MACROBENTHOS OF THE CONTINENTAL MARGIN (200-1000m) OF SOUTH EASTERN ARABIAN SEA WITH SPECIAL REFERENCE TO POLYCHAETES

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Ph. D. Thesis in Marine Biology

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Front Cover Illustration
Bottom topography of the study area
Inset: *Paraprionospio pinnata*, Capitellid, *Terebellides stroemii*, *Raninoides* sp., *Amygdalum* sp., *Bathypectinura heros.*

CERTIFICATE

This is to certify that the thesis entitled "**Macrobenthos of the continental margin (200-1000m) of South Eastern Arabian Sea with special reference to Polychaetes**" is an authentic record of the research work carried out by Mr. Abdul Jaleel K. U., 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.

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May, 2012

DECLARATION

I hereby declare that the thesis entitled "**Macrobenthos of the continental margin (200-1000m) of South Eastern Arabian Sea with special reference to Polychaetes**" is an authentic record of research work conducted by me under the supervision of Dr. R. Damodaran, Professor (Retd.), Department of Marine Biology, Microbiology & Biochemistry, Cochin University of Science & Technology and no part of it has been presented for any other degree or diploma in any University.

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Jaleel

Dedication

To my parents,
In consideration of love and affection.

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LIST OF ACRONYMS & ABBREVIATIONS

ANOVA	Analysis of Variance
BBL	Benthic Boundary Layer
CAP (or Cap)	Cape Comorin
CCA	Canonical Correspondence Analysis
CMLRE	Centre for Marine Living Resources & Ecology
CND (or Cnd)	Coondapur
CTD	Conductivity – Temperature – Depth
DO	Dissolved Oxygen
EAS	Eastern Arabian Sea
EEZ	Exclusive Economic Zone
FORVSS	Fishery & Oceanographic Research Vessel *Sagar Sampada*
IIOE	International Indian Ocean Expedition
JGOFS	Joint Global Ocean Flux Studies
KCH (or Kch)	Kochi
KLM (or Klm)	Kollam
KNR (or Knr)	Kannur
KWR (or Kwr)	Karwar
MLD	Mixed layer depth
MNG (or Mng)	Mangalore
MT	Million Tonnes
NEAS	North Eastern Arabian Sea
OC	Organic Carbon
OM	Organic Matter
OMZ	Oxygen Minimum Zone
PCA	Principal Component Analysis
POC	Particulate Organic Carbon
PON (or Pon)	Ponnani
PRIMER	Plymouth Routines in Multivariate Ecological Research

SEAS	South Eastern Arabian Sea
SST	Sea Surface Temperature
TOC	Total Organic Carbon
TVM (or Tvm)	Trivandrum
WICC	West India Coastal Current

Chapter I

INTRODUCTION

The marine ecosystem consists of two distinct but interdependent compartments: the pelagic, comprising the water column and benthic, comprising the sediment matrix. Marine sediments cover the ocean bottom and constitute the single largest ecosystem on earth in terms of spatial coverage (Snelgrove 1998, Bacci *et al*. 2009). The benthic compartment extends from intertidal region up to the deepest trenches and its most important feature is the heterogeneity in environmental features. Sanders and Hessler (1969) designated the major physiographic features of the sea floor as the continental shelf (<200m), continental slope (200-2000m), continental rise (2000-4000m) and abyssal plain (>4000m). The continental slope, which is the region of the seafloor between the continental shelf and continental rise, is characterized by a sharp gradient in depth over short distances. At the edge of the continental slope, the bottom levels out gradually, in the region designated as the continental rise.

The continental shelf and slope are together called the 'continental margin', which is considered to be a location of remineralization and burial of large quantities of organic carbon (Premuzic *et al*. 1982, Walsh *et al*. 1985). Approximately 26% of the anaerobic carbon oxidation in marine sediments occurs between 200 and 2000m water depth, even though that region represents only 9% of the seafloor (Henrichs & Reeburgh 1987). As a result of remoteness of the deep-sea floor, benthic fauna of this region and the role they play in the remineralization processes, remain poorly characterised relative to other parts of the ocean (Cowie & Levin 2009).

The first observations on life at the bottom of the deep-sea were made by the English biologist Edward Forbes, in the 1840s. He conducted dredging operations in the Aegean Sea to a depth of 230 fathoms (~420m) and discovered very few animals; all of which were diminutive (Spratt & Forbes 1847). In the following years, he concluded that life did not exist in the deep-sea, beyond 300 fathoms (~550m), and thus framed the 'azoic theory' for the deep-sea. Although in the following years living specimens were collected from greater depths, Forbes' theory proved to be persistent for a long time (Mills 1983). It was finally disproved by Michael Sars who recovered benthos from 600m depth off the Lofoten Islands in Norway and recorded more than 300 species (Sars 1868).

The term 'benthos' was first used by Haeckel, as derived from the Greek for 'depths of the sea'. It refers collectively to all aquatic organisms which live in, on or near the bottom of a water body. Benthos comprises an enormous variety of organisms, ranging from bacteria to large, mobile megafauna; and these organisms are also diverse in lifestyle and feeding modes (Cowie & Levin 2009). Benthos are normally divided into three functional groups, infauna, epifauna and hyper benthos i.e., those organism living within the substratum, on the surface of the substratum and just above it, respectively (Pohle & Thomas 2001). According to their size, benthic animals are classified into three groups: the macro, meio and microbenthos (Mare 1942). This classification depends on the mesh size of the sieves used to separate them, which varies arbitrarily in different studies. The macrobenthos are defined as organism retained in the sieve having mesh size between 0.5 and 1mm, while in recent years, the use of 0.3mm sieves (instead of 0.5mm) is also becoming popular. The major taxonomic groups represented among macrofauna are the annelids, crustaceans and molluscs, along with echinoderms, sipunculids etc. For meiobenthos, the lowest size attributed is 63μ and the upper limit depends upon the mesh size of the sieve used for separating macrobenthos from meiobenthos. Meiofauna are chiefly represented by nematodes, foraminiferans, harpacticoid copepods etc. The smallest size group, microbenthos, includes those organisms that are not retained in the finest sieve used for meiobenthos separation and include bacteria and most protozoans. Within the sediment matrix, the vertical extent of benthos is quiet limited, with organisms occupying only the top few centimeters. Practical differences in the sampling procedures adopted have led to the differentiation of benthos into soft bottom benthos and hard bottom benthos.

Benthic fauna are of considerable importance in marine food chains (McIntyre, 1971) as they are involved in recycling of minerals, organic carbon, nitrogen and sulfur on a global scale (Schweitzer 1974, Giblin *et al*. 1995, Heip *et al*. 2001). Most of the macrofauna are detritus feeders (either suspension or deposit feeders) and rely upon the organic material raining down from the upper euphotic zone in the form of detritus, fecal pellets or animal carcasses. In the water just above the sediment, a Benthic Boundary Layer (BBL) is formed, in which nutrients and organic materials along with microfauna are suspended by the friction of water moving over the substrate. The BBL which varies in thickness and is characterized by sharp energy gradients is of great importance in the remineralization process (Boudreau & Jorgensen 2001, Heip *et al*. 2001). By feeding on the organic matter in the BBL, macrofauna selectively or non-selectively remove the organic matter from the sediment-water interface. The burrowing activities of deposit feeders results in increased sediment oxygenation, vertical movement of sediment particles, repacking of sediments and alteration of sediment stability – a process known as bioturbation. The detritus feeders in the benthos, along with organisms which prey upon them, provide a conduit for the transfer of organic carbon back into the pelagic realm (Carlson *et al.* 1997, Snelgrove 1998). Benthos also form a source of food for many commercially important demersal fishes and also indirectly influences the availability of food for pelagic forms. Additionally, a good proportion of benthic fauna have pelagic larval stages that are important components of pelagic standing stock.

Many of the early studies on marine organisms from sediments were taxonomic in nature, describing new species and one of the pioneers in this regard was Carl von Linnaeus (1707-1778). Research on deep-sea fauna, byond depths for 200m began with the collections of the British ship H.M.S. *Challenger* (1872-1876). In the following decades numerous cruises were undertaken by scientists from many countries to explore the biological diversity of the deep sea. Sanders (1968) investigated benthic diversity in the deep sea, between southern New England and Bermuda Island and showed that benthic diversity of polychaetes and bivalves increased with depth from shallow coastal areas to 2000m; and at bathyal depths, reached a level comparable to that found in tropical soft bottom communities on the shelf. Subsequent observations have confirmed that high species diversity can be found in the deep sea throughout the world, particularly among the macrofauna and meiofauna (e.g. Jumars 1976, Hecker & Paul 1979, Rowe *et al*. 1982, Hyland *et al*. 1991, Blake & Grassle 1994, Gage 1996, Gooday *et al*. 1998, Paterson *et al*. 1998, Mendez 2007, Ingole *et al*. 2010). Over the past 50 years, biological research on continental margins has increased, owing to technological advancements and many such studies have improved our knowledge of the highly dynamic and complex ecosystem of deep continental margins.

Hyland *et al*. (1991) conducted a detailed survey on the Santa Maria basin shelf and slope, an oceanographically complex and productive region. They found that the area supports a highly diverse macrofauna including crustaceans, polychaetes and molluscs. Additionally, the study revealed the influence of upwelling-related high primary production on macrofaunal density in the continental margin. The continental slopes of the Atlantic Ocean are well studied, compared to other parts of the world. Studies conducted by Blake & Grassle (1994) along a depth gradient between 600-3500m off the Carolinas (North Atlantic Slope) yielded 1202 species, of which 520 were new to science.

Off Cape Hatteras, North Carolina Blake & Hilbig (1994) reported unusually dense assemblages of infaunal invertebrates from the continental slope (530-2003m). In this region, densities were highest on the upper slope; while species richness and diversity were on the lower side. These studies in particular support the view that high species diversities exist in the deep sea.

On the other side of the Atlantic Ocean, Paterson & Lambshead (1995) analysed the polychaete diversity on the Hebridean margin (up to the Rockall Trough basin) and their results revealed a parabolic pattern of polychaete species richness with the high peak at 1800m depth. In the Goban Spur region, Flach & Heip (1996) observed a dominance of polychaetes and most of these organisms were concentrated in the upper 1 cm of the sediments. Flach & Thomsen (1998) investigated the role of physical and chemical factors in structuring macrobenthic community in the north east Atlantic slope. They found that the density and biomass of macrofauna decreased with increasing depth; while the flow velocity and organic matter supply were also important structuring factors. In the same sampling sites, Flach & De Bruin (1999) reported increase in diversity and evenness with increasing depth. Distinct community assemblages were observed on the shelf, slope and abyss and this was at least partly explained on the basis of differences in life history strategies and organic matter supply (Flach & De Bruin 1999). Further north in the Faroe-Shetland Channel, Narayanaswamy *et al*. (2005, 2010) reported an increase in faunal biomass with depth, contrary to other such studies; while diversity exhibited a parabolic pattern, with a maximum at 350-550m (characterized by high temperature). Narayanaswamy *et al*. (2010), described regional variations in diversity of benthic fauna off the Shetland Islands. Species richness and diversity were highly correlated with temperature on transect west of the Islands; while to the north, these indices were negatively correlated with sedimentary variables (silt, clay, OM and temperature in combination).

Macrobenthos of the deep northern Gulf of Mexico from 200 to 3700m was studied by Wei *et al.* (2010). Bathymetric zonation of the macrofaunal community was observed for 6 major taxa and changes of faunal composition with depth reflected an underlying continuum of species replacement without distinct boundaries. The zonation pattern was correlated with depth and detrital particulate organic carbon (POC) export flux. In the continental margin off Crete (Aegean Sea, northeast Mediterranean), Tselepides *et al*. (2000) studied the macrobenthic composition, abundance, biomass and diversity together with sediment characteristics on a seasonal basis. Mean benthic biomass, abundance and diversity in this region was shown to decrease with depth, and the Crete margin was characterized by high diversity in the upper slope and very low diversity in the lower slope and deep-basin. In this study, significant correlations were obtained between macrofaunal distribution patterns and sediment parameters which led Tselepides *et al*. (2000) to conclude that besides depth, food availability (as manifested by the concentration of chloroplast pigments) is the principle regulating factor in the region. Thus, the prevailing hydrographic features that structure the pelagic food web are directly responsible for the propagation of organic matter to the benthos and also affect its community structure.

An examination of global bathymetric patterns of standing stock and body size in the deep-sea benthos (Rex *et al*. 2006) revealed that the abundance of macrofauna is significantly lower in the deep and decreases more rapidly with depth, than that of smaller groups (meiofauna and bacteria). Based on data collected from the North Atlantic, eastern Pacific and Indian Oceans Levin & Gage (1998) examined the relationships of environmental factors with macrobenthic community diversity. They found that depth, latitude, organic matter content and bottom water dissolved oxygen were significant factors that explain most of the variations in species richness, diversity, dominance and evenness.

The presence of low oxygen conditions in the Humboldt Current System (HCS) off Chile was shown to have important effects on the size structure and secondary production of the benthic communities living in this region (Quiroga *et al*. 2005). Studies on the influence of water mass, methane seeps and oxygen minimum zone (OMZ) on bathymetric distribution of benthic communities across the Chilean margin revealed that meio, macro and megafauna showed different responses to these factors (Sellanes *et al*. 2010). Studies conducted by Levin *et al*. (2002) on benthic responses to OMZ as a consequence of ENSO-related events in the Peru margin revealed that highest macrofaunal density and lowest diversity occurred in a site with lowest dissolved oxygen (DO) concentration and also recorded high abundance of gutless oligochaetes, which can tolerate very low DO level.

The Arabian Sea, in the northern Indian Ocean, covers about 1% of the world's ocean surface but accounts for about 5% of global marine production, due to intense upwelling during the southwest monsoon, along with reversed circulation and mixed layer deepening during the northeast monsoon (Qasim 1977, 1982). The seasonal upwelling, which results in high surface productivity and high export particle flux from the euphotic zone (Qasim 1977, 1982, Sen Gupta & Naqvi 1984, Nair *et al*. 1989, Haake *et al*. 1993, Rixen *et al.* 1996, 2000). For the northern and western Arabian Sea, very high mean annual particulate organic carbon fluxes into the deep ocean have been described (Witte 2000). Additionally, the amplitudes of seasonal variation in vertical particulate organic carbon flux are among the largest so far recorded in the open ocean (Ittekkot *et al*. 1996). The high organic production and limited sources of water replacement result in rapid utilization of oxygen and development of an intense and unusually deep oxygen minimum layer. This results in suppressed mid-water recycling of organic matter, allowing much more of it to sink to the depths without being recycled (Angel 1984, Haake *et al*. 1993, Cowie 2005). Thus, an enhanced flux of labile organic material is delivered to the deep sea benthic boundary. The OMZ in the Arabian Sea is located between depths of 100 to 1300m (Qasim 1982, Helly & Levin 2004, Hughes *et al*. 2009); and in regions where they are in contact with the sediments of the continental margin they have a profound impact on the distribution and biomass of bottom living organisms. When considering the vertical flux and processes that occur in the benthic boundary layer and within the surface sediments, the Arabian Sea continental margin and its surface sediments have greatest importance (Walsh 1991, Naqvi & Jayakumar 2000, Naqvi *et al*. 2005, Cowie 2005).

Most of the studies on marine benthos in India have been carried out on the shelf and inshore regions. Qualitative and quantitative aspects of benthos of the west coast have been studied by Kurian (1953, 1967, 1971), Seshappa (1953), Damodaran (1973), Parulekar *et al*. (1975), Sarladevi *et al*. (1991), Harkantra & Parulekar (1994), Sunilkumar & Antony (1994) and Sarladevi *et al*. (1996). The diversity, distribution, abundance and community structure of macrobenthos (benthic fauna >500µ) of the continental shelf of the west coast of India and the environmental influences on them are described by various workers (Jayaraj *et al*. 2007, 2008a, b, Joydas & Damodaran 2009, Joydas *et al*. 2009, Musale & Desai 2010, Smitha CK 2011). Of these, the studies carried out by Joydas & Damodaran (2009) is most comprehensive, covering five depths (30m to 200m) along 17 transects between Dwaraka (23^0N) and Cape Comerin (7^0N). The main objective of this study was to elucidate distribution patterns and standing crop of benthos in this region. The species richness and diversity in relation to environmental parameters were also described and some fascinating results were obtained: a decreasing trend in diversity, density and even in standing crop at the shelf edge.

Benthic fauna in the deep waters of Arabian Sea were collected during the voyage of the RIMS *Investigator I* & *II* between 1885 and 1925 (reviewed in Gage *et al.* 2000). A more or less azoic zone on the sea floor, between 100-1200m depth, along the western continental margin of the Arabian Sea was observed during the trawling and dredging operations of the Egyptian research vessel *Mabahiss* during the John Murray Expedition of 1933-1934 (Sewell 1934a, b, reviewed in Gage *et al.* 2000). The International Indian Ocean Expedition, IIOE (1962-65) focused on productivity and quantitative benthic sampling reported high standing crop in the deep Arabian Sea (Neyman *et al*.

1973). The value was relatively high for the low-latitude deep sea. The reason for this was suggested to be the pattern of seasonal upwelling and non-stationary eddies causing replenishment of nutrients (Gage *et al.* 2000).

In recent years, the influence of oxygen and organic matter availability and sediment characteristics on benthic communities and standing stock along the northern Arabian Sea continental margins (Oman and Pakistan) has been subject to numerous studies (Lamont & Gage 2000, Levin *et al*. 2000, Cowie & Levin 2009, Gooday *et al*. 2009, Hughes *et al*. 2009, Levin *et al*. 2009). Levin *et al.* (2000), conducted a study on macrobenthic community structure within and beneath the OMZ in the North West Arabian Sea (Oman margin), which dealt with macrofaunal abundance, biomass, body size, taxonomic composition, diversity and lifestyles, and the relation of these parameters to environmental conditions. In this study, it was found that the OMZ was dominated by soft bodied surface deposit feeding polychaetes (86-99% of macrofauna). Lamont & Gage (2000) reported the morphological adaptation of polychaetes in the Oman margin, in response to the low dissolved oxygen, which included enlargement in size and branching of branchiae to increase respiratory area, as observed in spionids and cossurids.

In the eastern Arabia Sea (Pakistan margin), the intensity and extent of the permanent OMZ has been reported to show seasonal variation, with shoaling of the upper OMZ boundary during the southwest monsoon season. This results in the extension of the OMZ to engulf the previously oxygenated regions at ~140m depth. In general, oxygen levels strongly influenced the taxonomic composition of all faunal groups. A drastic change in benthic community structure is reported to occur across the lower OMZ boundary that strongly coupled with the availability and quality of organic matter, as well as with the oxygen concentrations (Cowie & Levin 2009). Macrofaunal density was highest at 140m, but there was no elevation of density at the lower OMZ boundary (1200m). Macrofaunal density was extremely low in the OMZ core (300m) (Cowie & Levin 2009). Upon examining the responses of three groups (foraminiferans, macrofauna and megafauna) Gooday *et al.* (2009) found that species diversity was depressed at the OMZ core, and that this was more pronounced for macrofauna and megafauna than for foraminiferans.

High resolution sampling in the Pakistan margin impinged with OMZ, between 700-1100m led Levin *et al*. (2009) to suggest that for assemblages evolving under permanent severe hypoxia, food availability is a major factor that affects the faunal abundance; while oxygen and organic matter influence the pattern of diversity and dominance. Polychaetes were the most abundant group at all stations in the Pakistan margin but their density was not as high as those reported from Oman (Hughes *et al*. 2009). It was found that in general, data from the Oman margin were weak predictors of patterns seen off Pakistan, and results suggest the importance of local factors superimposed on the broader trends of macrofaunal community composition in OMZs (Hughes *et al*. 2009).

More recently, Ingole *et al*. (2010) studied the qualitative and quantitative pattern in distribution of macrofauna across a broad bathymetric transect (30m to 2545m) at 14^0N latitude (off Coondapur). There are also a few other studies on the deep-sea fauna around the Indian Ocean (Ingole 2003, Ingole & Koslow 2005, Ingole *et al*. 2005, Pavithran *et al*. 2007). However, detailed studies of benthos of continental margin beyond 200m in the South Eastern Arabian Sea (SEAS) with consistent and repeated sampling have not been carried out till date.

Studies on the continental margins across the world emphasized the role of benthic fauna of these regions in remineralization of organic matter as well as ecosystem processes on regional and global scales. Recent advances in modern techniques which facilitate harvesting, transport and storage have resulted in the extension of fishery activities to deeper areas, which were previously inaccessible. Impacts of such human activities can be properly studied only if baseline information is available on the continental margin fauna and the relation of faunal diversity to various forms and scales of habitat heterogeneity in this region (Menot *et al*. 2010). The paucity of information on qualitative and quantitative aspects of benthos along the continental margin of south west coast of India is addressed in the present study. This is the first systematic attempt of its kind for the area. The main objectives of the present study are:

- ❖ To estimate the standing crop of macrobenthos of the continental margin (from 200 to 1000m) and its variation in relation to depth and latitudes between Cape Comerin and Karwar.
- ❖ To study the density of macrobenthos along the continental margin and its temporal and spatial variation.
- ❖ To study the qualitative and quantitative composition of benthic polychaetes.
- ❖ To understand the community structure of polychaetes in relation to the heterogeneous environmental parameters and sediment characteristics.
- ❖ To study the impact of OMZ on the distribution of macrobenthic fauna along the continental margin of SEAS.

With the above objectives, five cruises were undertaken onboard FORV *Sagar Sampada* to cover the entire study area three times between 2003 and 2007. The study is a part of effort of the Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Science, Government of India, to gain information on the marine benthos in the Exclusive Economic Zone (EEZ) of India. The main objective of the project ("Benthic fauna of continental slope from 200-1000m depths of Arabian sea and Bay of Bengal") was to understand the distribution patterns of benthos along the continental slope, as a follow up of the benthic studies in the continental shelf along the west and east coast of India. The project also focused on evaluating species richness and diversity in relation to depth and environmental characteristics. The multi-institutional project was implemented at the Department of Marine Biology, Microbiology and Biochemistry, Cochin University of Science & Technology, the Centre for Advanced Studies in Marine Biology, Annamalai University, Marine Biology

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Chapter II

STUDY AREA, SAMPLING DESIGN & ANALYSIS

II. 1. Oceanographic setting and productivity patterns in the Eastern Arabian Sea

The Arabian Sea in the north-western Indian Ocean is a relatively small sea, located between 8 to 24ºN latitudes and 50 to 77ºE longitudes, but is among the biogeochemically active areas of the world ocean (Gage *et al*. 2000). The continental margin of South East Arabian Sea (SEAS), flanking the southwest coast of India is an Atlantic type passive or stable margin (Biswas 1989, Rao & Wagle 1997). The shelf basins evolved since the Paleocene epoch, following the stabilization of Indian plate after its collision with the Eurasian plate. The margin is characterized by a wide continental shelf in the north, which gradually narrows to the south. In contrast, the continental slope is narrow in the north and wider to the south, where the topography is also gentler, particularly between Ratnagiri and Mangalore and south of Kochi (Paropkari *et al*. 1991, 1992, 1993, Rao & Wagle 1997).

During the boreal summer, the solar heating of the Indian subcontinent causes a low pressure area over this region, establishing a north-south pressure gradient (Tomczak & Godfrey 1994) which drives the southwest (summer) monsoon (June-September). On the other hand, winter time cooling of the landmass causes a southward pressure gradient that drives the northeast (winter) monsoon (December-February). Thus, the Arabian Sea, which is enclosed to the north, west and east by land masses, is subjected to the seasonal variability of the monsoon wind system. As a result, distinctive patterns of circulation develop and intense to moderate upwelling occurs during the southwest monsoon off Somalia, Oman and off the west coast of India. While the dominant alongshore wind component induces coastal upwelling in the southern Arabian Sea, the cross shore component is involved in modifying the density structure in the north. The wind maxima along 17°N and 64°E or the Findlater Jet exerts upwelling (open ocean) just above the axis and sinking or downwelling below (Findlater 1977). Consequently, high biological production is recorded along the entire coastal belt as well as the open ocean region of the Eastern Arabian Sea (EAS) (Madhupratap *et al*. 1996, Muraleedharan & Prasannakumar 1996, Wiggert *et al*. 2005). As a result of this low level jet a clockwise circulation evolves in the Arabian Sea (Wyrtki 1971, Schott 1983, Swallow 1984). The equator-ward eastern boundary of this anti-cyclonic circulation is known as the West India Coastal Current, WICC (Shetye *et al*. 1990). To the south of Sri Lanka, the West India Coastal Current merges with the eastward flowing Southwest Monsoon Current which bends around the Sri Lankan coast and flows pole-ward into the Bay of Bengal (Vinayachandran 2004).

During the northeast monsoon, weak to moderate winds blow from the northeast and the surface flow is reversed to pole ward in eastern Arabian Sea (EAS). The major mechanism which defines the current pattern during this season is the long shore pressure gradient along the coast resulting from the arrival of remotely forced coastal Kelvin waves from the Bay of Bengal (McCreary *et al*. 1993, Bruce *et al*. 1994, Shenoi *et al*. 2004). The periods between the southwest and northeast monsoon (spring inter-monsoon, March-May and fall inter-monsoon, October-November) are characterized as transition periods with weak winds and unorganized circulation patterns (Shanker *et al*. 2002, Shenoi *et al*. 2005). The physical forcing mechanism, energy transfer systems and the biotic community of the eastern Arabian Sea exhibit distinct patterns in the north and south; and so the region can be treated as two different ecosystems viz; north eastern Arabian (NEAS) and SEAS (Madhupratap *et al*. 2001, Sanjeevan *et al*. 2010).

In the north, seasonal evaporation and precipitation have profound influence on the oceanographic characteristics of the region. The cold, dry continental air from the northeast and the consequent high evaporation causes convective mixing, resulting in nutrient enrichment at the surface (Prasannakumar & Prasad 1996). This process persists during the active winter season, between December and February, and the region is characterized by deep mixed layer (MLD>80m) and low sea surface temperature (<26ºC), with high biomass at primary and secondary levels (Madhupratap *et al*. 1996, Prasannakumar & Prasad 1996). During this time, the SEAS is relatively inactive, with weak to moderate northeasterly winds and more or less oligotrophic upper water column.

In addition, the excess evaporation in the area (NEAS) results in increased salinity of the surface water, even up to 36.8, which is designated as Arabian Sea High Saline Water (Rochford 1964). North Indian Intermediate water, which is formed with the contribution from Red Sea Water and Persian Gulf Water, occurs below the surface layer of this dense saline water (Wyrtki 1973, Prasannakumar & Prasad 1999). Persian Gulf Water occupies the 200-300m depth column (temperature: 13-14ºC, salinity: 35.2-35.25, density: 26.3-26.5kgm^{-3}) Red Sea Water occurs at 600-700m (temperature: 10-12ºC, salinity: 35.2-35.3, density: 27-27.3kgm^{-3}) (Shenoi *et al*. 2005).

The peak production during the northeast monsoon results in the consumption of most of the new nitrogen brought to the upper euphotic column (Prakash *et al*. 2008, Gandhi *et al*. 2010). Following this, during the spring inter-monsoon, enhanced solar radiation and weak wind forcing increases the stability of the water column which leads to less vertical mixing and a shallow MLD (<50m). Massive blooms of *Noctiluca* sp. occur as a key feature of the area during this season, as an extension of the productive northeast monsoon period. This bloom is supposed to be an extension of that observed along the Oman-Pakistan shelf, which is propagated southwards and it is suggested that they are maintained by regenerated production (Gomes *et al*. 2008, Gandhi *et al*. 2010).

Mean while, off Goa and in the oceanic/coastal region of the SEAS, massive blooms of *Trichodesmium erythraeum* and *T. thiebautii* (Padmakumar *et al*. 2010) are recorded as a regular phenomenon.

In the SEAS, the alongshore component of the southwest monsoon winds along with the remote forcing from the Bay of Bengal and the West India Coastal Current induces and maintains coastal upwelling in the South East Arabian Sea (SEAS), bringing less oxygenated (<3ml/l), nutrient rich (NO_3>1 μM) and cold (<27°C) subsurface water (from 40-80m) to the surface (Sharma *et al*. 1966, Johansen *et al*. 1981, Antony *et al*. 2002, Smitha *et al*. 2008, Gopalakrishna *et al*. 2008, Habeebrahman *et al*. 2008, Jayaram *et al*. 2010). This process occurs in the SEAS, between 8°N to ~16°N with an offshore mass transport to an average distance of 200km from the shore (Smitha BR 2011). The nutrient enrichment enhances biological production in the region, resulting in a hike in phytoplankton and zooplankton standing stock (Banse 1968, Habeebrahman *et al*. 2008). Furthermore, this season is known for its high abundance of fish eggs and larvae particularly close to the coast (Madhupratap *et al*. 1994, Longhurst & Wooster 1995, Binu *et al*. 2010).

Another peculiarity in the SEAS during this season is the strong pole-ward flowing West India Coastal Current, resulting from alongshore pressure gradient. This coastal current carries the less saline (<35), less dense Bay of Bengal water to the SEAS (Prasannakumar *et al*. 2004, Vinayachandran *et al*. 1999). The westward propagating Rossby Waves carry this water offshore (Shenoi *et al*. 2004). During the transition period from winter to summer (spring intermonsoon), the increased solar radiation and weak wind shear over the region, which is occupied with less saline water at the surface, results in anomalous warming of the upper water column (>30.5°C); this phenomenon is termed as the Arabian Sea warm pool (Shanker & Shetye 1997, Rao & Shivakumar 1999, Shenoi *et al*. 1999, Sanilkumar *et al*. 2004, Prasannakumar *et al*. 2005, Vinayachandran *et al*. 2007, Sabu & Revichandran 2011). During this period, the SEAS is characterized as stratified and oligotrophic.

The primary productivity regime of the eastern and central Arabian Sea shows seasonal fluctuations. During the fall inter-monsoon period the entire area is more or less oligotrophic and shows comparatively low primary production and chlorophyll concentration (Bhattathiri *et al*. 1996, Sanjeevan *et al*. 2010). The enhanced nutrient supply to the mixed layer during the winter monsoon in the NEAS (resulting from convective mixing) causes higher phytoplankton production and chlorophyll-a (Banse 1994, Wiggert *et al*. 2005). Enhanced primary productivity occurring as a result of coastal upwelling of the SEAS reaches its maximum towards the end of the south west monsoon, in September (Owens *et al*. 1993, Antoine *et al*. 1996, Habeebrahman *et al*. 2008). Column primary production is observed to be 364.3 mgC $m^{-2}d^{-1}$ in the NEAS during the summer monsoon, and more than 1000 mgC $m^{-2}d^{-1}$ during the northeast monsoon (Sanjeevan *et al*. 2010). While in the SEAS the value is 510 mgC $m^{-2}d^{-1}$ during summer monsoon and 243 mgC $m^{-2}d^{-1}$ during northeast monsoon. Average primary production in the eastern Arabian Sea during April–May reported to be 607 mgC $m^{-2}d^{-1}$ in the offshore areas and 876 mgC $m^{-2}d^{-1}$ in the shelf region (DeSouza *et al.* 1996).

The Eastern Arabian Sea has several distinctive features in its zooplankton community, when compared to the rest of the Arabian Sea (Sarma 2004). Intensive studies were carried out on the meso-zooplankton community of the Eastern Arabian Sea during the International Indian Ocean Expedition (IIOE, 1960–1965) and it was found that there were significant seasonal and geographical variations in mesozooplankton biomass. Results of this study indicated the occurrence of high biomass along the SEAS during summer monsoon and along the NEAS during the winter monsoon. In the following years several studies have confirmed the occurrence of high zooplankton biomass especially along the SEAS during the summer monsoon period and this is attributed to the phytoplankton bloom caused by coastal upwelling (Haridas *et al*. 1980, Madhupratap *et al*. 1990, Jyothibabu *et al*. 2008, 2010, Jasmine 2009, Ashadevi *et al*. 2010).

The availability of abundant organic detritus and microzooplankton as direct food for mesozooplankton may also enhance the zooplankton production in the upwelling regions. Similarly, a few studies conducted in the northern Arabian Sea revealed high mesozooplankton standing stock during the winter monsoon and spring inter monsoon period, which was attributed to the winter bloom of phytoplankton (Haq *et al*. 1973, Paulinose & Aravindakshan 1977). The Joint Global Ocean Flux study (JGOFS), undertaken in the Arabian Sea during the period 1992-1997 (with the work mostly restricted to central and western Arabian Sea) reported no pronounced seasonal and geographical variation in mesozooplankton biomass (Madhupratap *et al*. 1996, Wishner *et al*. 1998). However, recent studies conducted under the Marine Living Resources Programme brings out results pointing to the existence of seasonality in the distribution and abundance of zooplankton in the region. Peak production (biomass) occurs during winter and spring in the NEAS and during summer monsoon in the SEAS (Jasmine 2009, Jyothibabu *et al*. 2010).

The information regarding the deep sea fishery resources along the Indian continental slope is limited to a few recent works. Rich and diversified deep sea crustacean fauna have been reported (Mohamed & Suseelan 1973, Suseelan 1974, Suseelan *et al*. 1989). Rajasree (2011) reported fifteen species of deep sea prawns in the depth zones 150-550m off Kerala coast. Among the fin fishes, Oommen (1980) reported the existence of 63 species of fish (including 5 species of elasmobranchs) within the Quilon Bank (8-9ºN, 175-370m). Studies on non-conventional deep sea resources between 100 and 500m off the southwest coast of India (between Kochi and Cape Comorin) by Sajeevan *et al*. (2009) recorded 98 species in 52 families. Venu (2009) conducted a study on the distribution and abundance of deep sea fishes on the continental margin of SEAS beyond 200m (7-15ºN) and recorded 152 species belonging to 70 families.

The Arabian Sea is a biologically productive region, where the oceanographic and biological processes show strong seasonal variations. In such productive regions, marine benthos play in important role in remineralization and biogeochemistry. Thus, it is important to study the benthos of this region.

II. 2. Sampling Design

The area selected for the present study lies in the upper continental slope of the southwest coast of India and is located between 6.57ºN and 14.32ºN latitude and 72.58ºE and 77.20ºE longitude [Table 1, Figure 1] with depth ranging from 188 to 1100m. Nine bathymetric transects were selected, one in each degree, extending from Cape Comorin to Karwar; viz. Cape Comorin (along 77º 20'E), Trivandrum (7º50'N), Kollam (9ºN), Kochi (9º 50'N), Ponnani (10º 50'N), Kannur (11º 55'N), Mangalore (12º 45'N), Coondapur (13º 57'N) and Karwar (14º 32' N). These were 9 of 16 transects fixed along the entire west coast, as part of the multidisciplinary project 'Studies on Benthic Fauna of Continental slope from 200-1000m depths of Arabian Sea and Bay of Bengal'.

Three depth classes were fixed for each transect at 200m, 500m and 1000m with the aim of studying variation of benthic fauna in relation to depth and latitude. A total of five dedicated cruises were undertaken along the west coast to cover each of the 27 fixed stations three times. During each cruise, samples of macrofauna were collected onboard Fishery and Oceanographic Research Vessel *Sagar Sampada* (FORVSS). The first set of samples was collected in two cruises, FORVSS Cruise 219 (December, 2003), during which six transects from Karwar to Kochi were covered and FORVSS Cruise 225 (May, 2004) during which the remaining three transects, from Kollam to Cape Comorin were sampled. The second set of sampling was also completed in two cruises: FORVSS Cruise 228 (September, 2004; Coondapur and Karwar) and FORVSS Cruise 233 (April, 2005; Mangalore to Cape Comorin). During FORVSS Cruise 254 (May, 2007) all 9 transect were covered for the third time (from Cape to Karwar). Simultaneous to the collection of samples, observations were also made on physicochemical characteristics of seawater (temperature, dissolved oxygen, salinity) in accordance with standard procedure and using the on-board CTD. Dissolved oxygen was estimated manually by Winkler's method with the modification proposed by Strickland & Parsons (1972).

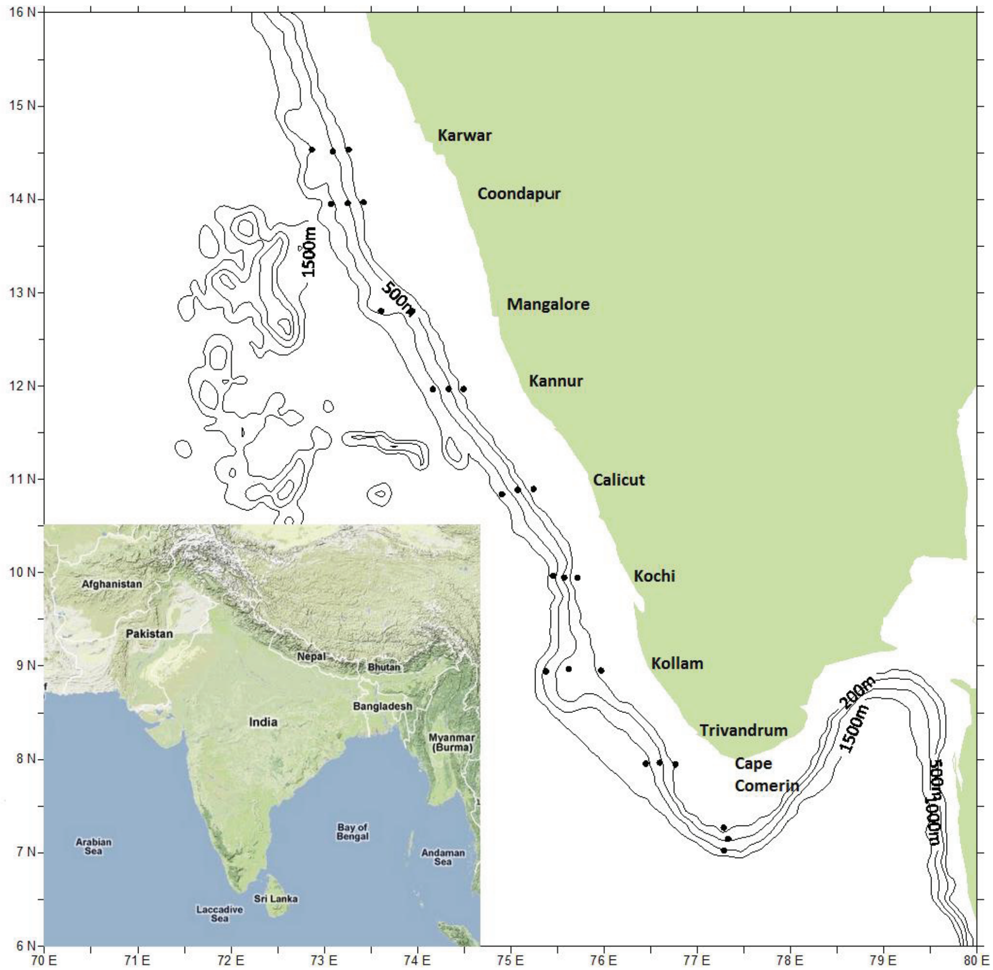

Figure 1. Map of the Study Area indicating the transects and sampling sites

II. 3. Collection and identification of macrobenthos

Soft-bottom (infaunal) benthos can be sampled relatively well by retrieving quantitative samples of sediment and sieving them to separate the fauna. Grabs and box corers are generally used for quantitative sampling of macro and meiofauna. There are also some, non-quantitative or semi-quantitative devices such as dredges which can sample larger areas, but they are hard to use for infauna and tend to damage delicate specimens. Another difficulty faced by benthic biologists is the large volume of sediment to deal with compared to biota retrieved. Benthic organisms are usually extracted by passing the sediment through a sieve or series of sieves. This is a difficult, time consuming process and needs to be carried out carefully onboard without damage to delicate organisms. It also limits the minimum size of biota that can be retrieved since sieves finer than 0.5mm retain large volumes of sediment.

During the study, A Kahlsico No. 214 WA250 modified Smith McIntyre grab having a bite area of $0.2m^2$ was used for collecting sediment samples [Plate 1]. This sampler has hinged buckets mounted within a framework, with powerful springs to assist penetration into the sediment (specially designed for deep water operations). Two trigger-plates, one on each side of the frame ensure that this is resting flat on the bottom before the springs are released. After closing of the grab (biting), the hauling was done by cables linked to the arms attached to each bucket with the help of a hydraulic winch. The top of each bucket is covered with a fine wire mesh to reduce the resistance and downwash on ascent and each mesh top is in the form of a flap hinged along its outer edge to allow convenient access to the sample.

Test sieve of 0.5mm mesh was used for separating macrobenthos and sieving was carried out onboard over a wooden platform under gently running sea water flow. After sieving, the organisms were carefully separated and together with residual sediment were fixed in 5-7% (neutral) formaldehyde containing Rose Bengal stain, labelled and stored for further examination. In the shore laboratory, the sediments were washed again under tap water and the material preserved in 5% formaldehyde. For qualitative enumeration, each sample was examined under a binocular microscope. The organisms were separated into different taxonomic groups (polychaetes, crustaceans, molluscs and other groups) for further identification. Polychaetes were identified up to species level as this group was dominant among the macrobenthos. Primarily, the keys of Fauvel (1953) and Day (1967) were used for the identification, supplemented with more recent taxonomic publications (e.g. Fauchald 1977, Maciolek 1985, Imajima 1990a-c, 1992a, b). Validity and taxonomic status of species were also checked and updated from the World Register of Marine Species (WoRMS, www.marinespecies.org). Other groups were identified to higher taxonomic levels to the extent possible, with the help of standard taxonomic references and available expertise. Prior to identification, wet weight of each group was determined by using a high precision electronic balance (SartoriusAG–ME215P, Germany with a precision of 0.01 mg).

II. 4. Sediment analysis

Approximately 250 g of wet sediment sample from each station was taken as soon as the grab was hauled for sediment analysis and dried onboard at 50^{O}C in an oven. In the shore lab, the sediment texture was analyzed with the help of particle size analyzer (Sympatec particle size analyzer, Germany). The relative composition of each grade (sand, silt, clay) was calculated and plotted on triangular graphs based on the nomenclature suggested by Shepard (1954); the composition of the sediments were expressed in percentage of sand, silt and clay. The organic carbon content was estimated by the wet oxidation method of El-Wakeel & Riley (1957) which was then converted into organic matter (Trask 1939). Organic matter was expressed as percentage of sediment dry weight examined.

II. 5. Data analysis

Various diversity indices are widely used in ecology for comparison of communities on spatial and temporal scales as well as for the assessment of environmental quality. The discriminating ability of diversity indices vary, depending on the type of study being conducted and on other aspects of the samples. For the analysis of diversity and community structure, different approaches were adopted in this study, which include univariate (species richness, Shanon-Wiener diversity, species dominance and evenness), multivariate (Multi-Dimensional Scaling) and graphical (species area plots, k-dominance curves, Canonical Correspondence Analyses). In the present study, statistical software, PRIMER 5 & 6 (Plymouth Routines in Multivariate

Ecological Research), SPSS 17, CANOCO 4.5, ORIGIN 8 and GRAPHER was used for the data analysis and representation.

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 5) was used, which plots the cumulative number of species against the cumulative number of samples (grabs). Various species estimators (such as CHAO1, CHAO2, Jacknife, UGE, SOBS etc., available in PRIMER 6) were used to predict the true number of species that would be observed as the number of samples tend to be infinity.

Univariate diversity indices such as species richness (Margalef's index, d), Species equitability (Pielou's index, J'), species diversity (Shannon-Wiener index, H') and species dominance (Simpson's index, λ') were worked out for polychaetes using PRIMER 6. The aim of these statistical indices is to reduce multivariate complexity of species assemblage data in to a single index. Species richness is a count of the number of species represented in a fixed number of individuals. Species equitability or evenness shows how evenly the individuals are distributed among the different species and species dominance shows the dominance of particular species among a given number of individuals. Species diversity index takes into account the number of species in a sample and also their relative abundance. The index is high in samples that have large numbers of unique species, or have greater species evenness.

Bray-Curtis similarity (PRIMER 6) was calculated with suitable transformation (square root) for the species-abundance data to group the samples with similar community composition following the procedure described by Clarke & Warwick (1994). Bray-Curtis similarity index and group average linkage were used for cluster analysis and non-metric multi dimensional scaling (n-MDS) ordination (Ludwig & Reynolds 1988). To compare the biodiversity between the depth ranges, dominance plots (in PRIMER 6) were drawn by ranking the species in decreasing order of their abundance. Relative abundance expressed as 'percentage of abundance' in the sample was plotted, against the increasing rank in the x-axis, the latter on a log scale.

Principal component analysis (PCA) was also conducted on environmental data to detect trends of variation of environmental characteristics across the study area. This analysis also uses an ordination plot to project the points of greater similarities closer together while samples more dissimilar are further apart. Unlike biological data, environmental data usually have mixed measurement scales, and similarity methods, such as normalised euclidean distance used in PCA, are more appropriate for environmental data (Clarke & Warwick 2001). A useful exercise before conducting PCA is to examine the environmental data in a draftsman scatter plot to ascertain whether there are variables that are highly correlated with one another, which may then be omitted from the PCA. In this study all the eight environmental variables measured were included for the PCA.

BVSTEP (PRIMER 6) was performed to identify the influential species in the study area, which determine the patterns in the community structure. It involves stepwise algorithm which operates sequentially and involves both forward and backward-stepping phases. At each stage, a selection was made of the best single species to add to or drop from the existing selected set. Typically this procedure started with a null set, picked the best single variable (maximizing ρ), then adding a second variable which gave the best combination with the first, then adding a third to the existing pair. The backward elimination phase then intervened, to check whether the first selected variable can be dropped, the combination of second and third selections alone not having been considered before. The algorithm proceeded in this fashion until no further improvement was possible by the addition of a single variable to the existing set or more likely here, the stopping criterion is met (exceeds 0.95).

By using the BIOENV sub-routine of PRIMER 6, the relationships between the environmental parameters and the biological distribution patterns in the study area were examined. For this, the species similarity matrix was analyzed for "rank correlation" with normalized Euclidean distance calculated for the environmental data matrix (Clarke & Ainsworth 1993). The rank correlation coefficient used for this analysis is a simple Spearman coefficient (ρ).

An attempt was also made to link selected polychaete species abundance with the measured environmental variables using Canonical Correspondence Analysis (CCA) (ter Braak & Smilauer 2002). The CANOCO software (version 4.5) was employed using a subset of important species, identified using BVSTEP and SIMPER in PRIMER-6. 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). The CCA plot was useful in determining which environmental factor influenced the distribution of the selected species. Monte Carlo permutation test (with forward selection) was used to test the significance of environmental variables explained the variance of species distribution and abundance ($P < 0.05$ level).

Some qualitative and quantitative aspects of SEAS margin macrofauna have been compared with data from the north-east coast of India (north western Bay of Bengal) that was collected concurrently, under the leadership of Dr. A. V. Raman, Andhra University (cited as Rao 2009, Ph.D. Thesis).

Table 1. Location of sampling sites during the cruises of FORV *Sagar Sampada*

Collection		I			II			III		
Cruises		219 (St. 9-26) & 225 (St. 0-8)			228 (St. 21-26) & 233 (St. 0-20)			254		
Duration		December, 2003 & May, 2004			September, 2004 & April, 2005			May, 2007		
St.	Location	Latitude (N)	Longitude (E)	Depth (m)	Latitude (N)	Longitude (E)	Depth (m)	Latitude (N)	Longitude (E)	Depth (m)
1	Cape Comorin	7º 10.27'	77º 20.87'	215	7º 09.20'	77º 19.07'	207	7º 10.02'	77º 19.21'	208
2	Cape Comorin	7º 00.19'	77º 20.14'	294	7º 00.00'	77º 20.40'	536	7º 07.25'	77º 06.57'	486
3	Cape Comorin	6º 57.19'	77º 21.99'	1100	6º 57.80'	77º 21.33'	999	7º 06.94'	77º 05.54'	897
4	Trivandrum	7º 50.55'	76º 41.17'	226	7º 50.60'	76º 40.19'	242	8º 27.76'	76º 23.63'	216
5	Trivandrum	7º 50.18'	76º 39.54'	450	7º 50.65'	76º 39.63'	420	8º 27.78'	76º 19.36'	490
6	Trivandrum	7º 50.04'	76º 37.90'	940	7º 50.62'	76º 36.88'	976	8º 25.99'	76º 06.12'	983
7	Kollam	9º 00.02'	75º 54.69'	282	9º 00.06'	75º 55.85'	267	8º 41.96'	76º 07.37'	236
8	Kollam	8º 55.30'	75º 29.03'	454	8º 59.89'	75º 27.82'	508	8º 42.45'	75º 27.98'	466
9	Kollam	9º 00.30'	75º 26.63'	750	9º 01.17'	75º 26.47'	1050	8º 42.29'	75º 27.30'	925
10	Kochi	9º 47.91'	75º 35.10'	202	10º 01.24'	75º 36.55'	180	9º 47.91'	75º 35.10'	275
11	Kochi	9º 50.14'	75º 34.54'	526	9º 58.28'	75º 82.99'	500	9º 50.14'	75º 34.54'	500
12	Kochi	9º 50.16'	75º 32.86'	988	9º 52.23'	75º 29.30'	1095	9º 50.16'	75º 32.86'	835
13	Ponnani	10º 48.99'	75º 13.98'	262	10º 59.28'	75º 07.96'	226	10º 48.99'	75º 13.98'	220
14	Ponnani	10º 49.23'	75º 11.73'	577	10º 58.96'	75º 05.20'	515	10º 49.23'	75º 11.73'	520
15	Ponnani	10º 50.25'	75º 06.59'	989	10º 59.29'	74º 59.52'	992	10º 50.25'	75º 06.59'	856
16	Kannur	11º 56.10'	74º 26.22'	205	11º 55.64'	74º 26.80'	208	11º 56.10'	74º 26.22'	215
17	Kannur	11º 55.93'	74º 23.13'	525	11º 56.54'	74º 22.66'	523	11º 55.93'	74º 23.13'	503
18	Kannur	11º 55.97'	74º 19.49'	945	11º 56.51'	74º 18.15'	958	11º 55.97'	74º 19.49'	880
19	Mangalore	12º 46.13'	74º 05.01'	214	12º 53.02'	73º 59.80'	200	12º 46.13'	74º 05.01'	219
20	Mangalore	12º 46.22'	74º 02.50'	438	12º 53.42'	73º 56.13'	494	12º 46.22'	74º 02.50'	508
21	Mangalore	12º 46.14'	73º 58.39'	991	12º 53.45'	73º 47.00'	1000	12º 46.14'	73º 58.39'	829
22	Coondapur	13º 57.88'	73º 19.51'	208	13º 31.42'	73º 25.82'	220	13º 57.88'	73º 19.51'	220
23	Coondapur	13º 58.07'	73º 14.52'	480	13º 29.80'	73º 24.89'	520	13º 58.07'	73º 14.52'	519
24	Coondapur	13º 58.23'	73º 10.41'	1053	13º 29.36'	73º 17.90'	1040	13º 58.23'	73º 10.41'	863
25	Karwar	14º 32.14'	73º 11.28'	213	14º 31.60'	73º 12.28'	216	14º 32.14'	73º 11.28'	215
26	Karwar	14º 32.14'	73º 07.13'	453	14º 31.95'	73º 06.96'	416	14º 32.14'	73º 07.13'	501
27	Karwar	14º 32.21'	73º 03.01'	998	14º 31.52'	72º 58.50'	1000	14º 32.21'	73º 03.01'	847

Chapter III

HYDROGRAPHY & SEDIMENT CHARACTERISTICS

III. 1. INTRODUCTION

The structure and composition of marine benthic communities are influenced by environmental factors, including temperature, salinity, bottom water oxygen and sediment characteristics. Either individually or in combination, these factors influence the biology of the organisms (Kinne 1963). Bathyal fauna are subject to sharp gradients in depth, temperature and dissolved oxygen, along with considerable heterogeneity in sediment texture and organic matter.

Marine invertebrates do not regulate their body temperature, but instead, they are homeotherms, having body temperatures identical to that of the ambient water. Temperature controls the rate of fundamental biochemical processes in organisms and consequently, changes in the environmental temperature can influence organismal, population, and community-level processes (Brown *et al*. 2004, Allen *et al*. 2006). Temperature can alter the richness and diversity of organisms in an area by controlling larval development and settlement. At the lower and higher extremes, temperature strongly influences the metabolic activity of animals (Levinton 1982).

Most living beings need oxygen to keep their cells alive and are constantly using it up to meet their respiratory needs. Bottom water oxygen concentrations in the deep oceans vary from near zero to over $6mll^{-1}$. In aquatic environments replenishment of dissolved oxygen takes place from the photosynthetic activity of phytoplankton and from atmospheric diffusion at the surface. When the supply of oxygen to the bottom is limited by strong stratification in the water column or the consumption rate exceeds replenishment, oxygen concentrations decline beyond the point that sustains most animal life. This condition of low dissolved oxygen 'hypoxia' is physiologically stressful to most marine organisms. Benthos, being mostly sedentary or sessile, is more vulnerable to hypoxia related stress. Salinity affects functional and structural responses of marine organisms through changes in total osmotic concentration, relative proportion of solutes, coefficient of absorption and saturation of dissolved gases. In the deep sea, variations in salinity are not as prominent as in coastal and inshore waters, and are usually results of changes in water masses and large-scale oceanographic circulation.

