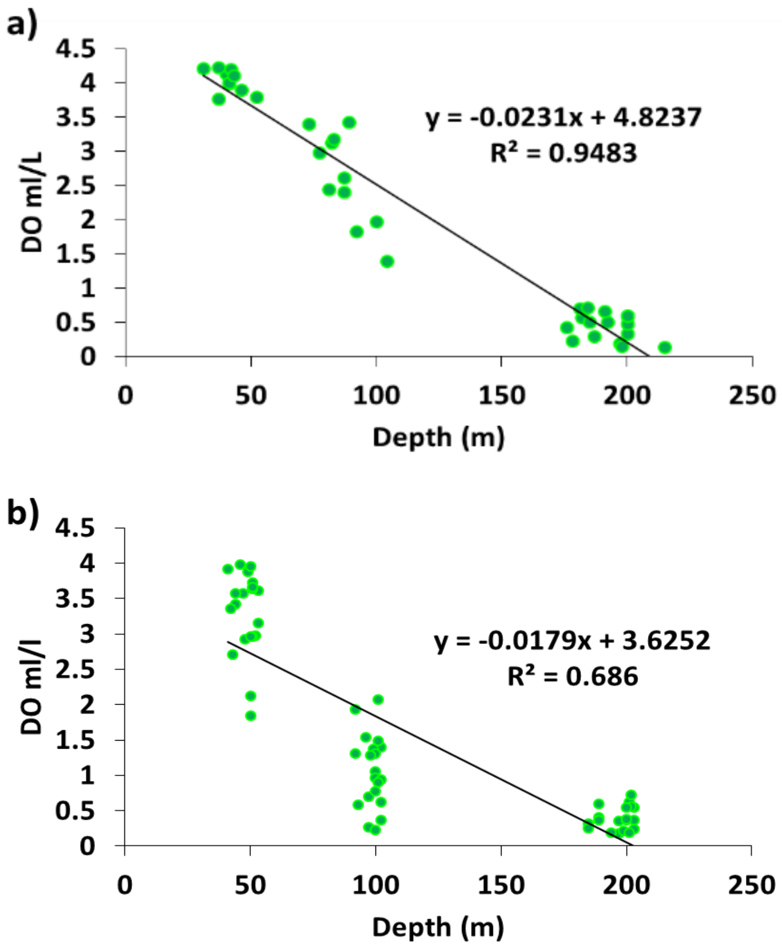


Fig 3. 6. Scatter plot showing relationship between near bottom water dissolved oxygen (DO) and depth during SS261 (a) and SS292 (b)

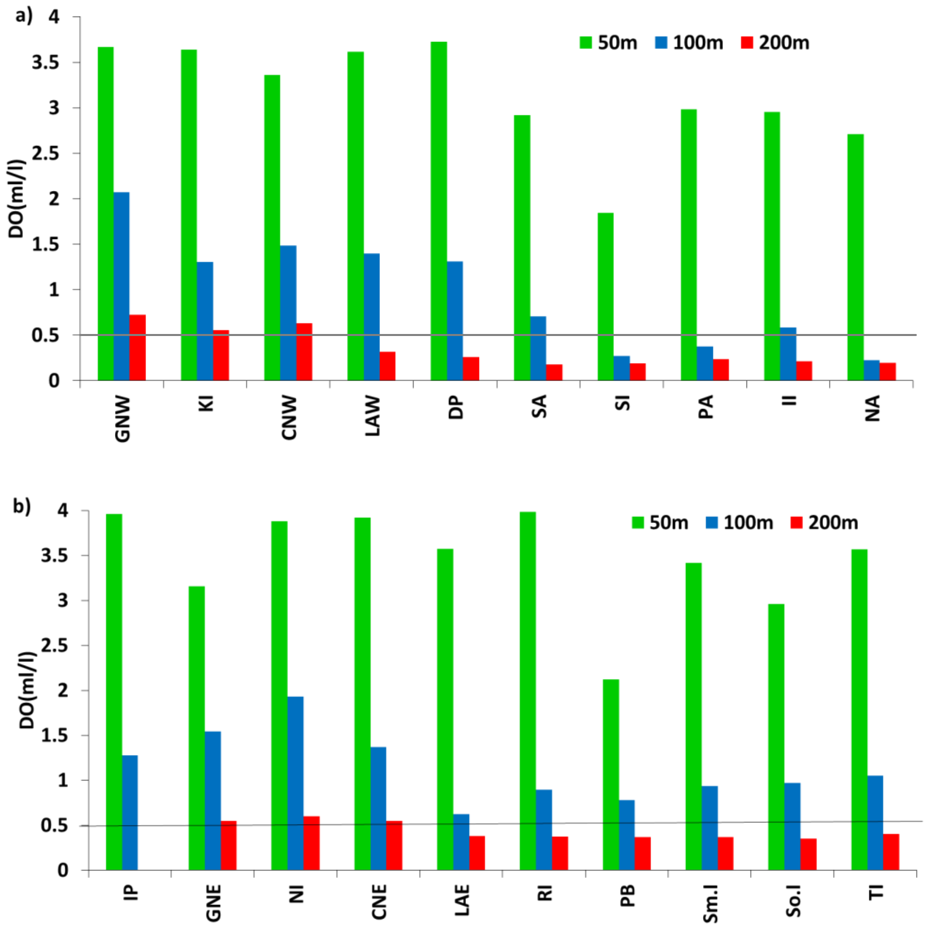


Fig 3. 7. Latitudinal variation in DO for different depth classes along Bay of Bengal sector (a) and Andaman Sea sector (b) during SS292

III. 2. 2. *Sediment Characteristics*

III. 2.2.1. *Sediment texture and grain size*

During SS261, the sediments of the shallow depth strata (50m) were coralline sand (86.3±24.0% sand, 10.7±21.9% silt, 2.9±3.6% clay), of median grain size (MGZ) ranging from 18.39 (South Andaman) to 483.25µm (Interview Island) with a mean of 332.48±139.20µm. In the intermediate depth category (100m) the texture was silty sand (79.3±23.3%

sand, 13.79±17.1% silt, 6.9±7.4% clay) with MGZ ranging between 41.25 (North Andaman) and 553.99µm (east coast of Little Andaman Island) with a mean of 255.06±183.61µm. In the higher depth category (200m), sediment was an admixture of sand (51.9±25.9%) and silt (32.2±21.8%) along with clay (15.9±11.3%) having a MGZ of 5.67 (Outram Island) to 403.55µm (east coast of Car Nicobar Island) with a mean of 91.16±96.16µm (Fig. 3.8, Fig. 3.9a, b). Significant bathymetric variations in sediment texture were observed in the present surveys (F=4.1245, P=0.009) and variation were more pronounced in fine sediments (silt F=4.0993, P=0.011; clay F=5.7489, P=0.003) rather than sandy sediments (sand F=2.7939, P=0.048).

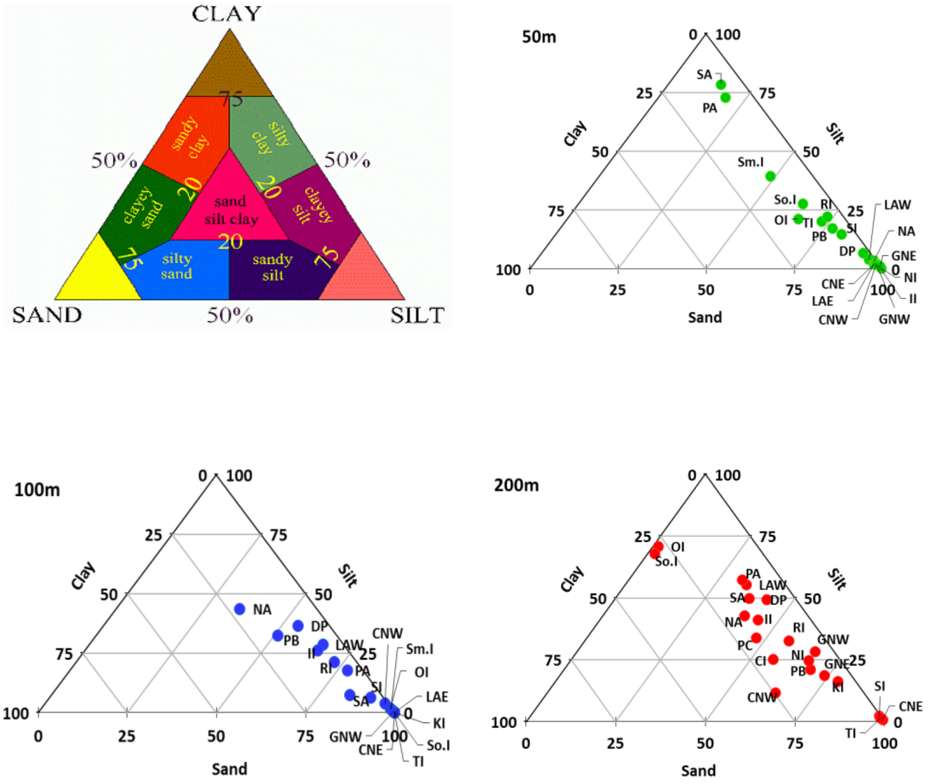


Fig 3. 8. Ternary diagram depicting sediment texture at each site (pooled) within the depth strata, following the classification of Shepard (1954)

During SS292 also, the shallow areas (50m) were dominated by coralline sand (78.28±27.10% sand, 18.27±24.06% silt and 3.45±3.83% clay) with MGZ ranging from 32.22 (South Andaman) to 557.28µm (North Andaman) with a mean of 267.26±201.94µm. Along 100m depth category, the sediment was silty sand with an average contribution of 81.53±21.67% sand, 14.25±15.75% silt and 4.25±6.58% clay and MGZ varied from 23.25 (Port Blair) to 525.99µm (east coast of Little Andaman Island) with a mean of 248.53±176.83µm. In the higher depth category (200m), the sediment was a mixture of sand and silt with an average contribution of 61.13±26.57% sand, 31.22±20.70% silt and 7.71±7.14% clay with MGZ ranging from 8.37 (Sound Island) to 480.41 (east coast of Car Nicobar Island) with a mean of 144.26±150.91µm (Fig. 3.8, Plate I). Exception to this general trend were noted, in the 50m and 100m depths of Indira Point, where the sediment consisted mainly of large pebbles and coral rubble with sand. Significant depth-wise variation in sediment texture were present around ANI ($F=3.0666$, $P=0.035$) with variations being more prominent in fine sediments (silt $F=3.5271$, $P=0.032$; clay $F=3.3013$, $P=0.044$) rather than sandy sediments (sand $P>0.05$). Within each depth category, latitudinal variations in sediment texture and MGZ were not significant along BoB and AS sectors ($P>0.05$) (Fig. 3.10a, b).

Significant variations in sediment texture were not observed between surveys in any depth category ($P>0.05$). Sand ($r= -0.396$, $p=0.001$) and median grain size ($r= -0.416$, $p=<0.01$) showed negative correlation with depth, whereas silt ($r=0.333$, $p=0.001$) and clay ($r=0.433$, $p=<0.01$) were positively correlated with depth.

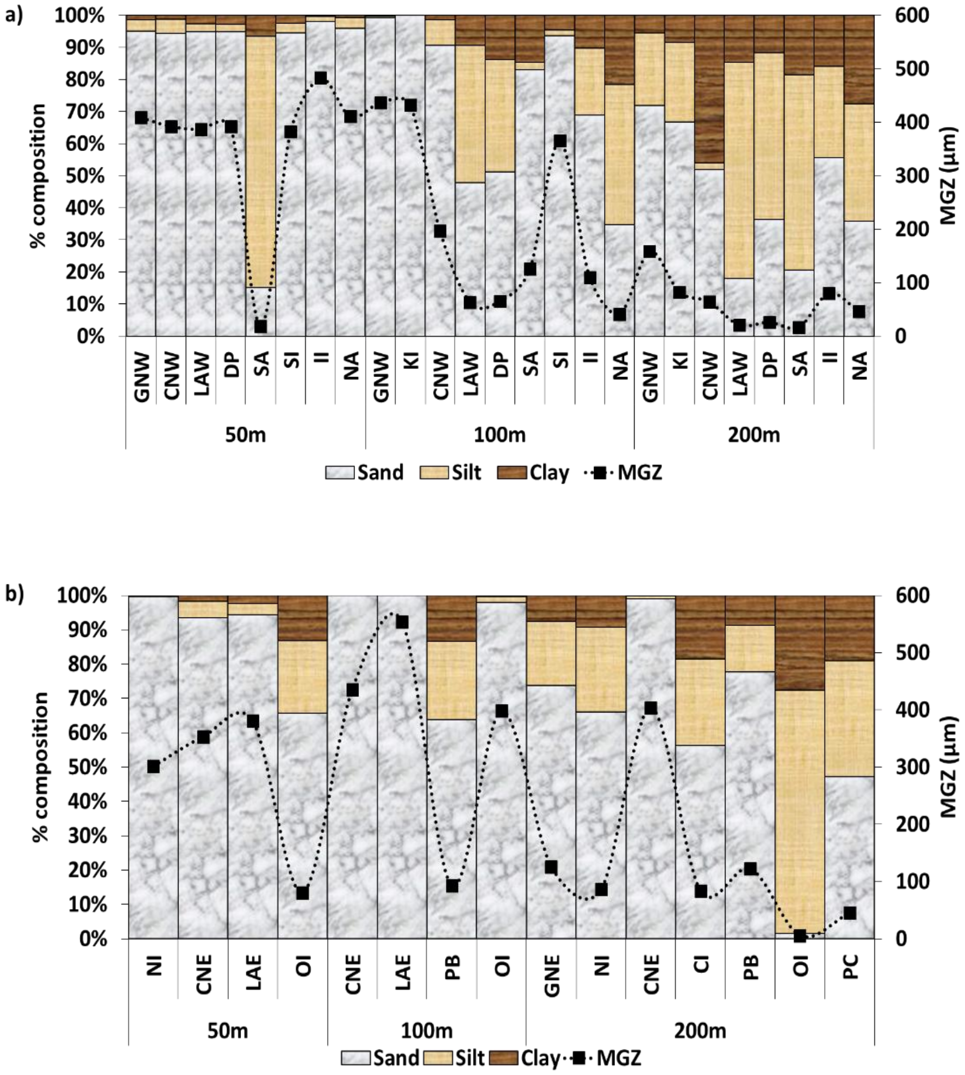


Fig 3. 9. Proportion of sand, silt, clay and MGZ of sediment at each site within each depth stratum of Bay of Bengal sector (a) and Andaman Sea sector (b) during SS261

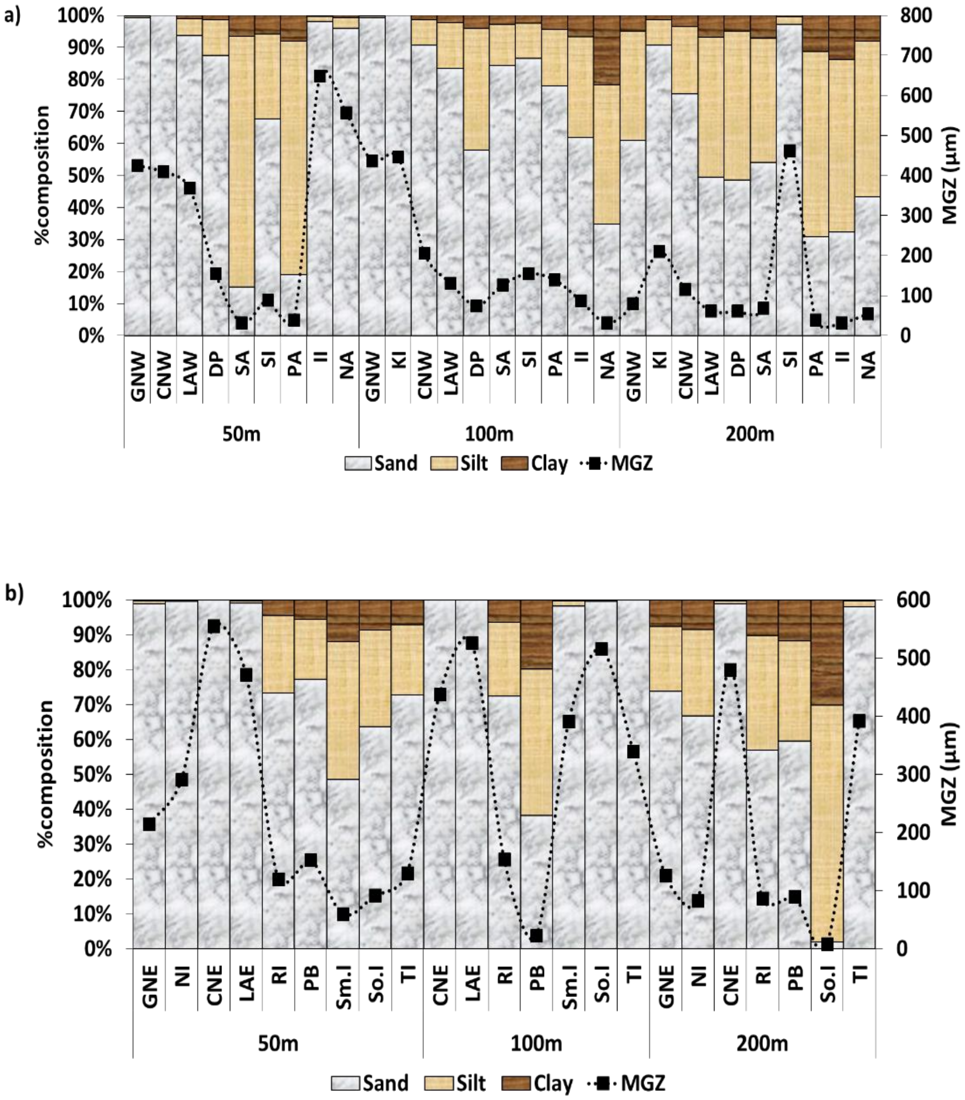


Fig 3. 10. Proportion of sand, silt, clay and MGZ of sediment at each site within each depth stratum of Bay of Bengal sector (a) and Andaman Sea sector (b) during SS292

III. 2. 2.2. *Sedimentary organic matter*

The organic matter (OM) content in the study area during SS261 varied between 0.05 (east coast of Little Andaman Island, 100m) and 2.68% (Interview Island, 200m). In the shallow depth (50m) values ranged from 0.24% (west coast of Car Nicobar Island & west coast of Great Nicobar Island) to 2.02% (North Andaman) with a mean of 0.75±0.62%; at intermediate depth (100m) the value varied between 0.05% (Little Andaman Island) and 2.14% (North Andaman) with a mean value was 0.68±0.57%. At higher depth strata (200m) the values ranged from 0.18% (Cinque Island and Nancowry Island) to 2.68% (Interview Island) with a mean value of OM was 0.97±0.92%) (Fig. 3.11, Fig. 3.12a, b). Significant variations in OM content with depth were not observed in the study area (P>0.05).

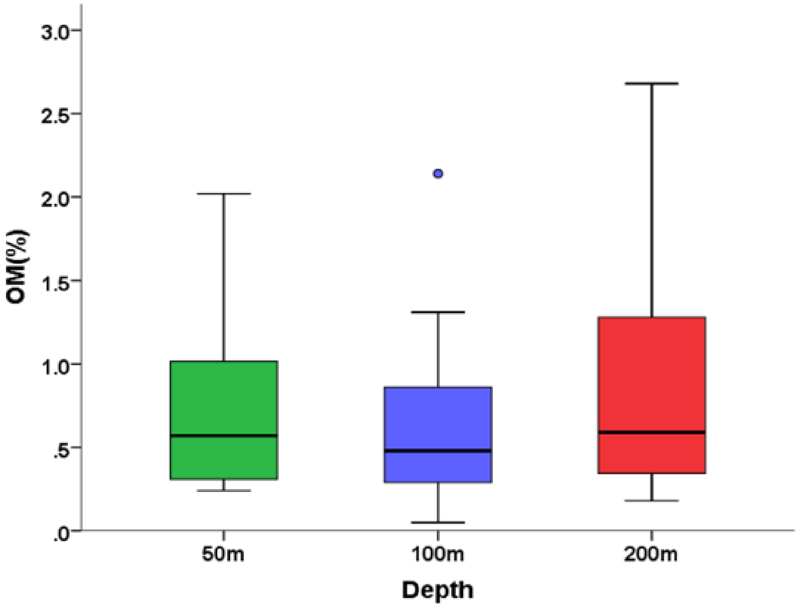


Fig 3. 11. Box-and-whisker plots of organic matter for different depth classes (SS261)

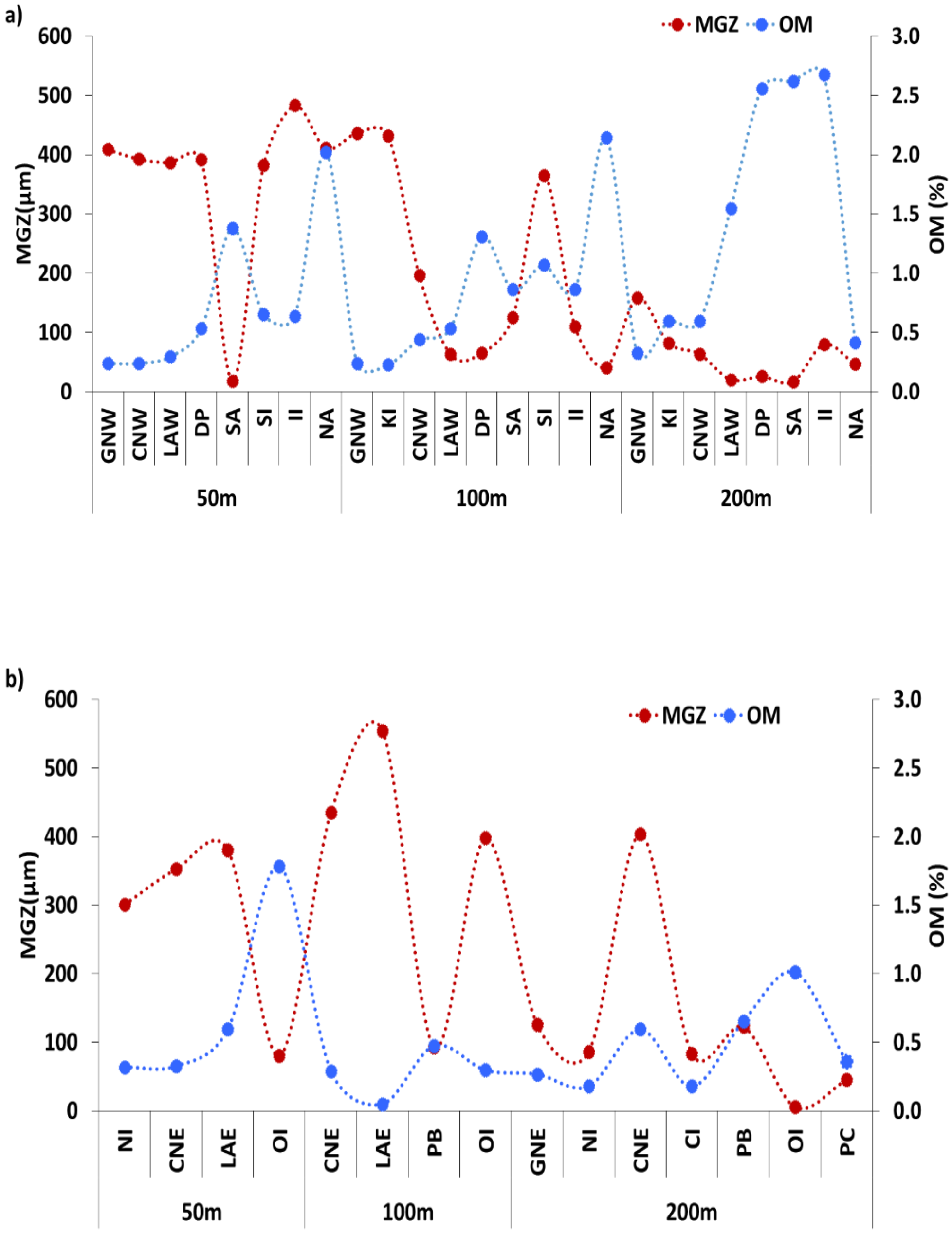


Fig 3. 12. Relationship between organic matter (OM) and median grain size (MGZ) at each site within each depth stratum of Bay of Bengal sector (a) and Andaman Sea sector (b) during SS261

The OM content in SS292 ranged from 0.06% (east coast of Little Andaman Island, 50m and 100m) to 3.90% (Sound Island, 200m) showing significant variation with depth (F=6.8621 P=0.004). Along each depth classes, OM varied from 0.06% (east coast of Little Andaman Island) to 1.50% (Smith Island) with a mean value of 0.63±0.38% (50m); 0.06% (Port Andaman) to 1.20% (Port Blair) with a mean value of 0.59±0.31% (100m); 0.18% (Katchall Island) to 3.90% (Sound Island with a mean of 1.46±1.16% (200m) (Fig. 3.13). In each depth category, latitudinal variations along BoB and AS sectors were not significant (P>0.05) (Fig. 3.14.a, b).

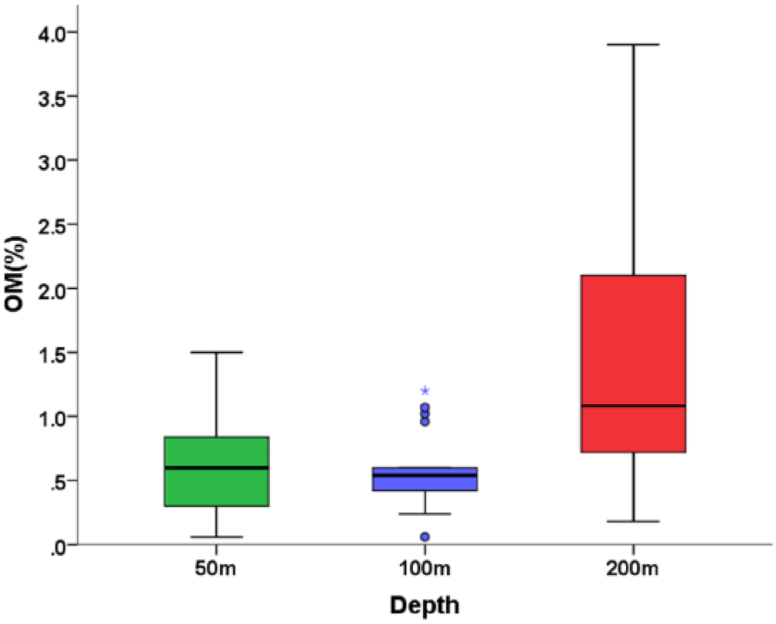


Fig 3. 13. Box-and-whisker plots of organic matter for different depth classes (SS292)

Significant variations in OM content were not obtained among surveys in all depth categories (P>0.05). OM were positively correlated with depth (r=0.314, p=0.002), silt (r= 0.626, p=0.000) and clay (r=0.407, p=0.000) while negatively correlated to sand (r= -0.621, p=0.00) and median grain size (r= -0.458, p=0.000).

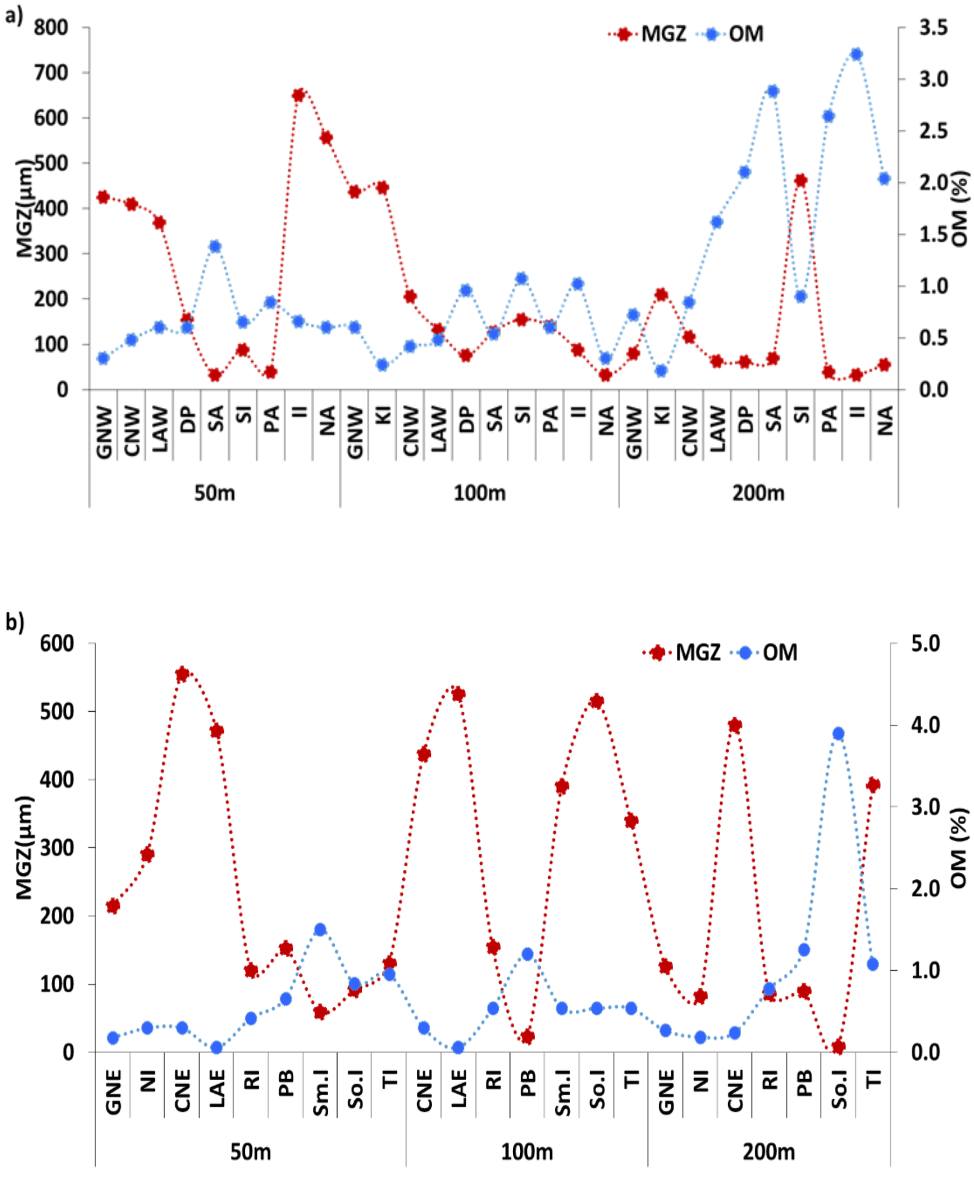


Fig 3. 14. Relationship between organic matter (OM) and median grain size (MGZ) at each site within each depth stratum of Bay of Bengal sector (a) and Andaman Sea sector (b) during SS292

III. 2.3. *Principal Component Analysis*

The variations in environmental factors with respect to depth is clearly depicted in PCA plot (Fig.3.14, Table 3.1). In this analysis 5 principal components explained 97.2% of variance, with 2 significant axes (PC1 and PC2) explaining 83% of the total variance between sites. The PC 1 axis (eigen value 4.83) and PC2 (eigen value 1.81) axes offering a total variance of 60.4% and 22.6% respectively. PC1 axis, clearly explain the variations in sediment characteristics (Sand, Silt, Clay, OM, MGS) while PC2 axis explained variations in the hydrographic parameters (temperature, salinity, DO). The shallow sites (50m) of Andaman and Nicobar Islands were dominated by coralline sand were characterised with high DO, temperature. The intermediate stations (100m) of Andaman Islands were characterised by silty sand, with relatively higher sand percentage in Nicobar Islands. Except along North Andaman and Port Blair, the sediment was a mixture of sand, silt and clay almost in equal proportions with high OM content in alldepth class or all sites.

In the higher depths (200m), the stations had relatively higher salinity and these sites were dominated by sandy silt sediments with relatively high OM content. Exceptions were seen along Sound Island and Outram Island, where the sites had clayey silt sediments with high OM. The higher depths (200m sites) of Nicobar Islands were characterised by relatively high sand content. Variations in bottom water hydrographic and sediment characteristics among island groups (Andaman Islands and Nicobar Islands) and between sea sectors (BoB and AS) in each depth category during SS261 and SS292 are given in the Table 3.2a & b.

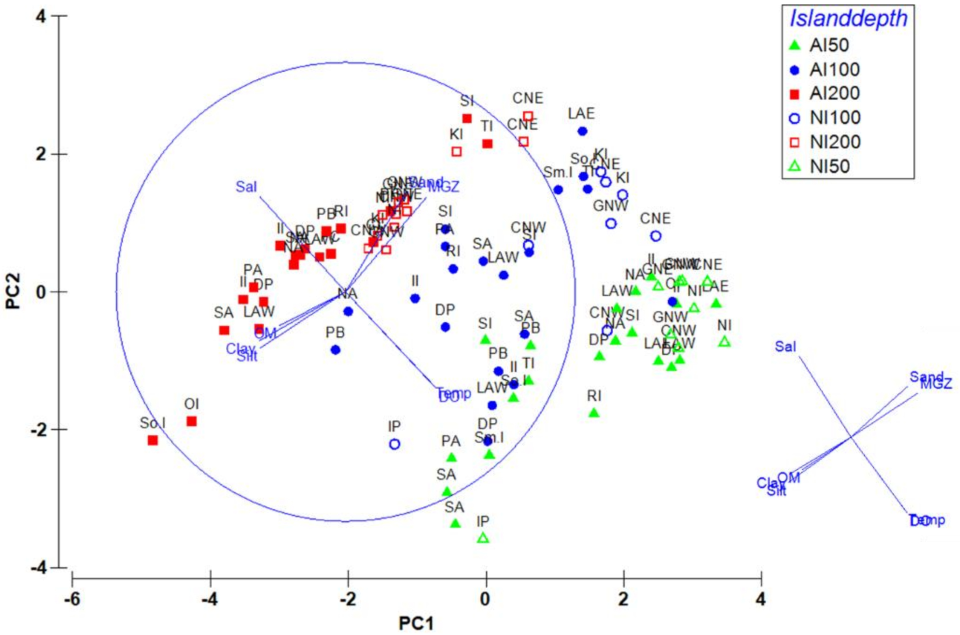


Fig 3. 15. Principal Component Analysis (PCA) of environmental variables (filled symbols denotes sites of SS292 while hollow symbols denotes sites of SS261)

Table 3.1. Results of Principal Component Analysis (PCA)

Variable	PC1	PC2	PC3	PC4	PC5
Temperature	0.336	-0.451	0.023	-0.072	0.411
Salinity	-0.317	0.497	0.005	0.03	0.343
DO	0.345	-0.463	-0.03	0.01	-0.086
Sand	0.348	0.311	-0.053	-0.793	0.022
Silt	-0.381	-0.275	-0.211	-0.396	0.557
Clay	-0.381	-0.228	-0.368	-0.35	-0.604
OM	-0.296	-0.197	0.889	-0.26	-0.108
MGZ	0.41	0.27	0.16	-0.135	-0.138

III. 3. *Discussion*

The near bottom hydrographic and sediment characteristics of Andaman and Nicobar waters exhibited significant spatial heterogeneity, particualrly with depth. The temporal variations in temperature during the north-east monsoon (NEM) season were insignificant at all depth strata, while the latitudinal variations were significant only for the higher depths of both BoB (100m) and AS (200m) sector. Temperature showed sharp decline with increasing depth (Parulekar & Ansari, 1981a). Bathymetric variations in salinity were significant while moving from shallow (50m) to deeper (200m) areas, and latitudinal variations were only significant along higher depth (200m) in both BoB and AS sector. Previous studies around ANI, during the winter monsoon season reported three water masses up to 150m depth (based on temperature and salinity), viz- northern dilute water mass, a transition water mass and southern Bay of Bengal water mass (Mathew & Pillai, 1990), of which the transition water dominated around Andaman Islands especially in NEM (Murty *et al*., 1981). The northern dilute waters is contibuted by the high riverine flow into Bay of Bengal from peninsular India and discharge of the Ayeyarwady river in Myanmar. The low density surface water from the Bay of Bengal enters the Andaman Sea through the Preparis Channel, while in the southeastern part of the study area, surface water enters the Andaman Sea from South China Sea through Malacca Strait and then intrude into the Bay of Bengal through the Great Passage. The water reaching the eastern side of Ten Degree Channel from north (Bay of Bengal water) and the southwest appears to flow into bay of bengal through Ten Degree Channel (Raju *et al*., 1981). The variations in seawater temperature and salinity may be attributed to the prevalance of different watermasses at various depths of Andaman and Nicobar waters. However, there is a lack of clear understanding of water masses around the ANI and since no detailed studies on these aspects have been conducted recently, and the inference are based on studies (Garg *et al.*, 1968; Babu & Sastry, 1976; Raju *et al.*, 1981; Murty *et al.*, 1981; Gupta *et al.*, 1981; Mathew & Pillai, 1990) published 3 decades ago.

The near bottom DO concentration around ANI decreased significantly with increasing depth, and significant latitudinal variations were observed at all depth stratas in BoB and higher depth stratum of AS sectors. High DO levels (>4ml l^{-1}) in the surface and sub-surface waters were evident around the ANI (Parulekar & Ansari, 1981a; Gupta *et al.*, 1981; Bhattathiri, 1984; Ansari & Abidi, 1989). The oxygen liberated by photosynthetic activity of coral reefs and active hydrodynamics near the coasts resulted in the high concentration of DO. The International Indian Ocean Expedition (IIOE), during the same season (in 1963), revealed that oxygen concentration in the upper water column along the east coast of Andaman Islands and south of Nicobar Islands (~60-80m) were very high (>4ml l^{-1}), while in the northernmost section of Andaman Islands, the high oxygen levels were limited to ~35m depth (Garg *et al.*, 1968). Garg *et al.*, (1968) and Bhattaathiri (1984) reported the thickness of oxygen rich layer to be less in Andaman Sea due to the spreading river discharge from Ayeyarwady river, which affected the distribution of oxygen in upper 75m during the NEM (Gangadhar Rao & Jayaram, 1968). In the intermediate depths (100m) fairly good concentration of oxygen levels were observed during the present surveys, but as depth increased further, the oxygen levels decreased drastically.

The DO values were relatively low in the in the deeper strata (200m) of the study area, particularly in the northern transects (above 10°N). Oxygen minimum conditions in bottom water (<0.5ml/l) were observed at

~200m depth only around Andaman Islands (above 10°N channel), but not around Nicobar Islands. In the latter region, the oxygen minimum conditions occurred at a higher depths of ~220-250m (present surveys, Salini *et al*., unpublished). The impingement of OMZs on the upper continental margins in Arabian Sea, Bay of Bengal and its impacts on benthic fauna are well studied (Ingole *et al*., 2010; Joydas & Damodaran, 2014; Abdul Jaleel *et al*., 2014; Raman *et al*., 2015). The OMZ conditions around ANI were been reported by Gupta *et al*., (1981), Ansari & Abidi (1989), Madhu *et al*., (2003) & Nair & Gireesh (2010). Major rivers like Ganga, Brahmaputra, Godavari, Mahanadi, Cauvery, Krishna and Ayeyarwady flows into the Bay of Bengal, with a pronounced increase in freshwater discharge during NEM (Sarma *et al*., 2016). This leads to the formation of strong, salinity controlled stratification in the surface layers, preventing vertical mixing, which leads to oligotrophic conditions (Shetye, 1993). Due to large volume of freshwater influx into BoB, the distribution of temperature is also altered, by the formation of a subsurface warm layer (inversion layer) between colder waters above and below. The major reasons for the temperture inversion are net surface heat loss, associated surface cooling and advection of cold fresher water over warm saline water (Thadathil *et al*., 2000). The temperature inversions occurs during November to February, mainly in the coastal and offshore waters by western BoB, but by January the inversion moves towards central and eastern BoB (Thadathil *et al*., 2000). In the BoB sector of ANI, the temperature and salinity inversions are distinct during December and January (Raju *et al*., 1981; Mathew & Pillai, 1990; Thadathil *et al*., 2000). Along with the stratification due to Ayeyarwady discharge, the presence of shallow sills in Andaman Sea sector, may hinder the water exchange leading to relative stagnation of water which may explain the occurrence of oxygen minimum conditions along the Andaman Sea sector of the Andaman Islands (Gupta *et al*., 1981). The oxygen minimum conditions in the BoB and AS sectors were found to intensify towards the north (Garg *et al*., 1968; Nair & Gireesh, 2010), even reaching up to 100m depth strata in the northern transects of BoB sector as observed during the present study.

The present findings are in agreement with previous studies in the study area during NEM, where the thickness of oxygen minimum layer around ANI varied between 150-600m with an impingement at a depth range of 150-200m. Lowest oxygen values were recorded at the northern most end of the ANI (Garg *et al*., 1968; Babu & Sastry, 1979; Gupta *et al*., 1981; Ansari & Abidi, 1989; Madhu *et al*., 2003). In the IIOE surveys (1963), the oxygen poor waters were reported at 250-420m depths in the southern sector of Nicobar Islands and 170-380m along the eastern part of Andaman Islands (Garg *et al*., 1968). Along the western BoB (east coast of Indian peninsula) the impingement of OMZ was encountered >176m (Naqvi *et al*., 1979; Raman *et al*., 2015; Khan *et al*., 2017) while in the Eastern Arabian Sea (west coast of India) the OMZ impingement occur at the shelf edge >150m (Ingole *et al*., 2010; Joydas & Damodaran, 2014; Abdul Jaleel *et al*., 2014).

Sediment texture exhibited significant bathymetric variations around ANI. Sand formed the major fraction of bottom deposits in the insular margin of ANI, with coralline sand being dominant in the near reef areas (50m) and decreasing gradually with depth (Parulekar & Ansari, 1981a; Rao & Kessarkar, 2001). The supply of sediment to the seafloor determines the textural pattern of an area (Fennessy & Green, 2015), and in the case of ANI the riverine input (terrigenous deposits) is relatively low compared to continental margins. The dominance of biogenic coarser sediment in the shallow depths is attributed to the presence of reefs (upto 50-75m depth) around the archipelago, with reef flats of 200-500m width (UNEP/IUCN, 1988; Brown, 2005; Mahendra *et al*., 2010; Velloth *et al*., 2014). At this depth stratum, sediments consisted mainly of eroded coral fragments and coralline sand (Parulekar & Ansari, 1981a), evincing that reefs plays a major role in characterizing the sediment texture and enhancing sediment deposition (Glynn, 1977; Demopoulos *et al*., 2014). Even further away from the reefs (100m), offshore transport of coral derived sediments was evident (Rao, 2010; Stella *et al*., 2011; Demopoulos *et al*., 2014). Strong bottom currents are known to re-suspend and sort bottom sediments, resulting in coarse-grained beds composed of sand to granule-sized, loose carbonate material with relatively high hydraulic conductivities and low content of organic matter (Li & Amos, 1999; Abdul Jaleel, 2012).

Similar textural characteristics occur along other tropical island margins in the world oceans viz. Hawaiian Archipelago (Fan & Grunwald, 1971), Mahe, Seychelles (Mackie *et al*., 2005), Cocos Island, Costa Rica (Sibaja-Cordero *et al*., 2014), Great Barrier Reef (Riddle, 1988) and Gulf of Carpentaria (Long *et al*., 1995) of Australia, Reunion Island (Bigot *et al*., 2006), Puerto Rico (Schneidermann *et al*., 1976; Schwab *et al*., 1996; Hernandez *et al*., 2009), Karah Island, Malaysia (Ibrahim *et al*., 2006), Palk Strait, off Jaffna, Sri Lanka (Dahanayaka *et al*., 2007), North Malè Atoll, Maldives (Morgan & Kench, 2012), Agatti, Kalpeni and Kavaratti attols of Lakshadweep (Rivonker & Sangodkar, 1997).

Since the Andaman and Nicobar Islands are volcanic in origin, the insular margins were quite steep, with a shelf less than 10-50km (Rao & Kessarkar, 2001). The steep depth gradients facilitate transport of finer particles to higher depths (Hashimi *et al*., 1981; Abdul Jaleel, 2012), and lead to settlement in the less dynamic, deeper areas. As depth increased in the ANI (200m), the sediment texture gradually shifted to silt, with low sand content (Ansari & Parulekar, 1981a; Rao & Kessarkar, 2001). Silt content was relatively high around Andaman Islands (52% sand, 38% silt) when compared to Nicobar Islands (78% sand, 18% silt). The high sand content in deeper areas along Nicobar Islands might be due to the vigorous hydrodynamic conditions prevailing (Abdul Jaleel, 2012) around small islands in the Nicobar Island chain (e. g. Car Nicobar Island, Katchall Island, Nancowry Island and Great Nicobar Island).

Sediment grain size has a major influence on the distribution of benthos, their life habit, feeding etc. (Levinton, 1995). Grain size parameters are also used as proxy's to sediment deposition in the aquatic environments (Folk & Ward, 1957) and also used to predict sediment transport in near shore environments, with coarse grain size and poor sorting indicating a high-energy environment (Bascom, 1951). Larger grain sized sediments dominated in the shallow depths, where sediment texture was coralline sand, but in deeper areas sediment texture was sandy silt with relatively smaller grain size. Grain size has a significant influence on build up of the substratum, which also determines the sedimentation rate, sediment permeability and OM content (Bergamaschi *et al*., 1997; Dashtgard *et al*., 2008). The sediment texture in an area is dependent on roughness of the sediments, settling velocity and threshold velocity. The sediments are transported up to 100m depth by sub tidal waves, but as depth increases turbidity currents come into action. The threshold velocities of sub tidal waves are higher than that of currents, so most of the fine sediments are easily carried away to deeper depths. According to Gray & Elliot (2009) the size of sediment particle <0.18mm (silt and clay) get tightly packed with minute pores creating a soft bottom which makes currents unable to re-suspend the particles.

The waters around ANI are known to be oligotrophic in nature (Ansari & Abidi 1981; Sarupria & Bhargava 1993; Rashiba 2010). Observations from the present study, on the low organic matter (OM) values of the study area (0.05-3.90%), supports the aforementioned fact, when compared to other productive continental shelves of peninsular Indian (Jayaraj *et al*., 2007; Ganesh & Raman, 2007; Joydas & Damodaran, 2009; Ingole *et al*., 2010; Khan *et al*., 2012; Manokaran *et al*., 2015). The quantity of organic matter in the sediments is dependent on organic matter source, productivity of the water column, oxygen availability, degradation, oscillating redox reactions, sediment texture, sorptive preservation on mineral surfaces, protective encapsulation within macromolecular organic matrices, temperature, bioturbation, microbial dynamics (Trask, 1955; Calvert, 1987; Mayer 1994; Hedges & Keil, 1995; Harnett *et al*., 1998; Wakeham & Canuel, 2006; Zonneveld *et al*., 2010).

In the shallow near-reef areas (50m) around ANI, OM content was low in coralline sandy sediments indicating that calcareous sands are the major sites for recycling of organic matter in coral reef areas (Wild *et al*., 2009). The capacity of coarse sediments to retain organic matter is very low due to large grain size, permeability, availability of more interstitial spaces and a host of microorganisms carrying out remineralization in the well-oxygenated waters (Gray & Elliot, 2009; Bayraktarov & Wild, 2014). Compared to Andaman Islands, the OM content around Nicobar Islands was lower, demonstrating that in high energy environments with strong water currents, the advective transport of particulates through porous sediments will be higher, hindering the deposition of OM in the sediment surface (Alongi *et al*., 1996).