Information on the habitat characteristics associated with a species is important because it is central to the understanding of their distribution. In the case of marine benthos, the nature of the sediments pose life-style challenges that are widely considered as the principal factor controlling composition and abundance. Sediments in the marine environment are principally derived either from terrigenous sources, or they may be biogenic or derived from other sources. Coarse sediments of terrigenous origin are commonly found on the continental slope and rise, being transported there by turbidity currents and sediment slumps. These sediments are primarily transported to the ocean as a result of glacial processes during ice ages and erosion from rocky marine areas (Gray 1974). Rivers play a major role in transporting sediments from continents to oceans, their contribution to marine sediments being 10 times that of glaciers and 100 times that of wind (Goldberg 1976).

Biogenic sediments are those which accumulate slowly in the deep sea, far from the sources of terrigenous sediments. They are composed largely of hard skeletal parts of planktonic and benthic organisms. Sediments composed of more than 30% microscopic skeletal debris are known as oozes. Oozes may be composed predominantly of calcareous (tests of foraminifera, coccolithophores and pteropods) or siliceous (shells of diatoms and radiolarians) materials. Calcareous oozes are the most common biogenic sediments and covering 48%

of the world ocean floor (Rothwell 2005, Hüneke & Mulder 2011). This type of ooze is limited to regions above the carbonate compensation depth at time of burial. Siliceous oozes, on the other hand are found only in areas with high biological productivity, such as the polar oceans, and upwelling zones near the equator. This is the least common type of sediment, covering only 15% of the world ocean floor (Rothwell 2005, Hüneke & Mulder 2011). A third kind of sediment, known as red clay or pelagic clay, accumulates in the deepest and most remote areas of the ocean floor. It contains biogenic materials (less than 30%) mixed with very fine quartz and clay minerals, authigenic deposits from the water column and micrometeorites, in varying proportions. Red clay covers about 38% of the world ocean floor. The primary origin of these sediments is unknown but the material is believed to be mostly derived from distant rivers, and windblown dust (Hüneke & Mulder 2011).

Particulate organic matter from the water column sinks through and eventually reaches the ocean floor and forms a potential source of food for benthic organisms. Marine sediments are considered as the largest reservoir of organic carbon on earth, and continental margins are important sites for the accumulation and burial of organic matter (Demaison & Moore 1980, Walsh *et al*. 1985, Cowie 2005). While the sinking of organic matter through the water column is essentially a physical process, once the organic matter enters the benthic boundary layer, its fate is to a large extent, decided by the benthic organisms. Through their feeding activities, they selectively remove organic particles from the water column and the benthic boundary layer, and part of this is deposited as feces above or within the sediments (Heip *et al*. 2001). Thus, by their feeding and burrowing activities, irrigation and ventilation of the sediments is achieved. The organic matter ingested by benthos is partly lost by egestion and respiration, while the remainder is channelized for somatic and reproductive growth of the organism. The newly formed animal biomass then becomes food for other organisms. As such, organic matter may cycle several times through the benthic food chain before eventually being degraded to inorganic carbon (Heip *et al*. 2001). Thus benthos directly or indirectly influences the texture, composition and organic content of the sediments (Cowie & Levin 2009). Several factors such as oxygen exposure, supply of reactive organic matter, sorptive preservation, mineral composition, winnowing and re-deposition may control sedimentary organic matter (Calvert *et al*. 1995, Hedges & Keil 1995, Cowie *et al.* 1999, Rao & Veerayya 2000, Tyson 2005, Burdige 2006). Elevated concentrations of organic carbon have been found in sediments underlying oxygen minimum zones (Hartnett *et al.* 1998, Keil & Cowie 1999, Ganeshram *et al*. 1999, Schulte *et al*. 2000, Levin *et al.* 2002, Mendez 2007).

Correlating benthic fauna to physical characteristics of sediments is generally accepted as an important step in understanding their distributional patterns. These characteristics include the composition of sand, silt and clay, grain size and organic matter content. Over the last few decades, the relationships between the distribution and diversity of soft sediment species and the sediment in which they reside have been the subject of numerous studies (Sanders 1968, Rhoads 1974, Snelgrove & Butman 1994, Flach & Thomsen 1998, Hughes *et al.* 2009, Ingole *et al.* 2010, Wei *et al.* 2010). According to Gray (1974), heterogeneous sediments appear to have a higher diversity than homogenous sediments.

The continental margin of western India is composed of a complex variety of sedimentary environments. The shelf break occurs between 80 and 140m, and the shelf basin is wider towards the north, narrowing progressively towards the south (Rao *et al.* 1983, Calvert *et al.* 1995). Various physical, chemical and geological processes control the sedimentation regime in the region. The south west shelf receives fluvial input from rivers which originate in the Western Ghats. Studies carried out on the sediment characteristics of the shelf region off the west coast of India (Nair & Pylee 1968, Nair 1975, Hashimi *et al*. 1978, Hashimi *et al*. 1981, Hashimi & Nair 1981, Paropkari *et al*. 1987, Narayana & Prabhu 1993, Jayaraj *et al*. 2007, Joydas & Damodaran 2009) have revealed that sand is the dominant sediment fraction towards the south and that clay dominates in the near shore regions. Studies conducted along the continental margin at 14° N latitude (Ingole *et al*. 2010) showed that the shallow shelf (34m) is dominated by silt, mid-shelf (50-100m) is dominated by sand and the slope is characterized by clayey-silt sediments.

As part of the present study, samples were collected during winter monsoon (FORVSS 219, December 2003) and during spring inter-monsoon (FORVSS 233, April 2005 and FORVSS 254, May 2007). Attempts were made to monitor hydrographical parameters in detail, along with organic matter and sediment texture, in order to relate them with the distribution pattern and community structure of benthic macrofauna along the continental margin of South Eastern Arabian Sea (SEAS).

III. 2. HYDROGRAPHY

III. 2. 1. *Bottom water temperature*

Variation of near-bottom temperature at the sampling sites during the three collections is presented in the Tables 3-5 and in Figure 2. During December, 2003 (FORVSS 219) sampling was carried out at 18 stations (Kochi to Karwar) along the SEAS and bottom water temperature varied from 7.44ºC (Coondapur, 1053m) to 16.70ºC (Karwar, 213m). Within each depth class, water temperature varied significantly. At 200m depth sites, the observed range was 14.18ºC (Kannur, 205m) and 16.70ºC (Karwar, 213m), with a mean temperature of 15.47±1.25ºC; while at the 500m sites, the range was between 9.97ºC (Kannur, 525m) and 11.74ºC (Mangalore, 438m) with a mean of 11.01±0.69ºC. At 1000m sites the observed range was 7.44ºC (Coondapur, 1053m) to 8.42ºC (Kochi, 988m), mean 7. 96±0.362ºC.

During May 2005 (FORVSS 225) nine stations were covered from three transect (Cape Comorin, Trivandrum and Kollam). At the 200m sites, lowest temperature recorded was 12.73ºC (Kollam, 282m) and highest at 14.49ºC (Trivandrum, 226m); while at the 500m sites, it ranged between 10.86ºC

(Trivandrum, 450m) and 11.62°C (Cape, 294m) and at the 1000m sites, the value varied from 6.8°C (Cape, 1100m) to 9.7°C (Trivandrum, 940m).

The bottom water temperature in April 2005 (FORVSS 233) ranged between 6.86°C (Kollam 1000m) and 16.06°C (Cape, 200m). Temperature showed a decreasing trend with depth; at 200m sites, it varied from 14.46°C (Karwar, 216m) to 16.06°C (Cape, 207m) with a mean value of 15.18±0.58°C; while at the 500m sites, the observed range was from 9.87°C (Trivandrum, 420m) to 11.38°C (Kannur, 523m), with mean of 10.93±0.53°C and at 1000m sites, the range was between 6.86°C (Kollam, 1050m) to 8.84°C (Kannur, 958m) with a mean value of 7.56±0.6°C.

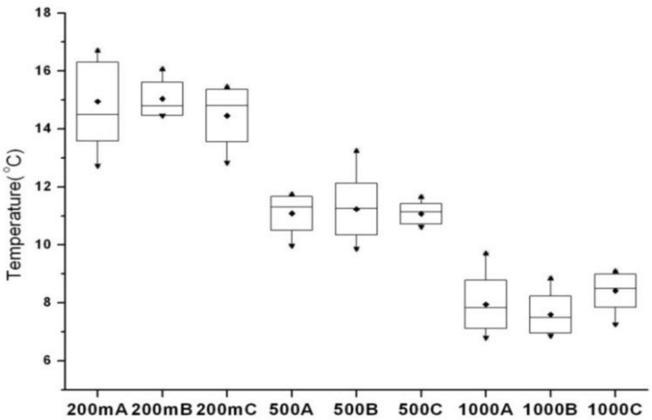

Figure 2: Comparison of bottom water temperature (°C) at each depth class
A: FORVSS Cruise 219, B: FORVSS Cruise 233 C: FORVSS Cruise 254
(Whiskers: Range, Box: SD, Inner hexagon: Mean, Line within Box: Median)

During FORVSS 254 (May 2007), 26 sites were sampled and bottom water temperature varied from 8.01°C (Trivandrum, 983m) to 15.45°C (Trivandrum, 216m). At 200m, temperature varied between 12.84°C (Kochi, 275m) to 15.45°C (Trivandrum, 216m), with mean value of 14.45±0.90°C; while at 500m depth, the value ranged from 10.62°C (Ponnani, 520m) to 11.65°C (Coondapur, 519m), with a mean of 11.07±0.35°C and at 1000m depths, it ranged from 8.01°C (Trivandrum, 983m) to 9.09°C (Karwar, 847m), with a mean of 8.472±0.57°C.

In the present study, a significant variation was found in bottom temperature with depth (ANOVA $F_{2, 76}$ =468.864, p<0.001) while there was no significant temporal ($F_{2, 76}$=0.269, p=0.765) and latitudinal variation ($F_{8, 70}$=0.067, p>0.05).

III. 2. 2. *Bottom water salinity*

The bottom water salinity in December 2003 (FORVSS 219) varied from 35.08 (Kochi, 988m) to 35.42 (Karwar, 453m) [Table 3, Figure 3]. At the 200m sites, the observed range was between 35.10 (Kochi, 188m) and 35.25 (Kannur, 205m), with a mean of 35.198±0.053; while at 500m sites, the range was between 35.19 (Kochi, 526m) and 35.42 (Karwar, 453m), with a mean of 35.288 ±0.102. Within 1000m depth range the observed variation was from 35.08 (Kochi, 988m) to 35.18 (Karwar, 998m) with a mean of 35.11±0.036. During May 2004 (FORVSS 225), bottom water salinity at the nine sampled stations varied from 34.98 (Cape, 215m) to 35.13 (Kollam, 500m). The maximum salinity recorded at 200m sites was 35.12 (Kollam), whereas at 500m, the highest value was 35.13 (Kollam) and at 1000m, 35.10 (Trivandrum) [Table 2, Figure 3].

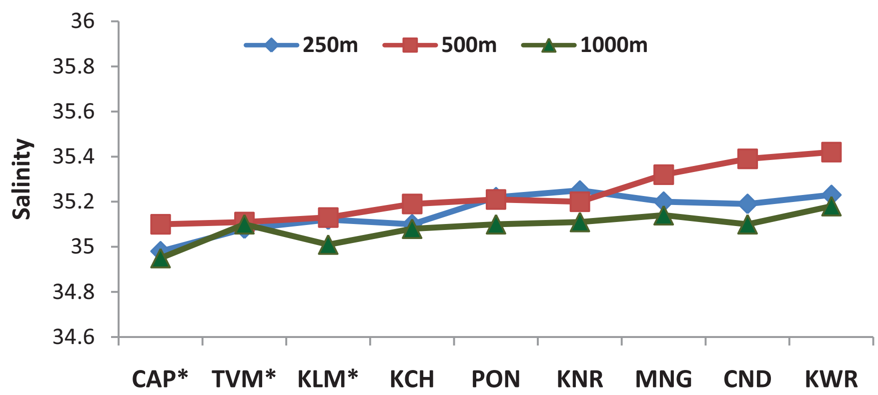

Figure 3: Bottom water salinity during FORVSS Cruise 219 & 225
*indicates transects sampled in Cruise 225

Bottom water salinity in April 2005 (FORVSS 233), varied from 34.97 (Cape, 999m) to 35.32 (Mangalore, 494m) [Table 4, Figure 4]. At 200m, the bottom water salinity ranged between 34.972 (Cape, 207m) and 35.23

(Mangalore, 200m), with mean value of 35.12±0.090; while at the 500m sites, 35.09 (Trivandrum, 420m) and 35.32 (Mangalore, 494m), with mean at 35.174±0.0973; and at 1000m the value ranged between 34.97 (Cape, 999m) and 35.17 (Kannur, 958m), with mean value of 35.042 ±0.074.

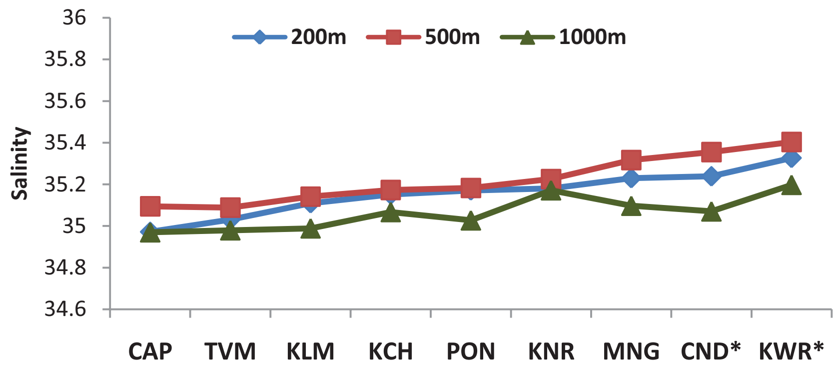

Figure 4: Bottom water salinity during FORVSS Cruise 228 & 233
*indicates transects sampled in Cruise 228

Near bottom salinity during May 2007 (FORVSS 254) varied from 35.03 (Cape, 208m) to 35.41 (Karwar, 501m). At the 200m sites, salinity ranged between 35.03 (Cape, 208m) and 35.31 (Karwar, 215m) with mean of 35.167±0.090. At 500m sites, the salinity ranged between 35.095 (Cape, 486m) and 35.41 (Karwar, 501m), with a mean of 35.205 ±0.1033 and at 1000m sites, between 35.032 (Cape, 897m) to 35.22 (Karwar, 847m) with a mean of 35.115±0.073 [Table 5, Figure 5].

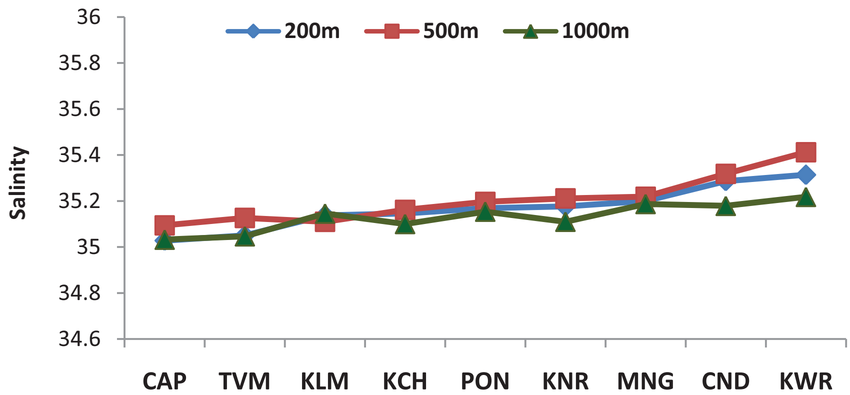

Figure 5: Bottom water salinity during FORVSS Cruise 254

There was no significant temporal variation (between collections) in bottom water salinity (ANOVA $F_{2, 76}$ =0.32, p=0.969), while variations with respect to depth (ANOVA $F_{2, 76}$ =12.724, p<0.001) and latitude (ANOVA $F_{8, 70}$ =13.646, p<0.001) were found to be statistically significant.

III. 2. 3. *Bottom water oxygen*

At the 18 sites sampled during FORVSS 219 (Kochi to Karwar), bottom water dissolved oxygen, varied from 0.107 (Karwar, 213m) to 0.847mll^{-1} (Ponnani, 989m) [Table 3, Figure 6]. The DO value varied with both depth and latitude. At the 200m sites, the observed range was between 0.107 (Karwar, 213m) and 0.683 mll^{-1} (Kochi, 188m), and the mean was 0.358±0.194mll^{-1}. At the 500m sites, the DO value ranged from 0.195 (Karwar, 453m) to 0.510 mll^{-1} (Coondapur, 480m), with a mean of 0.334±0.097; and at the 1000m sites, between 0.229 (Karwar, 998m) and 0.847 (Ponnani, 989m), with a mean of 0.558±0.226 mll^{-1}.

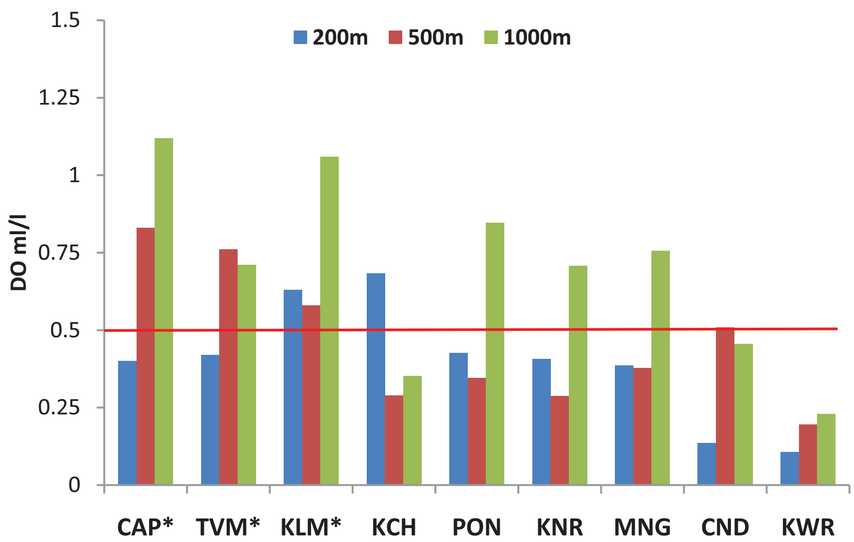

Figure 6: Bottom water DO during FORVSS Cruise 219 & 225
*indicates transects sampled in Cruise 225
Red line indicates DO value of 0.5 mll^{-1}

During May 2004 (FORVSS 225, 9 stations) the DO ranged between 0.4 and 1.12 mll^{-1} [Table 3, Figure 6]. At 200m sites, the lowest value recorded was 0.4 mll^{-1} (Cape, 215m) and the highest was 0.63 mll^{-1} (Kollam, 283m). At the 500m sites, the range was between 0.58 mll^{-1} (Kollam, 454m) and 0.83 mll^{-1} (Trivandrum, 450m); and at the 1000m sites, between 0.71 mll^{-1} (Trivandrum, 940m) and 1.12 mll^{-1} (Cape, 1100m).

The range of DO in April 2005 (FORVSS 233) was from 0.229 to 1.08 mll^{-1} [Table 4, Figure 7]. At 200m sites, the range was between 0.229 (Kannur, 208m) and 0.53 (Cape, 207m), with a mean of 0.398±0.104 mll^{-1}; at 500m between 0.246 mll^{-1} (Mangalore, 494m) and 0.65 mll^{-1} (Cape, 536m), with mean value of 0.513±0.134 mll^{-1} and at the 1000m sites between 0.293mll^{-1} (Ponnani, 992m) and 1.08 mll-1 (Kollam,1050m) with a mean value of 0.679 ±0.278 mll^{-1}.

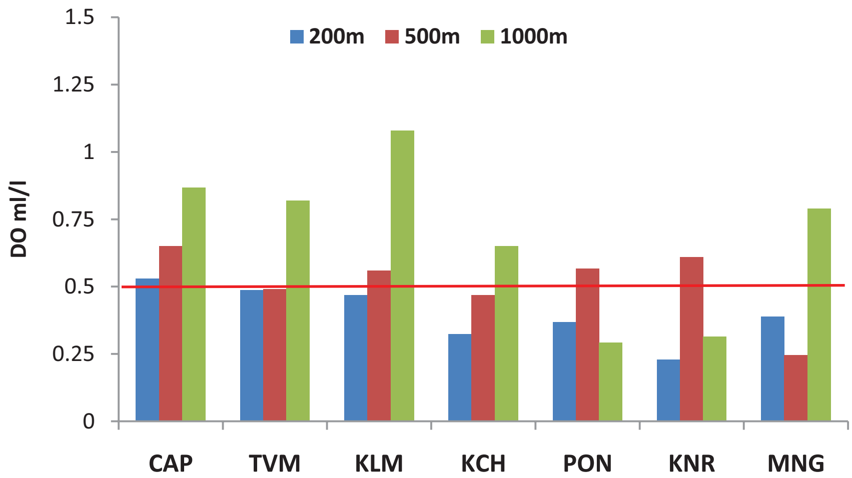

Figure 7: Bottom water DO during FORVSS Cruise 233
(Data from Cruise 228 is not represented)
Red line indicates DO value of 0.5 mll^{-1}

At the 27 stations sampled in May 2007 (FORVSS 254), the dissolved oxygen of near bottom water varied from 0.149 mll^{-1} to 0.833 mll^{-1} [Table 5, Figure 8]. At the 200m sites, the value ranged from 0.149 mll^{-1} (Karwar, 215m) to 0.622 mll^{-1} (Kollam, 236m), with a mean of 0.395±0.165mll^{-1}; while at the 500m sites it varied from 0.254 mll^{-1} (Karwar, 501m) to 0.732 mll^{-1} (Kollam, 466m), with a mean value of 0.49±0.172 mll^{-1} and at the 1000m sites, it ranged from 0.401 mll^{-1} (Mangalore, 829m) to 0.872 mll^{-1} (Kollam, 925m), with a mean value of 0.667±0.217 mll^{-1}.

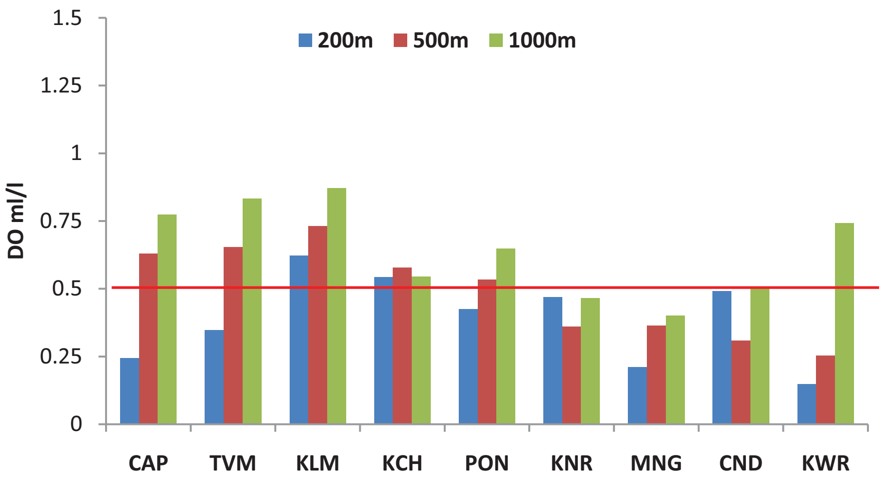

Figure 8: Bottom water DO during FORVSS Cruise 254
Red line indicates DO value of 0.5 mll^{-1}

A significant variation was found in bottom water oxygen with depth (ANOVA $F_{2, 76}$ =6.946, p=0.002) and latitude ($F_{8, 70}$=2.16, p=0.04), while there was no significant temporal variation ($F_{2, 76}$ =0.269, p=0.765).

III. 3. SEDIMENT CHARACTERISTICS

III. 3. 1. *Textural composition*

The surficial sediments of the study area showed considerable spatial (depth wise and latitudinal) variation in their composition. The coarsest sand, with biogenic materials like calcareous shells occurred on the shelf edge especially off the southern tip of India. Significant temporal (survey wise) variation in textural composition was observed only in the case of the clay fraction. In the deeper areas (1000m), the finer fractions, viz. silt and clay together constituted over 80% to sediment texture. In order to give a descriptive picture on sediment composition in the study area, the mean values of percentage composition of sand, silt and clay were taken for each site (in all three surveys) and is summerised as follows. The composition of textural fractions at all the sites for each cruise is given in Tables 6-8.

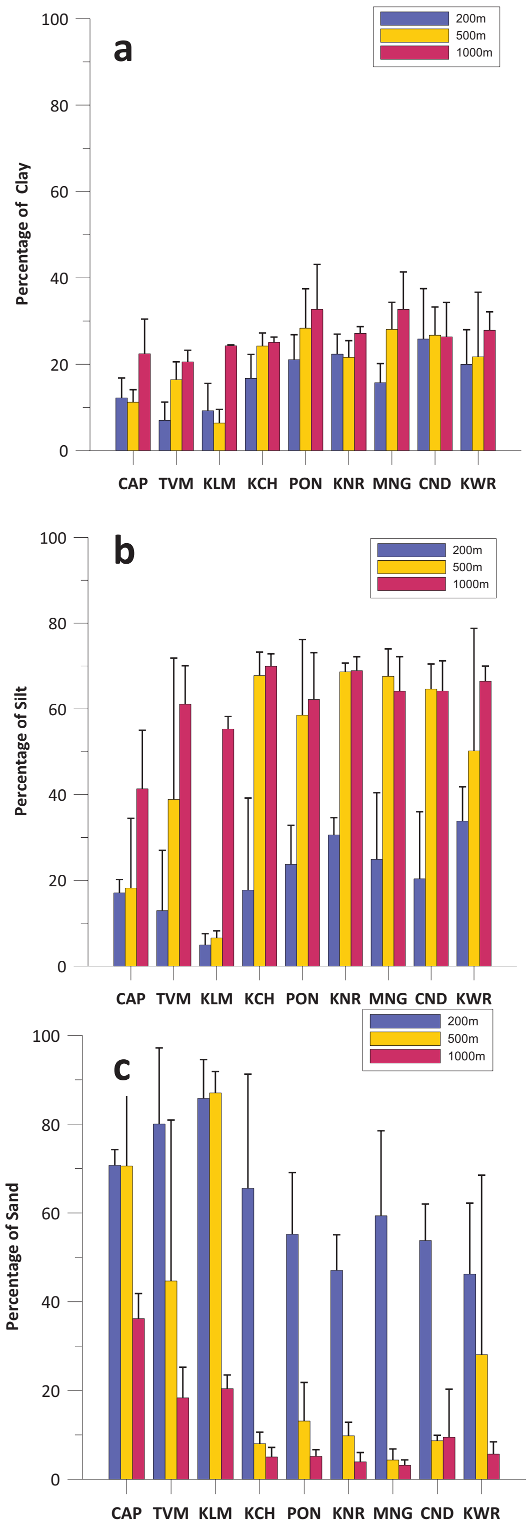

Figure 9: Sediment texture composition at the study sites
(a) Percentage of Clay, (b) Percentage of Silt & (c) Percentage of Sand

At the 200m sites, sand was the dominant fraction of bottom sediments in all transects. At this depth category, proportion of sand varied between 28 and 94% (mean 62.6±18.3%); that of silt varied between 1.5 and 43% (20.7±13.2%) and clay between 2.2 and 37.6% (16.7±8.1%) [Figure 9]. Among the 500m sites, the observed range for sand fraction was from 2.79 to 90.5% (28.3±32%), silt was from 3.62 to 74.8% (50.6±25.4%), and clay was from 4.15 and 38.87% (21.1±9.2%). At 1000m, the range of variation of sand was between 1.6 and 42.15% (11.6±11.5%), that of silt was between 26.7 and 74.8% (61.8±10.7%) and clay between 15.5 and 39.8% (26.6±6.6%).

There was significant depth related differences in sand, silt and clay content (sand: ANOVA, $F_{2, 76}$=36.354, $p<0.001$; silt: $F_{2, 76}$=38.804, $p<0.001$; clay: $F_{2, 76}$=10.219, $p<0.001$); variation between surveys was found to be insignificant in the case of sand and silt (Sand: $F_{2, 76}$=0.103, p=0.902; silt: $F_{2, 76}$=0.452, p=0.638) while there was significant difference in clay content (ANOVA, $F_{2, 76}$=6.39, p=0.003). During the third survey, at the 1000m depth category, the clay content was significantly lower. This was owing to the fact that during this collection, most of the deeper operations were restricted to about 800-900m.

Latitudinal variations were observed in the sediment texture (sand: $F_{2, 76}$ =3.466, p=0.002, silt: $F_{2, 76}$ =2.568, p=0.0168; clay: $F_{2, 76}$ =4.251, $p<0.001$). At the three southern-most transects (Cape Comorin, Trivandrum and Kollam), sand was the predominant textural component at 200 and 500m, while the proportion of silt was high at the remaining transects (Kochi, northwards to Karwar). Some of the shallow and deep sites showed considerable temporal variation in sediment composition [Figure 9]. At Kochi 188m, during the first survey (FORVSS 219), silt percentage was considerably high (42%) while during second and third survey the percentage was very low (~2% and 10% respectively) and considerable increase in the sand fraction was also observed from 36% in the first survey to 81.3% and 79.4% during second and third survey respectively. Among the 500m sites the survey based differences were more evident at Trivandrum and Karwar. At Trivandrum, during the first survey, the percentage of sand was considerably high (84%) while during second and third surveys the percentage decreased significantly (35% and 13% respectively) and accordingly considerable variation in the silt content (4%, 44% and 69% during first, second and third survey respectively). At Karwar, high variation in sand content was recorded during the study it was below 7% during first and third survey and 74% during second survey. Similarly marked difference in the percentage of silt was evident, from 58% in the first survey to 18.5% in the second survey and 74% in the third survey. Survey based variation in clay content was most evident at the 1000m depth category, owing to the difference in actul sampling depth.

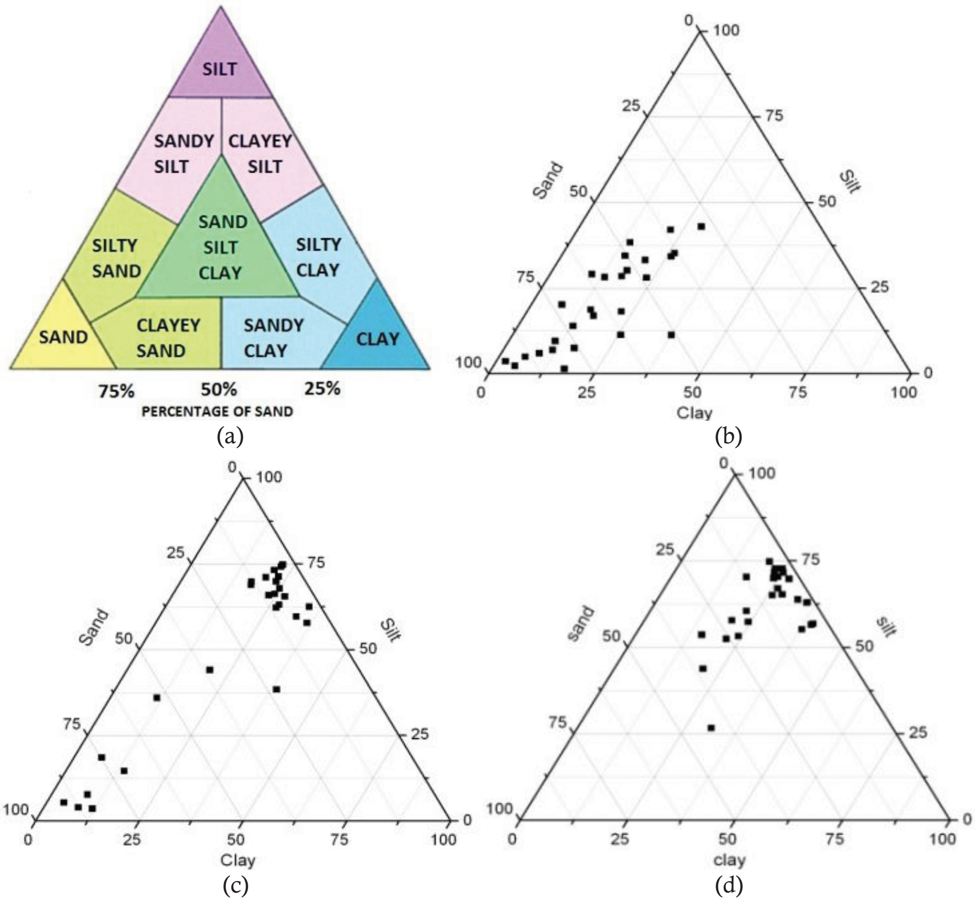

Figure 10. Ternary plots for each depth class during the study
(a) Schematic plot showing textural classes according to Sheppard's Classification
(b) Ternary plot for 200m sites, (c) Ternary plot for 500m sites & (d) Ternary plot for 1000m sites

According to the varying proportion of its components (sand, silt, clay), five textural classes could be recognised from the SEAS continental margin viz., sand, silty sand, sandy silt, clayey sand and admixture of sand, silt and clay. Among them the study area was dominated by sandy silt and clayey silt. At the 200m sites, the texture was predominantly silty sand in the northern transects (Kochi to Karwar) and it was sandy (>70%) at Cape, Trivandrum and Kollam [Figure 10]. The texture shifted to clayey silt at the 500m depth in the northern transects, while at Cape and Kollam the texture remained sandy and at Trivandrum, the sediment was an admixture of sand, silt and clay. At the 1000m sites, the sediment texture remained clayey silt in the northern transects and Trivandrum; while the texture was sandy silt in Cape and Kollam.

III. 3. 2. *Sediment organic matter*

Percentage of organic matter (OM) in the sediments of the study area showed temporal and spatial variations [Tables 6-8, Figures 11-14], with values ranging from 0.83 (Kochi& Mangalore, 200m) to 12.22% (Ponnani, 500m). During FORVSS 219 (December 2003), percentage of OM varied from 0.95 (Mangalore, 200m) to 7.38 (Kochi, 1000m) [Table 6, Figure 11]. Within each depth class, the difference was appreciable, with the observed range being between 0.95 (Mangalore) and 2.09% (Kochi) at 200m sites (mean: 1.57±0.47%); between 3.81 (Mangalore) and 5.52% (Ponnani) at 500m sites (4.42±0.69%); and between 3.66 (Karwar, 1000m) and 7.38% (Kochi, 1000m) at 1000m sites (4.73±1.36). The organic matter content of sediments during FORVSS 225 ranged between 2.3% (Trivandrum, 500m) and 9.15% (Trivandrum, 1000m) [Table 6, Figure 11].

During cruise FORVSS 233 (April 2005), percentage of OM was considerably higher at deeper stations (500 & 1000m) [Table 7, Figure 12], when compared to the previous collection, and the value ranged between 0.83 (Mangalore & Kochi, 200m) and 9.49% (Ponnani, 500m). At 200m sites, OM% ranged between 0.83 (Mangalore & Kochi) and 3.17% (Cape) (mean 1.92±0.99%); while at 500m, the value ranged between 1.72 (Kollam) and

9.49% (Ponnani) (5.88±2.41%) and at 1000m, the range was between 5.99 (Kannur) and 8.19% (Kochi) (6.78±0.78%).

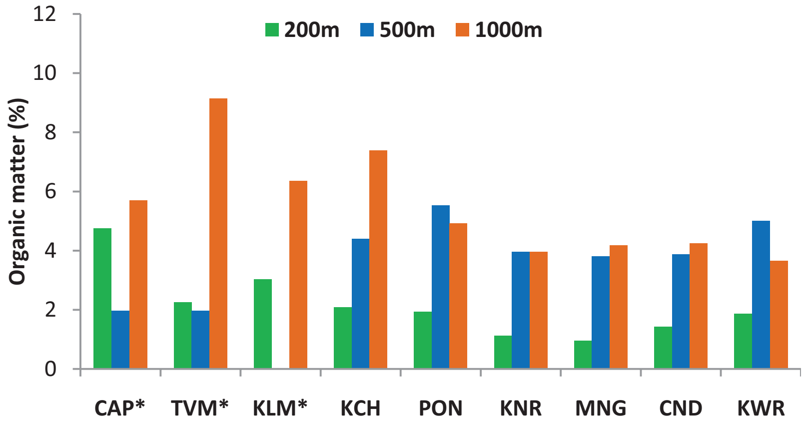

Figure 11: Organic matter (%) in sediments during FORVSS Cruise 219 & 225
* indicates transects sampled in cruise 225

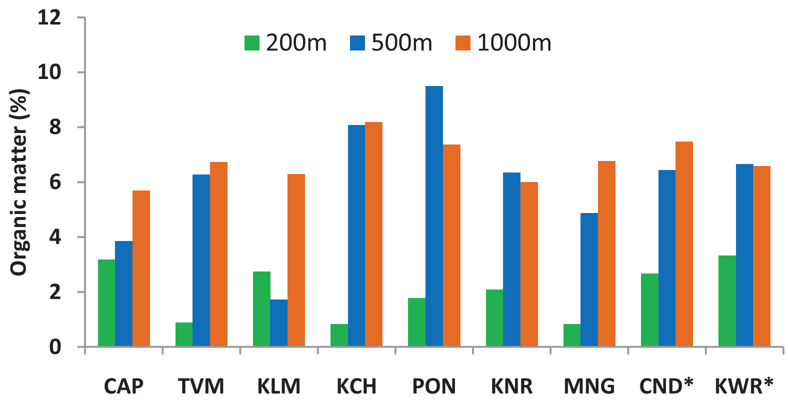

Figure 12: Organic matter (%) in sediments during FORVSS Cruise 228 & 233
* indicates transects sampled in cruise 228

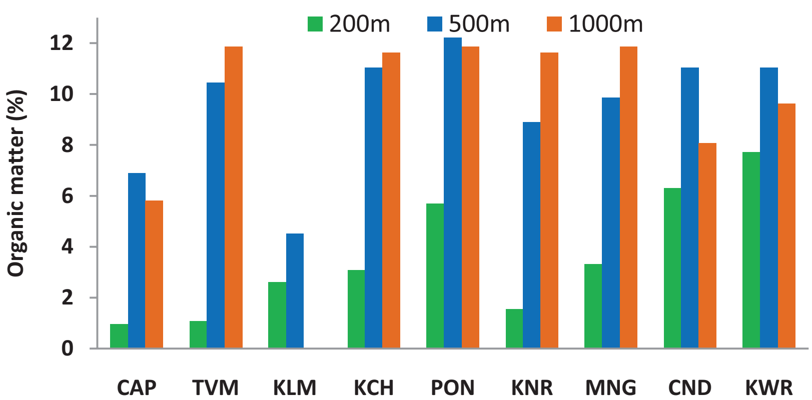

Figure 13: Organic matter (%) in sediments during FORVSS Cruise 254

Maximum organic matter content in the sediments, especially at deeper sites (1000m) was recorded during FORVSS 254 [Table 8, Figure 13], with values > 10%. Among the 200m sites, OM content (%) varied between 0.95 (Cape) and 7.71% (Karwar), with a mean of 4.61±2.32%; at 500m, it ranged between 4.51 (Kollam) and 12.22% (Ponnani), with mean value of 9.36±2.53%; and at 1000m, between 5.82 (Cape) and 11.87% (Trivandrum, Ponnani & Mangalore) with mean of 10.29±2.13%.

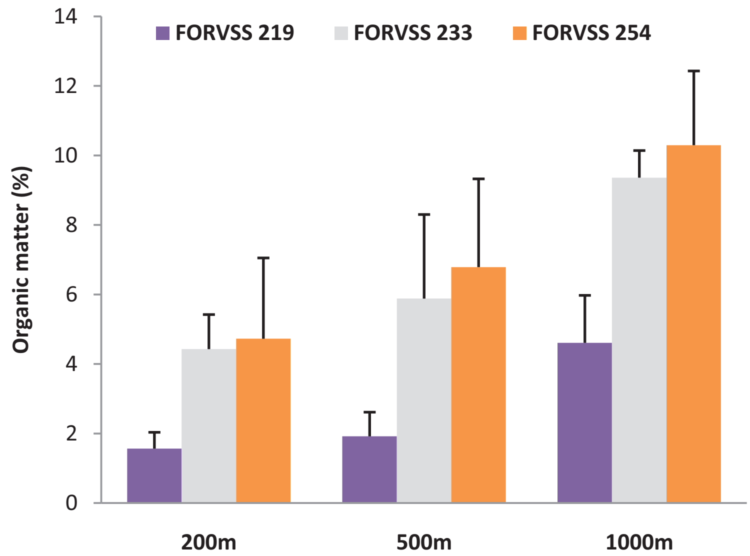

Figure 14: Mean organic matter (%) at the three depth classes during the three surveys

There was significant temporal and depth related variation in total organic matter content (survey: ANOVA $F_{2,\ 76}$ =12.68, p<0.001; depth: ANOVA $F_{2,\ 76}$ =26.944, p<0.001) but latitudinal variation was found to be insignificant (ANOVA $F_{8,\ 70}$ =0.647, p=0.736). Peak values for OM percentage was recorded during May, 2007 and among the three depth classes, higher values were obtained at 1000m [Figure 14]. The organic matter content of the sediments showed strong negative correlation with sand and positive correlation with silt [Figures 16 & 17]. The latter in turn was strongly correlated with depth [Figure 15].

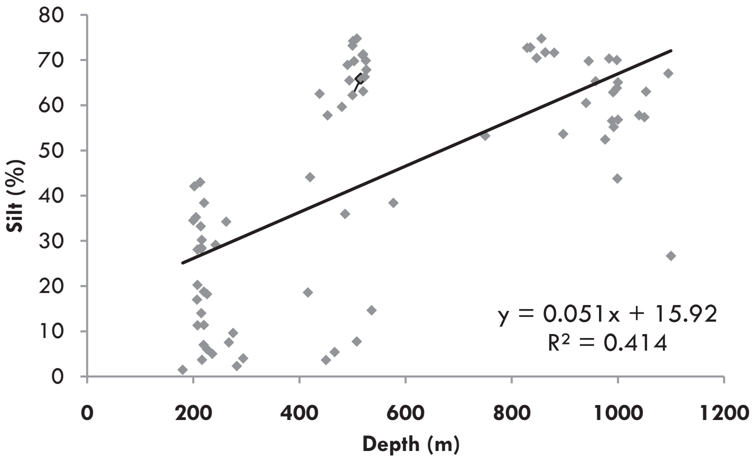

Figure 15: Scatter plot showing relationship between silt (%) of sediment and depth

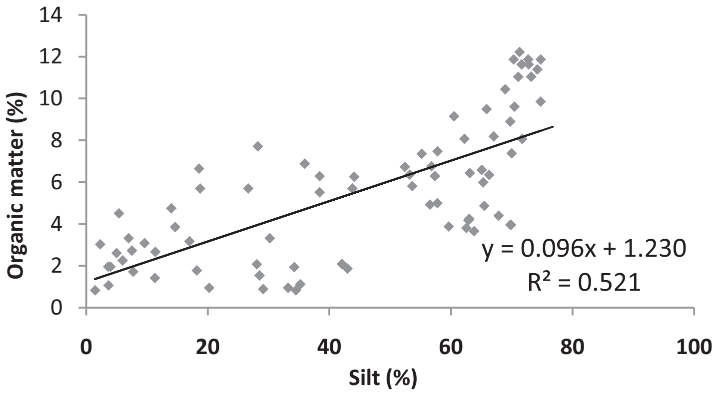

Figure 16: Scatter plot showing relationship between organic matter content and silt (%)

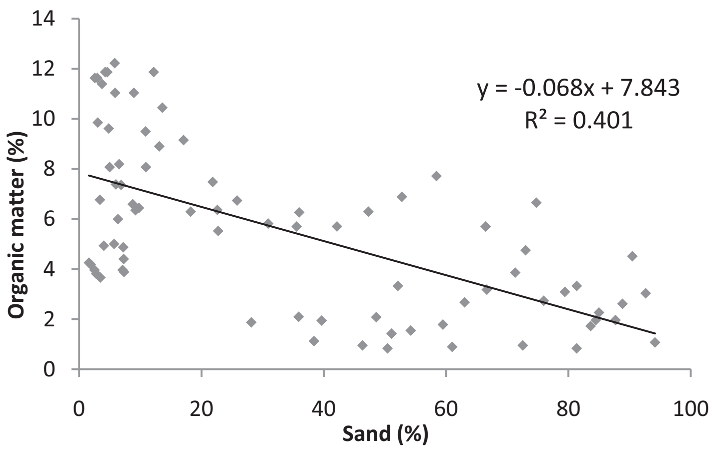

Figure 17: Scatter plot showing relationship between organic matter content and sand (%)

III. 4. PRINCIPAL COMPONENT ANALYSIS (PCA)

The pattern of variation in environmental data in relation to depth and location was made clear in the PCA ordination [Figure 18]. The analysis produced a total of 5 canonical axes, 3 of which explained 85.7% of the total variance between stations. Sediment texture (sand, silt, clay percentage), along with depth and temperature contributed significantly to the PC1, which accounted for 52.9% of the variance in the data (eigen value 4.21). PC2, which explained 22.7% of the total variance (eigen value 1.83), consisted primarily of hydrographical variables, viz. bottom water salinity and DO. Organic matter and clay content comprised the major portion of PC3 [Table 2]. In this analysis, Principal axes 1 & 2 were found to be important and together they explained about 72% of the variance.

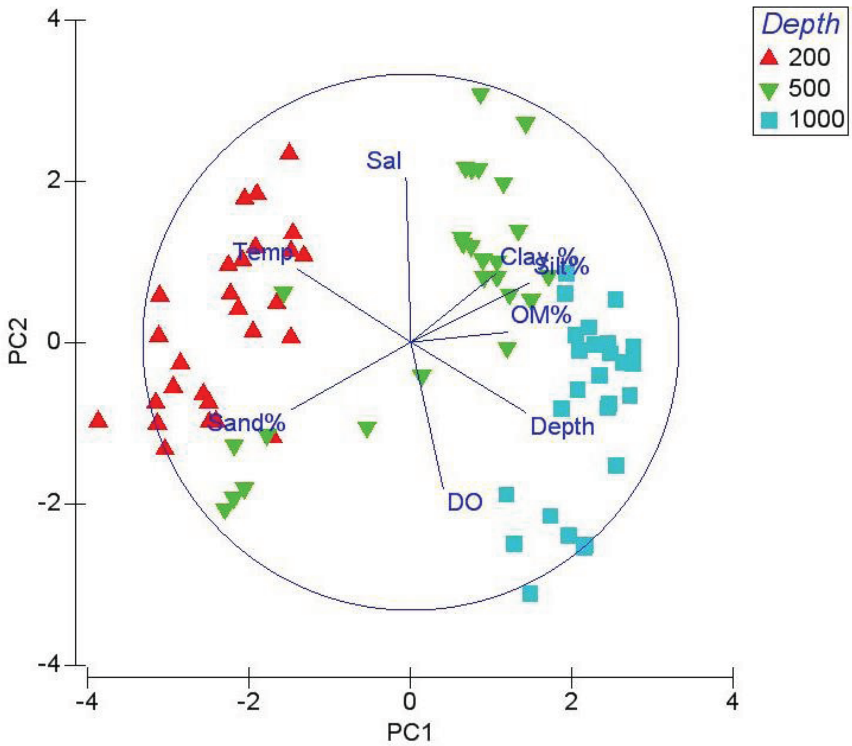

Figure 18: Principal Component Analysis (PCA) ordination of environmental variables

The shallow (200m and some 500m) sites with high sand content and higher temperature were ordinate on the left; and most deeper (500m & 1000m) sites with a greater composition of fine sediments (silt and clay), lower temperature and high organic matter content on the right. Sites with high salinity and low DO loaded towards the top of the PCA plot while well oxygenated sites having low salinity ordinate to the bottom. The environmental parameters loading to PC1, viz. sediment texture, organic matter and bottom water temperature were the ones showing clear trends with respect to depth, while it was evident that bottom water salinity and DO, which loaded towards PC2, both showed a clear latitudinal trend.

Table 2: Results of Principal Component Analysis (PCA)

Variable	PC1	PC2	PC3	PC4	PC5
Depth	0.428	-0.262	0.064	-0.130	0.440
Clay %	0.317	0.256	0.697	0.085	-0.173
Silt%	0.441	0.221	-0.138	-0.045	-0.261
Sand%	-0.446	-0.252	-0.092	0.012	0.260
OM%	0.360	0.037	-0.673	-0.014	-0.246
Temp	-0.422	0.272	-0.010	0.059	-0.534
Sal	-0.018	0.616	-0.166	0.599	0.479
DO	0.121	-0.547	0.044	0.782	-0.258

III. 5. DISCUSSION

In the present study, a significant decrease in bottom water temperature with depth was recorded, while there was no temporal and latitudinal variation. However, in December 2003, at shallow depths (200m), there was a gradual increase in bottom water temperature from south to north. In May 2007, the slightly higher temperature observed at the highest depth was due to the fact that in this survey (FORVSS 254), sampling was restricted to about 850-900m depths, owing to operational constrains. Among the hydrographical parameters, bottom water salinity varied within a narrow range, in relation to both latitude and depth. But these variations were found to be significant, owing to the consistent trend in the observed variation. A general progressive increase in salinity was observed from south to north. Moreover, slightly higher salinity was recorded around 500m when compared to 200m and 1000m and the southernmost transects recorded salinity minima at all depth classes.

The region around the southern tip of India is in contact with the Bay of Bengal and the Equatorial Indian Ocean. The Bay of Bengal water has comparatively low salinity due to high runoff and precipitation. Whereas the north western Arabian Sea is in communication with two landlocked seas, the Red Sea and the Persian Gulf, which contribute high saline waters to the Arabian Sea at depth of about 500m and 200m respectively (Rochford 1964, Shenoi *et al*. 1993). Shenoi *et al*. (2004) reported patches of high saline water in the Arabian Sea at a depth range between 180-600m, hugging the shelf break and continental slope. The Persian Gulf water mass having temperature and salinity in the ranges 13 to 14ºC and 35.20 to 35.25, respectively is present between 200 and 300m; while the Red Sea water mass, having temperature and salinity ranges of 10 to 12ºC and 35.20 to 35.30 was present between 600 and 700m (Shenoi *et al*. 2004). The northern extent of the Red Sea water is marked approximately by the latitude of 18ºN (Shetye *et al*. 1994) and its occurrence is also reported from 10º S (Shenoi *et al*. 2004). The salinity maximum in the present study was around the 500m sites for the northern most transect (Karwar).

According to Cowie (2005), among the many environmental parameters that vary across continental margins, especially beneath areas of upwelling, bottom-water oxygen concentrations and organic matter content exhibit some of the steepest gradients. At the 200 and 500m depths in the northern transects (shelf edge and upper slope region) considerable depletion in bottom water dissolved oxygen was observed, owing to the impingement of OMZ over the continental margin (Sen Gupta *et al*. 1976, 1980, Qasim *et al*. 1982, Levin *et al*. 2009, Ingole *et al*. 2010). It has been observed that minimum oxygen concentration along the continental margin in this region occurs between 150m and 1200m.

Oxygen minimum zones generally form where strong upwelling leads to high surface productivity that sinks and degrades, depleting the oxygen within the water column. OMZ formation is also strongly influenced by stagnant circulation, long residence times and the presence of oxygen-depleted source waters (Sarmiento *et al*. 1988). One of the largest OMZs of the world occurs in the Arabian Sea, where 285,000 km^2 of continental margin floor is impacted by oxygen minimum waters, between depths of 150 and 1500m (Cowie *et al*. 1999, Helly & Levin 2004) and the Arabian Sea OMZ accounts for 30% of the world's margins that are impacted by extreme hypoxia (<0.2ml/l; Helly & Levin 2004). The present findings are in accordance with the previous studies, with low DO being observed on the shelf edge (200m), particularly in the northern transects. The lowest oxygen values was recorded at Karwar 200m during December 2004 and May 2007, is indicative of the extreme hypoxic conditions prevailing in the Arabian Sea.

Comparatively high dissolved oxygen concentration was observed in the southern transects, where the hydrodynamic conditions differed from that of the north and is mainly influenced by water from the Bay of Bengal and Equatorial Indian Ocean. The dissolved oxygen concentration was found to be higher in 1000m sites. Similarly progressive increase in bottom DO below OMZ core was observed on the Indian margin (Ingole *et al*. 2010), Pakistan margin, below 1150m (Gooday *et al*. 2009), Oman margin (Levin *et al*. 2000), eastern Pacific Ocean (Levin *et al*. 1991) and Chile margin (Quiroga *et al*. 2005). Similar level of dissolved oxygen in the deeper water has been reported from the continental margins of Bay of Bengal (Rao 2009). The present observation revealed that proportion of sand decreased with depth (r^2=0.407) while that of silt increased considerably (r^2=0.414). The dominance of the coarse sediments in the shelf edge and upper slope is attributed to the vigorous hydrodynamic conditions prevailing in this region. The steep depth gradients of the upper slope may also facilitate downward transport of finer particles to higher depths, where the physical settings tend to be more stable (Hashimi *et al*. 1978, Hashimi & Nair 1981, Rao & Veerayya 2000).