With increasing depth in ANI, the OM content increased, as coralline sandy sediments gave way to fine sediments (sandy silt). This is attributed to high affinity of OM to sedimentary minerals, mineral surface area and hydraulic equivalency of fine grained particles (Premuzic *et al*., 1982; Calvert & Pedersen, 1992; Mayer, 1994; Keil *et al*., 1994; Hedges & Keil, 1995; Tyson, 1995; Rao & Veerayya 2000; Keil & Mayer, 2014). According to Mayer (1994) “surface adsorption/mesopore protection” hypothesis for organic matter preservation, the organic matter-mineral interactions protect organic matter from bacterial exoenzymes via small pore size decreasing the entry of enzymes, and steric constraints within the pores reduces the enzyme activity. Moreover, interstitial circulation in fine sediments is poor due to small pore size of the sediment, reducing the penetration of water into the sediment, thereby decreasing the oxidation of OM and enhancing preservation (Burone *et al*., 2003; Huettel *et al*., 2003; Gray & Elliot, 2009; Khan *et al*., 2012; Bayraktarov & Wild, 2014). The hydrographic and sediment parameters discussed above could potentially have profound influence on the distribution of benthic fauna, particularly, the macrofauna.

Table 3.2a. Bottom water hydrographic parameters and sediment characteristics of SS261 (mean±SD)

Islands 261	**Coast/ Sector**	**Depth (m)**	**Temperature (°C)**	**Salinity**	**DO (ml/l)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**OM (%)**	**MGZ (µm)**
Andaman	**West/BoB**	**50m**	27.84±0.25	32.97±0.45	4.01±0.15	82.20±32.91	15.2±30.94	2.61±2.21	0.92±0.65	345.57±164.60
		100m	26.54±1.33	33.87±0.42	2.67±0.80	63.22±22.55	24.36±19.17	12.42±5.80	1.13±0.56	128.52±120.11
		200m	13.78±0.72	34.96±0.02	0.21±0.08	33.27±15.12	49.08±16.32	17.65±6.04	1.96±0.98	38.12±26.15
	East/AS	**50m**	27.33	32.6	4.21	79.98	12.21	7.81	1.2	230.52
		100m	24.44±1.60	33.58±0.48	2.53±0.61	87.25±20.33	8.21±12.75	4.54±7.58	0.27±0.21	348.14±234.70
		200m	14.61±1.07	34.91±0.06	0.46±0.10	45.67±32.10	35.84±24.75	18.48±7.72	0.55±0.36	64.25±50.30
Nicobar	**West/BoB**	**50m**	27.32	32.72	3.94	94.74	3.96	1.3	0.24	400.7
		100m	23.77	33.93	2.63	96.65±5.27	2.84±4.48	0.51±0.79	0.30±0.12	355.00±137.43
		200m	13.94±0.36	34.92±0.04	0.66±0.06	63.53±10.36	16.50±12.52	19.97±22.54	0.51±0.15	101.60±50.01
	East/AS	**50m**	27.52	32.31	4.22	96.58	2.54	0.87	0.33	326.94
		100m	25.33	34.09	2.61	100	0	0	0.29	435.26
		200m	14.56±1.09	34.91±0.06	0.59±0.11	79.61±17.21	14.74±12.41	5.65±4.81	0.3±0.22	205.17±172.96

Table 3.2b. Bottom water hydrographic parameters and sediment characteristics of SS292 (mean±SD)

Islands 292	Coast/ Sector	Depth (m)	Temperature (°C)	Salinity	DO (ml/l)	OM (%)	Sand (%)	Silt (%)	Clay (%)	MGZ (µm)
Andaman	**West/ BoB**	**50m**	27.33±0.61	33.67±0.34	2.96±0.62	0.76±0.29	68.13±36.33	28.46±33.30	3.41±3.27	269.93±255.85
		100m	22.36±1.38	34.58±0.12	0.7±0.48	0.71±0.30	69.92±19.11	24.13±13.35	6.33±6.92	106.94±43.60
		200m	13.66±0.50	34.97±0.02	0.23±0.05	2.20±0.80	50.89±22.21	41.73±18.57	7.52±4.31	111.47±154.99
	East/ AS	**50m**	27.08±1.02	33.22±0.43	3.27±0.65	0.74±0.49	72.41±16.60	21.28±12.72	6.31±3.99	171.09±150.91
		100m	19.92±1.27	34.51±0.09	0.88±0.15	0.57±0.36	84.76±25.23	10.82±17.39	4.41±7.93	324.95±200.76
		200m	13.97±1.01	34.92±0.05	0.38±0.02	1.76±1.44	54.12±39.58	32.76±27.23	13.12±12.45	144.41±169.61
Nicobar	**West/ BoB**	**50m**	27±0.49	33.47±0.14	3.56±0.17	0.39	99.62	0.31	0.06	417.3
		100m	21.34±1.82	34.42±0.10	1.62±0.40	0.42±0.18	96.69±5.21	2.82±4.45	0.49±0.76	363.08±135.85
		200m	14.15±1.30	34.92±0.03	0.64±0.09	0.58±0.35	75.66±14.91	21.06±13.21	3.28±1.71	135.21±67.03
	East/ AS	**50m**	27.17±0.80	33.36±0.24	3.65±0.43	0.26±0.07	99.48±0.53	0.43±0.45	0.09±0.09	353.36±178.48
		100m	21.55±1.17	34.36±0.17	1.62±0.29	0.3	100	0	0	437.51
		200m	14.05±0.59	34.90±0.03	0.57±0.03	0.23±0.04	79.84±16.95	14.78±12.46	5.38±4.53	229.72±218.19

Chapter IV

Standing stock of macrobenthos

IV. 1. *Introduction*

Benthic animals are major contributors of secondary production in the marine realm, as they obtain energy by feeding on other organisms or detritus (Elliot & Taylor, 1989). They are also indispensable components in the dynamic processes of global carbon cycling (Snelgrove, 1999). Production is the increase in biomass (organic matter) of organisms either by accumulation of organic matter through growth (somatic production) or through reproduction, which varies between species (Gray & Elliot, 2009). Somatic production is the quantity of matter or energy which is potentially available as food for the next trophic level, forming an important component in energy flow and organic matter recycling (Brey, 1989). Secondary production is the generation of new biomass over time by non-photosynthetic organisms requiring organic substrate inputs (Maurer & Robertson, 1999). Quantification of secondary production is necessary to assess population dynamics, anthropogenic impacts (pollution, eutrophication), climate change (variations in temperature, precipitation etc.), management of biological resources in natural ecosystems, energy and material flow (food web quantification, role of animals in ecosystem), biotic interactions (competition, prey-predator relationships), food provision services from an ecosystem, assessments of environmental stress etc. (Dolbeth *et al.*, 2012).

Standing stock measures the organisms present in a unit area at a particular time which can be expressed in terms of number of organisms (density), weight (biomass) etc. (Thiel, 1982). The biomass of all organisms in an assemblage irrespective of their identities provides a clear understanding of their distribution and inter-relationships (Gray & Elliot, 2009). Quantification of benthic organisms (density and biomass) is crucial as they form a key link in the energy transfer between primary producers and tertiary consumers (Parulekar *et al.*, 1980; Reise 1985; Heip *et al.*, 1992; Ansari *et al.*, 1996). The quantitative sampling of the sea bottom began in the 20th century to estimate the availability of potential food for demersal fishes (Petersen, 1918; Blegvad, 1930; Jones & Slinn, 1956). The distribution of and abundance of macrofauna are dependent on the environmental as well as biological factors prevailing in a region (Galeron *et al.*, 2000).

Standing stock of macrofauna are known to decrease with increasing depth, distance from shore, and decreasing latitude from poles to tropics (Rowe, 1983; Gage & Tyler 1991; Heip *et al.*, 1992; Rex *et al.*, 2006; Wei *et al.* 2010). The first global analysis of bathymetric patterns of standing stock of prokaryotes, meiofauna, macrofauna and megafauna by Rex *et al.,* (2006) revealed that the decreasing trend in standing stock with increasing depth is a universal phenomenon which includes a shift in relative importance of different size groups. This general trend is broadly explained by the decrease in food input with increasing depth, and is also subject to regional variations in surface production and the assimilation efficiency in the water column (Sanders, 1968, 1969; Gage & Tyler, 1991; Quijon *et al.*, 2008; Wei *et al.*, 2010). The quality and quantity of particulate organic matter (OM) sinking from the water column is associated with its source, primary production, OM sinking rate, zooplankton grazing rate, and degradation in the water column, which in turn is dependent on seasons, mixed layer depth, hydrodynamic conditions, currents, water column depth, topography, habitat, nature of sediments etc. (Ambrose & Renaud, 1995; Rosenberg, 1995; Grebmeirer *et al.*, 1988). These factors exert great influence on the community structure, faunal composition, life histories, trophodynamics, body size and morphological diversity (Thiel, 1975; Young, 2003; Rowe *et al.*, 2003; McClain *et al.*, 2004; Rex *et al.*, 2005) etc. In other words, different size classes among benthos like megafauna, macrofauna and meiofauna, respond differently to the variations in food supply. Therefore the quantification of each group should be done separately, to estimate how differences in primary production affects various components of benthic community (Galeron *et al.*, 2000; Baldrighi *et al.*, 2014).

In regions having high production due to eutrophication, upwelling etc., enhanced particulate OM flux to the seafloor supports high standing stock of macrobenthos and strongly influence their community structure (Townsend & Cammen 1988; Rowe, 1971). In such regions, various factors, including stratification and OM degradation lead to depletion of the oxygen concentration in the sub-surface waters, i.e. hypoxia and anoxia (Levin *et al.*, 2009). Macrofaunal standing stock will be relatively less due to low concentration of oxygen and small sized organisms which are adapted to these adverse conditions will be the main inhabitants of such regions (Thiel, 1978; Rosenberg *et al.*, 1983; Diaz & Rosenberg 1995; Levin, 2003). Small sized organisms have relatively lower energy and oxygen requirements, and increased surface area to body mass ratio, which enhances oxygen uptake (Levin, 2003; Rex *et al*. 2006; Abdul Jaleel *et al*. 2014).

Waters around oceanic islands are oligotrophic in nature (Ansari & Abidi, 1981; Mackie *et al*., 2005; McCallum *et al*., 2015), with relatively low primary production. In general, OM flux to the bottom is limited, since most of the OM will be used up or degraded, in the water column itself. Thus, the region supports relatively low benthic biomass. It is well documented that the biomass in the surface waters are decreasing due to ocean warming, increased stratification, decrease in supply of nutrients for primary production and OMZ expansion (Joos *et al*., 1999; Steinacher *et al*., 2010; Jones *et al*., 2014). This results in reduced flux of particulate OM to the seafloor, with negative impacts on benthic communities especially of the deep sea (cold water coral reefs, seamounts, canyons, ridges), with direct effects on benthic biomass (Young & Eckelbarger, 1994; Smith *et al*., 2008; Ramirez-Llodra *et al*., 2010; McClain *et al*., 2012), body size (McClain *et al*., 2005), longevity, reproductive success (Young & Eckelbarger 1994), community structure and ecosystem function (Levin *et al*., 2001; Ruhl & Smith, 2004; Jones *et al*., 2014). Intensified bottom trawling activities have also become a serious threat to benthic fauna, as modern mechanised trawls with large swept area sweep out the bottom directly destroying the benthic ecosystems (Bergman & Hup, 1992; Collie *et al*., 2000; Kaiser *et al*., 2006; Queirós *et al*., 2006; Tillin *et al*., 2006; Cheung *et al*., 2010). The aforementioned anthropogenic disturbances may cause irreversible changes to benthic ecosystems by altering community structure and function (Jones *et al*., 2014; Hiddink *et al*., 2017). Most oceanic islands of India are protected under Coastal Regulation Act, 1991 of the Government of India. The Andaman and Nicobar Islands (ANI) covered under the present study fall under CRZ-IV areas, where only traditional fishing practices are permitted, to protect the reef ecosystems. Therefore, benthic fauna of the ANI margin are more vulnerable to (gradual or sudden) natural (e.g. earthquake, tsunamis, volcanic activity) and anthropogenic disturbances (ocean warming, acidification etc.), rather than trawling disturbances.

Quantitative studies on benthos of Indian waters reveal that biomass of macrofauna vary from 0.01 to 601gm^{-2} (Parulekar *et al.*, 1982). Mean macrofaunal density and biomass were found to be higher along the South Eastern Arabian Sea continental shelf compared to North Eastern Arabian Sea (Harkantra *et al.*, 1980; Jayaraj *et al.*, 2007; Joydas and Damodaran, 2009; Damodaran, 2010; Smitha 2011) while, it was higher in the southwestern Bay of Bengal than the northwestern Bay of Bengal (Ansari *et al.*, 1977; Ganesh & Raman, 2007; Damodaran, 2010; Smitha 2011; Khan & Lyla, 2012; Raja *et al.*, 2014; Manokaran *et al.*, 2015). Macrofauna on the continental shelf edge and upper slope of eastern Arabian Sea and western Bay of Bengal are found to be strongly impacted by of oxygen minimum zones (OMZ) (Ingole *et al.*, 2010; Abdul Jaleel, 2012; Raman *et al.*, 2015; Khan *et al.*, 2017).

Quantitative aspects of bottom fauna around ANI (11 to 2150m depths) was first studied by Parulekar and Ansari (1981a). The study revealed that within the 200m contour, the western ANI margin (Bay of Bengal Sector) was more productive than the eastern ANI margin (Andaman Sea Sector), while beyond 200 m the eastern margin was more productive than the western margin. In the regions adjacent to the ANI (Ayeyarawady margin, 20-1000m), the density and biomass decreased with depth (Ansari *et al.*, 2012). The west coast of Thailand recorded 2 times higher macrofaunal density and 3.9 times higher biomass in shallow waters than deeper waters (Chatananthawej & Bussarawit, 1987). Studies along Malacca

Strait (80-1350m) revealed that standing stock of meiofauna exceeds that of macrofauna by 12.5 times in weight and 780 times in density (Parulekar & Ansari, 1981b).

To estimate the standing stock of macrobenthos around Andaman and Nicobar Islands two surveys (SS261 and SS292) were conducted in the north-east monsoon season, employing stratified sampling at 50, 100 and 200 m depths along fixed transects. During SS261, 30 sites (59 grab samples) were covered along 17 transects, and macrofauna were separated using a 500µm mesh. During SS292, 50 sites (90 grabs) were surveyed, along 20 transects, and 300µm mesh was used to separate macrofauna. Sampling methodology, including the mesh sizes used in the two surveys are described in detail in Chapter 2. Grab samples with adequate sediments were only used for biological analysis. Latitudinal variations in the hydrographical parameters and sediments characteristics along the Bay of Bengal (BoB) and Andaman Sea (AS) sectors of Andaman and Nicobar Islands (ANI) have been analysed only in SS292, as the number of samples were relatively fewer in the Andaman Sea sector during SS261.

IV.2. *Results*

IV. 2.1. *Density of Macrofauna*

During SS261 (500µm) density of macrofauna varied from 440 (east coast of Great Nicobar, 200m) to 2475 ind.m^{-2} (west coast of Car Nicobar, 200m) with a mean of 1166±593 ind.m^{-2} while during SS292 (300µm) density ranged from 420 (Sound Island, 200m) to 5440 ind.m^{-2} (Spike Island, 50m) with a mean of 2274±1165 ind.m^{-2}. The differences in standing stock values of the two surveys were subjected to statistical analysis (PERMANOVA), but these values are treated with caution owing to the difference in mesh sizes, and are used only to statistically quantify the differences between the two sieves. Macrofaunal density around ANI was significantly higher (PERMANOVA F=25.878, P=0.001) in the 300µm sieve (SS292), owing to the inclusion of smaller sized organisms (300-500µm) also, particularly at 50m depth.

IV. 2.1.1. *Spatial variations in macrofaunal density*

During SS261 (500µm), the density at 50m depth varied from 483 (Duncan Passage) to 2213 ind.m^{-2} (west coast of Great Nicobar Island) with a mean of 1522±599 ind.m^{-2}; at 100m, values ranged from 595 (west coast of Little Andaman Island) to 1475 (Interview Island) with a mean of 920±318 ind.m^{-2}; and at 200m, from 440 (east coast of Great Nicobar Island) to 2475 (west coast of Car Nicobar Island) with a mean of 1024±607 ind.m^{-2} (Fig. 4.1). During SS292 (300µm), the density varied from 1810 (Indira Point) to 5440 (Spike Island) with a mean of 3109±934 ind.m^{-2} at 50m depth; from 780 (Spike Island) to 4110 ind.m^{-2} (east coast of Great Nicobar Island), with an average of 2107±1055 ind.m^{-2} at 100m; and from 420 (Sound Island) to 3300 ind. m^{-2} (Port Blair) with a mean of 1404±811 ind.m^{-2} at 200m (Fig. 4.1). Latitudinal variations on density of macrofauna along BoB and AS sectors were found to be insignificant (P>0.05).

The shallow depth strata (50m) harboured maximum density during both surveys, with a gradual decrease towards higher depths (200m). Significant bathymetric variations were present only in SS292 (F=15.704, P=0.001) whereas insignificant in SS261 (P>0.05). The decreasing trend in total faunal density with increasing depth was significant in SS292 (r= -0.567, p<0.01), but not in SS261 (p>0.05) (Fig. 4.2).

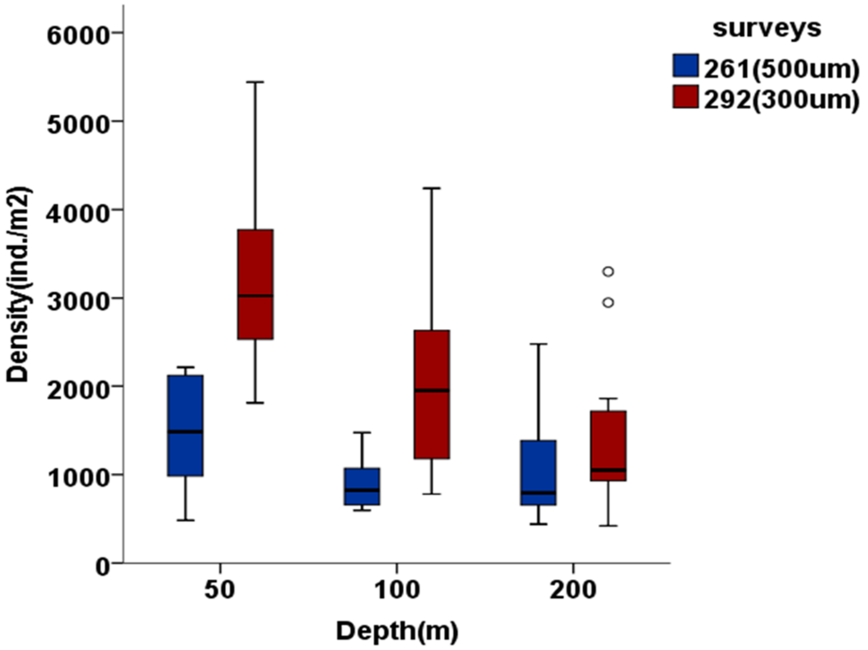


Fig. 4. 1. Box and whisker plot of density of macrofauna for different depth classes in SS261 and SS292

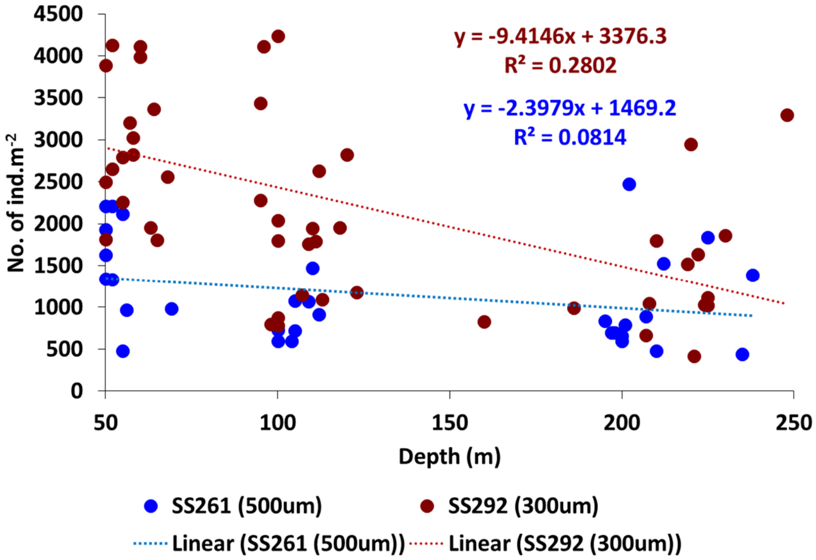


Fig. 4. 2. Scatter plot showing the relationship between density of macrofauna and depth

A total of 33 higher level taxa were identified among the macrofauna in the study area of which the major contributors to macrofaunal density were polychaetes, crustaceans, molluscs, echinoderms and other macrofaunal groups. The percentage contribution of major faunal groups to the total macrofaunal density is depicted in the Fig. 4.3.a, b.

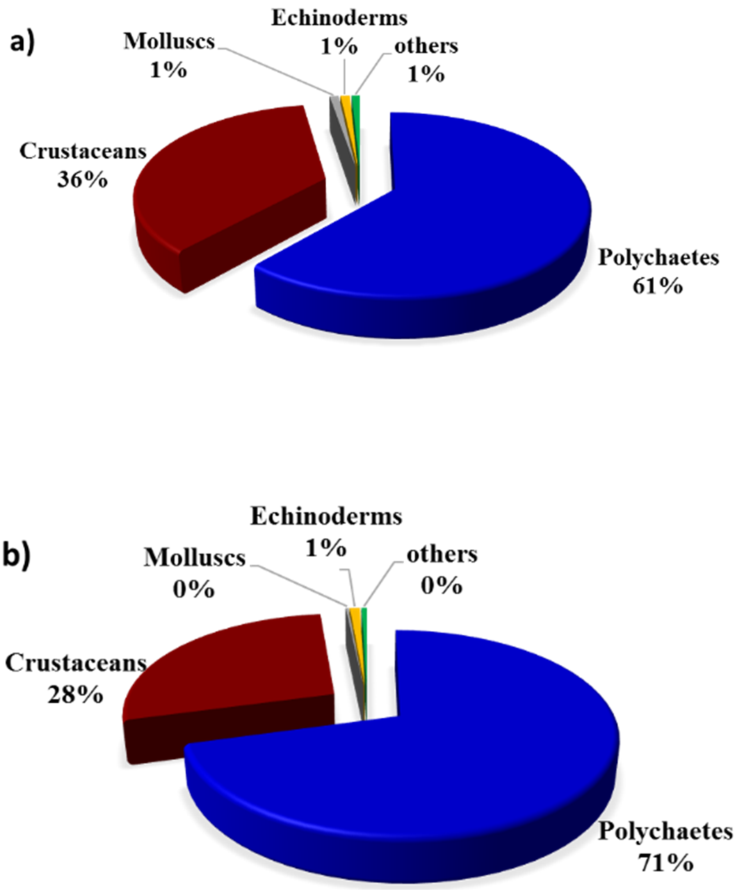


Fig. 4. 3. Contribution of faunal groups to total macrofaunal density in the study area during SS261 (a) and SS292 (b)

IV. 2.1.2. *Density of macrofaunal groups*

a) Density of Polychaetes

Polychaetes were the dominant group among macrofauna in the study area, contributing 61% (709±410 ind.m^{-2}) in SS261 (500µm) and 71% (1608±805 ind.m^{-2}) in the SS292 (300µm). Significant differences in polychaete density between the two surveys was observed only at 50m (F=35.434, P=0.001) and 100m (F=22.438, P=0.001) depths owing to the presence of small sized polychaetes. During SS261 (500µm), at 50m depth polychaete density ranged between 333 (Duncan Passage) to 1165 ind.m^{-2} (east coast of Little Andaman Island), with a mean of 678±297 ind.m^{-2}, while at 100m, it ranged from 358 (west coast of Little Andaman Island) to 825 ind.m^{-2} (Duncan Passage), with a mean of 579±203 ind.m^{-2} and at 200m from 223 (Duncan Passage) to 1975 ind.m^{-2} (west coast of Car Nicobar Island) with a mean of 828±547 ind.m^{-2} (Fig. 4.4). During SS292 (300µm), at 50m depth, the density of polychaetes varied from 520 (Indira Point) to 3420 ind.m^{-2} (Spike Island) with a mean of 1963±730 ind.m^{-2}; at 100m depth, 540 (Spike Island) to 2830 ind.m^{-2} (Rutland Island) 1550±743 ind.m^{-2}; at 200m depth, 360 (Sound Island) to 3210 ind.m^{-2} (Port Blair) 1224±815 ind.m^{-2} (Fig. 4.4). Latitudinal variations on the density of polychaetes were not significant in both BoB and AS sector (P>0.05).

Bathymetric variations in polychaete density were not significant in SS261 (P>0.05), while they were significant in SS292 (F=4.9929, P=0.011). During the latter survey, a significant decreasing trend with increasing depth was evident (r= -0.346 p= 0.012) (Fig. 4.5). The differences were found to be caused by variation in quantitative and qualitative (species) composition of polychaetes with the use of a finer sieve which retains smaller taxa in the finer mesh, and this is discussed in detail in Chapter 5.

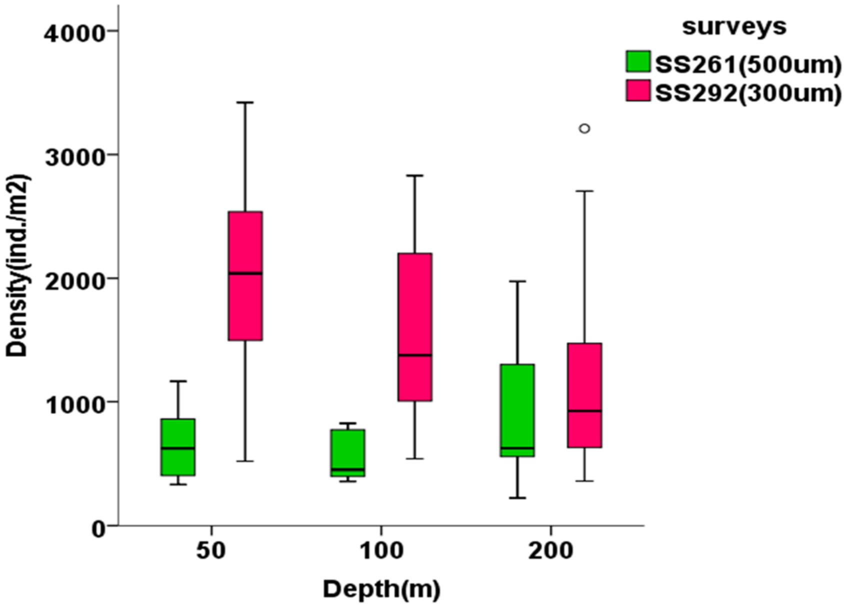


Fig. 4. 4. Box and whisker plot of density of polychaetes for different depth classes in SS261 and SS292

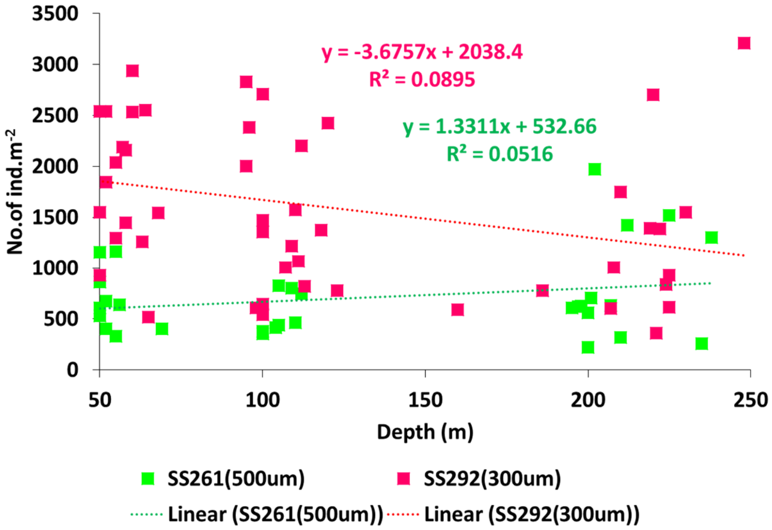


Fig. 4. 5. Scatter plot showing the relationship between density of polychaetes and depth

b) Density of Crustaceans

Crustaceans were the second dominant group among macrofauna in the study area, contributing 36% (417±412 ind.m^{-2}) in SS261 (500µm) and 28% (611±523 ind.m^{-2}) in SS292 (300µm). Significant differences in crustaceans density between the two surveys was observed only at 50m depth (F=4.223, P=0.042) owing to the retention of small sized crustaceans in finer mesh sieve (300µm), especially amphipods. During SS261 (500µm), the density of crustaceans at 50m depth varied from 140 (Duncan Passage) to 1510 ind.m^{-2} (west coast of Car Nicobar Island) with a mean of 816±440 ind.m^{-2}; at 100m depth, 150 (South Andaman) to 985 ind.m^{-2} (Interview Island) with a mean of 306±301 ind.m^{-2}; at 200m depth, 58 (North Andaman) to 415 ind.m^{-2} (west coast of Car Nicobar Island) with a mean of 170±120 ind.m^{-2} (Fig. 4.6). During SS292 (300µm) the density of crustaceans at 50m depth varied from 650 (Little Andaman Island) to 2057 ind.m^{-2} (west coast of Car Nicobar Island) with a mean of 1099±416 ind.m^{-2}; at 100m depth, 120 (east coast of Car Nicobar Island) to 1700 ind.m^{-2} (east coast of Great Nicobar Island) with a mean of 522±444 ind.m^{-2}; at 200m depth, 40 (South Andaman) to 485 ind.m^{-2} (west coast of Great Nicobar Island) with a mean of 155±115 ind.m^{-2} (Fig. 4.6). The density of crustaceans exhibited a decreasing trend with increasing latitudes only at 200m depth contour in both BoB ($r= -0.680$, $p=0.044$) and AS ($r= -0.972$, $p=0.001$) sectors.

Amphipods were the dominant group among crustaceans in both surveys contributing 72% and 83% of crustaceans in SS261 (500µm) and SS292 (300µm) respectively. Other crustacean taxa contributed less than 1% and were represented by caprellids, ispods, tanaids, cumaceans, mysids, stomatopods, crabs, lobsters and shrimps. Amphipods were the dominant taxon in all depth categories of the study area.

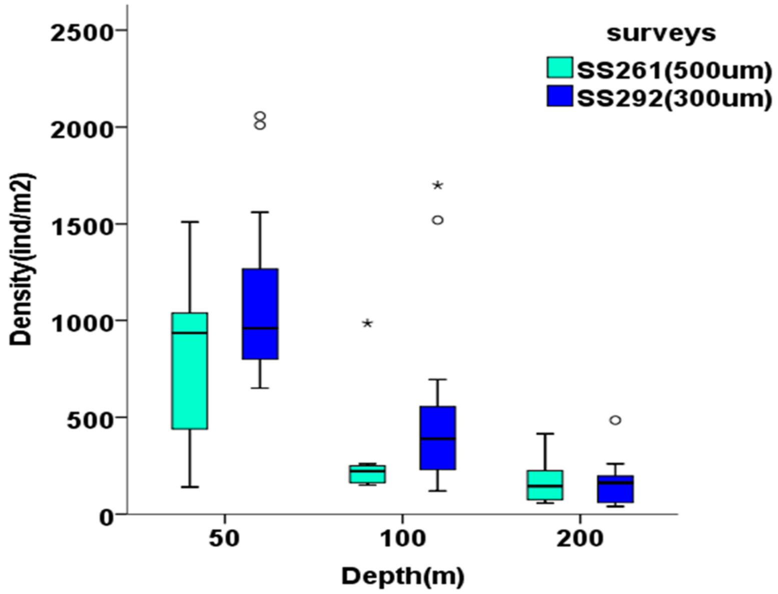


Fig. 4. 6. Box and whisker plot of density of crustaceans for different depth classes in SS261 and SS292

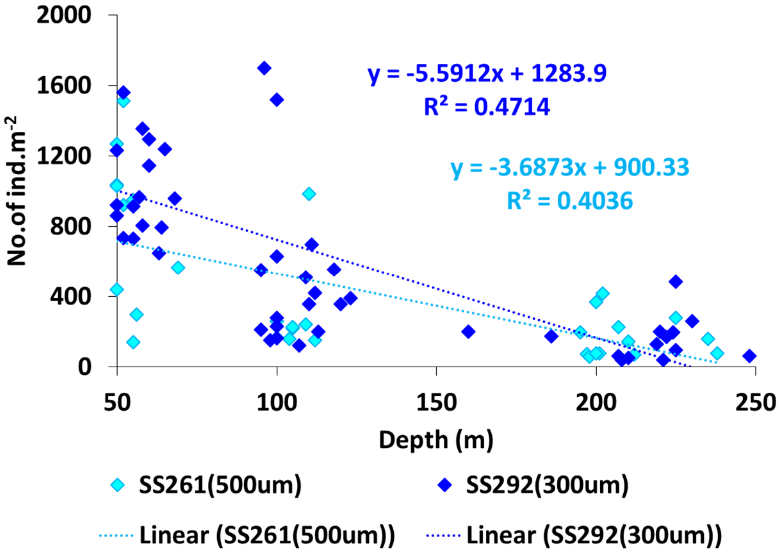


Fig. 4. 7. Scatter plot showing the relationship between density of crustaceans and depth

Bathymetric variations in crustacean density were significant in both surveys (SS261: F= 13.263, P=0.001; SS292: F=42.405, P=0.001) with a significant decreasing trend (SS261: r= -0.636, p<0.01; SS292: r= -0.704 p<0.01) with increasing depth (Fig. 4.7).

c) *Density of Molluscs*

Molluscs contributed less than or equal to 1% of the total macrofaunal abundance in the study area, i.e, 10±14 ind.m^{-2} in SS261 (500µm) and 6±10 ind.m^{-2} in SS292 (300µm). Mollusc were represented by bivalves, gastropods, scaphopods, chiton and caudofoveata of which bivalves were the dominant group and represented at all three depths, with wide variation in density across the study area. During SS261 (500µm), the density of molluscs at 50m depth varied from nil to 18 ind.m^{-2} (Little Andaman Island) with a mean of 2±6 ind.m^{-2}; at 100m depth, 10 (North Andaman) to 65 ind.m^{-2} (Little Andaman Island) with a mean 24±19 ind.m^{-2}; at 200m depth, nil to 28 ind.m^{-2} (Port Cornwallis) with a mean of 9±9 ind.m^{-2}. The mean density of molluscs during SS292 (300µm), at 50m depth varied from nil to 30 ind.m^{-2} (Indira Point) with a mean of 5±8 ind.m^{-2}; 100m depth, nil to 20 ind.m^{-2} (east coast of Great Nicobar Island) with a mean of 3±5 ind.m^{-2}; 200m depth, nil to 50 ind.m^{-2} (east coast of Great Nicobar Island) with a mean of 8±14 ind.m^{-2}.

d) *Density of Echinoderms*

Echinoderms contributed 1% of the total macrofauna in the study area, 10±17 ind.m^{-2} in SS261 (500µm) and 21±24 ind.m^{-2} in SS292 (300µm). The major contributors to echinoderm group were brittle stars, sea urchins, star fishes and sea cucumbers of which brittle stars were dominant and represented at all depths, with wide variation in density across the study area. During SS261 (500µm), the density of echinoderms at 50m depth varied from nil to 30 ind.m^{-2} (east coast of Car Nicobar Island) with a mean of 12±10 ind.m^{-2}; at 100m depth, nil to 30 ind.m^{-2} (North Andaman and Outram Island) with a mean of 7±10 ind.m^{-2}; at 200m depth, 0 to 85 ind.m^{-2} (west coast of Car Nicobar Island) with a mean of 11±23 ind.m^{-2}. The mean density of echinoderms in SS292 (300µm) at 50m depth varied from nil to 150 ind.m^{-2} (Duncan Passage) with a mean of 29±31 ind.m^{-2}; at 100m depth, nil to 60 ind.m^{-2} (Duncan Passage, Katchall Island) with a mean of 19±14 ind.m^{-2}; at 200m depth, nil to 55 ind.m^{-2} (Katchall Island) with a mean of 12±20 ind.m^{-2}.

e) Density of other macrofaunal groups

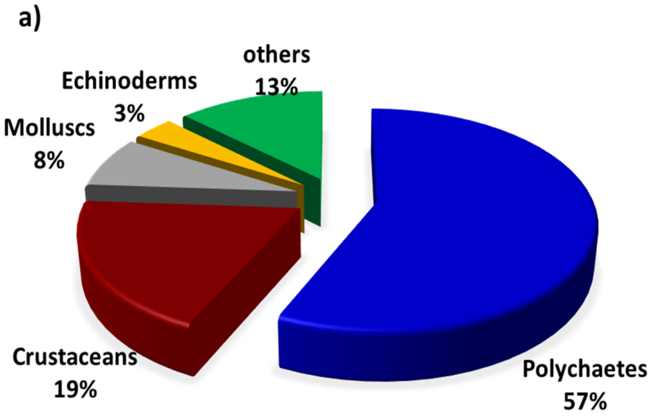
Other macrofaunal groups include corals fragments, sponges pieces, lancelets, sipunculids, sponges, nemerteans, nematodes, foraminifera, nudibranchs, sea pen, flatworm etc., contributed about ~1% of total macrofauna in the study area, 8±10 ind.m^{-2} in SS261 (500µm) and 11±19 ind.m^{-2} in SS292 (300µm), with wide variation in density across the study area. During SS261 (500µm), density of other macrofaunal groups at 50m depth varied from nil to 33 ind.m^{-2} (North Andaman) with a mean 14±12 ind.m^{-2}; at 100m depth, nil to 15 ind.m^{-2} (North Andaman) with a mean of 4±5 ind.m^{-2}; at 200m depth, nil to 30 ind.m^{-2} (east coast of Car Nicobar Island) with a mean of 7±8 ind.m^{-2}. During SS292 (300µm) the density of other macrofaunal groups at 50m depth varied from nil to 90 ind.m^{-2} (west coast of Great Nicobar Island) with a mean of 14±24 ind.m^{-2}; at 100m depth, nil to 60 ind.m^{-2} (Rutland Island) with a mean of 14±19 ind.m^{-2}; at 200m depth, nil to 25 ind.m^{-2} (Little Andaman Island) with a mean of 5±8 ind.m^{-2}.

IV. 2.2. *Biomass of Macrofauna*

The biomass of macrofauna during SS261 (500µm) varied from 1.37 gm^{-2} (east coast of Car Nicobar Island, 200m) to 12.14 gm^{-2} (Spike Island, 50m) with a mean biomass of 4.99±2.58 gm^{-2} while in SS292 (300µm) biomass ranged from 1.01 gm^{-2} (Port Andaman, 200m) to 11.08 gm^{-2} (Duncan Passage, 100m) with a mean biomass of 4.73±2.23 gm^{-2}. Biomass of macrofauna was more or less comparable in the two surveys ($P>0.05$) around ANI, which shows that the inclusion of organisms having a size between 500µm and 300µm, did not cause much variation in the mean biomass, owing to their much smaller body size. The contribution of each macrofaunal groups in the study area are given in Fig. 4.8a, b.

IV. 2. 2. 1. *Spatial variations in macrofaunal biomass*

In SS261 (500µm), the biomass varied from 3.34 (east coast of Car Nicobar Island) to 12.14 gm^{-2} (Spike Island) with a mean of 5.75±2.60 gm^{-2} at 50m depth; 2.86 (North Andaman) to 10.39 gm^{-2} (Duncan passage) with an average of 4.70±2.71 gm^{-2} at 100m depth; 1.37 (east coast of Car Nicobar Island) to 10.33 gm^{-2} (west coast of Car Nicobar Island) with a mean of 4.61±2.57 gm^{-2} at 200m depth (Fig. 4.9). During SS292 (300µm) at 50m depth the biomass varied from 2.29 (east coast of Car Nicobar Island) to 8.20 gm^{-2} (Smith Island) with a mean of 5.42±1.47 gm^{-2}; at 100m depth, 1.74 (Indira Point) to 11.08 gm^{-2} (Duncan Passage) with a mean of 5.04±2.56 gm^{-2}; at 200m depth, 1.01 (Port Andaman) to 10.26 gm^{-2} (west coast of Car Nicobar Island) with a mean of 3.52±2.27 gm^{-2} (Fig. 4.9). Latitudinal variations in macrofaunal biomass were not significant in both BoB and AS sectors ($P>0.05$).



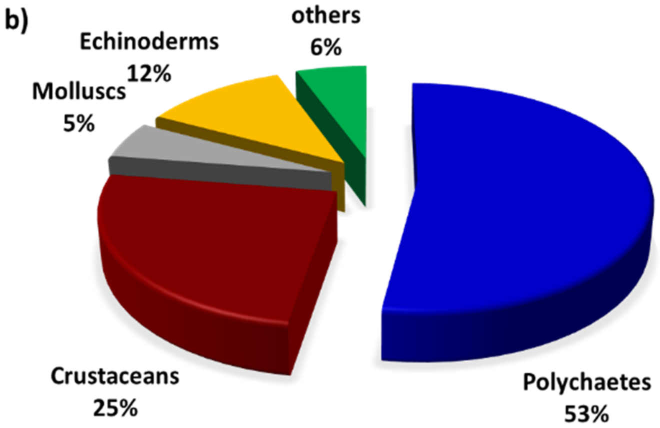


Fig. 4. 8. Contribution of faunal groups to total macrofaunal biomass in the study area during SS261 (a) and SS292 (b)

Significant bathymetric variations in macrofaunal biomass were observed in only in SS292 (F=5.9676, P=0.007) not in SS261 (P>0.05), with values decreasing with increasing depth (Fig. 4.10).

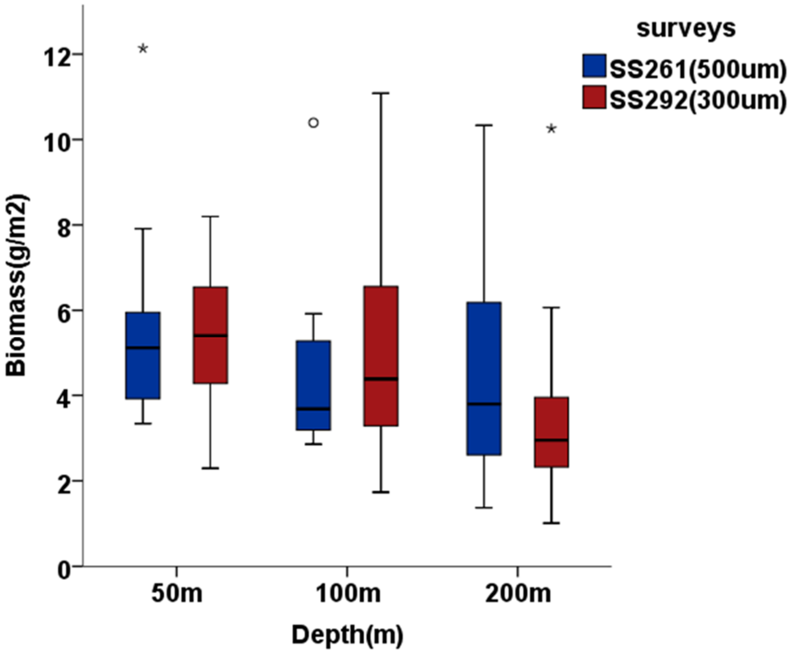


Fig. 4. 9. Box and whisker plot of biomass of macrofauna for different depth classes in SS261 and SS292

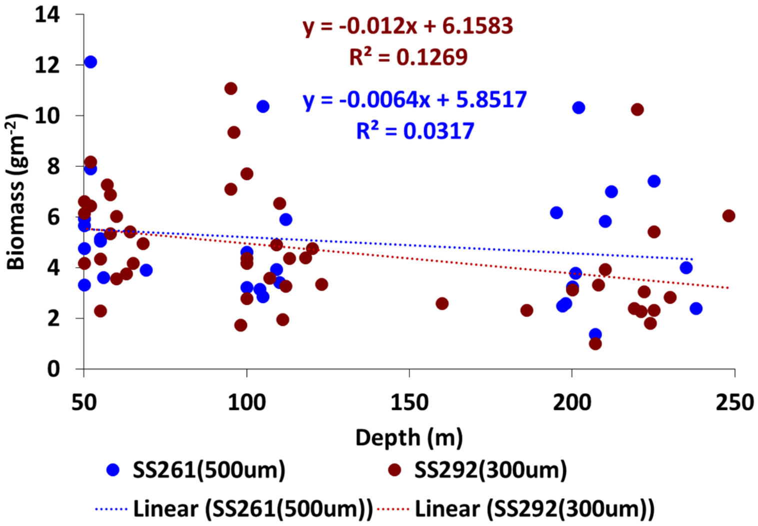


Fig. 4. 10. Scatter plot showing the relationship between biomass of macrofauna and depth

IV. 2. 2. 2. *Biomass of macrofaunal groups*

a) Polychaetes

Polychaetes were the dominant group among macrofauna of the study area, contributing 57% (2.89±2.02 gm^{-2}) in SS261 (500µm) and 53% (2.48±1.39 gm^{-2}) in the SS292 (300µm). During SS261 (500µm), the biomass of polychaetes at 50m depth varied from 1.03 (South Andaman) to 6.13 gm^{-2} (Spike Island) with a mean of 2.72±1.42 gm^{-2}; at 100m depth, from 1.15 (North Andaman) to 7.57 gm^{-2} (Duncan Passage) with a mean of 2.80±2.26 gm^{-2}; at 200m depth, from 0.93 (east coast of Car Nicobar Island) to 8.98 gm^{-2} (west coast of Car Nicobar Island) with a mean of 3.08±2.40 gm^{-2}.

During SS292 (300µm), the biomass of polychaetes at 50m depth varied from 1.08 (Indira Point) to 3.77 gm^{-2} (Spike Island) with a mean of 2.51±0.75 gm^{-2}; at 100m depth, from 0.71 (east coast of Car Nicobar Island) to 5.74 gm^{-2} (east coast of Great Nicobar Island) with a mean of 2.67±1.71 gm^{-2}; at 200m depth, from 0.75 (Port Andaman) to 6.51 gm^{-2} (west coast of Car Nicobar Island) with a mean of 2.28±1.62 gm^{-2} (Fig. 4.11).

Variations in polychaete biomass between surveys was found to be not significant ($P>0.05$). Similarly, bathymetric variations in polychaete biomass were not significant in both surveys ($P>0.05$) (Fig. 4.12).