Between 500 and 1000m sites proportion of clay remained almost unchanged. The silt fraction of the sediment increases from the outer shelf onto the slope, and organic-rich samples of the 500 and 1000m sites (mid-slope) were generally clayey-silts with less than 40% sand content, except Cape and Kollam. These relationships reflect the presence of relict, coarse-grained sediments on the outer shelf area, a common occurrence on many continental margins including the eastern Arabian Sea (Rao & Wagle 1997, Ingole *et al*. 2010). Beyond the shelf edge the proportion of coarse-grained material delivered to the sea floor decreases. Rivers and estuaries have a greater role in transport of terrigenous sediments to the continental shelf. Heavier or coarser particles are deposited on the shallow shelf and finer particles carried away by cross shelf waves to the deeper areas. Rao & Wagle 1997 reported that the slope of the eastern Arabian Sea is characterized by clayey silt sediments with abundant carbonate tests. The present results also agree well with the reports from the Indian continental margin (Ingole *et al*. 2010) and deep Indian basin.

Organic matter content of marine sediments is chiefly influenced by sediment texture, with fine-grained sediments containing more organic matter than coarse sediments (Trask 1953) because of the hydraulic equivalence of clay and organic particles (Calvert & Pedersen 1992) and the higher surface area to volume ratios of fine-grained particles (Mayer *et al*. 1985, Keil & Hedges 1993, Keil *et al*. 1994, Mayer 1994). Within OMZ regions, sediments are characterised by a high organic carbon content (Cowie *et al*. 1999, Ingole *et al*. 2010) and preservation of labile organic compounds such as amino acids, lipids and photosynthetic pigments (Smallwood *et al*. 1999, Vandewiele *et al*. 2009, Woulds & Cowie 2009). A study conducted by Paropkari *et al*. (1992) reported a continuous band of organic rich sediments (from Bombay to Cape Comorin). In the present study, organic matter content was comparatively low on the shelf edge and increased significantly down the slope. The highest OM content was found at the 1000m sites, and values greater than 5% by dry weight occurred at most of the 500 and 1000m sites, particularly in the 2nd and 3rd surveys (April 2005, May 2007). Ingole *et al*. (2010) reported silty sediments with high organic carbon from 1001m off Coondapur (4.4%). High organic carbon content was reported from slope sediments in other parts of the world (Blake & Grassle 1994, Levin *et al*. 2000, Gooday *et al*. 2009). Mendez (2007) reported up to 20% of organic matter from the southeastern Gulf of Carolina and in the eastern Arabian Sea, Rao & Wagle (1997) reported organic content up to 8% in the slope sediments. Rao & Veerayya (2000) reported organic carbon value of 1.82-3.84% in the slope and up to 5.86% from marginal highs of the same region.

From the present study, it is evident that there is a significant temporal variation in organic matter content; with comparatively low values obtained in all sites sampled during December 2003. This may be because of low primary production around this season, which results in limited export flux from the euphotic zone to deep sea. Jasmine (2009) reported that during the winter monsoon season, the South Eastern Arabian Sea is less productive than the North Eastern Arabian Sea. Exceptionally high values were obtained during the sampling of May 2007 (> 10% at 500 and 1000m sites) off all transects except Cape. During this cruise, a massive decaying bloom of *Trichodesmium* sp. was observed along the study area between Coondapur and Trivandrum while early stages of blooms of the same species were observed off Karwar and Coondapur. The inter-monsoon transition period of April-May is characterized by weak winds and weak hydrodynamic processes, which facilitates settlement of the bulk of organic matter from the blooms at the surface. This may explain the high organic contents of the sediments collected in May. This is an indication of the seasonal variation in organic flux to the sea bottom and the influence of hydrodynamic condition that helps the settling of organic matter. Thus the variations in productivity and prevailing hydrodynamic condition have a strong influence on organic matter content of bottom sediments of the SEAS continental margin.

Down slope movement of sediment on the western Indian slope, by turbidity flow and by re-suspension and re-settling, causes less organic matter and foraminifer shells to settle, especially on the upper part of the slope (von Stackelberg 1972, Naidu 1993). The locations of organic carbon maxima on continental slopes are not controlled by the bottom water oxygen levels but are probably produced by a combination of factors that control the texture of the sediments and the depth-related settling fluxes of organic carbon to the sea floor (Calvert 1987). Paropkari *et al*. (1987) reported that the organic matter present in the continental margin of western India is predominantly of marine origin. Organic matter is probably supplied to the shelf at high rates because of the inherent high rate of production in the area due to coastal upwelling and the short transit to the sea floor. However, active reworking of the middle and outer shelf sediments prevents the permanent accumulation of much of this deposited material, which instead, accumulates in quieter water beyond the shelf edge. Cross shelf transport of water column particulate organic matter (Walsh *et al*. 1981, 1985) may also contribute to the organic carbon content of the upper slope sediments.

In the northern transects (Karwar & Coondapur) high OM content occurs in the core oxygen minimum regions, at 200 and 500m sites, and equally high organic matter concentration were also found at the 1000m sites. At most of the 500 and 1000m stations of the remaining 7 transects as well, where the bottom water dissolved oxygen concentration is above $0.5 mll^{-1}$. At the shelf edge (200m sites), of these remaining transects, however, the OM content was low, despite the fact that low DO concentrations were recorded here. This may be attributed to the sandy texture of the sediments and the hydrodynamic conditions of the shelf edge.

Total organic carbon maxima on some other continental slopes, such as off northwestern Africa and northeastern and northwestern North America, also do not correspond with the depth of the oxygen minimum, and are evidently related to other factors (Calvert & Pedersen 1992). Likewise, Keil *et al*. (1994) concluded that the organic content of the sediments of the Washington continental slope is controlled largely by the surface area of the sediment particles, and hence texture, and is not directly related to the oxygen content of the bottom waters in this environment. Similarly, on the Oman margin total organic carbon was not correlated with dissolved oxygen concentration (Levin *et al*. 2000). Thus, from the present study it can be stated that the organic carbon maximum in the SEAS margin occurs between the 500-1000m and may extend further down the slope; while the oxygen minimum along the continental slope occurs between 200 and 1000m.

There was a consistent increase in the silt composition across the continental margin [Figure 15], and an obvious relationship between percentage OM and silt content (r^2=0.521); i.e., the more organic-rich sediments had associated with high silt content [Figure 16]. Thus grain size surface area and OM adsorption (Keil & Cowie 1999) appear to be the primary causes for the OM maximum at 1000m in this study. Paropkari *et al*. (1992) carried out an evaluation of the factors controlling the organic carbon content of the sediments of the Arabian Sea and concluded that bottom water anoxia in conjunction with a number of depositional parameters, such as sediment texture, sedimentation rates, width of the shelf, slope gradient, bottom currents and proportion of adsorptive clay minerals are the most important factor influencing the sedimentary organic carbon in this area.

The fact that organic carbon maxima and oxygen minima do not coincide on all the continental margins, it can be stated that bottom-water oxygen concentration may not be the primary factor determining the organic carbon content, or its state of preservation in the SEAS margin (Calvert *et al*. 1995). The sediment nature of the SEAS margin can thus be generally described as rich in organic matter but relatively deficient in oxygen, from the point of view of benthos. The highest oxygen concentration obtained in the entire study area is 1.4 mll^{-1}. The variations in environmental parameters showed clear spatial (depth and latitudinal) variations, with variations in sediment texture, organic matter and temperature being correlated with depth and bottom water salinity and DO showing a clear latitudinal trend.

Table 3: Hydrographic parameters of bottom water during FORVSS Cruise 219 & 225

St. No.	Location	Depth (m)	Temperature (°C)	Salinity	Dissolved Oxygen (ml/l)
1	**Cape Comorin***	215	14.430	34.980	0.400
2	**Cape Comorin***	294	11.620	35.100	0.830
3	**Cape Comorin***	1100	6.800	34.950	1.120
4	**Trivandrum***	226	14.490	35.080	0.420
5	**Trivandrum***	450	10.860	35.110	0.760
6	**Trivandrum***	940	9.700	35.100	0.710
7	**Kollam***	282	12.730	35.120	0.630
8	**Kollam***	750	7.260	35.010	1.060
9	**Kochi**	188	16.181	35.100	0.683
10	**Kochi**	526	11.302	35.190	0.289
11	**Kochi**	988	8.415	35.080	0.352
12	**Ponnani**	262	13.638	35.220	0.426
13	**Ponnani**	577	10.432	35.210	0.346
14	**Ponnani**	989	7.892	35.100	0.847
15	**Kannur**	205	14.180	35.250	0.408
16	**Kannur**	525	9.971	35.200	0.287
17	**Kannur**	945	8.338	35.110	0.707
18	**Mangalore**	214	15.879	35.200	0.386
19	**Mangalore**	438	11.741	35.320	0.378
20	**Mangalore**	991	7.817	35.140	0.757
21	**Coondapur**	208	16.266	35.190	0.136
22	**Coondapur**	480	11.523	35.390	0.510
23	**Coondapur**	1053	7.444	35.100	0.455
24	**Karwar**	213	16.696	35.230	0.107
25	**Karwar**	453	11.340	35.420	0.195
26	**Karwar**	998	7.836	35.180	0.229

*indicates sites sampled in Cruise 225

Table 4: Hydrographic parameters of bottom water during FORVSS Cruise 228 & 233

St. No.	Location	Depth (m)	Temperature (ºC)	Salinity	Dissolved Oxygen (ml/l)
27	**Cape Comorin**	207	16.060	34.972	0.530
28	**Cape Comorin**	536	13.233	35.095	0.650
29	**Cape Comorin**	999	7.490	34.970	0.868
30	**Trivandrum**	242	14.672	35.031	0.488
31	**Trivandrum**	420	9.866	35.089	0.490
32	**Trivandrum**	976	7.328	34.979	0.819
33	**Kollam**	267	15.789	35.109	0.469
34	**Kollam**	508	10.666	35.141	0.560
35	**Kollam**	1050	6.863	34.989	1.080
36	**Kochi**	180	14.583	35.151	0.323
37	**Kochi**	500	11.052	35.173	0.468
38	**Kochi**	1095	7.726	35.067	0.650
39	**Ponnani**	226	14.790	35.171	0.369
40	**Ponnani**	515	10.939	35.183	0.567
41	**Ponnani**	992	7.125	35.027	0.293
42	**Kannur**	208	14.965	35.181	0.229
43	**Kannur**	523	11.379	35.225	0.610
44	**Kannur**	958	8.835	35.171	0.315
45	**Mangalore**	200	15.394	35.230	0.390
46	**Mangalore**	494	11.361	35.316	0.246
47	**Mangalore**	1000	7.520	35.097	0.790
48	**Coondapur***	220	14.671	35.239	1.400
49	**Coondapur***	520	11.256	35.355	0.885
50	**Coondapur***	1040	7.092	35.070	1.266
51	**Karwar***	216	14.460	35.327	0.861
52	**Karwar***	416	11.348	35.403	0.487
53	**Karwar***	1000	8.364	35.198	0.576

*indicates sites sampled in Cruise 228

Table 5: Hydrographic parameters of bottom water during FORVSS Cruise 254

St. No.	Location	Depth (m)	Temperature (ºC)	Salinity	Dissolved Oxygen (ml/l)
54	**Cape Comorin**	208	14.070	35.028	0.245
55	**Cape Comorin**	486	10.667	35.095	0.631
56	**Cape Comorin**	897	8.297	35.032	0.775
57	**Trivandrum**	216	15.446	35.051	0.348
58	**Trivandrum**	490	10.883	35.127	0.654
59	**Trivandrum**	983	8.010	35.047	0.833
60	**Kollam**	236	13.994	35.138	0.622
61	**Kollam**	466	11.322	35.110	0.732
62	**Kochi**	275	12.836	35.146	0.543
63	**Kochi**	500	11.152	35.162	0.579
64	**Kochi**	835	8.494	35.100	0.545
65	**Ponnani**	220	13.496	35.169	0.426
66	**Ponnani**	520	10.622	35.197	0.534
67	**Ponnani**	856	8.818	35.154	0.649
68	**Kannur**	215	14.813	35.177	0.469
69	**Kannur**	503	10.826	35.212	0.360
70	**Kannur**	880	8.163	35.110	0.466
71	**Mangalore**	219	15.265	35.200	0.212
72	**Mangalore**	508	11.382	35.219	0.364
73	**Mangalore**	829	8.992	35.187	0.401
74	**Coondapur**	220	14.987	35.287	0.492
75	**Coondapur**	519	11.651	35.319	0.308
76	**Coondapur**	863	8.643	35.179	0.504
77	**Karwar**	215	15.231	35.314	0.149
78	**Karwar**	501	11.137	35.413	0.254
79	**Karwar**	847	9.090	35.218	0.743

Table 6: Sediment characteristics during FORVSS Cruise 219 & 225

St. No.	Location	Depth (m)	Clay (%)	Silt (%)	Sand (%)	Organic Carbon (%)	Organic Matter (%)
1	**Cape Comorin***	215	13.0	14.0	73.0	2.76	4.75
2	**Cape Comorin***	294	8.3	4.0	87.7	1.14	1.96
3	**Cape Comorin***	1100	31.2	26.7	42.2	3.31	5.70
4	**Trivandrum***	226	9.0	6.0	85.0	1.31	2.26
5	**Trivandrum***	450	11.9	3.6	84.5	1.14	1.96
6	**Trivandrum***	940	22.4	60.5	17.1	5.31	9.15
7	**Kollam***	282	5.1	2.3	92.6	1.76	3.03
8	**Kollam***	750	24.2	53.2	22.6	3.69	6.36
9	**Kochi**	188	22.0	42.1	35.9	1.21	2.09
10	**Kochi**	526	24.9	67.9	7.3	2.55	4.40
11	**Kochi**	988	24.0	70.0	6.0	4.28	7.38
12	**Ponnani**	262	26.1	34.2	39.6	1.13	1.94
13	**Ponnani**	577	38.9	38.4	22.7	3.20	5.52
14	**Ponnani**	989	39.4	56.6	4.0	2.86	4.93
15	**Kannur**	205	26.4	35.2	38.4	0.65	1.12
16	**Kannur**	525	23.0	69.9	7.1	2.30	3.96
17	**Kannur**	945	27.7	69.8	2.5	2.30	3.96
18	**Mangalore**	214	20.5	33.2	46.3	0.55	0.95
19	**Mangalore**	438	34.7	62.5	2.8	2.21	3.81
20	**Mangalore**	991	35.2	62.9	1.9	2.42	4.18
21	**Coondapur**	208	37.6	11.3	51.1	0.82	1.42
22	**Coondapur**	480	33.0	59.7	7.3	2.25	3.88
23	**Coondapur**	1053	35.4	63.0	1.6	2.47	4.25
24	**Karwar**	213	28.9	43.0	28.1	1.08	1.87
25	**Karwar**	453	36.5	57.8	5.7	2.90	5.00
26	**Karwar**	998	32.7	63.8	3.5	2.12	3.66

*indicates sites sampled in Cruise 225

Table 7: Sediment characteristics during FORVSS Cruise 228 & 233

St. No.	Location	Depth (m)	Clay (%)	Silt (%)	Sand (%)	Organic Carbon (%)	Organic Matter (%)
27	**Cape Comorin**	207	16.4	17.0	66.7	1.84	3.17
28	**Cape Comorin**	536	14.1	14.6	71.3	2.24	3.86
29	**Cape Comorin**	999	20.7	43.8	35.6	3.30	5.70
30	**Trivandrum**	242	9.9	29.1	61.0	0.52	0.89
31	**Trivandrum**	420	19.9	44.1	36.0	3.63	6.26
32	**Trivandrum**	976	21.8	52.4	25.8	3.91	6.74
33	**Kollam**	267	16.5	7.5	76.0	1.58	2.73
34	**Kollam**	508	8.6	7.7	83.6	1.00	1.72
35	**Kollam**	1050	24.4	57.4	18.2	3.65	6.29
36	**Kochi**	180	17.2	1.5	81.4	0.48	0.83
37	**Kochi**	500	26.9	62.2	10.9	4.68	8.07
38	**Kochi**	1095	26.4	67.0	6.5	4.75	8.19
39	**Ponnani**	226	22.3	18.2	59.5	1.03	1.78
40	**Ponnani**	515	23.3	65.9	10.9	5.51	9.49
41	**Ponnani**	992	37.9	55.2	6.9	4.27	7.36
42	**Kannur**	208	23.3	28.1	48.6	1.20	2.08
43	**Kannur**	523	24.5	66.3	9.2	3.68	6.35
44	**Kannur**	958	28.3	65.3	6.3	3.48	5.99
45	**Mangalore**	200	15.1	34.5	50.4	0.48	0.83
46	**Mangalore**	494	27.3	65.5	7.2	2.82	4.87
47	**Mangalore**	1000	39.8	56.8	3.4	3.92	6.76
48	**Coondapur***	220	25.6	11.4	63.0	1.55	2.67
49	**Coondapur***	520	27.1	63.1	9.8	3.73	6.44
50	**Coondapur***	1040	20.4	57.8	21.8	4.34	7.48
51	**Karwar***	216	17.7	30.2	52.1	1.93	3.32
52	**Karwar***	416	6.7	18.6	74.8	3.86	6.65
53	**Karwar***	1000	26.2	65.1	8.8	3.82	6.59

*indicates sites sampled in Cruise 228

Table 8: Hydrographic parameters of bottom water during FORVSS Cruise 254

St. No.	Location	Depth (m)	Clay (%)	Silt (%)	Sand (%)	Organic Carbon (%)	Organic Matter (%)
54	**Cape Comorin**	208	7.2	20.2	72.5	0.55	0.95
55	**Cape Comorin**	486	11.3	36.0	52.8	3.99	6.88
56	**Cape Comorin**	897	15.5	53.6	30.9	3.37	5.82
57	**Trivandrum**	216	2.2	3.7	94.2	0.62	1.07
58	**Trivandrum**	490	17.5	68.9	13.6	6.06	10.44
59	**Trivandrum**	983	17.5	70.3	12.2	6.88	11.87
60	**Kollam**	236	6.2	5.0	88.8	1.51	2.61
61	**Kollam**	466	4.1	5.4	90.5	2.62	4.51
62	**Kochi**	275	11.0	9.6	79.4	1.79	3.09
63	**Kochi**	500	20.9	73.2	5.9	6.40	11.04
64	**Kochi**	835	24.6	72.8	2.6	6.75	11.63
65	**Ponnani**	220	14.8	18.7	66.5	3.30	5.70
66	**Ponnani**	520	22.9	71.3	5.8	7.09	12.22
67	**Ponnani**	856	20.6	74.8	4.6	6.88	11.87
68	**Kannur**	215	17.3	28.5	54.2	0.89	1.54
69	**Kannur**	503	17.1	69.8	13.1	5.16	8.90
70	**Kannur**	880	25.4	71.6	3.0	6.75	11.63
71	**Mangalore**	219	11.7	7.0	81.4	1.93	3.32
72	**Mangalore**	508	22.2	74.8	3.0	5.71	9.85
73	**Mangalore**	829	23.0	72.7	4.2	6.88	11.87
74	**Coondapur**	220	14.3	38.4	47.3	3.65	6.29
75	**Coondapur**	519	20.0	71.1	8.9	6.40	11.04
76	**Coondapur**	863	23.3	71.7	5.0	4.68	8.07
77	**Karwar**	215	13.3	28.2	58.4	4.47	7.71
78	**Karwar**	501	22.0	74.2	3.7	6.61	11.39
79	**Karwar**	547	24.7	70.5	4.8	5.58	9.61

Chapter IV

STANDING CROP OF MACROBENTHOS

IV. 1. INTRODUCTION

Studies on the quantification of organisms were introduced into ocean biology by Hensen during the 1880s and quantitative study on shallow water benthos started with Peterson (1915). This approach was introduced to deep sea research by Zenkevitch (1963) on the Soviet R. V. *Vitiaz*, followed by the classic work of Sanders *et al*. (1965) on macrofauna. The subtidal benthos show large spatial and temporal variations in standing crop (Jumars & Gallagher 1982, Rowe 1983). Macrofaunal densities and biomass are generally known to decrease with increasing water depth. Several environmental and biological factors play an important role in determining distribution and abundance of benthos. The richness and diversity of benthic fauna in a site can be an excellent indicator of environmental characteristics of that region.

Benthos of the Indian waters was first studied by Annandale (1907). Quantitative studies on benthic fauna of Arabian Sea are much more recent, and the earliest reports pertain to south west coast shelf (Kurian 1953, Seshappa 1953). In the case of the west coast of India, most of the qualitative studies on benthos have been localized in and around various estuaries and in coastal waters (Damodaran 1973, Parulekar *et al*. 1980, Vizakat *et al.* 1991, Ansari *et al*. 1994, Sarladevi *et al*. 1996, Gopalakrishna & Nair 1998). A study carried out by Harkantra *et al*. (1980) along the entire west coast up to 75m revealed that in general, polychaetes were the most abundant group, followed by crustaceans and molluscs. Some authors have indicated the abundance of echiuroids, sipunculids (Harkantra & Parulekar 1994) and echinoderms (Harkantra *et al.* 1980) in certain regions. In recent years, a number of detailed investigations on both qualitative and quantitative aspects of macrofauna along the continental shelf have emerged (Ingole *et al.* 2010, Musale & Desai 2010, Smitha CK 2011).

During 1997 to 2002, the benthos of the continental shelf of the east and west coast of India were subjected to detail investigation. The mean abundance and biomass of macrofauna was found to be higher in the south west coast of India when compared to the northwest, north east and south east coasts (Ganesh & Raman 2007, Joydas & Damodaran 2009, Damodaran 2010). The study also revealed the pattern of distribution of the major faunal groups that contributed to density and biomass. Both in the east and west coast, the density and biomass decreased with increasing depth and the group that contributed most to density was the polychaetes, followed by crustaceans and mollusc (Ganesh & Raman 2007, Jayaraj *et al*. 2007, Joydas & Damodaran 2009, Damodaran 2010). The decrease in density and standing crop with increasing depth was apparent in the case of polychaetes and molluscs, while such a trend was not observed in the case of crustaceans (Damodaran 2010).

Based on limited observations along the west coast, Parulekar *et al*. (1982a) reported comparatively high biomass of benthos between 500 and 600m; and relatively low standing crop between 800 and 900m in the Arabian Sea. A study on abundance and biomass of deep-sea benthic fauna of the central and western Indian Ocean recorded comparatively high biomass of benthos from 1500-2000m depth and low biomass beyond 5500m, while density of macrofauna and meiofauna decreased with depth (Parulekar *et al*. 1982b). A recent study along a bathymetric transect of the south west Indian continental margin by Ingole *et al.* (2010) recorded lowest benthic biomass and densities within the OMZ region (1001m), while there was a gradual increase in density and biomass of macrofauna at basin depths (~2500m).

Estimation of secondary production is one of the most important steps for evaluating the trophic potential of an ecosystem. In the marine environment, benthic invertebrates are important links in energy flow, from the standpoint of secondary production and also recycling of organic matter (Crisp 1984). Quantitative data on benthos, thus, is a prerequisite for estimation of demersal fishery potential (Damodaran 1973, Parulekar *et al.* 1982a). Such estimates are in turn fundamental for devising rational management measures, not only of fisheries but of marine natural resources, as a whole. This chapter describes the patterns in abundance and biomass of macrofauna in spatial and temporal scales as well as the quantitative contribution of various taxonomic groups of macrobenthos.

IV. 2. RESULTS

In order to obtain adequate data on macrobenthos along the south-western Indian continental margin (from 200 to 1000m), 144 grab samples collected over three surveys and from three different depth categories (200, 500 and 1000m) were analysed. Density of macrobenthos during the study is given in Tables 9-11. About 16 diverse taxonomic groups were encountered among the macrofauna during the study. A total of 11,170 organisms were collected in the grab. Of these, 71% were polychaetes [Figure. 19], which was the dominant group, followed by crustaceans (13%) and molluscs (9%). Other groups like nemertines, echinoderms, sipunculids, fishes and anthozoans were also represented in small numbers; and together they accounted for 7% of the total specimens collected. The density of macrobenthos in the study area varied between 30 (FORVSS 219, Coondapur, 1000m) and 2143 Ind.m^{-2} (FORVSS 254, Coondapur, 200m) with an overall mean of 584.6±502.5 Ind.m^{-2}.

Biomass of macrofauna was estimated on wet weight basis after the organism were sorted into four major groups viz. polychaetes, crustaceans, molluscs, and ‘other organisms’, which included all faunal groups represented in few numbers. Macrobenthic biomass ranged from 0.88 gm^{-2} (FORVSS 219, Mangalore 1000m) to 18.16 gm^{-2} (FORVSS 233, Cape 200m) with a mean of 6.03±3.73 gm^{-2} [Tables 12-14]. In the entire study, polychaetes contributed 44% to total biomass of macrofauna, while crustaceans and molluscs contributed 17% and 22%, respectively [Figure 20].

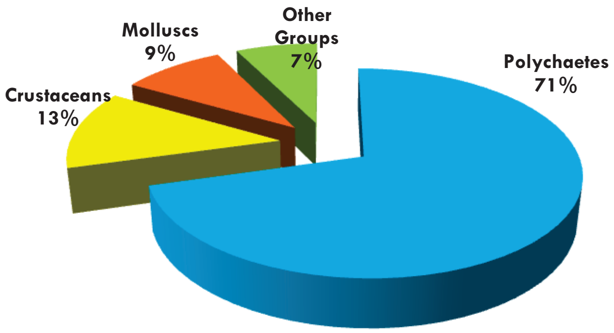

Figure 19. Composition of total macrofauna collected during the study (all depths)

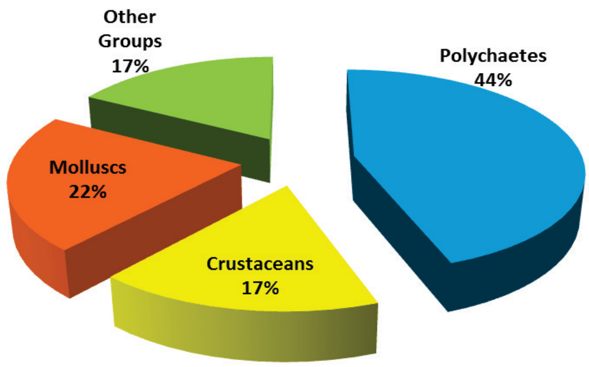

Figure 20. Composition of total macrofaunal biomass during the study (all depths)

Density and biomass of macrofauna showed significant variation with depth. Even though, there was no significant variation in density and biomass between latitudes and surveys, some of the site showed considerable variation in both. Statistical tools such as one way ANOVA was performed to test for significant differences in density and biomass of macrofauna and faunal groups during the study.

IV. 2. 1. Variation in density and biomass with depth

a) Density: There were no significant differences in numerical abundance between surveys [Figure 22] (ANOVA $F_{2, 76}$=0.324, P=0.724). So the data from all three surveys were pooled and the mean density for each site was calculated (based on the 6 grab samples collected from each sampling sites) [Figure 21]. The mean density in the study area ranged between 124±38 Ind.m^{-2} (Karwar, 1000m) and 1555±193 Ind.m^{-2} (Cape, 200m). Among the three depth categories, it was found that the mean density was lowest at 1000m (253.3±152 Ind.m^{-2}) and highest at 200m (1059.7±572.3 Ind.m^{-2}), with intermediate density at 500m (445.4±254.6 Ind.m^{-2}) [Figure 23]. The total macrofaunal density reduced by 75% from 200 to 1000m, and the decline was linear (r^2=0.425) [Figure 24]. From 200 to 500m the faunal reduction was about 55% and from 500m to 1000m it was about 43%. The mean density of macrofauna at each depth is summarised in Table 15.

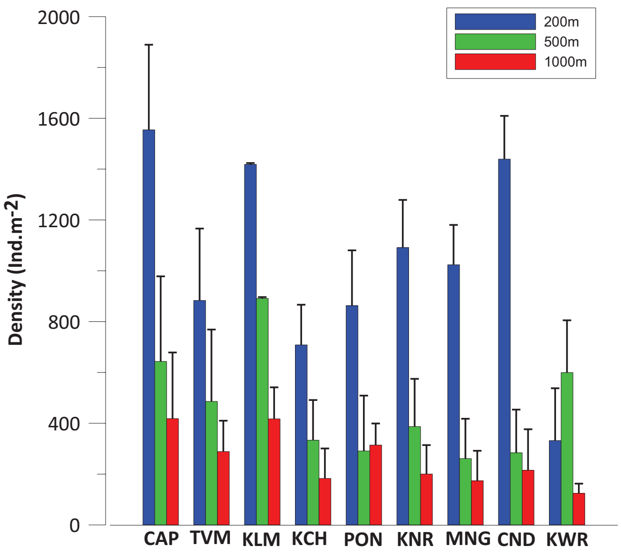

Figure 21. Mean density of macrofauna at each sampling site

At the 200m depth, the mean density was 960.2±532.4 Ind.m^{-2} in the first survey, 1048.3±584 Ind.m^{-2} in the second survey and 1096±665.24 Ind.m^{-2} in the third survey [Table 15, Figure 22]. The mean density at the 500m depth category were 399.12±115.23 Ind.m^{-2}, 532.8±293.8 Ind.m^{-2} and 405±315.79 Ind.m^{-2} in the first, second and third surveys, respectively; while the values were 216.8±190.2 Ind.m^{-2}, 344.6±126.8 Ind.m^{-2} and 191.87±78.32 Ind.m^{-2} at the 1000m depth category. In all surveys, significant difference in density was observed between the three depth classes (survey I: $F_{2, 23}$=15.396, P<0.001, survey II: $F_{2, 24}$=8.083, P=0.002; survey III: $F_{2, 23}$=10.173, P=0.001). In the third survey, the mean density at deeper stations was lower, when compared to the first two surveys.

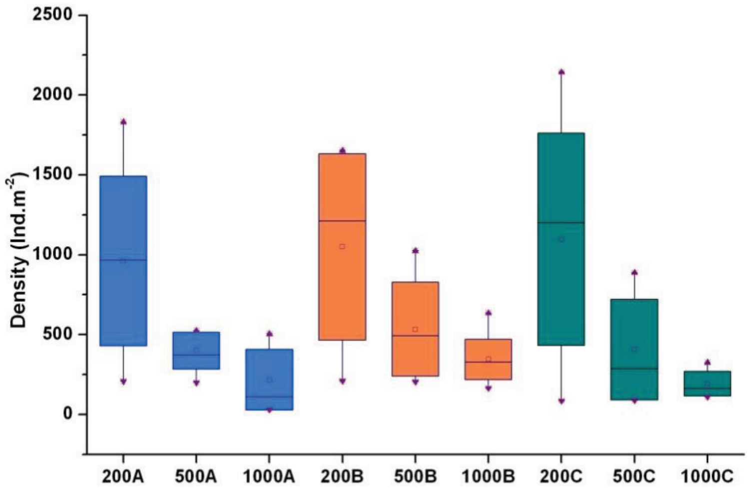

Figure 22. Mean density of macrofauna (for three depth classes in three surveys)
(Box: SD, Whisker: Range, Square: Mean)
A: Survey I, B: Survey II, C: Survey III

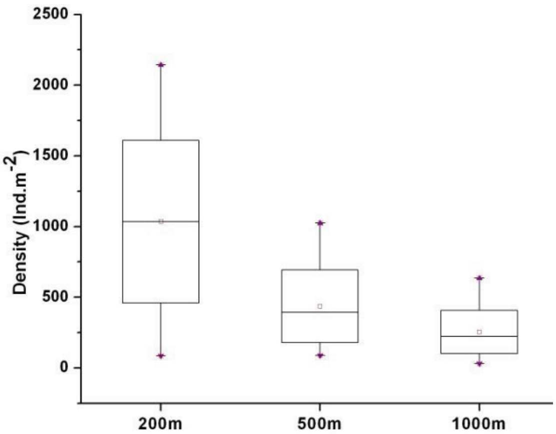

Figure 23. Mean density of macrofauna at the three depth classes

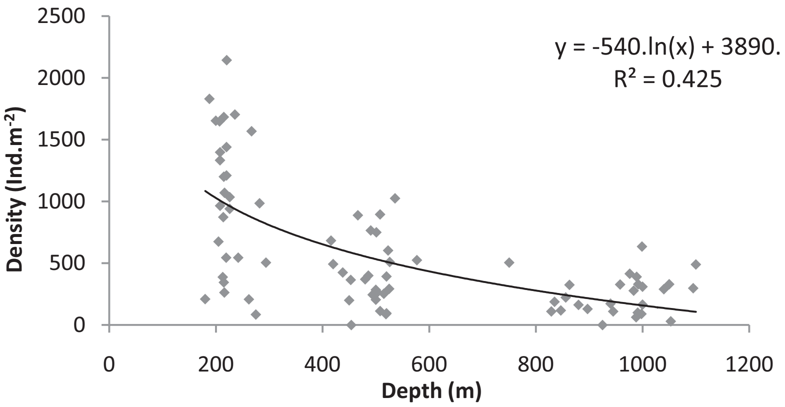

Figure 24. Plot showing relation of faunal density with depth

b) Biomass: The mean biomass of macrofauna ranged between 2.295±1.56 gm^{-2} (1000m) and 12.217±2.44 gm^{-2} (200m) of Mangalore transect [Figure 25]. The lowest mean biomass was found at the 1000m depth (4±2.62 gm^{-2}) and highest at 200m (7.52±4.47gm^{-2}); with an intermediate value at 500m (6.49±2.62gm^{-2}) [Figure 27]. The total macrofaunal biomass decreased by 46.8% from 200 to 1000m, and this variation with depth was found to be statistically significant ($F_{2, 76}$ =7.365, P=0.001) [Figure 28]. From 200 to 500m the decrease in biomass was about 13.7% whereas from 500m to 1000m it was about 33%.

Variation in biomass with depth was noticed in all surveys, but the variation between surveys was marginal [Table 16, Figure 26]. At 200m depth classes the mean biomass was 6.48 ±2.86 gm^{-2}, 8.11±4.49 and 7.95±5.91 gm^{-2} during first, second and third survey respectively [Table 16, Figure 26]. While at the intermediate depth (500m) the mean biomass values was comparatively higher during second survey (7.96±2.37 gm^{-2}) when compared to first (5.92±2.08 gm^{-2}) and third survey (5.19±3.96 gm^{-2}), as in the case of density. The 1000m depth category recorded lowest biomass in all surveys; and the mean values were 2.90±2.38 gm^{-2}, 4.79±2.87 gm^{-2} and 4.8±2.69gm^{-2} during the first, second and third surveys, respectively.

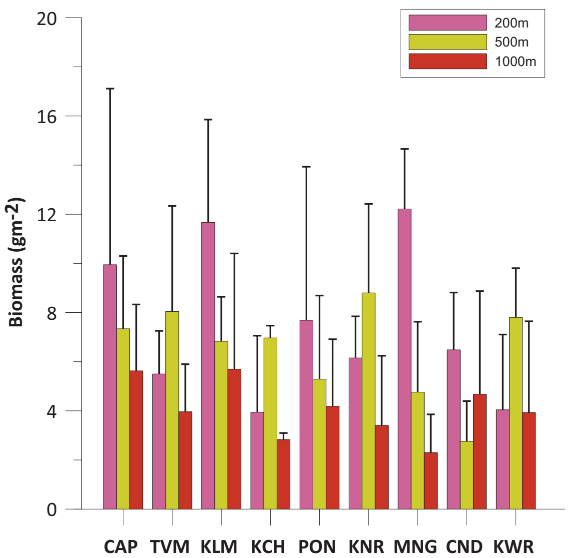

Figure 25. Mean biomass of macrofauna at each sampling site

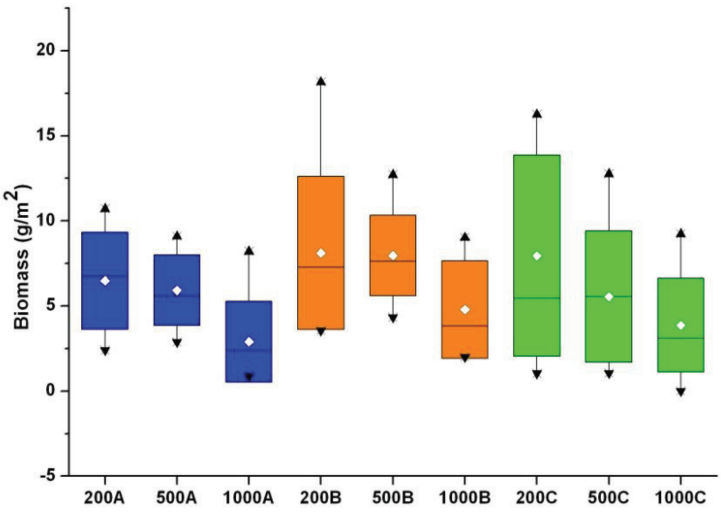

Figure 26. Mean biomass of macrofauna (for three depth classes in three surveys)
(Box: SD, Whisker: Range, Square: Mean)
A: Survey I, B: Survey II, C: Survey III

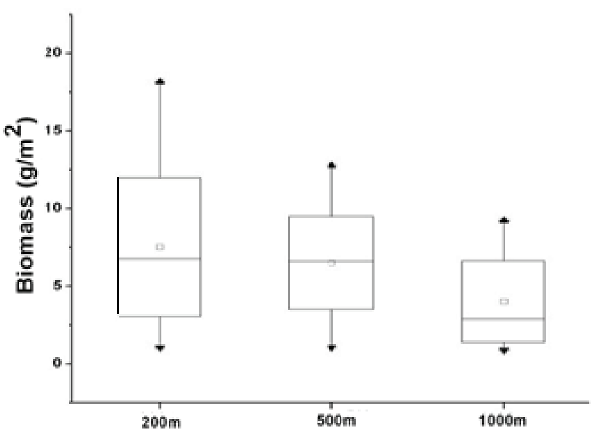

Figure 27. Mean biomass of macrofauna at the three depth classes

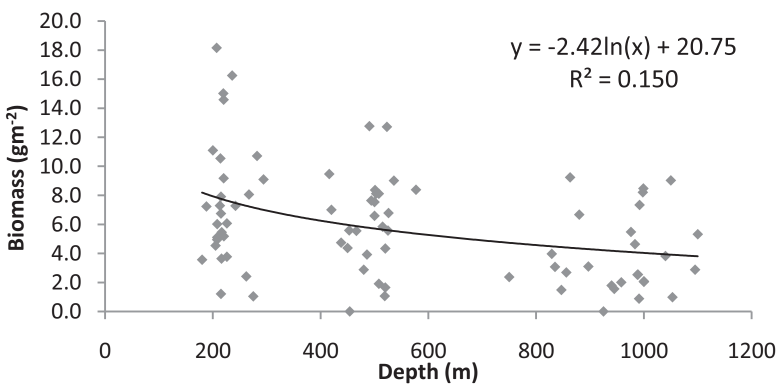

Figure 28. Plot showing relation of faunal biomass with depth

IV. 2. 2. Latitudinal and temporal variation in density and biomass

The bathymetric transects sampled during the study were situated about 1° apart, and environmental characteristics such sediment texture, organic content and dissolved oxygen also showed progressive changes along the study area. Distinct distribution patterns and faunal composition was noticed at various transects. Density and biomass of macrofauna at each site during the three surveys is presented in Tables 9-14.

a) Density: Latitudinal variation in numerical abundance of macrobenthos at each site is presented in Figure 21. Even though there was no significant variation in density between latitudes (ANOVA $F_{2,\ 76}$ =0.324, P=0.724) and surveys (ANOVA $F_{8,\ 70}$ =1.068, P=0.395), some transects showed considerable spatio-temporal variation. The mean density at 200m depth category was lowest at Karwar (333±64 Ind.m^{-2}) and highest at Cape (1555±193 Ind.m^{-2}). At the 500m depth category, the minimum value was recorded at Mangalore (261±157 Ind.m^{-2}) and maximum at Kollam (892±5 Ind.m^{-2}) and at 1000m sites, the densities were consistently lower at Karwar (124±38 Ind.m^{-2}) and highest at Cape (418±260 Ind.m^{-2}).

The southern transects, especially Cape and Kollam had relatively high macrobenthic density and the northernmost transect (Karwar), had the lowest density. In all transects, mean macrobenthic densities were highest at the shallow sites (~200m) except Karwar, where the density maximum was recorded at 500m (599±206 Ind.m^{-2}). Temporal variation in density was more prominent at Kochi 200m. At this site, high density was recorded during the first survey (1830 Ind.m^{-2}), while density was very low during the second and third survey (210 Ind.m^{-2} and 85 Ind.m^{-2}, respectively). Thus, this site had the greatest standard deviation [Figure 21]. At Ponnani 200m, comparatively low density was recorded during first survey (208 Ind.m^{-2}), but during second and third survey relatively high densities were recorded here (940 and 1440 Ind.m^{-2} respectively). At the intermediate depth category (500m), relatively high density was recorded at Kollam (892±5 Ind.m^{-2}), Cape (643±335 Ind.m^{-2}), Karwar

(599±206 Ind.m^{-2}) and Trivandrum (486±283 Ind.m^{-2}), while in the remaining transects (from Kochi to Coondapur) the density varied within a narrow range (261±157 to 387±188 Ind.m^{-2}). At this depth, during the third survey, very low macrofaunal density was recorded at Coondapur and Ponnani (88 and 93 Ind.m^{-2} respectively). At the deeper sites (1000m), density did not vary greatly between transects, with highest density at Cape (418 ±260 Ind.m^{-2}) and Kollam (418±124 Ind.m^{-2}) and lowest density at Karwar (124 ±38 Ind.m^{-2}). During the first survey, the deeper stations off Coondapur (30 Ind.m^{-2}), Kochi (63 Ind.m^{-2}) and Karwar (90 Ind.m^{-2}) had lowest density. However, relatively higher densities were observed during second and third survey at these sites.

b) Biomass: Total biomass of macrofauna varied with transects and surveys but the differences were not statistically significant (Transect: $F_{8, 70}$ =1.017, P=0.0.432; Survey: $F_{2, 76}$ =1.716, P=0.187). At 200m depth category, the mean biomass was lowest at Kochi (3.97±3.11gm^{-2}) and highest at Mangalore (12.22±2.44 gm^{-2}). Variation in total biomass with survey at this depth was most prominent at Cape, Kollam and Ponnani [Figure 25]. When the three northernmost transects were considered, there was a sharp decrease in total biomass from 12.22±2.44 gm^{-2} at Mangalore to 4.05±3.05 gm^{-2} at Karwar with an intermediate value at Coondapur (6.48±2.33 gm^{-2}). In the 500m depth category, the mean macrofaunal biomass was relatively high at Kannur (8.8±3.62gm^{-2}) and low at Coondapur (2.76±1.64 gm^{-2}). The latter site recorded lowest biomass values in all three surveys (2.874, 4.34 and 1.06 gm^{-2} during first, second and third surveys, respectively). At this depth (500m), the total biomass progressively decreased from Kannur, northwards to Coondapur, while values towards the south (Kochi to Cape) varied within a narrow range and did not show any latitudinal trend.

A remarkable observation during the study was the occurrence of high macrofaunal biomass at the 500m site off Karwar, with values comparable to the southern transects. Biomass values were lowest at the 1000m depth category, with values ranging between 2.3±1.56 gm^{-2} (Mangalore) and 5.7±4.71

gm^{-2} (Kollam). Among the southern transects, lowest biomass at this depth was recorded at Kochi (2.82±0.27 gm^{-2}). At this depth class, temporal variations were found to be high at Kollam, Coondapur and Karwar [Figure 25].

IV. 2. 3. Density & Biomass of faunal groups

While benthos is composed of organisms from diverse phyla, the annelids, crustaceans and molluscs are the major contributors to the total density and biomass of macrofauna.

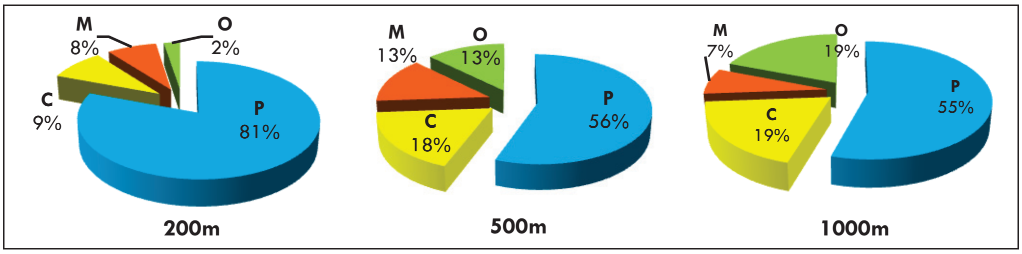

Figure 29. Contribution of faunal groups to density of macrobenthos at each depth
P: Polychaetes, C: Crustaceans, M: Molluscs & O: Other Groups

Other groups include echinoderms, nemertines, echiuroids and sipunculids in minor abundance. Various taxa exhibit different patterns of abundance across the continental margin, owing to influence of diverse environmental factors.

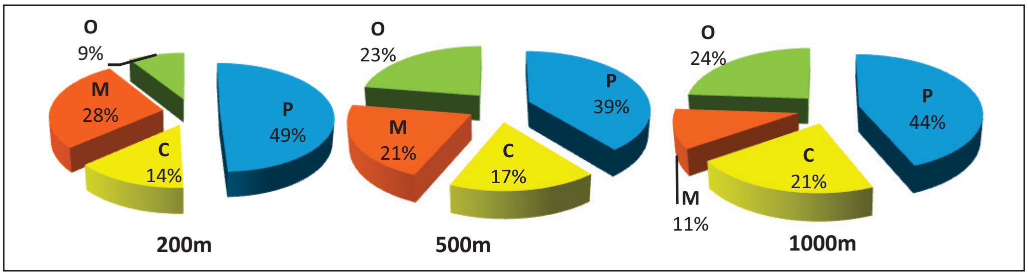

Figure 30. Contribution of faunal groups to biomass of macrobenthos at each depth
P: Polychaetes, C: Crustaceans, M: Molluscs & O: Other Groups

The percentage contribution of major groups to the density and biomass of macrofauna at each depth category are shown in Figure 29 & 30. Figures 31 & 32 depict the mean density and biomass of the faunal groups in the three depth classes.

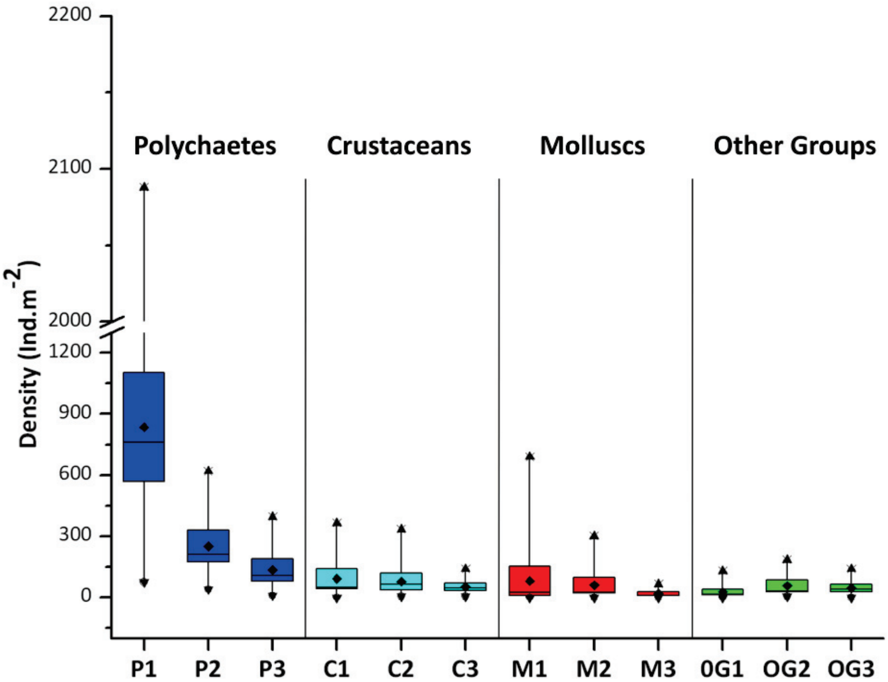

Figure 31. Mean densities of the faunal groups at each depth class
P: Polychaetes, C: Crustaceans, M: Molluscs, OG: Other Groups,
1: Survey I, 2: Survey II, 3: Survey III

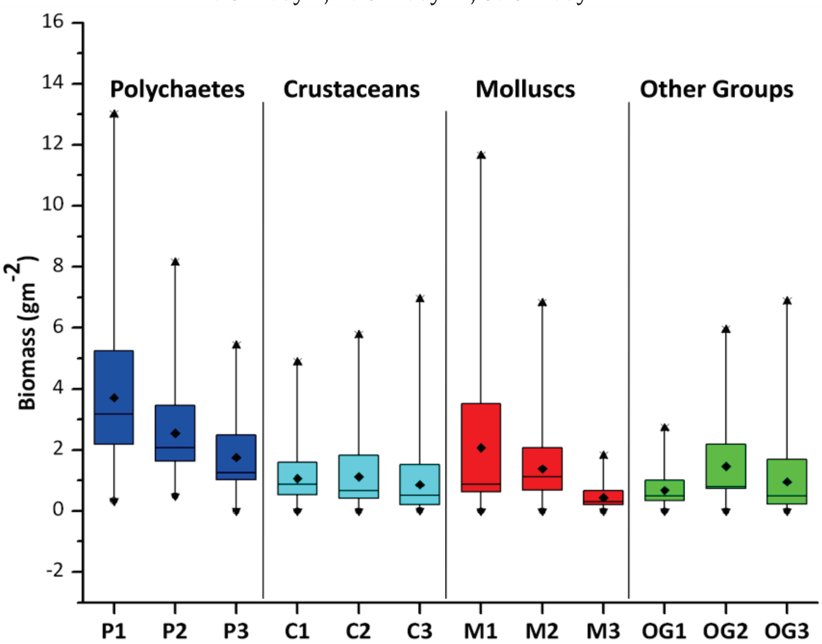

Figure 32. Mean biomass of the faunal groups at each depth class
P: Polychaetes, C: Crustaceans, M: Molluscs, OG: Other Groups,
1: Survey I, 2: Survey II, 3: Survey III

a) Polychaetes

Polychaetes were the most dominant group in terms of number of individuals, representing 71% of all organisms collected during the study. Their densities exceeded 50% of total macrofauna in all samples, while polychaete biomass represented about 30% that of total macrofauna. The abundance of polychaetes reflected that of macrofauna as a whole. Density of polychaete varied between 10 (FORVSS 219, Karwar 1000m) and 2088 Ind.m^{-2} (FORVSS 254, Coondapur 200m) in the entire study [Tables 9-11]. There was no significant difference in polychaete density between surveys ($F_{2,76}$ =0.038, P=0.963), but the differences between depth classes were found to be statistically significant ($F_{2,76}$ =34.197, P<0.001). The mean density of polychaete varied appreciably with depth and the mean value was found to be highest at 200m (835.4±534.9 Ind.m^{-2}) and lowest at 1000m (134.69±154.2 Ind.m^{-2}), with an intermediate value at 500m (251.6±155.7 Ind.m^{-2}) [Figure 31]. Mean polychaete density for the entire study was found to be 412.7±450.8 Ind.m^{-2}. The relative abundance of this group was 81%, 56% and 55%, at 200m, 500m and 1000m respectively [Figure 29].

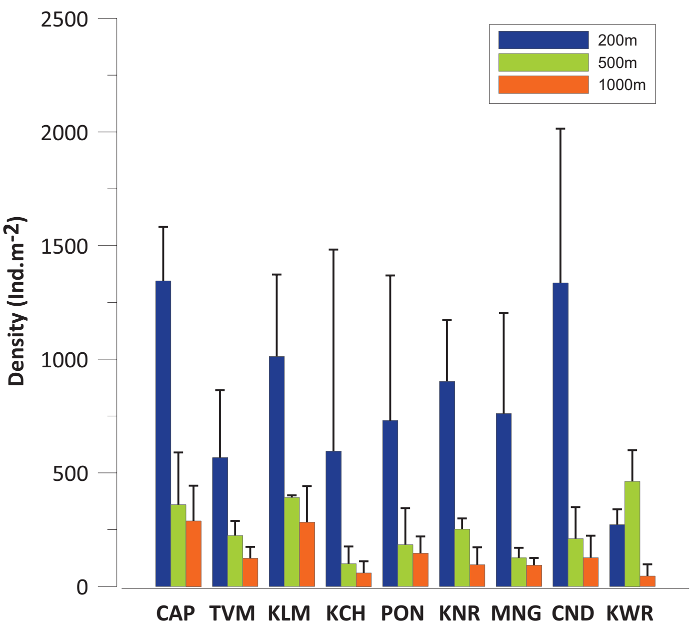

Figure 33. Density of polychaetes at each sampling site

The mean density of polychaetes at 200m was 793±492 Ind.m^{-2}, 819.4±537 Ind.m^{-2} and 893.8±627 Ind.m^{-2} during first, second and third surveys, respectively. At 500m depth, the mean density was relatively high during first survey (399±115.2 Ind.m^{-2}) when compared second and third survey (288.9±183.3 Ind.m^{-2} and 227.1±172.3 Ind.m^{-2}, respectively). At the 1000m depth, the mean density was maximum in the second survey (176.2±85.19 Ind.m^{-2}) followed by the first (134.6±154.2 Ind.m^{-2}) and third (88.1±49.6 Ind.m^{-2}) surveys. Among the three surveys, the relative abundance of this faunal group at 200m and 500m depth category varied within a narrow range (78 to 83% at 200m and 54 to 59% at 500m), while at 1000m, wide variation was observed (46 to 62%).

Mean polychaete density at each site is presented in Figure 33. At the 200m depth, highest mean polychaete density was observed at Coondapur (1336±678.4 Ind.m^{-2}) and Cape (1334.6±237.4 Ind.m^{-2}), while the lowest density was at Karwar (272±67.5 Ind.m^{-2}). Variation in density between surveys was noticed at Kochi, Ponnani, Kollam and Coondapur. During the first survey, polychaetes were found in high abundance at Kochi, but the abundance decreased to meagre levels during second and third surveys. In contrast, at Ponnani, low polychaete density was observed in the first survey and high densities were recorded in the second and third surveys. At Kollam, the density of polychaetes was low (985 Ind.m^{-2}) during the first survey, while it was relatively high in the second and third surveys (1568 and 1703 Ind.m^{-2}). At Coondapur, the density of polychaetes ranged between 920 Ind.m^{-2}(first survey) to 2143 Ind.m^{-2}(third survey).

At the 500m depth category, lowest polychaete abundance was recorded at Kochi (100±75.7 Ind.m^{-2}) and highest at Karwar (462.7±137.3 Ind.m^{-2}). The density of this group was comparatively high in the southern transects, especially Cape, Trivandrum and Kollam. At the 1000m depth category, polychaete density was lowest at Karwar (46±51.5 Ind.m^{-2}) and the highest at Cape (288.3±155 Ind.m^{-2}). Among the southern transects, Kochi had lowest polychaete density (59.6±51 Ind.m^{-2}) at this depth category. Except Kollam and Cape, all other deeper (1000m) sites had more or less similar densities of polychaetes.

The biomass of polychaetes ranged between 0.0025 gm^{-2} (FORVSS 219, Coondapur 1000m) and 12.99gm^{-2} (FORVSS 254, Ponnani 200m) [Table 12-14] with a contribution of 44% to the total macrofaunal biomass in the study area [Figure 20]. There was no significant difference in the biomass between surveys ($F_{2, 76}$ =1.876, P=0.16) but the differences between depth classes were found to be statistically significant ($F_{2, 76}$ =5.176, P=0.008). The variation between latitudes were also found to be of no significance ($F_{8, 70}$ =1.017, P=0.432). The mean biomass decreased with increasing depth and the value was 3.71± 3.05 gm^{-2} at 200m, 2.54± 1.83 gm^{-2} at 500m and 1.75±1.48 gm^{-2} at 1000m [Figure 32]. In the entire study polychaete biomass showed a decreasing trend with depth and the relative contribution of this group to total biomass were 49% at 200m, 39% at 500m, and 44% at 1000m [Figure 30].

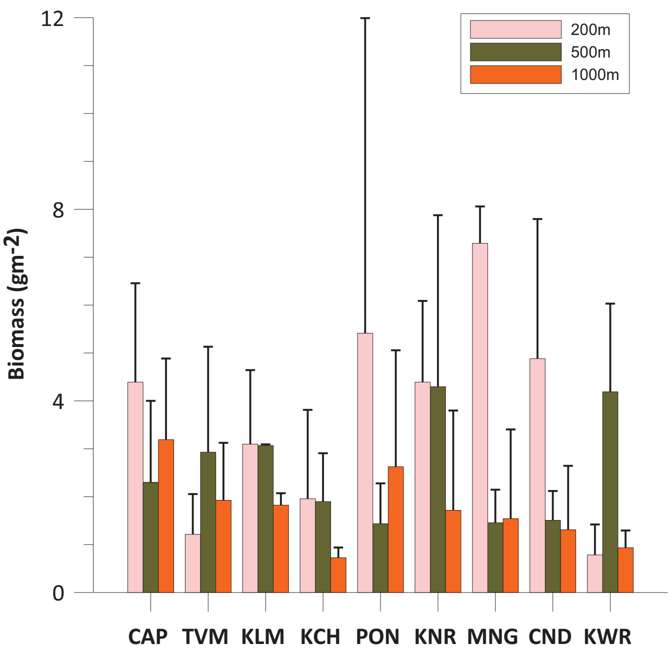

Figure 34. Biomass of polychaetes at each sampling site

Biomass of polychaete for each sampling site is presented in Figure 34. Among the 200m sites, temporal variation in density was apparent at Ponnani and Coondapur. During the first collection, these sites had the lowest numerical abundance that reflected in the biomass also. However, at this depth, comparatively high biomass was recorded off Kochi in the first survey, while low values were recorded in the second and third survey. At Trivandrum the biomass value was relatively low at 200m depth, as the polychaetes which were present in moderate densities were of relatively small size. At 500m depth, the mean infaunal biomass was highest at Kannur (4.30±3.58 gm^{-2}), while Ponnani (1.44±0.84 gm^{-2}) recorded the lowest biomass and the greatest standard deviation. At 1000m depth category, the biomass value was highest at Cape (3.19±1.69 gm^{-2}) and lowest at Kochi (0.73±0.21 gm^{-2}). This depth category showed a clear sequential decline biomass from south to north with comparatively low values at Karwar (0.93±0.36 gm^{-2}).

b) Crustaceans

Crustaceans were chiefly represented by the amphipods, ostracods and decapods, while other groups such as isopods, caprellids and cumaceans were also recorded in some stations. Density of crustaceans in the study area varied from nil (FORVSS 225, Trivandrum 200m) to 365 $Ind.m^{-2}$ (FORVSS 233, Kannur 200m) [Tables 9-11]. Mean density of crustaceans at each site is presented in Figure 35. There were no significant differences between depth classes ($F_{2, 76}$ =1.839, P=0.166) and between latitudes ($F_{2, 76}$ =1.061, P=0.4), while the differences in density of crustaceans between surveys was found to be statistically significant ($F_{2, 76}$ =5.085, P=0.008). This was because relatively higher densities of crustaceans were recorded during the second survey when compared to first and third. The mean density of crustaceans was 91±98 $Ind.m^{-2}$ at 200m, 78±80 $Ind.m^{-2}$ at 500m and 52±35.8 $Ind.m^{-2}$ at 1000m [Figure 31].

Though mean density varied within a narrow range among the three depths, crustaceans became relatively more abundant with increasing depth, i.e. they represented about 14% of macrofauna at 200m, 17% at 500m and 21% at

1000m [Figure 29]. Even at Karwar (1000m), where the total faunal density was lowest for the entire study, comparatively high density of crustacean was observed (45±17.3 Ind.m^{-2}).

Amphipods were among the more consistently abundant macrofaunal taxa, which were represented in virtually all samples from Cape Comorin to Karwar. Over 375 amphipods were collected in 144 grab samples and this group accounted for 4% of the total density of macrofauna. Over 309 ostracods were screened from grab samples. Abundance of this taxon was much higher at 200 and 500m depths of Kannur and Mangalore during first and second survey. The contribution of caprellids to the total abundance of macrofauna was appreciable (1.2%). Juvenile decapods were often encountered in the grab samples. Females of *Callianassa* sp. with juveniles in the brood pouch were found in the samples of FORVSS 233 & 254. Cumaceans were among the least abundant of crustaceans and contributed about 0.5% to total macrofauna; and *Raninoides* sp. was also represented.

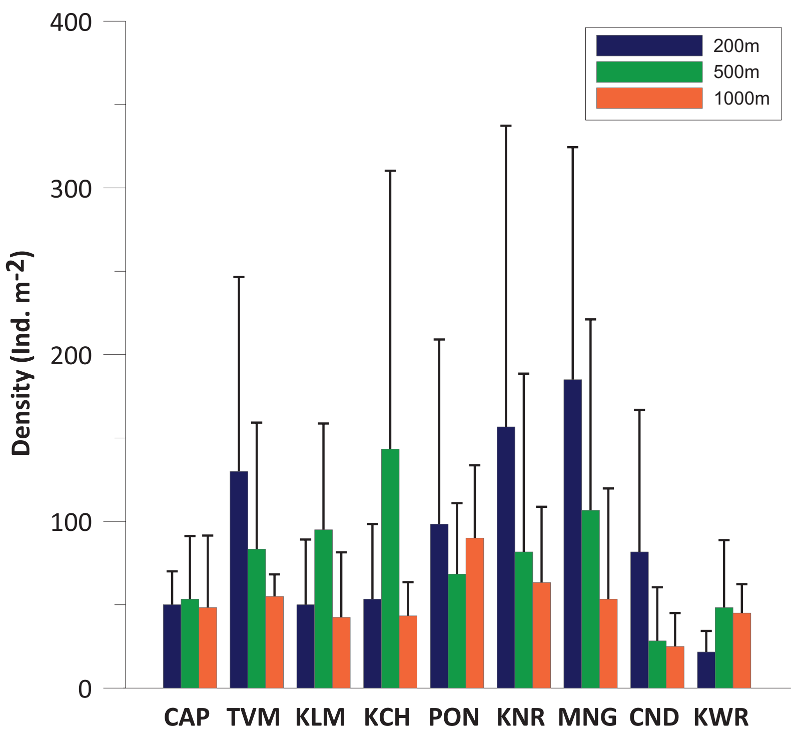

Figure 35. Density of crustaceans at each sampling site

Crustacean biomass in the study area ranged from nil (FORSS 225, Trivandrum 200m) to 6.95 gm^{-2} (FORVSS 254, Coondapur 1000m) [Tables 12-14] with a mean of 1.01±1.26 gm^{-2} and formed about 17% of the total biomass [Figure 20]. At 200m, the biomass value ranged between 0.16±0.14 (Karwar) and 3.12±1.64 gm^{-2} (Mangalore) with a mean of 1.06±1.06 gm^{-2}. At 500m the range was 0.30±0.29 (Karwar) to 2.5±2.85 gm^{-2} (Kannur) with a mean of 1.12±1.41 gm^{-2} and at 1000m the range was from 0.348±0.33 (Kannur) to 2.75±3.65 gm^{-2} (Coondapur) (mean, 0.86±1.32 gm^{-2}). The biomass of crustacean at each sampling site is presented in Figure 36. Crustaceans contributed about 14%, 17% and 21% to the total biomass at 200m, 500m and 1000m respectively [Figure 30]. The mean biomass of crustaceans in each depth class is shown in Figure 32.

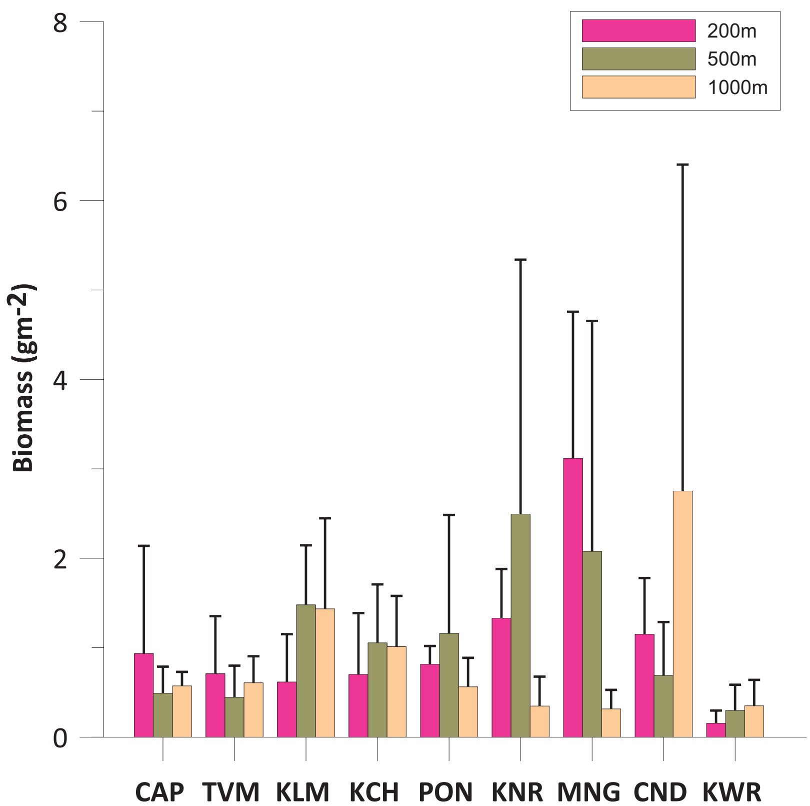

Figure 36. Biomass of crustaceans at each sampling site

c) *Molluscs*

Among the molluscs, the bivalves constituted a major group followed by scaphopods and gastropods. In all, 671 bivalves were collected from grab samples, making them one of the numerically dominant taxonomic groups (7.2% of total macrofauna) [Figure 19] in the slope region from 200 to 1000m. The shelf edge and upper slope sites (200m and 500m) of the three southern transects, viz. Cape, Trivandrum and Kollam, were distinct in their faunal composition from the other similar depth sites [Tables 9-11]. These stations had the high density of small bivalves, such as *Nuculana* sp., *Garfrarium tumidum*, *Tellina* sp. and *Dosinia* sp. Among the other species collected from the slope are *Limopsis* sp., *Cuspidaria* sp., *Solen* sp. etc. Scaphopods (60 individuals in all) were more common in the sandy bottom of southern transects, but were nearly absent in most other stations. Gastropods were represented in very few numbers and a total of 113 individuals were obtained from the grab samples. Some of the species identified were *Natica* sp., *Pyrene* sp., *Bursa* sp., etc.

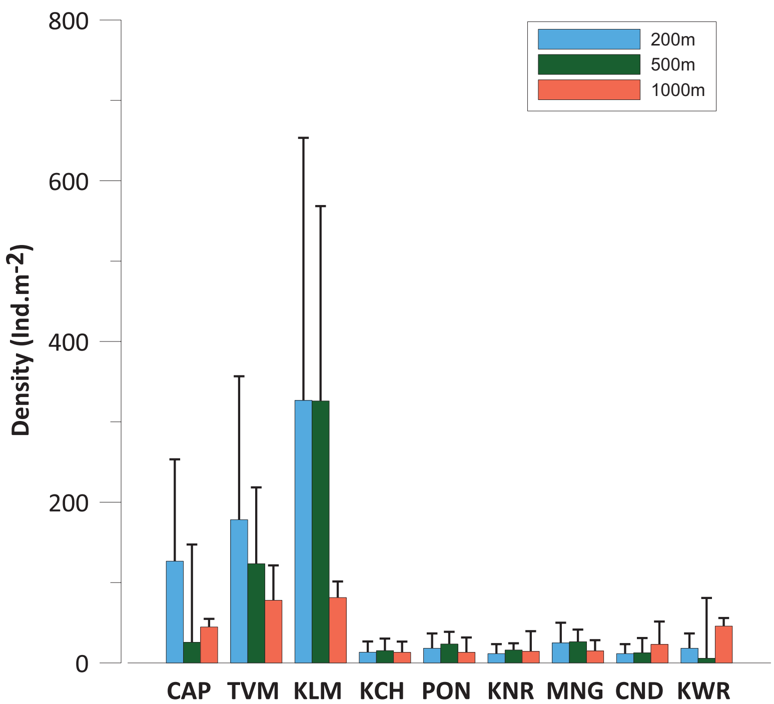

Figure 37. Density of molluscs at each sampling site

The mean density of molluscs at each sampling site is shown in figure 37. The highest abundance of molluscs was obtained at the 200m depth category (81±144 Ind.m^{-2}) and lowest abundance was at 1000m (20±18.5 Ind.m^{-2}) and intermediate density was at 500m (60.58±75.7 Ind.m^{-2}) [Figure 31]. Variations in density and biomass of molluscs between surveys were not statistically significant (density: $F_{2, 76}$ =0.666, P=0.963; biomass: $F_{2, 76}$ =0.524, P=0.594). Density of molluscs did not show any significant variation with depth ($F_{2, 76}$ =2.786, P=0.068) while there was significant difference in biomass between depth groups ($F_{2, 76}$ =4.959, P=0.009). Latitudinal variation in density and biomass were found to be statistically significant (density: $F_{8, 70}$ =5.333, P<0.001; biomass: $F_{8, 70}$ =3.193, P=0.004).

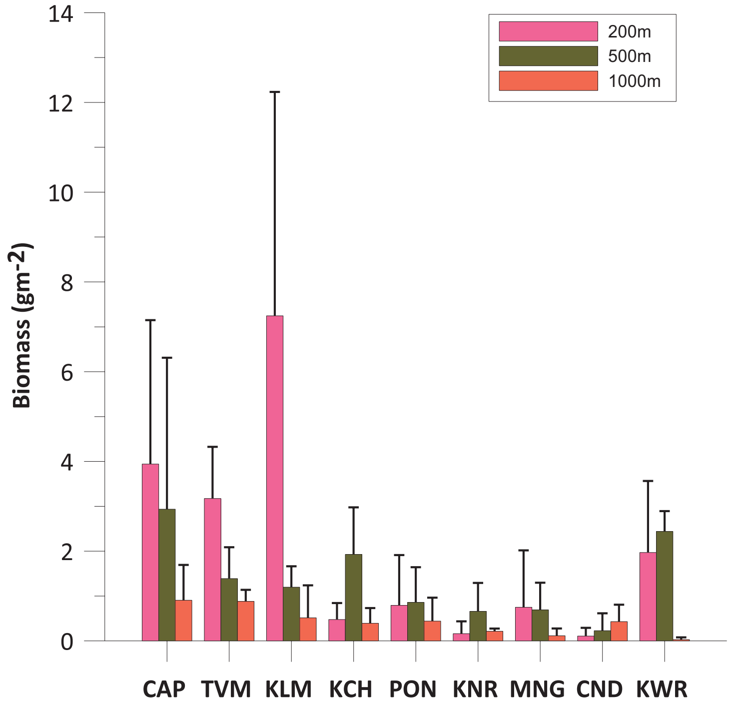

Figure 38. Biomass of molluscs at each sampling site

The wet weight of mollusc was taken with shell, but larger specimens (>3g) were not included when considering mean values. Mollusc represented about 22% of the total biomass [Figure 20]. Biomass of mollusc in the grab samples varied from nil to 8.26 gm^{-2} [Tables 12-14] with an average of 1.30±1.99 gm^{-2} for the study. The biomass of molluscs at each sampling site is given in Figure 38. There was a decrease in mean biomass of mollusc with depth; with high values (2.07±2.9 gm^{-2}) represented at shallow depth (200m), lowest values (0.43±0.46 gm^{-2}) at deeper stations (1000m) and intermediate value at 500m (1.38±1.40 gm^{-2}) [Figure 32].

d) Other Groups

Other groups represented in the samples were nematodes, foraminiferans (large sized), ophiuroids, nemertines, oligochaetes, sipunculids, fishes etc. Of these, nemertines were well represented at all depths and these contributed more than 1% to the total density in the study area [Figure 19]. Nematodes and foraminifers of large size were also recorded in many stations from the study area. The combined biomass of these groups varied from nil to 6.87 gm^{-2} [Table 12-14] and they accounted for 17% of total macrofaunal biomass in the entire study [Figure 20]. Figures 39 & 40 depict the mean densities and biomass of these groups.

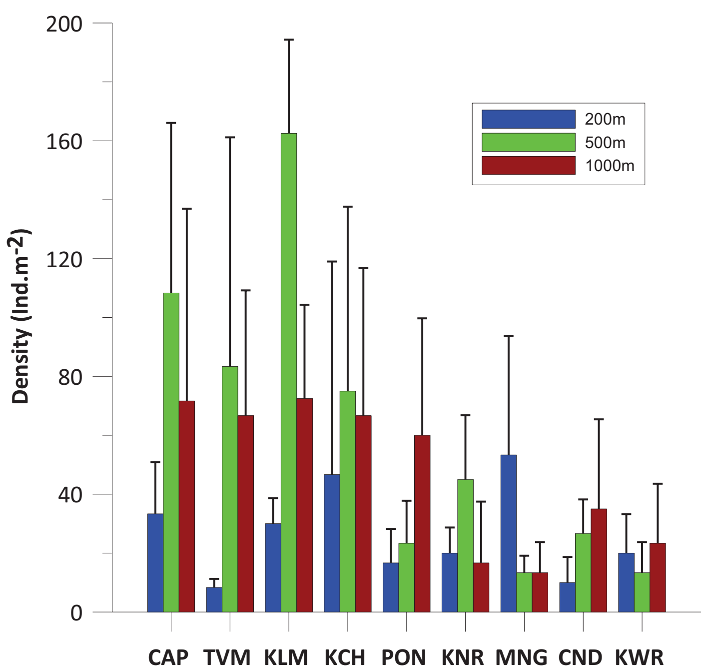

Figure 39. Density of 'other groups' at each sampling site

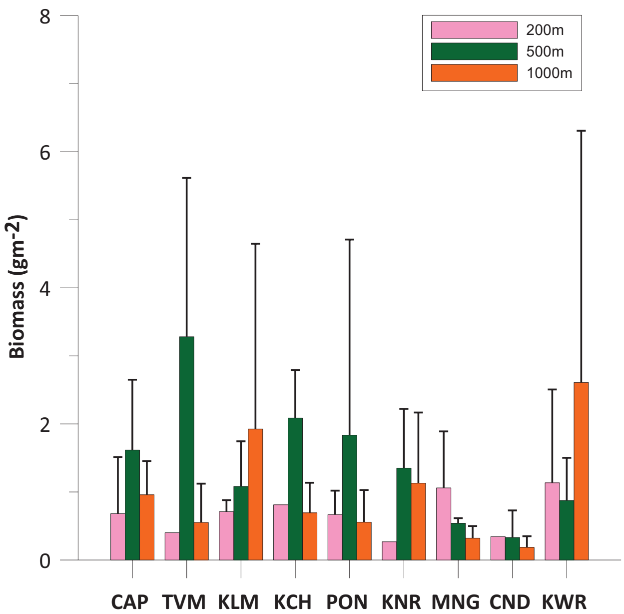

Figure 40. Biomass of 'other groups' at each sampling site

IV. 2. 4. Influence of environmental characteristics on standing crop

From the previous chapter it is evident that environmental parameters and sediment characteristics vary with depth and latitudes in the study area. Values of density and biomass were tested for correlation with the measured environmental variables using Pearson's correlation. Sediment texture characteristics and hydrographical parameters were used for this analysis. Results of the analyses are presented in Table 17.

a) Density: Density showed a positive correlation with sand content of the sediments ($r=0.589$, $p<0.001$) and a negative relation with clay ($r= -0.410$, $p<0.001$) and organic matter content ($r=-0.460$, $p<0.001$). Total density was negatively correlated with depth ($r=-0.610$, $p<0.001$) and silt content ($r=-0.585$, $p<0.001$). Among the hydrographic parameters, density showed strong positive correlation with bottom water temperature ($r=0.651$, $p<0.001$). Density of polychaetes showed a strong negative relationship with depth ($r=-0.602$, $p<0.001$), silt ($r=-0.538$, $p<0.001$) and clay content ($r=-0.336$, $p=0.002$); it showed a positive correlation with sand content ($r=0.530$, $p<0.001$). Density of mollusc was negatively correlated with clay ($r=-0.524$, $p<0.001$) and silt content (r=-0.441, p<0.001). Crustaceans and others groups did not display significant correlations with any of the abiotic parameters. However, the density of molluscs (r=-0.357, p=0.001) and other groups (r=-0.419, p<0.001) decreased from south to north.

b) Biomass: Biomass of macrofauna was negatively correlated with depth (r=-0.396, p<0.001) and the major components, the polychaete, also displayed similar trend with depth (r=-0.335, p=0.008). Total biomass was negatively correlated with clay (r=-0.314, p=0.005) and silt content (r=-0.356, p=0.001) while it was positively correlated with sand (r=0.377, p=0.001). Biomass showed a positive relation with bottom water temperature (r=0.369, p=0.001). Among the faunal groups, biomass of mollusc also showed a negative correlation with depth (r=-0.339, p=0.002), clay (r=-0.437, p<0.001) and silt content (r=-0.423, p<0.001); and as in the case of density, the value decreased from south to north (r=-0.330, p=0.003). The biomass of macrofauna did not show any correlation with other environmental variables viz. OM, DO and salinity.

IV. 2. 5. Trophic support to fishery

The average macrobenthic biomass for the study region was found to be 6.03 gm^{-2} (6030 kg km^{-2}). Most species of macrobenthos have a life span of about one year and if the suggestion of Sanders (1956) that the annual production is about twice the standing crop for these organisms holds true, then the annual macrobenthic production in the study area is about 915.35 kg C km^{-2} yr^{-1}. Using the conversion factor of Parulekar *et al.* (1980), according to which dry weight is equivalent to 22% of wet weight and organic carbon is 34.5% of dry weight, the organic carbon value for the study area is 4.2×10^{7} kg C yr^{-1} (total area: 46345 km^{2}). According to the laws of energy transfer, 10% of total organic carbon is expected to be assimilated by the next trophic level. For coastal waters, 60% of the live weight is expected to be fishes and for offshore waters 40% is considered to be represented by fish (Steel 1974). This value is converted to live weight by multiplication by a factor of 10. By this calculation, the macrofauna of the study area alone can be said to contribute to about 0.17 mT of fish biomass.

IV. 3. DISCUSSION

The variations in density of macrofauna in the study area were not statistically significant, either between surveys or between transects. With increasing depth, there was a sharp decline in macrofaunal density. The only exception was in the case of the Karwar transect, where the density at 500m was higher than that at 200m, with a decline in the value towards 1000m. The mean density decreased by 55% from 200m to 500m and by 75% from 200 to 1000m. Concurrent studies conducted along the north east slope of Bay of Bengal revealed more or less similar results, with a mean abundance of 1230 Ind.m^{-2}, for the similar depth range (200-1000m) and density of macrofauna showed a sharp decline from 200-1000m (Rao 2009).

In the present study, biomass of macrofauna showed considerable spatio-temporal variation in which depth wise variation was highly significant. Decrease in biomass was not as significant as that of density, because small sized organisms dominated at 200m and comparatively larger ones in the deeper sites. The mean biomass for north east continental slope (north western Bay of Bengal) was found to be 4.4 gm^{-2} (Rao 2009), while in the SEAS, it is found to be 6.03 gm^{-2}. Among the three depth categories studied along the SEAS, highest macrobenthic biomass was observed at the ~200m depth whereas in the case of Bay of Bengal, highest value was observed at 500m (6.3 gm^{-2}) followed by 200m (5.3 gm^{-2}). Lowest biomass was observed at the deeper sites of the continental margin (1.6 gm^{-2}) similar to that of SEAS (2.295 gm^{-2}). Further, a study conducted by Ingole *et al*. (2010) observed lowest abundance at 525m depth (528±156 Ind.m^{-2}) and relatively high biomass was recorded at the shelf edge and upper slope, i.e. at 102m and 525m with a lowest biomass at 1001m. Studies conducted along the entire continental shelf of the west coast of India reported a similar depth-related decrease in abundance and biomass of benthos and the mean biomass of macrofauna along the southwest shelf was

7.78 gm^{-2} (Damodaran 2010). The mean densities and biomass for each depth obtained during the present study (200m, 500m & 1000m) were considered together with the mean values obtained by Damodaran (2010) for the 30m, 50m, 100m, 150m depth classes in the same region (SEAS). An exponential decline in macrofaunal abundance (r^2=0.867) and biomass (r^2=0.820) was observed, as depicted in Figures 41 & 42. The reduction in abundance and biomass from 30m to 1000m in the SEAS was 90% and 67% respectively. The abundance of benthos, measured as either biomass or density, displayed exponential decrease with depth and distance from productive coastal systems, which is generally associated with the variation in environmental characteristics (Rowe *et al*. 1982, Rowe 1983, Gage & Tyler 1991, Etter & Grassle 1992, Flach & Heip 1996, Cosson *et al*. 1997, Levin *et al*. 2001, Gage 2002). The depth associated variations in total biomass were statistically significant and the linear decline in biomass of major faunal groups was evident throughout the present study.

Studies conducted by Parulekar *et al*. (1982 a, b) reported that faunal density was inversely related to depth in the eastern Arabian Sea margin. Similar patterns in density have been revealed in the slope regions in other parts of the world (Filatova & Levenstein 1961, Chuckchin 1963, Sanders 1968, Rex 1981, Tselepides *et al*. 2000). It is difficult to compare quantitatively the investigation of the SEAS margin to other similar studies along the margin of Pakistan, Oman etc. primarily because very few similar studies exist that have employed similar sampling techniques. In recent years, instead of 0.5 mm sieves, finer meshes (300 micron) are being employed for separation of macrofauna. Ecological factors, such as changing quality, quantity and availability of food (Sibuet *et al*. 1989, Flach & Thomsen 1998, Flach *et al*. 1998) may also influence the faunal density and composition. A global analysis of standing stock in the deep-sea benthos by Rex *et al*. (2006) revealed that the upper continental slope is characterised by high macrofaunal biomass, which decreases with depth more rapidly than that of meiofauna (Rowe & Menzel 1971, Rowe *et al*. 1974).

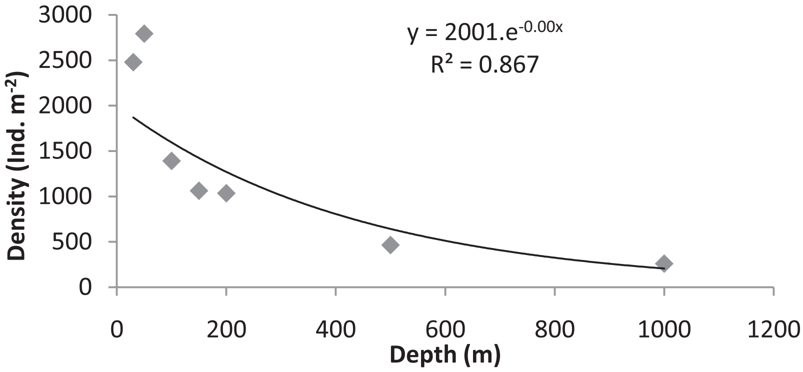

Figure 41. Mean abundance in relation to depth (30m-1000m) in the SEAS

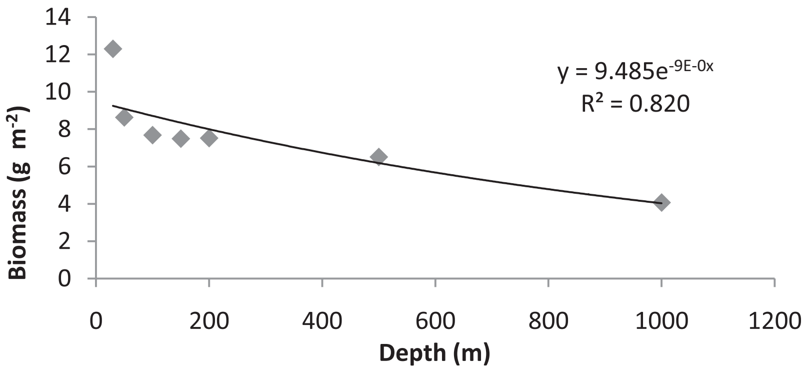

Figure 42. Mean biomass in relation to depth (30m-1000m) in the SEAS

Total macrofaunal density did not show any specific latitudinal trend. The lowest density and biomass of macrobenthos, in the present study, was observed at Karwar and Coondapur respectively, which experienced strong oxygen depleted condition and relatively high organic matter content. This was mainly due to the impingement of the permanent Arabian Sea OMZ, which is in general associated with reduced abundance and low biomass (Rosenberg *et al*. 1983, Levin *et al*. 1991, Wishner *et al*. 1995, Hughes *et al*. 2009). In the Kochi transect, the low macrofaunal density may be attributed to influence from the Cochin estuary coupled with anthropogenic inputs. However, at this site, a high abundance of macrofauna, dominated by the polychaete *Cossura coasta* was observed. This is likely to be a case of patchiness in faunal distribution. Marked down slope changes in benthic faunal composition are also well documented around the world continental margins (e.g. Rex *et al*. 1997, Levin *et al*. 2000) with highest faunal turnover in the upper bathyal region (Carney *et al*. 1983, Etter & Rex 1990). In the present study, polychaetes were found to be the dominant component, representing over 70% of macrofauna. Along the slope of north western Bay of Bengal, polychaetes were the major macrofaunal group and contributed about 91% of total abundance (Rao 2009). High abundance of polychaetes along the 200m contour (shelf edge) in the present study can be attributed to the heterogeneous sediments, with high sand content.

The relative abundance of crustaceans increased with increasing depth and dissolved oxygen. Diaz & Rosenberg (1995) stated that polychaetes are the most tolerant taxon to low oxygen, followed by bivalves, and crustaceans are less tolerant than both these groups. In the present study, low abundance of amphipods was noticed in locations with low oxygen concentration. Similar pattern in abundance of amphipods was found in the OMZ off Chile (Levin *et al*. 2000). Abundance and relative composition of molluscs was highest in the southern transects (Cape Comorin, Trivandrum and Kollam); and the abundance was highest at 200m followed by 500m. Among the molluscs, bivalves were the most important component in the sandy substrata of this region. Because of the high abundance of bivalves in deep-sea sediments, Allen & Sanders (1996) rank it as the second most common macrofaunal group, between polychaetes and crustaceans. Scaphopods tend to prefer dwelling in coarse sands, and they were common in the upper slope region of the three southern transects. Along the continental northeast Bay of Bengal, Rao (2009) reported that the crustaceans were the second dominant group, and that molluscs were rare at 200 and 500m. Relatively high abundance of mollusc was recorded here at 1000m, in contrast to the SEAS continental margin where the mollusc abundance decreased significantly with increasing depth and from south to north.

Remarkable difference in densities and biomass was found at similar depths of various transects, this could be related to the variation in abundance of major faunal groups (e.g. molluscs in the southern transects). This signifies the influence of local environmental condition and sediment nature in structuring the distribution pattern of benthos. In this study, no environmental variable can be indicated as the single factor in controlling the distribution of the benthic fauna along the SEAS continental margin. The pattern of decrease in total density and biomass with increasing water depth is a result of depth associated changes in sediment characteristics and other environmental factors. Among the hydrographical parameters, temperature (depth wise variation) and DO concentration (latitudinal) tend to be major factors causing differences in macrofaunal densities; and considerable variation in these parameters was found on the continental slope. All the 200m stations of the northern transects (Karwar and Coondapur) were located within the Arabian Sea Oxygen Minimum Zone and even in the other transects, most of the 200m stations were found to be in an oxygen depleted condition. Additionally, the high production at the surface results in increased organic flux to the sediments. Thus, the sediments of this region, which lie beneath the highly productive euphotic zone are not only organic-enriched, but are overlaid with waters having a low oxygen concentration.

Macrofauna play an important role in the energy flow of the benthic ecosystem (Parulekar *et al*. 1980, Ansari *et al*. 1996). The role of benthos in sustaining demersal fishery is well understood and it is generally accepted that macrofauna make sizable contributions to energy flow in continental margins (Damodaran 1973, Parulekar *et al.* 1980, Harkantra *et al.* 1980, Parulekar *et al.* 1982a, Ansari *et al.* 1996, Joydas & Damodaran 2009). Among the benthic organisms, polychaetes are the principal food items of the demersal fishes (Longhurst & Pauly 1987). In the SEAS margin, where the macrofauna were dominated by soft bodied organisms like polychaetes, crustaceans and nemertines, the macrobenthos are predicted to contribute 0.17 mT to demersal fish biomass.

Table 9. Density of macrofauna (Ind. m^{-2}) during FORVSS Cruise 219 & 225

St. No.	Location	Depth (m)	Polychaetes	Crustaceans	Molluscs	Other Groups	Total
1	**Cape Comorin***	215	1533	30	105	15	1683
2	**Cape Comorin***	294	275	10	145	75	505
3	**Cape Comorin***	1100	365	40	20	65	490
4	**Trivandrum***	226	715	0	315	5	1035
5	**Trivandrum***	450	170	15	5	10	200
6	**Trivandrum***	940	83	40	25	25	173
7	**Kollam***	282	715	5	230	35	985
8	**Kollam***	750	395	15	0	95	505
9	**Kochi**	188	1620	50	30	130	1830
10	**Kochi**	526	40	335	0	135	510
11	**Kochi**	988	23	25	5	10	63
12	**Ponnani**	262	128	50	0	30	208
13	**Ponnani**	577	365	100	20	40	525
14	**Ponnani**	989	225	60	0	105	390
15	**Kannur**	205	600	45	0	30	675
16	**Kannur**	525	243	15	0	35	293
17	**Kannur**	945	25	70	5	10	110
18	**Mangalore**	214	718	120	5	30	873
19	**Mangalore**	438	165	235	15	10	425
20	**Mangalore**	991	70	15	10	5	100
21	**Coondapur**	208	770	180	0	15	965
22	**Coondapur**	480	330	15	5	20	370
23	**Coondapur**	1053	15	5	10	0	30
24	**Karwar**	213	718	120	5	30	873
25	**Karwar**	453	165	235	15	10	425
26	**Karwar**	998	10	55	5	20	90

* indicates sites sampled during Cruise 225

Table 10. Density of macrofauna (Ind. m^{-2}) during FORVSS Cruise 228& 233

St. No.	Location	Depth (m)	Polychaetes	Crustaceans	Molluscs	Other Groups	Total
27	**Cape Comorin**	207	1423	70	120	35	1648
28	**Cape Comorin**	536	620	80	150	175	1025
29	**Cape Comorin**	999	390	95	10	140	635
30	**Trivandrum**	242	225	165	145	10	545
31	**Trivandrum**	420	208	70	140	75	493
32	**Trivandrum**	976	180	65	60	110	415
33	**Kollam**	267	1413	75	60	20	1568
34	**Kollam**	508	385	140	185	185	895
35	**Kollam**	1050	170	70	40	50	330
36	**Kochi**	180	90	100	10	10	210
37	**Kochi**	500	75	30	20	80	205
38	**Kochi**	1095	118	65	10	105	298
39	**Ponnani**	226	660	225	45	10	940
40	**Ponnani**	515	128	85	25	15	253
41	**Ponnani**	992	135	140	25	30	330
42	**Kannur**	208	988	365	30	15	1398
43	**Kannur**	523	303	205	25	70	603
44	**Kannur**	958	178	105	45	0	328
45	**Mangalore**	200	1223	345	55	30	1653
46	**Mangalore**	494	135	70	30	10	245
47	**Mangalore**	1000	130	130	25	25	310
48	**Coondapur***	220	1150	35	25	0	1210
49	**Coondapur***	520	243	65	45	40	393
50	**Coondapur***	1040	180	45	10	55	290
51	**Karwar***	216	203	35	15	10	263
52	**Karwar***	416	503	55	115	10	683
53	**Karwar***	1000	105	55	0	5	165

* indicates sites sampled during Cruise 228

Table 11. Density of macrofauna (Ind. m^{-2}) during FORVSS Cruise 254

St. No.	Location	Depth (m)	Polychaetes	Crustaceans	Molluscs	Other Groups	Total
54	**Cape Comorin**	208	1078	50	155	50	1333
55	**Cape Comorin**	486	185	70	70	75	400
56	**Cape Comorin**	897	110	10	0	10	130
57	**Trivandrum**	216	760	225	75	10	1070
58	**Trivandrum**	490	295	165	140	165	765
59	**Trivandrum**	983	108	60	45	65	278
60	**Kollam**	236	908	70	690	35	1703
61	**Kollam**	466	398	50	300	140	888
62	**Kochi**	275	75	10	0	0	85
63	**Kochi**	500	185	65	25	10	285
64	**Kochi**	835	38	40	25	85	188
65	**Ponnani**	220	1400	20	10	10	1440
66	**Ponnani**	520	60	20	0	15	95
67	**Ponnani**	856	78	70	30	45	223
68	**Kannur**	215	1120	60	5	15	1200
69	**Kannur**	503	210	25	0	30	265
70	**Kannur**	880	83	15	25	40	163
71	**Mangalore**	219	340	90	15	100	545
72	**Mangalore**	508	78	15	0	20	113
73	**Mangalore**	829	80	15	5	10	110
74	**Coondapur**	220	2088	30	10	15	2143
75	**Coondapur**	519	58	5	5	20	88
76	**Coondapur**	863	185	25	65	50	325
77	**Karwar**	215	275	20	15	35	345
78	**Karwar**	501	575	85	85	5	750
79	**Karwar**	847	23	25	25	45	118

Table 12. Biomass of macrofauna (gm^{-2}) during FORVSS Cruise 219 & 225

St. No.	Location	Depth (m)	Polychaetes	Crustaceans	Molluscs	Other Groups	Total
1	**Cape Comorin**	215	3.328	0.070	3.240	0.105	6.742
2	**Cape Comorin**	294	1.340	0.148	6.815	0.790	9.093
3	**Cape Comorin**	1100	3.905	0.413	0.398	0.603	5.318
4	**Trivandrum**	226	0.595	0.000	3.173	0.000	3.768
5	**Trivandrum**	450	1.288	0.050	1.455	1.578	4.370
6	**Trivandrum**	940	0.610	0.438	0.723	0.015	1.785
7	**Kollam**	282	1.793	0.008	8.260	0.650	10.710
8	**Kollam**	750	1.650	0.720	0.000	0.000	2.370
9	**Kochi**	188	4.100	0.735	0.875	1.520	7.230
10	**Kochi**	526	0.803	1.468	0.000	1.373	6.778
11	**Kochi**	988	0.565	1.650	0.115	0.200	2.530
12	**Ponnani**	262	1.213	0.688	0.000	0.265	2.413
13	**Ponnani**	577	1.705	0.000	1.525	5.153	8.383
14	**Ponnani**	989	1.325	0.915	0.000	0.300	2.540
15	**Kannur**	205	3.363	0.900	0.000	0.265	4.535
16	**Kannur**	525	3.685	0.658	0.000	0.518	5.570
17	**Kannur**	945	0.175	0.127	0.160	1.090	1.552
18	**Mangalore**	214	7.160	2.868	0.013	0.500	10.540
19	**Mangalore**	438	2.253	0.908	1.128	0.450	4.738
20	**Mangalore**	991	0.233	0.365	0.008	0.275	0.880
21	**Coondapur**	208	3.178	1.203	0.000	0.723	5.103
22	**Coondapur**	480	1.960	0.913	0.001	0.001	2.874
23	**Coondapur**	1053	0.003	0.975	0.003	0.000	0.980
24	**Karwar**	213	1.510	0.002	3.060	2.715	7.287
25	**Karwar**	453	2.068	0.001	1.955	1.558	5.580
26	**Karwar**	998	1.315	0.015	0.000	6.875	8.205

* indicates sites sampled during Cruise 225

Table 13. Biomass of macrofauna (gm^{-2}) during FORVSS Cruise 228 & 233

St. No.	Location	Depth (m)	Polychaetes	Crustaceans	Molluscs	Other Groups	Total
27	**Cape Comorin**	207	6.771	2.310	7.440	1.635	18.156
28	**Cape Comorin**	536	4.263	0.663	1.310	2.775	9.010
29	**Cape Comorin**	999	4.410	0.725	1.810	1.525	8.470
30	**Trivandrum**	242	0.875	0.875	4.325	1.200	7.275
31	**Trivandrum**	420	2.075	0.550	2.050	2.325	7.000
32	**Trivandrum**	976	2.200	0.950	1.175	1.150	5.475
33	**Kollam**	267	4.800	0.850	1.825	0.580	8.055
34	**Kollam**	508	3.085	1.950	1.525	1.550	8.110
35	**Kollam**	1050	2.000	2.150	1.025	3.850	9.025
36	**Kochi**	180	0.877	1.370	0.400	0.915	3.563
37	**Kochi**	500	2.105	1.395	1.250	2.785	7.535
38	**Kochi**	1095	0.965	0.568	0.295	1.048	2.875
39	**Ponnani**	226	2.032	1.050	2.080	0.903	6.065
40	**Ponnani**	515	2.110	2.602	1.053	0.072	5.837
41	**Ponnani**	992	5.430	0.495	0.310	1.100	7.335
42	**Kannur**	208	3.465	1.950	0.475	0.125	6.015
43	**Kannur**	523	8.142	1.055	1.262	2.255	12.715
44	**Kannur**	958	0.890	0.725	0.277	0.112	2.005
45	**Mangalore**	200	6.595	1.620	2.213	0.667	11.095
46	**Mangalore**	494	1.082	5.030	0.945	0.580	7.637
47	**Mangalore**	1000	0.720	0.500	0.300	0.517	2.037
48	**Coondapur***	220	8.247	0.497	0.317	0.110	9.172
49	**Coondapur***	520	1.750	1.142	0.672	0.770	4.335
50	**Coondapur***	1040	2.667	0.332	0.577	0.240	3.817
51	**Karwar***	216	0.327	0.187	2.708	0.415	3.637
52	**Karwar***	**416**	5.295	0.570	2.857	0.742	9.465
53	**Karwar***	**1000**	0.890	0.520	0.000	0.670	2.080

* indicates sites sampled during Cruise 228

Table 14. Biomass of macrofauna (gm^{-2}) during FORVSS Cruise 254

St. No.	Location	Depth (m)	Polychaetes	Crustaceans	Molluscs	Other Groups	Total
54	**Cape Comorin**	208	3.077	0.423	1.140	0.303	4.943
55	**Cape Comorin**	486	1.289	0.662	0.684	1.284	3.918
56	**Cape Comorin**	897	1.260	0.581	0.000	0.747	3.096
57	**Trivandrum**	216	2.170	1.254	2.026	0.005	5.454
58	**Trivandrum**	490	5.429	0.734	0.657	5.942	12.762
59	**Trivandrum**	983	2.963	0.438	0.742	0.490	4.633
60	**Kollam**	236	2.704	0.995	11.648	0.903	16.250
61	**Kollam**	466	3.051	1.010	0.871	0.616	5.549
62	**Kochi**	275	0.889	0.000	0.000	0.000	1.039
63	**Kochi**	500	2.785	0.303	1.396	2.101	6.585
64	**Kochi**	835	0.649	0.820	0.768	0.833	3.069
65	**Ponnani**	220	12.993	0.707	0.048	0.837	14.584
66	**Ponnani**	520	0.492	0.878	0.000	0.280	1.649
67	**Ponnani**	856	1.125	0.279	1.014	0.268	2.686
68	**Kannur**	215	6.347	1.140	0.004	0.416	7.907
69	**Kannur**	503	1.059	5.771	0.000	1.280	8.111
70	**Kannur**	880	4.084	0.193	0.205	2.186	6.667
71	**Mangalore**	219	8.115	4.866	0.023	2.013	15.017
72	**Mangalore**	508	1.025	0.296	0.000	0.584	1.904
73	**Mangalore**	829	3.675	0.084	0.035	0.173	3.967
74	**Coondapur**	220	3.221	1.751	0.007	0.199	5.178
75	**Coondapur**	519	0.812	0.013	0.007	0.227	1.060
76	**Coondapur**	863	1.261	6.950	0.709	0.315	9.233
77	**Karwar**	215	0.517	0.279	0.139	0.274	1.209
78	**Karwar**	501	5.208	0.326	2.500	0.329	8.363
79	**Karwar**	847	0.598	0.516	0.084	0.284	1.481

Table 15. Range & mean density (Ind. m^{-2}) of macrofauna at the three depths in the three surveys

	219 & 225	228 & 233	254
200m	208-1830 (960±532.37)	210-1653 (1048±583.98)	85-2143 (1096±665.24)
500m	200-525 (399±107.85)	205-1025 (532±293.81)	88-888 (405±315.79)
1000m	30-505 (216.8±190.2)	165-635 (344±126.78)	110-325 (191.87±78.32)

Table 16. Range & mean biomass (gm^{-2}) of macrofauna at the three depths in the three surveys

	219 & 225	228 & 233	254
200m	2.41-10.72 (6.48±2.86)	3.56-18.16 (8.11±4.49)	1.039-16.25 (7.95±5.91)
500m	2.87-9.09 (5.92±2.08)	4.34-12.72 (7.96±2.37)	1.06-12.76 (5.19±3.96)
1000m	0.88-8.21 (2.90±2.38)	2.01-9.025 (4.79±2.87)	1.48-9.23 (4.8±2.69)

Table 17. Pearson correlation of standing stock of macrofaunal groups with environmental variables

	Depth	Clay	Silt	Sand	OM	Temperature	Salinity	DO	Transect
Polychaete Density	**-0.602**	**-0.336**	**-0.538**	**0.530**	**-0.426**	**0.657**	-0.042	-0.072	-0.117
Crustacean Density	-0.215	0.041	-0.091	0.061	*-0.280*	*0.243*	0.016	*-0.228*	-0.034
Mollusc Density	*-0.261*	**-0.524**	**-0.441**	**0.507**	-0.206	0.209	-0.164	0.043	**-0.357**
Others Density	0.152	-0.145	-0.033	0.068	0.062	-0.182	**-0.320**	*0.266*	**-0.419**
Total Density	**-0.610**	**-0.410**	**-0.585**	**0.589**	**-0.460**	**0.651**	-0.095	-0.068	-0.217
Polychaete Biomass	**-0.335**	-0.173	*-0.288*	*0.281*	-0.141	**0.338**	0.027	-0.003	-0.006
Crustacean Biomass	-0.071	-0.052	0.061	-0.034	-0.038	0.095	0.087	-0.173	0.113
Mollusc Biomass	**-0.339**	**-0.437**	**-0.423**	**0.467**	*-0.279*	**0.302**	-0.129	0.016	**-0.330**
Others Biomass	0.059	0.135	0.088	-0.109	0.038	-0.107	-0.083	-0.075	-0.098
Total Biomass	**-0.396**	**-0.314**	**-0.356**	**0.377**	*-0.237*	**0.369**	-0.051	-0.077	-0.175

Bold: $p<0.01$, *Italics*: $p<0.05$

Chapter V

COMMUNITY STRUCTURE OF POLYCHAETES

V. 1. INTRODUCTION

Deep sea sediments of the world ocean are considered as reservoirs of biodiversity (Fiege 2010), harbouring millions of species from different phyla. Among them, the most prominent constituents of macrofauna are the polychaetes- the bristle bearing segmented worms belonging to phylum Annelida, class Polychaeta. They are found ubiquitously in almost all marine and estuarine sediments, with high abundance and diversity (Fauchald 1977, Grassle & Maciolek 1992, Ward & Hutchings 1996); and are important components of bathyal fauna as well (Blake & Grassle 1994, Levin *et al*. 2000, 2009, Narayanaswamy 2005, Hughes *et al*. 2009). Over 10,000 species, belongs to 83 families have been described in this class so far (Minelli 1993, Hutchings 1998). The majority of polychaete families occur worldwide and many genera have wide distribution.

According to Fauchald (1984), rapid radiation of this group took place around the Pre-Cambrian and Cambrian. Polychaetes have developed different living strategies to help them adapt to various habitats; which include, large variations in morphology, diverse feeding and reproductive modes. They are also good indicators of habitat quality (Sivadas *et al*. 2010, Murugesan *et al*. 2011). Grassle & Grassle (1974) and Levin *et al*. (2000) found that some polychaete species were highly opportunistic and responded rapidly to environmental perturbations. Furthermore, polychaete community mirrored the distribution pattern of total macrobenthic fauna (Faulchald 1973, Hughes *et al*. 2009).

Polychaetes directly or indirectly depend on organic matter produced in the euphotic zone for their nourishment. They exhibit a wide variety of feeding strategies including omnivory and carnivory, obtaining food either by scavenging or predation. Deposit feeding, by consuming bottom sediments as such and digesting the organic materials present in it and suspension feeding, by filtering out organic particles from the overlaying waters. Species are typically assigned to a feeding group or guild based on the morphology of the mouth parts. Several comprehensive works have been published on feeding modes of polychaete species, notably those of Fauchald & Jumars (1979) and Gaston (1987). In recent years, many studies have described trophic interactions of polychaetes in the continental margin of Pakistan (Hughes *et al*. 2009), Oman (Levin *et al*. 2000) and India (Ingole *et al*. 2010).