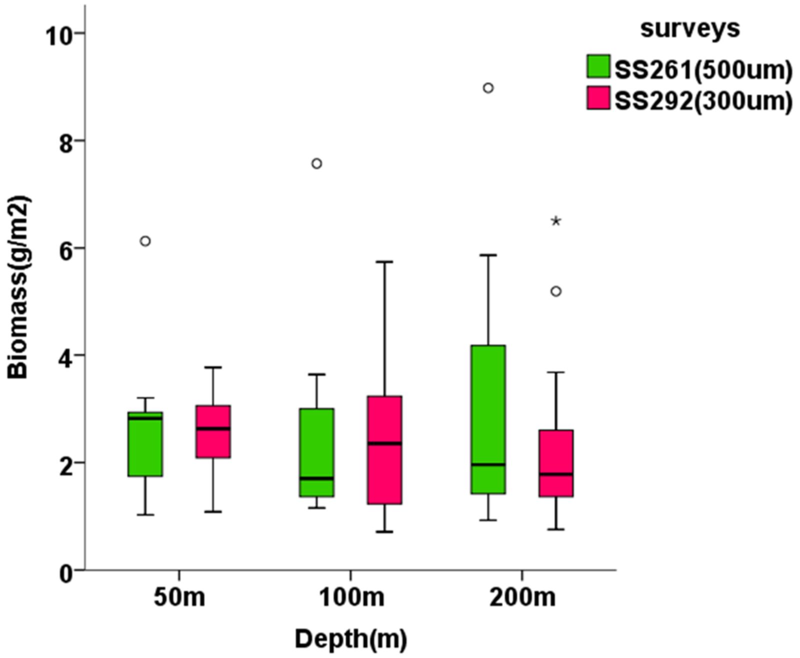


Fig. 4. 11. Box and whisker plot of biomass of polychaetes for different depth classes in SS261 and SS292

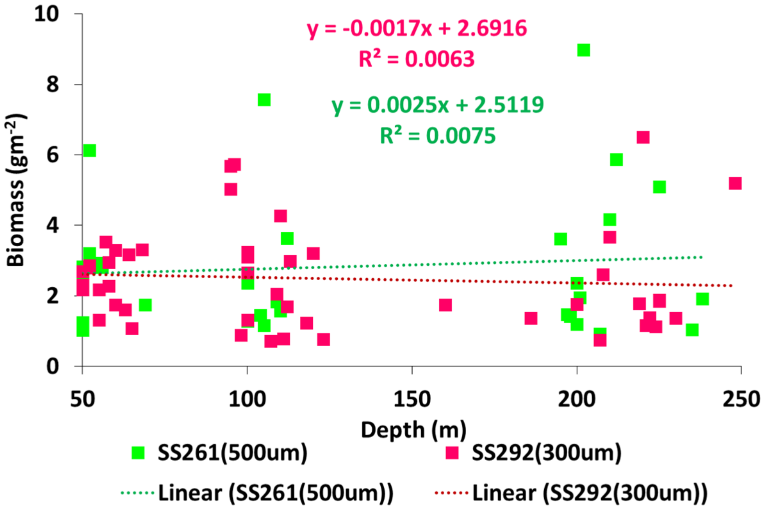


Fig. 4. 12. Scatter plot showing the relationship between biomass of polychaetes and depth

b) Crustaceans

Crustaceans were the second dominant group among the macrofauna of the study area, contributing 19% (0.99±0.87 gm^{-2}) in SS261 (500µm) and 25% (1.18±0.93 gm^{-2}) in SS292 (300µm). During SS261 (500µm), the biomass of crustaceans at 50m depth varied from 0.40 (Duncan Passage) to 3.94 gm^{-2} (west coast of Car Nicobar Island) with a mean of 1.77±0.97 gm^{-2}; at 100m depth, 0.08 (Little Andaman Island) to 1.97 gm^{-2} (South Andaman) with a mean of 0.88±0.59 gm^{-2}; 200m depth, 0.13 (Port Blair) to 1.11 gm^{-2} (Katchall Island) with a mean of 0.44±0.30 gm^{-2} (Fig. 4.13).

During SS292 (300µm) the biomass of crustaceans at 50m depth, varied from 0.54 (Port Andaman) to 3.93 gm^{-2} (Smith Island) with a mean of 1.75±0.98 gm^{-2}; at 100m depth, 0.47 (east coast of Car Nicobar Island, Interview Island) to 3.71 gm^{-2} (Duncan Passage) with a mean of 1.00±0.76 gm^{-2}; at 200m depth, 0.21 (east coast of Car Nicobar Island) to 2.62 gm^{-2} (west coast of Great Nicobar Island) with a mean of 0.64±0.59 gm^{-2} (Fig. 4.13). The decreasing trend in crustacean biomass with increasing latitude was significant in the 200m depth contour of BoB sector ($r= -0.761$, $p=0.017$) while the trend was insignificant along the AS sector.

Variations in crustacean biomass between surveys was found to be not significant ($P>0.05$). Bathymetric variations in macrofaunal crustacean biomass was significant in both surveys (SS261: $F=9.1847$, $P=0.002$; SS292: $F=13.865$, $P=0.001$) showing a decreasing trend with increasing depth (SS261: $r= -0.633$, $p<0.01$; SS292: $r= -0.43$, $p<0.01$) (Fig. 4.14).

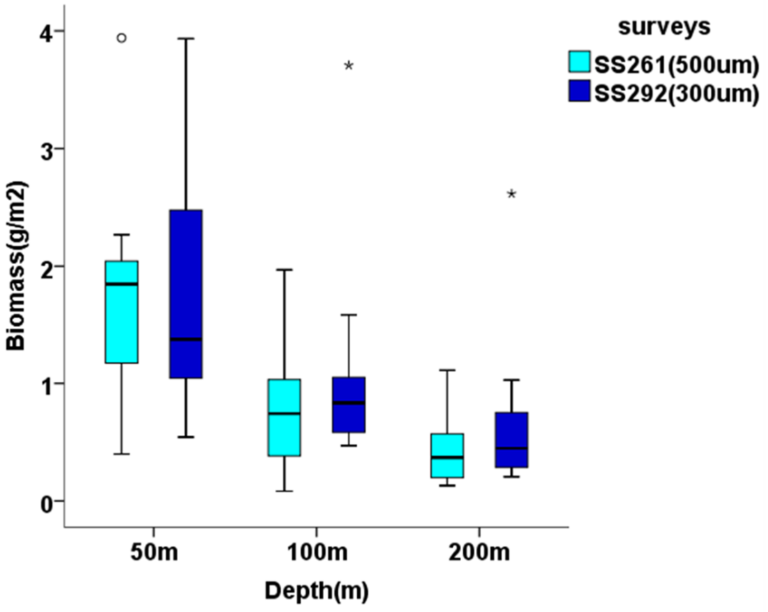


Fig. 4. 13. Box and whisker plot of biomass of crustaceans for different depth classes in SS261 and SS292

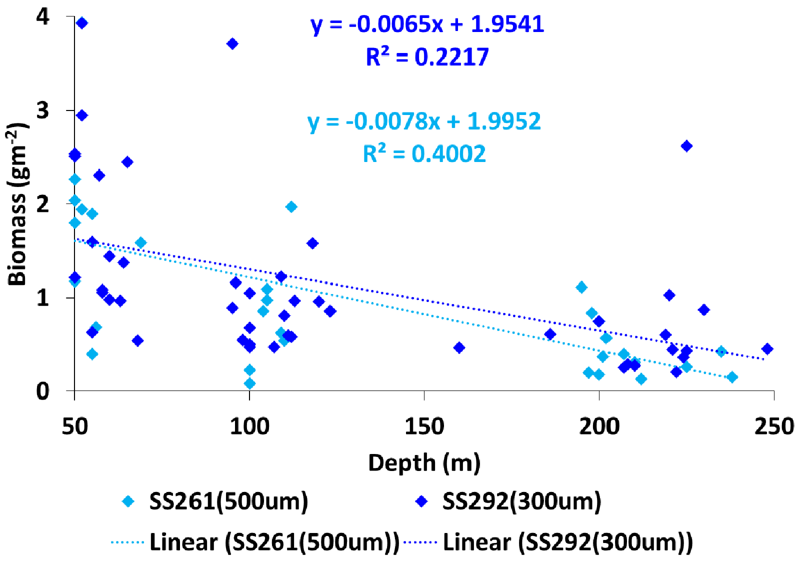


Fig. 4. 14. Scatter plot showing the relationship between biomass of crustaceans and depth

c) Molluscs

Molluscs contributed 8% (0.39±0.50 gm^{-2}) to the biomass in SS261 (500µm) and 5% (0.26±0.49 gm^{-2}) in SS292 (300µm). During SS261 (500µm), the biomass of molluscs at 50m depth varied from nil to 0.46 gm^{-2} (Little Andaman Island) with a mean of 0.05±0.15 gm^{-2}; at 100m depth, 0.01 (Little Andaman Island) to 1.45 gm^{-2} (Duncan Passage) with a mean of 0.53±0.49 gm^{-2}; at 200m depth, nil to 1.64 gm^{-2} (west coast of Great Nicobar Island) with a mean of 0.57±0.57 gm^{-2}. During SS292 (300µm), at 50m depth, the density of molluscs varied from nil to 1.03 gm^{-2} (Interview Island) with a mean of 0.14±0.31 gm^{-2}; at 100m depth, nil to 1.94 gm^{-2} (Duncan Passage) with a mean of 0.41±0.70 gm^{-2}; at 200m depth, nil to 0.98 gm^{-2} (west coast of Great Nicobar Island) with a mean of 0.22±0.30 gm^{-2}.

d) Echinoderms

Echinoderms contributed 3% (0.18±0.35 gm^{-2}) of the biomass in SS261 (500µm) and 12% (0.55±0.73 gm^{-2}) in the SS292 (300µm). During SS261 (500µm), the biomass of echinoderms at 50m depth varied from nil to 1.72 gm^{-2} (Duncan Passage) with a mean of 0.30±0.52 gm^{-2}; at 100m depth, nil to 0.10 gm^{-2} (North Andaman) with a mean of 0.02±0.04 gm^{-2}; 200m depth, nil to 0.80 gm^{-2} (Port Cornwallis) with a mean of 0.17±0.24 gm^{-2}. During SS292 (300µm) the biomass of echinoderms varied from nil to 2.90 gm^{-2} (Nancowry Island) with a mean of 0.64±0.62 gm^{-2}; 100m depth, nil to 4 gm^{-2} (South Andaman) with a mean of 0.78±0.97 gm^{-2}; at 200m depth, nil to 0.94 gm^{-2} (west coast of Car Nicobar Island) with a mean of 0.16±0.30 gm^{-2}.

e) Other macrofaunal groups

Other macrofaunal groups contributed 13% (0.57±0.81 gm^{-2}) to the biomass in SS261 (500µm) and 6% (0.27±0.41 gm^{-2}) in the SS292 (300µm).

During SS261 (500µm), the biomass of other macrofaunal groups at 50m depth varied from nil to 3.65 gm^{-2} (Spike Island) with a mean of 0.91±1.11 gm^{-2}; at 100m depth, 0.03 (North Andaman) to 1.08 gm^{-2} (Interview Island) with a mean of 0.48 ±0.45 gm^{-2}; at 200m depth, nil to 2.44 gm^{-2} (east coast of Great Nicobar Island) with a mean of 0.36 ± 0.65 gm^{-2}. The biomass of other macrofaunal groups in SS292 (300µm) at 50m depth from nil to 1.6 gm^{-2} (west coast of Great Nicobar Island) with a mean of 0.39±0.51 gm^{-2}; at 100m depth, 0 to 1.07 gm^{-2} (Rutland Island) with a mean of 0.18±0.29 gm^{-2}; at 200m depth, nil to 1.36 gm^{-2} (west coast of Car Nicobar Island) with a mean of 0.21±0.38 gm^{-2}.

IV. 2.3. *Influence of environmental factors on standing stock of macrofauna*

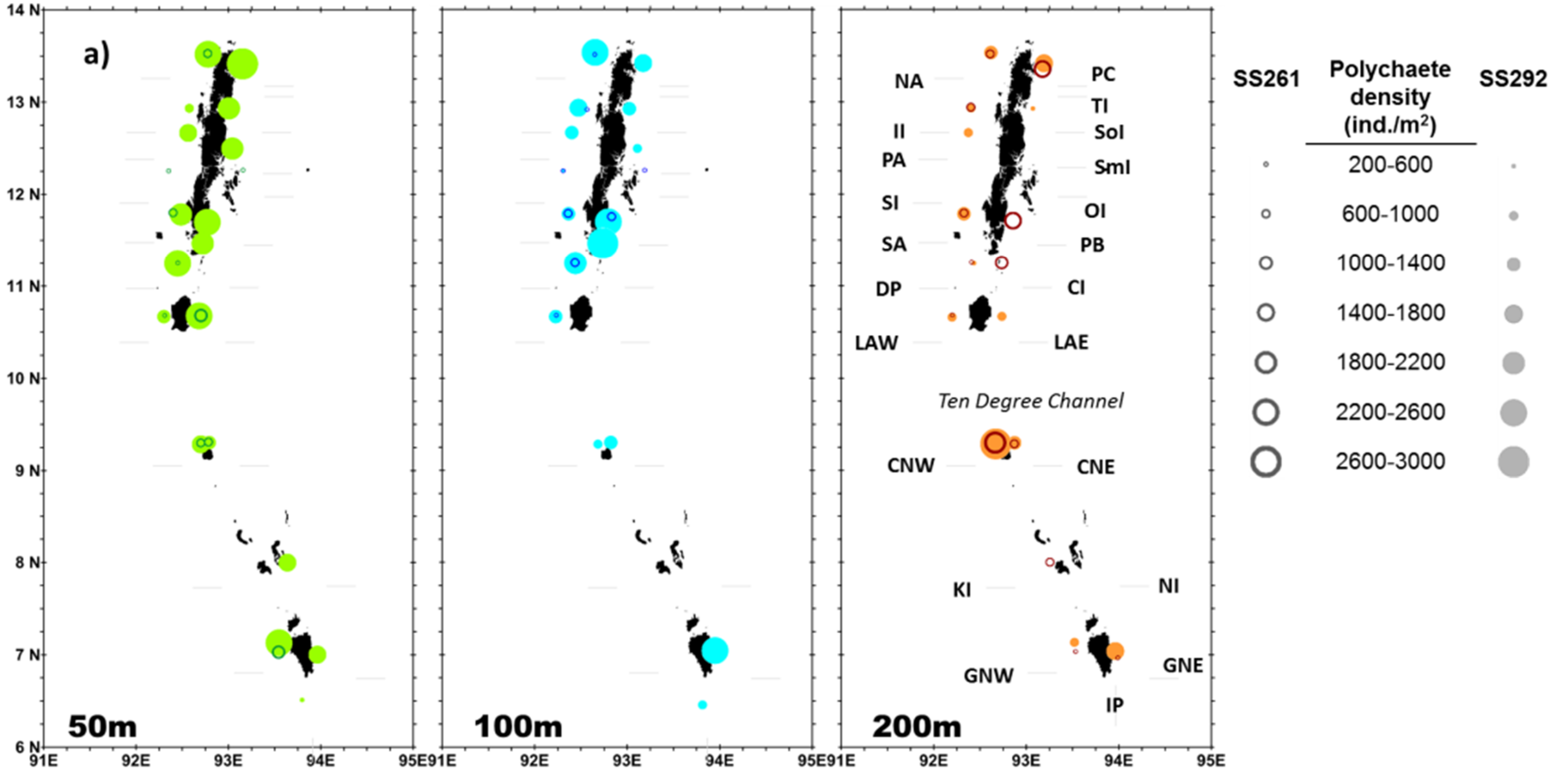
In order to elucidate the influence of hydrographical and sediment characteristics on the standing stock (abundance and biomass) of macrofauna, Pearson's correlation coefficient was employed. The variations in the density and biomass of macrofauna among island groups and along western and eastern margins/sectors in each depth category is provided in Table 4.1a, b & 4.2a, b. Influence of environmental parameters on macrofaunal density and biomass are detailed below.

a) Macrofaunal density

In SS261, the density of polychaetes showed a weak positive correlation with clay (r= 0.462, p=0.009). Density of crustaceans exhibited strong positive correlation with temperature (r=0.522, p=0.003) and DO (r=0.626, p<0.01), and strong negative correlation to salinity (r= -0.645, p<0.01) and depth (r= -0.636, p<0.01). Other faunal groups exhibited a weak positive correlation with sand (r= 0.370, p= 0.040) and weak negative correlation to clay (r= -0.454, p= 0.010) (Table 4.3a).

In SS292, the total macrofaunal density showed strong negative correlation with depth (r= -0.567, p<0.01). Among hydrographic parameters faunal density was positively correlated with DO (r=0.545, p<0.01) and temperature (r=0.576, p<0.01), and negatively correlated with salinity (r= -0.567, p<0.01). Correlation of faunal density with sediment composition were not significant, while density was negatively correlated with OM content of sediments (r= -0.409, p=0.004). Among macrofaunal taxa, polychaetes showed weak positive correlation with DO (r=0.308, p=0.026) and temperature (r=0.346, p=0.012), and a weak negative correlation with depth (r= -0.346, p=0.012), salinity (r= -0.385, p=0.005) and OM (r= -0.324, p=0.025). Crustaceans exhibited strong positive correlation to DO (r=0.706, p=<0.01) and temperature (r=0.717, p<0.01), and strong negative correlation to salinity (r= -0.641, p<0.01) and depth (r= -0.704, p<0.01). Crustaceans showed weak negative correlation to clay (r= -0.297, p=0.040) and OM (r= -0.390, p=0.006) and a weak positive correlation to sand (r=0.292, p=0.044). Echinoderms exhibited weak positive correlation with temperature (r-=0.280, p=0.044) and DO (r=0.29, p=0.037) (Table 4.3b).

The spatial variations in density of the major macrofaunal groups (polychaetes and crustaceans) are depicted by superimposing bubbles on a bathymetric map of the ANI margin (Fig 4.15a, b). The density of polychaetes and crustaceans were higher in the shallow depths (50m), characterised by calcareous sandy sediments and relatively high DO and decreased towards the deeper sites (200m) where sediments were silty sand, with higher OM and low DO.


a)
50m
100m
200m
14 N
13 N
12 N
11 N
10 N
9 N
8 N
7 N
6 N
91E
92E
93E
94E
95E
NA
PC
TI
II
SoI
PA
SmI
SI
OI
SA
PB
DP
CI
LAW
LAE
Ten Degree Channel
CNW
CNE
KI
NI
GNE
GNW
IP
SS261
Polychaete density (ind./m^2)
SS292
200-600
600-1000
1000-1400
1400-1800
1800-2200
2200-2600
2600-3000

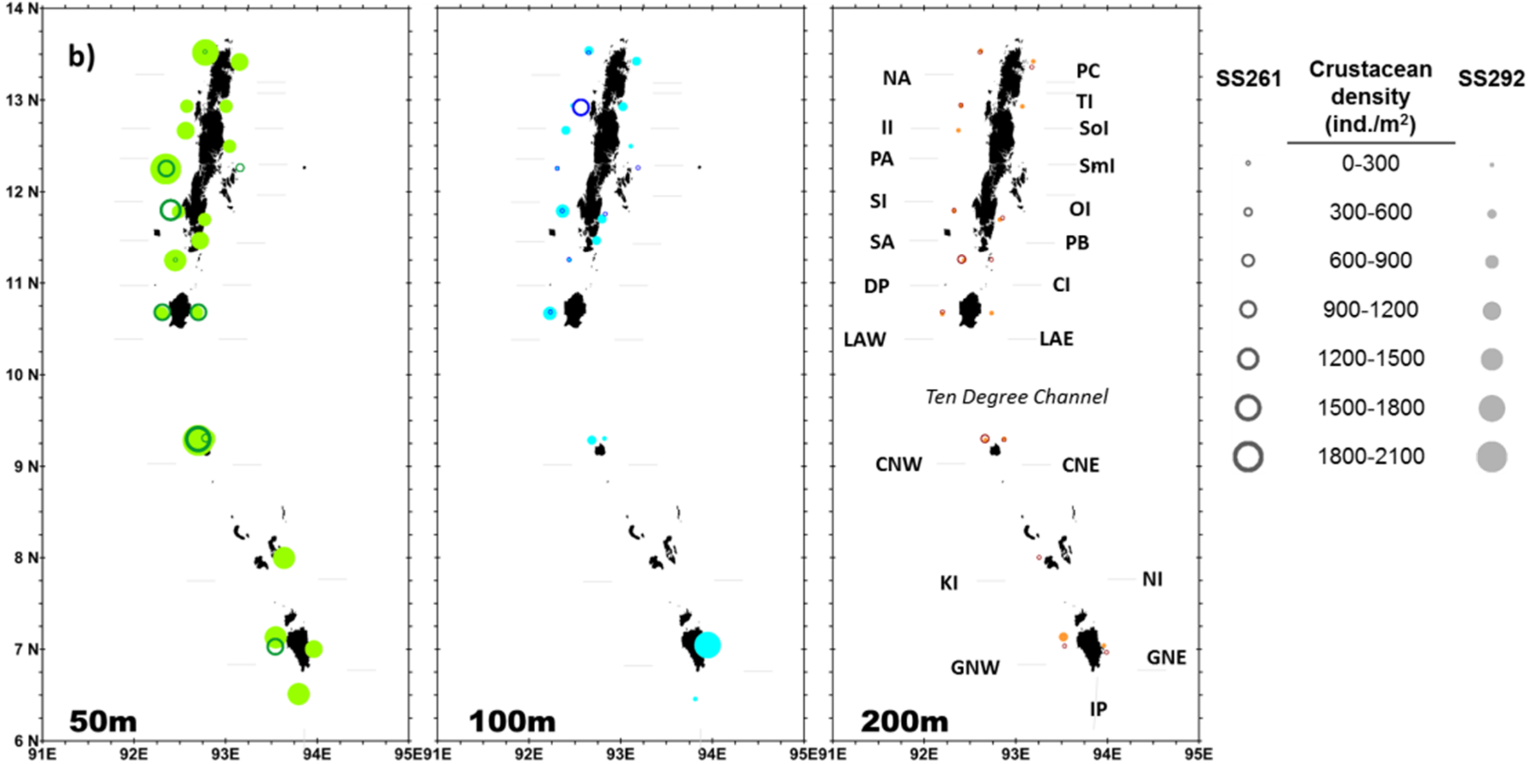


Fig. 4. 15. Density of polychaetes (a) and crustaceans (b) in each site at different depths during SS261 and SS292

b) Macrofaunal biomass

The biomass of polychaetes (SS261) showed weak positive correlation with clay (r=0.40, p=0.026) whereas the biomass of crustaceans showed positive correlation with temperature (r=0.504, p=0.005) and DO (r=0.562, p=0.001) and strong negative correlation with depth (r= -0.633, p<0.01) and salinity (r= -0.589, p=0.001) (Table 4.3.a).

In SS292, the total macrofaunal biomass was negatively correlated to depth (r= -0.360, p=0.009), salinity (r= -0.395, p=0.004) and OM (r= -0.315, p=0.029). Macrofaunal biomass showed weak positive correlation to temperature (r=0.383, p=0.005) and DO (r=0.319, p=0.021). Biomass of crustaceans was positively correlated to DO (r= 0.515, p<0.01) and temperature (r=0.508, p<0.01) and negatively correlated to salinity (r= -0.521, p<0.01) and depth (r= -0.473, p<0.01). Biomass of mollusc exhibited a weak positive correlation with temperature (r=0.313, p=0.024) and weak negative correlation to OM (r= -0.293, p=0.043). The biomass of echinoderms exhibited weak negative correlation with depth (r=-0.306, p=0.031). The biomass of other faunal groups also showed weak negative correlation with depth (r= -0.353, p=0.010) and salinity (r= -0.395, p=0.004) (Table 4.3.b). Macrofaunal biomass showed trends similar to density, being higher in the sandy sediments of the 50m sites with high DO, compared to the silty sand (with high OM) with low DO conditions of the 200m sites.

IV.3. *Discussion*

The density and biomass of benthic macrofauna in the ANI margin were studied during the north east monsoon (NEM) using sieves of two different mesh sizes in the two surveys (500µm in SS261 and 300µm in SS292) conducted. The density of macrofauna varied significantly between the two surveys (sieves), while no significant variations were observed in biomass. No significant bathymetric variations were observed in the density and biomass of macrofauna in the larger mesh sieve (500µm, SS261), while in the finer sieve (300µm, SS292) variations were prominent. Overall, latitudinal variations in density and biomass of macrofauna were not significant, except for density of crustaceans at 200m depth strata. Studies on standing stock of macrofauna around oceanic islands of the tropical belt are mainly concentrated within reef areas (up to 50m), beyond which studies are scarce. A comparison of the density of macrofauna around oceanic and coral reef islands in the tropical belt of ANI is provided in Table 4.4

The mean biomass of macrofauna around ANI was 4.99±2.58 gm^{-2} in SS261 (500µm) and 4.73±2.23 gm^{-2} in the SS292 (300µm). Previous studies on macrofauna around ANI using 500µm mesh sieve, recorded a mean biomass of 11.3 gm^{-2} at 11-200m depth range (Parulekar & Ansari, 1981a). The biomass values in the aforementioned study are relatively high, as compared to the values obtained in the present study. This might be due to variations in sampling depths (11-200m), and also due to the inclusion of reef taxa (e.g. Ophiuroids, Harpactcoids). Similarly the biomass of macrofauna was relatively higher in Ayeyarwady waters (off Myanmar), Andaman Sea (6.54±12.05 gm^{-2}) between 20 to 1000m depths (Ansari *et al.*, 2012). In the Malacca Strait, which connects South China Sea and Andaman Sea, an elevated biomass of 14.54 gm^{-2} (macro and meiofauna) was recorded at depths of 80-1350m (Parulekar & Ansari, 1981b). Studies on the macrofauna along the shelf of the west coast of Thailand (0-80m) using a larger mesh sieve (1mm) recorded a relatively high biomass of 23.4±39.7 gm^{-2} (Chatananthawej & Bussarawit, 1987). On comparing with other areas of Indian continental shelf (30-200m), the biomass (500µm) in the study area was relatively lower than southwest Bay of Bengal (6.83 gm^{-2}, Khan & Lyla 2012), but values were comparable with northwest Bay of Bengal

(4.12±0.4 gm^{-2} Ganesh & Raman, 2007; Damodaran, 2010). Biomass of macrofauna was relatively higher in the southeastern Arabian Sea (7.78 gm^{-2}) and northeastern Arabian Sea (5.70 gm^{-2}, Damodaran, 2010).

Around the ANI, significantly higher macrofaunal density was recorded with the use of a 300µm mesh sieve (SS292, 2274±1165 $ind.m^{-2}$), when compared to a 500µm sieve (SS261, 1166±593 ind. m^{-2}). Parulekar & Ansari (1981a) recorded relatively low density of macrofauna (460 $ind.m^{-2}$) between 11 and 200m around Andaman and Nicobar Islands. Similarly low densities have been recorded from the Malacca strait (258 $ind.m^{-2}$ between 80-1350m, Parulekar & Ansari, 1981b) and along west coast of Thailand (916±474 $ind.m^{-2}$ between 0-80 m, 1mm sieve, Chatananthawej & Bussarawit, 1987). However, density was comparable with Myanmar shelf, Andaman Sea (1120±43 $ind.m^{-2}$, 20-1000m, Ansari *et al.*, 2012). Compared with the shelf of other areas of Indian peninsula (30-200m), the mean density of macrofauna was relatively higher than the southwestern Bay of Bengal (776 $ind.m^{-2}$, Khan & Lyla, 2012) and northwestern Bay of Bengal (812±203 $ind.m^{-2}$, Damodaran, 2010), while it was lower than the southeastern Arabian Sea (1743 $ind.m^{-2}$, Damodaran, 2010) and northeastern Arabian Sea (1340 $ind.m^{-2}$, Damodaran, 2010).

The standing stock of macrofaunal communities in a region is dependent largely on the food reaching the seafloor in the form of sinking particulate matter (Gray, 1981; Quijon *et al.*, 2008). In the study area the standing stock was relatively low compared to other highly productive continental margins (e.g. Arabian Sea). This might be attributed to the oligotrophic conditions prevailing around ANI (Ansari & Abidi, 1981; Sarupria & Bhargava, 1993; Rashiba, 2010). Compared to continental margin the OM input by rivers in the island margins are relatively lower, and consequently oligotrophic conditions occur. Due to the prevailing strong hydrodynamic conditions around the ANI margins, the sediment texture was coralline sand with low OM content in the shallow depths with increasing silt and OM content towards the deep. Retention of OM in the large grain sized sediments of shallow depths are relatively low in hydrodynamically active sites compared to silty sediments of deeper areas (Gray & Elliot, 2009; Bayraktarov & Wild, 2014). Since the coralline sandy sediments provides enough interstitial spaces for small sized interstitial fauna, they form one of the major contributors to abundance around ANI whereas due to their small size their contribution to biomass was very low (Schlacher & Woolridge, 1996; Gage *et al.*, 2002; Barba *et al.*, 2010). Although the density of macrofauna was comparable with other continental margins, the biomass was relatively low.

Macrofaunal density in the study area showed a gradual decline from shallow to deeper areas in both surveys; exhibiting a 33% and 55% decrease during SS261 (500µm) and SS292 (300µm), respectively. Macrofaunal biomass also exhibited a similar declining trend by 20% and 35% during SS261 and SS292 respectively. Similar declining trends in standing stock of macrofauna with increasing depth along tropical continental and insular margins is well reported, and is attributed to the variations in hydrographical parameters, sediment nature and food availability (Riddle, 1988; Parulekar & Ansari, 1981a; Chatananthawej & Bussarawit, 1987; Ibrahim *et al.*, 2006; Ganesh & Raman, 2007; Joydas & Damodaran, 2009; Ansari *et al.*, 2011; Manokaran *et al.*, 2015). The bathymetric trends in macrofaunal standing stock in the present study are due to variations in the distribution of dominant faunal groups – the polychaetes and crustaceans, with depth.

In the ANI margin, polychaetes were the dominant group at all depths (Parulekar & Ansari, 1981a) and are the chief contributors to density and biomass in soft bottoms which is consistent with the reports from other parts of the world ocean (Alongi, 1990; Hutchings, 1998). This is because polychaetes have wide adaptive radiation strategies, which enable them occupy maximum possible ecological niches (Rouse & Pleijel, 2001). Polychaete density increased by 22% from shallow (50m) to deeper areas (200m) in SS261 (500µm) and decreased by 38% in SS292 (300µm), while polychaete biomass did not display significant bathymetric trends in SS261 (1% increase) and SS292 (9% decrease). This suggest the fact that small sized interstitial forms of polychaetes were the dominant fauna in the well oxygenated coralline sandy sediments of the near reef areas (McCarthy *et al.*, 2000; Narayanaswamy *et al.*, 2017). The use of finer mesh (300µm) for the second survey, clearly depicts the decreasing trend in polychaete density along the island margin, as compared to coarser sieve (500µm). Studies on the standing stock of macrofauna from earlier studies in the ANI (Parulekar & Ansari, 1981a) and around other tropical islands confirms that polychaetes followed by crustaceans dominate the macrofauna, with depth and sediment texture playing important roles in structuring the community [E.g. central Great Barrier Reef (Riddle, 1988), eastern Great Australian Bight (Currie *et al.*, 2009), Carnarvon Shelf (Przeslawski *et al.*, 2013), Australia; Karah Island, Malaysia (Ibrahim *et al.*, 2006); Reunion Island, South west Indian Ocean (Bigot *et al.*, 2006); Lakshadweep (Rivonker & Sangodkar, 1997)].

Crustaceans, the second dominant group among macrofauna in the study area are important contributors to the productivity of reefs and adjacent areas (Cowles *et al.* 2009). Bathymetrically, crustacean density showed 79% decrease in SS261 (500µm) and 86% decrease in SS292

(300µm), while crustacean biomass decreased by 75% and 63% in SS261 and SS292, respectively. The density of crustaceans around ANI was two times higher in the well oxygenated, coralline sandy sediments of the reef vicinity, characterised by large grain sized particles with enough interstitial spaces and low in OM content (Chou *et al*., 1999; Carvalho *et al*., 2011). Crustaceans were almost codominant with polychaetes in this depth strata. Studies conducted on benthic crustaceans in tropical island margins (Kramer *et al*., 2014; Riddle 1988; Navarro-Barranco & Guerra-Garcıa, 2016) revealed that coral rubble supports numerous crustacean taxa, including Amphipoda, Cumacea, Decapoda, Isopoda and Tanaids, with sediment grain size as a major factor influencing their distribution (Cacabelos *et al*., 2010).

Amphipods were the dominant group among crustaceans at all depths in the ANI margin, which agrees with the observations of Parulekar & Ansari, (1981a); Riddle (1988); Prato & Biandolino (2005); Navarro-Barranco *et al*., (2013); Navarro-Barranco & Guerra-García (2016). The coarser sediments at this depth offer ample interstitial microhabitats for small sized prey organisms (Preston & Doherty, 1994; Purcell & Bellwood, 2001; Sampaio *et al*., 2016), of predatory crustaceans. The relatively well-oxygenated conditions also play a key role in supporting good populations of these active predatory taxa. The sandy silt sediments in the deeper areas (200m) with poor interstices, and relatively low DO are proved to less suitable for the crustaceans when compared to well oxygenated coralline sandy sediments (Karakassis & Eleftheriou, 1997; Sampaio *et al*., 2016).

Molluscs, echinoderms and other macrofaunal groups contributed meagrely to density, without prominent bathymetric trends in distribution. Bivalves were the dominant group among mollusc. In general bivalves exhibits relatively high density in well oxygenated coralline sandy sediments (Taylor & Glover, 2004; Abdul Jaleel, 2012). Echinoderms density were high in well oxygenated near reef areas of Andaman and Nicobar Islands, chiefly represented by ophiuroids. The reef areas provide heterogeneous habitats that provide multiple functional niches for ophiuroids, including predation, scavenging, deposit and filter feeding (Ambrose *et al.*, 2001; Usha, 2016).

In the present study, macrofaunal standing stock was significantly lower in the deeper areas (200m) of the Andaman Islands, compared to the Nicobar Islands (5% and 28% lower density; 13% and 42% lower biomass in SS261 (500µm) and SS292 (300µm) respectively). The lower standing stock around Andaman Islands reflected the significantly lower density of polychaetes (5% and 20% lower in SS261 and SS292 respectively) and crustaceans (5% and 59% lower SS261 and SS292 respectively). This is attributed to the oxygen minimum conditions observed in the present study and reported previously by Parulekar & Ansari (1981a) and Helly & Levin (2004). Raman *et al.*, (2015) and Khan *et al.*, (2017) also reported on the impingement of the Bay of Bengal OMZ on the continental margin of the western Bay of Bengal. Under oxygen deficient conditions, macrofauna are widely reported to exhibit reduced standing stock (Rowe, 1971; Rosenberg *et al.*, 1983; Levin *et al.*, 2000; Abdul Jaleel, 2012; Joydas & Damodaran, 2014; Raman *et al.*, 2015; Khan *et al.*, 2017). Studies in OMZ impacted margins in the Pacific and Atlantic Oceans using finer (300µm) sieves (Table 4.5), recorded higher standing stock compared to the 200m sites around Andaman Islands (300µm, SS292). At this depth, the standing stock around the Andaman Islands was higher than the values reported for OMZ impacted Indian margins, which were studied using (500µm, SS261) sieves.

Polychaetes were dominant (91%) in the sandy silt sediments under the oxygen minimum conditions around Andaman Islands (200m) while crustaceans, molluscs and echinoderms were less tolerant to oxygen minimum conditions (Diaz & Rosenberg, 1995; Levin & Gage, 1998; Levin *et al.*, 2000; Levin, 2003; Gallardo *et al.*, 2004; Palma *et al.*, 2005; Quiroga *et al.*, 2005; Gooday *et al.*, 2009; Hughes *et al.*, 2009; Abdul Jaleel, 2012; Joydas & Damodaran, 2014; Raman *et al.*, 2015; Usha, 2016; Khan *et al.*, 2017). Echinoderms, in particular, are most vulnerable to oxygen depleted conditions, owing to their relatively active life modes and calcareous endoskeletons; and this group was altogether absent in the oxygen deficient conditions prevailing around the Andaman Islands (Rhoads & Morse, 1971; Diaz & Rosenberg 1994; Gooday *et al.*, 2009; Usha, 2016).

The density of amphipods decreased by 80-99% from near reef areas to deeper areas around Andaman Islands, low in DO levels, indicating that amphipods are sensitive to oxygen deficient conditions. Amphipods are hence regarded as good indicators of natural or disturbed environmental conditions (Bussarawich *et al.*, 1984; Conradi *et al.*, 1997). The macrofaunal crustaceans vulnerable to low oxygen conditions will be therefore absent in such areas (Levin & Gage, 1998) except for some species of amphipods possessing physiological mechanisms for oxygen uptake (Levin *et al.*, 2000). The density of amphipods was high at all depths of Nicobar Islands compared to Andaman Islands, even at higher depth (200m) and this is attributed to the higher percentage of sand with relatively higher DO levels (>0.5ml l^{-1}).

The assignment of size classes among benthic fauna is arbitrary, based on practical considerations, rather than on strict scientific rationale (Gage *et al.*, 2002). Mesh size is a major factor which affects the accuracy in estimation of standing stock and diversity of organisms in an area (Bachelet, 1990; James *et al.*, 1995; Schlacher & Woolridge, 1996). Selection of suitable mesh size should take into consideration the habitat to be sampled and nature of resident benthic communities (Gage *et al.*, 2002; Thompson *et al.*, 2003). According to Hessler & Jumars (1974) in sediments below oligotrophic waters, finer meshes are required to retain macrofauna as their size will be much smaller (or even 'meiofaunal') compared to productive waters. Since the Andaman and Nicobar waters are oligotrophic in nature (Ansari & Abidi, 1981), the choice of lower mesh size in the second survey (SS292, 300µm) was better suited in understanding of distributional patterns and its influencing factors.

In the present study, the macrofaunal density doubled in finer mesh sieve (SS292, 300µm) compared to coarser mesh sieve (SS261, 500µm). In general, this increase was more prominent in shallow areas (50m) than deeper areas (200m), revealing that small sized interstitial organisms are the dominant group around ANI, particularly taking advantage of the interstitial spaces of the coralline sands in the shallow depths. The finer meshes retain more number of individuals and enhance accuracy in estimation of standing stock and diversity (James *et al.*, 1995; Schlacher & Woolridge, 1996; Couto *et al.*, 2010; Pinna *et al.*, 2013). In general, the crustaceans, molluscs and echinoderms were better retained in the 500µm mesh, compared to polychaetes (Valenca & Santos, 2013). The size and shape of an organism is major factor for retention in a particular mesh (Rees 1984; Thompson *et al.*, 2003). The macrofaunal biomass values derived from the two surveys using two different sieve sizes within the study area were almost similar without significant variations. This is due to the fact that large sized organisms contribute more to total macrofaunal biomass, rather than small sized fauna (Steimle 1985; Schlacher & Woolridge, 1996; Gage *et al.*, 2002; Barba *et* *al*., 2010; Valenca & Santos, 2013). The present study based on two different mesh sizes, reaffirms the fact that smaller mesh sized sieves (300µm) are more suitable compared to larger mesh sieves (500µm) for assessing the standing stock of macrofauna around oceanic islands.

In the study area, large 'macrofauna' sized nematodes (<1% density) were included among the 'other macrofauna', and were included in the standing stock estimate. The omission of large nematodes in earlier studies was due to fact that distinction between 'macrobenthos' and 'meiobenthos' was originally based purely on the arbitrary classification of Mare (1942). The studies on community composition and body weight of nematodes in the deep Arctic, Gulf of Mexico and Bermuda slope (Sharma *et al*., 2011) showed that meiobenthic and macrobenthic nematode communities were entirely different in their community composition, body sizes (irrespective of depth) and functional response with depth. These observations give support for inclusion of large sized nematodes among macrofauna.

Numerous studies in shallow (Lewis & Stoner, 1981; Tanaka & Leite, 1998; Hammerstorm *et al*., 2012; Pinna *et al*., 2013) and deep waters (Sanders *et al*., 1965; Hessler and Jumars, 1974; Gage *et al*., 2002; Pavithran *et al*., 2009) prompt the scientific community to reconsider the benthic classification into macrobenthos and meiobenthos based on taxonomic composition rather than size (Gage *et al*., 2002). In recent years, 250-300µm sieves have been employed for benthic macrofaunal studies in deep sea surveys (Gage *et al*., 2002; Snelgrove, 1998). So the selection of appropriate sieve sizes, will lead to precision in qualitative and quantitative estimates of benthic communities in a region.

Table. 4. 1a. Density of macrofauna during SS261 (500µm)

	Islands	Coast/ Sector	Depth (m)	Density (ind.m^{-2})					
				Polychaetes	**Crustaceans**	**Molluscs**	**Echinoderms**	**Others**	**Total**
SS261 (500µm)	**Andaman Is.**	**West/ BoB**	**50**	504±131	733±489	4±8	14±10	16±15	1270±565
			100	541±194	318±329	25±20	8±11	4±6	896±341
			200	498±213	144±129	4±4	4±7	4±5	654±120
		East/ AS	**50**	785	758	0	5	5	1553
			100	803	240	18	3	5	1068
			200	1416±112	140±119	19±12	3±3	5±5	1583±231
	Nicobar Is.	**West/ BoB**	**50**	803	240	18	3	5	1068
			100	0	0	0	0	0	0
			200	1048±804	229±171	10±9	32±46	3±3	1322±1003
		East/AS	**50**	860	440	0	30	10	1340
			100	0	0	0	0	0	0
			200	430	220	0	15	5	670

Table. 4. 1b. Density of macrofauna during SS292 (300µm)

	Islands	Coast/ Sector	Depths (m)	Density (ind.m^{-2})					
				Polychaetes	**Crustaceans**	**Molluscs**	**Echinoderms**	**Others**	**Total**
SS292 (300µm)	**Andaman Is.**	**West/ BoB**	**50**	2056±866	1163±486	3±4	46±48	5±5	3272±1314
			100	1429±556	431±199	3±4	25±18	9±12	1897±574
			200	868±299	133±69	3±5	5±12	5±10	1015±288
		East/ AS	**50**	2331±390	838±183	2±3	17±9	18±23	3205±517
			100	1773±837	394±140	0	12±8	34±22	2213±924
			200	1561±1239	61±24	0	5±10	8±10	1635±1246
	Nicobar Is.	**West/ BoB**	**50**	2055	1643	10	20	45	3773
			100	1743	955	3	10	0	2170
			200	1322±1198	283±176	11±4	28±28	2±3	1646±1136
		East/ AS	**50**	1203±467	1108±224	10±14	21±3	6±13	2348±425
			100	1332±929	657±904	10±9	20±10	0	2018±1820
			200	1468	215	38	25	3	1748

Table. 4. 2a. Biomass of macrofauna during SS261 (500µm)

	Islands	Coast/ Sector	Depth (m)	Biomass (gm^{-2})					
				Polychaetes	Crustaceans	Molluscs	Echinoderms	Others	Total
SS261 (500µm)	Andaman Is.	West/ BoB	50	3.04±1.88	1.42±0.82	0.10±0.20	0.57±0.65	1.11±1.60	6.25±3.37
			100	2.96±2.43	0.92±0.63	0.53±0.54	0.02±0.04	0.40±0.43	4.83±2.95
			200	2.28±1.13	0.49±0.28	0.56±0.61	0.07±0.15	0.20±0.26	3.60±1.36
		East/ AS	50	2.34	1.74	0	0.06	0.41	4.54
			100	1.84	0.63	0.52	0	0.96	3.94
			200	4.29±2.10	0.18±0.07	0.62±0.51	0.34±0.41	0.18±0.13	5.61±2.79
	Nicobar Is.	West/ BoB	50	3.01	2.99	0	0.02	0.91	6.93
			100	0	0	0	0	0	0
			200	4.60±3.98	0.62±0.47	0.90±0.64	0.23±0.23	0.22±0.25	6.57±3.59
		East/ AS	50	1.25	1.17	0	0	0.91	3.34
			100	0	0	0	0	0	0
			200	0.98	0.41	0	0.06	1.24	2.69

Table. 4. 2b. Biomass of macrofauna during SS292 (300µm)

	Islands	Coast/ Sector	Depths (m)	Biomass (gm^{-2})					
				Polychaetes	Crustaceans	Molluscs	Echinoderms	Others	Total
SS292(300µm)	Andaman Is.	West/ BoB	50	2.83±0.72	1.52±0.88	0.16±0.39	0.73±0.29	0.28±0.35	5.52±0.98
			100	2.26±1.47	1.16±1.19	0.42±0.75	1.13±1.29	0.09±0.15	5.06±3.23
			200	1.56±0.64	0.43±0.15	0.09±0.13	0.05±0.13	0.11±0.18	2.24±0.78
		East/ AS	50	2.57±0.71	1.87±1.12	0.21±0.39	0.30±0.22	0.70±0.68	5.66±1.76
			100	3.64±1.39	0.97±0.16	0	0.46±0.44	0.47±0.39	5.55±1.21
			200	2.98±1.82	0.4±0.09	0	0.01±0.03	0.26±0.33	3.66±1.78
	Nicobar Is.	West/ BoB	50	2.4	3.0	0.05	0.54	0.47	6.46
			100	2.01	0.95	0.83	0.08	0	3.86
			200	3.37±2.71	1.47±1.01	0.55±0.38	0.43±0.47	0.45±0.79	6.28±3.64
		East/ AS	50	1.91±0.87	1.34±0.78	0.03±0.06	1.05±1.25	0.05±0.11	4.39±1.90
			100	2.44±2.86	0.73±0.38	0.80±0.88	0.93±0.96	0	4.90±3.97
			200	1.37	0.54	0.59	0.37	0.08	2.95

Table 4. 3a. Pearson correlation of standing stock of macrofaunal groups with environmental variables during SS261 (500µm)

Standing stock	Depth	Temp	Salinity	DO	Sand	Silt	Clay	OM
Total density	0.29	0.22	-0.34	0.32	0.17	-0.26	0.09	-0.35
Polychaete density	0.23	-0.22	0.16	-0.17	0.01	-0.22	0.46**	-0.29
Crustacean density	-0.64**	0.52**	-0.65**	0.63**	0.24	-0.14	-0.34	-0.19
Mollusc density	0.07	0.14	0.00	0.05	-0.10	0.11	0.02	-0.20
Echinoderm density	-0.05	0.03	-0.07	0.10	-0.14	-0.05	0.48	-0.10
Others density	-0.28	0.04	-0.16	0.09	0.37*	-0.25	-0.45*	-0.07
Total biomass	-0.18	0.17	-0.22	0.22	0.12	-0.21	0.14	-0.22
Polychaete biomass	0.08	-0.10	0.08	-0.08	-0.03	-0.14	0.40*	-0.10
Crustacean biomass	-0.63**	0.50**	-0.59**	0.56**	0.32	-0.26	-0.30	-0.16
Mollusc biomass	0.40*	-0.15	0.24	-0.19	-0.27	0.20	0.28	0.15
Echinoderm biomass	-0.09	0.04	-0.22	0.12	0.11	-0.10	-0.07	-0.20
Others biomass	-0.18	0.30	-0.28	0.31	0.19	-0.08	-0.33	-0.24

Table 4. 3b. Pearson correlation of standing stock of macrofaunal groups with environmental variables SS292 (300µm)

Standing stock	Depth	Temp	Salinity	DO	Sand	Silt	Clay	OM
Total density	-0.57**	0.58**	-0.57**	0.55**	0.19	-0.19	-0.14	-0.41**
Polychaete density	-0.35*	0.35*	-0.39**	0.31*	0.07	-0.09	0.00	-0.32*
Crustacean density	-0.70**	0.72**	-0.64**	0.71**	0.29*	-0.27	-0.30*	-0.39**
Mollusc density	0.19	-0.16	0.17	-0.01	0.13	-0.12	-0.15	-0.25
Echinoderm density	-0.25	0.28*	-0.23	0.29*	0.18	-0.14	-0.28	-0.27
Others density	-0.204	0.19	-0.24	0.18	-0.01	-0.01	0.08	-0.06
Total biomass	-0.36**	0.38**	-0.39**	0.32*	0.17	-0.15	-0.21	-0.32*
Polychaete biomass	-0.09	0.08	-0.12	0.04	0.03	-0.03	-0.06	-0.14
Crustacean biomass	-0.47**	0.51**	-0.52**	0.52**	0.14	-0.13	-0.16	-0.22
Mollusc biomass	0.05	0.31*	-0.19	0.15	0.20	-0.18	-0.22	-0.29*
Echinoderm biomass	-0.30*	-0.05	0.09	-0.08	0.06	-0.04	-0.12	-0.12
Others biomass	-0.35*	0.18	-0.39**	0.26	0.02	-0.03	0.00	-0.05

*** Correlation is significant at the 0.05 level**

**** Correlation is significant at the 0.01 level**

Table. 4. 4. Density of macrofauna around tropical oceanic and coral reef islands

Ocean	Locality	Depth (m)	Gear	Mesh size (µm)	Mean density (ind m^{-2})	References
Pacific	Great Barrier Reef, Australia	1-15	Corer	500	16271	Riddle, 1988
	Central Great Barrier Reef, Australia	15-46	Boxcorer	500	2530	Alongi, 1989
	western continental margin of Australia	100-1000	Corer	500	95-1890	McCallum et al., 2015
	Carnarvon shelf, western Australia	9-125	Grab	500	280	Przeslawski et al., 2013
	Gulf of Carpentaria, Australia	20-80	Dredge	1000	203	Long and Poiner, 1994
	Las Perlas Islands, Panamá	1-109	Dredge	1000	317	Mair et al., 2009
	Islas Naos & Tortuga, Panamá	1.5-2.5	Corer	1000	5220	Lee, 1978
	Gorgona, Colombia	5-15	Corer	500	612	Cortés et al., 2012
	Gorgona, Colombia	10	Corer	500	9035	Valencia et al., 2014
	New Caledonia	13.6-21.1	Dredge	2000	115	Chardy et al., 1988
	Uvea Atoll, New Caledonia	14-40	Dredge	2000	60	Garrigue et al., 1998
	Great Astrolabe Reef lagoon, Fiji	17-42	Dredge	2000	64	Schlacher et al. 1998
	Great Astrolabe Reef lagoon, Fiji	17-43	Grab	20,5,2mm	190-2310	Newell and Clavier, 1997
	Viti Levu, Fiji	0-30	Grab	1000	849	Mohammed and Coppard, 2008
	Tahiti, French Polynesia	1-21	Corer	500	9229	Frouin and Hutchings, 2001
	Tahiti, French Polynesia	1-21	Corer	2000	222	Frouin, 2000
	Moorea, French Polynesia	1-21	Sucker	2000	1756	Thomassin et al., 1982
	Moruroa, French Polynesia	0.5-43	Sucker	2000	768	Villiers, 1988
	Isla del Coco, Costa Rica	3-75	Grab	500	1826	Sibaja-Cordero et al., 2016
	Mamala Bay, O'ahu, Hawaii	10-20	Corer	500	15300	McCarthy et al., 2000

	O'ahu, Hawaii	10	Corer	500	8686	McCarthy et al., 1998
	Hong Kong Islands	13-23	Dredge	400	101	Shin and Thompson, 1982
	Hong Kong Islands	5-47	Dredge	500	323	Shin and Ellingsen, 2004
	Tre, Mieu and Tham islands, Vietnam	19-24	Dredge	500	637	Udalov et al., 2006
	Pulau Semakau, Singapore	1-20	Dredge	1000	61	Chou et al., 2004
	Singapore islands	6-34	Grab	1000	770	Lu, 2005
	Mlonggo, Java, Indonesia	5-30	Dredge	500	468	Warwick and Ruswahyuni, 1987
	Tangerang, Banten, Java, Indonesia	1-20	Dredge	500	875	Sahidin et al., 2014
	Seribu islands, Java, Indonesia	9-64	Dredge	2000	996	Kastoro et al., 1991
	Jakarta Bay, Java	1-12	Dredge	500	19511	Al-Hakim, 2010
	Porong, Wonokromo and Bengawan Solo, Java, Indonesia	0.3-20	Dredge	500	1057	Kastoro et al., 1989
	Karah Island, Malaysia	10-25	Grab	500	719	Ibrahim et al., 2006
Atlantic	Rocas Attol	1-24	Corer	500	11255-71201	Netto et al., 1999
	Cuban Archipelago	1-2.5	SCUBA	500	11-222	Armenteros et al., 2012
Indian	Mahe, Seychelles	13-63	Grab	500	508	Mackie et al., 2005
	Reunion Island	20-140	Grab	1000	522-531	Bigot et al., 2006
	Mauritius Island (macro+meio)	296-4550	Grab	500	10848	Ingole et al., 1992
	Lakshadweep Islands	intertidal	Corer	500	448-1852	Rivonker and Sangodkar, 1997
	Shingle and Krusadai Island	intertidal	Grab	500	307-497	Magdoom et al., 2010
	Andaman and Nicobar Islands	11-2150	Grab	500	406	Parulekar and Ansari, 1981
	Andaman and Nicobar Islands	50-200	Grab	500	1166	Present study
	Andaman and Nicobar Islands	50-200	Grab	300	2234	Present study

Table. 4. 5. Standing stock of macrofauna in the oxygen minimum zone (OMZ) impingement depths of the world oceans

Region	DO (ml l^{-1})	Depth (m)	Density (ind.m^{-2})	Biomass (g.m^{-2})	Mesh size (µm)	References
Namibia, Africa	0.06-0.39	80-117	300-3350	109afdw gm^{-2}	1000	Zettler et al., 2009
Chile	0.10	122	16478±4842	60.9±87.4	300	Gallardo et al., 2004
Chile	0.13	206	21280±11817	17±12.9	300	Gallardo et al., 2004
Pakistan	0.11	140	10464	4.3	300	Gooday et al., 2009
South Eastern Arabian Sea (14°N)	0.38	102	3722	13.3	300	Ingole et al., 2010
Andaman Islands	0.30	200	1263±816	2.81±1.39	300	Present study (SS292)
Nicobar Islands	0.60	200	1686±809	4.95±3.15	300	Present study (SS292)
North Eastern Arabian Sea	0.04	200	588	4.47	500	Damodaran, 2010
South Eastern Arabian Sea	0.35	200	1060±572	7.52±4.47	500	Abdul Jaleel, 2012
North Western Bay of Bengal	0.35	150-206	410	1.41±0.35	500	Raman et al., 2015
South Western Bay of Bengal	0.11	176-200	355	4.9	500	Khan et al., 2017
Andaman Islands	0.34	200	1002±505	4.35±2.09	500	Present study (SS261)
Nicobar Islands	0.63	200	1060±811	5.02±3.44	500	Present study (SS261)

Chapter V

Community structure of polychaetes

V.1. Introduction

The term biocenosis (i.e. biotic community, biological community, ecological community) was coined by Karl Möbius in 1877 to describe the interacting organisms living together in a habitat. In modern ecology, a community or biocoenosis is an assemblage of populations of two or more different species occupying the same geographical area in a particular time. In marine ecosystem, macrofauna plays a major role in nutrient cycling, dispersion, burial of sediments and secondary production (Snelgrove, 1998). They are good indicators of the ecosystem health, since most of the taxa are sedentary and those which are sessile are not likely to migrate out of their habitat (Dauer, 1993).

The structuring of macrofaunal benthic communities are generally controlled by a variety of environmental factors that have direct effect on their physiology and behaviour (Ramey & Snelgrove, 2003; McArthur *et al.*, 2010). Abiotic surrogates which include the environmental variables are divided into resource gradients (e. g. energy consumed by species), direct physical and chemical gradients (e. g. sediment grain size, temperature, salinity, oxygen, pressure), and indirect gradients (depth, latitude etc.). The spatial variables like depth, latitude and longitude which are indirect gradients exerts influence on the direct gradients like oxygen, temperature, salinity, sediment composition etc. (Snelgrove *et al.*, 2001; Gray, 2002; Meynard & Quinn, 2007; McArthur *et al.*, 2010). The combined effect of these variables have a major influence on species assemblages and in their distribution. Depth is one major variable affecting the benthic biodiversity from inshore to deep-sea (Gray, 2001), with increasing species richness and decreasing biomass with increasing depth (Snelgrove, 2001; Levin *et al.*, 2001). The substratum, mainly sediment composition and grain size is an important factor influencing the size, morphology and life history of species (Jones, 1950), while substratum stability is a major factor affecting the communities and richness in an area. Topographic and habitat complexity provides refuges and a variety of habitats and enhance biodiversity (McArthur *et al.*, 2010). Productivity of the water column is another factor affecting the distribution of benthic organisms, as the detrital matter from the water column forms one of the major food resources (Carney, 2005) for the bottom fauna. Hydrodynamics affects the distribution of larvae, organic matter settlement etc. (McArthur *et al.*, 2010) controlling the distribution and composition of benthic fauna.

Polychaetes are the dominant group among macrobenthic fauna (Knox, 1977; Gambi & Giangrande, 1986; Hutchings, 1998; Levin *et al.*, 2000) in terms of abundance and species richness in soft substrates (Fauchald, 1977; Grassle & Maciolek, 1992; Ward & Hutchings, 1996). Polychaetes are ubiquitous (at family and genus level) but their species distribution has distinct pattern (Hutchings, 1998). Polychaetes reside in the interstitial spaces, in burrows or tubes or move freely through the sediment and thereby enhances bioturbation (Rhoads, 1974; Aller, 1988; McLusky & McIntyre, 1988; Jones & Jago, 1993; Dittmann, 1996; Kristensen *et al.*, 2012), through particle reworking during burrow construction, ingestion, defecation, and burrow ventilation. They are one of the key components in benthic food chains, as they are food sources of many demersal fishes, molluscs, crustaceans, echinoderms etc. (Knox, 1960). They exhibit a variety of reproductive strategies and are known to settle first among macrobenthic invertebrates during recruitment, owing to their short life cycle (Wu & Shin, 1997; Grassle & Morse-Porteous, 1987). Polychaetes are sensitive to changes in the surrounding environment (Meksumpun & Meksumpan, 1999) and are used as indicators or markers of ecosystem health (Pearson & Rosenberg, 1978; Gambi & Giangrande, 1986; Bellan *et al.*, 1988; Pocklington & Wells 1992) in view of their more or less sedentary life habit. Under adverse environmental conditions some species will perish off or avoid such conditions, while some are opportunists capable of rapidly colonizing even under adverse conditions (Grassle, 1974; Levin *et al.*, 2000). Polychaetes are thus used as surrogates for estimation of diversity, dynamics and functioning of benthic communities (Olsgard *et al.*, 2003; Giangrande *et al.*, 2005).

The composition and distribution of marine benthic communities are strongly influenced by physiological requirements, e. g. food intake, which is affected by the feeding pattern, food availability etc. (Sanders 1958; Roth & Wilson, 1998; Ramey & Snelgrove, 2003) which in turn depend on the hydrodynamic conditions in the region (Roth & Wilson, 1998; Wieking & Kroncke, 2005; Manokaran *et al.*, 2013). Along with this, other factors such as productivity, water depth, sediment texture, particle size, substratum stability, oxygen content, bottom currents etc. influences the food availability of bottom fauna, predation, recruitment etc., which in turn mould the trophic composition of benthic communities (Maurer & Leathem, 1981; Probert, 1984; Gaston, 1987; de Pavia, 1993; Roth & Wilson, 1998; Pagliosa, 2005; Dolbeth *et al.*, 2009; Mattos *et al.*, 2013). A guild is defined as a group of species that exploit the same class of environmental resources in a similar way (Root, 1967; Fauchald & Jumars, 1979; Simberloff & Dyan, 1991) regardless of their phylogenetic relationships. Nowadays, feeding guilds are being widely used in environmental impact assessment studies, as it decreases taxonomic effort (Han *et al*., 2016). Studies across the world (Rhoads & Young, 1970; Gaston, 1987; de Pavia, 1993; Pinedo *et al*., 1997; Roth & Wilson, 1998; Muniz *et al*., 1998; Muniz & Pires, 1999; Desrosiers *et al*., 2000; Arasaki *et al*., 2004; Pagliosa, 2005; Dolbeth *et al*., 2009; Macdonald *et al*., 2010; Castanedo *et al*., 2011; Mattos *et al*., 2013; Abdul Jaleel, 2012; Manokaran *et al*., 2013; Carvalho *et al*., 2013; Han *et al*., 2016) indicate that the evaluation of distribution of polychaete feeding guilds is useful in determining macrobenthic trophic structure as a whole (Maurer & Leathem, 1981; Gambi *et al*., 1982), for assessing environmental impacts (Dauer, 1984; Han *et al*., 2016), understanding benthic processes (Gray & Elliot, 2009) etc. The feeding guild of polychaetes was initially studied by Fauchald & Jumars (1979) and recently updated by Jumars *et al.* (2015); who classified the group based on food, feeding habits and locomotory patterns into Predators (Herbivores, Carnivores, Omnivores), Deposit feeders (Surface feeders, Subsurface deposit feeders) and Suspension feeders.

Oceanic island margins are pristine environments, characterised by highly diverse communities having great proportions of endemics and species with greater dispersal abilities (Allen, 2008; Snelgrove, 1999; Gray, 2002; Clark *et al*., 2010; Rowden *et al*., 2010; Anderson *et al*., 2013). Tropical oceanic islands with high cover of coral reefs, sustain exceptionally high species richness and diversity (Reaka-Kudla, 1997; Gray, 1997; Bouchet *et al*., 2002). Although the benthic communities of continental margins have been well studied, attention on a broad-scale spatial structure on benthos around island ecosystems and their functioning have not yet been given enough focus (Long & Poiner, 1994; Riddle, 1988; Currie *et al.*, 2009). It is a necessity to elucidate the environmental factors structuring the benthic aasemblages around oceanic islands inorder to assess the impacts of changing oceanographic regimes due to natural (e. g. earthquakes, tsunamis) as well as anthropogenic influences (e. g. pollution, global warming) affecting the biodiversity as well as fuctioning of the ecosystem (Anderson *et al.*, 2013). Ocean warming due to climate change can have severe impacts on the coral reefs (e. g. coral reef bleaching), the associated and adjacent benthic communities as these harbour ecologically sensitive fauna with low resilience (Chown *et al.*, 1998).

The spatial distribution of macrofauna and the environmental parameters influencing them in the continental shelf (Ganesh & Raman, 2007; Jayaraj *et al.*, 2008; Joydas & Damodaran 2009; Manokaran *et al.*, 2015) as well as in the slope (Ingole *et al.*, 2010; Abdul Jaleel, 2012; Raman *et al.*, 2015; Khan *et al.*, 2017) off peninsular India are well studied. Species richness and diversity of polychaetes in these areas decreased with increasing depth in the shelf (30-200m), whereas, in the slope, diversity increased with increasing depth (200m-1000m). Strong spatial variations in polychaete species assemblages were evident, which were attributed to the prevailing hydrographical and sediment characteristics in the region. Although studies on benthos have been carried out in the reef and adjacent areas around Lakshadweep (Rivonker & Sangodkar, 1997; Susan *et al.*, 2014) and Andaman and Nicobar Islands (Fauvel, 1953, Tampi and Rangarajan, 1964; Soota *et al.*, 1977; Parulekar & Ansari, 1981a; James *et al.*, 1969; Misra & Chakraborty, 1991; Rao, 2010; Rajasekaran & Fernando, 2012; Veeramuthu *et al.*, 2013; Gopal *et al.*, 2014, 2016), emphasis on community structure of macrobenthos along the insular margins have not been attempted. The present study is a pioneer attempt to characterize the community structure of polychaetes around Andaman and Nicobar Islands as a whole. Spatial and temporal variations in community patterns are elucidated using conventional univariate measures (species richness, species diversity, species evenness and species dominance). For marine soft sediments multivariate measures are more useful to delineate the small changes in faunal composition (Gray *et al*., 1990; Warwick & Clarke 1991, 1993; Ellingsen, 2002). In the present study, multivariate measures are used to visualize differences in species composition in the region and their relationship with environmental factors.

V.2. Results

In the study area, during SS261 (500µm), 43 families of polychaetes were represented, comprising of 22 errant families and 21 sedent families. During SS292 (300µm), 52 families of polychaetes belonging to 6 orders were recorded during comprising of 26 errants families, 24 sedent families and 2 families under Polychaeta incertae sedis. The families which were represented exclusively during SS292 (300µm) were Sphaerodoridae, Iphionidae, Aphroditidae (belonging to errants), Fabriciidae, Longomastidae, Pectinariidae, Scalibregmatidae (belonging to sedents), Saccocirridae, and Protodrilidae (under polychaeta incerta sedis). Among errants, the most species rich family was Syllidae in both surveys (SS261: 22 species, SS292: 40 species) while among sedents, Spionidae contributed maximum species (SS261: 30 species, SS292: 35 species). All families were represented at all depths except Iphionidae, Pectinariidae, Travisiidae and Saccocirridae (represented only at 50m), Longomastidae (only at 100m), Eulepethidae, Aphroditidae, Scalibregmatidae, Chaetopteridae and Sabellariidae (absent at 200m) (Fig. 5. 1a, b).

A total of 606 polychaete species belonging to 279 genera were recorded from the insular margin of Andaman and Nicobar Islands (ANI) during the present study (Appendix 1). During SS261 (500µm) 338 species belonging to 179 genera were recorded and during SS292 (300µm) 480 species belonging to 250 genera were documented. The common polychaete species with relatively higher abundance during SS261 were *Aphelochaeta filibranchia* (4.54%), *Levinsenia oculata* (4.43%), *Kirkegaardia dorsobranchialis* (4.28%) and *Aonidella dayi* (4.27%) and during SS292 relatively highly abundant species were *Ampharete agulhaensis* (2.91%), *Prionospio* (*Minuspio) spp.* (2.86%), *Spiophanes* spp. (2.72%)*, Aonidella dayi* (2.62%) etc.

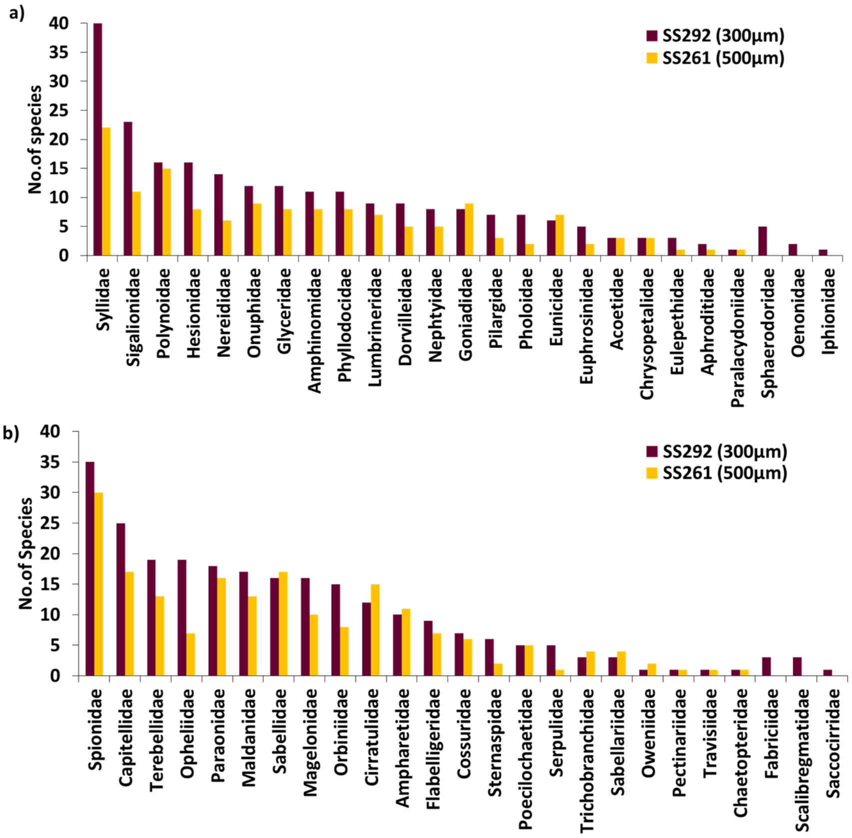
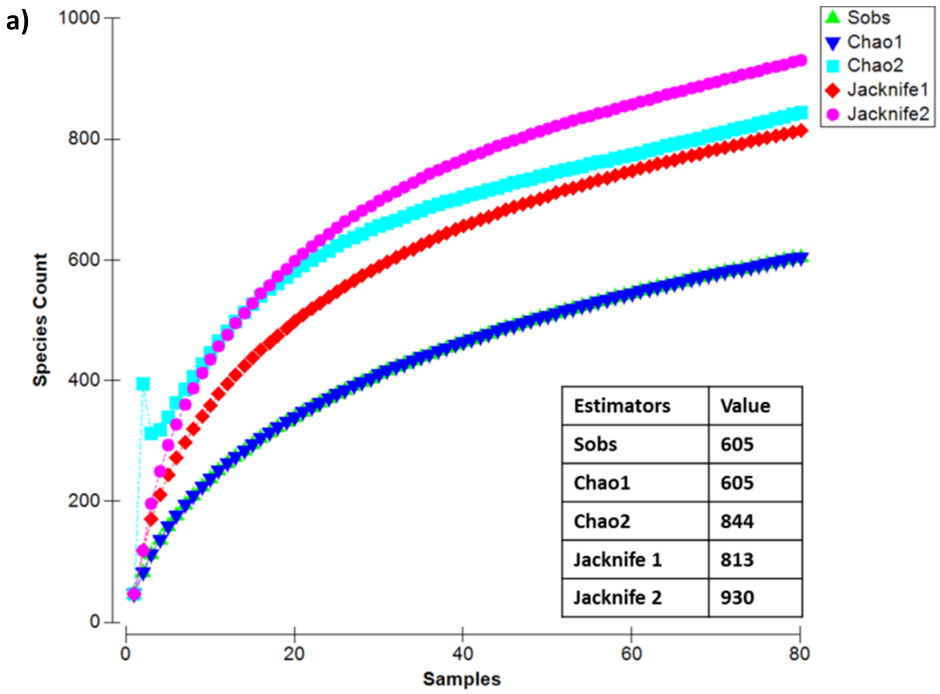


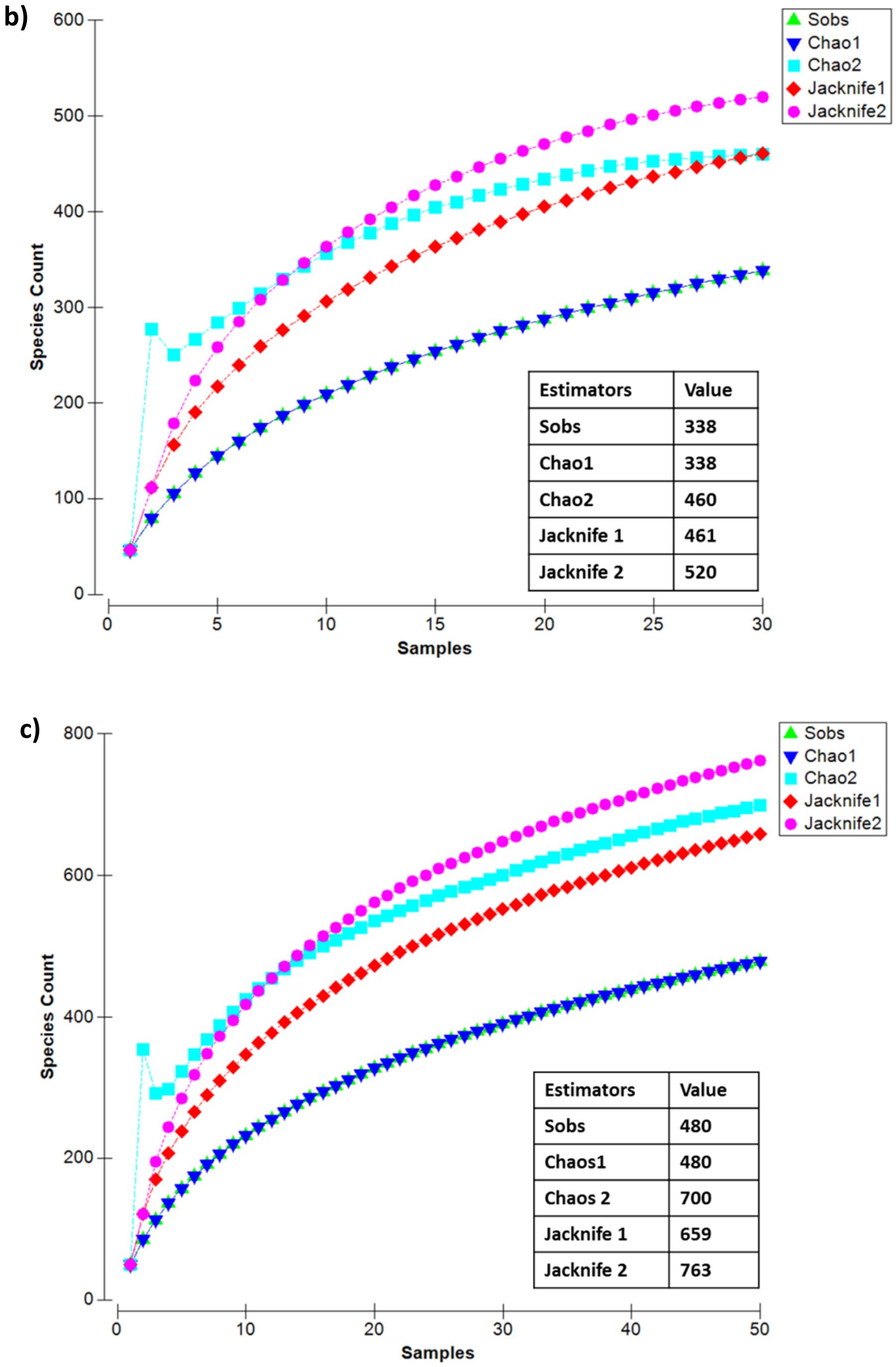
Fig. 5. 1. Number of polychaete species represented among errants (a) and sedent (b) polychaete families in SS261 (500µm) and SS292 (300µm)

In order to check the sufficiency of sampling in the study area, species accumulation curves were plotted for the entire study area. Species estimators were used to predict the number of species that would be observed if the number of samples is increased. In the present study 606 species were documented, and species accumulation curve did not reach the asymptote. Species estimators predicted that as many as 930 species (Jacknife 2) may be encountered in the study area, revealing that only 65% of the maximum estimated diversity has been obtained (Fig. 5. 2a) through the present collections. The abundance based coverage estimator (ACE) and incidence coverage estimator (ICE) estimates 635 species and 700 species respectively in the study area.



Estimators	Value
Sobs	605
Chao1	605
Chao2	844
Jacknife 1	813
Jacknife 2	930

Fig. 5. 2a. Species accumulation curve on polychaete species of the entire study area



Estimators	Value
Sobs	338
Chao1	338
Chao2	460
Jacknife 1	461
Jacknife 2	520

Estimators	Value
Sobs	480
Chaos1	480
Chaos 2	700
Jacknife 1	659
Jacknife 2	763

Fig. 5. 2b-c. Species accumulation curve on polychaete species of the study area during SS261 (500µm) (b) and SS292 (300µm) (c)

Species accumulation plot were also analysed separately for each survey, considering that different mesh sieves were used in each survey. In SS261, 338 polychaete species were recorded (Fig. 5.2b), with the likelihood of obtaining up to 520 species (Jacknife 2) and in SS292, 480 species were recorded (Fig. 5.2c) while species estimators predicting up to 763 species (Jacknife 2) in the study area.

V. 2. 1. Univariate indices of polychaete diversity

During SS261 (500µm), the number of species (S) ranged from 22 (South Andaman, 50m) to 73 (Little Andaman Island, 50m) with a mean value of 47±14, whereas, in SS292 (300µm) number of species ranged from 18 (Sound Island, 200m; west coast of Great Nicobar Island, 200m) to 86 (west coast of Car Nicobar Island, 50m) with a mean of 49±17. Species richness (d) during SS261 varied from 4.32 (South Andaman, 50m) to 12.25 (west coast of Little Andaman Island, 50m) with a mean of 8.06±2.06 and in SS292, values ranged between 4.09 (west coast of Great Nicobar Island, 200m) and 14.33 (west coast of Car Nicobar Island, 50m) with a mean of 8.84±2.63.

Species diversity (H') in SS261 varied from 4.41 (Port Blair, 200m) to 6.02 (North Andaman, 50m) with mean value of 5.27±0.43 and in SS292 from 4.12 (west coast of Great Nicobar Island, 200m) to 6.34 (west coast of Car Nicobar Island, 50m) with a mean value of 5.39±0.57. High species evenness (J') was recorded around ANI in both surveys (>0.90).

Significant differences were noted between the two surveys in species number (PERMANOVA F=13.651, P=0.001), species richness (F=14.903, P=0.001), species diversity (F=15.4, P=0.001) and species evenness (F=3.3618, P=0.036). The k-dominance curve measures the intrinsic species diversity and was plotted based on ranked species abundance data in each surveys. During SS261 (500µm), 67 species together attained 80% of the cumulative dominance, while during SS292 (300µm) 100 species were required (Fig. 5.3).

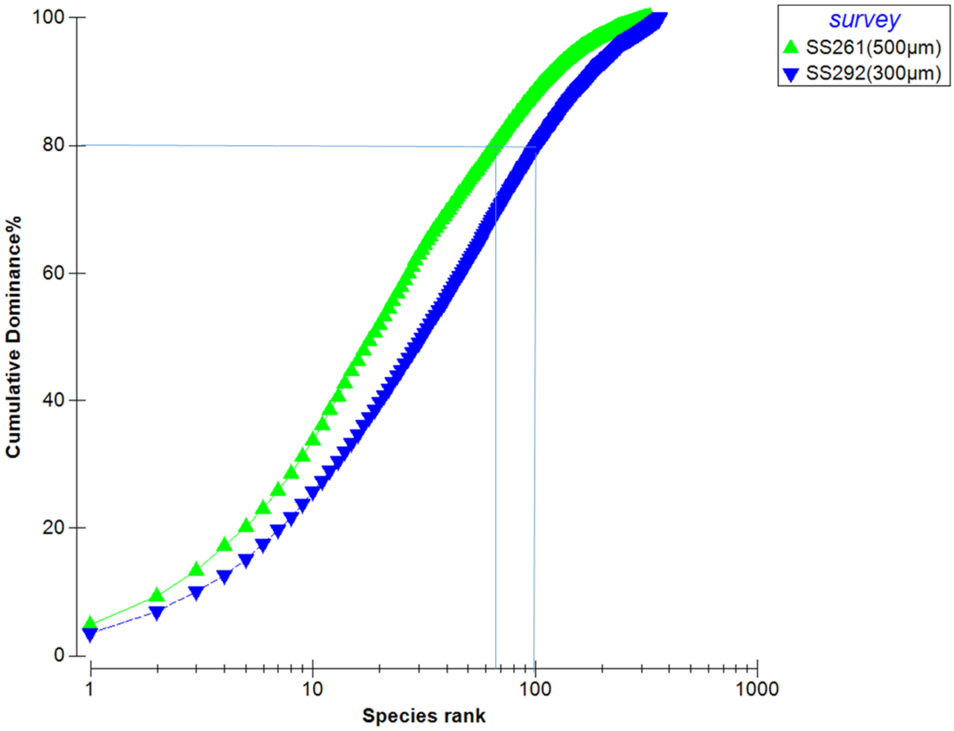


Fig. 5. 3. k-dominance curve for polychaete species during SS261 (500µm) and SS292 (300µm)

V. 2. 2. Bathymetric variations in polychaete diversity

The highest number of polychaete species (S) was recorded in the shallow depth (50m) during both surveys when compared to higher depths (200m). During SS261 (500µm) the number of species at the shallow depth (50m) varied from 22 (South Andaman) to 73 (west coast of Little Andaman Island) with a mean of 54±18 and during SS292 (300µm) the value ranged from 42 (east coast of Car Nicobar Island) to 86 (west coast of Car Nicobar Island) with a mean value of 63±12.

During SS261, at 100m depth the value ranged between 26 (North Andaman) to 59 (Interview Island) with mean of 43±12 and in SS292 value ranged from 22 (Indira Point) to 67 (Table Island) with a mean value of 43±14. In the higher depth (200m) the number of species varied from 29 (Port Blair) to 57 (Katchall Island) with a mean of 43±8 during SS261, and in SS292 values ranged from 18 (Sound Island, west coast of Great Nicobar Island) to 66 (west coast of Car Nicobar Island) with a mean of 37±14 (Fig. 5.4.a, b, c, d).

Species richness (d) exhibited relatively high values in the shallow depths (50m) when compared to higher depths. In SS261 (500µm), species richness ranged from 4.32 (South Andaman) to 12.25 (west coast of Little Andaman Island) with a mean of 9.19±2.65 whereas in SS292 (300µm), values varied between 7.97 (east coast of Car Nicobar Island) and 14.33 (west coast of Car Nicobar Island) with a mean of 10.98±1.71 in 50m contour.

At 100m contour, values varied from 5.22 (North Andaman) to 9.98 (Interview Island) with a mean of 7.59±1.79 in SS261 while in SS292 values varied between 4.51 (Indira Point) and 11.75 (Table Island) with a mean of 7.93±2.16. Species richness ranged from 4.95 (Port Blair) to 9.71 (Katchall Island) with a mean of 7.43±1.35 in SS261 and in SS292 from 4.09 (west coast of Great Nicobar Island) to 11.46 (west coast of Car Nicobar Island) with a mean of 7.10±2.24 in 200m contour (Fig.5.4a,b,c, d).

High species diversity (H') was recorded in all depth strata around ANI. Species diversity ranged from 4.43 (South Andaman) to 6.02 (North Andaman) with a mean of 5.49±0.51 in SS261 (500µm) and in SS292 (300µm) values varied between 5.31 (east coast of Car Nicobar Island) and 6.34 (west coast of Car Nicobar Island) with a mean value of 5.84±0.28. In the intermediate depth category (100m) species diversity ranged from 4.60 (North Andaman) to 5.68 (Interview Island) with a mean of 5.19±0.39 and in SS292 value varied between 4.35 (Indira Point) to 5.95 (Table Island) with a mean value of 5.23±0.49.

In higher depth category, species diversity ranged from 4.41 (Port Blair) to 5.69 (Katchall Island) with a mean of 5.14±0.34 in SS261 and in SS292 values varied from 4.12 (west coast of Great Nicobar Island) to 5.89 (west coast of Car Nicobar Island) with a mean value of 5.01±0.57. Species evenness (J') was relatively high (≥ 0.9) at all depth categories in both surveys. (Fig. 5.5a, b, c, d).

During SS261 (500µm), significant bathymetric variations were not observed in species number, richness, diversity and evenness (P>0.05) whereas in SS292 (300µm), significant bathymetric variations were observed in species number (F=14.588, P=0.001), richness (F=15.129, P=0.001), diversity (F=14.63, P=0.001) but not significant in species evenness (P>0.05).

Latitudinal variations in number of species (S: F=29.528, P=0.018), richness (d: F=52.15, P=0.01) and diversity (H': F=43.533, P=0.023) were significant along the 200m depth strata in the BoB sector while in other depth strata (50m, 100m) significant variations were not observed (P>0.05). Likewise in the AS sector, significant variations were observed in the number of species (S: F=30.288, P=0.004) and richness (d: F=26.79, P=0.002) along the 50m depth contour while in other depth strata (100m, 200m) variations were not significant (P>0.05). Significant decreasing trend with increasing latitude in the species evenness (J') were only observed in the shallow depth strata of AS sector (r= -0.660, p=0.038, 50m) whereas, in BoB sector significant trend was not observed.

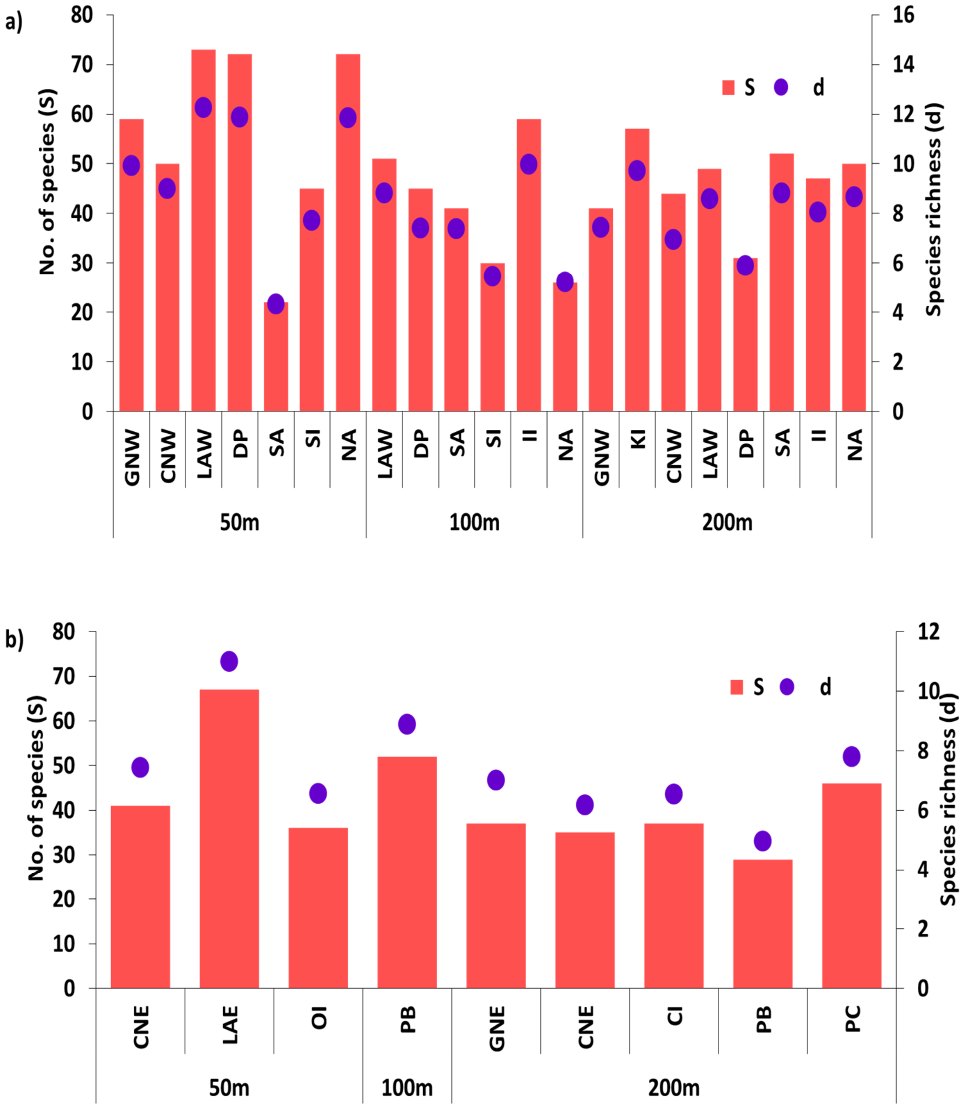


Fig. 5. 4. Number of species (S) and species richness (d) at each site in different depth strata along Bay of Bengal sector (a) and Andaman Sea sector (b) during SS261 (500µm)

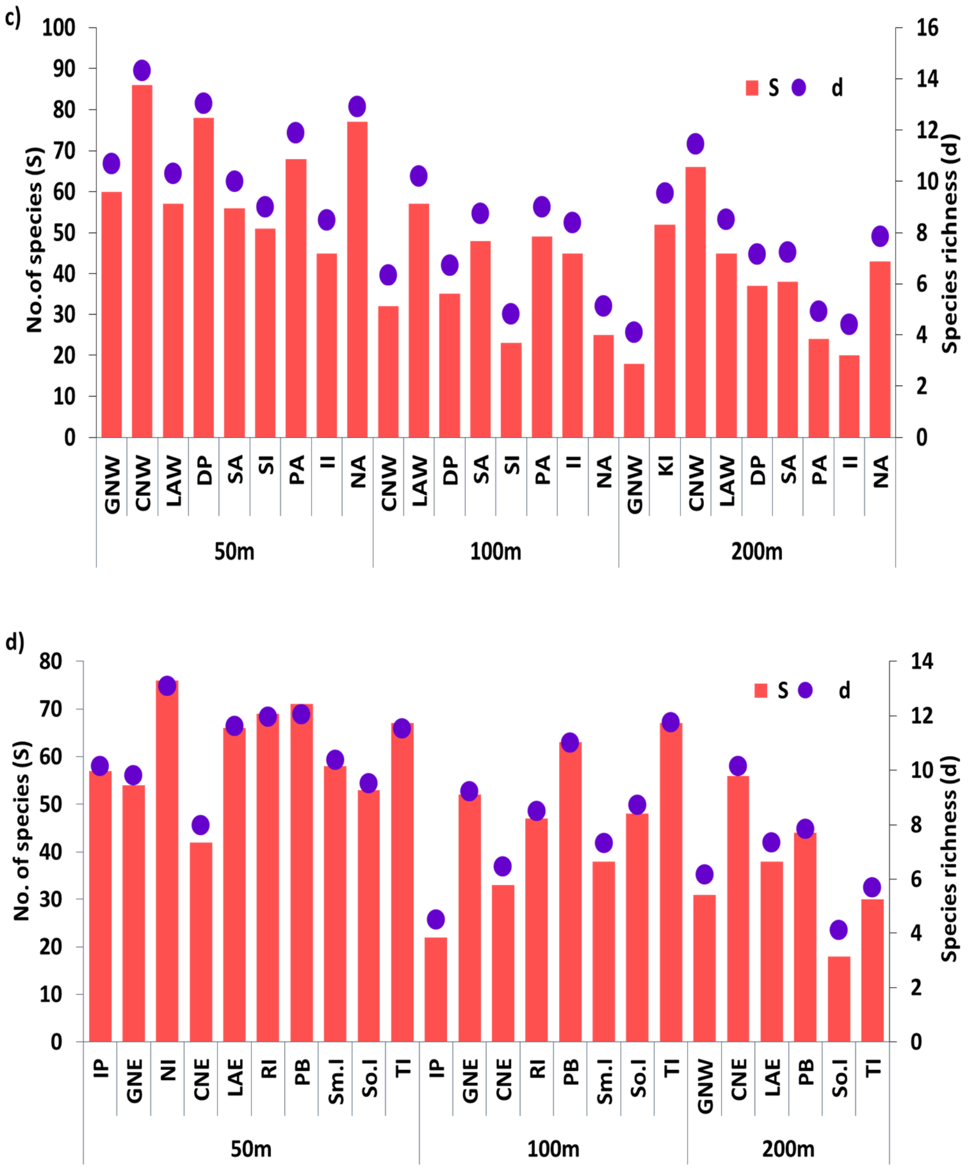
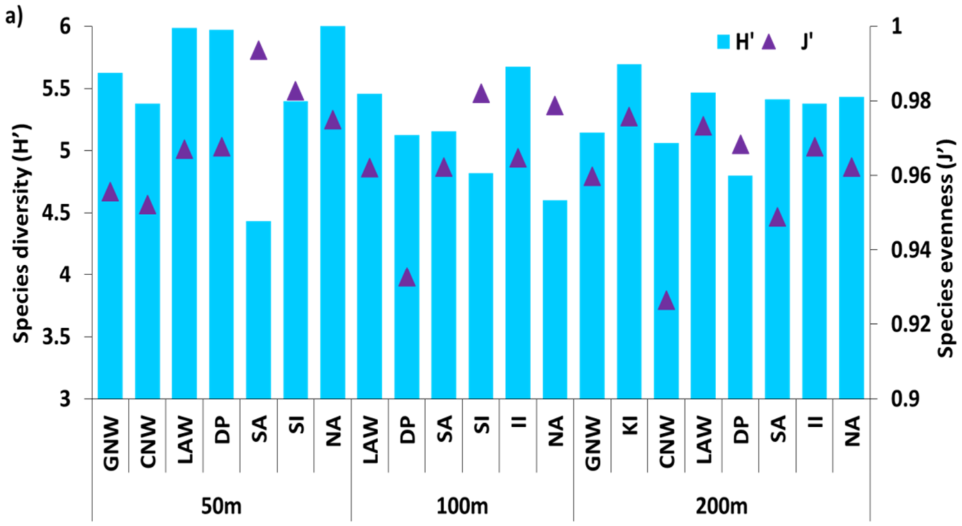


Fig. 5. 4. Number of species (S) and species richness (d) at each site in different depth strata along Bay of Bengal sector (c) and Andaman Sea sector (d) during SS292 (300µm)



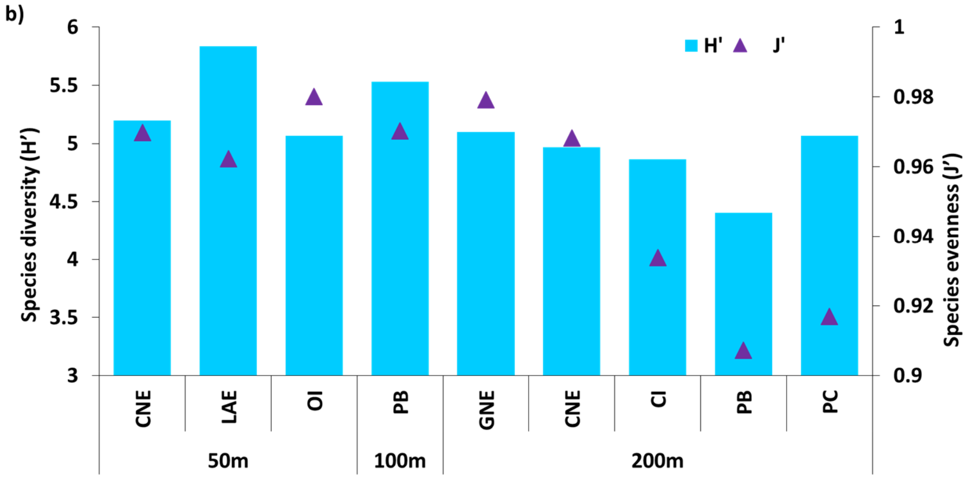
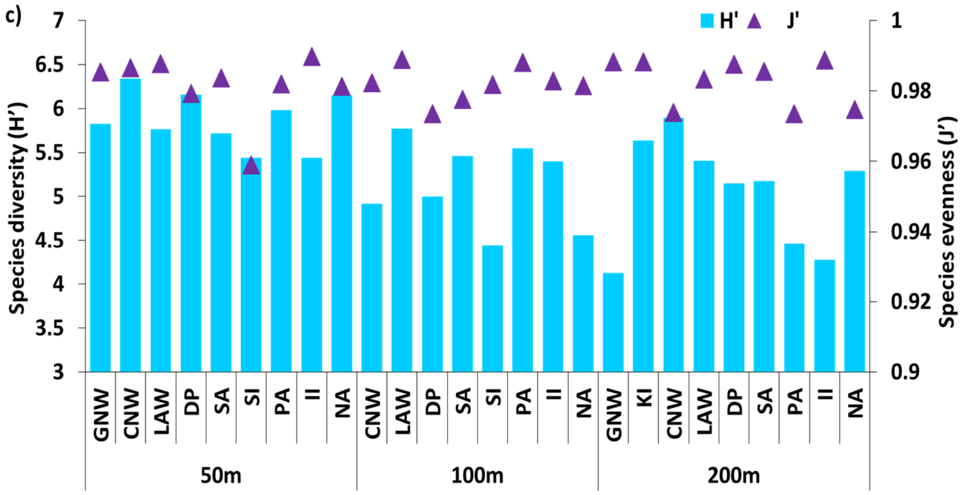


Fig. 5. 5. Species diversity (H'$\log_2$) and species evenness (J') at each site in different depth strata along Bay of Bengal sector (a) and Andaman Sea sector (b) during SS261 (500µm)



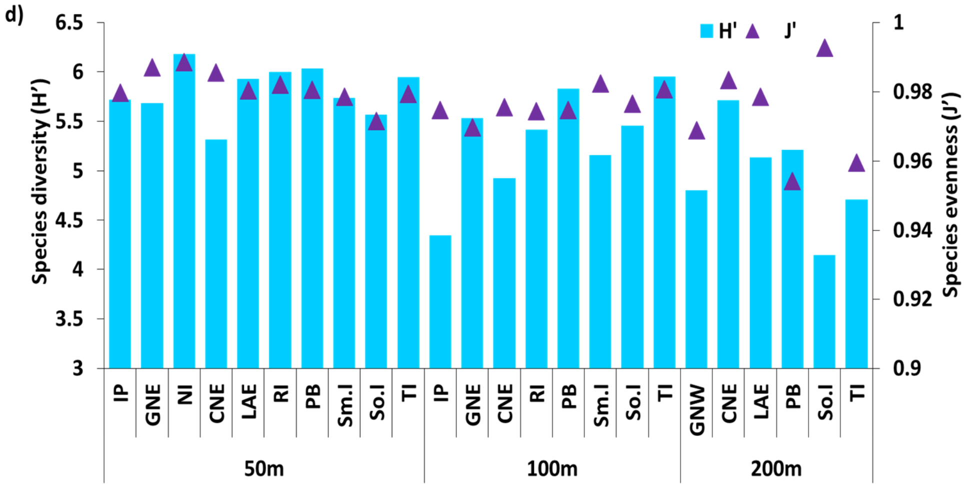


Fig. 5. 5. Species diversity (H'log$_2$) and species evenness (J') at each site in different depth strata along Bay of Bengal sector (c) and Andaman Sea sector (d) during SS292 (300µm)

V.2.3. Taxonomic distinctness

Conventional diversity measures give values based on the abundance of species. Considering that two different mesh sieves were used during the two surveys, the conventional measures cannot be used for direct comparison. Average taxonomic distinctness (Δ+) are different from conventional diversity since they incoporate taxonomic relatedness from hierarchial Linnean classification and are not dependent on degree of sampling effort (i. e., not on the abundance data, sampling gear, sieve size etc.) but simply on the presence or absence of species.