Selective and non-selective deposit feeding polychaetes, that obtain food directly from the organic matter in the sediments are in general, major components of macrofauna; and polychaetes as a group are an important source of food for a wide variety of organisms living on and near the seabed. The deposit feeding polychaetes play a pivotal role in almost all marine ecosystems, by acting as conduits for sedimentary organic matter to be restored back to the marine food web. The deposit-feeding and burrowing movement of polychaetes can enhance bioturbation which ultimately results in the degradation or redistribution of organic matter (Fauchald & Jumars 1979, Levin *et al*. 1997). Most polychaetes have pelagic larval stages which enrich the pelagic plankton community and form a food source for many organisms in the water column. The key role of polychaetes in the benthic food web as well as their importance to the pelagic communities, by way of the planktonic larvae, makes them of central importance in benthic-pelagic coupling processes.

Biodiversity can be expressed and quantified in several ways; and the identification of organisms at species level is the basis of biodiversity studies. One of the basic studies on community concepts in marine ecology is that of Mills (1969) in which a community is defined as "a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment and separable from the other groups by means of ecological survey". Important community properties include the number of species present and the measure of species diversity, which reflects on both the number and relative abundance of species. Morin (1999) gave a good overview of the different approaches to delineate the communities: physically (by discrete habitat boundaries), taxonomically (by the identity of dominant indicator species), interactively (by the existence of strong interaction among the species) or statistically (by pattern of assemblages of various species).

Over the last few decades, there is a scientific debate on latitudinal gradients in the distribution pattern of benthic macroinvertebrate diversity which states that 'the diversity increasing towards the tropics' (Rex *et al*. 1993) as well as depth related pattern of increasing diversity from shallow to the deep sea (Sanders 1968, Grassle & Maciolek 1992). Rex (1983) described patterns in diversity of four major groups (Polychaeta, Gastropoda, Cumacea and Protobranchia) across a bathymetric range from 0–5000m for the NW Atlantic, and he found a parabolic pattern in diversity with maxima at intermediate depth (2000–3000m). Levin & Gage (1998) found an exponential increase in diversity of macrofauna with depth from 154 to 3400m. Gray (1997) opined that more quantitatively comparable data is needed from the tropical areas and southern hemisphere to prove or disprove the generality of these hypotheses. The aforementioned findings and the scarcity of comprehensive data (especially from the continental slope of India) emphasize the need for systematic regional scale studies on deep sea benthos.

Studies on benthic macrofauna usually involve the deployment of sampling devices such as a grab or box-corer, which retrieve sediment samples along with the resident fauna. From the sediments, the macrofauna are sieved, sorted out and they may be identified to the lowest taxonomic level possible. For interpretation and comparison of the datasets thus generated, a variety of numerical and statistical techniques are applied. In this study, polychaete community structure and diversity was analysed on the basis total number of species (S), Shannon–Wiener diversity (H', log_2; Shannon & Weaver, 1963) Margalef's species richness (d, Margelef 1968), Pielou's evenness (J, Pielou 1966) and Simpson dominance (λ', Simpson 1949).

Among the environmental parameters that influence the benthic fauna on the continental margin of the Arabian Sea, oxygen and organic matter are of special importance (Levin 2003). Several recent investigations have described changes in the structure and composition of benthic faunas across OMZs, including the Arabian Sea OMZ (reviewed in Levin 2003, Levin *et al*. 2009). Studies conducted by Ingole *et al*. (2010) reported that the reduction in diversity and dominance of some polychaete taxa in the OMZ core region of western Indian continental margin. Water depth (Rex 1981, Rex *et al*. 1997*,* Paterson & Lambshead 1995), hydrodynamic and related sediment properties (Etter & Grassle 1992*,* Gage 1997, Flach & Thomsen 1998), topography of the bottom and food availability (Snelgrove & Butman 1994) were also considered as the major factors controlling the distribution and community composition of bathyal macrofauna. Rex *et al*. (1997) opined that ecological, oceanographic and historical processes influence diversity on spatial and temporal scales. In this chapter, the diversity pattern of polychaetes in the study area is discussed, along with their community structure in relation to environment.

V. 2. RESULTS

V. 2. 1. Univariate indices of polychaete diversity

Faunistic analysis of polychaetes collected between 2003 and 2007 at 27 sites in the study area yielded a total of 194 species in 107 genera belonging to 37 families. The families best represented in the study area in terms of number of species were the Spionidae (25 species) followed by Paraonidae (15), Cirratulidae (14), Capitellidae (9), Terebellidae (9), Nereidae (8), Lumbrineridae (8), Onuphidae (8), Amphaeritidae (8), Glyceridae (7), Syllidae (6), Sabellidae (6), Amphinomidae (4), Nephtyidae (4), Pilargidae (4), Flabelligeridae (4), Orbiniidae (3), Phyllodocidae (3) and Eunicidae (2).

Families represented by single species in high abundance included Cossuridae, Trochochaetidae, Pectinariidae and Sternaspidae.

The numerically dominant species in this study area were *Tharyx dorsobranchialis* (11.1% of total polychaetes), *Levinsinia oculata* (8.2%), *Prionospio polybranchiata* (7.9%), *Cossura coasta* (7.7%) and *Tharyx annulosus* (7.6%). Apart from these, other species of Spionidae (*Prionospio cirrifera*, 4.2%; *Paraprionospio pinnata*, 3.6%; *Aonidella cirrobranchiata*, 1.8%; *Prionospio ehlersi,* 1.7% and *Spiophanes* sp. 1, 1.3%), Cirratulidae (*Tharyx filibranchia,* 3.9% and *T. marioni,* 1.9%) and Paraonidae (*Paraonis gracilis*, 4.1%; *Aricidea* sp. 1, 2.4% and *A. fauveli*, 1.1%) were also very abundant. The other species contributing significantly to the abundance of polychaetes included *Notomastus aberans* (2.1%), *Amphicteis gunneri* (1.4%), *Magelona cincta* (1.2%) and *Aglaophamus dibranchis* (1.1%). The data on species composition and abundance of polychaetes collected during the study were processed to identify the number of species present in each depth category. It was found that the lowest species count was recorded at the shallow (200m) depth (114 species) followed by the deeper (1000m) sites (134 species), while relatively high species count was obtained at the intermediate (500m) depth (144 species). The total count of species did not vary much between the three surveys; with a value of 134, 147 and 132 species in the first, second and third survey, respectively.

a) Variation in polychaete diversity with survey

The species number (S), richness (d), diversity (H'), evenness (J') and dominance (λ') at each station during the three surveys is given in Tables 18-20. During the first survey, total number of species in a station varied between one (Coondapur, 1000m) and 40 (Cape, 1000m) (mean 17.65±10.45); it varied between 9 (Kochi, 200m) and 41 (Cape, 1000m) (mean 21.1±7.95) in the second survey and between 7 (Kochi, 200m) and 39 (Kollam, 500m) (mean 16.5±8.8) during the third survey. Species richness (d) in the first survey ranged from nil (Coondapur, 1000) to 6.61 (Cape, 1000m) (mean 2.95±1.65); between 1.76 (Karwar, 500m) and 6.71 (Cape, 1000m) (mean 3.58±1.32) during the second survey, and between 1.05 (Karwar, 200m) and 6.35 (Kollam, 500m) (mean 2.88±1.32) during the third survey.

A relatively high evenness index was recorded during the study and the mean value recorded was 0.74±0.22 (first survey), 0.78±0.13 (second survey) and 0.80±0.15 (third survey). The minimum value of Shannon-Wiener diversity during first survey was nil (Coondapur, 1000m) and maximum was 4.33 (Ponnani, 500m) (mean 2.89±1.08), whereas in the second survey, diversity was comparatively high at almost all station with the value ranging between 2.04 (Karwar, 500m) and 4.81 (Cape, 1000m) (mean 3.39±0.79). During the third survey the value ranged between 1.34 (Coondapur, 200m) and 4.44 (Kollam, 500m) (mean 3.11±0.79).

As with the analysis of data on faunal density, polychaete species diversity data from the 27 sites were used to test the variability with survey. The result of ANOVA indicated that the time of survey was not a significant factor determining polychaete diversity, Species number (S) ($F_{2, 76} = 1.835$, $p = 0.167$), Simpson richness (d') ($F_{2, 76} = 1.883$, $p = 0.159$), Shannon-Wiener diversity (H') ($F_{2, 76} = 2.097$, $p = 0.13$), Evenness (J') ($F_{2, 76} = 0.854$, $p = 0.430$) and dominance (λ') ($F_{2, 76} = 1.825$, $p = 0.168$).

b) Variation in polychaete diversity with depth

Figures 43-47 show the numbers of species, richness, diversity, evenness and dominance indices at each site during the study. Number of polychaete species in a station at 200m depth varied from 7 at Kochi to 36 at Cape (mean, 18.85±8.55); while it varied from 7 to 39 at 500m (mean, 19.27±9.41) and from 1 to 41 at 1000m (mean 17.15±9.89). Species richness (d) at 200m varied from 1.047 (Kochi) to 5.131 (Trivandrum). The mean value for species richness (d) was more or less similar at 500m (3.38±1.52) and 1000m (3.31±1.62) but much lower at 200m (2.75±0.73). Species richness (d) ranged from 1.207 (Coondapur) to 6.349 (Kollam) and nil (Coondapur) to 6.704 (Cape) at 500 and 1000m respectively. Diversity (H') at 200m sites was lowest at Coondapure (1.341) and higher at Trivandrum (4.19); and the mean diversity for this depth category was 2.78±0.68. At 500m, the minimum value of species diversity was 1.025 at Karwar and maximum was 4.544 at Kollam (mean 3.31±1.04). At 1000m stations the observed range was from nil (Coondapure) to 4.809 (Cape 1000m) with a mean of 3.32±1.04.

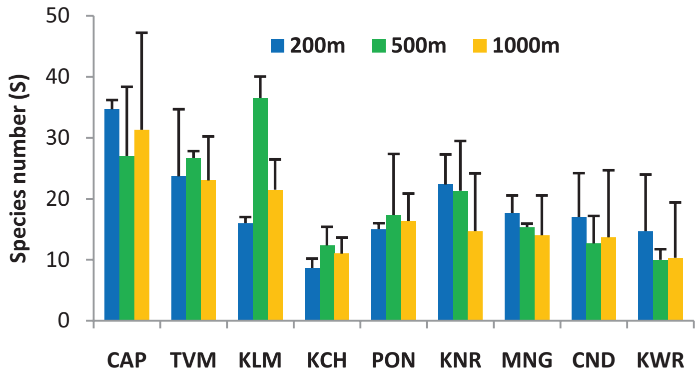

Figure 43. Species number (S) for each site in the study area

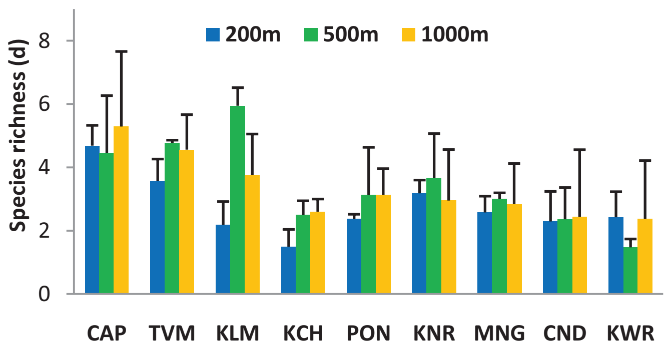

Figure 44. Species richness (d) for each site in the study area

Mean evenness index for polychaete species at each depth category were compared, and the values were found to be highest at 1000m (0.86±0.19) followed by 500m (0.80±0.14) and were lowest at 200m (068±0.13). Relatively low evenness and high species dominance was observed at the northern transects (Coondapur and Karwar) and at shallow depths (200m) off Kochi and Kollam [Figures 46 & 47].

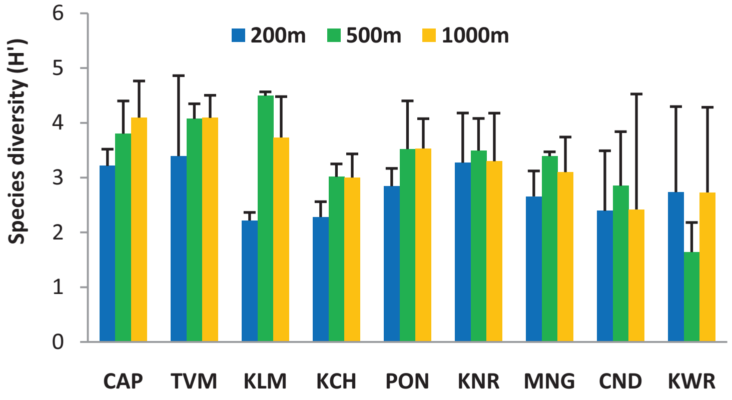

Figure 45. Species diversity (H') for each site in the study area

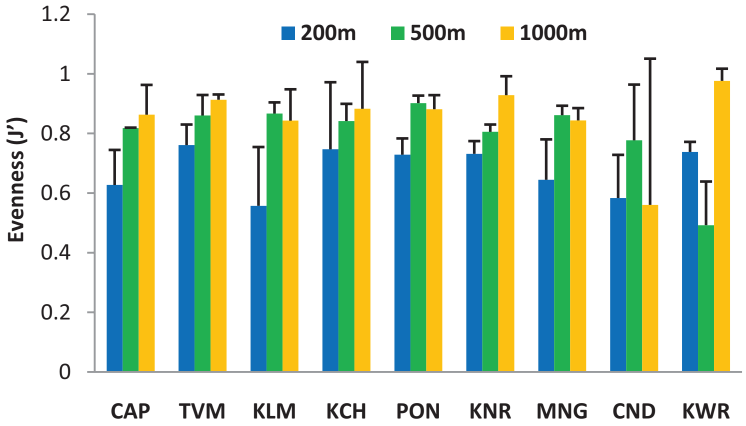

Figure 46. Evenness (J') for each site in the study area

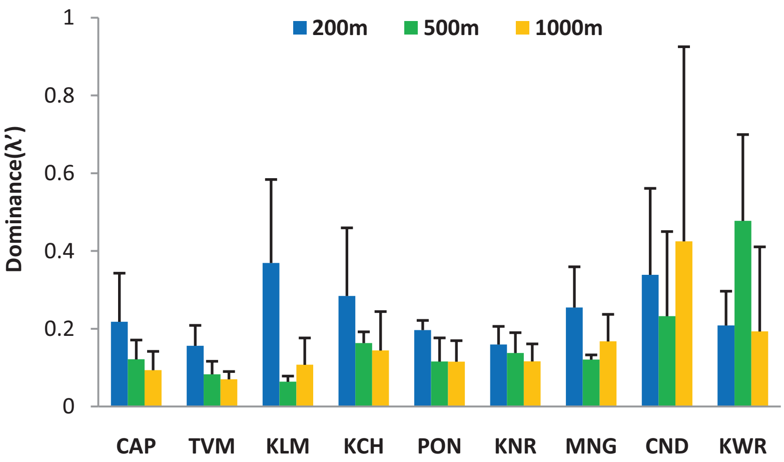

Figure 47. Dominance (λ') for each site in the study area

The diversity (H'), and evenness (J') varied significantly with depth (H': $F_{2, 76} = 3.23$, p = 0.041; J: $F_{2, 76} = 8.753$, $p<0.001$) while no significant differences were found in the number of species (S: $F_{2, 76} = 0.379$, p = 0.686), Margalef's specie richness (d: $F_{2, 76} = 1.518$, p = 0.226) and dominance (λ': $F_{2, 76} = 2.022$, p = 0.139).

c) Variation in polychaete diversity with transects

Species richness (d) varied from 2.19±0.62 (Kochi) to 4.81±1.54 (Cape). Higher numbers of species (31±10.34) as well as higher abundance (663.8±542.2) was observed at the Cape transect, while the lowest species count (10.66±2.69) and density (252.77±515.18) was recorded at Kochi. However, species diversity (H') was highest at Trivandrum (3.85±0.549) and lowest at Karwar (2.37±1.07). Relatively low evenness and high dominance was recorded at Coondapur (J: 0.64±0.29; λ', 0.33±0.31). On the other hand highest evenness and lowest dominance was recorded at Trivandrum (J: 0.845±0.083; λ': 0.103±0.052). In general, a latitudinal trend in species richness and diversity was evident throughout the study at all depth categories [Figures 44 & 45]. The southern transects from Kollam to Cape showed a more consistent pattern in species distribution, with high species richness and diversity. One of the important observations of the present study was the occurrence of lowest density and species diversity at Kochi despite similar environmental conditions as other transects (based on measured parameters).

To check the variations in polychaete diversity with transects statistically, one way-ANOVA was performed on transect wise pooled diversity data. The number species (S), Margalef's (d), diversity (H') and dominance (λ') varied significantly between the transects (S: $F_{8, 70} = 7.89$, $p<0.001$; d: $F_{8, 70} = 5.632$, $p<0.001$; H: $F_{8, 70} = 3.377$, p = 0.002). However, the evenness (J) did not show any significant difference ($F_{8, 70} = 1.392$, p = 0.215).

V. 2. 2. Graphical Methods

a) Species Area Plot and Species Estimator

The species accumulation plot for the grab samples was plotted, which helps to determine if the species collected during the survey adequately describe the actual species composition of the study area. The plot approached the upper asymptote, indicating that the study area was sampled sufficiently [Figure 48]. During first survey 134 species were obtained and during the second there was an addition of 59 species, while in the third survey fewer species were added (20 species). This further indicated that required sample size was attained with the third survey.

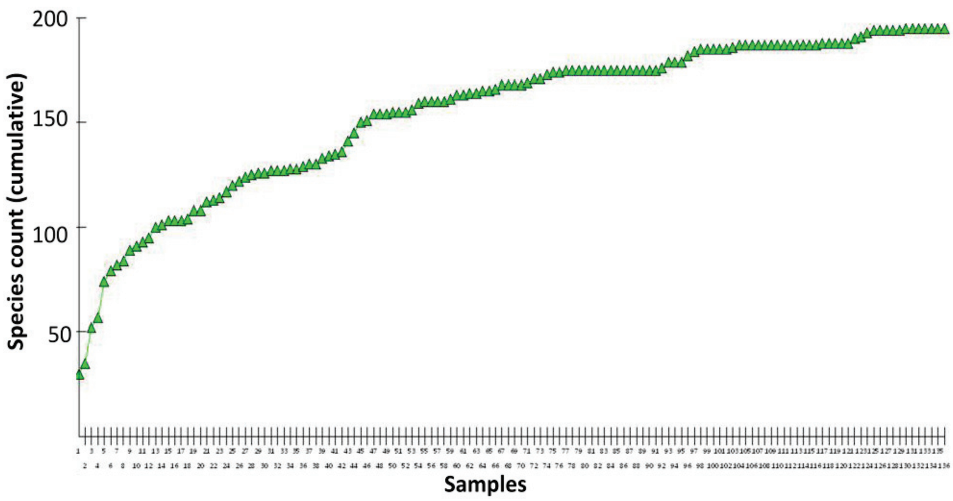

Figure 48. Species area plot for polychaete species in the study area

Species estimators were used to predict the true number of species that would be observed as the number of samples tend to be infinity. The total number of species estimated by the species estimators varied from 185 to 244 species [Figure 49]. While the minimum estimate was given by Sobs and UGE, the maximum estimate was given by Jacknife2. The number of polychaete species estimated by Chao1, Chao2, Jacknife1, Bootstrap and MM were 195, 220, 236, 244, and 216 respectively.

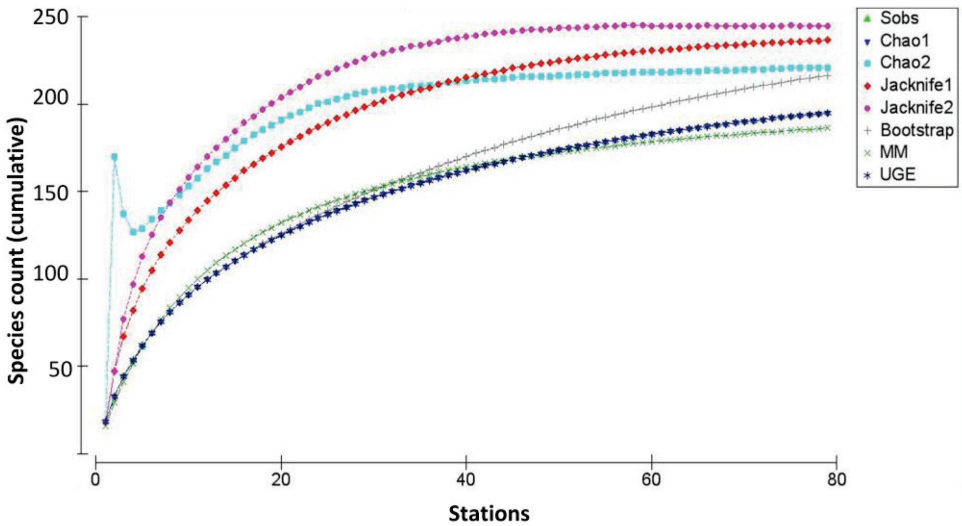

Figure 49. Species estimators for polychaete species in the study area

b) k-dominance curve

In this graphical plot, species are ranked in order of importance along the horizontal axis while the cumulative contribution of each of these to the total density is plotted along the vertical. The k-dominance curve measures the intrinsic diversity, and in this plot the lower lines represent samples with higher diversity. In the present study, multiple k-dominance plots were constructed for all surveys, transects and depths using statistical software PRIMER [Figures 50-53].

During first survey the 500m site of Karwar had the highest dominance and a single species of cirratulid (*Tharyx marioni*) contributed more than 85% of the total abundance [Figures 50]. It is implied that this transect would have a low species diversity index. Kochi 200m and Coondapur 500m showed comparatively high dominance (70%) which was mainly due to the high abundance of *Cossura coasta* at Kochi and *Prionospio ehlersi* at Coondapur. Ponnani 500m showed the least dominance and had highest diversity (H'=4.33). In the second survey [Figure 51], highest dominance was observed at the 200m station of Cape Comorin, where the most abundant species *Levinsenia oculata*, contributed more than 60% of the total abundance. The highest diversity during this survey was at the 1000m station of Cape Comerin (H'=4.81). During the third survey [Figure 52], high dominance was recorded at Kollam and Coondapur 200m where the most dominant species was *Tharyx dorsobranchialis* at the former station and *Prionospio cirrifera* in the latter (second most dominant species was *P. polybranchiata* at Coondapur). The highest diversity observed during this survey was at 1000m station of Trivandrum.

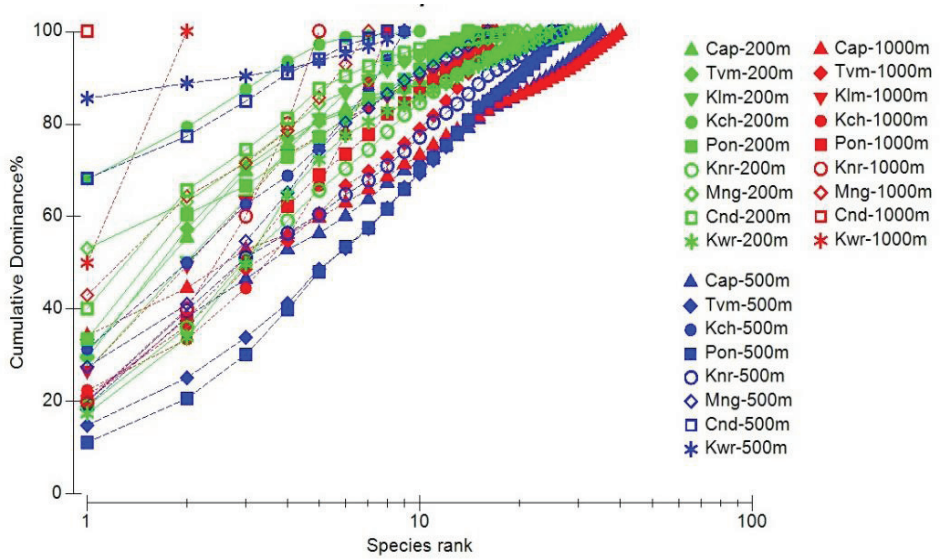

Figure 50. k-dominance curve for polychaetes during FORVSS Cruise 219 & 225

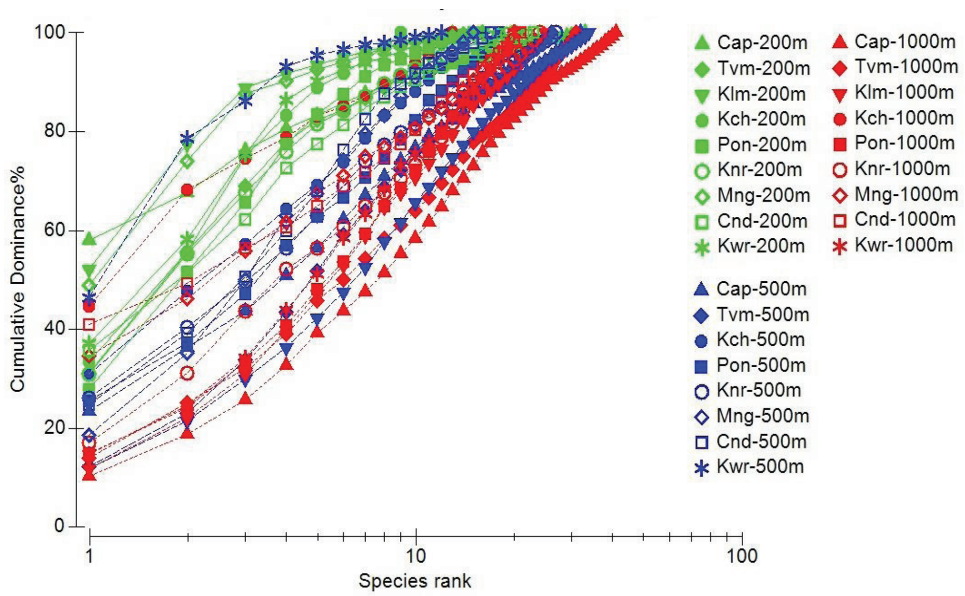

Figure 51. k-dominance curve for polychaetes during FORVSS 228 & 233

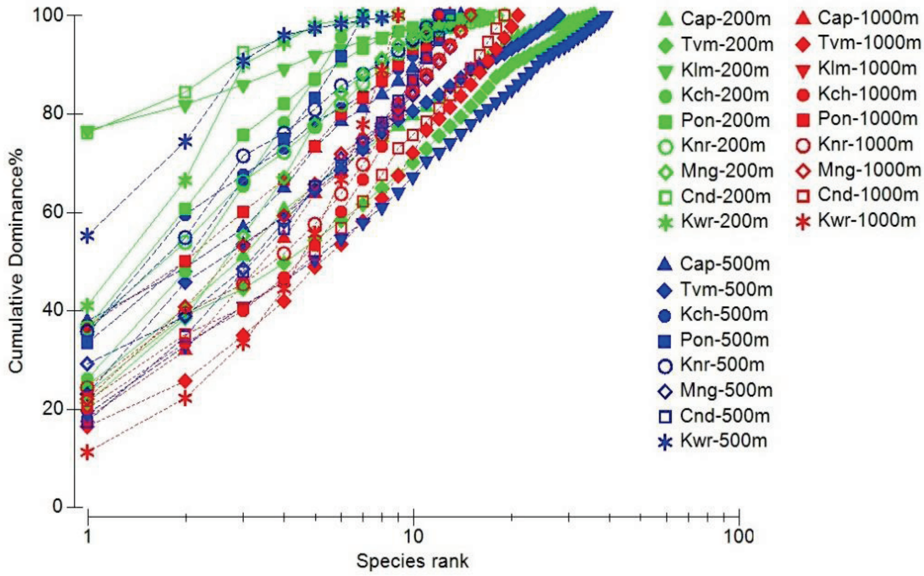

Figure 52. k-dominance curve for polychaetes during FORVSS 254

The k-dominance curve of species abundance data pooled for each depth is presented in Figure 53. Eighty percent of total organisms were represented by 11 species at 200m, 30 species at 500m and 40 species at 1000m. The present study revealed that high polychaete diversity occurs along the continental margin, especially at higher depths; and that there was relatively high species dominance at shallow depths.

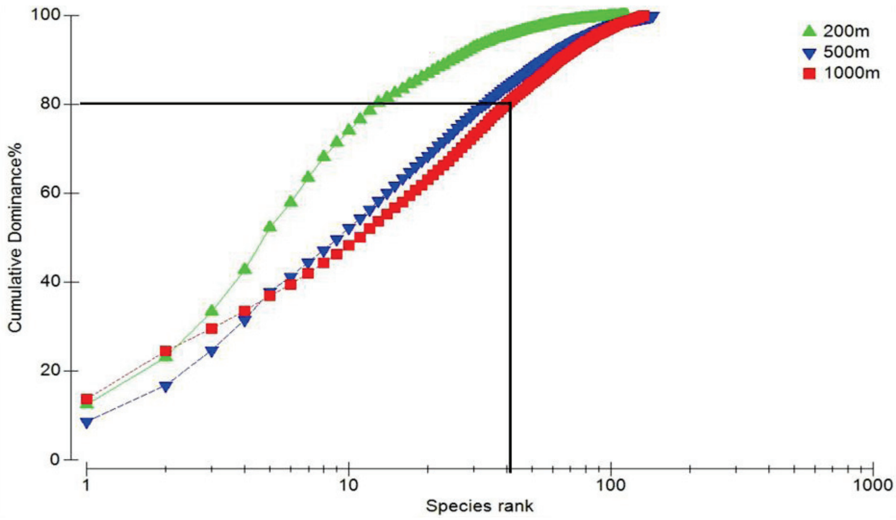

Figure 53. k-dominance curve at the three depth classes

V. 2. 3. Multivariate analyses of community structure

a) Family level

The debate on taxonomic sufficiency has so far concentrated on data collected from inshore and continental shelf areas (Warwick *et al*. 1988, Raut *et al*. 2005, Joydas *et al*. 2009) little comparative analyses have been undertaken in deeper water (Narayaswami *et al*. 2003). In the present study, polychaete species abundance from each station was aggregated to the family level; and cluster analysis, non-metric multidimensional scaling (MDS) and analysis of similarity (ANOSIM) using the PRIMER package (Clarke & Warwick 1994) were carried out. Bray-Curtis similarity was used to construct a similarity matrix on square root transformed data. To classify the stations based on grouping of polychaete families, the similarity matrix was subject to hierarchical agglomerative classification, employing group-average linkage. Figure 54 depicts a clear separation of stations into a shallow group (200m), intermediate depth group (500m) and deep water group (1000m) at 45% similarity level with some exceptions. The evaluation of R-values revealed that greatest community differences were found between shallow (200m) and deeper stations (ANOSIM, R=0. 441, P=0.1%); whereas the faunal differences at family level from 200 to 500m (ANOSIM, R=0. 351, P=0.1%) and 500 to 1000m (ANOSIM, R=0. 277, P=0.1%) were also statistically significant. At this similarity level, 4 main groups (FA, FB, FC & FD) and 5 sub-groups were identified [Figure 54]. Due to low abundance of fauna at deeper stations (1000m) of Karwar and Coondapur, these were outliers (first survey). One way ANOSIM (identified through SIMPROF, P<0.5) revealed that highly significant differences exist in faunal assemblages at the family level between these four groups (ANOSIM, R=0.699, P=0.1%).

The stations grouped under FA were mostly shallow (200m), the only exception being the 500m stations of Karwar; and this group could be separated into three sub cluster, FA1 (57.3% similarity), FA2 (57.5%) and FA3 (73.08%). In the FA1 cluster eight families: Spionidae (27.6%), Paraonidae (24.3%), Cirratulidae (17.6%), Amphaeritidae (5.6%), Cossuridae (5.5%), Terebellidae (4.6%), Nephtyidae (2.8%), Maldanidae (2.7%) contributed more than 90% of the total polychaete abundance. Cluster FA2 consisted of 200m stations of Kollam, Coondapur and 500m stations of Karwar; which were characterized by the preponderance of Cirratulidae (57.5%) along with Spionidae (19%), Ampharetidae (9.6%), Cossuridae (3.7%) and Capitellidae (3.2%). At the 200m station off Karwar (Cluster FA3), only three families viz. Cirratulidae (43%), Cossuridae (40%) and Spionidae (16.3%) were represented.

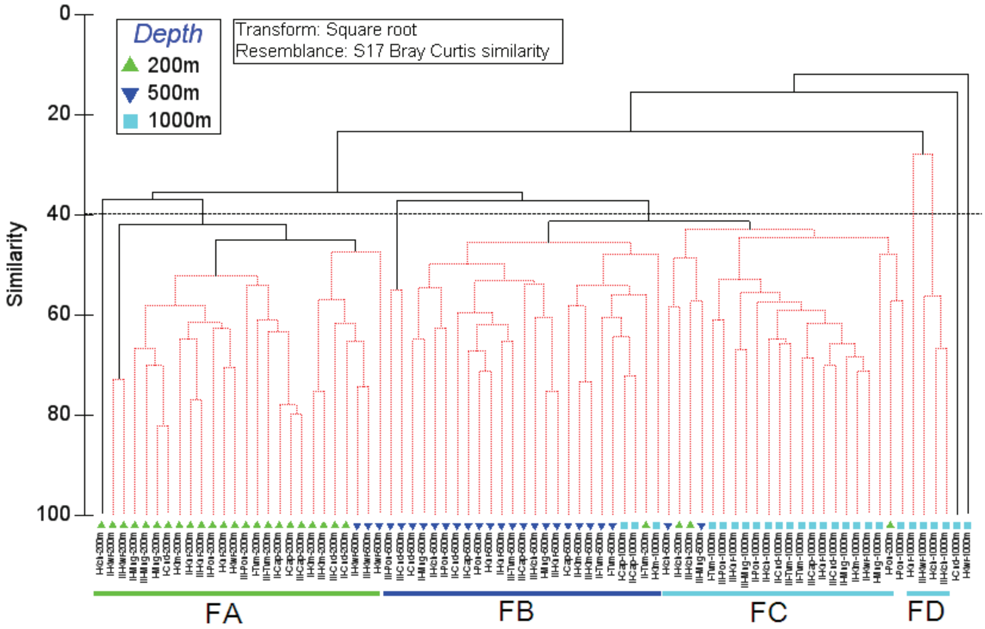

Figure 54. Dendrogram using polychaete family level data for each station

Cluster FB consisted mainly of 500m stations (24 stations). The 1000m stations off Cape (I&II) and Kollam (I) and the 200m station off Trivandrum (II) also grouped with this cluster at 50% similarity. Among the 12 families that contributed 90% of the faunal abundance, Spionidae (34%), Capitellidae (12.4%), Paraonidae (12%), Lumbrineridae (7.2%) and Cirratulidae (6%) were dominant. In this group, abundance of errant families increased appreciably (~23%). Cluster FC was composed of most 1000m stations in the study area; with the 200m station off Ponnani (I) and Kochi (II &III) also showing affinity to this group. This was mainly due to the low abundance of fauna at the latter station, similar to the characteristic composition at higher depths. The families, which contributed most to similarity within this cluster, were Cossuridae (20%), Capitellidae (18.6%), Spionidae (18%), Paraonidae (10.5%), Nereididae (5.7%), Cirratulidae (5.5%), Lumbrineridae (5%), Pilargidae (3.8%) and Maldanidae (2.7%). The abundance of spionids and paraonids decreased from cluster FB to cluster FC while the abundance of cossurids increased considerably at deeper stations (FC). Cluster FD was composed of 1000m station off Kannur (I), Karwar (III), Kochi (I & III), at 44% similarity, which were characterised by low density and dominance of Cirratulidae (30.6%), Capitellidae (16%), Pilargidae (14.6%) and Spionidae (13%).

The survey based differences between the faunal assemblages were not significant (ANOSIM R=0.017, P=16.7%) and so, the family level data for each site was pooled. The nMDS derived from the pooled data, also clearly shows the deep-shallow difference in polychaete assemblages even at the family level [Figure 55]. The 200m sites off Karwar and Kochi formed a group at 65% similarity, and were distinct from all other clusters.

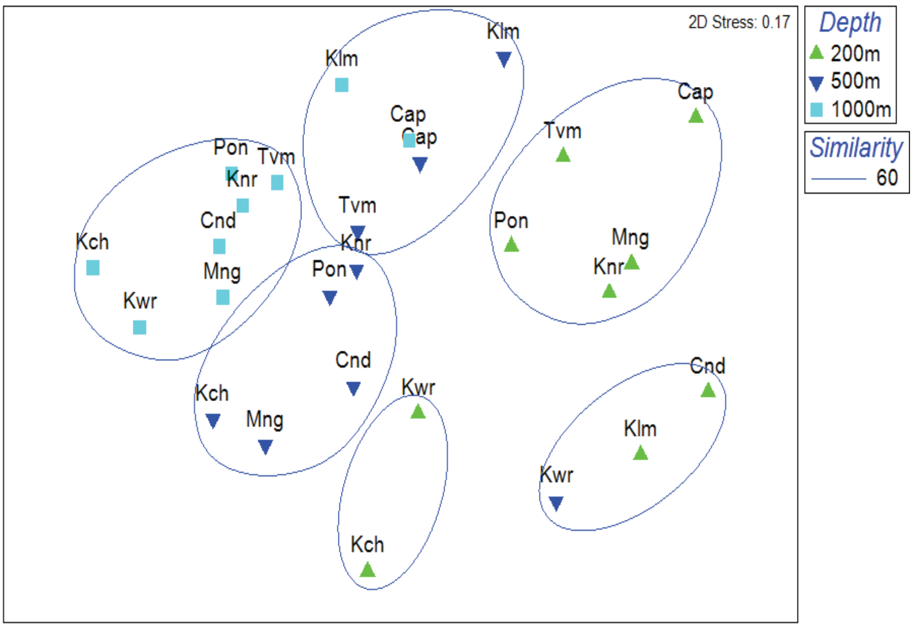

Figure 55. nMDS for polychaete family level data at each site

b) Species level

Before computing the similarity matrices, the data from the 79 stations 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). Hierarchical clustering analysis based on Bray-Curtis similarity was then carried out to test the similarity among the stations. Hierarchical cluster analysis and SIMPROF test on full set of data revealed that of the 79 stations, 76 stations grouped into 6 significant clusters ($p<0.05$), of which two could be further distinguished into 5 sub-clusters, while the 1000m stations off Kannur, Coondapur and Karwar (first survey) were outliers [Figure 56]. The six major clusters are designated from SA to SF; and cluster SA is sub-divided into SA1, SA2 and SA3, while cluster SF is divided into SF1 and SF2. Cluster analysis shows that the percentage similarity between samples at species level is much lower (20 to 43%) than at family level (40 to 50%).

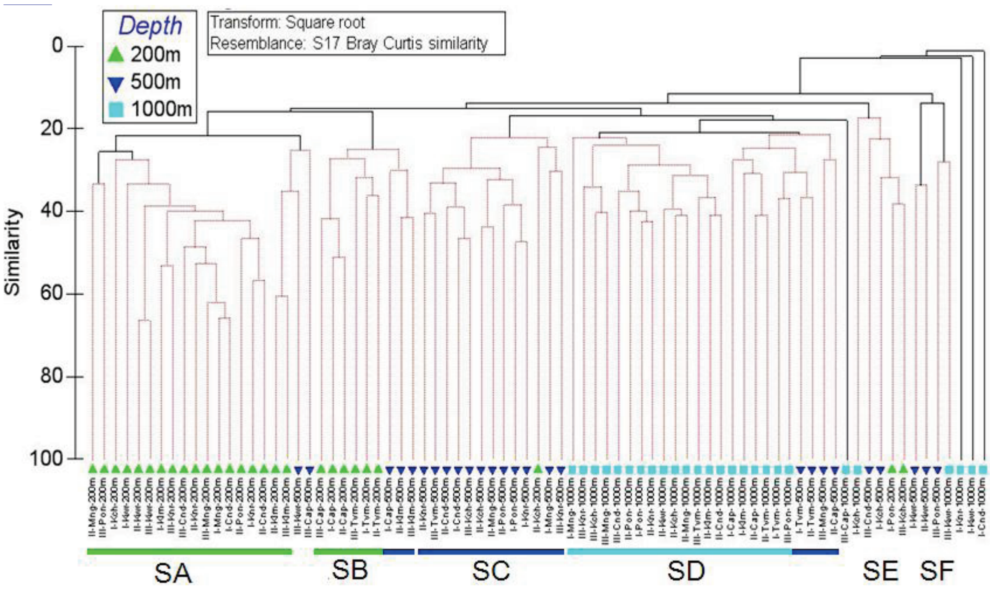

Figure 56. Dendrogram using polychaete species data for all stations

Cluster SA was composed of all the 200m stations except Cape and Trivandrum along with the 500m stations off Karwar (III survey) and Cape (III) at 22% similarity. SIMPROF analysis revealed three significant sub clusters (SA1, SA2 and SA3) within cluster SA ($p <0.05$). This cluster separated from cluster SB at 15% similarity level. Cluster SB was composed of the 200m stations off Cape and Trivandrum and the 500m station off Kollam. Within these two clusters (SA & SB) all the 200m stations except off Kochi (survey II & III) and Ponnani (survey I) were grouped at 15% similarity. Assemblages at Kochi and Ponnani transects showed a departure from those at other 200m stations mainly because these station had the lowest faunal abundance during these surveys, making them more similar to the assemblages at 500 and 1000m.

Cluster SC was composed of almost all 500m stations from Kochi to Coondapur; and the 200m station off Kochi (II) was also grouped with these stations, with similar faunal abundance. Cluster SD was composed of nearly all the 1000m stations and the 500m stations of Cape (II), Trivandrum (I and II) and Mangalore (III). Cluster SE contained station off Kochi (200m-III, 500m-I, and 1000m-I), Ponnani (200m-I) and Coondapur (500m-I); while in Cluster SF, the 500m stations off Karwar (I &II) formed a significant group (SF1) at 35% similarity and the 500m station off Ponnani and 1000m station off Karwar formed another cluster (SF2) at 30% similarity. In general, samples taken at the same depth were clustered together irrespective of season and it is evident that depth or some depth associated factors were most critical in dictating the clustering of stations, while the sub-clusters tended to distinguish the location (i.e., transect).

It is important to note that temporal changes were of no significance (ANOSIM R=0.017, P=16.7%) in determining the similarity levels at which groups were defined. Survey wise faunal differences were not responsible for the major grouping, although they were quite apparent in some transects (e.g. Kochi - survey I, 1000m stations of Kannur, Coondapur and Karwar - survey I). It was evident from the species accumulation plots that all depths were sampled sufficiently during the study. That is to say, the pooling of data collected at each site during the three surveys (i.e. 6 grabs) would give a clear picture of the polychaete communities in the study area. For further analysis of faunal assemblages, the average abundance for each site (from 6 grabs) was taken, subjected to square root transformation and subsequently analysed for Bray-Curtis similarity. The similarity within the clusters was much higher for the site-averaged data, when compared to the station wise data.

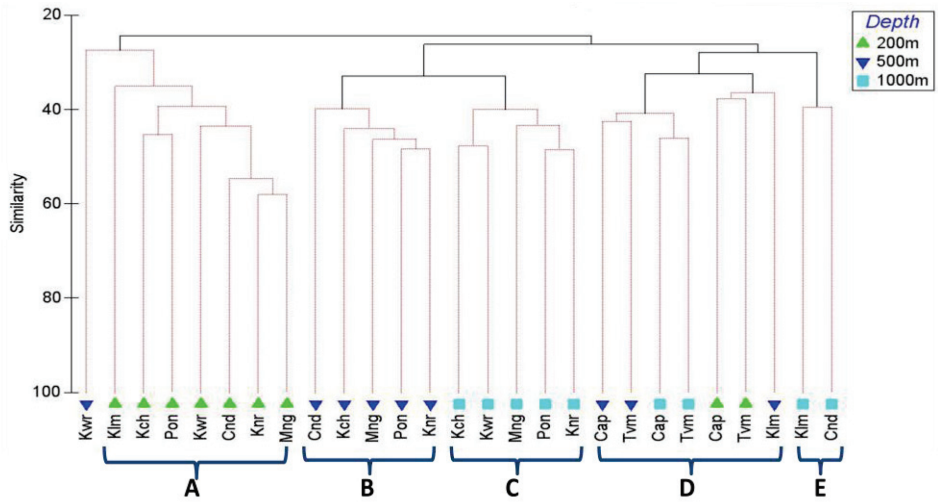

Figure 57. Denrogram for polychaete species data at each site

The result of cluster analysis based on the pooled abundance data of polychaete species collected between 2003 and 2007 are illustrated in Figure 57. The clustering was similar to that obtained from the survey-wise data [Figure 56]. Regional difference in community structure was further evident from this plot. All the 200m sites, except Cape and Trivandrum formed a significant cluster at 38% similarity (Group A). Within this cluster, Kannur and Mangalore (200m) showed highest similarity (60%) and these were separated from Coondapur at 55% similarity. These three sites were distinguished from Kochi & Ponnani at 40% and from Kollam at 35% similarity.

The 500m site off Karwar formed an outlier at 25% similarity and all these sites together were separated from all others at 22% similarity. Two distinct clusters were formed, both at 42% similarity ($p<0.5$), group B constituting the 500m sites and Group C constituting the 1000m sites. The 500m and 1000m sites of the three southern transect (Cape, Trivandrum and Kollam) along with the 1000m site off Coondapur constituted Group D. The 200m sites of Cape and Trivandrum were grouped in this cluster at 37%

similarity, being far removed from the other 200m sites of the study area. Group B & C was composed of the deeper sites (500m and 1000m) of the 6 northern transects, with the exception of Karwar (500m) and Coondapur (1000m). All these sites were clubbed together at 37% similarity. The 200m sites of Cape and Trivandrum were most similar to the 500m site off Kollam (37% similarity) and these three sites constituted a significant sub cluster, D1 ($p<0.5$). Group D2 was constituted by the 500m and 1000m sites off Cape and Trivandrum (42% similarity, $p<0.5$) and E was constituted of the 1000m sites off Kollam and Coondapur (40% similarity, $p<0.5$). The pattern of clustering of the sites underlines the importance of latitudinal position (i.e. transect) in faunal similarity, as well as that of depth.

SIMPER (similarity percentage) analysis was conducted to identify the species responsible for the defined clustering pattern. Thus, six significant ($p<0.05$) polychaete assemblages were distinguished in the study area. The presence or absences of some characteristic species or the variation in abundance of predominant species were the basis for similarities and dissimilarities between assemblages. ANOSIM was conducted to test the null hypothesis that there was no significant difference in faunal composition among these groups. The result indicated that significant differences existed between each pair of groups. Differences were significant between the shallow and intermediate depth sites ($R=0.851$, $P=0.2\%$), between the shallow and deep sites ($R=0.864$, $P=0.2\%$).

Twelve species accounted for almost 80% of the similarity within Group A, which include *Cossura coasta* (13.81%), *Prionospio cirrifera* (10%), *Tharyx dorsobranchialis* (10%), *Prionospio polybranchiata* (8.5%), *Paraprionospio pinnata* (7.7%), *Tharyx filibranchia* (7.6%) and *Paraonis gracilis* (5%). The abundance of species that contribute extensively to the dissimilarity between shallow (Group A, 200m) and deeper water stations (Group C, 1000m) were *Prionospio polybranchiata*, *Tharyx dorsobranchialis*, *Prionospio cirrifera*, *Tharyx filibranchia*, *T. annulosus*, *Cossura coasta*, *Notomastus aberans*, *Notomastus fauveli* etc. In Group

D1, which contained the remaining 200m stations of Cape, Trivandrum and 500m station off Kollam (37% similarity) the most abundant species, which also contributed most to the average similarities were *Aonidella cirrobranchiata* (9% to the average similarity), *Tharyx dorsobranchialis* (6.3%), *Magelona cincta* (6.2%), *Aricidea belgicae* (6.2%), *Laonice cirrata* (5%) and *Spiophanes* sp. 1 (5%). Difference from the other 200m stations (Group A) was mainly a result of abundance of some species. Among them, *Cossura coasta* and *Tharyx annulosus* were absent and shallow water dominant species like *Prionospio polybranchiata*, *P. cirrifera* and *Tharyx filibranchia* had relatively low abundance in Group D1. *Aricidea capensis*, *Isolda pulchella* and *Schistomeringos rudolphii* were the characteristic species of this group.

Pattern of abundance and diversity also varied between groups. Group A was characterized by relatively low diversity (2.5±0.58) and high polychaete abundance (747±440 No.m^{-2}). The species count varied from 9±2 (Kochi) to 22±5 (Kannur) and the richness (d) between 1.47±0.26 (Karwar 500m) and 3.18±0.91 (Kannur) with an average of 2.25±0.63. When compared to the other groups, the evenness was low with a mean value of 0.65±0.122. The species assemblage in Group D1 (Cape, Trivandrum 200m & Kollam 500m) was characterized by highest species count (mean 32±5.4), along with comparatively high species richness (4.76±1.34) and diversity (H'=3.7±0.47). The polychaete abundance recorded a maximum in this group (767±181 No. m^{-2}).

Group B, represented 500m sites of 5 transects (at 43% similarity) from Kochi to Coondapur which were statistically distinct from all other assemblages. The characteristic species (dominant and frequent) of this group that contribute most to similarity include *Paraprionospio pinnata* (13%), *Prionospio ehlersi* (11.5%), *Laonice* sp. (7.29%), *Lumbrineris metorana* (7.2%) and *Spiophanes* sp. 1 (6.7%). The average dissimilarity between Group A (200m) and Group B (500m) was 76%; the abundance of *Tharyx dorsobranchialis*, *Cossura* *coasta*, *Prionospio polybranchiata* and *Tharyx annulosus* was responsible for this dissimilarity.

The stations of Group C formed a distinct cluster with a mean abundance of 176±92.17, mean species richness of 2.93±0.91 and mean diversity of 3.25±0.56. The intermediate depth (Group B) differs from deeper depths (Group C) in their species composition and abundance. Group C was characterized by the high abundance of *Cossura coasta* (18%), *Notomastus fauveli* (8.7%), *Tharyx dorsobranchiali*s (8.5%), *Notomastus aberans* (7.9%) and *Nereis* sp. (6%). When compared to intermediate depths (500m), the abundance of *Prionospio ehlersi*, *Paraprionospio pinnata* and *Prionospio cirrifera* were relatively low in this assemblage. Species count ranged from 10.3±9 (Karwar) to 16.3±4.5 (Ponnani), density from 45±50 to 145±76, species richness (d) from 2.36±1.84 to 3.13±0.83 (mean, 2.8±1.19) and H' from 2.72±1.56 to 3.53±0.54 (mean 3.01±1.19). Relatively high evenness and low density of polychaete fauna was observed in this assemblage.

Group E (Kollam & Coondapur, 1000m) and D2 (Cape and Trivandrum, 500 & 1000m) were analysed for their similarity in species abundance and diversity. The species that contribute most to similarity in Group D2 were *Cossura coasta*, *Notomastus aberans*, *Tharyx marioni*, *Prionospio polybranchiata*, *Magelona cincta* and *Glycera longipinnis*; and in Group E were *Cossura coasta*, *Notomastus aberans*, *Paraonis gracilis*, *Nereis* sp. and *Schistomeringos rudolphii* etc. In general, there was a gradual decrease in density from Group A to Group C. Species richness and diversity were highest along the southern transects (D1 & D2) and this reflected well marked regional north-south differences in assemblages.

The affinities among the stations were established using non-metric multi-dimensional scaling. The stress value (Kruscal) measures the degree of coupling between sample distances and actual distances in the ordination. Ordination by multidimensional scaling (MDS), based on the site-wise species-level similarity matrix, displayed a similar pattern [Figure 58], i.e. the same groups were identified with a stress values of 0.21. In order to analyze the distinct faunal assemblages of the southern (Cape, Trivandrum and Kollam) and northern transacts (Kochi to Karwar), further analyses were carried out while considering the fauna of these regions separately [Figure 59].

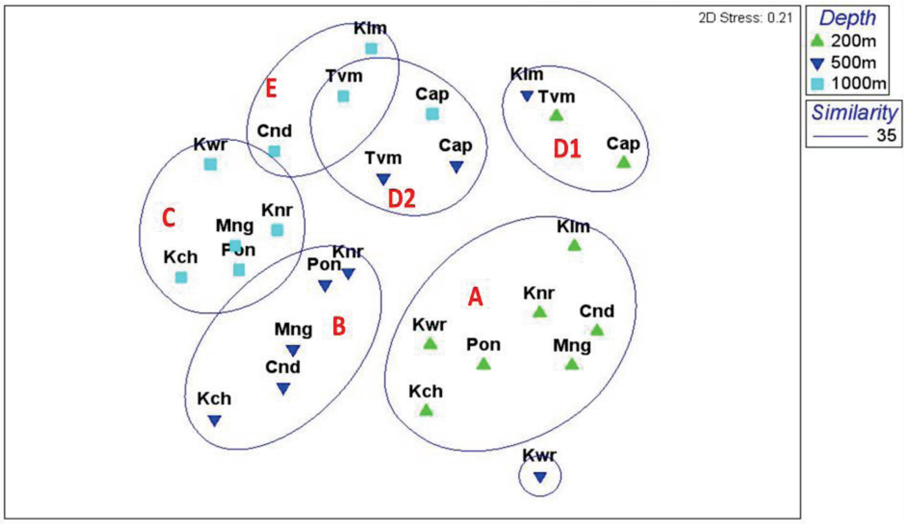

Figure 58. nMDS using polychaete species data for each site

The faunal relationship between the various sites and depth categories became clearer when the data of these two regions were plotted independently. From Figure 59(a) it is clear that there were no significant differences in faunal assemblages at 500 and 1000m depths of Cape and Trivandrum. From this plot it could further be surmised that Kollam transect had entirely different faunal assemblages at the three depth categories. The 200m site of Kollam were located far away from the 200m sites of Cape & Trivandrum; and in the cluster plot of all the sites, this station showed affinity to the same depth group of the northern transects. While the 500m site of Kollam showed more affinity towards the 200m sites of Cape and Trivandrum, the deeper site was also clearly separated from the other two sites. The MDS ordination of sites from Kochi to Karwar [Figure 59b] showed that all three depth categories in these transects were clearly separated, with 200m, 500m and 1000m sites forming discrete clusters, having a stress value of 0.15. Only the 500m site off Karwar showed a deviation from the common depth wise clustering and was an outlier.