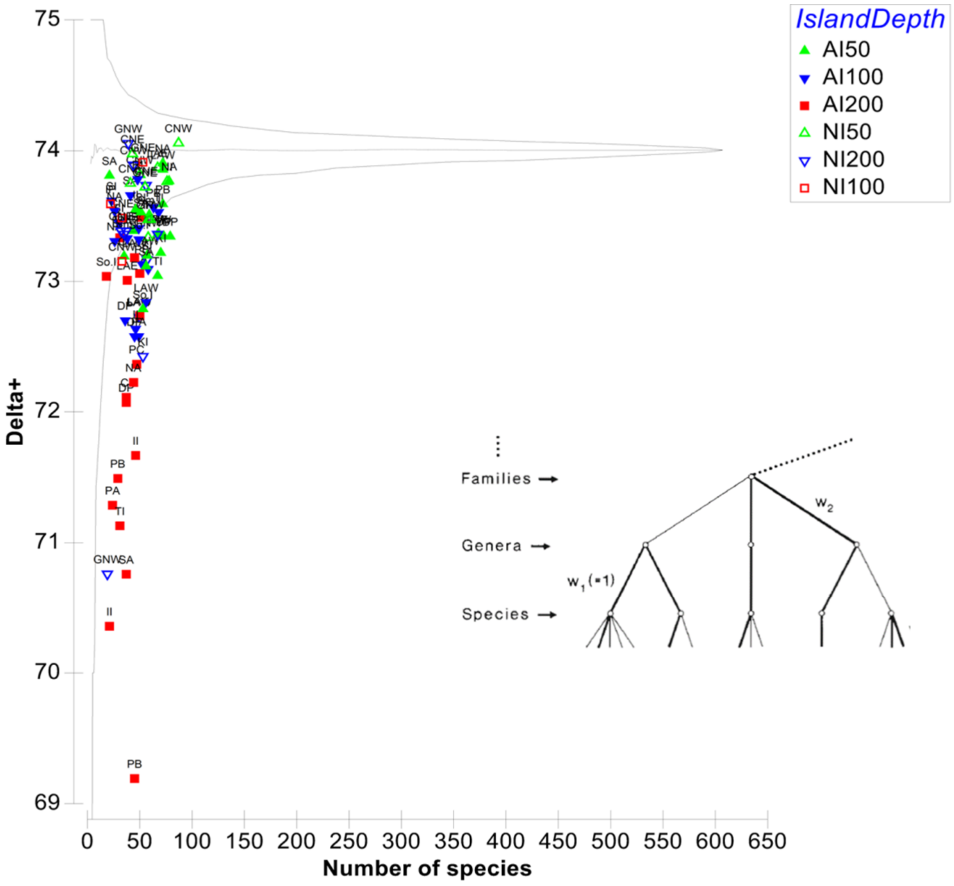


Fig. 5. 6. Taxonomic distinctness plot on polychaete species at each site in the study area

Thus, this index gives precisely the variation in diversity of species among sampling sites, which is generally used to depict the diversity of the region when multiple sampling methods are used. The taxonomic funnel (Fig. 5. 6) depicts the taxonomic distinctness of each sampling site in the study area, against the number of species represented in each site. The ordination is such that sites having high taxonomic distinctness values (Δ+) fall inside the funnel, and sites with lower Δ+ values fell outside the funnel. The taxonomic distinctness value around the islands was very high ranging between 69.19 (Port Blair, 200m) and 74.06 (west coast of Car Nicobar Island, 50m).

V. 2. 4. Multivariate analysis of polychaete species assemblages

V. 2. 4. 1. Bathymetric variations in polychaete species assemblages and diversity

The data from the sites sampled were square root transformed to reduce the impact of the species with the highest abundance on the assessment of the community similarities (Clark & Warwick 2001, Clark & Gorley 2006). Non-metric Multidimensional scaling (nMDS) analysis based on Bray-Curtis similarity was then carried out to elucidate the similarity among the stations.

Bathymetric variations in polychaetes communities were found to be significant in the study area (PERMANOVA SS261 F=2.3536, P=0.001; SS292 F=2.1056, P=0.001). However, the sites did not form any depth-related clusters in the nMDS ordinations of either survey, possibly owing to the occurrence of some species across more than one depth category in the study area as a whole (Fig. 5.7 a, b).

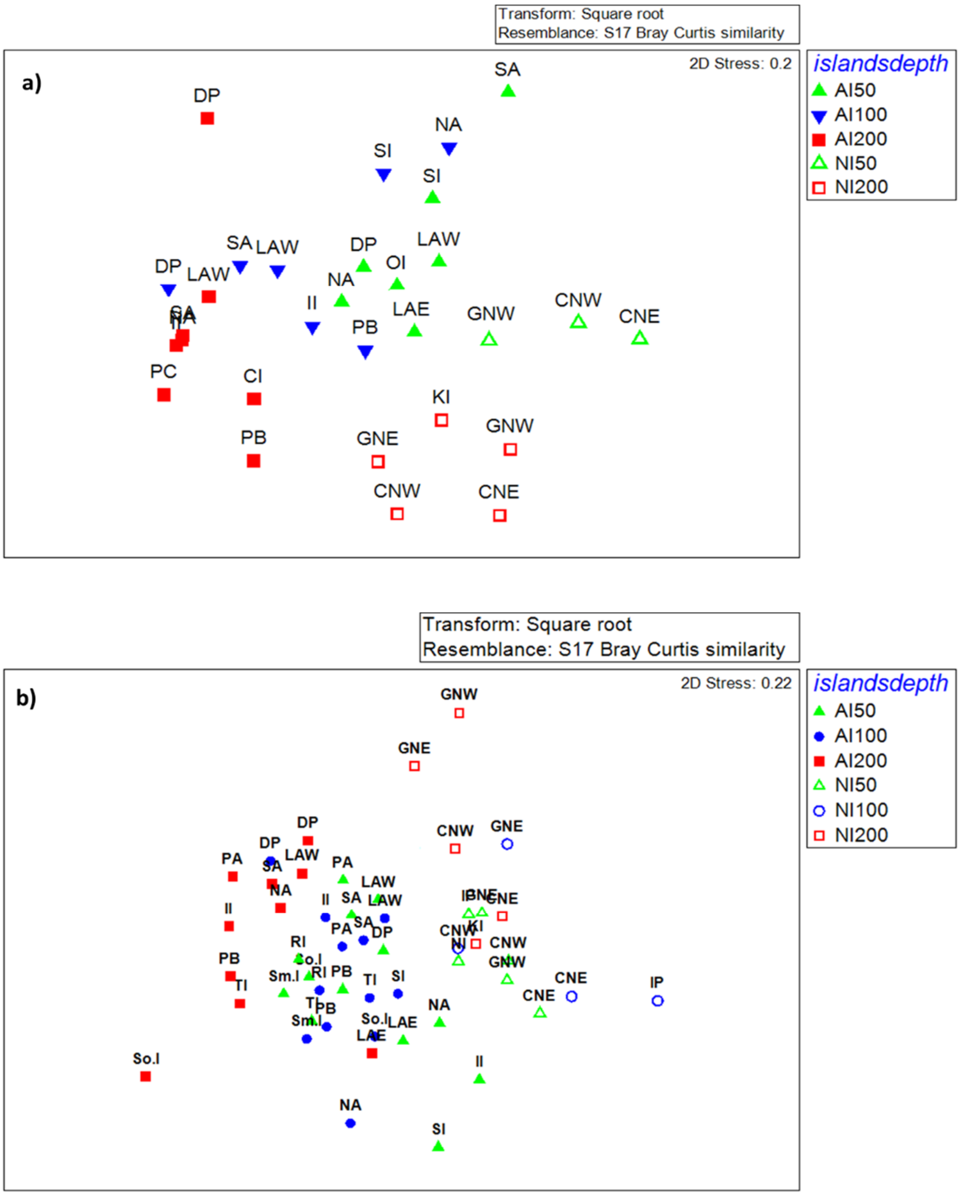
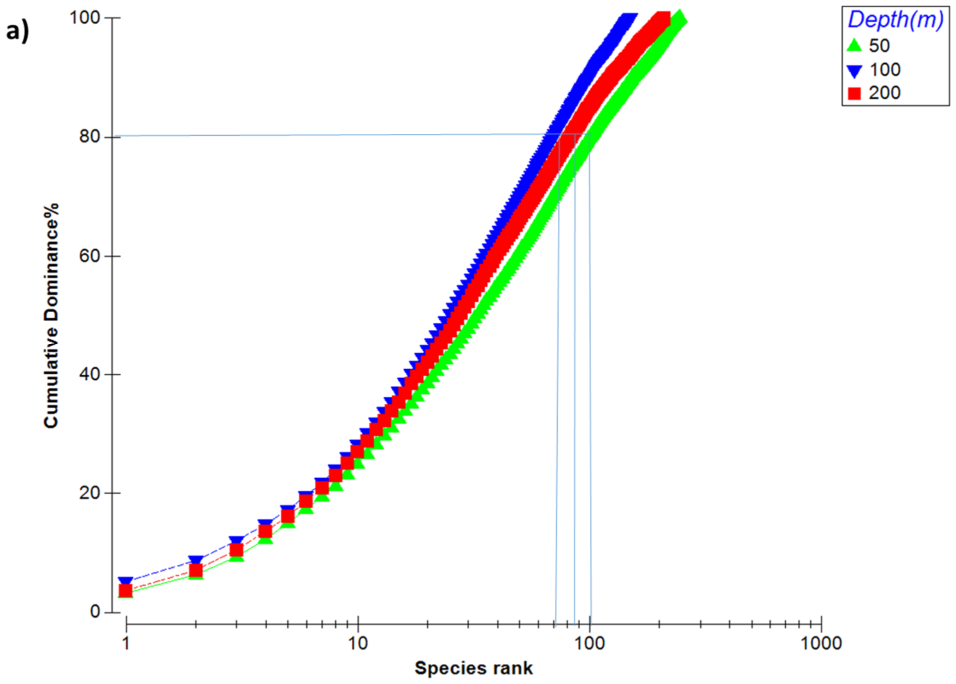


Fig. 5. 7. nMDS plot on polychaete species during SS261 (a) and SS292 (b)

A SIMPER analysis was carried out to determine the species causing similarity within each depth category and dissimilarity between depth categories. During SS261 (500µm), the shallow depth (50m) sites showed 28.86% average similarity, owing to contribution by *Eunice indica* (7.36%), *Syllis* spp. (6.80%), *Nereis* spp. (5.99%) and *Syllis cornuta* (5.61%). The intermediate depth (100m) sites (average similarity of 28.68%) were characterised by dominance of species like *Aonidella dayi* (13.2%), *Prionospio cirrifera* (7.29%), *Aricidea* spp. (5.56%), and *Notomastus aberans* (5.08%) and the higher depth (200m) sites (average similarity 24.66%) with *Prionospio* spp. (7.34%), *Notomastus aberans* (6.96%), *Amphaerete* spp. (6.27%), *Sigambra parva* (6.22%), *Kirkegaardia dorsobranchialis* (5.94%) and *Levinsenia oculata* (5.52%). The 76.23% dissimilarity between 50 and 100m was caused by 176 species, 50 and 200m (80.91%) by 185 species; 100m and 200m (75.93%) by 153 species (Table 5.1 a, b, c).

During SS292 (300µm), the species in shallow depth category (50m) exhibited 26.36% average similarity, with *Micronephtys sphaerocirrata* (5.16%), *Aonidella dayi* (4.56%) and *Syllis cornuta* (4.18%), being dominant. The intermediate depth (100m) stations, contributed an average similarity (20.90%) with dominance of species like *Spiophanes* spp. (10.74%), *Aonidella* dayi (4.99%), *Amphicteis gunneri* (4.52%) and *Glycera lapidum* (4.31%). The higher depth (200m) sites contributed an average similarity of 20.98% with *Prionospio (Minuspio)* spp. (7.71%), *Spiophanes* spp. (7.15%), *Amphicteis gunneri* (6.21%), *Kirkegaardia dorsobranchialis* (5.61%) and *Aricidea* spp. (5.44%). The average dissimilarity between 50m and 100m depth (76.78%) was caused by 258 polychaete species; 50m and 200m (80.64%) by 251 species; 100m and 200m (79.58%) by 202 species (Table 5.1 d, e, f). The characteristic features of polychaete species assemblages in each depth category of both surveys are presented in Table 5.3a, b.



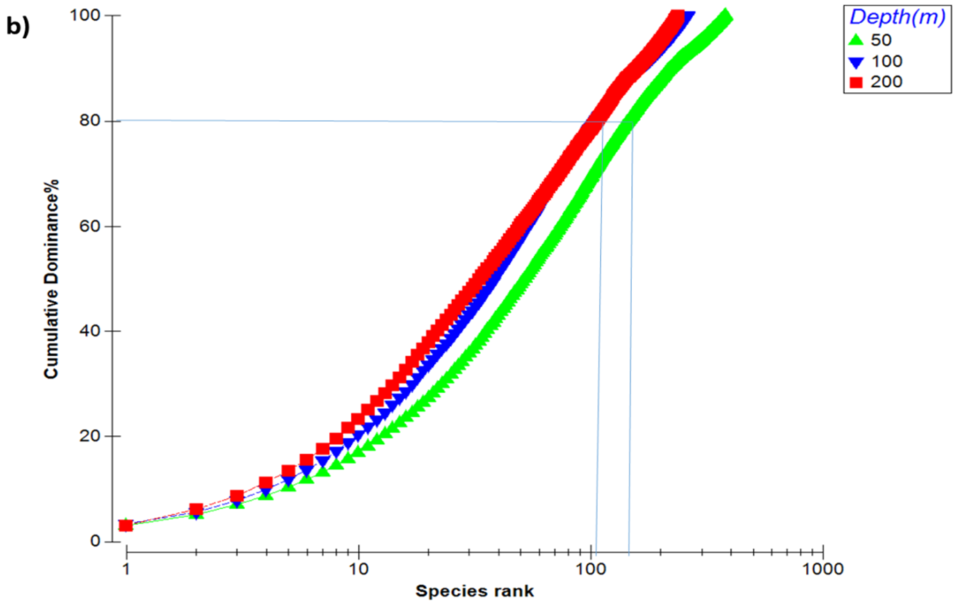


Fig. 5. 8. k-dominance curve on polychaete species at each depth strata during SS261 (a) and SS292 (b)

Bathymetric variations in polychaete communities were found to be more prominently documented by treating the study area as separate sub-regions, e. g. west coast of Andaman Islands (SS292 F=2.1494, P=0.001). The k-dominance curve plotted using polychaete species abundance data pooled for each depth category is presented in Fig.5. 8a, b. In the shallow depth stratum (50m), 80% of the cumulative dominance was attained by 100 species during SS261 (500µm) and 150 species in SS292 (300µm). But in the intermediate depth (100m) 70 species and higher depth category (200m) 85 species were required in SS261 whereas 105 species were needed to reach 80% cumulative dominance in SS292 at 100 and 200m depth.

V. 2. 4. 2. Regional variations in polychaete assemblages and diversity

The nMDS analysis on polychaetes species abundance data of 30 sites (SS261, 500µm) formed 2 separate clusters at 25% similarity (stress value of 0.2), revealing that species assemblages of Andaman Islands (AI) and Nicobar Islands (NI) exhibit differences in their community structure (Fig. 5.9a), both quantitatively and qualitatively (F=2.7504 P=0.001). SIMPER analysis showed that the polychaetes species contributing similarity between the stations within Group AI (avg. similarity 25.58%) included *Aonidella dayi* (8.86%), *Notomastus aberans* (6.33%) and *Prionospio* spp. (5.83%). In Group NI (avg. similarity 25.26%), similarity causing species included *Glycera* spp. (10.77%), *Eunice indica* (7.56%), *Syllis cornuta* (5.97%) and *Prionospio* spp. (5.48%). The dissimilarity (79.95%) among the Island groups was contributed by 180 species. The dissimilarity causing species are given in Table 5.2a.

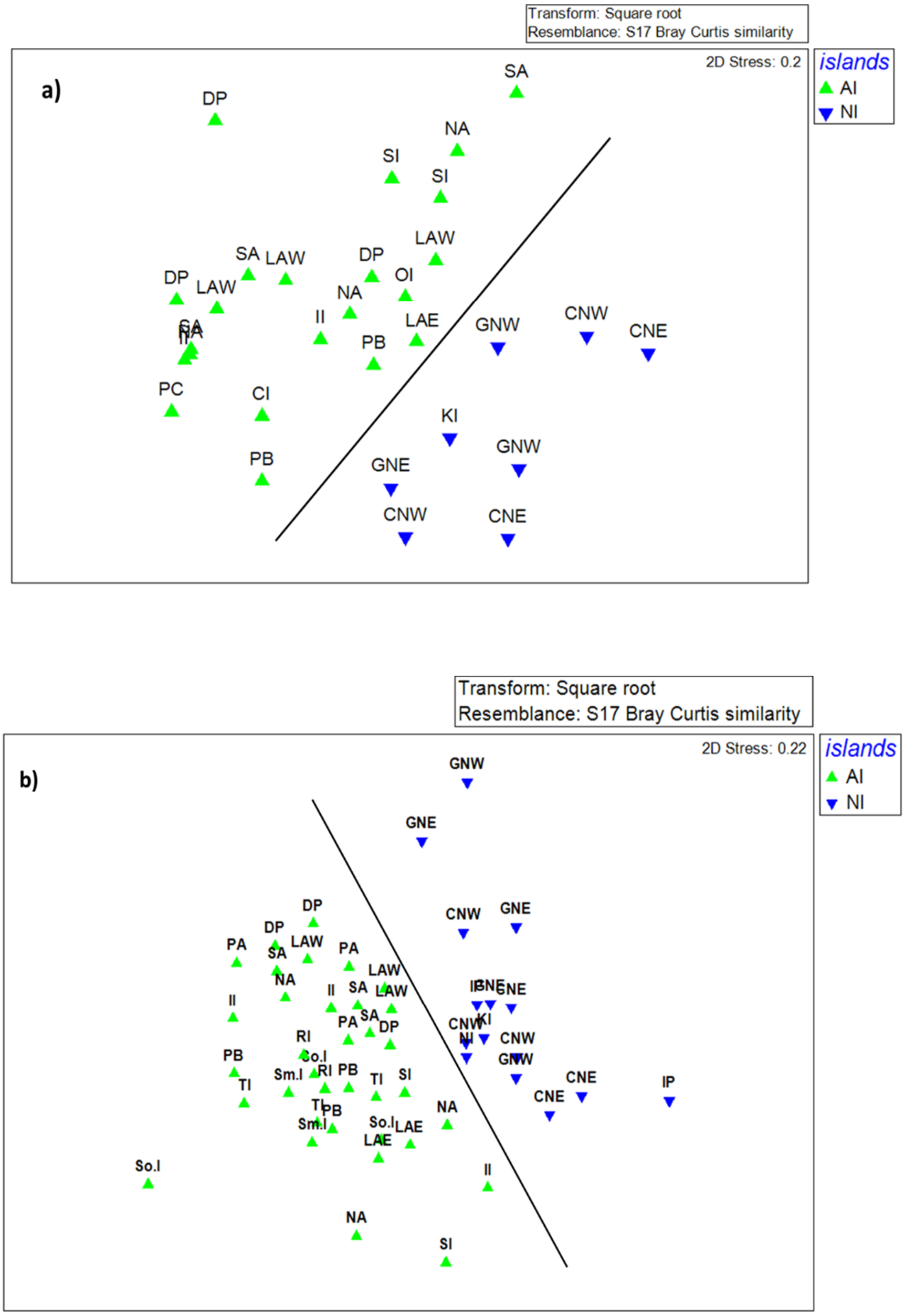


Fig. 5.9. nMDS plot on polychaete species in during SS261 (a) and SS292 (b)

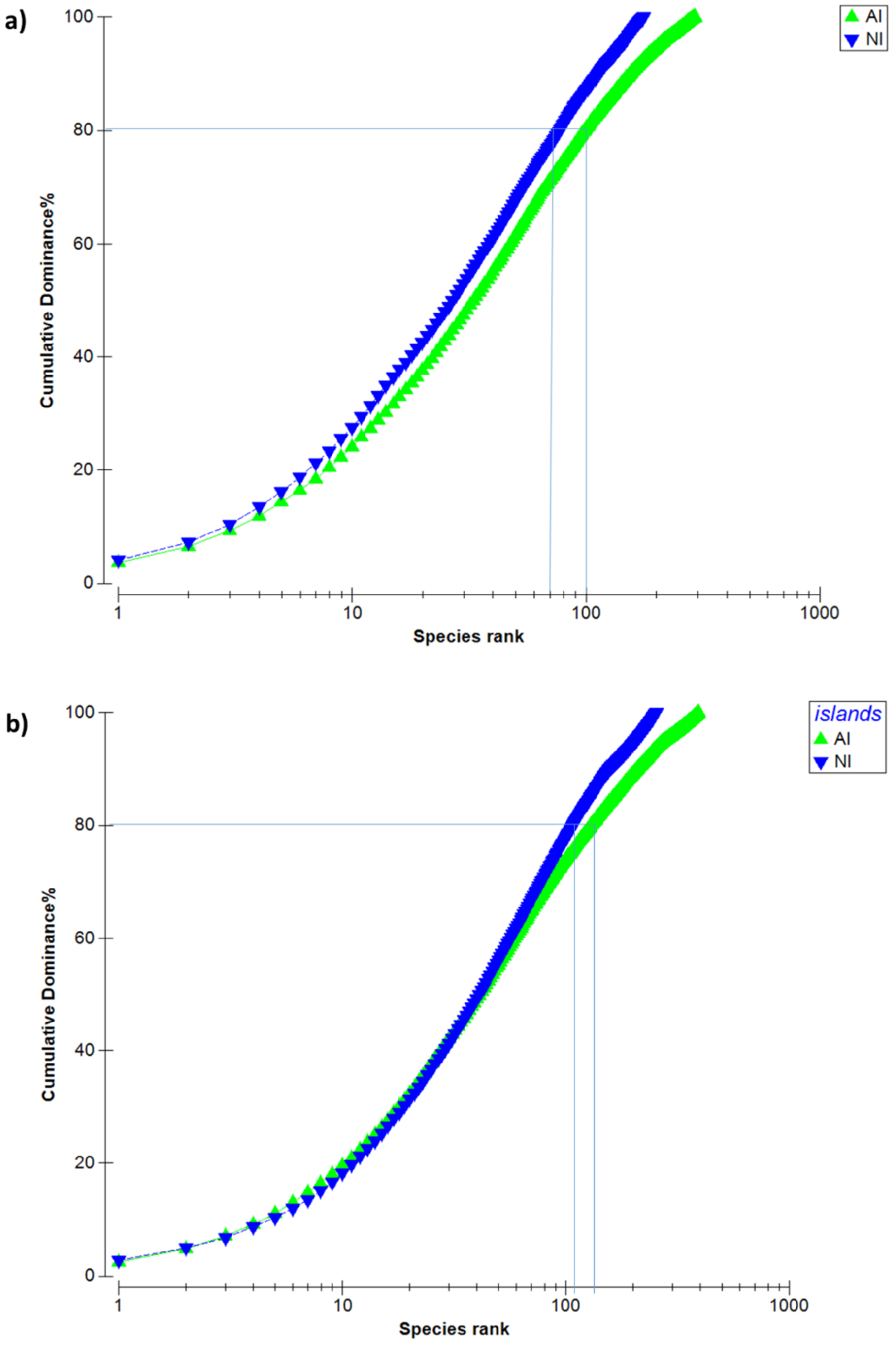


Fig. 5.10. k-dominance curve for polychaete species in each island groups during SS261 (a) and SS292 (b)

The nMDS analysis on polychaetes species abundance data of 50 sites (SS292, 300µm) formed 2 clusters at 25% similarity (with stress value 0.2) revealing that species assemblages of both Island groups (Andaman Islands and Nicobar Islands) exhibit differences in their community structure (Fig. 5. 9b) both quantitatively and qualitatively (F=5.0785 P=0.001). SIMPER analysis showed that the polychaetes species contributing similarity within Group AI (avg. similarity 25.41%) were *Spiophanes* spp. (6.83%), *Prionospio* (*Minuspio)* spp. (6.13%), *Aricidea lopezi* (4.22%) and *Kirkegaardia dorsobranchialis* (4.17%). In Group NI (avg. similarity 25.00%), similarity causing species were *Glycera lapidum* (7.01%) and *Aricidea catherinae* (4.06%). The average dissimilarity (83.30%) among the Island groups were contributed by 251 species. The dissimilarity causing species are given in Table 5. 2b.

Significant variations were not observed in species richness (S and d) and species diversity (H') between the two island groups during both surveys (p>0.05). The characteristic features of polychaete species assemblages in each region during both surveys are presented in Table. 5. 3a, b. The k-dominance curve (Fig. 5. 10 a, b) of polychaete species in SS261, showed that 80 species were required to contribute 80% of the cumulative dominance in Nicobar Islands while 100 species were required for Andaman Islands whereas 80% of the cumulative dominance in SS292, is contributed by 150 species in Andaman islands and 120 species in Nicobar Islands.

To check for variations in polychaete species assemblages along the western and eastern margin of Andaman Islands and Nicobar Islands, PERMANOVA and MDS analysis were done on polychaete abundance data of SS292. Since the number of sampled sites was relatively less in the AS sector in SS261, a similar comparison of the margins was not possible. The variation in polychaetes assemblages in the western and eastern margin of Andaman Islands during SS292 were significant (F=4.4266, P=0.001), whereas variations along the western and eastern sides of Nicobar Island chain were not significant (P>0.05).

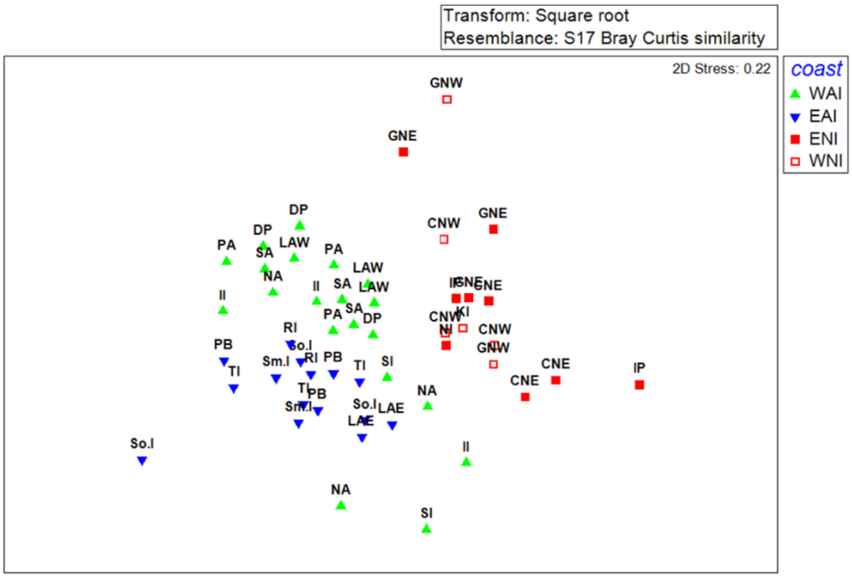


Fig. 5.11. nMDS plot on polychaete species during SS292 (300µm)

Two main groups (Fig. 5.11, 5.12) were formed mainly Group WAI-western margin of Andaman Islands with an average similarity of 27.04%, with *Prionsopio* (*Minuspio)* spp. (8.29%), *Spiophanes* spp. (7.28%) and *Amphicteis gunneri* (5.64%) being the dominant ones; Group EAI- eastern margin of Andaman Islands contributed 31.44% average similarity, with dominant ones like *Ampharete agulhaensis* (8.45%), *Prionospio* spp. (5.59%), *Lumbrineris meteorana* (4.63%) and *Spiophanes* spp. (4.55%).The average dissimilarity between the western and eastern margins of Andaman Islands was 77.73%, with contribution of 231 species (Table 5. 5). The characteristic features of polychaete species assemblages in each margins during both surveys are presented in Table.5. 4

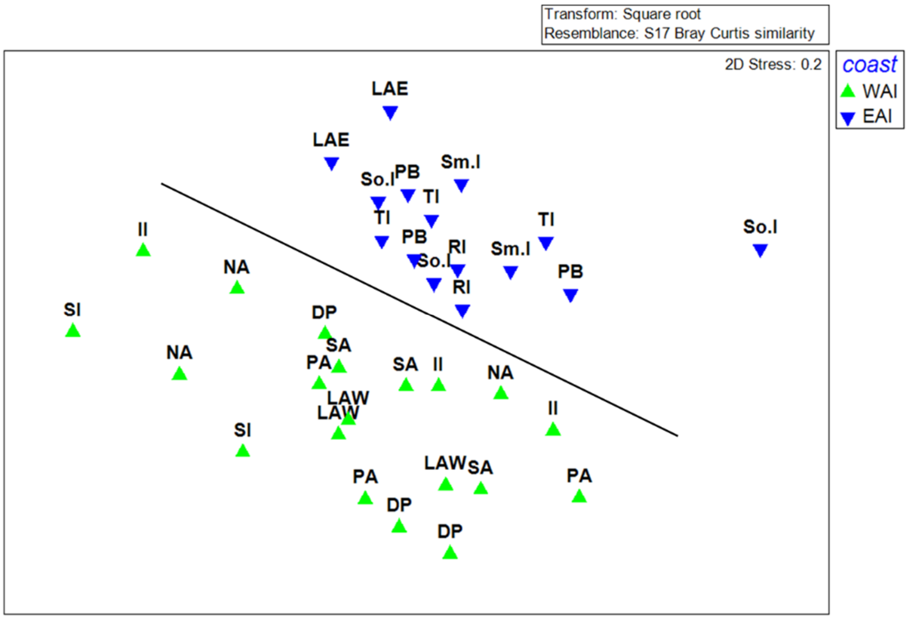


Fig. 5.12. nMDS plot on polychaete species along the western and eastern margins of Andman Islands during SS292 (300µm)

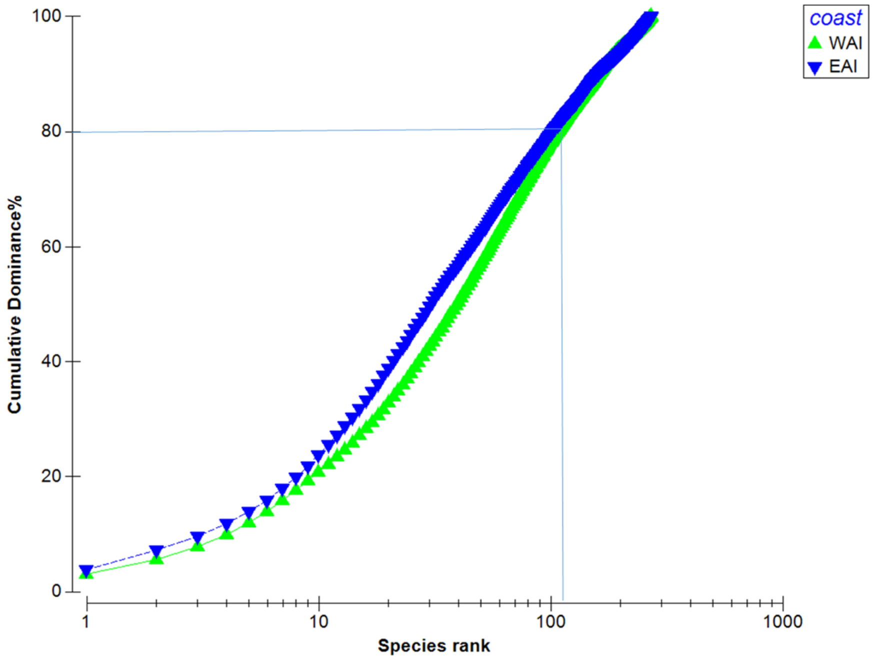


Fig. 5.13. k-dominance curve for polychaete species along western and eastern margins of Andaman Islands during SS292 (300µm)

The observed species numbers, species richness, species diversity and species evenness (P>0.05) did not vary significantly between the western and eastern margins of Andaman Islands. The k-dominance curve (Fig. 5. 13) for both margins of Andaman Islands shows that 80% of the cumulative dominance is met by 110 species in the eastern margin of Andaman Islands.

V. 2. 5. Functional diversity of polychaetes

The 52 families (606 species) of polychaetes recorded in the present study were classified into 4 feeding modes –Predators (PR), Surface deposit feeders (SDF), Subsurface deposit feeders (SSDF) and Suspension feeders (SF) based on Fauchald and Jumars (1979) and Jumars *et al*., (2015). Percentage contribution of the four guilds PR, SDF, SSDF, SF were 31%, 44%, 19% and 6% respectively in SS261 (500µm) whereas in SS292 (300µm) they formed 41%, 35%, 20% and 4% respectively.

Predators (PR) were the dominant guild in the shallow depth (50m) representing 58% (SS261, 22 families) and 48% (SS292, 26 families) of polychaetes, whereas the percentage contribution of PR gradually decreased to 23% (SS261, 20 families) and 44% (SS292, 24 families) at 100m depth and further decreased to 18% (SS261, 20families) and 24% (SS292, 20 families) at 200m depth. PR was chiefly represented by Syllids, Glycerids, Eunicids, Hesionids, Nephtyids and Lumbrinerids etc. which were carnivorous forms with well-developed jaw apparatus (Fig. 5. 14 a, b).

Surface deposit feeders (SDF) were comparatively low in the 50m contour contributing 27% (SS261, 6 families) and 30% (SS292, 7 families) of total polychaetes. With increasing depth the percentage contribution of SDF gradually increased, to 54% (SS261, 7 families) and 37% (SS292, 6 families) at 100m depth and increased further at 200m depth to 50%

(SS261, 7 families) and 43% (SS292, 7 families). The major contributors to this feeding guild were Spionids, Cirratulids and Ampharetids. Sub-surface deposit feeders (SSDF) were also relatively less abundant at 50m depth strata, 12% (SS261, 10 families) and 18% (SS292, 12 families), while as depth increased, the density of SSDF increased to 20% (SS261, 6 families) 16% (SS292, 11 families) at 100m depth strata, and 23% (SS261, 9 families) 29% (SS292, 8 families) at 200m depth strata. SSDF were dominated by Paraonids, Capitellids and Cossurids (Fig. 5. 14 a, b).

The contribution of suspension feeders (SF) was very low at all depths of the study area. At 50m depth, their contribution was 3% (SS261) and 4% (SS292), at 100m depth 3% (SS261 and SS292) and at 200m depth 9% (SS261) and 4% (SS292) (Fig. 5. 14 a, b). In SS261, SF was represented by 4 families namely Serpulids, Sabellarids, Chaetopterids (represented only at 50 depth) and Sabellids (represented at all depths) and in SS292, SF was represented by 5 families namely Fabriciids, Serpulids, Sabellarids, Chaetopterids (represented only at 100 depth) and Sabellids (represented at all depths).

Regionally (among Andaman Islands and Nicobar Islands), in the shallow depth (50m) the contribution of PR (increase of 11% in SS261 and 20% in SS292) and SF (increase of 12%, in SS261 and 44% in SS292) was higher in Nicobar Islands when compared to Andaman Islands. However the contribution of SDF (decrease of 25% SS261 and 62% SS292) and SSDF (decrease of 63% SS261 and 45% SS292) was relatively low in Nicobar Islands. Similarly, in the higher depth (200m) also, the contribution of PR (increase by 76% SS261and 61% in SS292) and SF (increase by 84% SS261 and 42% in SS292) was relatively very high in the Nicobar Islands compared to Andaman Islands whereas SDF (decreased by 18% SS261 and 29% SS292) and SSDF (decreased by 56% SS261 and 9% SS292) was low.

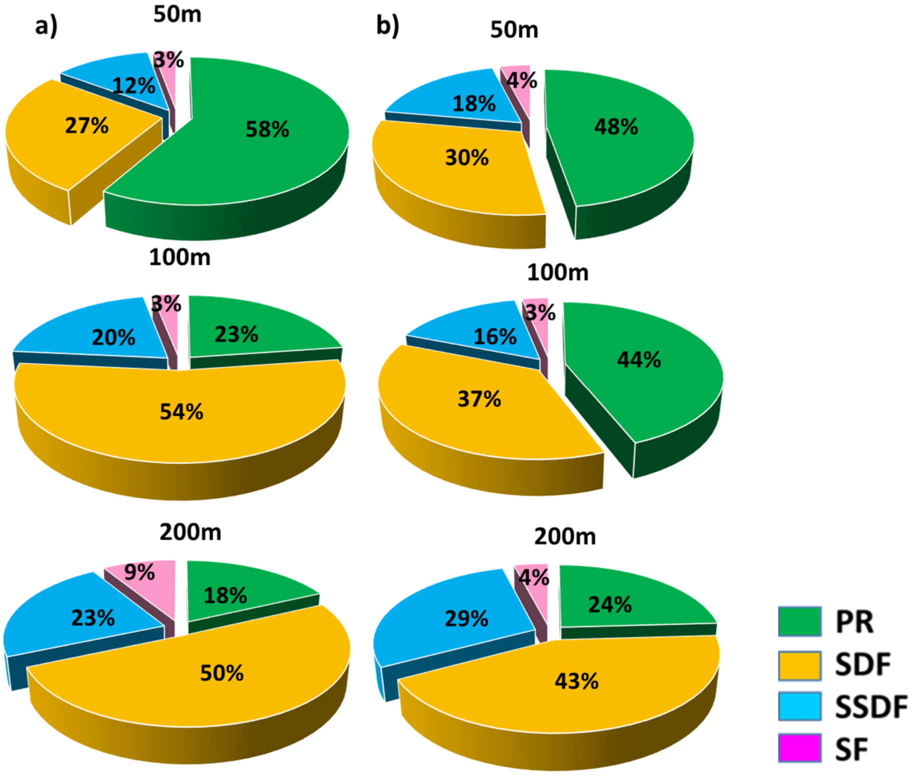


Fig. 5.14. Composition of feeding guild of polychaetes at different depths during SS261 (a) and SS292 (b)

Likewise, in the shallow depth (SS292), the contribution of PR (increased by 21%) and SF (increased by 30%) was higher in the western margin of Andaman Islands, compared to the eastern margin. On the other hand, the proportion of SDF (decreased by 42%) and SSDF (decreased by 23%) were relatively lower in the western margin. At higher depths (200m), the contribution of PR (increased by 53%) and SSDF (increased by 49%) was higher in the eastern margin when compared to western margin, whereas, contribution of SF decreased (by 65%). The contribution of SDF was almost equal in both margins.

Significant latitudinal variations in the abundance of SDF (F=10.1, P=0.044) and SSDF (F=86.721, P=0.001) was observed at 50m depth contour of AS sector. Significant decreasing trend in the abundance of PR (r= -0.639, p=0.047) and SF (r=-0.747, p=0.0133) with increasing latitude were observed in the shallow depth strata (50m) of the AS sector whereas SDF (r=0.779, p=0.008) and SSDF (r=0.767, p=0.010) exhibited significant increase. In higher depth (200m) of the AS sector, SF (r=-0.846, p=0.034) exhibited a decreasing trend with increasing latitude.

V. 2. 6. Linking polychaete distribution to environmental parameters

Statistical analysis was done to test for correlations between biological parameters, namely number of species (S), species richness (d), diversity (H’), evenness (J’) and environmental variables using Pearson’s coefficient (Table 5.6). The number of polychaete species (S), species richness (d), species evenness (J’) and species diversity (H’) exhibited significant negative correlation with increasing depth (S: r= -0.474, p=<0.001, d: r= -0.485, p=<0.001, J’: r= -0.295, p=0.008, H’: r= -0.486, p=<0.001). In regard to hydrographic parameters the number of polychaete species, species richness and diversity showed significant positive correlation with DO [S: r=0.523, p=<0.001, d: r=0.507, p=<0.001, H’: r=0.493, p=<0.001] and temperature [S: r=0.430, p=<0.001, d: r=0.433, p=<0.001, H’: r=0.436, p=<0.001] and were negatively correlated with salinity [S: r= -0.505, p=<0.001, d: r= -0.493, p=<0.001, H’: r= -0.473, p=<0.001] (Table 5.6). With respect to sediment parameters, the number of polychaete species, species richness and diversity showed positive correlation with sand (S: r= 0.337, p=0.003, d: r= 0.348, p=0.002, H’: r=0.366, p=0.001) and MGZ (S:

r= 0.305, p=0.008, d: r=0.316, p= 0.006, H’: r= 0.319, p=0.006) while negatively correlated to silt [S: r= -0.305, p=0.007, d: r= -0.299, p=0.008, H’: r= -0.317, p=0.005], clay [S: r= -0.290, p=0.011, d: r= -0.340, p=0.002, H’: r= -0.349, p=0.002] and OM [S: r= -0.338, p=0.003, d: r= -0.340, p=0.002, H’: r= -0.352, p=0.002]. Among these significant negative correlation was with clay (r= -0.432 p=<0.001) (Table 5.6). Average taxonomic distinctness (Δ+) of polychaete species around ANI were positively correlated with DO (r=0.378, p=0.001), temperature (r=0.421, p=<0.001), sand (r=0.306, p=0.007), and MGZ (r=0.359, p=0.002) while it was negatively correlated with depth (r= -0.567, p=<0.001), salinity (r= -0.382, p=0.001), silt (r= -0.31, p=0.004), clay (r= -0.153, p=0.180) and OM (r= -0.417, p=<0.001) (Table 5.6).

BIOENV analysis was carried out using the 9 measured environmental variables (Depth, DO, Temperature, Salinity, Sand, Silt, Clay, MGZ and OM), along with polychaete species abundance data. The result revealed that depth, clay and OM were the best subset of environmental variables, that could explain maximum variation in faunal composition among the sites, with a Spearman correlation coefficient, ρ of 0.363 (Table 5.7). Canonical correspondence analysis (CCA) was carried to elucidate the influence of environmental factors on the polychaete communities in the study area. Monte carlo permutation test was used to find out significant environmental variables responsible for the variance in species composition. The CCA axis 1 (eigen value 0.282) and axes 2 (eigen value 0.155) explained 40.21% and 22.09% respectively of the variation in the data. The CCA axis 1 was the major axis separating stations based on depth and depth related factors (DO, salinity, temperature, sand, silt, clay, MGZ, OM) into shallower and deeper sites (Fig. 5. 15 a,b; Table 5.8).

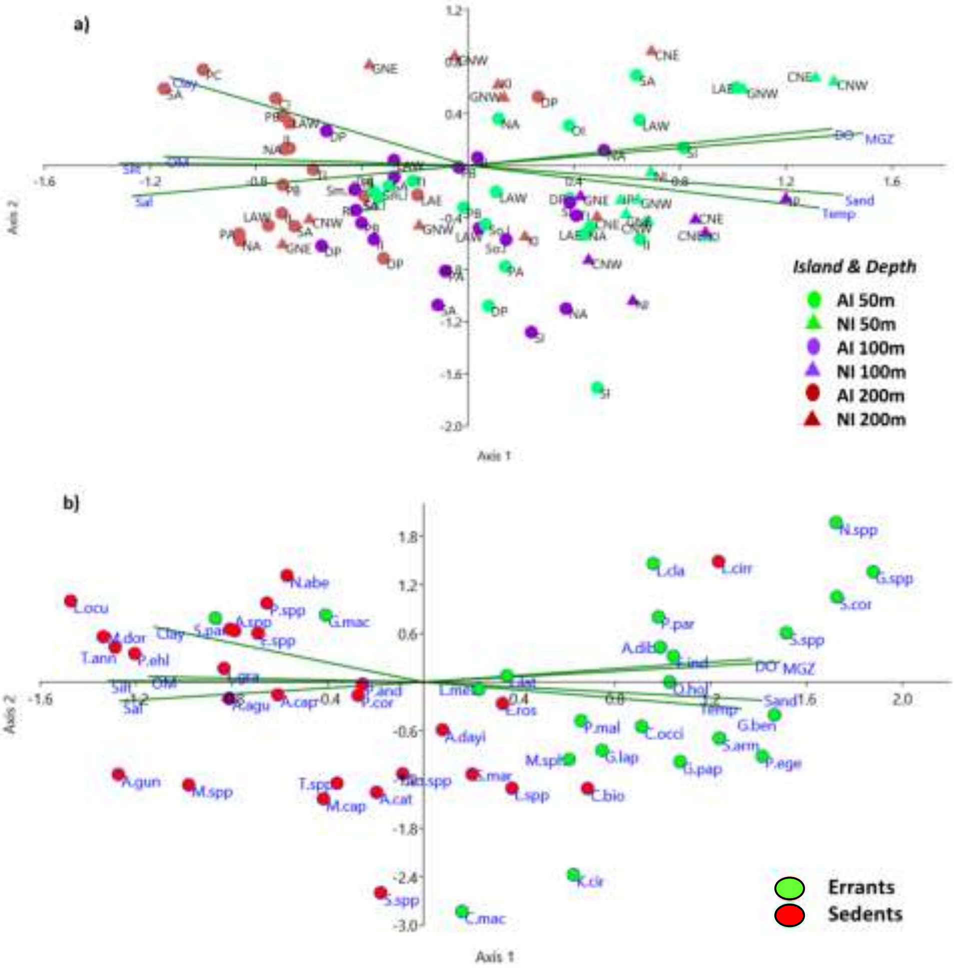


Fig. 5.15. Canonical Correspondence Analysis (CCA) plot showing scatter plot of each site (a) important influential species (b) in the study area

The shallow depth sites (50m) of ANI were characterised with highly oxygenated waters with relatively high temperature, with coralline sandy substartum comprising of large grain-sized particles. Errant polychaete species like *Aglaophamus dibranchis, Micronephtys sphaerocirrata, Syllis cornuta, Syllidia armata, Protodorvillea egena, Leocrates claparedii, Chrysopetalum occidentale, Eunice indica, Onuphis holobranchiata, Glycera papillosa, Glycera benguellana, Glycera lapidum, Phyllodoce malmgreni, Paralacydonia paradoxa, Neries* spp., etc. were relatively more abundantat at this depth. Exceptions were seen in 50m depth of certain transects, like Table Island, Smith Island, South Andaman, Rutland Island etc.