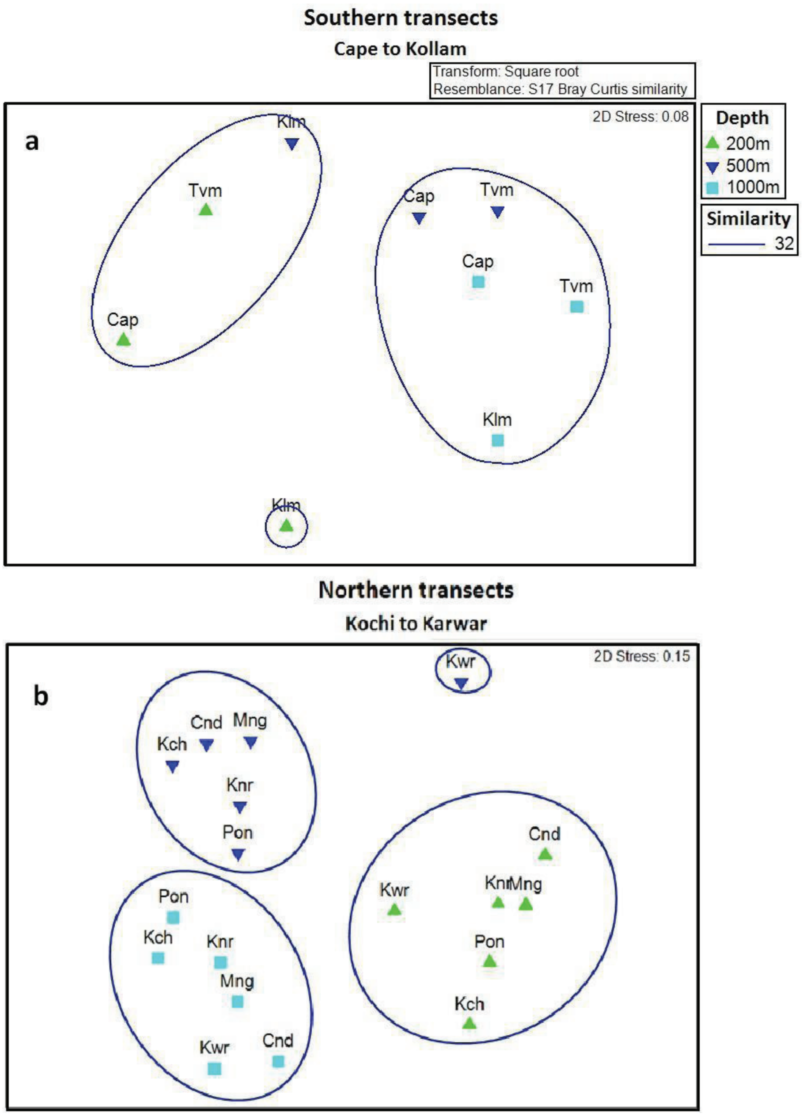

Figure 59. nMDS for polychaete species data of southern (a) and northern (b) sites

Comparison of MDS plots of the species level data [Figure 58] with that of aggregated family level data [Figure 55], taken for each site showed that separation between the shallow and deep stations was slightly more evident at the family level. This suggests that as abundances were aggregated to higher taxonomic levels, the general patterns of the community structure were retained. The stress associated with the ordination plots was marginally lower at family level (0.17) than species level (0.2), indicating a better 2D representation of the data at the family level.

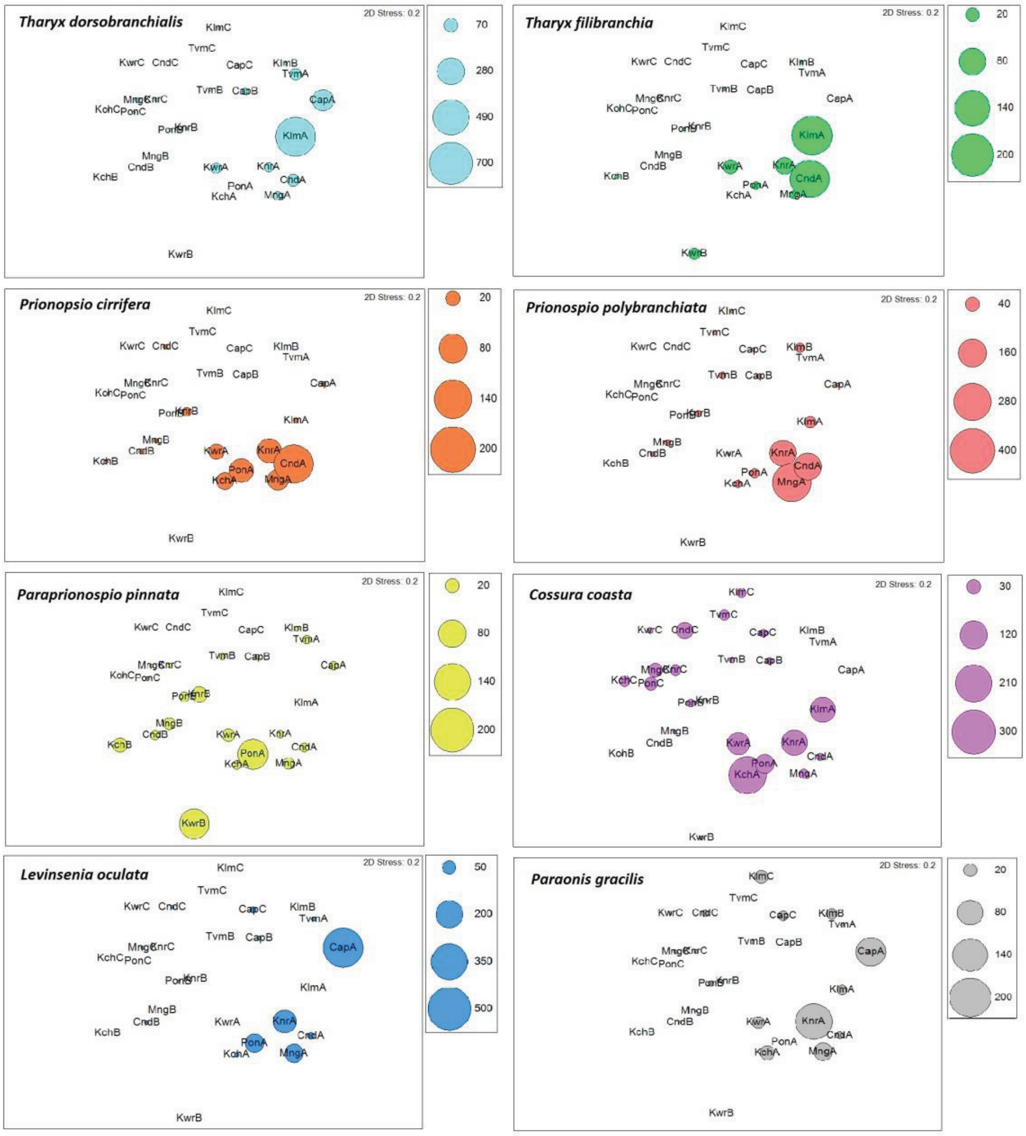

Figure 60. Bubble plots for dominant polychaete species in the study area
(Square root transformed species data for each site, Bray-Curtis similarity)
A: 200m, B: 500m, C: 1000m

V. 2. 4. Feeding guild composition

Within an assemblage of polychaetes, a few or all feeding guild may be represented, viz. suspension feeders, surface deposit feeders, subsurface deposit feeders and carnivores or omnivores. The available food resources in the sediments are thereby utilized and partitioned between these trophic guilds.

In general, the adaptations of carnivores and omnivores include development of sensory appendages such as antennae and eye spots (e.g. Aphroditidae, Nereididae), the presence of prominent and usually retractable jaws (Glycerinates, Paralacydoniidae, and Nereididae), well developed parapodia for swimming (Nephtyidae, Nereididae and Aphroditidae) and masticatory gizzards (Syllidae). In the case of suspension feeders, prominent filtering apparatus like palps (Chaetopteridae) and food-gathering tentacles (Sabellidae, Serpulidae) are developed and the organisms lay buried in the sediment with only the palps or tentacles projecting out; these species are usually sessile and are usually tube dwellers (Serpulidae). In the case of deposit feeders, the range of selectivity and position of the species in the sediment matrix shows considerable diversity; the species may be selective or non-selective deposit feeders and they may position themselves at the sediment surface (surface deposit feeders) or they may lay entirely buried within the sediment (sub-surface deposit feeders). In general non selective deposit feeders tend to have an eversible pharynx that facilitates ingestion of sediments (Capitellidae, Orbiniidae), and some families have prostomium modified as wedges or shovels (Maldanidae, Magelonidae). Surface deposit feeders often have well developed tactile and food capturing tentacles (Spionidae, Cirratulidae etc.).

The species represented in the present study were assigned to one of four feeding guilds: carnivores (CVR), surface deposit feeders (SDF), subsurface deposit feeders (SSDF) and suspension feeders (SF) and those species which could not be confidently classified into any of these were grouped as unknown (U). The composition and structure of the polychaete feeding guilds were investigated using the species abundance data. For the purpose of comparison, analysis was carried out with emphasis on changes along and across the depth gradient.

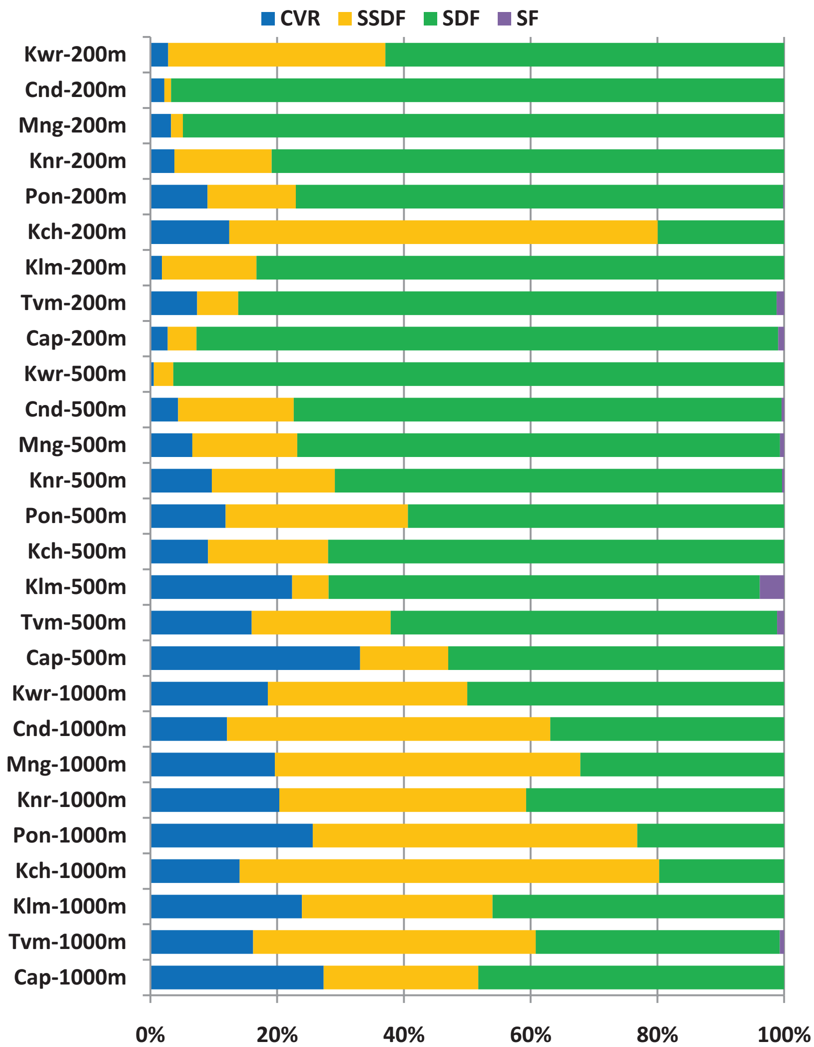

Figure 61. Distribution of polychaete feeding guilds in the study area

The feeding guild densities showed significant differences along the depth gradient. The most striking feature was the high abundance of surface deposit feeders (SDF, 75%) or interface feeders [Figure 61], which were mainly constituted by selective feeding taxa such as spionids, cirratulids and paraonids (non selective) [Table 21]. These taxa selectively take up organic particles from the surface of the sediments without ingesting sediment particles. Variation in mean abundance of the feeding guilds with depth is plotted in Figure 62. There was a significant difference in feeding guild composition with depth (CVR: $F_{2, 76}$ =16.457, p<0.001, SDF: $F_{2, 76}$ =39.693, p<0.001, SSDF: CVR: $F_{2, 76}$ =17.32, p<0.001), with the relative abundance of SDF gradually changing with increasing depth.

The SDF constituted 82% of polychaetes at 200m, 72% at 500m and 39% at 1000m depth. The relative abundance of this guild did not vary significantly between the surveys, with percentage contribution of 67%, 77% and 82% during the first, second and third survey respectively. The abundance of carnivores increased with increasing depth; and accounted for 4.3%, 13.2% and 21.2% of polychaetes at the 200, 500 and 1000m depths respectively. The relative abundance of carnivores also did not vary significantly between surveys. The carnivores were comparatively low at northern transect from Kannur to Karwar, especially in the upper slope region. Subsurface deposit feeders (non-selective) were also relatively low at 200m sites except off Kochi (67.6%) and Karwar (34%). Suspension feeders were nearly absent in the study area, being represented only at a few sites off Trivandrum, Kollam and Mangalore in very low numbers.

A linear decline in the relative abundance of surface deposit feeders (SDF) was found with increasing water depth and this was coupled with a linear increase in the relative abundance of subsurface deposit feeders (SSDF). At the 1000m stations, ~24 to 66% of the polychaetes were subsurface deposit feeders (mean 38.7%). At 200m depth off Kochi and Karwar, high dominance of the specialist subsurface deposit feeder, *Cossura coasta* was observed. In general the most abundant SSDF belonged to families Cossuridae, Capitellidae and Maldanidae. The SDF guild was represented by Spionidae, Paraonidae Cirratulidae and Terebellidae which were in general, the most abundant families in the SEAS margin. The selective and non selective deposit feeding nature of these families makes them suitable to share the abundant organic matter available in the region without much interspecies competition for food.

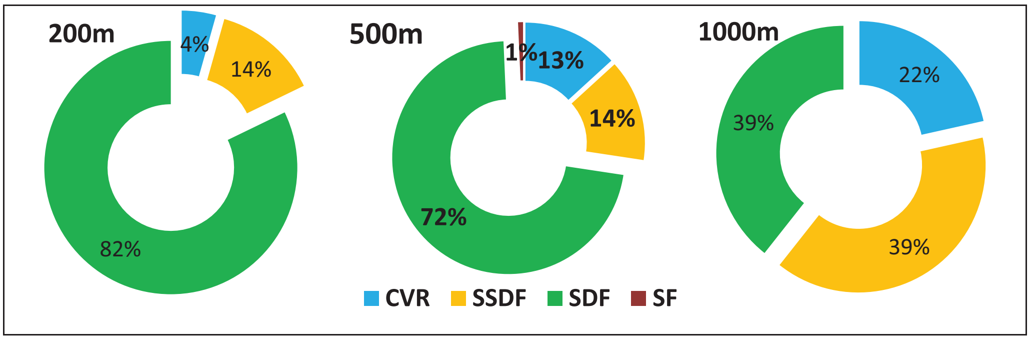

Figure 62. Composition of feeding guilds at the three depths

V. 2. 5. Mean individual body weight of polychaetes

The mean individual body weight of polychaetes was estimated by dividing total polychaete biomass by total polychaete density at each station. It was found that individual body weight differed significantly ($F_{2, 76} = 5.411$, $p = 0.006$) between stations located in the shelf edge (200m) and slope (500 & 1000m). The oxygen depleted upper slope sites with predominantly sandy sediments harbored a greater number of small sized polychaetes, while the silty sediments of the mid-slope, supplied with oxygen rich water, harboured polychaetes with higher individual body weight [Figure 63].

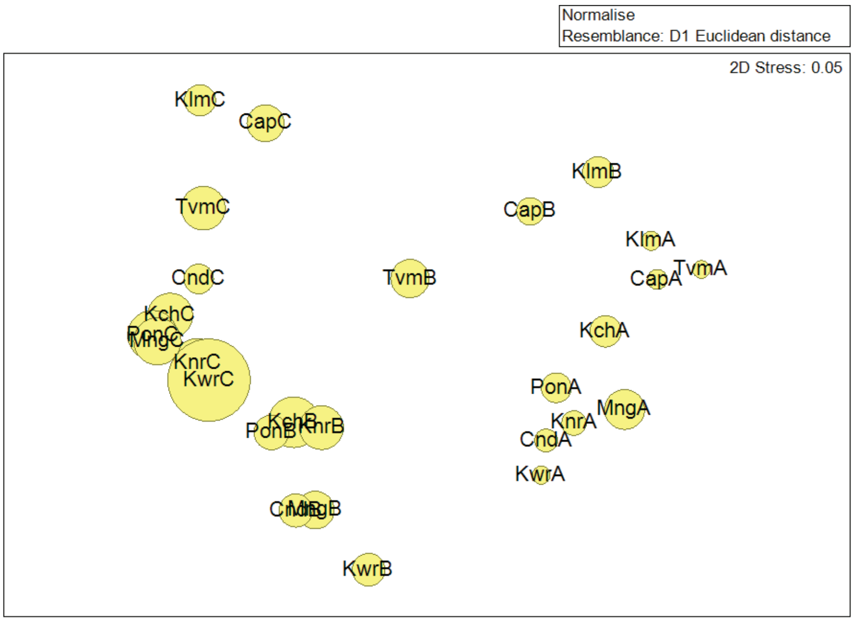

Figure 63. Mean body weight of polychaetes at each site
A: 200m, B: 500m, C: 1000m

The small sized fauna that dominated at the shelf edge were *Prionospio polybranchiata*, *Paraonis gracilis*, *Levinsenia oculata*, *Tharyx dorsobranchialis*, *T. annulosus*, *T. marioni* and *Cossura coasta*. *Aricidea fauveli*, *Aricidea* sp. 3 and *Aonidella cirrobranchiata* were also abundant in this region. The deeper region was dominated by maldanids, capitellids, lumbrinerids, terebellids, and ampharetids which are characterised by large body size.

V. 2. 6. Polychaete communities in relation to environment

Statistical analysis was made in which the biological parameters, namely number of species (S), species richness (d), diversity (H'), evenness (J') and dominance (λ') were tested for significant correlation with the environmental variables using Pearson's correlation. Table 22 gives the Pearson correlation coefficients and the corresponding significance levels for all possible combinations between polychaete diversity indices and the suite of environmental parameters. Species evenness (J') and diversity (H') had a weak positive (J': r=0.406, p <0.001; H': r=0.223, p <0.001) correlation with depth. However, Margalef's species richness (d) did not show any significant correlation with depth.

There was a positive correlation of species number (S) with percentage sand (r=0.393, p <0.001), evenness with percentage of silt (r=0.288, p <0.05) and evenness with OM (r=0.316, p <0.001). There was significant negative correlation between species number and percentage silt (r=-0.530, p <0.001) and between evenness and percentage sand (r=-0.246, p <0.001). Diversity and species richness did not show any significant correlation with sand, silt, clay or organic content (P >0.05). Evenness (r=-0.425, p <0.001) and diversity (r=-0.262, p<0.05) showed a negative correlation with temperature. Species richness and diversity showed an increase with increase in DO (d: r=0.290, p=0.044; H', r=0.264, p=0.029). There was a marked decrease in species richness and species diversity (d: r=-0.522, p<0.001; H': r=-0.440, p<0.001) and a considerable increase in dominance (r=0.319, p=0.004) from south to north.

Further, BIOENV analysis was carried out using the 8 environmental variables with species abundance data [Table 23]. The result revealed that depth, sand and salinity were the best subset of environmental variables along with transects, that could explain most variation in faunal composition among the sites and the Spearman correlation coefficient, ρ was 0.362.

Non metric multidimensional scaling (nMDS) was employed to investigate the patterns of variation of the environmental data among the stations [Figure 64b]. The dissimilarity of environmental parameters between stations were measured based on normalized Euclidean distance. The MDS ordination (stress value 0.12) showed apparent differences in the environmental characteristics between the three different depth categories except at Cape, Trivandrum and Kollam. In these 3 transects, the shelf edge and upper slope region (200m and 500m) had more or less similar textural composition, and these formed one cluster, distinct from the remaining 200m and 500m. Even the 1000m depth stations were grouped separately from the 1000m stations of other transects. The pattern of distribution of polychaete communities [Figure 64a] thus corresponded well to the pattern of variation in sediment and environmental characteristics [Figure 64b].

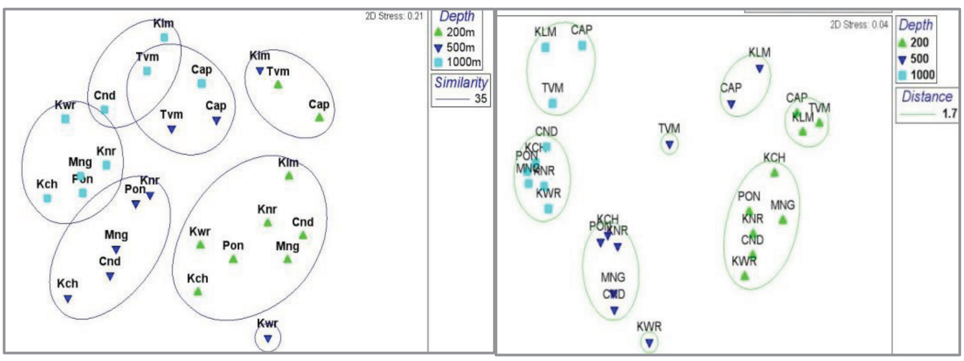

Figure 64. Comparison of nMDS of polychaetes species abundance (a) & environment data (b)

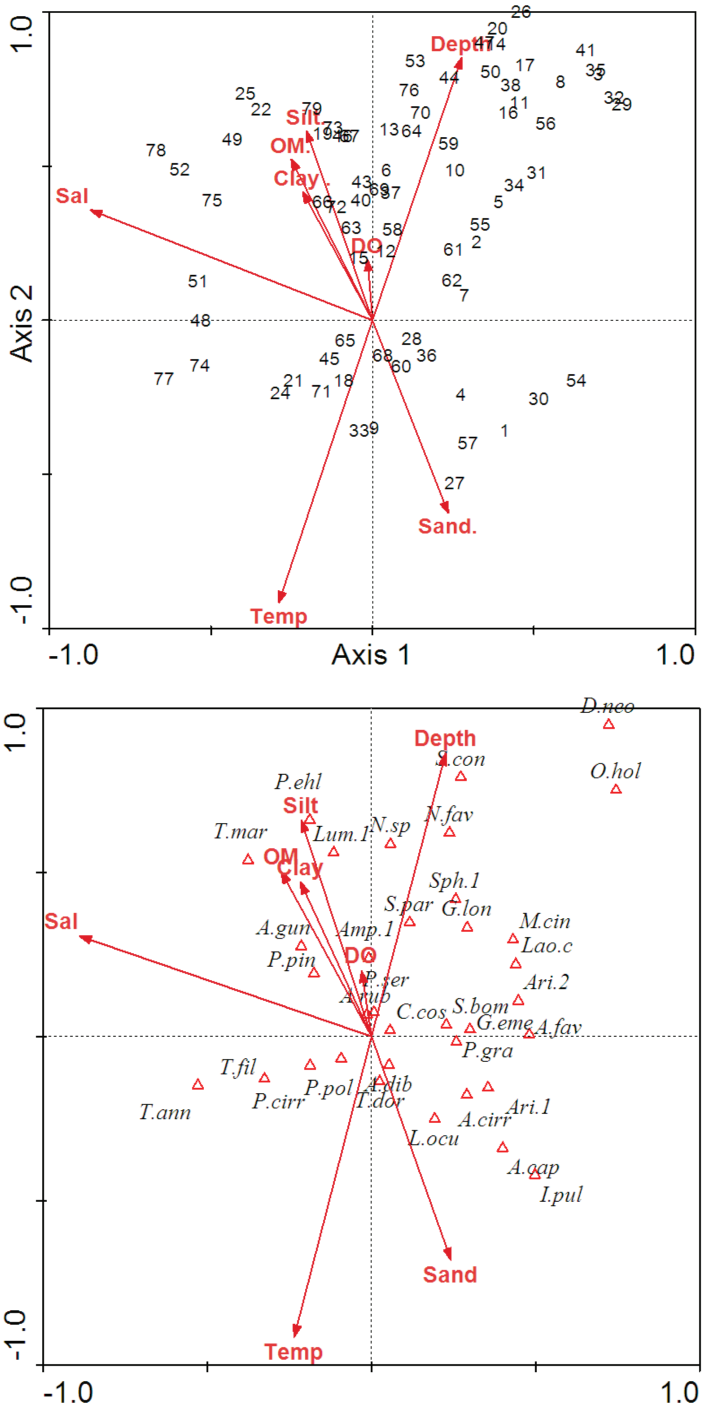

Figure 65: Canonical Correspondence Analysis (CCA) showing scatter plot for 79 stations* in the SEAS (a) & CCA showing 31 most important infaunal species (b)**

* Station numbers given in Tables 2-4

** List of important species & abbreviation given in Table 25

The Canonical Correspondence Analysis (CCA) was carried out to determine which environmental factors influence the distribution of the selected species [Table 24 & Figure 61]. Monte Carlo permutation test (with forward selection) was used to find out significant environmental variables responsible for the variance of species distribution ($P < 0.05$). The CCA axes 1 and 2 explained 27 and 22% of the species variation respectively. Axis 1 of the CCA ordination plot (eigenvalue 0.403) separated the low saline (<35) sites of the south (Cape, Trivandrum & Kollam) from the high-saline sites of the north (salinity, r=-0.8726) and all other environmental parameters contributed almost equally to this eigenvector except DO. The remaining sites were separated further by CCA axis 2 (eigenvalue 0.327), primarily on the basis of depth (r=0.8520) and depth-related variables viz., temperature (r=-0.9164), sediment texture (sand, r=-0.6253; silt, r=0.6142; clay, r=0.4153), organic matter (r=0.5222) and DO (r=0.1963).

The CCA axes 3 and 4 were capable of together explaining 13.3% of variation in the environmental parameters (eigenvalue 0.231 & 0.200). Axis 3 was influenced by sediment texture (sand, r=-0.641; silt, r=-0.5203; clay, r= -0.685), while axis 4 was influenced chiefly by organic matter content (r=0.6549). All four CCA axes showed high values of species environment correlation (r=0.853, 0.800, 0.701 and 0.757 for axis 1 to 4).

The shallow stations (200m) of the southern region had high sand content and relatively low DO values when compared to 500m and 1000m stations. In the stations-environment CCA biplot, these stations were strongly influenced by sand% and temperature; and they were positioned in the lower right quadrant [Figure 65]. The polychaete species *Isolda pulchella*, *Paraonis gracilis, Aonidella cirrobranchiata*, *Aricidea* sp. 1, *A. capensis*, *Levinsenia oculata*, *Tharyx dorsobranchialis* and *Aglaophamus dibranchis* which were well distributed at these sites, were found to be strongly linked to the sand and temperature. However, the 500m and 1000m sites of the same transects had comparatively high DO; and sand was the dominant sediment fraction at 500m (upper right quadrant). The species which were influenced by these conditions include *Diopatra neapolitana* (Cape, 1000m), *Onuphis holobranchiata* (Cape, 1000m), *Keferstenia cirrata*, *Glycera longipinnis*, *Goniada eremita*, *Magelona cincta*, *Spiophanes bombyx*, *Aricidea fauveli* and *Aricidea belgicae*. Abundance of errants, in general, showed a positive relation with sand content and DO.

The 200m sites of the northern transects (Kochi to Karwar) were characterised by high salinity (especially towards the north) and relatively lower sand content and low DO; and they were placed in the lower left quadrant of the CCA ordination. The polychaete species showing high correlation with these conditions included *Prionospio cirrifera, P. polybranchiata, Tharyx annulosus* and *T. filibranchia.* In general, at the deeper sites off Kochi to Karwar (excluding Coondapur and Karwar 500m) the silt and clay fractions were high, with high organic matter content and relatively high DO. These sites were placed in the upper left quadrant of the CCA ordination. These conditions were found to be linked with the distribution of species like *Prionospio ehlersi*, *Paraprionospio pinnata*, *Tharyx marioni, Nereis* sp., *Ninoe* sp., *Lumbrineris sp1 Notomastus fauveli*, *Amphicteis gunneri* and *Amphrete* sp. 1. The 500m sites of Coondapur and Karwar had very high salinity, low DO and relatively high silt, clay and organic content. Macrofaunal abundance was generally very low in this region. *Cossura coasta, Poeceliochaetus Serpens* and *Amphitrite* sp.1 distributed almost all environmental conditions.

V. 3. DISCUSSION

V. 3. 1. Patterns of polychaete diversity

In the present study, the density of polychaetes, their distribution pattern and diversity showed significant spatial variations (with respect to depth and latitude), while temporal variations were not found to be significant. Polychaete density decreased while species diversity increased with increasing depth. Species diversity increased from north to south, with highest values being recorded at Cape Comorin transect and lowest values at Karwar. Similarly, species richness (S and d) was highest in the southern transects and lowest at Karwar, with an exception at Kochi transect, where richness was unexpectedly low. Evenness increased with increasing depth and was invariably higher at the southern transects, while the lowest values were recorded at Coondapur. Conversely, high dominance was observed at the shelf edge and in the northern transects.

In general, the 200m sites of SEAS are located near the highly productive coastal region, from where substantial quantities of organic matter are delivered to the water column. The degradation of these organic materials leads to depletion of dissolved oxygen in the subsurface waters. The organic matter which reaches the surface sediments get mineralized quiet rapidly, which causes further decrease in dissolved oxygen in the near-bottom water. Most of these sites (200m) recorded oxygen value below 0.5ml l^{-1} (more than 1/3 of the stations sampled). In the northern transects, where the Arabian Sea OMZ impinges on the continental margin, severely oxygen depleted conditions were observed at the 200m, 500m and even 1000m sites, while considerably low oxygen conditions prevailed in the 200m sites of the southern transects as well. Redistribution and resuspension of organic matter in the surface sediments by turbidity currents at the shelf edge makes them more readily available for degradation. Organic matter that reaches the shelf edge via vertical fluxes is readily carried, by lateral advection, down the continental slope. Burial of OM to deeper layers of sediments in the shelf edge is also limited by high sand content of the sediments in this region. While the OM content was relatively lower at the 200m sites when compared to deeper sites, it was not substantially low (2.4%). Higher values of organic matter (OM) were encountered at the deeper sites here and DO values were above critical levels.

At high levels of productivity, diversity may decrease, possibly due to reduced spatial heterogeneity of food resources, changes in competitive structure, or enhanced environmental stress (Rosenzweig & Abramsky 1993, Levin *et al*. 2001, Levin *et al*. 2009), like low DO. Polychaete species showed moderate to low Shannon-Wiener diversity values at the 200m sites and the lowest values of the index reflected the marked numerical dominance of a few species. Macrofauna typically exhibit low species richness, high dominance and a predominance of polychaetes in OMZ settings (Levin 2003, Gallardo *et al*. 2004). High species diversity appeared to be maintained by the relatively dynamic hydrography combined with high productivity (e.g. Cape), whereas the heavy environmental stress, due to low bottom DO, impose a physical constraint on biota and it reduces the abundance and diversity of polychaete fauna (Thistle *et al*. 1985, 1991*,* Hughes *et al* 2009). Levin & Gage (1998), established an oxygen threshold (<0.45 mll^{-1}) above which effects of oxygen concentration on macrobenthic diversity are minor but below which oxygen becomes a critical factor and influences evenness and diversity. Similar to the Pakistan margin (Levin *et al*. 2009), species diversity and evenness in the present study was positively correlated with bottom DO but did not show any significant correlation with OM content. Levin & Gage (1998) suggested that DO controls the number of species that occur in a particular region, since the level of tolerance to hypoxia dictates the occurrence of species; whereas OM controls the abundance of hypoxia tolerant species.

The present results concur with this suggestion, as it was found that below this threshold of 0.45mll^{-1} along the SEAS continental margin, DO concentration was the most influential factor controlling the diversity and evenness. At 500 and 1000m, as DO starts to rise and stress due to low oxygen reduces, a variety of other environmental factors begin to exert an influence on diversity and additionally, habitat heterogeneity becomes more pronounced (Gooday *et al*. 2010). Species richness was found to be positively correlated with sand percentage and DO in the present study but was not positively correlated with quantity of organic matter. In the present study, the maximum OM percentage was observed in the deeper sites (the mid slope region) of the Eastern Arabian Sea. But the density and standing crop did not show any significant relation with OM% i.e., organic matter availability is not a limiting factor in the SEAS continental margin. Among the factors influencing diversity and evenness under such conditions, the quality of OM and nature of sediments are of particular importance (Gooday *et al*. 2010). The low species richness and diversity at the northern transects especially Karwar, is mainly due to the influence of extreme hypoxic condition in the eastern Arabian Sea. Density of macrofauna was very low at 200 and 1000m station of northern transects, during December 2003, and in this survey DO value was found to be very low at these stations. In general, increasing levels of environmental stress results in decrease in diversity (H'), decrease in species richness (d), decrease in evenness (J) and increase in dominance (Clarke & Warwick 2001) as observed in the present study. The area with intermediate levels of disturbance harbours diverse polychaete fauna (Snelgrove & Grassle 2001) as observed in the southern transects and deeper sites, where the DO level is comparatively high. Even in the southern transects, at shelf edge with low DO, some of the species showed high dominance.

V. 3. 2. Polychaete species assemblages

The Continental margins of SEAS encompass extensive, steep vertical gradients in environmental parameters such as temperature, DO, OM, sediment characteristics. These environmental gradients have a significant role in defining the community distribution pattern of soft bottom macrofauna (Diaz & Rosenberg 1995, Pearson & Rosenberg 1978, Snelgrove & Butman 1994, Laine 2003). The data for each site in the present study (6 grabs) were pooled, to obtain mean abundance of polychaete species for each site, since no temporal variations were observed. This evened out the more or less high variability among the collections and gave a more representative picture of the community at each site (Ellingsen 2001). Community analysis of polychaetes in the SEAS continental margin revealed the existence of 6 distinct assemblages in the three depth classes (27 sites). Distinct community patterns were observed in the region from Kochi to Karwar, with a regional cluster in the southern region (Cape to Kollam). At the shelf edge (200m), upper slope (500m) and deeper sites (1000m), distinct faunal assemblages were observed. The pattern of distribution of polychaete assemblages corresponded well to the pattern of variation in the measured sediment characteristics and environmental parameters, as in evident from the nMDS plots of environmental and polychaete abundance data. The shelf edge (200m) and upper slope (500m) sites in the study area were found to be under naturally disturbed condition due to low oxygen conditions, which were more intense in the transects north of Kochi.

A detailed analysis of regionalized data (northern and southern regions) showed good biological ordination with a reliable stress value, lower than 0.2 (Clark 1993). It was revealed that in the northern region, the major differences in the three depth classes were due to the abundance of dominant species among cirratulids (*Tharyx dorsobranchialis*, *T. annulosus*), spionids (*Prionospio polybranchiata*, *P. cirrifera*, *P. ehlersi*), paraonids (*Levinsenia oculata*, *Paraonis gracilis*), cossurids, capitellids and lumbrinerids, rather than the presence of rare species. The species *Prionospio polybranchiata*, *P. cirrifera* and *Paraprionospio pinnata* occurred in higher abundance at shallow depths (200m); and *Tharyx dorsobranchialis*, *T. annulosus*, *Paraonis gracilis* and *Levinsenia oculata* were also observed. All these species are relatively smaller in size, capable feeding from the interphase or surface layer of sediments, and some like *Paraprionospio pinnata* and *Prionospio ehlersi* have extended branchiae to enhance oxygen uptake. These species are best adapted for the prevailing conditions in the region – with high sand content, low DO level and relative high abundance of freshly deposited organic matter. In an environmentally disturbed or stressed area, high densities of small, fast growing and rapidly colonizing opportunistic species are likely to get established (Ellis *et al.* 2000, Levin *et al*. 2009).

The 500m site off Karwar also grouped with the 200m cluster; and at this site, a single species, *Tharyx marioni* dominated. Among the aforementioned species, *Prionospio polybranchiata* and *P. cirrifera* were less abundant at 500m in the northern transects, where silt was the predominant texture. The assemblages at this depth category were dominated by

Paraprionospio pinnata and *Prionospio ehlersi*, along with *Laonice* sp., *Magelona* sp., lumbrinerids, *Spiophanes* sp. 1 and *Amphicteis gunneri*. Paraprionospio pinnata is known to prefer silty sediments with high organic matter content (Sukumaran & Sarladevi 2009) and this species is also well suited to thrive under low oxygen conditions (Levin 2003). As reported by Ellis *et al.* (2000) moving further from an environmentally disturbed area, a transition zone occurs, which is still dominated by opportunistic species although not at such high densities. The abundance of these 'opportunistic' species decreased at the 1000m depth category, where a diverse assemblages of subsurface deposit feeders (cossurids, capitellids, and maldanids) and carnivores (nereids, lumbrinerids etc.) along with surface deposit feeders (terrebellids, ampharetids etc.) were observed. The aforementioned carnivores and surface deposit feeders are slow growing; large sized polychaetes (Ellis *et al.* 2000) and they were a major component of the assemblage at 1000m. This region is characterized by high percentage of silt, comparatively high oxygen, and stable bottom when compared to the shelf edge and upper slope region.

The sites located in the southern region (Cape to Kollam) aggregated as a single major cluster, distinct from the three clusters of the northern region; and within this, the three depth classes were clearly separated, with the exception of the 500m site off Kollam. The environmental as well as sediment characteristics at the three depths of the southern region were distinct from that of comparable depths in the north. Similar distinctions were evident in the species compositions as well, with some species being characteristic for the southern region. It is to be noted that the southern transects harbored most of the errant species encountered during the entire study. The assemblages at the shelf edge (200m) were distinct from those at the deeper sites, while there was no clear distinction between assemblages at the 500m and 1000m. Sediments in shelf edge and upper slope are dominated by sand fractions while silt increases progressively beyond 500m depth. Characteristic species such as *Aonidella cirrobranchiata, Magelona cincta, Laonice cirrata, Aricidea capensis, A.*

longobranchiata, Isolda pulchella, Keferstenia cirrata and *Cirrophorous branchiatus* were found in high abundance at 200m depths in the southern region.

The deeper sites had relatively lower abundance of *Aonidella cirrobranchiata, Tharyx dorsobranchialis, Aricidea capensis* and *Cirrophorous branchiatus*; and were also characterised by near absence of *Keferstenia cirrata* and *Isolda pulchella* making the assemblages here distinct from those at 200m. The characteristic deep-water species *Notomastus aberans* and *Cossura coasta* were also found in good numbers at these sites, along with maldanids, capitellids, *Ninoe sp.,* nereids and lumbrinerids. Thus, the deeper sites of the south were much more biologically similar to those of the north, but did not cluster together with them. This was due to the high species richness and density in the south (Cape, Trivandrum, Kollam). Some species like *Aonidella cirrobranchiata* form dominant components of polychaetes in the continental margin of the western Bay of Bengal; and *A. cirrobranchiata* was present only in the southern transects in the SEAS margin.

The distribution of these macrobenthic communities is correlated with the type of sediment, which is related to a wider set of environmental conditions, such as current speed and organic content of the sediment (Gray 1974, Creutzberg *et al*. 1984, Buchanan 1984, Snelgrove & Butman 1994). In the SEAS margin, bottom water temperature, salinity, DO, sediment texture and organic matter content all showed significant depth-associated trends while in the case of bottom water salinity and sediment texture (in particular, sand content), consistent latitudinal trends were also observed. The BIO-ENV analysis revealed that depth, sand (%) and salinity were the best subset of environmental variables to explain community patterns; and these parameters caused the best similarity between biotic and abiotic data. It should be noted that salinity emerged as an important factor due to significant depth-associated and latitudinal variations, rather than any direct influence of this parameter on the faunal composition. However, diversity differences between assemblages were associated, in major part, with variability in sediment composition and bottom water DO. In the individual correlation analysis, the influence of DO on diversity and richness was clearly observed. Distributions of benthic fauna in relation to sediment granulometric composition are delineated in numerous studies on the basis of substrate type (Gray 1974, Jayaraj *et al*. 2008b, Sanders 1968). The zoned distribution of species is mainly attributed to gradients in environmental parameters (Warwick 1988, Wei *et al*. 2010) that occur with depth, and affect the biology of marine organisms, their physiology and ecological interactions (Rex 1976*,* Carney 2005). Organic matter may serve as the food source to various benthic organisms, but since it contains an unknown refractile proportion it does not display as a strong correlation in this study. Absolute correlation between the community structure patterns with the environmental parameters in the SEAS was low, owing to regional north-south differences. In the Faroe-Shetland channel, (150-1000m) Narayanaswamy *et al*. (2005) reported a parabolic diversity pattern of polychaetes with maximum at 350-550m depth. Further, detailed analysis of the regionalized data revealed that hydrographical (temperature) and sedimentological (silt and clay) influenced the diversity and regional ecology. In the present study, distinct north-south differences in environmental conditions were observed, similar to the distinct temperature regimes and sediment texture patterns observed by Narayanaswamy *et al.* (2010) in the Faroe-Shetland Channel.

The grouping of sites into distinct clusters and geospatial region which was revealed in the environmental nMDS was strengthened by the results of the Canonical Correspondence Analysis (CCA). The CCA further provided a clear picture of the manner in which the environmental variables influenced species distribution. The CCA plot and Monte Carlo analysis showed that while temperature, sediment texture and organic matter varied in conjunction with depth (CCA axis 2), variation in salinity (CCA axis 1) was not solely depth-related. The intrusion of low-saline Bay of Bengal water, around the southern tip of India into the SEAS is known to occur (Prasannakumar *et al*. 2004) and high-saline Persian Gulf water in the northern transects resulted in a latitudinal distinction in the case of salinity. The species found in the shallow sites (200m) of the southern transects were closely associated with low salinity, high sand content and low organic matter; while those of the northern transects (200m) were linked with relatively lower sand content, higher salinity and higher organic content. The characteristic species of deeper sites (500m and 1000m) of the south were associated with low salinity, high DO, relatively finer sediments (compared to shallow sites) and higher organic matter. The species of the deeper slope in the north (500m & 1000m) were strongly associated with silt and clay sediments having very high organic matter, high salinity (500m) and relatively high DO (1000m). The strong linkage of certain species assemblages to the characteristic environments of certain regions or depths through the whole study (across 9 transects, 27 sites and 3 collections) is clear evidence for the adaptation and tolerance of specific fauna to particular environmental conditions.

V. 3. 3. Size characteristics of polychaetes

In the continental margin of SEAS, the organisms most abundant at the 200m depth are smaller in size and therefore have higher surface area to volume ratio. These locations were characterized by loose sandy sediments with biogenic materials like shell fragments, which provided ample interstitial spaces for these small sized organisms to occupy. Additionally, this is evidence for body size regulation in oxygen depleted areas (Veit-Köhler *et al*. 2009, Gooday *et al*. 2010, Levin 2003). These organisms belong to families Cirratulidae, Spionidae, Paraonidae and Cossuridae; which are found to be dominant members of macrofaunal communities in almost all continental margins, including Chile (Quiroga *et al*. 2005, Palma *et al*. 2005), Oman (Levin *et al*. 2000), Pakistan (Hughes *et al*. 2009) and India (Ingole *et al*. 2010).

While many studies have stressed the significant of body size of benthic fauna in OMZs little is known about the processes that modulate the distribution of body size within this region (Roy 2002, Quiroga *et al*. 2005). Some workers conclude that the pattern of body size distribution along bathymetric gradients is related to physiological and ecological factors or is determined by phylogenetic factors (Rex & Etter 1998, Rex *et al*. 1999); or influenced by availability of food (Theil 1975, 1979). Among the ecological factors, the DO concentration is believed to play an important role in determining body size of individuals (Chapelle & Peck 1999, McClain & Rex 2001). The influence of DO on body size is thought to be chiefly physiological, while other factors such as life history (Peters 1983, Warwick 1984), the physical characteristics of sediment (Schwinghamer 1981, Drgas *et al*. 1998, Duplisea 2000), the gradient of organic matter (Schwinghamer 1988) may also constrain the body size of fauna. In the SEAS continental margin, sediment texture and oxygen availability is considered to be an important factor determining the mean individual body weight. It was revealed that in the southern transects, where sand was the dominant textural class, the mean individual body size of organisms was low, even at 1000m depth. Smaller size-classes are important components of benthic communities in productive areas such as upwelling zones where high productivity-biomass ratios enhance energy flow and nutrient processing (Rowe & Menzel 1971, Peters 1983, Levin *et al*. 2000, 2002, Quiroga *et al*. 2005).

V. 3. 4. Food availability and feeding modes of polychaetes

The bathymetric distribution of polychaete feeding types is directly related to the quantity, quality, and position (buried or in benthic boundary layer) of organic matter available in the sediments. The surface deposit feeders or interphase feeders strongly dominate on the continental margin, below the water column where upwelling-related high primary production occurs (Levin *et al*. 2000). In the present study the most noticeable trend with depth was the increase in the carnivore (CVR) component beyond 200m, compensated by a proportional decrease in the surface deposit feeding component (SDF) and the gradual increase in the sub-surface deposit feeding (SSDF) component from shallow to deeper depths. All feeding types were well represented at 1000m. Such a trend is considered advantageous in a nutrient limited environment, like the mid shelf sediments which contain more refractory material than the shelf edge. Gaston (1987) also found that surface deposit feeders dominated in most areas on the continental shelf of the Middle Atlantic Bight. Similar observation was reported from Indian continental shelf (Jayaraj *et al*. 2007) and continental slope (Ingole *et al*. 2010). High numbers of this group of polychaetes were related to recently settled food in a food-limited area (Gaston 1987). Absence or near absence of true suspension feeders in the study area revealed the existence of physical condition not suitable for them.

The distribution of trophic guilds is based on many environmental and sedimentary parameters (Probert 1984, Pearson & Rosenberg 1987, Gaston 1987) which are intimately associated. Factors such as bottom stability, organic content, oxygen concentration and grain size of sediments are found to be significantly correlated with trophic composition of benthic communities (Gaston 1987). The combined effect of these factors is evident in the feeding guild organization in the SEAS margin. The positive relationship between organic matter and deposit feeders, and the increase of carnivores where deposit feeders were less abundant, has been observed at the Oman and Crete margins (Levin *et al*. 2000, Tselepides *et al*. 2000). Surface deposit feeders (SDF) prefer to feed directly on newly deposited organic matter at the sediment-water interface, while sub-surface deposit feeders (SSDF) primarily feed on older organic matter below the surface sediments (Rosenberg 1995, Muniz & Pires 1999, Dolbeth *et al*. 2007). That is to say, SSDF are often associated with areas with relatively low hydrodynamic impacts and high organic matter content in the sediments (Rosenberg 1995, Muniz & Pires 1999, Dolbeth *et al*. 2007). Accordingly, SSDF guild was more abundant in the deeper areas, below 500m depth, which were characterized by fine clayey silt sediments.

A major component of organic materials in the mid-slope sediments are refractory in nature. Under such conditions, adaptations for carnivory, scavenging and non-selective deposit feeding modes are advantageous. The relative abundance of carnivores increased towards the deeper sites; and at the shallow and intermediate depths, it decreased from south to north. This low relative abundance of this group at the shallow sites and towards the north suggests that this group may be dependent on high DO concentrations. As in the present study, the proportion of carnivores increased with depth, along with a proportionate decline in the deposit-feeding component (Ingole *et al*. 2010). In this study, high dominance of cirratulids and paraonids was observed on the shelf edge and upper slope region of southern transects. These organisms are capable of feeding on the recently settled food from the interstitial space in which they reside. There was no significant difference in the relative abundance of SDF between surveys. However, there was a considerable increase in this feeding guild from first to third survey. Similarly there was considerable increase in OM content of surface sediments from first survey to third survey.

V. 3. 5. Anthropogenic and natural disturbances

The well-being of marine ecosystems has suffered severe damage due to human intervention (Menon *et al*. 2000*,* Martin *et al*. 2008, 2011). Majority of the benthic fauna are sedentary and sessile; and thus, cannot avoid any environmental perturbation (Danulat *et al*. 2002), hence they are sensitive indicator of changes in the environment caused by natural and anthropogenic disturbances. The impacts of anthropogenic activities have previously been thought to be negligible in the deep sea, but it has now been revealed that continental slope environments are often closely coupled to events on land and adjacent coastal systems (Menot *et al*. 2010). In the present study, low density, depressed richness and diversity was observed at Kochi, when compared to adjacent transects. This could possibly be due to the unhealthy nature of the seabed off Kochi as a result of enhanced anthropogenic activity along this coastal area. The macrofaunal community off Kochi is species poor and mainly consists of sub-surface deposit feeding (SSDF) species like *Cossura coasta*; capitellids, spionids in very low abundance and carnivores like *Aglaophamus dibranchis* and *Sigambra parva* that are adapted for adverse environmental conditions. In the 200m site off Kochi (first survey), the SSDF species *Cossura* *coasta* was found to be the dominant component of macrofauna (>60%), while macrofauna were scarce at this site in the other two surveys.

The Cochin estuary is one of the largest estuarine systems along the west coast of India, with seven rivers discharging their nutrient load into it (Madhu *et al*. 2007). The anthropogenic activities in this region generates 104×103 m^3 of industrial and 260m^3 of domestic wastes per day, which are being released directly into the estuary without any treatment (Balachandran *et al*. 2006, Martin *et al*. 2008). Excess organic materials, pollutants and toxicants are transported away from the coasts by cross shelf and down slope transport. Continental margins are considered as depositional centers for pollutants produced by human activities and it is evident that bathyal regions are the final dumping site of organic matter as well as pollutants (Menot *et al*. 2010).

In the upper slope region off Kochi, benthic organisms are subjected to burial risk and sediment instability due to high concentration of suspended particles discharged from the estuary. The accumulation rate of sediment can also affect benthic fauna, since high sedimentation rates are hazards to less motile and sessile organisms. Periodic disturbance by sediment slides and turbidity flows (Rao & Wagle 1997) could potentially affect macrofaunal communities in continental margin environments (Levin *et al.* 2001). Such disturbances tend to reduce habitat heterogeneity in the region, which is essential for supporting species diversity. It may also be noted that the slope off Kochi is relatively steeper, particularly between the 200m and 500m site, when compared to other transects. This may have implications on the sedimentation rates in the upper slope off Kochi. Moreover, cossurids which were dominant among polychaetes off Kochi is considered to be an indicator of sediment instability (Ellis *et al.* 2000) and also one of the characteristic species of bathyal fauna impacted with environmental stress (Levin *et al*. 1997, Rao 2009). Blake & Grassle (1994) observed that cossurids were dominant in the slope off the Carolinas (North Atlantic) where the sedimentation rates were high. In the present study, *Cossura coasta* was found in high abundance at Kochi, Kollam, Ponnani and Karwar. These are all areas with estuarine and river discharges, and therefore the sedimentation rates at these sites is likely to be high.

Both natural and anthropogenic stressors are important in defining the structure of macrofauna. The 200 and 500m sites of northern transects were subjected to a degree of natural stress due to the impingement of the Arabian Sea OMZ (Ingole *et al*, 2010), particularly in surveys I and III. In general, hypoxic conditions such as those off Karwar have well defined impacts on the macrofaunal abundance and diversity (Childress & Siebel 1998, Gray *et al*. 2002, Levin 2003, Stramma *et al*. 2010). However, the polychaete richness and diversity at Karwar were higher than that of Kochi.

Sediment characteristics of Karwar and Kochi provided no indication of differences in environmental factors that could affect macrofaunal abundance and diversity. Off Karwar, at the 500m site, abundance of polychaetes was high, and dominance was also found to be high; drawing a similarity with the upper slope (200m) sites of the study area. The dominance of an indicator species, *Cossura coasta* (Levin *et al*. 1997, Rao 2009, Jayaraj *et al*. 2007) at Kochi and Karwar proves that these areas are subject to natural or anthropogenic impacts, if not both. The exact nature and magnitude of these impacts could not be determined by the measured data, and further study is required in this region. The areas are also to be studied from the perspective of anthropogenic impact rather than physical process on the sedimentary environment, such as estuarine sedimentation.

V. 3. 6. Comparisons with other continental margin studies

Owing to the methodological differences, comparison of the quantitative composition of polychaetes in the present study with studies from other continental margins (Pakistan, Oman, Peru, Chile etc.) was not attempted. However, the qualitative nature as well as the biological features can be compared. Global bathyal data on benthic faunal abundance and biomass indicate a reduction in density at the OMZ core (Rosenberg *et al*. 1983, Mullins *et al*. 1985*,* Wishner *et al*. 1995) and an increase at the OMZ boundaries (Levin 2003). Quiroga *et al*. (2005) concluded that disregarding location, macrofauna on the continental margins exposed to OMZs, are biologically similar in terms of presenting high densities and similar species compositions. In the Peru margin (Palma *et al*. 2005), the dominant species were similar to species found in the present study, and included *Cossura chilensis*, *Paraprionospio pinnata*, *Cirratulus cirratus* and *Magelona phyllisae* which contributed over 80% of fauna in the OMZ.

Although densities are often depressed where oxygen levels are lowest (Levin, 2003), the Pakistan Margin appears unique in having a very low macrofaunal density within the OMZ core (Hughes *et al.* 2009). The near absence of macrofauna in the Pakistan margin beyond 700m depths suggests that the oxygen levels in this site were below a critical threshold (Woulds *et al*. 2007, 2009*,* Levin *et al*. 2009). On the Volcano 7 seamount off Mexico, average macrofaunal densities on the lower summit (770–850m) were much higher than on the upper summit, flank and base of the seamount. The oxygen levels were lowest at the upper summit (Levin *et al*. 1991).

In the Pakistan margin, polychaetes, crustaceans and molluscs exhibit reduced species richness within the OMZ (Hughes *et al.* 2009, Levin *et al.* 2009). Nemertines have been reported in high abundance in the continental margin of Oman (Levin *et al*. 2000) and Pakistan (Hughes *et al*. 2009); and in the present study also, this group was represented in good numbers between 200 and 1000m depths, with relatively higher abundance at the deeper sites (1000m). At comparable depths, Shannon–Wiener diversity (at common logarithmic base 2) was higher on the Oman margin (4.1 at 1000m off Oman compared with ~2.0 at 940m off Pakistan). As in the present study, dominance of polychaete species in the Pakistan margin was found to be negatively correlated with water depth and DO while evenness showed a positive correlation with depth (Levin *et al*. 2009). On the Pakistan margin, polychaetes accounted 32-87% of total density while they accounted for 90-96% in the Oman margin. In the OMZ core region

(300m) of Pakistan margin 3 families dominated viz. Paraonidae, Pilargidae and Spionidae; but in the present observation, dominance of Spionidae, Cirratulidae, Paraonidae, and Cossuridae were recorded in the less oxygenated 200m depth category. While pilargids were represented in the samples, their dominance was not observed. At the 1200m depths of Pakistan margin, cirratulids, spionids were the dominant groups while these families were rare at 940m. At the 1000m depth class cossurids, capitellids, cirratulids, maldanids and nereids were dominated in the present study.

Spionidae is one of the most consistently well represented families along with Cirratulidae on the upper OMZ (400–700m) off Oman (Levin *et al*. 2000), and this was the case in the present study also. Both families were also important at the shallowest Pakistan station (140m) and near the lower OMZ boundary (1200m) (Hughes *et al*. 2009). In the SEAS margin, Spionidae and Cirratulidae were the dominant families along with Paraonidae. Cossuridae were dominant in the lower part of the slope (1000m), although they were also present in large numbers in the 200m sites off Kochi, Kollam, Ponnani and Karwar. Cossuridae are common in many bathyal OMZs, including the Pakistan margin (Hughes *et al*. 2009) where they are present at depths of 940–1200 m, both areas with high organic carbon and also off central Chile (Blake & Grassle 1994, Gallardo *et al.* 2004*,* Palma *et al.* 2005). The abundance of capitellids at 140 and 1200m off Pakistan contrasts with Oman (Levin *et al*. 2000) but is paralleled on the Chile margin (Gallardo *et al*. 2004) and at 1000m depths in the SEAS margin as well. Polychaetes as a group, were abundant in the OMZ core (100–200 m) off Central Chile (Gallardo *et al*. 2004) and off Peru (Giere & Krieger 2001). Off Chile, the Paraonidae were abundant at sites above and below the OMZ regions as well as the upper shelf and the basin (Gallardo *et al*. 2004). *Paraprionospio pinnata*, which is known to tolerate low oxygen concentrations, was abundant at the OMZ core (Gallardo *et al*. 2004). The dominance of *P. pinnata* has also been reported within the OMZ off Concepcion (Palma *et al*. 2005).

Studies by Ingole *et al.* (2010) on the Indian continental margin at 14ºN revealed depressed diversity and species richness at 500m and 1000m. According to this study, the upper slope region was dominated by spionids (*Paraprionospio pinnata*), and mid slope fauna were dominated by cossurids and cirratulids (1001m). Capitellids were the next most dominant family in their study. The highest diversity and species richness was observed in the basin (2001m), rather than the shallower depth (34m). In the present study, similar observations were made along the same transect (Coondapur), where lowest species richness and diversity was recorded at the 500m depth site.

The concurrent studies conducted by Rao (2009), along the north east slope of Bay of Bengal with the same sampling gear and methodology, also revealed some interesting results. In the upper slope (~200m) sites, where the impingement of OMZ was noticed, polychaetes showed high dominance and constituted 98% of the total macrofauna. Among them *Aonidella cirrobranchiata, Cossura coasta* and cirratulids showed high abundance, and together they constituted 66-98% of the total polychaete abundance. The percentage contribution of polychaetes was lowest at 1000m (62%) and highest at intermediate depth (~75%). Spionidae, Cossuridae and Cirratulidae accounted for most of the polychaetes between 200-500m, Paraonidae, Trochochaetidae and other polychaetes (e.g. Amphinomidae, Eunicidae and Nereidae) appeared to be important at 1000m. The results of the present study were corroborated with that of the Bay of Bengal study. Low species richness and diversity was observed at 200m depth in the Bay of Bengal when compared with 500m and 1000m. Evenness was very low on the upper slope and species number and species richness decreased with increasing depth. This study also revealed a latitudinal gradient in diversity as in the SEAS margin, with high diversity in the southern transects (Divi Point, Kakinada, and Visakhapatnam) than northern transects (Barua, Chilka and Paradeep). *Cossura coasta*, *Sigambra parva*, *Paraprionospio pinnata* and *Aonidella cirrobranchiata* were most important species in the north western Bay of Bengal. The first three species were important components of macrofauna in the entire SEAS margin, and *Aonidella cirrobranchiata* was important in the southern region of SEAS. Diversity and species richness across the upper boundary of the Bay of Bengal OMZ strongly correlated with water depth and bottom DO (Rao 2009, Gooday *et al*. 2010).

TABLE 18. Diversity indices of polychaetes during FORVSS Cruise 219 & 225

Station		S	N	d	J'	H'(log_2)	Lambda'
1	**Cap-200m***	35	1533	4.636	0.624	3.198	0.183
2	**Cap-500m***	35	275	6.053	0.820	4.205	0.090
3	**Cap-1000m***	40	365	6.610	0.750	3.992	0.141
4	**Tvm-200m***	23	715	3.347	0.684	3.092	0.189
5	**Tvm-500m***	26	170	4.868	0.911	4.284	0.061
6	**Tvm-1000m***	17	82.5	3.626	0.899	3.673	0.093
7	**Klm-200m***	15	715	2.130	0.772	3.017	0.165
8	**Klm-1000m***	18	395	2.843	0.768	3.204	0.156
9	**Kch-200m**	10	1620	1.218	0.496	1.649	0.486
10	**Kch-500m**	9	40	2.169	0.900	2.852	0.151
11	**Kch-1000m**	8	22.5	2.248	0.983	2.948	0.096
12	**Pon-200m**	14	120	2.715	0.769	2.926	0.194
13	**Pon-500m**	27	365	4.407	0.911	4.334	0.060
14	**Pon-1000m**	16	225	2.770	0.871	3.483	0.112
15	**Knr-200m**	28	597.5	4.224	0.781	3.753	0.106
16	**Knr-500m**	25	240	4.379	0.833	3.868	0.102
17	**Knr-1000m**	5	25	1.243	1.000	2.322	0.167
18	**Mng-200m**	21	717.5	3.041	0.594	2.607	0.308
19	**Mng-500m**	16	165	2.938	0.824	3.298	0.134
20	**Mng-1000m**	7	70	1.412	0.841	2.360	0.244
21	**Cnd-200m**	19	770	2.708	0.623	2.647	0.243
22	**Cnd-500m**	8	330	1.207	0.569	1.707	0.483
23	**Cnd-1000m**	1	15	0.000	0.000	0.000	1.000
24	**Kwr-200m**	25	332.5	4.133	0.777	3.608	0.114
25	**Kwr-500m**	9	310	1.395	0.324	1.025	0.733
26	**Kwr-1000m**	2	10	0.434	1.000	1.000	0.444

* indicates sites sampled during Cruise 225

TABLE 19. Diversity indices of polychaetes during FORVSS Cruise 228 & 233

Station		S	N	d	J'	H'(log_2)	Lambda'
27	**Cap-200m**	33	1423	4.408	0.511	2.579	0.357
28	**Cap-500m**	32	620	4.821	0.817	4.084	0.095
29	**Cap-1000m**	41	390	6.704	0.898	4.809	0.044
30	**Tvm-200m**	13	225	2.216	0.782	2.895	0.185
31	**Tvm-500m**	26	208	4.686	0.887	4.171	0.066
32	**Tvm-1000m**	31	180	5.777	0.908	4.499	0.055
33	**Klm-200m**	16	1413	2.068	0.515	2.060	0.350
34	**Klm-1000m**	34	385	5.543	0.893	4.544	0.053
35	**Kch-200m**	25	170	4.673	0.917	4.260	0.058
36	**Kch-500m**	9	90	1.778	0.812	2.575	0.203
37	**Kch-1000m**	15	105	3.008	0.841	3.285	0.143
38	**Pon-200m**	13	118	2.518	0.702	2.596	0.259
39	**Pon-500m**	15	423	2.316	0.751	2.935	0.173
40	**Pon-1000m**	18	128	3.507	0.873	3.641	0.106
41	**Knr-200m**	21	135	4.077	0.933	4.098	0.063
42	**Knr-500m**	20	988	2.756	0.703	3.038	0.182
43	**Knr-1000m**	27	298	4.565	0.798	3.794	0.113
44	**Mng-200m**	24	178	4.441	0.879	4.029	0.080
45	**Mng-500m**	16	1223	2.110	0.542	2.167	0.322
46	**Mng-1000m**	15	135	2.854	0.877	3.428	0.109
47	**Cnd-200m***	20	130	3.903	0.804	3.476	0.150
48	**Cnd-500m***	23	1150	3.122	0.704	3.186	0.181
49	**Cnd-1000m***	17	243	2.914	0.830	3.393	0.122
50	**Kwr-200m***	21	178	3.862	0.771	3.385	0.187
51	**Kwr-500m***	12	203	2.071	0.717	2.571	0.222
52	**Kwr-1000m***	12	503	1.769	0.570	2.044	0.329

* indicates sites sampled during Cruise 228

TABLE 20. Diversity indices of polychaetes during FORVSS Cruise FORVSS 254

Station		S	N	d	J'	H'(log_2)	Lambda'
54	**Cap-200m**	36	1075	5.014	0.747	3.860	0.114
55	**Cap-500m**	14	185	2.490	0.818	3.113	0.179
56	**Cap-1000m**	13	110	2.553	0.941	3.482	0.095
57	**Tvm-200m**	35	755	5.131	0.817	4.189	0.096
58	**Tvm-500m**	28	295	4.748	0.782	3.760	0.122
59	**Tvm-1000m**	21	107.5	4.276	0.933	4.097	0.063
60	**Klm-200m**	17	907.5	2.349	0.384	1.571	0.593
61	**Klm-1000m**	39	397.5	6.349	0.840	4.442	0.074
62	**Kch-200m**	7	57.5	1.481	0.932	2.616	0.165
63	**Kch-500m**	13	185	2.299	0.784	2.902	0.197
64	**Kch-1000m**	12	37.5	3.035	0.964	3.457	0.078
65	**Pon-200m**	16	1400	2.071	0.666	2.666	0.223
66	**Pon-500m**	7	60	1.465	0.921	2.585	0.181
67	**Pon-1000m**	12	75	2.548	0.841	3.013	0.171
68	**Knr-200m**	19	1120	2.564	0.711	3.022	0.191
69	**Knr-500m**	12	210	2.057	0.785	2.815	0.198
70	**Knr-1000m**	15	82.5	3.173	0.906	3.541	0.102
71	**Mng-200m**	16	338.3333	2.576	0.798	3.193	0.134
72	**Mng-500m**	15	77.5	3.218	0.882	3.445	0.119
73	**Mng-1000m**	15	80	3.195	0.887	3.464	0.108
74	**Cnd-200m**	9	2087.5	1.047	0.423	1.341	0.593
75	**Cnd-500m**	13	57.5	2.962	0.932	3.447	0.092
76	**Cnd-1000m**	19	185	3.448	0.911	3.869	0.088
77	**Kwr-200m**	7	275	1.068	0.720	2.022	0.289
78	**Kwr-500m**	9	575	1.259	0.584	1.850	0.371
79	**Kwr-1000m**	9	22.5	2.569	1.000	3.170	0.070

TABLE 21. Feeding guild of polychaete families

Family	Feeding Guild
Pholoidae	Carnivore (CVR)
Polynoidae	Carnivore (CVR)
Sigalionidae	Carnivore (CVR)
Chrysopetalidae	Carnivore (CVR)
Amphinomidae	Carnivore (CVR)
Phyllodocidae	Carnivore (CVR)
Alciopidae	Carnivore (CVR)
Pilargidae	Carnivore (CVR)
Hesionidae	Carnivore (CVR)
Syllidae	Carnivore (CVR)
Nereididae	Carnivore (CVR)
Nephtyidae	Carnivore (CVR)
Paralacydoniidae	Carnivore (CVR)
Glyceridae	Carnivore (CVR)
Goniadidae	Carnivore (CVR)
Eunicidae	Carnivore (CVR)
Onuphidae	Carnivore (CVR)
Lumbrineridae	Carnivore (CVR)
Oenonidae	Carnivore (CVR)
Dorvilleidae	Surface deposit feeder (SDF)
Spionidae	Surface deposit feeder (SDF)
Magelonidae	Surface deposit feeder (SDF)
Cirratulidae	Surface deposit feeder (SDF)
Poecilochaetidae	Surface deposit feeder (SDF)
Chaetopteridae	Surface deposit feeder (SDF)
Orbiniidae	Surface deposit feeder (SDF)
Paraonidae	Surface deposit feeder (SDF)
Opheliidae	Sub-surface deposit feeder (SSDF)
Cossuridae	Sub-surface deposit feeder (SSDF)
Capitellidae	Sub-surface deposit feeder (SSDF)
Maldanidae	Sub-surface deposit feeder (SSDF)
Flabelligeridae	Surface deposit feeder (SDF)
Sternaspidae	Sub-surface deposit feeder (SSDF)
Pectinariidae	Surface deposit feeder (SDF)
Ampharetidae	Surface deposit feeder (SDF)
Trichobranchidae	Surface deposit feeder (SDF)
Terebellidae	Suspension feeder (SF)
Sabellidae	Suspension feeder (SF)
Sabellariidae	Suspension feeder (SF)
Serpulidae	Suspension feeder (SF)

TABLE 22. Pearson correlation of diversity indices, feeding guild composition (%) & body size with environmental variables

	Depth	Clay	Silt	Sand	OM	Temperature	Salinity	DO	Transect
S	-0.084	*-0.266*	**-0.392**	**0.393**	*-0.231*	0.055	**-0.461**	*0.233*	**-0.536**
N	**-0.595**	**-0.336**	**-0.530**	**0.524**	**-0.418**	**0.650**	-0.043	-0.067	-0.118
d	0.141	-0.166	-0.190	0.201	-0.036	-0.173	**-0.481**	**0.290**	**-0.522**
J'	**0.406**	0.051	*0.288*	*-0.246*	**0.316**	**-0.425**	-0.201	0.137	-0.171
H'	*0.223*	-0.114	-0.022	0.051	0.118	*-0.262*	**-0.393**	*0.264*	**-0.440**
λ'	-0.193	0.104	-0.056	0.015	-0.185	0.213	*0.281*	-0.179	**0.319**
CVR	**0.549**	0.208	*0.262*	*-0.271*	0.166	**-0.518**	**-0.315**	*0.267*	-0.162
SSDF	**0.515**	*0.243*	**0.380**	**-0.376**	**0.353**	**-0.434**	*-0.238*	**0.316**	-0.029
SDF	**-0.700**	**-0.288**	**-0.430**	**0.429**	**-0.361**	**0.623**	**0.362**	**-0.390**	0.120
SF	-0.085	**-0.309**	-0.165	*0.222*	-0.025	0.043	-0.031	-0.034	-0.111
MIBW	**0.353**	0.216	**0.323**	**-0.322**	*0.258*	**-0.336**	-0.011	-0.132	0.172

Bold: p<0.01, *Italics*: p<0.05

TABLE 23. BIOENV Results (Spearman rank correlation)

Correlation	Variables
0.362	Depth, Sand, Salinity
0.349	Sand, Salinity
0.339	Depth, Sand, Temperature, Salinity
0.338	Sand, Temperature, Salinity
0.336	Depth, Sand, OM, Salinity
0.324	Sand, OM, Salinity
0.322	Depth, Sand, Temperature, Salinity
0.319	Sand, Silt, OM, Salinity
0.317	Depth, Sand, OM, Temperature, Salinity
0.310	Depth, Clay, Sand, Salinity

TABLE 24. Canonical Correspondence Analysis (CCA) Results

Axes	1	2	3	4	Total inertia
Eigenvalues	0.401	0.324	0.224	0.196	6.157
Species-environment correlations	0.852	0.796	0.689	0.75	
Cumulative percentage variance:					
Species data	6.5	11.8	15.4	18.6	
Species-environment relation	27.2	49.1	64.3	77.6	
Sum of all eigenvalues	6.157				
Sum of all canonical eigenvalues	1.476				

TABLE 25. Subset of polychaetes species used for Canonical Correspondence Analysis (CCA)

Sigambra constricta	(S.con)	*Tharyx annulosus*	(T.ann)
Sigambra parva	(S.par)	*Tharyx dorsobranchialis*	(T.dor)
Nephtys dibranchis	(A.dib)	*Tharyx filibranchia*	(T.fil)
Glycera longipinnis	(G.lon)	*Tharyx marioni*	(T.mar)
Goniada emerita	(G.eme)	*Poecilochaetus serpens*	(P.ser)
Diopatra neapolitana	(D.neo)	*Aricidea fauveli*	(A.fav)
Onuphis holobranchiata	(O.hol)	*Aricidea* sp. 1	(Ari.1)
Lumbrineris sp. 1	(Lum.1)	*Aricidea (Allia) belgicae*	(Ari.2)
Ninoe sp.	(N.sp)	*Aricidea (Aricidea) capensis*	(A.cap)
Aonidella cirrobranchiata	(A.cirr)	*Levinsenia oculata*	(L.ocu)
Laonice cirrata	(Lao.c)	*Paraonis gracilis*	(P.gra)
Paraprionospio pinnata	(P.pin)	*Cossura coasta*	(C.cos)
Prionospio cirrifera	(P.cirr)	*Notomastus fauveli*	(N.fav)
Prionospio (Prionospio) ehlersi	(P.ehl)	*Ampharete* sp. 1	(Amp.1)
Prionospio polybranchiata	(P.pol)	*Amphicteis gunneri*	(A.gun)
Spiophanes bombyx	(S.bom)	*Isolda pulchella*	(I.pul)
Spiophanes sp. 1	(Sph.1)	*Amphitrite* sp.1	(A.rub)
Magelona cincta	(M.cin)		

Chapter VI

SUMMARY & CONCLUSION

The continental margins are geologically complex and hydrodynamically active regions of the ocean, where vital biogeochemical processes take place from a global perspective. The Eastern Arabian Sea is one of the most productive regions of the world, and as a result, vast amount of organic matter is supplied to the sub surface waters and sea bed of the Arabian Sea. The role of benthos in biogeochemistry and energy transfer in such productive region is pivotal, since the bulk of remineralization of detritus in the marine realm takes place in the sediments. Being food sources for many organisms in the benthic realm and also periodically supplying meroplankton to the water column, benthos are important links in marine food webs and are key players in bentho-pelagic coupling.

Despite the worldwide interest in the benthos of this region, the fauna of the continental margins around the Arabian Sea, particularly within the Indian Exclusive Economic Zone (EEZ), remain among the most poorly studied areas of the world. Some general ecological and faunal surveys have been carried out in the estuarine and shallow coastal areas in the South Eastern Arabian Sea (SEAS), and also on the continental margins. Between 1997 and 2002, the continental shelf (30 to 200m) of India was subject to detailed survey, with regard to benthos, under the CMLRE-MoES funded multi-institutional research project on benthic productivity. In the period 2002-2007, this study was extended to the continental slope (from 200 to 1000m), and the present study forms a part of this programme.

In this study, data on faunal abundance, standing crop and faunal composition, together with sedimentary and environmental parameters were collected from three depths (200m, 500m & 1000m) in nine bathymetric transects along the South Eastern Arabian Sea (from Cape Comorin to Karwar) during three surveys. The data was analysed with the aim of understanding the patterns in distribution of macrofauna over the continental margin of the South Eastern Arabian Sea (SEAS) and to delineate the environmental parameters that influence the standing crop and faunal composition. Special emphasis was placed on the diversity, distribution and community structure of polychaetes, as they form the dominant group of macrofauna in the SEAS (71%).The major environmental factors that regulate the distribution of this faunal group in the SEAS were also examined.

As expected, the temperature of bottom water decreased significantly with depth; but there was no marked temporal or latitudinal variation. While the salinity of bottom water varied within a narrow range, the variations with depth and latitude were consistent and therefore, significant. Salinity of bottom water was lowest at 1000m and highest at 500m, with intermediate values at 200m. A consistent latitudinal trend of increasing salinity from south to north was observed, throughout the study, as a result of infiltration of high saline Persian Gulf and Red Sea water from the north and low saline Bay of Bengal water from the south.

The shelf edge region of the study area was characterised with relatively low oxygen conditions, as a result of the degradation of large quantities of organic matter which is delivered from the highly productive coastal area. In the northern part of the study area (from Kochi, north to Karwar), this oxygen deficiency was further strengthened by the influence of the Arabian Sea oxygen minimum zone (OMZ), which resulted in severe oxygen depleted conditions in the northernmost transects, even at 500m and 1000m. Comparatively high oxygen concentrations were observed in the southern region, where the hydrodynamic conditions were distinct from the north, mainly due to influences from the Bay of Bengal and Equatorial Indian Ocean.

In the present study, five textural classes of sediments were identified from the SEAS margin, viz. sand, silty sand, sandy silt, clayey silt and admixture of sand, silt and clay. The composition of sand was higher in the southern region and decreased progressively towards the north. On the shelf edge and upper slope regions in the south (Cape to Kollam) in particular, sandy sediments dominated. Sand was an important component of shelf edge sediments even in the north, but the silt content in these sediments was also high. Sediments of deeper sites were dominated by finer fractions (silt and clay), in the entire region. Surface sediments on the SEAS margin were highly enriched with organic carbon; and the organic content of the sediments are chiefly influenced by sediment texture - with fine-grained sediments retaining more organic matter than coarse sandy sediments. Organic matter content was comparatively low on the shelf edge and increased significantly down the slope. Strong temporal variation in organic matter was noted, with a peak in April-May, during which period, the SEAS is characterised by massive phytoplankton blooms (eg. *Trichodesmium* sp.) and more or less weak hydrodynamic conditions.

As a general trend, density and biomass of macrofauna decreased with increasing water depth. The decline in density was more pronounced while the decrease in biomass was not so drastic. The only exception to this trend was observed at Karwar, where the density at 500m was higher than the shelf edge. There was no significant variation in density and standing crop of macrofauna between surveys. The mean density of macrofauna during the study varied from 30 Ind.m^{-2} (Coondapur 1000m, survey I) to 2143 Ind.m^{-2} (Coondapur 200m, survey III) with a mean density of 584.34 Ind.m^{-2} (considering all depths and surveys). The mean density decreased by 55% from 200m to 500m and by 75% from 200 to 1000m. The mean biomass of macrofauna in the SEAS margin is 6.03 gm^{-2} (considering all depths and surveys). The reduction in standing crop from 200m to 500m was 13.5%, while the net decline from 200m to 1000m was 46.7%. Although highest densities were found at the shelf edge, total biomass was not high here, due to low mean individual weight of the dominant group, the polychaetes. At comparable depths, differences in hydrographic and sediment characteristics resulted in differences in density, biomass and also faunal composition. Lowest macrofaunal density and biomass values were recorded at Karwar and Coondapur, where the influence of the Arabian Sea OMZ was strongest. Faunal abundance was also remarkably low at Kochi; this is likely to be due to inputs from the highly polluted Cochin Estuary.

Sixteen diverse taxonomic groups were recorded during the study; and as in other marine soft-bottom communities around the world, polychaetes dominated - both in density and biomass, followed by crustaceans. Molluscs, in particular bivalves, were found in high abundance in the upper slope sediments of the southern region. In general, the less oxygenated sandy sediments of this region harbored small bodied polychaetes, while relatively well oxygenated silty sediments of the deeper regions favoured large sized species. The density of macrobenthos showed positive correlation with temperature, sand content, bottom water DO and negative relation with water depth, finer sediments (silt and clay content).

The qualitative composition of polychaetes was examined in detail; and a total of 195 species were recorded in the study area from 144 grab samples collected over the three surveys. To assess the species richness, diversity, community structure and the environmental parameters governing the community pattern, the species abundance data generated in the study were analysed using various statistical techniques and software. Species diversity of polychaetes was lower at the shelf edge and increased with depth. Relatively higher species richness and diversity was encountered in the southern transects, while exceptionally low richness and diversity were recorded at Karwar and Kochi.

One of the basic necessities of an organism is food and the ability of marine benthic organisms to establish and maintain themselves in a particular habitat is governed by food availability. In the SEAS margin, substantial amount of food is available for benthos in the form of organic matter in the sediments. The sediment characteristics and hydrography varied with depth and transects, and thus several distinct types of faunal assemblages were found here. The region as a whole was dominated by surface deposit feeding polychaetes, particularly at the shelf edge, below the productive coastal waters. The proportion of this trophic guild decreased with increasing depth, and at higher depths subsurface deposit feeders, carnivores and omnivores were favoured.

The polychaete assemblages at the shelf edge and upper slope were dominated by genus *Prionospio* (Spionidae), particularly in the silty sediments of the northern transects. The species in this genus are reported to switch from surface deposit feeding to suspension feeding habit. Among the species of this genus, *P. polybranchiata* and *P. cirrifera*, which were numerically dominant, are relatively small in size and endowed with food-gathering tentacles and numerous gills, which enable these 'opportunistic' species to flourish in the shelf edge and upper slope regions of SEAS, where the oxygen concentrations are low and organic matter content is appreciably high. Other polychaetes which occur in high abundance under these 'stressed' conditions include the deposit feeders *Tharyx dorsobranchialis*, *T. annulosus* and *T. marioni* (Cirratulidae), *Paraonis gracilis*, *Levinsenia oculata*, *Aricidea* spp. etc. These organisms make use of organic matter available in the interstitial spaces of sediments in which they reside. In the deeper sites, where the organic matter may be more refractory in nature, non-selective deposit feeders and carnivores became relatively more abundant. The specialist subsurface deposit feeder *Cossura coasta* was the top ranked species in both shelf edge and deep-water assemblages of the SEAS. It was represented in almost all the studied sites, with high abundance at 200m off Kochi and Karwar and is a characteristic species of continental slopes impacted with environmental stress. Along the SEAS margin, the environmental variables that influence the polychaete feeding guild composition were the texture of the sediments and the oxygen content of bottom water, rather than depth and quantity of organic matter. The bottom oxygen level had a particularly strong influence on the distribution of carnivores in the study area.

Multivariate analysis of polychaete community structure revealed the existence of distinct communities along and across the transects. Sites separated by relatively large distances, but having similar depths showed less difference in community structure than sites at different depths. Thus, depth or depth-associated environmental variations emerged as an important structuring factor for the macrofaunal communities. Polychaete communities in the SEAS could be divided into three major assemblages: the shelf edge (200m), intermediate (500m) and deep-water (1000m) communities.

Multivariate analysis on a subset of species (selected using BEST tool in PRIMER-6) revealed the same pattern, indicating that community structure was largely determined by the dominant species. Polychaete assemblages also showed some regional differences in their species composition, with the southern region (Cape Comorin to Kollam) harboring richer and diverse fauna, when compared to the northern region. This regional distinction notwithstanding, there were marked differences in species composition between the shelf edge and deeper assemblages in the southern region. The regional and depth-related patterns in polychaete community structure clearly reflected the differences in hydrodynamic and sediment characteristics of the region. Species dominance and densities were higher at the highly dynamic sandy sediments of the shelf edge when compared to the relatively calm deeper regions with finer sediments. Species richness and diversity were higher in the hydrodynamically active southern region, when compared to the north.

Most polychaete species have pelagic larval stages which facilitate dispersal of species across appreciable distances, in the absence of physical or other barriers. However, some polychaete species were found to be restricted to certain depths or regions in the SEAS, despite relatively short distances between adjacent sampling sites in each transect. A variety of environmental characters, acting in combination are likely to play a key role in restricting the distribution and proliferation of these organisms. Variations in sediment texture and dissolved oxygen content of bottom water played a key role in creating depth-associated differences as well as regional differences in faunal abundance. The temperature of bottom water also played a major role in creating depth-related species distribution patterns. The continental margin of the SEAS can be divided into two distinct sub-regions or sectors - the southern sector (from Cape Comorin to Kollam) and northern sector (from Kochi, north to Karwar), where very different environmental and hydrographic regimes prevail; and where qualitatively distinct faunal communities have been found to exist.

Anthropogenic activities and natural disturbances exert an influence on biodiversity and ecosystem health on the continental margin also. Marine sediments are an excellent place to look for signs of human-induced stress and benthos are effective indicators of such disturbance. In the SEAS margin, low species richness and diversity was observed at Kochi, influenced by high load of anthropogenic inputs from Cochin Estuary. Similar conditions were observed at the naturally disturbed area with extremely low DO at Karwar. Among these two regions, species richness and diversity was relatively high at Karwar when compared to Kochi.

In recent years, continental margins are being hailed as important sites for exploitation of fossil fuel deposits, particularly in India. Depletion of shallow water fishery resources has progressively pushed the fishing activity into deeper waters. Recent research indicates that oxygen minimum zones across the world are undergoing vertical and horizontal expansion as a result of ocean warming and resultant reduced mixing. Impacts of such human activities on the relatively narrow, vulnerable continental slopes cannot be understood without carrying out basic and systematic studies. The present study is the first detailed investigation on the standing crop, abundance and composition of macrofauna in the South Eastern Arabian Sea continental margin, between 200m and 1000m depth, where the qualitative and quantitative information on benthos is lacking. It provides baseline information on the abundance and standing crop of macrofauna in the region. The faunal composition, distribution and diversity of polychaetes across the study area are described in detail. The study provides an insight on the role of various environmental factors in defining the distribution of macrofauna along the SEAS margin. The macrofaunal communities in the SEAS margin were found to be spatially heterogeneous in terms of community structure and distribution. Detailed analyses are provided on distribution and habitat preference of dominant polychaete species and discriminating species responsible for distinct community assemblages.

In the present study, only a limited set of environmental factors that potentially play a role in structuring the distribution pattern of macrofauna have been examined. Several other important parameters, such as the qualitative composition of sediment organic matter, chlorophyll content, grain size of sediments, bottom currents, estimation of pollutants, vertical particle fluxes etc. have not been considered here. It is certain that further studies on SEAS margin benthos with consideration of these factors and with seasonal sampling will greatly improve the current understanding of the ecology of this region. Future studies will also benefit from the use of high resolution sampling strategies with equipments such as box corers or multiple corers. It is important to carry out further studies in the SEAS margin, particularly from the standpoint of understanding the influence of oxygen minimum zones as well as marine pollution and other anthropogenic activities on benthos.

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Annexure I

ABUNDANCE OF MACROFAUNA*
IN THE
SOUTH EASTERN ARABIAN SEA
CONTINENTAL MARGIN (200-1000m)

DECEMBER 2003-MAY 2007

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* ABUNDANCE OF ALL FAUNAL GROUPS, EXCLUDING POLYCHAETES

TABLE I

Abundance of faunal groups at 200m depth sites during Survey I (FORVSS 219 & 225)

Groups	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Foraminiferans	0	0	0	0	0	0	0	0	0
Sea pens	0	0	0	0	0	0	0	0	0
Nematodes	0	0	0	10	5	5	0	5	0
Nemertines	0	5	5	25	5	10	0	0	0
Oligochaetes	0	0	0	0	10	0	0	0	0
Priapulids	0	0	0	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	5	0	0	0
Pycnogonids	0	0	0	0	0	0	0	0	0
Crustaceans									
Amphipods	25	0	0	0	25	25	30	25	0
Caprellids	0	0	0	5	0	0	0	0	0
Isopods	0	0	0	10	5	0	5	0	5
Tanaids	0	0	0	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0	0
Cumaceans	0	0	0	0	0	0	0	0	0
Ostracods	0	0	0	0	10	5	25	125	5
Callianessa sp.	0	0	0	0	0	0	35	15	0
Prawns	5	0	0	25	5	5	10	5	0
Mysids	0	0	0	0	0	0	0	0	0
Crabs	0	0	0	0	5	5	5	5	0
Lobsters	0	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0	0
Other decapods	0	0	5	10	0	5	10	5	0
Zoea	0	0	0	0	0	0	0	0	0
Megalopa	0	0	0	0	0	0	0	0	0
Alima	0	0	0	0	0	0	0	0	0
Stomatopods	0	0	0	0	0	0	0	0	0
Molluscs									
Bivalves	60	185	225	10	0	0	5	0	20
Gastropods	5	0	5	20	0	0	0	0	5
Scaphopods	40	130	0	0	0	0	0	0	0
Echinoderms									
Asteroids	0	0	0	0	0	0	0	0	0
Ophiuroids	0	0	0	10	0	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0
Fishes	0	0	0	0	0	0	0	0	0
Eggs	0	0	0	0	0	0	0	0	0
Unidentified organisms	15	0	30	85	10	15	30	10	15

TABLE II

Abundance of faunal groups at 500m depth sites during Survey I (FORVSS 219 & 225)

Groups	Cap 500	Tvm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Foraminiferans	0	0	0	0	0	0	0	0
Sea pens	0	0	0	0	0	0	0	0
Nematodes	5	0	0	0	0	0	5	0
Nemertines	15	10	20	15	5	10	0	0
Oligochaetes	0	0	0	0	0	0	0	0
Priapulids	0	0	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0
Pycnogonids	0	0	0	0	0	0	0	0
Crustaceans								
Amphipods	5	5	15	10	0	5	0	5
Caprellids	0	0	10	0	0	0	0	0
Isopods	0	0	5	5	0	5	5	0
Tanaids	0	0	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0
Cumaceans	0	0	0	0	0	0	0	0
Ostracods	0	0	155	10	0	220	5	0
Callianessa sp.	0	0	5	0	0	0	0	0
Prawns	0	0	140	65	5	5	0	0
Mysids	0	0	0	0	0	0	0	0
Crabs	0	0	0	10	5	0	0	0
Lobsters	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0
Other decapods	5	10	5	0	5	0	5	0
Zoea	0	0	0	0	0	0	0	0
Megalopa	0	0	0	0	0	0	0	0
Alima	0	0	0	0	0	0	0	0
Stomatopods	0	0	0	0	0	0	0	0
Molluscs								
Bivalves	110	5	0	15	0	15	0	15
Gastropods	5	0	0	5	0	0	5	10
Scaphopods	30	0	0	0	0	0	0	0
Echinoderms								
Asteroids	0	0	0	0	0	0	0	0
Ophiuroids	0	0	0	0	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0
Fishes	0	0	0	0	0	0	0	0
Eggs	0	0	0	0	0	0	0	0
Unidentified organisms	55	0	115	25	30	0	15	25

TABLE III

Abundance of faunal groups at 1000m depth sites during Survey I (FORVSS 219 & 225)

Groups	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Foraminiferans	0	0	0	0	0	0	0	0	0
Sea pens	0	0	0	0	0	0	0	0	0
Nematodes	0	0	0	0	0	5	0	0	5
Nemertines	10	10	10	0	15	0	0	0	0
Oligochaetes	0	0	5	0	0	0	0	0	0
Priapulids	0	0	5	0	0	0	0	0	0
Sipunculids	5	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0	0
Pycnogonids	0	0	0	0	0	0	0	0	0
Crustaceans									
Amphipods	20	15	10	5	40	20	5	0	10
Caprellids	5	5	0	5	0	0	0	0	0
Isopods	5	0	0	5	15	0	0	0	0
Tanaids	0	0	0	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0	0
Cumaceans	0	0	0	0	0	0	0	0	0
Ostracods	0	15	0	0	5	50	5	0	45
Callianessa sp.	0	0	0	0	0	0	0	0	0
Prawns	5	0	5	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0	0
Crabs	0	0	0	0	0	0	0	0	0
Lobsters	0	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0	0
Other decapods	5	5	0	10	0	0	5	5	0
Zoea	0	0	0	0	0	0	0	0	0
Megalopa	0	0	0	0	0	0	0	0	0
Alima	0	0	0	0	0	0	0	0	0
Stomatopods	0	0	0	0	0	0	0	0	0
Molluscs									
Bivalves	10	10	0	5	0	5	10	10	5
Gastropods	10	15	0	0	0	0	0	0	0
Scaphopods	0	0	0	0	0	0	0	0	0
Echinoderms									
Asteroids	0	0	0	0	0	0	0	0	0
Ophiuroids	0	0	5	0	0	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0
Fishes	0	0	0	0	0	0	0	0	0
Eggs	0	0	0	0	0	0	0	0	0
Unidentified organisms	50	15	70	10	90	5	5	0	15

TABLE IV

Abundance of faunal groups at 200m depth sites during Survey II (FORVSS 228 & 233)

Groups	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Foraminiferans	5	0	10	0	5	5	20	0	10
Sea pens	0	0	0	0	0	0	0	0	0
Nematodes	0	5	0	0	0	10	0	0	0
Nemertines	0	0	5	10	5	0	0	0	0
Oligochaetes	5	0	5	0	0	0	5	0	0
Priapulids	0	0	0	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0	0
Pycnogonids	0	0	5	0	0	0	0	0	0
Crustaceans									
Amphipods	15	40	20	25	115	80	25	0	5
Caprellids	5	25	25	5	40	95	35	0	0
Isopods	0	20	10	10	5	5	0	0	0
Tanaids	0	0	0	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0	0
Cumaceans	10	35	0	0	5	5	0	0	0
Ostracods	5	20	5	45	30	115	225	0	25
Callianessa sp.	0	0	0	0	10	40	25	18	0
Prawns	0	10	10	0	10	15	15	5	5
Mysids	0	0	0	0	5	0	0	0	0
Crabs	0	5	0	0	0	0	0	0	0
Lobsters	0	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0	0
Other decapods	35	0	0	0	0	0	0	0	0
Zoea	0	0	0	0	0	0	10	0	0
Megalopa	0	5	0	5	0	5	5	0	0
Alima	0	0	0	0	0	0	0	0	0
Stomatopods	0	5	0	10	5	5	5	12	0
Molluscs									
Bivalves	85	85	0	5	15	25	10	20	10
Gastropods	15	40	0	5	30	5	40	5	5
Scaphopods	20	20	0	0	0	0	5	0	0
Echinoderms									
Asteroids	0	0	0	0	0	0	0	0	0
Ophiuroids	0	0	0	0	0	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0
Fishes	0	5	0	0	0	0	5	0	0
Eggs	0	0	0	0	0	0	0	0	0
Unidentified organisms	25	0	0	0	0	0	0	0	0

TABLE V

Abundance of faunal groups at 500m depth sites during Survey II (FORVSS 228 & 233)

Groups	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Foraminiferans	50	25	30	5	5	15	5	25	10
Sea pens	0	0	0	15	0	0	0	0	0
Nematodes	35	10	100	5	0	0	0	0	0
Nemertines	10	35	30	5	0	30	5	10	0
Oligochaetes	0	0	10	0	0	0	0	0	0
Priapulids	0	0	0	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0	0
Pycnogonids	0	0	0	0	0	0	0	0	0
Crustaceans									
Amphipods	25	30	80	15	25	30	10	30	15
Caprellids	0	15	10	5	10	35	55	0	0
Isopods	0	0	0	5	10	0	0	5	0
Tanaids	0	0	10	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0	0
Cumaceans	5	5	5	0	0	10	0	0	0
Ostracods	35	5	15	0	0	115	0	10	5
Callianessa sp.	0	10	0	0	0	0	0	0	0
Prawns	5	5	10	5	20	15	5	15	35
Mysids	0	0	0	0	0	0	0	0	0
Crabs	0	0	0	0	5	0	0	5	0
Lobsters	0	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0	0
Other decapods	0	0	0	0	0	0	0	0	0
Zoea	0	0	0	0	15	0	0	0	0
Megalopa	0	0	0	0	0	0	0	0	0
Alima	0	0	0	0	0	0	0	0	0
Stomatopods	10	0	10	0	0	0	0	0	0
Molluscs									
Bivalves	85	90	160	15	15	20	15	25	95
Gastropods	40	40	20	5	5	5	10	10	20
Scaphopods	25	10	5	0	5	0	5	0	0
Echinoderms									
Asteroids	0	0	0	0	0	0	0	0	0
Ophiuroids	10	5	5	0	0	5	0	0	0
Echinoids	5	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0
Fishes	0	0	10	0	0	5	0	0	0
Eggs	65	0	0	80	10	10	0	5	0
Unidentified organisms	0	0	0	0	0	5	0	0	0

TABLE VI

Abundance of faunal groups at 1000m depth sites during Survey II (FORVSS 228 & 233)

Groups	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Foraminiferans	30	50	0	35	0	0	20	20	0
Sea pens	0	0	0	0	0	0	0	0	0
Nematodes	85	40	25	5	10	0	5	5	0
Nemertines	5	5	10	10	10	0	0	0	5
Oligochaetes	0	5	5	0	0	0	0	0	0
Priapulids	0	5	5	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0	0
Pycnogonids	0	5	0	5	5	5	10	0	5
Crustaceans									
Amphipods	60	30	25	5	40	20	40	30	10
Caprellids	5	10	15	5	15	55	55	0	0
Isopods	10	5	5	0	0	0	5	5	0
Tanaids	0	0	0	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0	0
Cumaceans	5	5	0	10	10	10	0	0	0
Ostracods	10	10	10	5	65	15	20	10	30
Callianessa sp.	0	0	0	0	0	0	0	0	0
Prawns	5	0	0	0	0	0	0	0	5
Mysids	0	0	0	0	0	0	0	0	0
Crabs	0	0	0	0	0	0	0	0	0
Lobsters	0	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0	0
Other decapods	0	0	0	0	0	0	0	0	0
Zoea	0	0	5	30	5	0	0	0	5
Megalopa	0	0	5	5	0	0	0	0	0
Alima	0	0	0	0	0	0	0	0	0
Stomatopods	0	0	5	0	0	0	0	0	0
Molluscs									
Bivalves	10	40	30	5	20	40	20	5	0
Gastropods	0	20	5	5	5	5	5	5	0
Scaphopods	0	0	5	0	0	0	0	0	0
Echinoderms									
Asteroids	0	0	5	0	0	0	0	0	0
Ophiuroids	5	0	0	5	5	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	5	0
Fishes	0	5	0	0	5	0	0	0	0
Eggs	10	0	0	35	0	0	0	25	0
Unidentified organisms	5	0	0	15	0	0	0	0	0

TABLE VII

Abundance of faunal groups at 200m depth sites during Survey III (FORVSS 254)

Groups	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Foraminiferans	15	0	0	0	5	5	20	15	30
Sea pens	0	0	0	0	0	0	70	0	0
Nematodes	0	0	0	0	0	0	0	0	0
Nemertines	0	5	5	0	0	5	0	0	0
Oligochaetes	20	0	10	0	0	0	0	0	0
Priapulids	5	0	0	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0	0
Pycnogonids	0	0	0	0	0	0	0	0	0
Crustaceans									
Amphipods	35	200	40	0	10	20	10	5	20
Caprellids	0	0	0	0	0	5	5	0	0
Isopods	5	5	0	5	0	0	5	0	0
Tanaids	0	0	0	0	0	0	0	0	0
Copepods	0	0	5	0	0	0	0	0	0
Cumaceans	0	5	0	0	5	0	0	0	0
Ostracods	10	0	0	0	0	5	0	0	0
Callianessa sp.	0	10	0	0	0	30	45	25	0
Prawns	0	0	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0	0
Crabs	0	0	0	0	0	0	0	0	0
Lobsters	0	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0	0
Other decapods	0	5	25	5	5	0	15	0	0
Zoea	0	0	0	0	0	0	0	0	0
Megalopa	0	0	0	0	0	0	0	0	0
Alima	0	0	0	0	0	0	10	0	0
Stomatopods	0	0	0	0	0	0	0	0	0
Molluscs									
Bivalves	110	75	690	0	5	5	5	5	5
Gastropods	5	0	0	0	5	0	10	5	10
Scaphopods	40	0	0	0	0	0	0	0	0
Echinoderms									
Asteroids	0	0	0	0	0	0	0	0	0
Ophiuroids	0	5	0	0	0	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0
Fishes	0	0	10	0	5	0	0	0	0
Eggs	0	0	0	0	0	0	0	0	0
Unidentified organisms	10	0	10	0	0	5	10	0	5

TABLE VIII

Abundance of faunal groups at 500m depth sites during Survey III (FORVSS 254)

Groups	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Foraminiferans	10	80	35	0	0	0	10	5	5
Sea pens	0	0	0	0	0	0	0	0	0
Nematodes	15	0	75	0	0	0	0	5	0
Nemertines	15	5	25	0	0	30	10	0	0
Oligochaetes	0	10	0	0	0	0	0	0	0
Priapulids	5	5	0	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0	0
Pycnogonids	0	0	0	0	0	0	0	0	0
Crustaceans									
Amphipods	50	25	5	20	10	25	15	0	80
Caprellids	0	0	0	0	0	0	0	0	0
Isopods	10	0	0	0	0	0	0	0	0
Tanaids	0	0	0	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0	0
Cumaceans	0	130	0	0	0	0	0	0	0
Ostracods	0	5	0	5	0	0	0	0	0
Callianessa sp.	5	0	5	0	0	0	0	0	0
Prawns	0	0	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0	0
Crabs	0	0	0	0	0	0	0	0	0
Lobsters	0	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	0	0	0
Other decapods	5	5	40	40	10	0	0	5	5
Zoea	0	0	0	0	0	0	0	0	0
Megalopa	0	0	0	0	0	0	0	0	0
Alima	0	0	0	0	0	0	0	0	0
Stomatopods	0	0	0	0	0	0	0	0	0
Molluscs									
Bivalves	70	135	295	25	0	0	0	0	75
Gastropods	0	5	0	0	0	0	0	5	10
Scaphopods	0	0	5	0	0	0	0	0	0
Echinoderms									
Asteroids	0	5	0	0	0	0	0	0	0
Ophiuroids	5	10	0	0	0	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0	0
Fishes	0	0	5	0	0	0	0	0	0
Eggs	10	50	0	0	10	0	0	5	0
Unidentified organisms	15	0	0	10	5	0	0	5	0

TABLE IX

Abundance of faunal groups at 1000m depth sites during Survey III (FORVSS 254)

Groups	Cap 1000	Tvm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Foraminiferans	0	30	55	10	5	0	40	0
Sea pens	0	0	0	0	0	0	0	15
Nematodes	0	5	0	5	5	0	0	0
Nemertines	0	0	5	0	20	5	10	5
Oligochaetes	0	0	0	10	0	0	0	20
Priapulids	0	5	0	0	0	0	0	0
Sipunculids	0	0	0	0	0	0	0	0
Echiuroids	0	0	0	0	0	0	0	0
Pycnogonids	0	0	0	0	0	0	0	0
Crustaceans								
Amphipods	0	40	20	50	10	0	15	30
Caprellids	0	0	0	0	0	0	0	0
Isopods	5	0	0	0	0	0	0	0
Tanaids	0	0	0	0	0	0	0	0
Copepods	0	0	0	0	0	0	0	0
Cumaceans	0	5	0	5	0	0	0	0
Ostracods	5	0	5	0	0	0	0	0
Callianessa sp.	0	5	5	0	0	0	0	0
Prawns	0	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0
Crabs	0	0	0	0	0	0	0	0
Lobsters	0	0	0	0	0	0	0	0
Hippa	0	0	0	0	0	0	5	0
Other decapods	0	10	10	15	5	15	5	5
Zoea	0	0	0	0	0	0	0	0
Megalopa	0	0	0	0	0	0	0	0
Alima	0	0	0	0	0	0	0	0
Stomatopods	0	0	0	0	0	0	0	0
Molluscs								
Bivalves	0	40	15	15	15	5	65	5
Gastropods	0	5	5	15	5	0	0	20
Scaphopods	0	0	5	0	5	0	0	0
Echinoderms								
Asteroids	0	0	0	0	0	0	0	0
Ophiuroids	5	5	5	5	0	0	0	0
Echinoids	0	0	0	0	0	0	0	0
Holothuroid	0	0	0	0	0	0	0	0
Fishes	0	0	5	0	5	0	0	0
Eggs	0	10	15	15	0	5	0	0
Unidentified organisms	5	10	0	0	5	0	0	5

Annexure II

POLYCHAETE SPECIES ABUNDANCE IN THE SOUTH EASTERN ARABIAN SEA CONTINENTAL MARGIN (200-1000m)

DECEMBER 2003-MAY 2007

TABLE I

Polychaete species abundance at 200m depth during Survey I (FORVSS 219 & 225)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Pholoidae									
Pholoe minuta	-	-	-	-	-	-	-	-	-
Polynoidae									
Harmothoe profunda	-	-	-	-	-	-	-	-	-
Harmothoe sp.	3	-	-	-	-	3	10	-	3
Sigalionidae									
Labiosthenolepis sp.	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	-	-	-	-
Aphroditidae									
Aphroditidae UI	-	-	-	-	-	-	-	-	-
Chrysopetalidae									
Paleanotus chrysolepis	-	-	-	-	-	-	-	-	-
Amphinomidae									
Chloeia sp.	-	-	-	-	-	-	-	-	3
Eurythoe sp. 1	-	-	-	-	-	-	-	-	-
Linopherus sp.	10	-	-	-	-	-	-	-	3
Amphinomidae UI	-	-	-	-	-	-	-	-	-
Phyllodocidae									
Eulalia sp.	-	-	-	-	-	-	-	-	-
Eumida sanguinea	-	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	-	-	-	-	-	-	-	-
Alciopidae									
Alciopidae UI	-	-	-	-	-	3	-	-	-
Pilargidae									
Ancistrosyllis sp.	-	-	-	-	-	-	-	-	-
Sigambra constricta	-	-	-	-	-	-	-	-	-
Sigambra parva	-	-	-	25	5	3	-	5	5
Pilargis sp.	-	-	-	-	-	-	-	-	-
Hesionidae									
Kefersteinia cirrata	-	-	-	-	-	-	-	-	-
Leocrates claparedii	-	-	-	-	-	-	-	-	-
Podarke angustifrons	-	-	-	-	-	-	3	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-	-
Syllidae									
Syllis cornuta	-	-	-	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	-	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-	-
Syllis sp. 1	-	-	-	-	-	-	-	-	3
Syllidae UI	-	-	-	-	-	-	-	-	-
Nereididae									
Ceratonereis sp.	-	-	-	-	-	-	-	-	-
Leonnates indicus	-	-	-	-	-	-	-	-	-
Alitta succinea	-	-	-	-	-	-	-	-	-
Nereis sp. 1	-	-	-	-	-	-	-	-	-
Nereis sp. 2	-	-	-	-	-	-	-	-	-
Platynereis sp.	-	-	-	-	-	-	-	-	-
Tylonereis sp.	-	-	-	-	-	-	-	-	-
Nereididae UI	-	-	-	-	3	-	-	-	-