The 100m stations showed conditions intermediate between the shallow and deeper areas. The 100m stations of Nicobar Islands showed higher affinity to the shallow sites, owing to the relatively high DO, coralline sandy sediments with relatively high abundance of *Glycera lapidum, Glycera benguellana, Syllis* spp*.,* etc. Certain 100m stations of Andaman Islands (Spike Island, North Andaman, Table Island) also showed more similarity to shallow sites with highly abundant species like *Eunice indica, Micronephtys sphaerocirrata, Syllis* spp*., Glycera papillosa* etc. The 100m stations of the Andaman Islands (west coast of Little Andaman Island, Duncan Passage, South Andaman, Port Andaman, Interview Island, Smith Island, Port Blair, Rutland Island) were characterised by higher silt content, and with relatively high abundance of species like *Aonidella dayi, Spiophanes* spp*., Prionospio (Minuspio)* spp*., Ampharete agulhaensis, Levinsenia gracilis, Prionospio* spp. etc.

The higher depth sites (200m) were characterised with low DO (<0.5ml l^{-1}), relatively low temperature, high salinity and substratum made of fine sediments (relatively high silt content) with high OM content. Oxygen minimum conditions were noted on both margins of the Andaman Islands (150-200m). The communities in this region exhibited relatively higher abundance of species like *Ampharete agulhaensis, Amphicteis gunneri, Levinsenia gracilis, Aricidea capensis, Prionospio* spp*., Prionospio* (*Minuspio)* spp*., Prionospio ehlersi, Tharyx annulosus, Sigambra parva* etc. At these depths, South Andaman, Port Cornwallis, Cinque Island transects, having moderate clay content along with silt, were dominated by

Kirkegaardia dorsobranchialis, Levinsenia oculata, Ampharete agulhaensis, Notomastus aberans, Ampharete spp., *Aricidea* spp., *Euclymene* spp. etc. In the case of Nicobar Island, the oxygen minimum conditions (>0.5ml l^{-1}) were observed at depths beyond the present sampling depths (~250-300m). At the 200 m sites off this island group, the substratum was sandy with low silt content and the region harboured species like *Syllis* spp., *Glycera* spp., *Glycera benguellana, Glycera lapidum, Goniada maculata, Eunice indica, Prionospio* spp., *Aonides* spp., *Laonice* spp. etc. Exceptions were seen along certain transects around ANI viz. east coast of Little Andaman Island, Spike Island, east coast of Car Nicobar Island, Katchall Island.

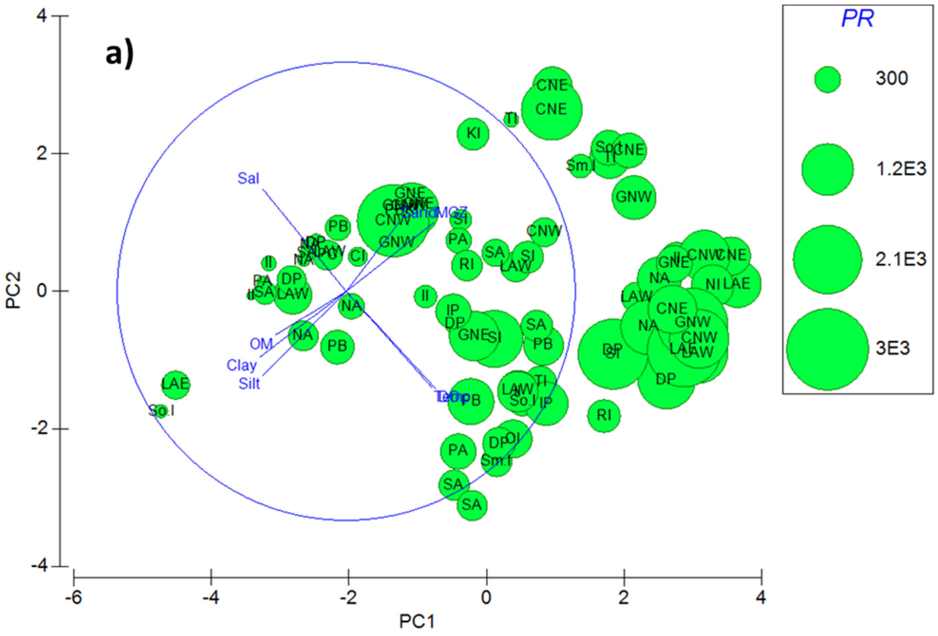


Fig. 5.16. PCA plot of environmental variables with superimposed bubbles that indicate feeding guild of polychaetes a) Predators (PR)

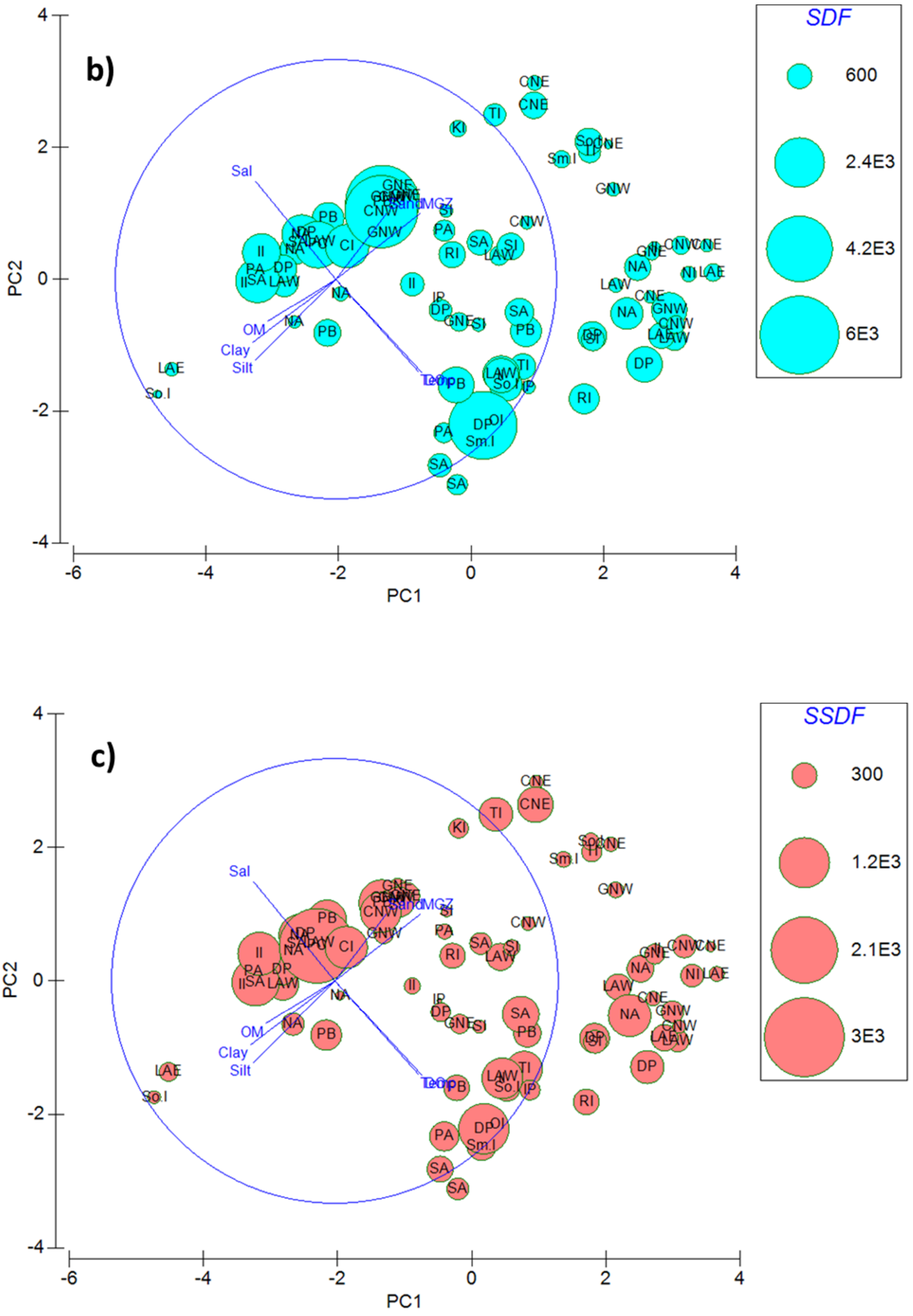


Fig. 5.16. PCA plot of environmental variables with superimposed bubbles that indicate feeding guild of polychaetes b) Surface deposit feeders (SDF), c) Sub-surface deposit feeders (SSDF)

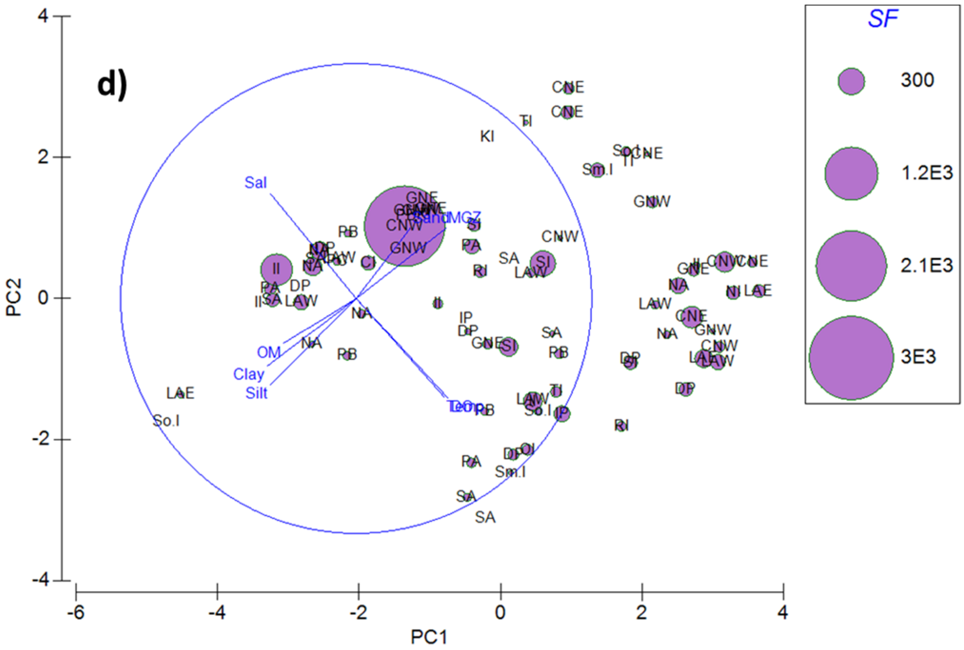


Fig. 5.16. PCA plot of environmental variables with superimposed bubbles that indicate feeding guild of polychaetes
d) Suspension feeders (SF)

The abundance of PR exhibited positive correlation with DO (r=0.530, p=<0.001), temperature (r=0.417, p=<0.001), sand (r=0.319, p=0.004), MGZ (r=0.4217, p=<0.001) and negative correlations with depth (r=-0.465, p=<0.001), salinity (r=-0.540, p=<0.001), silt (r=-0.325, p=0.003) and OM (r=-0.303, p=0.006) content. SDF exhibited positive correlation with clay (r=0.427, p=<0.001) and weak negative correlation to grain size (r=-0.242, p=0.029). SSDF showed weak positive correlation to clay (r=0.343, p=0.002) and weak negative correlation to MGZ (r=-0.261 p=0.018) of sediments. (Table 5. 5). SF did not show significant correlation with any of the environmental parameters.

In order to link the distribution of polychaete feeding guilds with the overall environmental conditions in the study area as a whole, the abundance of each feeding mode (PR, SDF, SSDF, and SF) in each site were superimposed as bubbles on the environmental PCA plot (Fig 5. 16). The density of PR was high in the 50m sites, which were characterised by coralline sandy sediments and high DO content. Density of PR gradually progressively reduced to higher depths (200m), where sandy silt sediments with relatively high OM formed the substratum and DO content was low. Exceptions were seen in the 200m sites of Nicobar Islands, where sediment was relatively more sandy, and DO was relatively higher compared to Andaman Islands. Density of SDF and SSDF were higher at the 200m sites, when compared to the 50m sites. Density of SF was relatively low in the study area as a whole.

V. 3. Discussion

The present study on the polychaete communities of Andaman and Nicobar insular margin recoreded 606 species, including new and possibly endemic species, and with many species being new records to the archipelago or to the northern Indian Ocean (Plates II-IV). A new species of obrbiniid polychaete *Pettibonella shompens* Gopal *et al.* 2014, was described through the present surveys, based on specimens collected from a single site (50m, depth off Car Nicobar Island), and named after the dwindling Shompen tribe native to the Nicobar Islands (Gopal *et al.* 2014; Appendix 2). This is only the second species to be described under this genus (after the type *Pettibonella multiuncinata* Solis-Weiss & Fauchald, 1989), which is characterised by distinctive swan-shaped hooks in abdominal setigers. A second new species in family Opheliidae - *Armandia sampadae* Gopal *et al.* 2016, was also described through the present surveys at 50m depth off Rutland and North Andaman Islands (Andaman Islands), and was named after the research vessel FORV *Sagar Sampada*. This species was found to be distinct from all 31 species of the genus owing to the presence of a pair of large, flattened, rounded, stalked, pigmented, leaf-shaped ventral papillae at the ventral base of the ringed anal funnel and occurrence of a pair of sub-triangular black pigmented spots in the basal portion of the ventral papillae (Gopal *et al*., 2016, Appendix 2). Another species of the family Euphrosiniidae *Palmyreuphrosyne* sp., collected off Car Nicobar Island (50m) is recorded for the first time from the Indian Ocean, and this is the rediscovery of the genus after a century. A very rare deep-sea brittle star species, *Ophiomyces delata* (Ophiohelidae) was collected among macrofauna at an unusually shallow depth (54m) in the Duncan Passage (Andaman Islands). This represented the first record of the ophioheline lineage in the shelf sediments since the Jurassic, and it could provide insights into the evolutionary history and systematics of the family (Parameswaran *et al*. 2016, Appendix 2).

Earlier studies within the intertidal and coral reef areas of ANI have reported 188 species of polychaetes (Fauvel 1953, Tampi & Rangarajan, 1964; Soota *et al*., 1977; James *et al*., 1969; Misra & Chakraborty, 1991; Rao, 2010; Rajasekaran & Fernando, 2012; Veeramuthu *et al*., 2013). The present surveys record markedly higher numbers of polychaete species (606 species) compared to other continental and island margins of India. Along the continental shelf (30-200m) of the Indian peninsula, Joydas & Damodaran (2009) reported 165 species from entire eastern Arabian Sea, Ganesh & Raman (2007) recorded 60 species from north western Bay of Bengal, Manokaran *et al*. (2015) recorded 113 species from south western Bay of Bengal and Misra & Chakraborthy (1991) recorded 69 species from the reefs areas of Lakshadweep Islands. Among 606 polychaete species recorded in the present study, 212 species occurred only in a single site (singletons) and 94 species occurred in exactly two sites (doubletons). In total, 306 polychaetes having limited occurrence (rare species) accounted for 50% of the species diversity in the study area (Fig. 5. 17). According to species estimators, about 65% sampling sufficiency was achieved through the present study, which points to the possibility of encountering more species of polychaetes with intensive sampling. This indicates that the ANI support exceptionally high macrobenthic polychaete diversity.

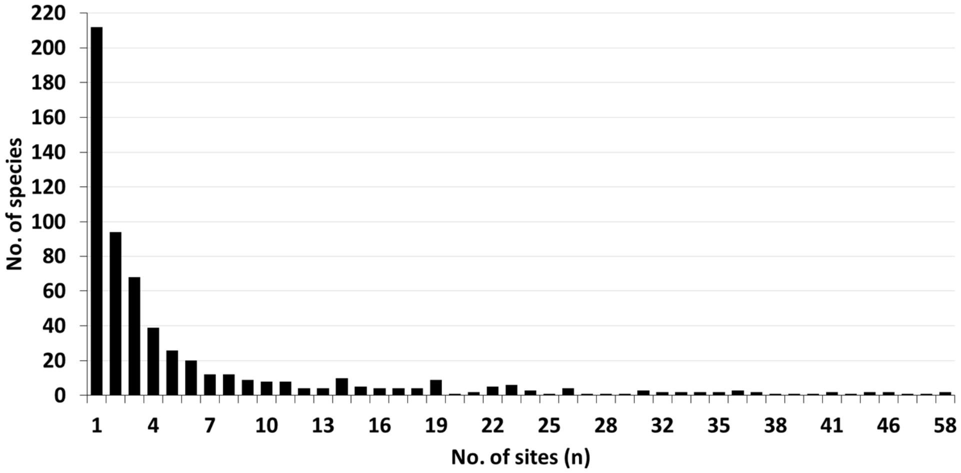


Fig. 5. 17. Proportion of rare species based on number of species (y axis) occurring at exactly n sites (x axis)

In the present study, significant variations were observed among polychaete fauna collected using two distinct sieve (mesh) sizes, with 11% increase in species richness in the finer mesh sieve (300µm). The increase in number of species in the finer mesh sieve was mainly due to retention of small sized species. The observed species richness and species diversity of polychaetes showed significant bathymetric variations in the finer mesh sieve (300µm), while diversity indices were not significant in the larger mesh sieve (500µm) revealing that interstitial species were a major contributor to diversity in the region, especially in the near-reef areas.

During the present study, highest polychaete species richness and diversity were recorded in the vicinity of reefs, which decreased with increasing depth. The decreasing trend in species richness and diversity of polychaetes is well reported in the tropical continental shelves of the northern Indian Ocean (Ganesh & Raman, 2007; Joydas & Damodarn, 2009; Manokaran *et al*., 2015; Abdul Jaleel *et al*., 2015) and island margins (Riddle, 1988; Chatananthawej & Bussarawit, 1987; Rivonker & Sangodkar, 1997; Ibrahim *et al*., 2006; Bigot *et al*., 2006; Przeslawski *et al*., 2013). However, in contrast to other margins of the northern Indian Ocean, species evenness was very high in all three depth strata in the present study (J'>0.9). The higher diversity in the near-reef areas was due to high diversity in families like Syllidae, Hesionidae etc., which are mainly interstitial forms that reside in the interstitial spaces of the coarse coralline sands, and which were more prominently represented in the finer mesh sieve. With increasing depth, species belonging to families Spionidae, Cirratulidae and Paraonidae, which have smaller body size, and are able to thrive in low oxygen conditions in fine sediments, contributed significantly to the difference in diversity between the coarser and finer mesh sieves.

The use of smaller mesh sieves are necessary in an oligotrophic margin, where organic matter reign is low to the bottom and where small-sized individuals constitute important components of the fauna. In the highly productive eastern boundary upwelling system of the SEAS, significant qualitative distinctions were not observed with the use of finer mesh sieves, despite the marked increase in standing stock during the upwelling season (Nikitha, 2016). By contrast, the use of coarser mesh sieves in oligotrophic environments may lead to under representation or omission of small sized and rare interstitial species (e. g. Sphaerodorids, Fabriciidae, Scalibregmatidae, Saccocirridae, Iphionidae, Protodriliidae, Questidae), which are important components of biodiversity in such regions. This in turn will reduce the precision of species richness estimates, diversity and evenness (Gage *et al*., 2002). Thus, the use of smaller sieve size proves better suited for studying species diversity under oligotrophic conditions (Hessler 1974; Gage *et al*., 2002, Pavithran *et al*., 2009).

The polychaete communities of the study area could be delineated into two distinct regional assemblages – in the Andaman group of Islands (AI) and Nicobar group of Islands (NI). The distinctions in polychaete assemblages among island groups may be due to local-scale processes (McArthur *et al*., 2010), variations in geological and oceanographic features like seascape complexity, seabed morphology, currents, bed shear stress, topographic relief, , distance from the reefs, habitat complexity etc. (Thrush *et al*., 2001; Pitcher *et al*., 2008; Buhl-Mortensen *et al*., 2010; Anderson *et al*., 2013; Martins *et al*., 2013), which leads to spatial variations in hydrographic regime, productivity, sediment texture, biological interactions (competition, predation etc.) and ultimately results in heterogeneity (Rex *et al*., 1981; Vroom *et al*., 2005) in population density, presence of rare species etc.

Variations in species composition among the islands groups (AI and NI) and within the island margins (western and eastern margins of Andaman Islands) is attributed to the presence of rare species and variation in the percentage contribution of common species. The proportion of rare species strongly influences the beta diversity (Routledge, 1977) and high diversity is often related to the number of rare species, which are organisms having low abundance or narrow distributional range (Brown, 1984; Gaston, 1994; Ellingsen *et al*., 2007) that are relatively more vulnerable to environmental stress (Thomas & Mallorie, 1985). The most species-rich sites around Andaman and Nicobar Islands harboured many rare species, with respect to abundance and range size (Ellingsen, 2001, 2002, 2007). A total of 509 species were recorded around the Andaman Islands, out of which 276 species were limited occurrence (191 singletons and 85 species doubletons). Likewise, in Nicobar Islands 326 species were recorded, of which 250 species had limited occurence (134 singletons and 116 doubletons). The number of singleton species was 37% higher in the finer mesh sieve (183 species in 300µm and 127 species in 500µm) and doubletons increased by 12% in finer mesh sieve (75 species in 300µm and66 species in 500µm). The highest number of singleton species was recorded in the near reef areas (204 species at 50m), when compared to higher depths (157 species at 100m and 140 species at 200m). Occurrence of rare species is usually related to habitat specificity, environmental tolerance and dispersal ability of these taxa (Gaston, 1994; Gaston *et al.*, 1997). Rare species tend to be relatively less tolerant to changes in environmental conditions, and thus, such taxa were more preponderant in the relatively well oxygenated, heterogeneous subtrates in the near-reef areas. With increasing depth, the environmental conditions changed restricting the range size of the rare species (Thrush *et al.*, 2001; Hewitt *et al.*, 2005). Rare species influence the stability and resilience of soft sediment communities (Folke *et al.*, 1996; Naeem & Li, 1997), are major contributors to ecosystem functioning, and are indicators of ecosystem health.

Distinctions in species composition of polychaetes of Andaman Islands and Nicobar Islands may also be attributed to dispersal of larvae and their settlement. Larval dispersal is an active process which contributes to connectivity among ecosystems in the marine realm (Pilditch *et al.*, 2015) and for maintenance of biodiversity. Most marine benthic invertebrates have planktonic larvae which have great dispersal abilities, and the settlement of the larvae in suitable habitats structures the species composition of an area (Carson & Hentschel, 2006). The suitability of habitats can vary with space and time, greatly affecting the dispersal, settlement and survival of larvae. Based on the life history traits, the dispersal potential of polychaete larvae is divided into three categories - high, medium and low (Carson & Hentschel, 2006). The high dispersal category includes species which can disperse over several kilometres and can exchange larvae with other populations. Medium dispersal species can disperse only few kilometres, while the low dispersal category includes those species whose larvae less than 1 km, and those having direct development (Hellberg, 1996; Shanks, 2009). Planktotrophic larvae have a high dispersal ability, lecithotrophic larvae have medium dispersal abilities (Todd, 1998) and epitokes, which are pelagic morphs (e. g. Syllids) capable of sexual reproduction and swimming (Franke, 1999), have low dispersal abilities. In general, common and widely distributed species have larvae which have high dispersal abilities while the rare species are those with low dispersal potential larvae.

The recirculating currents, coastal boundary currents and oceanographic process prevailing in a region affect larval settlement and persistence of a species in an area (Largier, 2003; Parker & Tunnicliffe, 1994). The settlement of larvae includes behavioural searching phase (Rodriguez *et al.*, 1993; Qian, 1991; Qian & Dahms, 2005) and recognition for visual and chemical cues (Woodin 1991; Pawlik 1992; Woodin *et al.*, 1993; Rodriguez *et al.*, 1993; Rittschof *et al.*, 1998; Qian, 1999; Carson & Hentschel, 2006). The environmental cues can be organic constituents in the sediments (e. g. for *Capitella* sp.), bacterially derived settlement cues (e. g. *Hydroides elegans*), turbulent flume flows, sediments elements for tube building (*Eupolymnia nebulosa*), sand grains and tube cement (e. g. Sabellariids), fatty acids (e. g. *Capitella* sp.), carbohydrates, peptides, inorganic ions, biofilms, bacteria, hydrogen sulphide (e. g. *Capitella* sp.) etc. and species-specific traits (Turner *et al.*, 1997) such as the presence of adult colonies (e. g. Sabellarids and Serpulids). In high energy environments (strong waves and currents), post settlement dispersal is pronounced, but organisms which can burrow deeper or actively emerge will oppose their transport along the substratum as bedload (Lundquist *et al*., 2006).

Taxa with low dispersal potential include species of families Syllidae, Sphaerodoridae, Trichobranchidae, Maldanidae etc., medium dispersal potential families includes Terebellidae, Ampharetidae, Sabellidae, Orbiniidae, Onuphidae, Nereididae, Dorveliidae, Cirratulidae and high dispersal potential families include Spionidae, Sigalionidae, Serpulidae, Sabellariidae, Polynoidae, Poecilochaetidae, Phyllodocidae, Pectinariidae, Oweniidae, Opheliidae, Nephtyidae, Magelonidae, Glyceridae, Goniadidae, Eunicidae, Capitellidae, Chaetopteridae, Amphinomidae (Carson & Hentschel, 2006). Densely populated patches of infaunal invertebrates often maintain their dominance in the community by preventing the recruitment of larvae of other species (Woodin, 1976). Bioturbators suffocate larvae, tube builders exclude larvae through preemption of space and defecation on the sediment surface, suspension feeders filter larvae from plankton and meiofaunal predators preys on settling juveniles (Watzin, 1983, 1986), and hydrodynamics may even help to settle the larvae on the substratum.

The Andaman group of Islands is more or less a single mass of island above the Ten Degree Channel, whereas the Nicobar Islands are comprised of small broken islands below this channel. The hydrodynamic conditions in the Nicobar Islands are relatively more active compared to Andaman Islands, and the influence of hydrodynamic conditions on the substratum was clear on the sediment texture as well as organic matter content. The two island groups offer significantly distinct settlement regimes to polychaete larvae, which are reflected in the distinct species composition in the

Andaman Islands and Nicobar Islands. Gray *et al*., (2005) and Fontana *et al*., (2008) suggested that in macrobenthic communities presence of rare species can mainly be attributed to immigration from outside the sampled area. Moreover, the Andaman Sea is connected to South China Sea towards the south, through the Malacca Strait. The seasonal transport of water (Raju *et al*., 1981; Ibrahim & Yanagi, 2006; Daryabor *et al*., 2016) flowing through the Malacca Strait to Andaman Sea from South China Sea may be facilitating dispersal of polychaete larvae from the Coral Triangle, which extends from the Philippines to the Solomon Islands and an epicentre of marine diversity (WWF, 2008), comprising of 76% of the total known species of the world (Veron *et al*., 2009). High polychaete diversity is reported along the eastern margin of the Andaman Sea, off western Thailand (Bussarawit *et al*., 2008), and also in the present study area (western Andaman Sea, east coast of ANI).

Habitat complexity in the form of sediment grain size and texture (McCallum *et al*., 2015) around ANI may also be a major reason for the distinction between the two island ecosystems. In the near-reef areas (50m) of both island groups, coralline sandy sediments with coral fragments, gravel etc. enabled the colonisation by more polychaete species, and supported higher richness. The intermediate sites (100m), were characterised by heterogeneous (silty sand) sediments, in the Andaman Islands, and sandy sediments in the Nicobar Islands. The substrates at the higher depths (200m) of both island groups were predominantly silty around the Andaman Islands, and texture was sandy with low silt content around the Nicobar Islands. At these higher depths (100 and 200m), diversity was relatively lower than the near-reef areas. Habitat structure and habitat complexity (Zajac, 2008; Cordes *et al*., 2010; Weinstein *et al*., 2015) strongly influence variability among individual sites, in terms of macrofaunal abundance and species composition. Within the shallow depths of the Andaman Islands, localised differences in sediment texture around off South Andaman, Port Andaman, Smith Island, Sound Island, etc. with relatively silty sediments, was a major factor influencing distinctions in species assemblages. Habitat complexity increases community stability by decreasing population oscillations, provides refuge from predation, increase the availability of breeding grounds, resource partitioning, microhabitat availability, compartmentalization, number of pathways for energy flow, OM interception, biodiversity etc. (Mortensen *et al.*, 1995; Kovalenko *et al.*, 2012). Habitat complexity enhances the co-existence of species by offering a variety of niches and reducing niche overlap, thereby increasing species richness (Smith *et al.*, 2014).

Sediment stability, a major factor influencing the composition of benthic assemblages and is affected by boundary layer flow regimes (Newell *et al.*, 1998), drag and lift forces on the substratum. The drag on the substratum is dependent on the flow direction and velocity of the flow, while the stability of the substratum depends on slope, particle size and degree of water motion on bed (Bagnold, 1963). The ANI have steep slope, with sharp depth gradients and the depth range 50 to 200m is extend to only <10nm. Those organisms which can withstand the flow velocity or drag forces, by virtue of structural or biological characteristics, appendage stiffness and morphology etc. will establish themselves in the substratum. Some organisms can cope with ambient hydrodynamic conditions by switching feeding modes between deposit feeding and suspension feeding, in response to flow and sediment transport regimes, and this has been well reported among polychaetes (Fauchald & Jumars, 1979; Dauer *et al.*, 1981). Besides these, the seafloor topographic complexity also plays a role in the distribution of benthic organisms as it determines habitat availability, regulates foraging patterns, alters boundary layer flow, affects larval settlement, oxygen transport, sediment deposition and erosion and deposition of organic matter (Ke *et al.*, 1994; Widdows *et al.*, 1998; Green *et al.*, 1998; Erlandsson *et al.*, 1999; Lenihan 1999; Kostylev *et al.*, 2003). Localised variations in sediment stability and habitat complexity may contribute significantly to the observed patterns in community compositions in the present study.

The shallow reefs in the tropical belt supports the world's greatest diversity of marine organisms (Roberts *et al.*, 2002) that form hotspots of biodiversity, with invertebrates being major contributors (Gray, 1997; Stella *et al.*, 2011). In the present study, highest species richness and diversity was recorded in the vicinity of reef areas of ANI. The effect of vicinity to reefs results in "reef halos", which refers to areas of high benthic diversity and abundance (Posey and Ambrose, 1994; Langlois *et al.*, 2005; Demopoulos *et al.*, 2014). Around ANI extend upto 50-75m depth, with wide reef flats having a width of 200-500m (UNEP/IUCN, 1988; Bahuguna & Nayak, 1998; Brown, 2005; Mahendra *et al.*, 2010; Velloth *et al.*, 2014). The three dimensional habitat complexity of the reefs also enhances the diversity of fauna in the reefs and adjacent areas (Wilson *et al.*, 2007; Demopoulos *et al.*, 2014). The typical polychaetes in the near-reef areas of the study area were Syllids, Aphroditids, Polynoids, Eulepethids, Pholoids, Acoetids, Sigalionids, Nereids, Sabellids, Pectinariids, Serpulids, Sphaerodorids etc.

Syllids were the most species-rich taxon in the shallow coralline sediments of the study area as they are highly motile and are able to occupy the interstitial spaces owing to their relatively small size (Martins *et al.*, 2013). Syllids were found to dominate in reef derived of carbonate sediments along the middle and outer shelf reefs of central Great Barrier

Reef (Riddle, 1988) and south west Indian ocean seamounts. Tube dwelling suspension feeders like Sabellids, Serpulids, Oweniids, Pectinariids were highly abundant in the the near-reef areas (Flint and Rabalais, 1980; Gravina *et al.*, 1989; Narayanaswamy *et al.*, 2017), because many of these (e. g. sabellids, oweniids, pectinarids) have agglutinated tubes built from small sediment particles fastened together with matrix-organic cement. In the case of serpulids, the tubes are calcareous and they are important encrusting organisms in many marine communities especially in coral reefs, forming extensive reef structures (ten Hove, 1979; ten Hove & Hurk 1993).

Polychaete families like Aphroditidae, Polynoidae, Eulepethidae, Pholoidae, Acoetidae and Sigalionidae, known as 'scale worms' along with nereids, are active predators, preferring the well-oxygenated coarse sandy sediments, preying on small-sized interstitial fauna within reef halos. Among these, Acoetidae and some species of Sigalionidae possess spinning glands, which produce chaetal fibres for entrapping sand grains to construct tubes (Rouse & Pleijel, 2001). Eunicids and Onuphids are known to occupy dig galleries in dead coral skeletons, using their well-developed jaws or live attached to the interstices of coral, sponges, or coarse sand (Myers, 1972; Hutchings, 1981; Fauchald, 1992). Amphinomids are known to be destructive organisms in the reef areas as they feed on live corals and associated fauna (Kohn & Lloyd, 1973). Small sized polychaetes like Sphaerodorids, *Protodrilus* spp., *Saccocirrus* sp., *Questa* sp. were collected only in finer mesh sieve (300µm), indicating that these are among the resident interstitial taxa in the near-reef sediments (Dorgham *et al.*, 2014). The coralline sandy sediment with coral rubble, gravel, shells, spicules etc (poorly sorted) which itself is a measure of structural complexity provide enough microhabitats for polychaetes to dwell, move and feed. Such heterogeneous sediments with larger grain size harbours greater number of species (Gray, 1974; Etter & Grassle, 1992; McCarthy *et al.*, 2000) as it favours colonisation of both errants (predators) and sedents (deposit and suspension feeders). Similarly, high diversity of polychaetes species have been reported in the coralline sandy sediments along the island margins (McCarthy *et al.*, 1998, 2000; Mackie *et al.*, 2005; Demopoulos *et al.*, 2014; Sibaja-Cordero *et al.*, 2016; Ruiz-Abierno & Armenteros, 2017). The errant polychaetes were the major group within the depth stratum of the study area, with dominant carnivorous species like *Micronephtys sphaerocirrata, Keferstenia cirrhata, Syllis cornuta, Opisthodonta longicirrata, Protodorvillea egena, Chrysopetalum maculata, Eunice indica, Onuphis holobranchiata, Glycera* spp.*, Goniada maculata, Lumbrineries meteorana* and *Neries* spp.

Besides habitat complexity, other habitat related factors also play a major role in determining the polychaete species assemblages in a region. Prevailing hydrodynamic regime affects the sedimentary characteristics, hydrography etc., which influence the establishment and maintenance of animal-sediment relationships (Snelgrove & Butman, 1994). Significant bathymetric variations in polychaete assemblages were evident in the insular margin of Andaman and Nicobar. Species richness and diversity of polychetes decreased with increasing depth and the variations in species assemblages along the depth gradient were due to differences in bathymetric range size of a species, which were related to its tolerance to local or regional environmental conditions. These include nature of current energy, productivity, substratum, depth, temperature, salinity, dissolved oxygen (hydrographic parameters) and sand, silt, clay, median grain size, organic matter (sedimentary parameters) etc. (Glover *et al.*, 2002; Hernandez-Alcantara *et al.*, 2014; Snelgrove & Butman, 1994; McArthur *et al.*, 2010). Studies on macrofauna associated with deep-sea *Lophelia pertusa* habitats in the Gulf of Mexico (Demopoulos *et al*., 2014) depicted significant differences in macrofaunal community compoition among near-coral and background sediments, demonstrating that taxa turnover happens (fully or partly) as distance increases from the reefs. The polychaete assemblages of the intermediate depth stratum (100m) were showing intermediate characteristics, between shallow and deeper strata. The intermediate sites around the Nicobar Islands were characterised by fairly high DO and silty sand substrata. The most abundant species in this island group were mainly errants like *Glycera lapidum, Syllis cornuta, Glycera benguellana, Protodorvillea egena, Syllis* spp*.,* and *Chrysopetalum occidentale*. In the Andaman Island group, the transects like Spike Island, North Andaman and Table Island were typified bysandy sediments, similar to the shallow, near-reef sites. Species (errants) like *Chrysopetalum maculata, Kefersteinia cirrhata, Syllis cornuta, Pionosyllis ehlersi, Syllis* spp*., Glycera lapidum, Eunice indica, Tharyx* spp*., Cauleriella bioculata, Aricidea lopezi, Amphicteis gunneri* and *Laonice* spp. were typical taxa in these sites. The other intermediate depth sites of Andaman Islands showed similarity to deeper sites in having silty sand sediments, with relative dominance of sedent species like *Aonidella* spp., *Spiophanes* spp., *Prionospio* (*Minuspio*) spp., *Laonice* spp., *Prionospio* spp., *Amphicteis gunneri*, *Ampharete agulhaensis*, *Aricidea lopezi* and *Aricidea* spp.

Prevalence of OMZ conditions (<0.5 mll^{-1}) around Andaman Islands was observed at a depth range of 150-200m and even at 100m in the northernmost sites. But in the case of Nicobar Islands, the DO at the 200m depth strata was >0.5 mll^{-1}. The relatively active hydrodynamic conditions around Nicobar Islands, as reflected by the higher DO levels and relatively sandy sediment texture with low silt content. These conditions support certain errant polychaetes to thrive in conjunction with sedents around the

Nicobar Islands (200m). The species causing similarity among the deeper sites of the Nicobar Islands were *Notomastus aberrans, Goniada maculata, Prionopsio* spp*., Sigambra parva, Glycera* spp*., Eunice indica* and *Ampharete* spp. In the case of Andaman Islands, the deeper depth were characterised with sandy silt substratum and relatively high organic matter with oxygen minimum conditions. High densities of Spionids, Cirratulids, Paraonids and Ampharetids were found in this depth stratum (Gallardo *et al*., 2004; Hughes *et al*., 2009; Ingole *et al*., 2009; Joydas & Damodaran, 2014; Abdul Jaleel *et al*., 2014; Raman *et al*., 2015) of Andaman Islands.

Species inhabiting such adverse conditions are known to possess adaptive morphological structures (Lamont & Gage 2000; Smith *et al*., 2000; Levin 2003). Spionids were the relatively abundant group among polychaetes in the low oxygenated depths (200m) of Andaman Islands, chiefly represented by *Prionospio phuketensis, Prionospio andamanensis, Prionospio (Minuspio)* spp*., Spiophanes* spp*., Laonice* spp*.,* etc. These species have extended branchiae, particularly at the anterior end of their body. Likewise, among Paraonids, *Aricidea lopezi*, *Levinsenia oculata* and *Levinsenia gracilis* were abundant in such conditions, revealing that their small size with high surface area volume ratio and branchiae enhances their capacity for oxygen uptake from oxygen deficient waters (Levin, 2003; Abdul Jaleel *et al*., 2014). Cirratulids were another dominant group, with species like *Kirkegaardia dorsobranchialis* and *Tharyx* spp., having thread like branchiae in their entire body (Jayaraj *et al*., 2008; Abdul Jaleel *et al*., 2014). Among Ampharetids, *Amphicteis* spp., was the dominant species which also possesses well developed branchial structures in the anterior end.

In the OMZ impacted areas of the northern Indian Ocean, *Prionospio* spp*., Spiophanes* spp., and *Cossura coasta* are the dominant species along

Bay of Bengal (Raman *et al.*, 2015); *Prionospio pinnata, Prionospio cirrifera, Prionospio cirrobranchiata, Prionospio polybranchia, Aricidea fauveli, Cirriformia* spp., *Aonides oxycephala*, *Mediomastus* spp., *Tharyx* spp., *Cossura coasta*, *Levinsenia gracilis* and *Levinsenia oculata* dominated along different parts of the Arabian Sea margin (Ingole *et al.*, 2010; Joydas & Damodaran, 2014; Abdul Jaleel *et al.*, 2014), and *Prionospio* (*Minuspio*) sp. dominated off Masirah Island in the Oman margin (Gage *et al.*, 2000; Levin *et al.*, 1997, 2000; Hughes, 2009). The biochemical adaptations of some OMZ tolerant polychaete species (particularly spionids) have been studied in detail, and they reveal that pyruvate oxidoreductase enzymes are involved in their anaerobic metabolism, enabling them to survive in such hypoxic conditions (Gonzalez & Quinones, 2000; Livingstone *et al.*, 1983; Gade & Grieshaber, 1986; Schottler & Grieshaber, 1988).

According to Levin (2003), the family pattern of polychaetes in the OMZ region mirrors the hydrodynamic, bathymetric and geologic conditions rather than direct impacts of the oxygen-poor conditions. The species richness and diversity in OMZ impinged depth of Andaman Islands were relatively low (in comparison to other depths) and this was due, in part, to the disappearance of species which are intolerant to low oxygen conditions (Levin, 2003; Gallardo *et al.*, 2004; Palma *et al.*, 2005; Gooday *et al.*, 2009; Zettler *et al.*, 2009). Besides this, relatively higher OM was also a factor influencing the diversity within the OMZ regions, independent of oxygen levels (Jayaraj *et al.*, 2008). Studies in the eastern Pacific and Indian Oceans reveals that while oxygen has major control over species richness, OM availability has maximum influence on dominance and evenness (Levin & Gage, 1998) or abundance of hypoxic tolerant species (Gooday *et al.*, 2009). But later studies on Pakistan margin OMZ fauna, led Levin *et al.*

(2009) to postulate that species richness is affected by sediment OM content and quality, while diversity and dominance were affected by both OM content and DO. In addition to this, the sediment granulometry also exerts influence on macrofaunal diversity of an area (Gooday *et al.*, 2009). In the south-eastern Arabian Sea, studies conducted on the polychaete diversity of the OMZ margin (Abdul Jaleel *et al.*, 2014) showed that the polychaete assemblages in the shelf edge (200m) of the southern sector and northern sector were entirely different, with higher diversity in the hydrodynamically active area with sandy substratum within the southern sector, and lower in the silty sediments of the northern sector.

Unlike with other OMZ impinged margins, the polychaete communities of oxygen minimum areas around the Andaman Islands were characterised by relatively weaker species dominance (i. e. higher evenness), and those species adapted to low oxygen conditions had an even distribution. In other OMZ areas, the oxygen minimum zones were related to high biological conditions in the overlaying waters along with sluggish hydrodynamics, where the sediments were fine with high OM. But in the oligotrophic waters of Andaman Islands, the sandy silt substratum was moderately sorted, with a heterogeneous mixture of large (sand) and small (silt) sized grain particles, providing ample pore size for the penetration of oxygen deeper into the sediments (Weston, 1988; Abdul Jaleel *et al.*, 2014). These conditions might be supporting more diverse species assemblages, rather than proliferation of dominant species alone. Within the OMZ settings, OM availability is major factor influencing the dominance and evenness (Levin and Gage, 1998), with the continuous OM deposition in productive waters resulting in the elimination of most species and enhancing the dominance of adapted species. Studies on the macrofaunal communities on the shelf of Crete (Karakassis & Eleftheriou, 1997) showed that depth is a major gradient in the oligotrophic waters, as all the dependent variables vary concurrently with depth, and OM flux to the substratum is seriously limited. Studies conducted on the western Australian margin showed that the Leeuwin current reduces coastal nutrient levels, and energy is a limiting factor which does not reach the higher levels, which diminishes the diversity on the shelf (McCallum *et al*., 2015). The distribution of polychaetes in the study area was dependent on a combination of hydrographical and sediment characteristics prevailing in the region. The community shift in polychaete assemblages in a small depth range (50-200m) in steep depth gradients around ANI are moulded by depth related sedimentary and hydographic parameters than depth itself (Weston, 1988).

The Andaman and Nicobar Islands are oligotrophic in nature, supporting low biomass with high species richness between 50 and 200m depths. In general, hydrodynamic conditions prevailing in the region have a major influence on the food supply (in the form of OM) to benthic organisms. Most of the OM will be resuspended in hydrodynamically active sites, which will be easily used up by the selective deposit feeders at the sediment-water interphase or by the suspension feeders. The functional traits of polychaetes depend on their morphological features and the colonization of different functional groups in a region indicates the sedimentary characteristics prevailing in the region (Papageorgiou *et al*., 2009; Struck, 2011). When some species prevent another from utilizing certain food resources, indirect competition occurs, whereas if they are able to use the available resources (food and space) without competition, it implies resource partitioning. Resource partitioning is a major criteria for delineating biodiversity of a region (Sánchez-Hernández, 2017), by limiting interspecific competition, thereby controlling the number of species that are able to coexist (Schoener, 1974). High species richness around ANI might be due to resource partitioning, as availability of prey for predators would be high. The availability of diverse forms of (small-sized) prey in the study area could also support numerous selective predator taxa (Hillebrand & Shurin, 2005; Hillebrand & Matthiessen, 2009). Deposit feeders (selective and non-selective) feed on the deposited OM, and suspension feeders feed on suspended OM particles, according to their optimum particle size. Thus, segregation in resource utilization (food and space) is a major reason for the co-existence of all major feeding guild in the region. Concordantly, habitat complexity (space) enhanced the availability of food for predatory as well as OM feeders, thereby supporting high diversity within all these guilds. In the study area, the regional variations in species composition (among island groups, western and eastern margins of Andaman Islands) were attributed to the variations in the percentage contribution of the feeding guilds in each depth categories and among sites. The variation in the feeding guild groups are dependent on the availability of food, sediment nature, hydrodynamics, competition etc.

In the present study, predators (PR) were the dominant guild in the vicinity of reefs and appeared to be associated with coarse coralline sand with low OM content. The density of PR in the region is dependent on prey abundance, prey diversity, foraging mode, diel patterns, habitat segregation for feeding, which are major determinants of resource partitioning (Sánchez-Hernández *et al.*, 2017). The high population of PR in the well oxygenated, large grain-sized sediments (with greater pore size) was due to the presence of interstitial forms that are major food sources for the carnivorous polychaetes (Gaston, 1987; Maurer & Leathem, 1981; Pavia, 1993; Pinedo *et al.*, 1997; Muniz *et al.*, 1998; Muniz & Pires, 1999; Joydas & Damodaran, 2009; Dolbeth *et al.*, 2009; Castanedo *et al.*, 2011; Abdul Jaleel, 2012; Manokaran *et al.*, 2013; Han *et al.*, 2016). The most abundant predatory polychaete families in the study area like Syllids, Glycerids, Hesionids and Lumbrinerids are organisms with well-equipped jaw apparatus as well as small body size (Pagliosa, 2005), making them suitable to thrive in the vicinity of reefs. The predators that dominated the coarse sandy sediments were equipped with axial muscular pharynx, jaws, feeding palps, head appendages, parapodia with chaetae etc. In the Carnarvon shelf (Ningaloo Reef), Australia carnivores/scavengers were the dominant guild in the coralline sandy sediments (Przeslawski *et al.*, 2013). According to Cheung *et al.*, (2008), high abundance of predators is always accompanied with high environmental quality, and this is true in the case of ANI, which is an oceanic island with coral reefs.

The abundance of predators decreased by 57-70% to deeper sites as sediment texture changed to relatively sandy silt and where low oxygen levels prevailed. Further, the limited pore size of fine sediments, which forms a barrier for interstitial organisms to proliferate in low oxygen conditions. Only those PR with unarmed pharynx (e.g. Amphinomidae), which could feed in the sediment-water interface were able to thrive in such conditions (Gaston, 1987; Muniz & Pires, 1999; Pagliosa, 2005). The PR were very low in the deeper regions (200m) of the Andaman Islands, where OMZ conditions were prevalent, while at the same depth of Nicobar Islands, where the DO levels was above 0.5ml/l, the contribution of PR was much higher (1.3 times). The dominance of motile polychaetes in the shallow depths of ANI is due to the unstable nature of the habitat having high sediment movement (Gaston, 1987) and churning, under hydrodynamically active conditions and steep depth gradients. According to Muniz *et al.*, (1999), the dominance of PR is an indicator of high degree of community specialization, with high diversity.

Surface deposit feeders (SDF) are those polychaetes which feed on the sediment water interface (Fauchald & Jumars, 1979). They are equipped with well-developed feeding tentacles or palps (Spionids, Cirratulids and Ampharetids) for active feeding on OM (Pagliosa, 2005), parapodia with uncini etc. Deposit feeders utilize OM bound particles in the substratum as the food source. The percentage of deposit feeders increased with depth (13-23%) exhibiting a positive correlation with silt and OM content (Gaston, 1987; Pinedo *et al*., 1997; Muniz *et al*., 1998; Joydas & Damodaran, 2009; Abdul Jaleel, 2012; Manokaran *et al*., 2013). Deposit feeders (SDF and SSDF) prefer regions with more or less stable substratum, with low hydrodynamic activity on the sea floor, since currents restricts feeding and movement of deposit feeders (Jumars & Fauchald, 1977; Maurer & Leathem, 1980; Pagliosa, 2005; Castanedo *et al*., 2011; Mattos *et al*., 2013). Under sluggish hydrodynamic conditions, the deposition of OM in sediments is favoured, thereby supporting good populations of deposit feeders (Rhoads & Young, 1970; Castanedo *et al*., 2012). In the vicinity of reefs around ANI, where active hydrodynamic conditions prevail, substratum was coarse coralline sand with low OM, deterring the establishment of deposit feeders. In comparison to the Nicobar Islands, the percentage contribution of deposit feeders to the feeding guild around Andaman Islands was higher, and this might be due to the presence of finer sediments in shallow depths along some parts of the latter area. In the coralline sands of the reef vicinity, spionids were the most abundant family among SDF, possibly because they are able to establish in substrata with high sediment mobility (Maurer & Leathem, 1980; Dauer *et al*., 1981; Pavia, 1993), and are reliant on freshly deposited detritus (Gaston, 1987). Besides this, spionids can switch their feeding mode from surface deposit feeding to suspension feeding in response to changes in environmental (i. e.

depositional) regimes (Dauer *et al.*, 1981; Pagliosa, 2005; Manokaran *et al.*, 2013; Han *et al.*, 2016).

Subsurface deposit feeders (SSDF) are active burrowers which ingest sediment directly, assimilate the constituent OM and egest the remaining sediments. The distribution of this group is mainly influenced by presence of sufficient food (OM) in the sediment matrix (Gaston, 1987; Muniz & Pires, 1999). The bioturbating activity of deposit feeders greatly enhances the transfer of OM and mixing of the oxygen into deeper layers of the sediments. Bioturbation increases the microbial activity in the sediment, and these microbiota form a major food source for deposit feeders (Rosenberg, 1995; Muniz *et al.*, 1998; Dolbeth *et al.*, 2009). The percentage of SSDF in the coarser sediments was very low, as the presence of dead shell pieces, sponge spicules, coral fragments etc. interrupt their feeding (Pavia, 1993; Pagliosa, 2005). The change of sediment texture to sandy silt in the deeper areas of the study area supported higher abundance of SSDF. The prevailing low hydrodynamic conditions in deeper depths enhance the deposition and burial of OM in the fine sediments, which form a rich food source for SSDF (Muniz & Pires, 1999; Dolbeth *et al.*, 2009; Mattos *et al.*, 2012; Abdul Jaleel, 2012).

Suspension feeders (SF) are organisms which feed on the suspended food particles in the water column, mainly in the form of particulate OM, organic aggregates and bacteria (Levinton, 1972; Jumars & Fauchald, 1977), by using well-developed tentacular crowns with branched ciliated lobes. In the present study, SF were most abundant in the coarse sandy sediments (Sanders, 1958; Rhoads & Young 1970; Muniz & Pires, 1999), as the shell fragment, sponge spicules in the sediments are ideal building blocks for building their tubes (Pavia, 1993). They were also able to take advantage of the hydrodynamically active conditions prevailing in the region, which favoured the resuspension of OM to the water column (Dolbeth *et al.*, 2009). The percentage of SF was very low in sandy silt sediments, which were not well suited for this group compared to coralline sandy sediments (Rhoads & Young, 1970; Levinton, 1972; Jayaraj *et al.*, 2007).

Bathymetric variations in the feeding guilds, and variations in the abundance of feeding groups in each depth strata in response to the environmental conditions of the two islands groups explain the observed regional distinctions in the study area. In the reef areas, the sediment texture was coralline sand in all transects around Nicobar Islands whereas, there were some pockets of relatively silty sediments in certain transects around Andaman Islands (South Andaman, Port Andaman, Sound Island, Smith Island) that caused prominent variations in the relative abundance of predators. The percentage contribution of PR and SF were relatively high in Nicobar Islands as compared to Andaman Islands, whereas the contribution deposit feeders were relatively higher in the Andaman Islands. Likewise, at higher depths, the sediments was relatively siltier with low oxygen content around Andaman Islands, which supported dominance of deposit feeders. Whereas around Nicobar Islands the sediments were sandy, with relatively high oxygen content, sustaining higher proportions of PR and SF. A significant decreasing trend in the abundance of PR and SF with increasing latitude, and increase in the abundance of deposit feeders at the shallow depths reflects the increase in percentage of finer sediments towards northern latitudes in the Andaman Sea sector. This might be due to the influence of discharge from the Ayeyarwady River and deposition of silty sediments in the northern most transects of Andaman Islands or due to terrestrial influences from the Andaman Islands.

The polychaete communities of ANI, represented by all feeding types, indicate that adaptive ecological conditions prevails in the region for most of the polychaetes fauna (Gamito & Futardo, 2009) and habitat heterogeneity supported diverse species assemblages, with diverse feeding guilds and resource partitioning (Simboura *et al*., 2000). The establishment of different species in a region having almost similar morphological traits, demonstrates the fact that habitat related factors exerts a major role in structuring polychaete assemblages (Otegui *et al*., 2016).

According to Pielou (1975), high diversity occurs in a community in which species are present in differnet genera (606 species belonging to 279 genera) rather than occurrence of majority of species under fewer genera or to same genus). In the near-reef areas, 468 species were recorded, and highest number of genera (236) were reported in this depth strata. Although the number of genera and species decreased with increasing depth, the degree of diversification in the generic level was high in the higher depth strata (328 species belonging to 161 genera at 200m). Taxonomic distinctness was very high in the study area ($\Delta^+ \geq 69$), revealing the high diversification of polychaete species. Though lowest number of species in the study area was recorded in 200m depth of Sound Island (18 species), the average taxonomic distinctness was high (73.04), demonstrating the highly diversified nature of the community. By contrast, lowest average taxonomic distinctness value (69.19) was noted at 200m depth off Port Blair, despite the occurrence of 45 species. This demonstrates that in order to explain the diversity of a region ecologists should not only depend solely on number of species and their relative abundance, but also on the level of diversification in each taxonomic level (e.g. family, genera, species). Somerfield *et al.* (1997) suggested that the decrease in taxonomic distinctness as a response to increased stress might be due to selective removal of species from an assemblage, or due to replacement of diversified assemblages by a few, more closely related species. These type of indices are strongly reccomended to study the diversity changes over a time scale, due to athropogenic or natural disturbances, identifying biodiversity hotspots for conservation purposes etc. (Bevilacqua *et al.*, 2009). Since the Andaman and Nicobar Islands are prone to pronounced, episodic natural disturbances like earthquakes and tsunamis taxonomic distinctness measures can be used to examine effectively their aftermaths on the species diversity of the area, even with the use of multiple sampling methodologies. The unique geographic position of the Andaman & Nicobar archipelago, at the junction between the Indian Ocean, Bay of Bengal and the Indo-Pacific archipelagos (including the Coral Triangle) enabling dispersal of species from all these biogeographical provinces may be contributing to the exceptionally high species richness and diversity of polychaetes in the region (Sibaja-Cordero *et al.*, 2016).

Table 5. 1a. Dissimilarity contributing polychaete species among the assemblages (nMDS, depth-wise) obtained through SIMPER analysis during SS261 (500µm)

Groups 50m & 100m

Average dissimilarity = 76.23%

	Group 50m	**Group 100m**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Aonidella dayi	7.82	13.75	1.59	1.63	2.08	2.08
Syllis cornuta	9.14	1.95	1.53	1.26	2.01	4.09
Glycera	8.81	1.88	1.51	1.08	1.98	6.07
Aphelochaeta filibranchia	0.35	9.4	1.45	0.51	1.9	7.97
Prionospio cirrifera	1.35	8.94	1.43	1.58	1.88	9.85
Syllis spp.	9.11	2.25	1.43	1.39	1.88	11.73
Eunice indica	9.79	5.62	1.27	1.42	1.66	13.39
Levinsenia oculata	1.22	7.47	1.26	1.07	1.66	15.05
Glycera papillosa	5.53	3.17	1.11	1.22	1.46	16.51
Ampharete agulhasensis	1.71	5.91	1.07	1.03	1.41	17.92
Aglaophamus dibranchis	7.09	3.69	1.05	1.26	1.38	19.3
Spiophanes duplex	0.5	6.23	1.05	1.6	1.37	20.68
Aricidea lopezi	1.71	6.32	1.03	1.02	1.35	22.03
Nereis spp.	6.29	1.01	0.95	1.71	1.25	23.28
Kirkegaardia dorsobranchialis	2.98	4.62	0.93	1.07	1.22	24.5
Laonice cirrata	5.21	1.59	0.87	1.21	1.15	25.64
Onuphis geophiliformis	3.75	3.48	0.77	1.18	1.01	26.65
Micronephthys sphaerocirrata	4.35	4.72	0.76	1.28	1	27.65
Sigambra parva	2.64	4.85	0.76	1.23	0.99	28.64
Lumbrineris aberrans	4.28	1.01	0.75	1.15	0.99	29.63
Scoloplos marsupialis	2.17	3.46	0.75	0.83	0.98	30.61

Table 5. 1b. Dissimilarity contributing polychaete species among the assemblages (nMDS, depth-wise) obtained through SIMPER analysis during SS261 (500µm)

Groups 50m & 200m

Average dissimilarity = 80.91%

	Group 50m	**Group 200m**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Kirkegaardia dorsobranchialis	2.98	10.24	1.73	1	2.14	2.14
Levinsenia oculata	1.22	9.68	1.66	0.95	2.05	4.18
Syllis cornuta	9.14	2.13	1.49	1.35	1.85	6.03
Glycera spp.	8.81	4.25	1.44	1.21	1.78	7.81
Eunice indica	9.79	3.17	1.34	1.47	1.66	9.47
Ampharete	1.77	9.36	1.33	0.86	1.64	11.11
Syllis spp.	9.11	2.65	1.32	1.38	1.63	12.74
Aricidea lopezi	1.71	7.07	1.28	0.97	1.58	14.32
Aonidella dayi	7.82	5.09	1.22	1.31	1.51	15.83
Notomastus aberans	5.44	8.94	1.22	1.22	1.5	17.34
Aglaophamus dibranchis	7.09	0.93	1.12	1.29	1.38	18.72
Aricidea spp.	3.61	5.95	0.99	1.2	1.23	19.94
Ampharete agulhasensis	1.71	5.33	0.98	0.89	1.21	21.15
Nereis spp.	6.29	0.93	0.96	1.76	1.18	22.33
Lumbrineris tetraura	2.56	6.14	0.94	0.85	1.16	23.5
Glycera papillosa	5.53	0	0.93	0.78	1.15	24.65
Laonice cirrata	5.21	2.96	0.9	1.23	1.12	25.77
Euchone rosea	4.7	2.36	0.83	1.53	1.02	26.8
Goniada maculata	1.06	5.13	0.82	1.45	1.01	27.81
Onuphis geophiliformis	3.75	2.67	0.79	0.95	0.98	28.79
Aricidea capensis	0.5	4.5	0.79	0.91	0.97	29.76
Micronephthys sphaerocirrata	4.35	0.24	0.74	1.19	0.92	30.68

Table 5. 1c. Dissimilarity contributing polychaete species among the assemblages (nMDS, depth-wise) obtained through SIMPER analysis during SS261 (500µm)

Groups 100m & 200m

Average dissimilarity = 75.93%

	Group 100m	**Group 200m**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Aonidella dayi	13.75	5.09	1.88	1.7	2.47	2.47
Levinsenia oculata	7.47	9.68	1.79	1.12	2.35	4.83
Aphelochaeta filibranchia	9.4	3.27	1.77	0.65	2.33	7.16
Kirkegaardia dorsobranchialis	4.62	10.24	1.71	1.01	2.25	9.42
Prionospio cirrifera	8.94	2.79	1.53	1.63	2.02	11.44
Aricidea lopezi	6.32	7.07	1.5	1.12	1.98	13.41
Ampharete spp.	3.02	9.36	1.45	0.93	1.9	15.32
Ampharete agulhasensis	5.91	5.33	1.28	1.16	1.69	17.01
Notomastus aberans	5.52	8.94	1.23	1.26	1.62	18.62
Lumbrineris tetraura	2.53	6.14	1.14	0.97	1.5	20.12
Eunice indica	5.62	3.17	1.06	1.11	1.4	21.52
Aricidea spp.	6.03	5.95	1.05	1.52	1.39	22.91
Spiophanes duplex	6.23	1.31	0.97	1.5	1.27	24.18
Micronephthys sphaerocirrata	4.72	0.24	0.95	1.26	1.25	25.43
Aricidea capensis	2.76	4.5	0.94	1.02	1.23	26.67
Goniada maculata	3.83	5.13	0.82	1.3	1.08	27.74
Jasmineira caudata	1.01	4.29	0.8	0.53	1.06	28.8
Caulleriella bioculata	4.49	0	0.8	1.24	1.05	29.85
Onuphis geophiliformis	3.48	2.67	0.79	0.93	1.04	30.89

Table 5. 1d. Dissimilarity contributing polychaete species among the assemblages (nMDS, depth-wise) obtained through SIMPER analysis during SS292 (300µm)

Groups 50m & 100m **Average dissimilarity = 76.78%**	**Group 50m**	**Group 100m**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Ampharete agulhasensis	3.4	4.45	1.07	1.16	1.4	1.4
Micronephthys sphaerocirrata	5.9	2.54	1.07	1.36	1.39	2.79
Glycera lapidum	4.44	3.52	1	1.22	1.31	4.09
Aonidella spp.	5.56	4.11	0.94	1.12	1.23	5.32
Spiophanes spp.	3.98	6.44	0.93	1.49	1.22	6.54
Kefersteinia cirrhata	3.47	2.11	0.85	0.83	1.1	7.64
Prionospio (Minuspio) spp.	4.25	3.48	0.83	1.27	1.08	8.72
Syllis cornuta	4.91	2.85	0.82	1.34	1.07	9.79
Eunice indica	3.81	3.73	0.78	1.28	1.01	10.81
Lumbrineris meteorana	2.61	2.58	0.77	0.99	1	11.8
Prionospio andamanensis	3.03	1.85	0.76	0.95	0.99	12.79
Kirkegaardia dorsobranchialis	2.46	3.01	0.72	1.09	0.94	13.73
Caulleriella bioculata	2.75	2.47	0.69	1.13	0.9	14.63
Amphicteis gunneri	1.56	3.62	0.69	1.3	0.9	15.53
Euchone rosea	3.35	1.91	0.67	1.25	0.87	16.4
Prionospio spp.	3.35	2.05	0.66	1.29	0.86	17.26
Opisthodonta longocirrata	3.06	1.07	0.65	1.13	0.85	18.11
Levinsenia gracilis	2.72	1.4	0.65	1.09	0.85	18.96
Aricidea lopezi	2.69	2.86	0.65	1.22	0.84	19.8
Prionospio phuketensis	2.62	1.21	0.64	0.94	0.84	20.64
Laonice spp.	3.33	2.58	0.64	1.25	0.84	21.48
Chrysopetalum maculata	1.81	2.74	0.64	1.13	0.83	22.31
Tharyx spp.	2.18	2.58	0.62	1.15	0.81	23.11
Notomastus aberans	2.24	1.63	0.62	0.85	0.8	23.92
Syllis spp.	2.4	1.52	0.6	1.05	0.78	24.7
Pionosyllis malmgreni	2.17	0.94	0.6	0.78	0.78	25.48
Protodorvillea egena	2.33	1.75	0.58	1.11	0.75	26.23
Scoloplos marsupialis	2.84	1.41	0.56	1.16	0.73	26.96
Aricidea spp.	2.61	2.72	0.56	1.15	0.72	27.68
Syllidia armata	2.01	1.69	0.55	0.98	0.72	28.41
Glycera papillosa	1.86	1.07	0.55	0.69	0.72	29.12
Phyllodoce malmgreni	1.17	2.7	0.55	1.15	0.71	29.84
Glycera spp.	2.47	1.02	0.55	1.03	0.71	30.55

Table 5. 1e. Dissimilarity contributing polychaete species among the assemblages (nMDS, depth-wise) obtained through SIMPER analysis during SS292 (300µm)

Groups 50m & 200m **Average dissimilarity = 80.64%**	**Group 50m**	**Group 200m**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Micronephthys sphaerocirrata	5.9	0.63	1.32	1.46	1.63	1.63
Aonidella spp.	5.56	1	1.21	1.21	1.5	3.13
Amphicteis gunneri	1.56	5.3	1.13	1.03	1.4	4.52
Prionospio (Minuspio) spp.	4.25	5.09	1.08	1.33	1.33	5.86
Glycera lapidum	4.44	2.79	1.07	1.09	1.33	7.19
Syllis cornuta	4.91	0.63	1.06	1.37	1.31	8.5
Kirkegaardia dorsobranchialis	2.46	4.24	0.94	1.15	1.16	9.66
Aricidea lopezi	2.69	3.58	0.92	1	1.14	10.81
Ampharete agulhasensis	3.4	3.35	0.9	1.25	1.11	11.92
Prionospio andamanensis	3.03	2.5	0.84	1.04	1.04	12.96
Levinsenia gracilis	2.72	3.43	0.83	1.09	1.03	13.99
Kefersteinia cirrhata	3.47	0.51	0.82	0.68	1.02	15
Eunice indica	3.81	0.72	0.82	1.43	1.01	16.02
Prionospio phuketensis	2.62	2.45	0.79	1	0.98	17
Opisthodonta longocirrata	3.06	1.24	0.78	1.12	0.96	17.97
Aricidea spp.	2.61	3.79	0.76	1.14	0.94	18.9
Euchone rosea	3.35	2.85	0.75	1.27	0.93	19.83
Lumbrineris meteorana	2.61	2.05	0.73	1	0.9	20.74
Laonice spp.	3.33	2.55	0.71	1.23	0.88	21.62
Prionospio spp.	3.35	2.94	0.68	1.22	0.85	22.46
Aricidea catherinae	2.17	2.42	0.68	1.04	0.84	23.31
Tharyx spp.	2.18	1.89	0.67	1.03	0.83	24.13
Syllis spp.	2.4	0.97	0.65	0.95	0.81	24.94
Levinsenia oculata	0.87	2.45	0.64	0.83	0.79	25.73
Scoloplos marsupialis	2.84	0.72	0.62	1.15	0.77	26.5
Spiophanes spp.	3.98	3.46	0.62	1.04	0.77	27.27
Caulleriella bioculata	2.75	0.63	0.62	0.94	0.77	28.04
Protodorvillea egena	2.33	0.63	0.58	0.97	0.72	28.76
Glycera spp.	2.47	0.51	0.58	0.99	0.71	29.47
Prionospio ehlersi	1.55	2.61	0.57	1.15	0.71	30.18
Dendronereis spp.	2.47	0	0.56	0.87	0.7	30.88

Table 5. 1f. Dissimilarity contributing polychaete species among the assemblages (nMDS, depth-wise) obtained through SIMPER analysis during SS292 (300µm)

Groups 100m & 200m						
Average dissimilarity = 79.58%	**Group 100m**	**Group 200m**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Ampharete agulhasensis	4.45	3.35	1.43	1.15	1.8	1.8
Amphicteis gunneri	3.62	5.3	1.38	1.14	1.73	3.53
Prionospio (Minuspio) spp.	3.48	5.09	1.34	1.24	1.68	5.21
Aricidea lopezi	2.86	3.58	1.2	1.04	1.51	6.72
Kirkegaardia dorsobranchialis	3.01	4.24	1.2	1.1	1.5	8.22
Spiophanes spp.	6.44	3.46	1.18	1.42	1.49	9.71
Aonidella spp.	4.11	1	1.16	1.17	1.46	11.17
Levinsenia gracilis	1.4	3.43	1.06	0.9	1.34	12.51
Eunice indica	3.73	0.72	1.04	0.95	1.31	13.81
Glycera lapidum	3.52	2.79	1.01	1.09	1.27	15.08
Aricidea spp.	2.72	3.79	0.98	1.11	1.23	16.31
Prionospio andamanensis	1.85	2.5	0.91	0.81	1.15	17.46
Prionospio spp.	2.05	2.94	0.91	1.06	1.15	18.61
Lumbrineris meteorana	2.58	2.05	0.9	0.94	1.13	19.74
Tharyx spp.	2.58	1.89	0.87	1.09	1.09	20.84
Euchone rosea	1.91	2.85	0.86	1.11	1.08	21.91
Laonice spp.	2.58	2.55	0.85	1.12	1.06	22.98
Syllis cornuta	2.85	0.63	0.84	1.04	1.05	24.03
Aricidea catherinae	1.55	2.42	0.81	0.92	1.02	25.05
Chrysopetalum maculata	2.74	0.42	0.81	0.99	1.01	26.07
Micronephthys sphaerocirrata	2.54	0.63	0.79	0.79	0.99	27.05
Prionospio phuketensis	1.21	2.45	0.78	0.85	0.98	28.03
Aonides spp.	2.04	1.81	0.76	1.01	0.96	28.99
Levinsenia oculata	0.79	2.45	0.76	0.86	0.95	29.95
Phyllodoce malmgreni	2.7	0.72	0.75	1.11	0.94	30.89

Table 5. 2a. Dissimilarity contributing polychaete species among the assemblages (nMDS, island groups) obtained through SIMPER analysis during SS261 (500µm)

Groups AI & NI

Average dissimilarity = 79.95%

	Group AI	**Group NI**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Glycera spp.	2.95	11.45	1.79	1.37	2.23	2.23
Aonidella dayi	10.22	1.97	1.66	1.54	2.07	4.31
Syllis cornuta	2.86	8.72	1.45	1.24	1.81	6.11
Levinsenia oculata	8.23	1.17	1.43	0.93	1.79	7.91
Ampharete spp.	4.09	8.82	1.39	0.79	1.73	9.64
Kirkegaardia dorsobranchialis	8.06	2.24	1.38	0.91	1.73	11.37
Aricidea lopezi	6.97	0	1.25	0.96	1.57	12.93
Notomastus aberans	7.33	5.98	1.25	1.43	1.56	14.5
Eunice indica	4.92	8.77	1.23	1.33	1.54	16.03
Lumbrineris tetraura	2.88	7.46	1.18	0.9	1.48	17.51
Syllis spp.	4.22	6.04	1.1	1.18	1.38	18.89
Jasmineira caudata	0.32	6.97	1.08	0.6	1.35	20.24
Ampharete agulhasensis	5.8	0	1.04	0.93	1.31	21.55
Aricidea spp.	5.87	3.32	0.97	1.2	1.21	22.76
Laonice cirrata	2.6	5.57	0.96	1.16	1.2	23.96
Prionospio cirrifera	5.11	0	0.93	0.89	1.16	25.12
Jasmineira elegans	1.19	5.43	0.87	0.79	1.09	26.21
Aphelochaeta filibranchia	5.09	0	0.87	0.47	1.09	27.3
Aglaophamus dibranchis	3.91	2.86	0.86	1.01	1.08	28.38
Goniada maculata	2.73	5.5	0.84	1.34	1.05	29.43
Prionospio spp.	5.72	7.05	0.79	1.34	0.99	30.42

Table 5. 2b. Dissimilarity contributing polychaete species among the assemblages (nMDS, island groups) obtained through SIMPER analysis during SS292 (300µm)

Groups AI & NI						
Average dissimilarity = 82.30%	Group AI	Group NI				
Species	Av.Abd	Av.Abd	Av.Diss	Diss/SD	Contrib%	Cum.%
Glycera lapidum	2.74	5.78	1.2	1.41	1.46	1.46
Prionospio (Minuspio) spp.	5.24	1.95	1.15	1.17	1.4	2.86
Amphicteis gunneri	3.09	3.92	1.09	0.93	1.32	4.19
Ampharete agulhasensis	4.6	1.68	1.07	1.05	1.3	5.48
Aricidea (Acmira) lopezi	4.22	0.21	1.03	1.05	1.25	6.73
Kirkegardia dorsobranchialis	4.17	0.84	0.98	1.04	1.19	7.92
Syllis cornuta	2.29	4.54	0.96	1.27	1.17	9.09
Aonidella spp.	4.44	2.07	0.96	1.07	1.17	10.27
Micronephthys sphaerocirrata	3.81	1.92	0.93	1.05	1.13	11.39
Pionosyllis malmgreni	0.29	3.79	0.92	0.97	1.12	12.51
Spiophanes	5.28	3.05	0.89	1.15	1.08	13.59
Syllis spp.	0.91	3.49	0.85	1.14	1.03	14.62
Lumbrineris meteorana	2.33	2.68	0.82	0.97	0.99	15.61
Prionospio spp.	3.59	1	0.81	1.13	0.99	16.6
Aricidea (Acmira) catherinae	1.5	3.33	0.8	1.04	0.97	17.57
Glycera benguellana	0.26	3.28	0.79	0.98	0.97	18.53
Euchone rosea	2.53	3.23	0.77	1.15	0.94	19.47
Eunice indica	3.14	2.21	0.77	1.02	0.94	20.41
Prionospio andamanensis	3.16	0.93	0.77	0.84	0.93	21.34
Syllidia armata	0.76	3.3	0.77	1.13	0.93	22.28
Levinsenia gracilis	2.94	1.49	0.76	0.89	0.92	23.2
Kefersteinia cirrhata	2.1	2.24	0.75	0.83	0.92	24.12
Chrysopetalum occidentale	0	3.19	0.75	0.89	0.92	25.03
Aricidea spp.	3.26	2.39	0.75	1.06	0.91	25.94
Laonice spp.	2.69	3.24	0.73	1.15	0.89	26.83
Opisthodonta longocirrata	1.48	2.8	0.72	0.88	0.87	27.7
Protodorvillea egena	1.11	2.87	0.71	1.25	0.86	28.56
Pisione africana	0	2.79	0.71	0.75	0.86	29.42
Prionospio phuketensis	2.4	1.47	0.68	0.89	0.83	30.25

Table 5. 3a. Characteristics of polychaete species assemblages among island groups within each depth category during SS261 (500µm)

Sieve mesh size	**SS261 (500µm)**					
Depths	**50m**		**100m**		**200m**	
Region	**Andaman Is.**	**Nicobar Is.**	**Andaman Is.**	**Nicobar Is.**	**Andaman Is.**	**Nicobar Is.**
Temperature (°C)	27.77±0.30	27.38±0.12	25.75±1.71	24.29±2.62	14.2±0.96	14.25±0.80
Salinity	32.92±0.43	32.58±0.26	33.76±0.44	33.99±0.44	34.93±0.05	34.91±0.05
Oxygen (ml l^{-1})	4.03±0.16	4.03±0.23	2.61±0.69	2.63±0.80	0.34±0.16	0.63±0.09
Sand (%)	15.07-98	93.54-99.62	34.73-99.96	90.58-100	1.52-77.71	51.94-98.97
Silt (%)	1.59-78.35	0.32-4.77	0.04-43.62	0-8.0	13.51-70.80	0.85-24.86
Clay (%)	0.41-13.20	0.06-1.69	0-21.65	0-1.42	8.78-27.68	0.17-45.95
OM (%)	0.99±0.65	0.28±0.05	0.85±0.62	0.30±0.10	1.34±1.04	0.43±0.19
Abundance (ind.m^{-2})	584±280	897±242	554±200	NS	842±505	807±671
Biomass (gm^{-2})	2.84±1.61	2.43±1.03	2.61±2.16	NS	3.03±1.75	3.15±3.44
Observed species (S)	55±21	50±9	43±12	NS	43±9	43±9
Species diversity (H')	5.5±0.6	5.4±0.2	5.2±0.4	NS	5.1±0.4	5.2±0.3
PR (%)	55	67	23	NS	9	31
SDF (%)	28	23	54	NS	57	41
SSDF (%)	14	6	20	NS	31	12
SF (%)	2	4	3	NS	3	17
Similarity causing species (contributing more than 5%)	*Notomastus aberans (7.6%)*	*Glycera* spp. *(17%)*	*Aonidella dayi (13.22%)*	*NS*	*Levinsenia oculata (9.03%)*	*Notomastus aberans (9.24%)*
	Eunice indica (6.63%)	*Syllis cornuta (14.59%)*	*Prionospio cirrifera (7.30%)*	*NS*	*Aricidea lopezi (8.63%)*	*Goniada maculata (8.12%)*
	Aonidella dayi (6.58%)	*Syllis* spp. *(9.04%)*	*Aricidea* spp. *(5.56%)*	*NS*	*Kirkegaardia dorsobranchialis (8.45%)*	*Prionospio* spp. *(7.59%)*
	Neries spp. *(6.02%)*	*Eunice indica (6.73%)*	*Notomastus aberans (5.08%)*	*NS*	*Prionospio* spp. *(5.44%)*	*Sigambra parva (7.05%)*
	Syllis spp. *(5.14%)*					*Glycera* spp. *(6.38%)*
						Eunice indica (6.10%)
						Ampharete spp. *(5.81%)*

Table 5. 3b. Characteristics of polychaete species assemblages among island groups within each depth category during SS292 (300µm)

Sieve mesh size	**SS292 (300µm)**					
Depths	**50m**		**100m**		**200m**	
Region	**Andaman Is.**	**Nicobar Is.**	**Andaman Is.**	**Nicobar Is.**	**Andaman Is.**	**Nicobar Is.**
Temperature (°C)	27.21±0.80	27.27±0.73	21.23±1.79	21.20±1.41	13.81±0.76	14.10±0.90
Salinity	33.46±0.43	33.53±0.36	34.55±0.11	34.45±0.19	34.94±0.04	34.91±0.03
Oxygen (ml l^{-1})	3.11±0.63	3.65±0.30	0.78±0.37	1.57±0.31	0.30±0.08	0.60±0.07
Sand (%)	15.07-99.05	98.93-100	34.73-100	90.68-100	1.62-98.05	60.88-98.97
Silt (%)	0.79-78.35	0-0.89	0-43.62	0-7.95	0.32-67.96	0.85-34.24
Clay (%)	0.16-11.93	0-0.18	0-21.65	0-1.37	0.32-30.19	0.17-8.41
OM (%)	0.75±0.38	0.31±0.11	0.69±0.29	0.32±0.20	2.04±1.03	0.41±0.29
Abundance (ind.m^{-2})	2183±677	1487±647	1573±674	1193±808	1145±830	1380±853
Biomass (gm^{-2})	2.71±0.70	2.08±0.73	2.83±1.54	2.27±2.21	2.13±1.37	2.57±2.21
Observed species (S)	63±10	63±16	45±14	35±13	34±10	45±20
Species diversity (H')	5.83±0.25	5.84±0.37	5.33±0.47	4.93±0.48	4.89±0.46	5.23±0.75
PR (%)	42	63	34	73	16	38
SDF (%)	36	16	44	16	49	32
SSDF (%)	20	13	18	10	31	25
SF (%)	3	7	4	2	3	5
Similarity causing species (contributing more than 5%)	*Micronephtys sphaerocirrata (5.72%)*	*Glycera lapidum (6.99%)*	*Spipophanes spp. (11.98%)*	*Glycera lapidum (10.21%)*	*Prionospio (Minuspio) spp. (11.16%)*	*Aricidea catherinae (8.95%)*
	Aonidella spp. (5.59%)	*Syllis cornuta (6.58%)*		*Syllis cornuta (8.01%)*	*Kirkegaardia dorsobranchialis (7.95%)*	*Aricidea spp. (6.55%)*
				Glycera benguellana (7.21%)	*Prionospio spp. (6.78%)*	*Amphicteis gunneri (6.16%)*
				Protodorvillea egena (6.36%)	*Spiophanes spp. (6.04%)*	*Spiophanes spp (5.03%)*
				Sysllis spp. (6.30%)	*Aricidea lopezi (5.59%)*	*Sigambra parva (5.00%)*
				Paradoneis lyra (5.89%)		
				Chrysopetalum occidentale (5.63%)		

Table 5. 4. Characteristics of polychaete species assemblages among island margins within each depth category during SS292 (300µm)

Sieve	**SS292 (300µm)**					
Region/Sector	**WAI/BoB**			**EAI/AS**		
Depth	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Temperature (°C)	27.33±0.61	22.36±1.38	13.66±0.50	27.08±1.02	19.92±1.27	13.97±1.01
Salinity	33.67±0.34	34.58±0.12	34.97±0.02	33.22±0.43	34.51±0.09	34.92±0.05
Oxygen (ml/l)	2.96±0.62	0.7±0.48	0.23±0.05	3.27±0.65	0.88±0.15	0.38±0.02
Sand (%)	15.07-98.15	34.73-86.65	31.15-97.25	48.59-99.05	38.25-100	1.85-98.05
Silt (%)	1.54-78.35	10.85-43.62	2.29-58.52	0.79-39.48	0-41.99	1.62-67.96
Clay (%)	0.31-6.58	2.3-21.65	0.46-13.77	0.16-11.93	0-19.76	0.32-30.19
OM (%)	0.76±0.29	0.71±0.30	2.20±0.80	0.74±0.49	0.57±0.36	1.76±1.44
Abundance (ind.m^{-2})	2056±866	1429±556	868±299	2331±390	1773±837	1561±1239
Biomass (gm^{-2})	2.83±0.72	2.26±1.47	1.56±0.64	2.57±0.71	3.64±1.39	2.98±1.82
Observed species (S)	62±13	40±13	35±10	64±7	53±12	33±11
Species diversity (H')	5.80±0.30	5.17±0.51	4.96±0.47	5.87±0.18	5.56±0.32	4.80±0.49
PR (%)	49	32	13	34	36	20
SDF (%)	28	46	56	43	43	42
SSDF (%)	19	18	25	21	18	37
SF (%)	4	4	5	2	3	1
Similarity causing species (contributing more than 5%)	*Micronephtys sphaerocirrata* (5.81%) *Aonidella* spp. (5.08%)	*Spiophanes* spp. (10.03%) *Aonidella* spp. (7.73%) *Amphicteis gunneri* (7.35%) *Aricidea lopezi* (5.29%) *Eunice indica* (5.02%)	*Prionospio (Minuspio)* spp. (10.45%) *Amphicteis gunneri* (9.44%) *Kikegaardia dorsobranchialis* (8.99%) *Spiophanes* spp. (8.16%) *Levinsenia oculata* (5.72%)	*Prionospio andamensis* (4.52%) *Lumbrineries meteorana* (4.45%)	*Ampharete agulhaensis* (7.36%) *Spiophanes* spp. (5.67%)	*Amphaerete agulhaensis* (12.39%) *Prionospio* spp. (11.33%) *Linopherus paucibranchiata* (10.77%) *Aricidea lopezi* (7.26%) *Levinsenia gracilis* (6.54%)

Table 5. 5. Dissimilarity contributing polychaete species among the assemblages (nMDS, island margins) obtained through SIMPER analysis during SS292 (300µm)

Groups WAI & EAI						
Average dissimilarity = 77.73%	**Group WAI**	**Group EAI**				
Species	**Av.Abd**	**Av.Abd**	**Av.Diss**	**Diss/SD**	**Contri%**	**Cum.%**
Ampharete agulhasensis	1.74	8.4	1.72	1.65	2.21	2.21
Lumbrineris meteorana	0	5.44	1.23	1.8	1.59	3.8
Prionospio andamanensis	1.24	5.72	1.22	1.16	1.57	5.37
Aonidella spp.	4.3	4.62	1.13	1.16	1.45	6.82
Prionospio (Minuspio) spp.	6.24	3.9	1.11	1.32	1.43	8.25
Micronephthys sphaerocirrata	4.29	3.17	1.07	1.23	1.37	9.62
Levinsenia gracilis	1.45	4.94	1.05	0.99	1.36	10.98
Aricidea lopezi	3.64	4.98	1.03	1.04	1.33	12.31
Amphicteis gunneri	4.62	1.07	1.03	1.17	1.33	13.64
Kirkegaardia dorsobranchialis	4.11	4.25	1	1.11	1.28	14.92
Notomastus aberans	0.38	4.13	0.93	1.15	1.2	16.12
Aricidea spp.	2.13	4.77	0.87	1.05	1.11	17.23
Glycera lapidum	2.4	3.19	0.84	0.97	1.08	18.31
Eunice indica	2.82	3.56	0.84	1.04	1.08	19.39
Spiophanes	5.49	5.01	0.82	1.13	1.05	20.44
Prionospio spp.	2.6	4.91	0.81	1.23	1.05	21.49
Tharyx spp.	1.96	3.73	0.81	1.15	1.04	22.53
Nothria conchylega	0.27	3.47	0.8	1.07	1.03	23.56
Prionospio phuketensis	2.34	2.47	0.8	0.92	1.03	24.59
Caulleriella bioculata	2.3	3.47	0.78	1.25	1.01	25.59
Sigambra tentaculata	1.01	3.45	0.75	1.09	0.97	26.56
Linopherus paucibranchiata	0	2.78	0.75	0.88	0.96	27.52
Laonice spp.	3.44	1.7	0.75	1.19	0.96	28.49
Syllis cornuta	1.3	3.62	0.74	1.28	0.95	29.43
Kefersteinia cirrhata	2.59	1.45	0.73	0.73	0.94	30.38

Table 5. 6. Pearson correlation of feeding guild and diversity indices with environmental variables

	Depth	Temp	Sal	DO	Sand	Silt	Clay	OM	MGZ
PR	-.465**	.417**	-.540**	.530**	.319**	-.325**	-.130	-.303**	.427**
SDF	.129	-.142	.041	-.060	-.072	-.065	.427**	-.027	-.242*
SSDF	.189	-.194	.104	-.097	-.129	.030	.343**	.024	-.261*
SF	.123	-.137	.101	-.082	-.028	-.129	.461	-.049	-.047
S	-.474**	.430**	-.505**	.523**	.337**	-.305**	-.290*	-.338**	.305**
d	-.485**	.433**	-.493**	.507**	.348**	-.299**	-.340**	-.340**	.316**
J'	-.295**	.204	-.085	.130	.143	-.010	-.432**	.119	.158
H'	-.486**	.436**	-.473**	.493**	.366**	-.317**	-.349**	-.352**	.319**
Δ+	-.567**	.421**	-.382**	.378**	.306**	-.319**	-.153	-.417**	.359**

**Correlation is significant at the 0.01 level

*Correlation is significant at the 0.05 level

Table 5. 7. BIOENV results (Spearman rank correlation)

Correlation	Variables
0.363	Clay, OM, Depth
0.355	Silt, Clay, OM, Depth
0.355	Sand, Clay, Om, Depth
0.354	Sand, Silt, Clay, Depth
0.353	Clay, OM, MGZ, Depth
0.348	DO, Silt, Clay, OM, Depth
0.348	Temperature, Silt, Clay, OM, Depth
0.347	Temperature, Sand, Clay, OM, MGZ, Depth
0.345	Sand, Clay, OM, MGZ, Depth
0.345	DO, Sand, Clay, OM, Depth

Table 5. 8. Subset of polychaete species used for Canonical Correspondence Analysis (CCA)

P.mal	*Phyllodoce malmgreni*	**Ar.spp**	*Aricidea* spp.
S.par	*Sigambra parva*	**L.ocu**	*Levinsenia oculata*
L.cla	*Leocrates claparedii*	**L.gra**	*Levinsenia gracilis*
K.cir	*Kefersteinia cirrhata*	**E.spp**	*Euclymene* spp.
S.arm	*Syllidia armata*	**A.agu**	*Ampharete agulhasensis*
S.cor	*Syllis cornuta*	**Am.spp**	*Ampharete* spp.
S.spp	*Syllis* spp.	**A.gun**	*Amphicteis gunneri*
N.spp	*Nereis* spp.	**E.ros**	*Euchone rosea*
A.dib	*Aglaophamus dibranchis*	**J.ele**	*Jasmineira elegans*
M.sph	*Micronephthys sphaerocirrata*	**N.abe**	*Notomastus aberans*
P.par	*Paralacydonia paradoxa*	**M.cap**	*Mediomastus capensis*
G.ben	*Glycera benguellana*	**P.and**	*Prionospio andamanensis*
G.pap	*Glycera papillosa*	**P.spp**	*Prionospio* spp.
G.spp	*Glycera* spp.	**P.ehl**	*Prionospio ehlersi*
G.mac	*Goniada maculata*	**P.cor**	*Prionospio cornuta*
E.ind	*Eunice indica*	**A.dayi**	*Aonidella dayi*
O.hol	*Onuphis holobranchiata*	**S.spp**	*Spiophanes* spp.
L.lat	*Lumbrineris latreilli*	**Ao.spp**	*Aonides* spp.
L.met	*Lumbrineris meteorana*	**L.cirr**	*Laonice cirrata*
P.ege	*Protodorvillea egena*	**L.spp**	*Laonice* spp.
C.bio	*Caulleriella bioculata*	**M.spp**	*Minuspio* spp.
T.ann	*Tharyx annulosus*	**C.occi**	*Chrysopetalum occidentale*
K.dor	*Kirkegaardia dorsobranchialis*	**C.mac**	*Chrysopetalum maculata*
T.spp	*Tharyx* spp.	**G.lap**	*Glycera lapidum*
S.mar	*Scoloplos marsupialis*	**A.cat**	*Aricidea catherinae*
A.cap	*Aricidea capensis*		

Chapter VI

Summary & Conclusion

There is a long history of benthic studies in the continental margins of the northern Indian Ocean, particularly around peninsular India. More recently, between 1997 and 2017, systematic surveys of the Indian EEZ were conducted in this region along predetermined latitudinally organised bathymetric transects (30-1000m) through the multi-institutional Marine Living Resources Programme of the Ministry of Earth Sciences, Govt. of India. These studies have provided a broad synthesis of the quantitative aspects of benthos covering all size classes (macro, meio and microfauna), the community structure of major groups (e.g. polychaetes, nematodes, echinoderms) and the environmental factors influencing faunal distribution and ecology. The present study aims to provide baseline data on standing stock of macrofauna and community structure in the spatially extensive but relatively unexplored margin of the Andaman and Nicobar Island arc within the Indian EEZ. The archipelago is situated towards the eastern side of the Bay of Bengal, in a tectonically active region, and is surrounded by fringing coral reefs. The oceanic waters around the archipelago are oligotrophic in nature. Hydrographic features of the study area are influenced by the Bay of Bengal, Andaman Sea (i.e. Ayeyarawady River), equatorial Indian Ocean and Malacca Strait.

Stratified sampling surveys in the ANI margin (6-14°N, 92-94°E) were carried out on board FORV *Sagar Sampada* (SS261 and SS292) during the northeast monsoon season in the ANI margin covering 95 sampling stations. When compared to the recent studies in the continental shelves around the Indian peninsula, the sampled depth range of sampling sites in the present surveys were restricted, between 50 and 200m, owing to the prevalence of coral reefs nearer to the shore. The three depth strata's covered in the present surveys (50, 100 and 200m), were separated in most transects by a distance less than 10 nautical miles, indicating the steepness of the margin. This steep bathymetric gradient, proximity to coral reefs and prevailing oligotrophic conditions were reflected in the sediment characteristics (texture, grain size and organic matter content) of the study area. The near-reef (50m) sites were characterised by coarser coralline sand, with significant biogenic materials (sponge spicules, mollusc and echinoderm shell fragments etc.) and low organic matter (OM) content. With increasing depth, the sediment nature turned to finer sandy silt with relatively higher OM. Along with these bathymetric variations, regional distinctions were also noted in the sediment characteristics, with relatively higher silt and OM content around Andaman Islands compared to Nicobar Islands. As generally expected in tropical margins, the temperature and dissolved oxygen (DO) of bottom waters showed a decreasing trend with increasing depths, along with an increasing trend in salinity. Regional distinctions were observed in DO, particularly in the deeper areas, with oxygen minimum conditions (DO<0.5ml/l) prevailing around the Andaman Islands (100 and 200m). Two surveys were conducted during the same season (North east monsoon, 2009 and 2011) did not show any significant differences in the environmental conditions (sediment characteristics and hydrography of bottom water) of the study area.

Since both surveys were conducted in the same season, a 500µm mesh sieve was used to separate the macrofauna during the first survey with a view to compare the standing stock and diversity of the region with other parts of the Indian EEZ. In this survey, mean density of macrofauna (1165±593 ind. m^{-2}) was intermediate between the western Bay of Bengal and eastern Arabian Sea margins, while mean biomass (4.99±2.58 gm^{-2}) was lower than that of the aforementioned areas. During the second survey a 300µm sieve was used, taking into consideration the results of the first survey and the results of studies from other tropical oligotrophic insular margins. The macrofaunal density during second survey (2274±1165 ind. m^{-2}) was significantly higher than the first, while biomass was comparable (4.73±2.23 gm^{-2}). In both the surveys, polychaetes were the dominant group among macrofauna, followed by crustaceans.

Though standing stock of macrofauna decreased with increasing depth during both surveys, this trend was most pronounced during the second survey (55% decrease in density and 35% decrease in biomass), when compared to the first survey (density by 33% and biomass by 20%). The decrease in faunal density was a reflection of depth associated variations in density of polychaetes and crustaceans. These groups were more or less equi-dominant in the shallow depth (50m), while towards the deep (200m) density of crustaceans decreased drastically in both surveys and polychaetes dominated. At the shallow depth (50m) density of these groups, particularly polychaetes, was much higher in the finer mesh sieve (second survey, 300µm) than that in the coarser one (first survey, 500µm). A significant decrease in polychaete density was observed with increasing depth only in the finer sieve, and at 200m depth the values were more or less comparable with both sieves. These results clearly illustrate that smaller sized fauna among polychaetes and crustaceans, are important components of macrobenthos in the near-reef areas around the Andaman & Nicobar Islands. The coralline sand with biogenic materials at these depths provides ample interstitial space for small-sized fauna. Predatory taxa among crustaceans and polychaetes proliferate here, due to availability of plentiful prey organisms. The active hydrodynamic features of the region probably, enhance oxygen penetration into the sediments to meet the physiological demands of active predators. Density of the crustaceans decreased towards the deeper areas, owing to the decrease in grain size (and interstitial space availability) as well as DO.

In the present study, a total of 606 species of polychaetes belonging to 279 genera and 52 families were recorded, from ~36,000 individuals collected from 149 grabs. In the coarser mesh (500µm, 59 grabs), 338 species (179 genera, 43 families) were collected, and an additional 268 species (100 genera and 9 families) were recorded with the use of a finer sieve (300µm, 90 grabs) and more intensive sampling. Two new species of polychaete, *Pettibonella shompens* Gopal et al., 2014 and *Armandia sampadae* Gopal et al., 2016 have been described from the present surveys, with several new records of polychaete species. Species estimators predict the presence of as many as 930 species in the study area with further intensified sampling and that only 65% sampling sufficiency was achieved through the present surveys. The region as a whole was characterised by high polychaete species richness (Margalef's richness index >4.09), species diversity (Shannon-Weiner diversity index >4.12) and species evenness (Pielou's evenness >0.9), but showed very low dominance relative to other parts of the northern Indian Ocean. Species richness and diversity exhibited maximum values in near-reef areas (50m) with a decrease towards higher depths, while species evenness was appreciably high at all depths. In the study, Syllidae was the most species rich family among the errants (40 species), and among sedents, Spionidae (35 species) was the most diverse group. The study revealed highest number of errant polychaete species ever recorded in the northern Indian Ocean. The region was also characterised by a high proportion of rare species, with 212 species being recorded from a single site. On the whole the numerically abundant polychaetes were *Aphelochaeta filibranchia* and *Levinsenia oculata* in the first survey (500µm); and *Prionospio* (*Minuspio*) spp. and *Spiophanes* spp. in the second survey (300µm).

In the study area, the polychaete species composition showed bathymetric variations, reflecting shift in (functional) community structure. The near-reef areas (50m) which were characterised by coralline sands and high bottom water DO sustained taxonomically and functionally diverse assemblage of polychaetes, which were characteristically of smaller size (e.g. syllids, nereids, sphaerodorids, eunicids). The ample pores within sediments were ideally suited for these interstitial taxa. The availability of small-sized prey and well-oxygenated conditions supported a wide array of predatory taxa, including *Eunice indica*, *Syllis* spp., *Micronephtys sphaerocirrata*, *Chrysopetalum occidentale*, *Glycera lapidum* and *Neries* spp. Despite low sedimentary OM content, (selective) surface deposit feeders (spionids and paraonids) were also important functional groups at this depth along with true suspension feeders (serpulids and sabellids), as they are able to selectively feed on suspended OM at the sediment-water interphase. With increasing depth in the study area, sediments texture shifted towards sandy silt, with higher OM content. This favoured the deposit feeders (surface and sub-surface), with high species richness and evenness at the 200m depth. These were predominantly sedent taxa (e.g. *Prionospio* spp., *Notomastus aberans, Spiophanes* spp., *Levinsenia oculata*), which have lower oxygen demands than predators, and are thus able to thrive under the relatively low DO conditions prevailing at this depth. Polychaete communities of the intermediate depth (100m) were similar to the shallow (50m) or deeper (200m) areas, according to their environmental conditions, while some showed intermediate characters.

When considering the study area as a whole, polychaete communities also showed significant regional distinctions (Andaman-Nicobar, Bay of Bengal sector-Andaman Sea sector). These were caused by the variations in species composition, occurrence of rare and characterising species, as well as relative composition of common species and functional groups, which were in turn determined by variations in environmental conditions (sediment texture, OM and DO). At the shallow depth (50m), sediments of the eastern margin of the Andaman Islands (Andaman Sea sector) were relatively silty, particularly towards the north, which was reflected in the functional and taxonomic composition of polychaetes. In both Bay of Bengal and Andaman Sea sectors, the bottom water DO at the 200m depth showed a significant decrease towards the north, which resulted in regional distinctions between the Andaman and Nicobar islands. Despite the prevalence of oxygen minimum conditions (DO <0.5 ml/l) in the northern transects (i.e. around Andaman Islands), the macrofaunal communities of the region were less ‘impacted’ compared to other OMZs impacted margins, like the eastern Arabian Sea and western Bay of Bengal.

Based on two systematic surveys in the margins of the Andaman and Nicobar Islands, covering 96 sites between 50 and 200m depths, the present survey provides baseline data on the standing stock and composition of macrofauna as well as the species diversity and community structure of polychaetes. Such data is of primary importance, considering that the region is tectonically active and susceptible to earthquakes and tsunamis. Moreover, coral reef ecosystems around the world are facing imminent threats related from man-made changes in the environment, ocean warming and ocean acidification, which underlines the need for comprehensive biodiversity documentation in and around coral reefs. The study revealed the occurrence of highly diverse polychaete communities, with several new species being described through the surveys, and the highest polychaete species count in the northern Indian Ocean. This can be used as a supplementary information while evaluating the region as a marine biodiversity hotspot. The study clearly documents the aptness of using finer mesh sieves (i.e. 300µm rather than 500µm) to study the qualitative aspects of macrofauna in coralline sediments as well as under oligotrophic oceanic island margins. Within the narrow bathymetric range (50-200m) covered in the study, across a wide latitudinal area (6-14°N, 92-94°E), spatial variations in faunal composition and polychaete communities were found to be determined chiefly by sediment texture (proximity to reefs) and oxygen concentrations in bottom water. Further studies with seasonally and spatially resolved sampling, coverage beyond the present depth strata and focusing on other faunal groups are likely to provide further insights into benthic ecology of Andaman and Nicobar Islands.

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Appendix 1

Presence/Absence of polychaete species at different depths around Andaman and Nicobar Islands during SS261 (500µm) and SS292 (300µm)

Survey & sieve mesh size	SS261 (500µm)			SS292 (300µm)		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Polynoidae						
Antinoe lactea	-	+	-	-	-	-
Antinoe spp.	-	-	-	+	-	-
Drieschia sp.1	+	-	-	+	-	-
Lepidonotus tenuisetosus	+	-	-	+	-	-
Lepidonotus carinulatus	+	-	-	-	-	-
Lepidonotus spp.	+	-	+	+	-	-
Lepidasthenia elegans	-	-	+	-	-	-
Lepidasthenia spp.	-	-	+	+	-	-
Macellicephala mirabilis	+	-	-	-	-	-
Macellicephala sp.1	-	-	-	-	-	+
Malmgrenia spp.	+	+	-	-	-	-
Eunoe spp.	+	-	-	-	-	-
Hololepidella nigropunctata	+	-	-	-	-	-
Drieschia pelagica	-	-	-	+	-	-
Subadyte pellucida	-	-	-	+	-	-
Scalisetosus sp.1	-	-	-	+	-	-
Harmothoe sp.1	-	-	-	+	-	-
Harmothoe sp.2	-	-	-	+	-	-
Harmothoe sp.3	-	-	-	+	-	-
Harmothoe sp.4	-	-	-	+	-	-
Harmothoe sp.5	-	-	-	+	-	-
Harmothoe profunda	+	-	+	-	+	-
Harmothoe gilchristi	-	+	-	-	-	-
Harmothoe saldanha	-	+	-	-	-	-
Harmothoe spp.	+	+	+	+	+	-
Sigalionidae						
Pholoides spp.	+	-	-	+	-	-
Neopsammolyce petersi	+	-	-	+	+	-
Psammolyce spp.	+	-	-	-	-	-
Pisione africana	-	-	-	+	+	+
Pisione sp.1	+	-	-	+	-	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Pisionidens sp.1	-	-	-	+	-	+
Pisionidens indica	-	-	-	+	-	+
Pisionella sp.1	-	-	-	+	-	-
Fimbriosthenelais zetlandica	-	+	-	-	-	-
Sthenelais boa	-	+	-	-	+	+
Sthenelais sp.1	-	-	-	-	-	+
Sthenelais sp.2	-	-	-	+	-	-
Sthenelais sp.3	-	-	-	+	-	-
Sthenelais spp.	+	+	+	+	-	-
Sigalion capensis	+	-	-	-	-	-
Sigalion mathildae	+	-	-	+	-	-
Sigalion sp.1	-	-	-	+	+	-
Sigalion spp.	-	-	-	+	-	-
Pholoides dorsipapillatus	-	-	-	+	+	-
Pelogenia sp.1	-	-	-	+	+	-
Euthalenessa festiva	-	-	-	+	-	-
Euthalenessa digitata	-	-	-	+	+	-
Euthalenessa oculata	+	-	-	-	-	-
Euthalenessa spp.	+	+	-	+	-	-
Hartmanipsammolyce peluda	-	-	-	+	-	-
Neopsammolyce spinosa	-	-	-	-	+	-
Mayella sp.1	-	-	-	+	-	-
Acoetidae						
Zachsiella nigromaculata	+	-	-	+	-	-
Eupanthalis aena	-	-	-	+	+	-
Eupanthalis edriophthalma	-	-	-	-	-	-
Eupanthalis spp.	+	+	-	-	-	-
Polyodontes maxillosus	-	-	+	-	-	-
Polyodontes spp.	-	-	-	+	-	-
Iphionidae						
Iphionella risensis	-	-	-	+	-	-
Aphroditidae						
Laetmonice sp.1	+	-	-	-	-	-
Aphrogenia villosa	-	-	-	+	-	-
Hermionopsis levisetosa	-	-	-	+	-	-
Pholoidae						
Imajimapholoe sp.1	-	-	-	+	-	-
Laubierpholoe antipoda	-	-	-	+	-	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Heteraphrodita altoni	-	-	-	+	-	-
Pholoe minuta	+	-	+	-	-	-
Pholoe sp.1	-	-	-	+	-	-
Pholoe sp.2	-	-	-	+	-	-
Pholoe sp.3	-	-	-	-	-	+
Pholoe spp.	+	+	+	+	+	+
Eulepethidae						
Grubeulepis geayi	-	-	-	+	-	-
Pareulepis spp.	+	+	-	+	-	-
Eulepethus hamifer	-	-	-	-	+	-
Chrysopetalidae						
Bhawania goodei	-	-	-	+	+	-
Bhawania spp.	+	-	-	-	-	-
Chrysopetalum occidentale	-	-	-	+	+	+
Chrysopetalum maculata	-	-	-	+	+	+
Paleanotus chrysolepis	+	-	-	-	-	-
Paleanotus sp.1	+	-	-	-	-	-
Euphrosinidae						
Palmyreuphrosyne sp.1	-	-	-	-	+	-
Euphrosine capensis	-	-	-	+	+	-
Euphrosine armadillo	-	-	-	+	-	-
Euphrosine myrtosa	+	-	-	+	-	-
Euphrosine spp.	+	-	+	+	-	-
Amphinomidae						
Notopygos hispida	+	-	-	-	-	-
Notopygos sp.1	-	-	-	+	+	-
Notopygos sp.2	-	-	-	-	+	-
Notopygos spp.	+	-	-	+	+	+
Linopherus sp.2	-	-	-	+	-	+
Eurythoe matthaii	+	-	+	+	+	-
Chloeia inermis	-	-	-	+	+	+
Chloeia spp.	+	-	-	-	-	+
Eurythoe spp.	-	-	+	-	-	-
Linopherus microcephala	+	-	+	+	-	+
Linopherus paucibranchiata	+	+	-	+	+	+
Linopherus parvecarunculata	-	-	-	-	-	+
Linopherus spp.	-	-	-	+	-	+
Paramphinome sp.1	-	-	+	-	-	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Phyllodocidae						
Eteone siphodonta	+	+	+	+	+	-
Eteone spp.	-	+	-	+	-	+
Phyllodoce (Anaitis) capensis	+	+	-	-	-	-
Phyllodoce longipes	+	-	+	+	+	+
Phyllodoce malmgreni	+	+	+	+	+	+
Phyllodoce madeirensis	+	-	-	-	-	-
Phyllodoce fristedti	-	-	-	+	+	+
Phyllodoce spp.	+	-	+	+	+	-
Eulalia magalaensis	-	-	-	+	-	-
Eulalia spp.	-	-	+	+	-	+
Sige macroceros	-	-	-	+	+	+
Mystides angolaensis	-	-	-	+	-	-
Mystides spp.	-	-	-	+	-	-
Pilargidae						
Pseudexogone imajimai	-	-	-	-	-	+
Pseudexogone spp.	-	-	-	+	+	-
Sigambra parva	+	+	+	+	+	+
Sigambra robusta	+	-	+	-	-	-
Sigambra tentaculata	-	-	-	+	+	+
Sigambra pettiboneae	-	-	-	+	-	-
Sigambra spp.	-	-	-	+	-	-
Ancistrosyllis falcata	-	-	-	-	-	+
Synelmis rigida	-	-	+	-	-	-
Hesionidae						
Podarkeopsis capensis	+	+	+	+	+	+
Hesione pantherina	+	-	-	-	-	-
Leocrates claparedii	+	-	+	+	+	+
Psamathe fusca	+	+	-	+	+	+
Psamathe spp.	+	-	-	-	-	-
Syllidia armata	+	-	-	+	+	+
Syllidia spp.	+	+	-	-	-	-
Nereimyra sp.1	-	-	-	+	-	-
Nereimyra spp.	+	-	-	-	-	-
Micropodarke dubia	-	-	-	+	+	-
Hesione splendida	-	-	-	+	+	+
Hesione spp.	-	-	-	+	-	-
Hesiospina aurantiaca	-	-	-	+	+	+

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Hesionides arenaria	-	-	-	-	+	-
Hesionides spp.	-	-	-	+	+	-
Gyptis spp.	-	-	-	-	+	-
Podarkeopsis spp.	-	-	-	-	+	-
Oxydromus sp.1	-	-	-	+	-	+
Oxydromus sp.2	-	-	-	-	+	-
Hesiocaeca sp.1	-	-	-	+	-	-
Syllidae						
Proceraea sp.1	+	-	+	-	-	-
Myrianida spp.	+	-	+	+	-	+
Exogone heterosetosa	+	-	-	+	+	+
Exogone verugera	-	-	+	+	-	+
Exogone normalis	-	-	-	-	+	-
Exogone naidina	-	-	-	+	-	-
Exogone spp.	+	+	-	+	+	+
Opisthosyllis brunnea	+	-	-	-	+	-
Opisthosyllis spp.	+	-	-	+	-	-
Paraehlersia ehlersiaeformis	-	+	-	+	+	+
Paraehlersia ferrugina	+	+	+	+	+	+
Pionosyllis malmgreni	+	+	+	+	+	+
Pionosyllis spp.	+	+	+	+	+	+
Sphaerosyllis sublaevis	+	-	+	+	+	+
Sphaerosyllis semiverrucosa	+	-	-	+	+	+
Sphaerosyllis georgeharrisoni	-	-	-	-	+	+
Sphaerosyllis capensis	-	-	-	-	+	+
Sphaerosyllis spp.	+	-	+	+	+	-
Opisthodonta russelli	-	-	-	+	+	-
Opisthodonta longocirrata	+	+	-	+	+	+
Erinaceusyllis erinaceus	-	-	-	-	+	-
Trypanosyllis ankyloseta	-	-	-	+	-	-
Trypanosyllis spp.	+	-	-	+	+	-
Haplosyllis spongicola hamata	-	-	-	+	-	-
Haplosyllis spongicola	+	-	-	-	+	-
Branchiosyllis cirropunctata	-	-	-	-	-	+
Branchiosyllis exilis	+	-	-	-	+	-
Syllis vittata	-	-	-	+	-	-
Syllis armillaris	-	-	-	+	-	+
Syllis gracilis	-	-	-	-	+	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Syllis cornuta	+	+	+	+	+	+
Syllis hyalina	+	-	-	+	-	-
Syllis taprobaensis	+	-	-	-	+	-
Syllis prolifera	-	-	-	-	+	-
Syllis amica	-	-	-	+	+	+
Syllis spp.	+	+	+	+	+	+
Eurysyllis tuberculata	-	-	-	+	-	-
Eusyllis spp.	-	-	-	-	-	+
Lamellisyllis spp.	-	-	-	-	+	-
Levidorum sp.1	-	-	-	+	-	-
Levidorum sp.2	-	-	-	+	-	-
Nereididae						
Ceratonereis sp.1	+	-	-	+	-	-
Websterinereis punctata	+	-	-	-	-	-
Leonnates indicus	+	-	-	-	-	-
Tylonereis spp.	-	-	+	+	-	+
Neanthes agulhana	+	-	-	-	-	-
Nereis persica	-	-	-	+	-	-
Nereis jacksoni	-	-	-	+	-	-
Neries sp.1	-	-	-	+	-	-
Nereis sp.2	-	-	-	+	-	-
Nereis sp.3	-	-	-	+	-	-
Nereis spp.	+	+	+	+	-	-
Dendronereis sp.1	-	-	-	+	+	-
Namanereis sp.2	-	-	-	+	+	-
Namanereis sp.3	-	-	-	+	-	-
Namalycastis sp.1	-	-	-	+	-	-
Dawbinia sp.1	-	-	-	+	-	-
Platynereis sp.1	-	-	-	+	-	-
Nephtyidae						
Aglaophamus malmgreni	-	-	-	+	-	-
Aglaophamus verrilli	-	-	-	+	-	-
Aglaophamus lyrochaeta	-	-	-	-	+	-
Micronephthys minuta	-	-	-	+	-	-
Aglaophamus macroura	-	+	-	-	-	-
Aglaophamus dibranchis	+	+	+	+	+	+
Inermonephtys inermis	+	+	-	-	+	-
Micronephthys sphaerocirrata	+	+	+	+	+	+

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Nephtys spp.	+	-	+	+	-	-
Paralacydoniidae						
Paralacydonia paradoxa	+	+	+	+	+	+
Glyceridae						
Glycera benguellana	+	+	-	+	+	+
Glycera tridactyla	+	+	+	-	+	-
Glycera natalensis	+	+	-	+	+	-
Glycera papillosa	+	+	-	+	+	+
Glycera longipinnis	-	+	+	-	+	+
Glycera subaenea	+	-	+	-	-	-
Glycera lancadivae	+	-	+	-	-	-
Glycera alba	-	-	-	-	+	+
Glycera tesselata	-	-	-	-	+	+
Glycera oxycephala	-	-	-	+	+	-
Glycera spp.	+	+	+	+	+	+
Glycera lapidum	-	-	-	+	+	+
Glycera nicobarica	-	-	-	+	+	+
Hemipodia sp.1	-	-	-	-	+	+
Goniadidae						
Goniadella gracilis	-	-	-	-	+	-
Goniadella sp.1	+	-	-	-	-	-
Goniadides carolinae	-	-	-	+	+	+
Goniada gigantea	-	-	-	+	-	+
Goniada tridens	-	-	-	+	+	+
Goniada emerita	+	-	-	+	+	+
Goniada maculata	+	+	+	+	+	+
Goniada spp.	+	-	+	+	+	+
Goniadopsis sp.1	+	-	-	-	-	-
Ophioglycera eximia	+	-	-	-	-	-
Ophioglycera sp.1	+	-	+	-	-	-
Glycinde capensis	-	-	+	-	-	-
Glycinde kameruniana	-	-	+	-	-	+
Eunicidae						
Eunice aphroditois	-	-	+	-	-	-
Eunice indica	+	+	+	+	+	+
Eunice vittata	+	+	-	-	+	-
Eunice spp.	+	-	+	+	+	+
Marphysa sanguinea	+	-	-	+	-	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Marphysa adenensis	+	-	-	-	-	-
Marphysa sp.1	+	-	+	-	-	-
Onuphidae						
Diopatra neapolitana capensis	+	-	+	-	-	-
Diopatra sp.1	-	-	+	-	-	-
Hyalinoecia tubicola	+	-	-	+	-	-
Hyalinoecia sp.1	-	-	+	-	-	-
Rhamphobrachium sp.1	+	-	-	+	-	-
Nothria conchylega	+	+	+	+	+	+
Onuphis eremita	+	+	-	-	+	-
Onuphis geophiliformis	+	+	+	+	+	+
Onuphis holobranchiata	+	+	+	+	+	+
Onuphis spp.	+	+	+	+	+	+
Heptaceras quinquedens	-	-	-	+	-	-
Hyalospinifera sp.1	-	-	-	-	-	+
Heptaceras sp.1	-	-	-	+	-	-
Diopatra neapolitana	-	-	-	+	-	-
Paradiopatra sp.1	-	-	-	+	-	-
Oenonidae						
Drilonereis sp.1	+	-	-	-	-	-
Drilonereis falcata	-	+	+	+	+	+
Arabella iricolor	+	-	-	+	-	-
Lumbrineridae						
Lumbrinerides spp.	-	-	-	+	+	+
Lumbrineriopsis spp.	-	-	-	+	+	+
Augeneria sp.1	-	-	-	+	-	-
Lumbrineris aberrans	+	+	+	+	+	-
Lumbrineris heteropoda	-	-	+	+	+	+
Lumbrineris latreilli	+	-	+	+	+	+
Lumbrineris meteorana	+	+	+	+	+	+
Lumbrineris tetraura	+	+	+	-	-	-
Lumbrineris spp.	+	+	+	+	+	+
Ninoe lagosiana	+	-	-	-	-	-
Ninoe jessicae	-	-	-	-	-	+
Dorvilleidae						
Protodorvillea spp.	-	-	+	-	-	-
Protodorvillea biarticulata	+	+	+	+	+	+
Protodorvillea egena	+	+	+	+	+	+

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Dorvillea angolana	-	-	-	-	+	+
Dorvillea spp.	+	+	-	-	-	-
Schistomeringos rudolphi	+	+	+	+	+	+
Schistomeringos neglecta	-	-	-	-	+	-
Schistomeringos pectinata	-	-	-	-	+	-
Meiodorvillea sp.1	-	-	-	-	-	+
Iphitime sp.1	-	-	-	+	-	-
Sphaerodoridae						
Sphaerodoropsis sp.1	-	-	-	+	+	-
Sphaerodoropsis sp.2	-	-	-	+	-	-
Sphaerodoropsis spp.	-	-	-	+	+	+
Sphaerephesia sp.	-	-	-	+	-	+
Ephesiella sp.1	-	-	-	+	-	-
Flabelligeridae						
Brada spp.	+	+	+	-	-	-
Pycnoderma sp.1	+	-	-	-	-	-
Pherusa saldanha	-	-	-	+	+	-
Pherusa laevis	-	-	-	+	-	-
Pherusa tropica	-	+	-	+	+	+
Pherusa spp.	+	-	+	+	-	+
Diplocirrus erythroporus	-	-	-	+	-	-
Diplocirrus capensis	-	+	+	+	-	-
Diplocirrus spp.	+	-	+	+	+	+
Flabelliderma sp.1	-	-	-	+	+	-
Flabelligera sp.1	-	-	+	-	-	+
Cirratulidae						
Caulleriella capensis	+	+	+	-	-	+
Caulleriella bioculata	+	+	-	+	+	+
Caulleriella spp.	+	-	+	-	-	-
Chaetozone setosa	+	-	+	-	-	-
Chaetozone sp.1	-	-	-	-	+	-
Cirratulus africanus	-	+	+	-	+	+
Cirratulus spp.	-	+	+	-	+	+
Protocirrineris chrysoderma	-	+	-	-	-	-
Cirriformia saxatilis	-	+	+	-	-	-
Cirriformia tentaculata	-	-	+	-	+	+
Cirriformia afer	-	-	-	-	-	+
Cirriformia spp.	-	-	+	+	+	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Tharyx annulosus	+	+	+	+	+	+
Tharyx spp.	+	+	+	+	+	+
Kirkegaardia dorsobranchialis	+	+	+	+	+	+
Aphelochaeta filibranchia	+	+	+	+	+	+
Aphelochaeta marioni	+	+	+	-	-	-
Orbiniidae						
Leitoscoloplos kerguelensis	+	+	+	+	+	-
Orbinia monroi	-	+	-	-	-	-
Scoloplos (Scoloplos) marsupialis	+	+	+	+	+	+
Scoloplos (Leodamas) uniramus	+	-	-	-	+	-
Scoloplos (Leodamas) johnstonei	+	-	+	+	+	+
Scoloplos sp.1	-	-	-	+	+	+
Scoloplos (Leodamas) madagascariensis	-	-	-	+	+	-
Scoloplos (Scoloplos) armiger	-	-	-	-	+	-
Scoloplos spp.	+	+	+	-	+	+
Phylo sp.1	-	-	+	-	-	-
Pettibonella shompens	+	-	-	+	-	-
Scolaricia dubia	-	-	-	+	-	-
Scolaricia capensis	-	-	-	-	+	-
Scoloplella capensis	-	-	-	+	-	+
Protoariciella sp.1	-	-	-	-	+	-
Proscoloplos sp.1	-	-	-	-	+	-
Questa sp.1	-	-	-	+	-	-
Paraonidae						
Aricidea (Strelzovia) belgicae	+	+	-	-	-	-
Aricidea (Strelzovia) curviseta	-	+	+	-	+	-
Aricidea (Strelzovia) belgicae	-	-	-	+	+	-
Aricidea (Aricidea) capensis	+	+	+	+	+	+
Aricidea (Aricidea) longicirrata	-	-	-	+	+	+
Aricidea (Aricidea) thailandica	-	-	-	+	+	-
Aricidea (Acmira) lopezi	+	+	+	+	+	+
Aricidea (Acmira) cerrutii	+	+	+	+	+	+
Aricidea (Acmira) simplex	+	-	+	+	+	+
Aricidea (Strelzovia) hartleyi	-	-	-	+	+	+
Aricidea (Acmira) catherinae	-	-	-	+	+	+
Aricidea longobranchiata	-	+	+	-	-	-
Aricidea spp.	+	+	+	+	+	+
Cirrophorus branchiatus	-	+	+	+	-	+

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Cirrophorus spp.	-	-	-	+	+	-
Levinsenia flava	-	+	+	-	-	-
Levinsenia oculata	+	+	+	+	+	+
Levinsenia gracilis	+	+	+	+	+	+
Levinsenia sp.1	-	-	-	+	-	-
Paraonides sp.1	-	-	+	-	-	-
Paradoneis lyra	+	+	+	+	+	+
Paradoneis lyra capensis	+	-	+	-	-	-
Paradoneis armata	-	-	-	+	+	+
Paradoneis sp.1	+	-	+	-	-	-
Opheliidae						
Ophelia roscoffensis	+	-	-	-	-	-
Ophelia agulhana	+	-	-	-	-	-
Ophelina acuminata	+	-	-	-	-	-
Ophelia spp.	+	-	+	+	-	-
Ophelina spp.	+	-	-	+	+	-
Armandia lanceolata	-	-	-	+	-	-
Armandia agilis	-	-	-	+	-	-
Armandia intermedia	-	-	-	+	-	-
Armandia sampadae	-	-	-	+	-	-
Armandia longicaudata	-	-	-	+	-	-
Armandia andamana	-	-	-	-	-	+
Armandia simodaensis	+	-	-	-	-	-
Armandia spp.	+	-	+	+	+	-
Armandia sp.1	-	-	-	+	-	-
Armandia sp.2	-	-	-	-	-	+
Armandia sp.3	-	-	-	+	-	-
Armandia sp.4	-	-	-	+	-	-
Armandia sp.5	-	-	-	+	-	-
Armandia sp.6	-	-	-	+	-	-
Armandia sp.7	-	-	-	-	-	+
Polyophthalmus spp.	-	-	-	+	+	+
Ophelia anomala	-	-	-	+	-	-
Ophelia sp.1	-	-	-	+	-	+
Travisiidae						
Travisia sp.1	+	-	-	+	-	-
Maldanidae						
Axiothella jarli	+	+	-	-	-	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Euclymene luderitziana	-	+	-	-	-	-
Euclymene oerstedii	-	+	+	+	-	+
Euclymene quadrilobata	-	-	-	+	-	+
Euclymene lombricoides	-	-	-	+	-	-
Euclymene spp.	+	+	+	+	+	+
Lumbriclymene cylindricauda	+	-	-	-	-	-
Lumbriclymene spp.	+	-	+	-	+	-
Maldanella capensis	-	-	-	-	-	+
Maldanella spp.	+	-	-	+	+	+
Maldane sp.	+	-	-	-	-	-
Nicomache spp.	-	-	+	+	-	+
Rhodine sp.1	-	-	+	-	+	-
Petaloproctus sp.1	-	-	-	-	-	+
Leiochone tenuis	-	-	-	-	-	+
Praxillella affinis	-	-	-	+	-	-
Praxillella spp.	-	-	-	-	+	+
*Sabaco*sp.1	-	-	-	-	-	+
Johnstonia spp.	-	-	-	-	+	+
Isocirrus sp.1	-	-	-	-	-	+
Asychis sp.1	-	-	-	-	+	-
Graviella sp.1	-	-	+	-	-	-
Oweniidae						
Owenia fusiformis	-	+	+	+	-	+
Myriochele sp.1	-	-	+	-	-	-
Ampharetidae						
Ampharete acutifrons	-	-	+	-	-	-
Ampharete agulhasensis	+	+	+	+	+	+
Ampharete kerguelensis	+	-	+	+	+	+
Ampharete sp.1	+	-	+	-	-	-
Ampharete sp.2	-	-	-	+	+	-
Ampharete spp.	+	+	+	+	-	+
Amphicteis gunneri	+	+	+	+	+	+
Amphicteis spp.	+	-	+	-	-	-
Isolda pulchella	-	-	+	-	-	-
Isolda spp.	-	-	+	+	-	-
Ampharete luederitzi	+	-	+	-	-	-
Samythella affinis	+	-	+	-	-	-
Samythella sp.1	-	-	-	+	-	-

Survey & sieve mesh size	SS261 (500µm)			SS292 (300µm)		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Melinna sp.1	-	-	-	-	-	+
Sosane sp.1	-	-	-	-	-	+
Auchenoplax sp.1	-	-	-	+	-	-
Terebellidae						
Loimia medusa	-	+	+	-	+	-
Loimia spp.	-	-	+	+	+	-
Terebella plagiostoma	-	-	+	-	-	-
Pista unibranchia	-	+	+	+	+	+
Pista brevibranchia	-	+	-	+	-	-
Pista cristata	-	-	-	+	+	-
Pista australis	-	-	-	-	+	-
Pista spp.	-	-	+	+	-	-
Polycirrus swakopianus	+	-	-	+	-	-
Polycirrus tenuisetis	+	-	-	-	-	-
Polycirrus haematodes	-	-	-	+	-	-
Polycirrus spp.	+	-	+	+	+	+
Streblosoma persica	+	+	+	-	-	-
Streblosoma spp.	-	-	+	+	-	-
Eupolymnia nebulosa	-	-	-	-	+	-
Lanassa sp.1	-	-	-	+	+	-
Amaeana sp.1	-	-	-	+	-	-
Euthelepus kinsemboensis	-	-	+	-	-	-
Euthelepus sp.1	-	-	-	-	-	+
Thelepus setosus	-	-	-	+	-	-
Artacama sp.1	-	-	-	-	-	+
Amphitrite sp.1	-	-	-	+	+	-
Amphitrite sp.2	-	-	-	+	-	-
Trichobranchidae						
Terebellides gilchristi	-	+	-	-	-	-
Terebellides stroemii	+	+	+	+	+	-
Terebellides sp.1	-	-	+	-	-	-
Trichobranchus glacialis	+	-	+	+	-	-
Trichobranchus sp.1	-	-	+	+	-	-
Sabellidae						
Paradialychone filicaudata	+	+	+	+	+	+
Chone letterstedti	+	-	+	+	+	+
Chone spp.	+	-	+	+	+	+
Desdemona ornata	+	-	-	-	-	-

Survey & sieve mesh size	SS261 (500µm)			SS292 (300µm)		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Euchone capensis	+	+	+	+	-	-
Euchone rosea	+	+	+	+	+	+
Euchone spp.	+	-	+	+	+	+
Notaulax phaeotaenia	+	+	-	-	-	-
Jasmineira caudata	-	+	+	-	-	-
Jasmineira elegans	+	+	+	+	+	+
Jasmineira spp.	+	-	+	+	-	-
Branchiomma sp.1	+	-	-	-	+	-
Oriopsis ehlersi	+	-	-	-	-	-
Amphicorina spp.	+	+	-	-	-	+
Potamilla spp.	-	+	+	+	+	-
Sabella spallanzanii	+	-	-	-	-	-
Sabellastarte spp.	+	-	-	+	+	-
Euchone limnicola	-	-	-	+	-	+
Dialychone collaris	-	-	-	+	-	-
Pseudopotamilla reniformis	-	-	-	-	+	-
Dialychone sp.1	-	-	-	+	+	-
Fabriciidae						
Fabricia sp.1	-	-	-	+	-	-
Fabriciola sp.1	-	-	-	-	-	+
Novafabricia sp.1	-	-	-	+	+	+
Sabellariidae						
Sabellaria sp.1	+	-	-	-	-	-
Phalacrostemma sp.1	-	-	+	+	-	-
Lygdamis indicus	+	-	-	-	-	-
Lygdamis sp.1	-	-	-	+	-	-
Idanthyrsus macropaleus	+	-	-	-	-	-
Idanthyrsus sp.1	-	-	-	+	+	-
Serpulidae						
Hydroides uncinata	-	-	-	+	+	+
Hydroides spp.	+	-	-	+	-	-
Filogranula sp.1	-	-	-	-	+	-
Spirobranchus kraussii	-	-	-	-	+	-
Pectinariidae						
Pectinaria capensis	-	-	-	+	-	-
Pectinaria sp.1	+	-	-	-	-	-
Sternaspidae						
Caulleryaspis laevis	-	-	-	+	-	+

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Caulleryaspis sp.1	-	-	+	+	-	-
Petersenaspis sp.1	-	-	-	+	-	+
Sternaspis sp.1	-	-	-	+	-	-
Sternaspis sp.2	-	-	-	-	-	+
Sternaspis spp.	+	-	+	-	+	-
Capitellidae						
Capitella capitata	+	+	+	-	-	-
Capitella spp.	-	+	-	-	-	+
Leiochrides africanus	+	+	+	+	+	+
Leiochrides spp.	+	-	+	-	-	-
Notomastus aberans	+	+	+	+	+	+
Notomastus fauvelii	+	+	+	+	-	+
Notomastus latericeus	-	-	-	+	-	+
Notomastus sp.1	+	-	-	-	-	-
Notomastus spp.	-	+	+	-	-	+
Mediomastus capensis	-	+	-	+	+	+
Scyphoproctus armatus	+	+	+	+	+	+
Neonotomastus spp.	+	-	-	+	+	-
Mediomastus spp.	-	+	+	+	-	+
Capitellethus spp.	+	-	+	+	-	+
Leiocapitellides spp.	-	+	-	+	-	-
Parheteromastus spp.	+	-	-	+	+	-
Heteromastides spp.	-	-	+	-	-	+
Neomediomastus spp.	-	-	+	+	+	+
Leiocapitella hartmanae	-	-	-	+	+	-
Neoheteromastus spp.	-	-	-	+	+	-
Heteromastus filiformis	-	-	-	+	-	-
Heteromastus spp.	-	-	-	+	+	-
Eunotomastus sp.1	-	-	-	+	-	-
Dasybranchus bipartitus	-	-	-	-	+	-
Dasybranchus sp.1	-	-	-	-	+	-
Notodasus sp.1	-	-	-	-	-	+
Pseudoleiocapitella sp.1	-	-	-	-	-	+
Parheteromastides sp.1	-	-	-	-	-	+
Cossuridae						
Cossura sp.1	-	-	+	+	+	+
Cossura sp.2	-	-	+	+	+	+
Cossura sp.3	-	-	+	+	-	+

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Cossura sp.4	+	-	+	+	-	+
Cossura sp.5	+	-	+	+	+	+
Cossura sp.6	-	-	-	+	+	+
Cossura spp.	+	-	+	+	+	+
Poecilochaetidae						
Poecilochaetus serpens	-	-	-	+	+	+
Poecilochaetus sp.1	+	+	+	+	-	-
Poecilochaetus sp.2	+	+	+	+	-	-
Poecilochaetus sp.3	+	+	+	+	+	+
Poecilochaetus sp.4	-	-	+	-	-	-
Poecilochaetus sp.5	-	-	+	-	-	-
Poecilochaetus spp.	-	-	-	-	+	-
Magelonidae						
Magelona tinae	-	+	-	+	-	+
Magelona pulchella	+	-	-	+	-	+
Magelona cincta	+	+	+	+	+	+
Magelona symmetrica	+	+	-	+	+	+
Magelona kamala	-	-	+	-	-	-
Magelona wilsoni	-	+	-	-	-	-
Magelona cepiceps	-	-	-	+	+	+
Magelona pygmaea	-	-	-	+	-	-
Magelona lusitanica	-	-	-	+	+	+
Magelona johnstoni	-	-	-	-	+	-
Magelona capensis	-	-	-	+	-	-
Magelona crenulifrons	-	-	-	-	+	+
Magelona minuta	-	-	-	+	-	-
Magelona mahensis	-	-	-	+	-	-
Magelona papillicornis	-	-	-	+	+	-
Magelona sp.1	-	-	-	+	+	-
Magelona sp.2	-	-	-	+	-	-
Magelona sp.3	+	+	-	-	-	-
Magelona sp.4	-	+	-	-	-	-
Magelona sp.5	+	+	-	-	-	-
Magelona spp.	-	-	+	-	+	+
Spionidae						
Paraprionospio pinnata	+	+	+	+	+	+
Prionospio andamanensis	+	+	+	+	+	+
Prionospio saldanha	+	+	-	-	-	-

Survey & sieve mesh size	**SS261 (500µm)**			**SS292 (300µm)**		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Prionospio ehlersi	+	+	+	+	+	+
Prionospio henriki	-	-	+	-	+	-
Prionospio komaeti	-	+	+	+	+	+
Prionospio cornuta	+	+	+	+	+	+
Prionospio malmgreni	-	-	+	+	+	+
Prionospio cirrifera	+	+	+	-	-	-
Prionospio polybranchiata	-	-	+	-	-	-
Prionospio grossa	-	-	+	-	-	-
Prionospio neenae	+	+	-	+	+	+
Prionospio nielseni	-	-	-	+	+	+
Prionospio phuketensis	-	-	-	+	+	+
Prionospio sp.1	-	-	-	-	+	+
Prionospio sp.2	-	-	-	-	-	+
Prionospio sp.3	-	-	-	-	-	+
Prionospio sp.4	-	-	-	+	-	+
Prionospio sp.5	-	-	-	-	-	+
Prionospio sp.6	+	-	-	+	-	-
Prionospio spp.	+	+	+	+	+	+
Minuspio delta	-	-	-	-	-	+
Prionospio (Minuspio) spp.	+	+	+	+	+	+
Prionospio (Aquilaspio) sp.1	-	-	-	+	-	+
Prionospio (Apoprionospio) sp.1	-	-	-	-	-	+
Aonidella dayi	+	+	+	+	+	+
Aonidella sp.1	-	-	-	-	-	+
Spiophanes bombyx	+	+	+	+	+	+
Spiophanes duplex	+	+	+	-	-	-
Spiophanes spp.	-	-	+	+	+	+
Aonides oxycephala	+	+	+	-	-	-
Aonides paucibranchiata	+	-	-	-	-	-
Aonides spp.	+	+	+	+	+	+
Boccardia sp.1	-	-	+	-	-	-
Laonice cirrata	+	+	+	-	-	-
Laonice weddellia	-	-	+	-	-	-
Laonice spp.	+	-	+	+	+	+
Scolelepis (Parascolelepis) gilchristi	+	-	+	-	-	-
Scolelepis (Scolelepis) squamata	+	-	+	-	-	-
Scolelepis lefebvrei	-	+	-	-	-	-
Scolelepis spp.	-	-	+	+	+	+

Survey & sieve mesh size	SS261 (500µm)			SS292 (300µm)		
Species	**50m**	**100m**	**200m**	**50m**	**100m**	**200m**
Malacoceros indicus	-	+	+	-	-	-
Malacoceros spp.	-	-	-	+	+	-
Spio sp.1	-	-	-	-	+	-
Pygospio sp.1	-	-	-	+	-	-
Pseudopolydora sp.1	-	-	-	+	-	-
Polydorella sp.1	-	-	-	+	-	+
Longomastidae						
Heterospio sp.1	-	-	-	-	+	-
Scalibregmatidae						
Scalibregmella sp.1	-	-	-	+	-	-
Proscalibregma sp.1	-	-	-	+	+	-
Scalibregma sp.1	-	-	-	+	-	-
Saccociriidae						
Saccocirrus sp.1	-	-	-	+	-	-
Protodrilidae						
Protodrilus sp.1	-	-	-	+	+	+
Chaetopteridae						
Chaetopterus sp.1	+	-	-	-	-	-

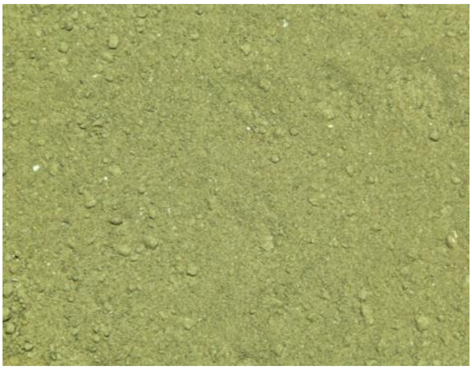
Plate I

1. Coarse coralline sand

2. Fine coralline sand

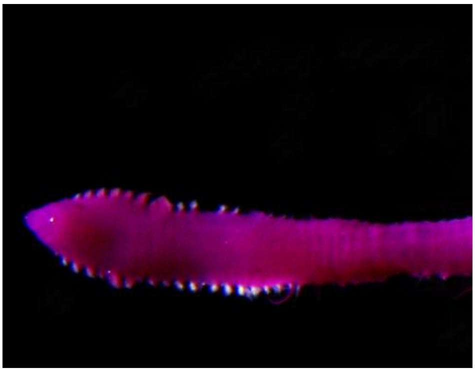
3. Coral & shell fragments

4. Silty sand



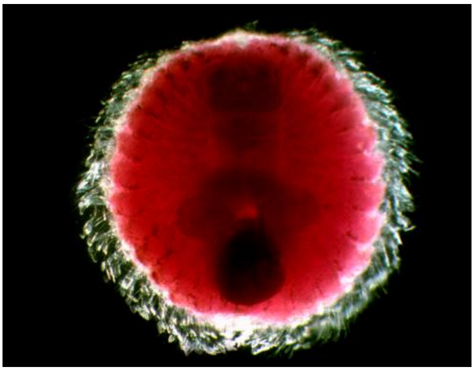
5. Silt

Plate II

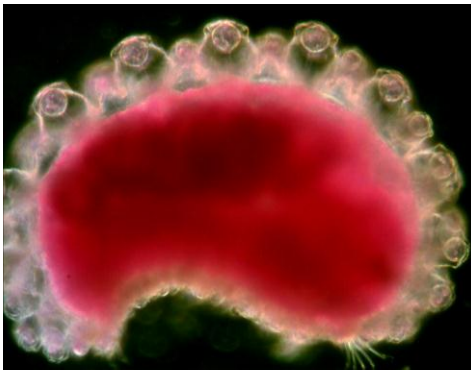


1. *Pettibonella shompens*

2. *Armandia sampadae*

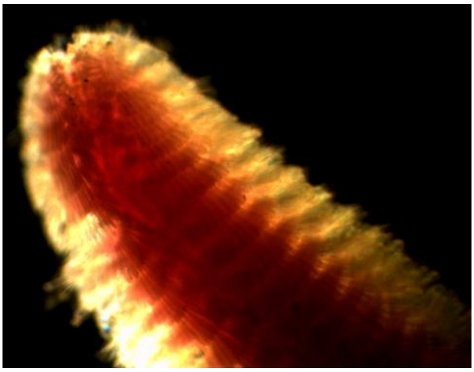


3. *Palmyreuphrosyne sp.*



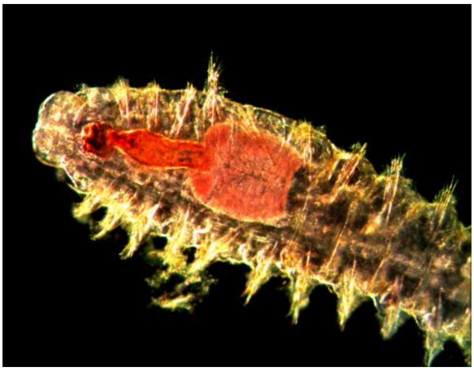
4. *Sphaerodoropsis sp.*

5. *Rhamphobranchium sp.*



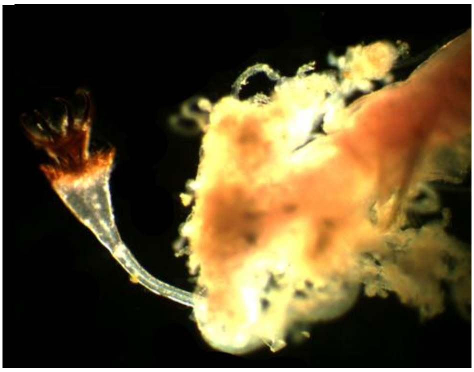
6. *Chrysopetalum occidentale*

Plate III

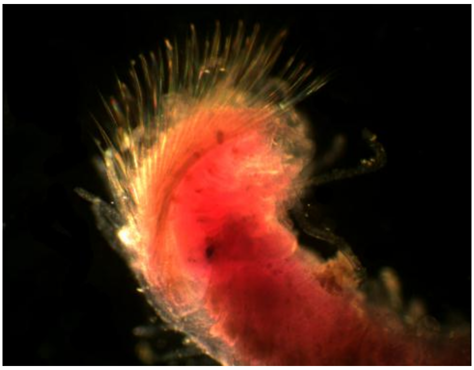


1. *Sphaerosyllis georgeharrisoni*

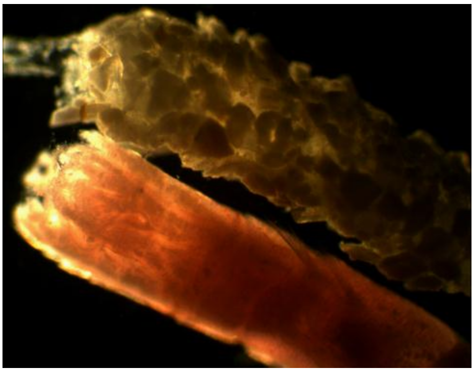
2. *Leocrates cleparedii*



3. *Hydroides uncinata*



4. *Lygdamis sp.*

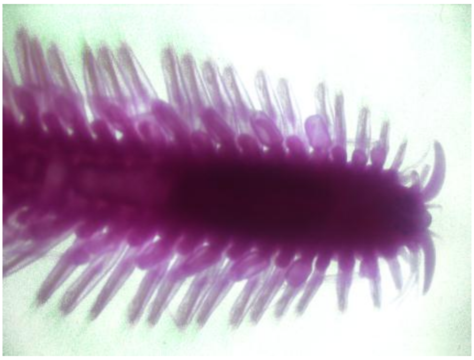


5. *Owenia fusiformis*

6. *Notaulax phaeotaenia*

Plate IV

1. *Heteraphrodita altoni*



2. *Dreischia pelagica*

3. *Paraprionospio pinnata*

4. *Euphrosyne armillado*

5. *Proscalibregma sp.*

6. *Phyllodoce malmagreni*