TABLE I

Polychaete species abundance at 200m depth during Survey I (FORVSS 219 & 225)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Nephtyidae									
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	5	-	-	185	33	13	5	3	-
Nephtys polybranchia	10	10	-	-	3	3	-	-	-
Nephtys sp.	-	-	-	-	-	-	5	-	-
Paralacydoniidae									
Paralacydonia paradoxa	-	-	-	-	-	-	-	-	-
Glyceridae									
Glycera convoluta	-	-	-	-	-	-	-	-	-
Glycera longipinnis	-	5	-	-	-	5	-	-	3
Glycera rouxii	3	5	-	-	3	-	-	-	-
Glycera unicornis	-	-	-	-	-	-	-	-	-
Glycera sp. 1	-	-	-	-	-	-	-	-	-
Glycera sp. 2	-	-	-	-	-	-	-	-	-
Glycera spp.	-	-	-	-	-	-	3	-	-
Goniadidae									
Ophioglycera sp.	-	-	-	-	-	-	-	-	-
Glycinde kameruniana	-	-	-	5	-	-	-	-	-
Goniada emerita	15	10	-	-	-	3	3	-	-
Eunicidae									
Eunice indica	-	-	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-	-
Onuphidae									
Diopatra neapolitana	-	-	-	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	-	-
Kinbergonuphis investigatoris	-	-	-	-	-	-	-	-	-
Onuphis emerita	-	-	-	-	-	-	-	-	-
Onuphis holobranchiata	-	5	-	-	-	-	-	-	-
Onuphis sp. 2	-	-	-	-	-	-	-	-	-
Onuphis spp.	-	-	-	-	-	-	-	-	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-	-
Lumbrineridae									
Lumbrineris aberrans	-	-	-	-	-	-	-	-	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 1	-	-	-	-	-	-	-	-	5
Lumbrineris sp. 2	-	-	-	-	-	-	-	-	-
Lumbrineris spp.	-	-	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	-	-	3	-	-	-
Oenonidae									
Arabella iricolor iricolor	-	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	-	-	-	-
Dorvilleidae									
Schistomeringos rudolphii	3	-	-	-	-	-	-	-	-
Spionidae									
Aonides spp.	3	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	83	210	-	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-	-
Laonice cirrata	15	-	-	-	-	-	-	-	-
Laonice sp.	-	-	-	-	-	-	-	-	3

TABLE I

Polychaete species abundance at 200m depth during Survey I (FORVSS 219 & 225)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Malacoceros indicus	-	-	-	-	-	-	-	-	-
Paraprionospio pinnata	10	5	-	-	3	15	50	20	53
Polydora sp.	-	-	5	-	-	-	-	-	-
Prionospio cirrifera	8	-	15	130	40	113	63	308	-
Prionospio (Prionospio) ehlersi	-	-	-	-	-	-	-	-	-
Prionospio polybranchiata	3	-	95	-	-	50	380	198	-
Prionospio sp. 1	5	-	-	-	-	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-	-
Prionospio sp. 4	-	10	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-	-
Prionospio spp.	18	10	-	-	-	-	-	3	3
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	8	-	-	-	-	-	-	-	-
Spiophanes bombyx	-	-	-	-	-	-	-	-	-
Spiophanes sp. 1	13	5	-	-	8	8	-	3	-
Spiophanes sp. 2	-	-	-	-	-	-	-	-	-
Spionidae UI	-	-	-	-	-	-	-	-	5
Heterospionidae									
Heterospio sp.	-	-	-	-	-	-	-	-	-
Magelonidae									
Magelona cincta	10	15	5	-	-	-	-	-	-
Cirratulidae									
Aphelochaeta filiformis	3	-	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-	-
Caulleriella capensis	-	-	10	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	-	-	-	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	-	-	-	-	-	-	-
Tharyx annulosus	-	-	-	-	-	3	73	68	55
Tharyx dorsobranchialis	220	-	170	-	-	28	18	50	25
Tharyx filibranchia	-	-	75	-	-	88	5	18	10
Tharyx marioni	-	-	20	-	-	-	-	-	-
Cirratulidae UI	-	-	-	-	-	5	-	-	18
Poecilochaetidae									
Poecilochaetus serpens	-	-	-	-	-	-	20	53	-
Chaetopteridae									
Chaetopterus sp.	-	5	-	5	-	3	-	-	-
Spiochaetopterus sp.	-	-	-	-	-	-	-	-	-
Orbiniidae									
Haploscoloplos kerguelensis	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-	-
Paraonidae									
Aricidea fauveli	20	-	40	-	-	15	-	3	3
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-	-

TABLE I

Polychaete species abundance at 200m depth during Survey I (FORVSS 219 & 225)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Aricidea (Acmira) simplex	-	-	-	-	-	-	-	-	-
Aricidea (Allia) belgicae	38	45	-	-	-	-	-	-	-
Aricidea (Aricidea) capensis	-	200	-	-	-	-	-	-	-
Aricidea sp. 1	468	5	-	-	-	25	3	-	-
Aricidea sp. 2	-	-	-	-	-	-	-	-	-
Aricidea sp. 3	-	-	-	-	-	-	-	-	-
Aricidea spp.	-	-	5	-	-	-	-	-	-
Aricidea (Aedicira) spp.	-	25	-	-	-	-	-	-	-
Cirrophorus branchiatus	-	95	-	-	-	-	-	-	-
Levinsenia oculata	380	15	-	-	-	103	3	5	-
Paraonides lyra	-	-	-	-	-	-	-	-	-
Paraonis gracilis	18	-	50	100	-	5	40	15	50
Paraonidae UI	-	-	-	-	-	-	-	-	-
Opheliidae									
Ophelina sp.	-	-	-	-	-	-	-	-	-
Cossuridae									
Cossura coasta	-	-	190	1100	8	40	5	3	58
Capitellidae									
Capitella capitata	-	-	-	-	-	-	-	-	-
Dasybranchus spp.	-	-	-	-	-	-	-	-	-
Leiochrides africanus	3	-	-	-	-	-	-	-	3
Mediomastus sp.	-	-	-	-	-	-	-	-	-
Notomastus aberans	-	-	-	60	-	-	-	-	5
Notomastus fauveli	-	10	-	-	5	-	-	-	5
Notomastus latericeus	-	-	-	5	-	-	-	-	-
Notomastus sp.	-	-	-	-	-	8	-	-	3
Capitellidae UI	-	-	-	-	-	3	-	-	5
Maldanidae									
Euclymene oerstedi	-	-	-	-	-	-	-	-	-
Euclymene santandarensis	3	-	-	-	-	-	-	-	-
Euclymene spp.	30	-	-	-	5	-	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	3	-	-	-	-
Maldane sarsi	-	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	-	-	-	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	-	-	-
Maldanidae UI	-	-	-	-	-	-	-	-	3
Flabelligeridae									
Brada sp.	-	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-	-
Sternaspidae									
Sternaspis scutata	-	-	10	-	-	-	-	-	-
Pectinariidae									
Pectinaria sp.	-	-	-	-	-	-	-	-	-
Ampharetidae									
Ampharete acutifrons	-	-	-	-	-	-	-	3	-
Ampharete sp. 1	-	-	15	-	-	23	3	5	-

TABLE I

Polychaete species abundance at 200m depth during Survey I (FORVSS 219 & 225)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Ampharete sp. 2	-	-	-	-	-	-	-	-	-
Ampharete spp.	-	-	-	-	-	23	-	-	-
Amphicteis gunneri	5	5	10	5	-	3	5	-	-
Isolda pulchella	88	-	-	-	-	-	-	-	-
Sabellides spp.	3	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	8	-	-
Trichobranchidae									
Terebellides stroemii	-	-	-	-	-	-	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-	-
Terebellidae									
Amphitrite cirrata	5	-	-	-	-	-	-	8	-
Amphitrite sp. 1	-	5	-	-	-	10	18	5	-
Pista cristata	-	-	-	-	-	-	-	-	-
Pista fasciata	-	-	-	-	-	-	-	-	-
Pista macrolobata	-	-	-	-	-	-	-	-	-
Pista unibranchia	18	-	-	-	-	-	-	-	-
Pista sp.	-	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-	-
Terebellidae UI	-	10	-	-	-	-	-	-	-
Sabellidae									
Chone collaris	-	-	-	-	-	-	-	-	-
Chone letterstedti	-	-	-	-	-	-	-	-	-
Fabricia spp.	3	-	-	-	-	-	-	-	-
Jasmineira elegans	-	-	-	-	-	-	-	-	-
Oriopsis sp.	-	5	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	3	-	-	-	-
Sabellariidae									
Idanthyrsus macropalea	-	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-	-
Serpulidae									
Hydroides sp.	-	-	-	-	-	-	-	-	-
Metavermilia acanthophora	13	-	-	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	-	3	-	-	-	8

TABLE II

Polychaete species abundance at 500m depth during Survey I (FORVSS 219 & 225)

Species	Cap 500	Tvm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Pholoidae								
Pholoe minuta	-	-	-	-	-	-	-	-
Polynoidae								
Harmothoe profunda	-	-	-	-	-	-	-	-
Harmothoe sp.	-	-	-	-	-	-	-	-
Sigalionidae								
Labiosthenolepis sp.	-	-	-	5	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	-	-	-
Aphroditidae								
Aphroditidae UI	3	-	-	-	-	-	-	-
Chrysopetalidae								
Paleanotus chrysolepis	-	-	-	-	-	-	-	-
Amphinomidae								
Chloeia sp.	-	-	-	-	-	-	-	-
Eurythoe sp. 1	-	3	-	-	-	-	-	-
Linopherus sp.	3	-	-	-	-	5	-	-
Amphinomidae UI	-	-	-	-	-	-	-	-
Phyllodocidae								
Eulalia sp.	3	-	-	-	-	-	5	-
Eumida sanguinea	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	3	-	-	-	-	-	-	-
Alciopidae								
Alciopidae UI	-	-	-	-	-	-	-	-
Pilargidae								
Ancistrosyllis sp.	-	-	-	-	-	-	-	-
Sigambra constricta	-	-	3	-	3	-	-	-
Sigambra parva	-	-	-	5	3	-	-	-
Pilargis sp.	-	-	-	-	-	-	-	-
Hesionidae								
Kefersteinia cirrata	8	-	-	-	3	-	-	-
Leocrates claparedii	-	-	-	-	-	-	-	-
Podarke angustifrons	-	-	-	5	5	3	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-
Syllidae								
Syllis cornuta	-	-	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-
Syllis sp. 1	-	-	-	-	-	-	-	-
Syllidae UI	10	-	-	-	-	-	-	-
Nereididae								
Ceratonereis sp.	-	-	-	-	-	-	-	-
Leonnates indicus	5	-	-	-	-	-	-	-
Alitta succinea	-	-	3	-	-	-	-	-
Nereis sp. 1	5	-	-	5	5	-	-	-
Nereis sp. 2	-	-	-	-	-	-	-	-
Platynereis sp.	-	-	-	-	-	-	-	-
Tylonereis sp.	-	5	-	-	-	-	-	-
Nereididae UI	-	-	-	-	-	-	-	-

TABLE II

Polychaete species abundance at 500m depth during Survey I (FORVSS 219 & 225)

Species	Cap 500	Tvm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Nephtyidae								
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	-	-	-	-	-	-	-	-
Nephtys polybranchia	-	-	-	5	-	-	-	-
Nephtys sp.	-	-	-	-	-	-	-	-
Paralacydoniidae								
Paralacydonia paradoxa	-	-	-	-	-	-	-	-
Glyceridae								
Glycera convoluta	-	-	-	-	-	-	-	-
Glycera longipinnis	-	5	-	-	8	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-
Glycera unicornis	-	-	-	-	-	-	-	-
Glycera sp. 1	-	-	-	-	-	-	-	-
Glycera sp. 2	-	-	-	-	-	-	-	-
Glycera spp.	-	-	-	-	-	-	-	-
Goniadidae								
Ophioglycera sp.	-	-	-	-	-	-	-	-
Glycinde kameruniana	3	-	-	-	-	-	-	-
Goniada emerita	3	-	-	-	-	-	-	-
Eunicidae								
Eunice indica	53	3	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-
Onuphidae								
Diopatra neapolitana	-	-	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	-
Kinbergonuphis investigatoris	-	-	-	-	5	-	-	-
Onuphis emerita	-	-	-	-	3	-	-	-
Onuphis holobranchiata	3	5	-	-	-	-	-	-
Onuphis sp. 2	-	-	-	-	-	-	-	-
Onuphis spp.	-	-	-	5	-	-	-	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-
Lumbrineridae								
Lumbrineris aberrans	-	-	-	-	-	-	-	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	5
Lumbrineris sp. 1	-	3	-	30	-	15	10	-
Lumbrineris sp. 2	-	-	-	-	-	-	-	-
Lumbrineris spp.	-	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	-	-	3	-	5
Oenonidae								
Arabella iricolor iricolor	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	-	-	-
Dorvilleidae								
Schistomeringos rudolphii	-	-	-	-	-	-	-	-
Spionidae								
Aonides spp.	18	3	-	-	-	-	-	-
Aonidella cirrobranchiata	23	-	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-
Laonice cirrata	-	5	-	-	-	23	-	-
Laonice sp.	-	-	-	-	10	10	-	10

TABLE II

Polychaete species abundance at 500m depth during Survey I (FORVSS 219 & 225)

Species	Cap 500	Tvm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Malacoceros indicus	3	8	-	5	-	3	-	-
Paraprionospio pinnata	-	5	3	10	28	23	25	-
Polydora sp.	3	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	5	-	3	-	-	-
Prionospio (Prionospio) ehlersi	5	-	8	20	5	-	225	-
Prionospio polybranchiata	5	8	-	-	-	18	-	-
Prionospio sp. 1	-	-	-	-	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-
Prionospio sp. 4	-	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-
Prionospio spp.	3	5	3	35	10	45	-	5
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	10	3	-	-	-	-	-	-
Spiophanes bombyx	5	-	-	-	-	-	-	-
Spiophanes sp. 1	5	15	3	40	48	-	20	-
Spiophanes sp. 2	-	-	-	-	-	-	-	-
Spionidae UI	-	-	-	-	-	-	-	-
Heterospionidae								
Heterospio sp.	-	-	-	-	-	-	-	-
Magelonidae								
Magelona cincta	10	18	-	-	-	-	-	-
Cirratulidae								
Aphelochaeta filiformis	-	-	-	-	-	-	-	-
Caulleriella bioculata	-	3	-	-	-	-	-	-
Caulleriella capensis	-	-	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	-	-	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	-	-	-	-	-	-
Tharyx annulosus	-	-	-	-	-	-	-	-
Tharyx dorsobranchialis	-	-	-	15	8	-	-	-
Tharyx filibranchia	-	-	-	5	-	-	-	-
Tharyx marioni	-	3	-	-	-	3	-	265
Cirratulidae UI	-	-	-	-	-	3	-	-
Poecilochaetidae								
Poecilochaetus serpens	10	8	-	-	-	-	-	-
Chaetopteridae								
Chaetopterus sp.	3	-	-	-	-	-	-	-
Spiochaetopterus sp.	-	-	-	-	-	-	-	-
Orbiniidae								
Haploscoloplos kerguelensis	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	5	-	-	-
Scoloplos (Leodamas) uniramus	3	-	-	-	-	-	-	-
Paraonidae								
Aricidea fauveli	-	13	-	-	-	-	-	-
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-

TABLE II

Polychaete species abundance at 500m depth during Survey I (FORVSS 219 & 225)

Species	Cap 500	Tvm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Aricidea (Acmira) simplex	-	-	-	-	-	-	-	-
Aricidea (Allia) belgicae	3	3	-	15	-	-	-	-
Aricidea (Aricidea) capensis	3	-	-	-	-	-	-	-
Aricidea sp. 1	-	-	-	-	3	-	30	-
Aricidea sp. 2	-	-	-	-	-	-	-	-
Aricidea sp. 3	-	3	-	-	-	-	-	-
Aricidea spp.	-	3	-	10	-	-	-	5
Aricidea (Aedicira) spp.	-	-	-	-	-	-	-	5
Cirrophorus branchiatus	-	-	-	-	-	-	-	-
Levinsenia oculata	5	-	-	10	-	-	-	-
Paraonides lyra	53	-	-	5	3	-	-	-
Paraonis gracilis	-	-	-	10	-	3	-	-
Paraonidae UI	-	-	-	-	-	-	-	-
Opheliidae								
Ophelina sp.	-	-	-	-	-	-	-	-
Cossuridae								
Cossura coasta	-	13	3	35	3	-	-	-
Capitellidae								
Capitella capitata	-	-	-	-	-	5	-	-
Dasybranchus spp.	-	-	-	-	-	-	-	-
Leiochrides africanus	-	-	-	-	-	-	-	-
Mediomastus sp.	-	-	-	-	-	-	-	-
Notomastus aberans	-	25	-	35	48	-	-	-
Notomastus fauveli	-	-	-	15	13	-	-	-
Notomastus latericeus	-	-	-	-	-	-	-	-
Notomastus sp.	3	-	-	-	-	-	-	-
Capitellidae UI	-	-	13	5	-	3	-	-
Maldanidae								
Euclymene oerstedi	-	-	-	-	-	-	-	-
Euclymene santandarensis	-	-	-	-	-	-	-	-
Euclymene spp.	-	-	-	-	-	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	-	-	-	-
Maldane sarsi	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	-	-	-	-	8	-	-	-
Rhodine sp.	-	-	-	-	8	-	-	-
Maldanidae UI	-	3	-	10	-	-	10	-
Flabelligeridae								
Brada sp.	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	5	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-
Sternaspidae								
Sternaspis scutata	-	-	-	-	-	-	-	-
Pectinariidae								
Pectinaria sp.	-	-	-	-	-	-	-	5
Ampharetidae								
Ampharete acutifrons	-	-	-	-	-	-	5	-
Ampharete sp. 1	-	-	-	15	-	-	-	-

TABLE II

Polychaete species abundance at 500m depth during Survey I (FORVSS 219 & 225)

Species	Cap 500	Tvm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Ampharete sp. 2	-	-	-	-	-	-	-	-
Ampharete spp.	-	-	-	-	-	-	-	-
Amphicteis gunneri	3	-	-	-	8	-	-	-
Isolda pulchella	-	-	-	-	-	-	-	-
Sabellides spp.	3	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	-	-
Trichobranchidae								
Terebellides stroemii	-	-	-	5	3	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-
Terebellidae								
Amphitrite cirrata	-	-	-	-	-	-	-	-
Amphitrite sp. 1	3	-	-	-	-	-	-	-
Pista cristata	-	-	-	-	-	-	-	5
Pista fasciata	-	-	-	-	-	-	-	-
Pista macrolobata	3	-	-	-	-	-	-	-
Pista unibranchia	-	-	-	-	-	-	-	-
Pista sp.	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-
Terebellidae UI	-	-	-	-	-	-	-	-
Sabellidae								
Chone collaris	-	-	-	-	-	-	-	-
Chone letterstedti	-	-	-	-	-	-	-	-
Fabricia spp.	-	-	-	-	-	-	-	-
Jasmineira elegans	-	-	-	-	-	-	-	-
Oriopsis sp.	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	-	-	-	-
Sabellariidae								
Idanthyrsus macropalea	-	8	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-
Serpulidae								
Hydroides sp.	-	-	-	-	-	-	-	-
Metavermilia acanthophora	-	-	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	5	-	-	-	-

TABLE III

Polychaete species abundance at 1000m depth during Survey I (FORVSS 219 & 225)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Pholoidae									
Pholoe minuta	-	-	-	-	-	-	-	-	-
Polynoidae									
Harmothoe profunda	-	-	-	-	-	-	-	-	-
Harmothoe sp.	-	-	-	-	-	-	-	-	-
Sigalionidae									
Labiosthenolepis sp.	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	-	-	-	-
Aphroditidae									
Aphroditidae UI	3	-	-	-	-	-	5	-	-
Chrysopetalidae									
Paleanotus chrysolepis	-	-	-	-	-	-	-	-	-
Amphinomidae									
Chloeia sp.	-	-	-	-	-	5	-	-	-
Eurythoe sp. 1	3	-	-	-	-	-	-	-	-
Linopherus sp.	-	-	-	-	-	-	-	-	-
Amphinomidae UI	-	-	-	-	-	-	-	-	-
Phyllodocidae									
Eulalia sp.	-	-	-	-	-	-	-	-	-
Eumida sanguinea	3	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	-	-	-	-	-	-	-	-
Alciopidae									
Alciopidae UI	-	-	-	-	-	-	-	-	-
Pilargidae									
Ancistrosyllis sp.	-	-	-	-	-	-	-	-	-
Sigambra constricta	3	-	-	5	10	-	5	-	-
Sigambra parva	3	-	10	-	10	-	5	-	-
Pilargis sp.	-	-	-	-	-	-	-	-	5
Hesionidae									
Kefersteinia cirrata	-	-	-	-	-	-	-	-	-
Leocrates claparedii	-	-	-	-	-	-	-	-	-
Podarke angustifrons	-	-	-	-	-	-	-	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-	-
Syllidae									
Syllis cornuta	-	5	5	-	-	-	-	-	-
Syllis hyalina	-	-	10	-	-	-	-	-	-
Syllis prolifera	-	-	-	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-	-
Syllis sp. 1	-	-	-	-	-	-	-	-	-
Syllidae UI	3	-	-	-	-	-	-	-	-
Nereididae									
Ceratonereis sp.	-	-	-	-	-	-	-	-	-
Leonnates indicus	3	-	-	-	-	-	-	-	-
Alitta succinea	-	-	-	-	-	-	-	-	-
Nereis sp. 1	-	-	5	-	5	-	-	-	-
Nereis sp. 2	-	-	-	-	-	-	-	-	-
Platynereis sp.	-	-	-	-	-	-	-	-	-
Tylonereis sp.	8	-	-	-	-	-	-	-	-
Nereididae UI	-	-	-	-	-	-	-	-	-

TABLE III

Polychaete species abundance at 1000m depth during Survey I (FORVSS 219 & 225)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Nephtyidae									
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	-	3	-	-	-	-	15	-	-
Nephtys polybranchia	-	-	-	-	10	-	-	-	-
Nephtys sp.	-	-	-	-	-	-	-	-	-
Paralacydoniidae									
Paralacydonia paradoxa	-	-	5	-	-	-	-	-	-
Glyceridae									
Glycera convoluta	3	-	10	-	-	-	-	-	-
Glycera longipinnis	3	3	-	-	-	-	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-	-
Glycera unicornis	-	-	-	-	-	-	-	-	-
Glycera sp. 1	-	-	-	-	-	-	-	-	-
Glycera sp. 2	3	-	-	-	-	5	-	-	-
Glycera spp.	-	-	-	-	-	5	-	-	-
Goniadidae									
Ophioglycera sp.	-	-	-	-	5	-	-	-	-
Glycinde kameruniana	-	-	-	-	-	-	-	-	-
Goniada emerita	3	3	15	-	5	-	-	-	-
Eunicidae									
Eunice indica	-	3	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-	-
Onuphidae									
Diopatra neapolitana	-	-	55	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	-	-
Kinbergonuphis investigatoris	-	-	-	-	-	5	-	-	-
Onuphis emerita	-	-	-	-	-	-	-	-	-
Onuphis holobranchiata	125	-	5	-	-	-	-	-	-
Onuphis sp. 2	-	-	-	3	-	-	-	-	-
Onuphis spp.	-	-	-	-	-	-	-	-	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-	-
Lumbrineridae									
Lumbrineris aberrans	-	-	-	-	-	-	-	-	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 1	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 2	-	3	5	-	-	-	-	-	-
Lumbrineris spp.	-	-	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	-	-	-	-	-	-
Oenonidae									
Arabella iricolor iricolor	-	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	-	-	-	-
Dorvilleidae									
Schistomeringos rudolphii	-	-	-	-	-	-	-	-	-
Spionidae									
Aonides spp.	-	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	-	3	-	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-	-
Laonice cirrata	-	-	-	-	-	-	-	-	-
Laonice sp.	3	-	-	-	-	-	-	-	-

TABLE III

Polychaete species abundance at 1000m depth during Survey I (FORVSS 219 & 225)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Malacoceros indicus	-	-	-	-	-	-	-	-	-
Paraprionospio pinnata	-	-	-	-	-	-	-	-	-
Polydora sp.	-	3	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	-	3	-	-	-	-	-
Prionospio (Prionospio) ehlersi	-	-	-	-	15	-	-	-	-
Prionospio polybranchiata	5	-	-	-	-	-	-	-	-
Prionospio sp. 1	-	-	-	-	-	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-	-
Prionospio sp. 4	-	-	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-	-
Prionospio spp.	8	-	-	-	-	-	-	-	-
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	3	-	-	-	-	-	-	-	-
Spiophanes bombyx	3	-	-	-	-	-	-	-	-
Spiophanes sp. 1	-	-	-	-	5	-	-	-	-
Spiophanes sp. 2	38	-	-	-	-	-	-	-	-
Spionidae UI	-	-	-	-	-	-	-	15	-
Heterospionidae									
Heterospio sp.	3	-	-	-	-	-	-	-	-
Magelonidae									
Magelona cincta	13	-	90	-	-	-	-	-	-
Cirratulidae									
Aphelochaeta filiformis	3	-	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-	-
Caulleriella capensis	3	-	-	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-	-
Chaetozone setosa	-	5	-	-	-	-	-	-	-
Cirratulus cirratus	-	5	-	-	-	-	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	5	-	-	-	-	-	-
Tharyx annulosus	3	-	-	-	-	-	-	-	-
Tharyx dorsobranchialis	3	-	-	3	-	-	-	-	-
Tharyx filibranchia	-	-	-	3	-	-	-	-	-
Tharyx marioni	-	10	-	-	-	5	-	-	-
Cirratulidae UI	-	-	-	-	-	-	-	-	-
Poecilochaetidae									
Poecilochaetus serpens	3	-	-	-	5	-	-	-	-
Chaetopteridae									
Chaetopterus sp.	-	-	-	-	-	-	-	-	-
Spiochaetopterus sp.	-	-	-	-	-	-	-	-	-
Orbiniidae									
Haploscoloplos kerguelensis	3	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-	-
Paraonidae									
Aricidea fauveli	5	-	5	-	5	-	-	-	-
Aricidea (Acmira) catherinae	-	-	5	-	-	-	-	-	-

TABLE III

Polychaete species abundance at 1000m depth during Survey I (FORVSS 219 & 225)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Aricidea (Acmira) simplex	-	-	-	-	-	-	-	-	-
Aricidea (Allia) belgicae	-	3	-	-	-	-	-	-	-
Aricidea (Aricidea) capensis	-	-	-	-	-	-	-	-	-
Aricidea sp. 1	-	-	-	-	-	-	-	-	-
Aricidea sp. 2	-	-	-	-	-	-	-	-	-
Aricidea sp. 3	-	-	-	-	-	-	-	-	-
Aricidea spp.	-	-	-	-	-	-	-	-	-
Aricidea (Aedicira) spp.	-	-	-	-	-	-	-	-	-
Cirrophorus branchiatus	13	-	-	-	-	-	-	-	-
Levinsenia oculata	8	-	-	-	-	-	-	-	-
Paraonides lyra	-	-	-	-	-	-	-	-	-
Paraonis gracilis	3	-	40	-	-	-	5	-	5
Paraonidae UI	-	-	-	-	-	-	-	-	-
Opheliidae									
Ophelina sp.	-	-	-	-	-	-	-	-	-
Cossuridae									
Cossura coasta	-	13	5	-	40	-	30	-	-
Capitellidae									
Capitella capitata	5	-	-	-	-	-	-	-	-
Dasybranchus spp.	-	-	-	-	-	-	-	-	-
Leiochrides africanus	-	-	-	-	-	-	5	-	-
Mediomastus sp.	-	-	-	-	-	-	-	-	-
Notomastus aberans	10	18	105	3	30	-	-	-	-
Notomastus fauveli	13	-	-	3	-	-	-	-	-
Notomastus latericeus	-	-	-	-	-	-	-	-	-
Notomastus sp.	-	-	-	-	-	-	-	-	-
Capitellidae UI	-	-	-	3	5	-	-	-	-
Maldanidae									
Euclymene oerstedi	-	-	-	-	-	-	-	-	-
Euclymene santandarensis	-	-	-	-	-	-	-	-	-
Euclymene spp.	-	-	-	-	-	-	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	-	-	-	-	-
Maldane sarsi	3	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	-	-	-	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	-	-	-
Maldanidae UI	30	3	-	-	45	-	-	-	-
Flabelligeridae									
Brada sp.	-	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-	-
Sternaspidae									
Sternaspis scutata	-	-	-	-	-	-	-	-	-
Pectinariidae									
Pectinaria sp.	-	-	-	-	-	-	-	-	-
Ampharetidae									
Ampharete acutifrons	-	-	-	-	-	-	-	-	-
Ampharete sp. 1	10	3	-	-	-	-	-	-	-

TABLE III

Polychaete species abundance at 1000m depth during Survey I (FORVSS 219 & 225)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Ampharete sp. 2	-	-	-	-	-	-	-	-	-
Ampharete spp.	-	-	-	-	-	-	-	-	-
Amphicteis gunneri	10	3	15	-	-	-	-	-	-
Isolda pulchella	-	-	-	-	-	-	-	-	-
Sabellides spp.	-	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	-	-	-
Trichobranchidae									
Terebellides stroemii	-	-	-	-	-	-	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-	-
Terebellidae									
Amphitrite cirrata	-	-	-	-	-	-	-	-	-
Amphitrite sp. 1	5	-	-	-	-	-	-	-	-
Pista cristata	-	-	-	-	-	-	-	-	-
Pista fasciata	-	-	-	-	-	-	-	-	-
Pista macrolobata	-	-	-	-	-	-	-	-	-
Pista unibranchia	-	-	-	-	-	-	-	-	-
Pista sp.	-	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-	-
Terebellidae UI	5	-	-	-	5	-	-	-	-
Sabellidae									
Chone collaris	-	-	-	-	-	-	-	-	-
Chone letterstedti	-	-	-	-	-	-	-	-	-
Fabricia spp.	-	-	-	-	-	-	-	-	-
Jasmineira elegans	-	-	-	-	-	-	-	-	-
Oriopsis sp.	-	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	-	-	-	-	-
Sabellariidae									
Idanthyrsus macropalea	-	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-	-
Serpulidae									
Hydroides sp.	-	-	-	-	-	-	-	-	-
Metavermilia acanthophora	-	-	-	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	-	25	-	-	-	-

TABLE IV

Polychaete species abundance at 200m depth during Survey II (FORVSS 228 & 233)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Pholoidae									
Pholoe minuta	-	-	-	-	-	-	-	-	-
Polynoidae									
Harmothoe profunda	-	-	-	-	-	-	8	15	-
Harmothoe sp.	-	-	-	-	-	18	3	-	-
Sigalionidae									
Labiosthenolepis sp.	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	-	-	-	-
Aphroditidae									
Aphroditidae UI	-	-	-	-	-	-	13	-	-
Chrysopetalidae									
Paleanotus chrysolepis	-	-	-	-	-	-	-	-	-
Amphinomidae									
Chloeia sp.	-	-	-	-	-	-	-	-	-
Eurythoe sp. 1	-	-	-	-	-	-	-	-	-
Linopherus sp.	-	-	-	-	-	-	-	-	-
Amphinomidae UI	-	-	-	-	-	-	-	-	-
Phyllodocidae									
Eulalia sp.	-	-	-	-	-	-	-	-	-
Eumida sanguinea	8	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	-	-	-	-	-	-	-	-
Alciopidae									
Alciopidae UI	-	-	-	-	-	-	-	-	-
Pilargidae									
Ancistrosyllis sp.	-	-	-	-	-	-	-	-	-
Sigambra constricta	-	-	-	-	-	-	-	-	-
Sigambra parva	-	-	-	5	-	8	5	5	3
Pilargis sp.	-	-	-	-	-	-	-	-	-
Hesionidae									
Kefersteinia cirrata	-	-	-	-	3	-	-	5	-
Leocrates claparedii	-	-	-	-	-	-	-	-	-
Podarke angustifrons	-	-	-	-	-	-	-	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-	-
Syllidae									
Syllis cornuta	-	-	-	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	-	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-	-
Syllis sp. 1	5	-	-	-	-	-	-	-	-
Syllidae UI	-	-	-	-	-	-	-	-	-
Nereididae									
Ceratonereis sp.	-	-	-	-	-	-	-	-	-
Leonnates indicus	-	-	-	-	-	-	-	-	-
Alitta succinea	-	-	-	-	-	-	-	-	-
Nereis sp. 1	-	-	-	-	-	-	3	-	-
Nereis sp. 2	-	-	-	-	-	-	-	-	-
Platynereis sp.	-	-	-	-	-	-	-	-	-
Tylonereis sp.	-	-	-	-	-	-	-	-	-
Nereididae UI	-	-	-	-	-	-	-	-	-

TABLE IV

Polychaete species abundance at 200m depth during Survey II (FORVSS 228 & 233)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Nephtyidae									
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	5	-	-	-	60	-	-	25	-
Nephtys polybranchia	-	-	-	-	-	-	-	-	-
Nephtys sp.	-	-	-	-	-	-	-	-	-
Paralacydoniidae									
Paralacydonia paradoxa	-	-	-	-	-	-	-	-	-
Glyceridae									
Glycera convoluta	-	-	5	-	-	-	-	-	-
Glycera longipinnis	3	-	8	-	3	-	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-	-
Glycera unicornis	-	-	-	-	-	-	-	-	-
Glycera sp. 1	3	-	-	-	-	-	-	-	-
Glycera sp. 2	-	-	-	-	-	-	-	-	-
Glycera spp.	-	-	-	-	-	-	-	-	-
Goniadidae									
Ophioglycera sp.	-	-	-	-	-	-	-	-	-
Glycinde kameruniana	-	-	-	-	-	-	-	-	-
Goniada emerita	5	5	10	-	-	-	-	15	-
Eunicidae									
Eunice indica	-	-	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-	-
Onuphidae									
Diopatra neapolitana	-	-	-	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	-	-
Kinbergonuphis investigatoris	-	-	-	-	-	-	-	-	-
Onuphis emerita	-	-	-	-	-	-	-	-	-
Onuphis holobranchiata	-	-	-	-	-	-	-	-	-
Onuphis sp. 2	-	-	-	-	-	-	-	-	-
Onuphis spp.	-	-	-	-	-	-	-	-	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-	-
Lumbrineridae									
Lumbrineris aberrans	-	5	-	-	-	-	-	-	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 1	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 2	-	-	-	-	-	-	-	-	-
Lumbrineris spp.	-	-	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	-	-	-	-	-	-
Oenonidae									
Arabella iricolor iricolor	-	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	-	-	-	-
Dorvilleidae									
Schistomeringos rudolphii	-	-	-	-	-	-	-	-	3
Spionidae									
Aonides spp.	-	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	10	55	5	-	-	-	168	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-	-
Laonice cirrata	13	5	-	-	-	-	-	-	-
Laonice sp.	-	-	-	-	-	-	-	-	-

TABLE IV

Polychaete species abundance at 200m depth during Survey II (FORVSS 228 & 233)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Malacoceros indicus	-	-	-	-	-	-	-	-	-
Paraprionospio pinnata	-	-	-	18	5	-	-	5	-
Polydora sp.	-	-	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	-	-	118	28	-	125	8
Prionospio (Prionospio) ehlersi	-	-	-	-	10	-	-	-	-
Prionospio polybranchiata	5	-	25	30	-	240	598	40	5
Prionospio sp. 1	-	-	-	-	-	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-	-
Prionospio sp. 4	3	-	-	3	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-	-
Prionospio spp.	-	-	23	-	-	123	-	-	-
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	-	-	-	-	-	-	-	10	-
Spiophanes bombyx	5	5	-	-	-	-	-	10	-
Spiophanes sp. 1	5	-	-	-	-	-	-	25	-
Spiophanes sp. 2	-	-	-	-	-	-	-	-	-
Spionidae UI	-	-	-	-	-	-	-	-	-
Heterospionidae									
Heterospio sp.	-	-	-	-	-	-	-	-	-
Magelonidae									
Magelona cincta	28	20	10	-	-	-	-	5	-
Cirratulidae									
Aphelochaeta filiformis	-	-	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-	-
Caulleriella capensis	8	-	-	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	-	-	-	-	-	-
Cirratulus sp. 1	5	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	25	-	-	-
Cirriformia afer	-	-	-	-	-	-	-	-	-
Tharyx annulosus	-	-	-	-	3	55	8	180	23
Tharyx dorsobranchialis	138	30	735	-	5	5	28	55	35
Tharyx filibranchia	-	-	360	-	18	8	-	410	43
Tharyx marioni	-	-	-	-	-	-	20	-	3
Cirratulidae UI	-	-	-	-	-	-	-	-	-
Poecilochaetidae									
Poecilochaetus serpens	-	-	-	3	-	8	20	5	-
Chaetopteridae									
Chaetopterus sp.	-	-	-	3	-	-	-	-	-
Spiochaetopterus sp.	-	-	5	-	-	-	-	-	-
Orbiniidae									
Haploscoloplos kerguelensis	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-	-
Paraonidae									
Aricidea fauveli	63	5	-	-	-	-	-	-	-
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-	-

TABLE IV

Polychaete species abundance at 200m depth during Survey II (FORVSS 228 & 233)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Aricidea (Acmira) simplex	-	-	-	-	-	-	-	-	-
Aricidea (Allia) belgicae	5	5	-	-	-	-	-	-	-
Aricidea (Aricidea) capensis	-	70	-	-	-	-	-	-	-
Aricidea sp. 1	23	-	3	-	5	-	-	10	-
Aricidea sp. 2	-	-	-	-	-	-	-	-	-
Aricidea sp. 3	120	-	-	-	-	-	-	-	-
Aricidea spp.	13	-	5	-	-	-	-	-	-
Aricidea (Aedicira) spp.	-	-	-	-	-	-	-	-	-
Cirrophorus branchiatus	3	-	-	-	-	-	-	-	-
Levinsenia oculata	825	-	-	-	50	305	308	45	-
Paraonides lyra	-	10	-	-	-	-	-	-	-
Paraonis gracilis	-	-	3	8	-	28	3	-	-
Paraonidae UI	-	-	-	-	-	-	-	-	-
Opheliidae									
Ophelina sp.	-	-	-	-	-	-	-	-	-
Cossuridae									
Cossura coasta	-	-	160	-	100	83	10	5	75
Capitellidae									
Capitella capitata	5	-	-	-	-	-	-	-	-
Dasybranchus spp.	-	-	-	-	-	-	-	-	-
Leiochrides africanus	-	-	-	-	-	-	-	-	-
Mediomastus sp.	-	-	-	-	-	-	-	-	-
Notomastus aberans	5	-	40	3	-	-	-	-	-
Notomastus fauveli	-	5	-	-	15	-	-	-	-
Notomastus latericeus	-	-	-	20	-	-	-	-	-
Notomastus sp.	5	-	-	-	-	-	-	10	-
Capitellidae UI	5	-	-	-	-	-	-	10	3
Maldanidae									
Euclymene oerstedi	-	-	-	-	25	13	-	-	-
Euclymene santandarensis	-	-	-	-	-	-	-	-	-
Euclymene spp.	35	5	-	-	-	3	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	-	-	-	-	-
Maldane sarsi	-	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	20	-	-	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	-	-	-
Maldanidae UI	-	-	-	-	-	8	-	-	-
Flabelligeridae									
Brada sp.	-	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-	-
Sternaspidae									
Sternaspis scutata	-	-	-	-	-	3	-	-	-
Pectinariidae									
Pectinaria sp.	-	-	-	-	-	-	3	-	-
Ampharetidae									
Ampharete acutifrons	-	-	-	-	-	-	-	-	-
Ampharete sp. 1	3	-	18	-	-	8	-	-	-

TABLE IV

Polychaete species abundance at 200m depth during Survey II (FORVSS 228 & 233)

	Cap	Tvm	Klm	Kch	Pon	Knr	Mng	Cnd	Kwr
Species	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
Ampharete sp. 2	-	-	-	-	-	-	-	-	-
Ampharete spp.	-	-	-	-	-	-	-	-	-
Amphicteis gunneri	-	-	-	-	5	13	-	120	3
Isolda pulchella	40	-	-	-	-	-	-	-	-
Sabellides spp.	-	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	-	-	3
Trichobranchidae									
Terebellides stroemii	-	-	-	-	-	-	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-	-
Terebellidae									
Amphitrite cirrata	-	-	-	-	-	-	-	-	-
Amphitrite sp. 1	-	-	-	-	-	13	30	15	-
Pista cristata	-	-	-	-	-	-	-	-	-
Pista fasciata	-	-	-	-	-	-	-	-	-
Pista macrolobata	-	-	-	-	-	-	-	-	-
Pista unibranchia	8	-	-	-	-	-	-	-	-
Pista sp.	-	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-	-
Terebellidae UI	-	-	-	-	-	-	-	-	-
Sabellidae									
Chone collaris	-	-	-	-	-	-	-	-	-
Chone letterstedti	-	-	-	-	-	-	-	-	-
Fabricia spp.	-	-	-	-	-	-	-	-	-
Jasmineira elegans	-	-	-	-	-	-	-	-	-
Oriopsis sp.	-	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	-	-	-	-	-
Sabellariidae									
Idanthyrsus macropalea	-	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-	-
Serpulidae									
Hydroides sp.	-	-	-	-	-	-	-	-	-
Metavermilia acanthophora	3	-	-	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	-	-	-	-	-	-

TABLE V

Polychaete species abundance at 500m depth during Survey II (FORVSS 228 & 233)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Pholoidae									
Pholoe minuta	-	-	-	-	-	-	-	-	-
Polynoidae									
Harmothoe profunda	-	-	-	-	-	-	-	-	-
Harmothoe sp.	-	-	-	-	-	5	-	-	-
Sigalionidae									
Labiosthenolepis sp.	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	3	-	-	-
Aphroditidae									
Aphroditidae UI	-	-	-	-	-	-	-	-	-
Chrysopetalidae									
Paleanotus chrysolepis	-	-	-	-	-	-	-	-	-
Amphinomidae									
Chloeia sp.	-	-	13	-	-	-	-	-	-
Eurythoe sp. 1	-	-	-	-	-	-	-	-	-
Linopherus sp.	-	-	-	-	-	-	-	-	-
Amphinomidae UI	-	-	-	-	-	-	-	-	-
Phyllodocidae									
Eulalia sp.	-	-	-	-	3	-	3	-	-
Eumida sanguinea	-	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	5	-	-	-	-	-	-	-
Alciopidae									
Alciopidae UI	-	-	-	-	-	-	-	-	-
Pilargidae									
Ancistrosyllis sp.	-	-	-	3	-	-	-	-	-
Sigambra constricta	-	-	-	3	5	-	8	-	-
Sigambra parva	5	-	-	-	3	-	3	-	3
Pilargis sp.	-	-	-	-	-	-	-	-	-
Hesionidae									
Kefersteinia cirrata	-	-	33	-	-	3	-	5	-
Leocrates claparedii	-	-	3	-	-	-	-	-	-
Podarke angustifrons	10	-	8	-	-	-	-	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-	-
Syllidae									
Syllis cornuta	-	-	-	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	3	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-	-
Syllis sp. 1	-	-	-	-	-	-	-	-	-
Syllidae UI	-	-	-	-	-	-	-	-	-
Nereididae									
Ceratonereis sp.	-	-	-	-	-	-	-	-	-
Leonnates indicus	-	-	-	-	-	-	-	-	-
Alitta succinea	-	25	-	-	-	-	-	-	-
Nereis sp. 1	-	3	-	-	-	3	-	-	-
Nereis sp. 2	-	3	-	-	-	-	-	-	-
Platynereis sp.	145	-	-	-	-	-	-	-	-
Tylonereis sp.	-	-	-	-	-	-	-	-	-
Nereididae UI	-	-	-	-	-	-	-	-	-

TABLE V

Polychaete species abundance at 500m depth during Survey II (FORVSS 228 & 233)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Nephtyidae									
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	-	-	-	-	-	-	-	-	-
Nephtys polybranchia	-	-	-	-	-	3	-	-	-
Nephtys sp.	-	-	-	-	-	-	-	-	-
Paralacydoniidae									
Paralacydonia paradoxa	-	-	-	-	-	-	-	-	-
Glyceridae									
Glycera convoluta	20	-	-	-	-	-	-	-	-
Glycera longipinnis	10	10	10	3	-	-	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-	-
Glycera unicornis	-	-	-	-	-	8	-	-	-
Glycera sp. 1	10	-	-	-	-	-	-	-	-
Glycera sp. 2	-	-	-	-	-	-	-	-	-
Glycera spp.	-	-	-	-	-	-	-	-	-
Goniadidae									
Ophioglycera sp.	-	-	-	-	-	-	-	-	-
Glycinde kameruniana	-	-	-	-	-	-	-	-	-
Goniada emerita	-	3	-	-	-	-	-	-	-
Eunicidae									
Eunice indica	-	-	-	-	-	-	-	5	-
Marphysa sp.	-	-	-	-	-	-	-	-	-
Onuphidae									
Diopatra neapolitana	-	-	-	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	-	-
Kinbergonuphis investigatoris	-	-	-	3	5	-	-	3	-
Onuphis emerita	-	-	-	-	-	3	-	-	-
Onuphis holobranchiata	-	8	-	-	-	-	-	-	-
Onuphis sp. 2	25	-	-	-	-	-	-	-	-
Onuphis spp.	-	-	-	-	-	-	-	-	-
Rhamphobrachium sp.	-	3	-	-	-	-	-	-	-
Lumbrineridae									
Lumbrineris aberrans	-	-	-	-	-	-	-	-	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	5	-	-	-	-
Lumbrineris sp. 1	15	-	-	-	8	10	-	23	-
Lumbrineris sp. 2	-	3	-	-	-	5	5	-	-
Lumbrineris spp.	-	-	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	5	-	-	8	-	-
Oenonidae									
Arabella iricolor iricolor	-	-	3	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	3	-	-	-
Dorvilleidae									
Schistomeringos rudolphii	-	-	-	-	-	-	-	-	-
Spionidae									
Aonides spp.	-	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	-	-	45	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	3	-	-	-
Laonice cirrata	5	-	8	-	-	-	-	-	-
Laonice sp.	-	-	20	18	13	-	23	3	-

TABLE V

Polychaete species abundance at 500m depth during Survey II (FORVSS 228 & 233)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Malacoceros indicus	-	-	5	-	-	-	-	-	-
Paraprionospio pinnata	5	5	5	33	13	43	25	3	163
Polydora sp.	-	-	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	-	-	-	20	-	-	-
Prionospio (Prionospio) ehlersi	5	-	-	5	-	78	20	60	-
Prionospio polybranchiata	10	18	15	-	-	-	8	13	-
Prionospio sp. 1	-	-	5	-	-	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-	-
Prionospio sp. 4	-	-	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-	-
Prionospio spp.	45	23	23	-	15	28	3	-	-
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	3	-	-
Scolelepis (Scolelepis) squamata	-	-	3	-	-	-	-	-	-
Spiophanes bombyx	35	-	10	-	-	5	-	-	-
Spiophanes sp. 1	-	-	5	8	3	18	3	3	-
Spiophanes sp. 2	-	-	3	-	-	-	-	-	-
Spionidae UI	5	-	-	-	-	-	-	-	-
Heterospionidae									
Heterospio sp.	-	-	-	-	-	-	-	-	-
Magelonidae									
Magelona cincta	-	-	38	-	-	-	-	-	-
Cirratulidae									
Aphelochaeta filiformis	-	20	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-	-
Caulleriella capensis	-	-	-	-	-	-	-	-	38
Caulleriella sp.	5	-	-	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	5	-	-	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	-	-	-	-	-	-	-
Tharyx annulosus	80	-	-	-	-	-	-	-	-
Tharyx dorsobranchialis	-	-	-	-	-	-	-	-	3
Tharyx filibranchia	-	3	3	5	-	-	-	-	5
Tharyx marioni	30	5	-	-	-	15	-	-	233
Cirratulidae UI	-	-	-	-	-	-	-	-	-
Poecilochaetidae									
Poecilochaetus serpens	-	-	25	-	-	-	-	-	3
Chaetopteridae									
Chaetopterus sp.	-	-	-	-	-	3	-	-	-
Spiochaetopterus sp.	15	-	-	-	-	-	-	-	-
Orbiniidae									
Haploscoloplos kerguelensis	10	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	5	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-	-
Paraonidae									
Aricidea fauveli	5	-	-	-	-	3	-	-	-
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-	-

TABLE V

Polychaete species abundance at 500m depth during Survey II (FORVSS 228 & 233)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Aricidea (Acmira) simplex	5	-	-	-	-	-	-	-	-
Aricidea (Allia) belgicae	-	23	20	-	-	-	18	-	-
Aricidea (Aricidea) capensis	5	-	5	-	-	-	-	-	-
Aricidea sp. 1	5	-	-	-	-	-	5	35	-
Aricidea sp. 2	-	-	-	3	-	-	-	-	-
Aricidea sp. 3	-	-	-	-	-	-	-	-	-
Aricidea spp.	-	3	10	-	-	-	-	-	-
Aricidea (Aedicira) spp.	-	-	-	-	-	-	-	-	-
Cirrophorus branchiatus	-	-	-	-	-	-	-	-	-
Levinsenia oculata	5	-	-	-	-	-	-	-	-
Paraonides lyra	-	-	5	-	-	-	-	-	-
Paraonis gracilis	-	3	15	-	3	-	-	3	-
Paraonidae UI	5	-	-	-	-	5	-	-	-
Opheliidae									
Ophelina sp.	-	-	-	-	-	-	-	-	-
Cossuridae									
Cossura coasta	35	3	-	-	3	-	-	3	5
Capitellidae									
Capitella capitata	-	-	3	-	-	5	-	-	-
Dasybranchus spp.	-	-	-	3	-	-	-	-	-
Leiochrides africanus	-	-	-	-	-	-	-	-	3
Mediomastus sp.	-	-	-	-	-	-	-	15	-
Notomastus aberans	45	15	-	-	3	20	-	20	-
Notomastus fauveli	-	-	-	-	-	-	-	5	-
Notomastus latericeus	-	-	-	-	-	-	-	-	-
Notomastus sp.	-	-	13	-	-	-	5	28	13
Capitellidae UI	-	-	5	-	-	-	-	-	-
Maldanidae									
Euclymene oerstedi	-	-	-	-	-	-	-	-	-
Euclymene santandarensis	-	-	-	-	-	-	-	-	-
Euclymene spp.	5	8	-	-	5	-	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	-	-	-	-	-
Maldane sarsi	-	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	-	-	-	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	-	-	-
Maldanidae UI	-	5	-	-	-	3	-	-	-
Flabelligeridae									
Brada sp.	-	-	-	-	5	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-	-
Pherusa tropica	-	10	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-	-
Sternaspidae									
Sternaspis scutata	-	3	-	-	-	-	-	-	-
Pectinariidae									
Pectinaria sp.	-	-	-	-	-	-	-	-	-
Ampharetidae									
Ampharete acutifrons	-	-	-	-	-	-	-	20	-
Ampharete sp. 1	5	3	5	-	33	-	-	-	35

TABLE V

Polychaete species abundance at 500m depth during Survey II (FORVSS 228 & 233)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Ampharete sp. 2	-	-	-	-	-	-	-	-	-
Ampharete spp.	-	-	-	-	-	-	-	-	-
Amphicteis gunneri	5	-	20	3	5	-	-	-	3
Isolda pulchella	-	-	-	-	-	-	-	-	-
Sabellides spp.	-	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	3	-	-	-
Trichobranchidae									
Terebellides stroemii	-	3	-	10	3	-	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-	-
Terebellidae									
Amphitrite cirrata	-	-	-	-	-	-	-	-	-
Amphitrite sp. 1	-	-	-	-	-	-	-	-	-
Pista cristata	5	-	-	-	-	-	-	-	-
Pista fasciata	-	-	-	-	-	-	-	-	-
Pista macrolobata	-	-	-	-	-	-	-	-	-
Pista unibranchia	-	-	-	-	-	-	-	-	-
Pista sp.	-	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-	-
Terebellidae UI	-	-	-	-	-	-	-	-	-
Sabellidae									
Chone collaris	-	-	-	-	-	-	-	-	-
Chone letterstedti	-	-	3	-	-	-	-	-	-
Fabricia spp.	-	-	-	-	-	-	-	-	-
Jasmineira elegans	-	-	3	-	-	-	-	-	-
Oriopsis sp.	-	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	-	3	-	-	-
Sabellariidae									
Idanthyrsus macropalea	-	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-	-
Serpulidae									
Hydroides sp.	-	-	-	-	-	-	-	-	-
Metavermilia acanthophora	-	-	-	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	-	-	-	-	-	-

TABLE VI

Polychaete species abundance at 1000m depth during Survey II (FORVSS 228 & 233)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Pholoidae									
Pholoe minuta	-	-	-	-	-	-	-	-	-
Polynoidae									
Harmothoe profunda	-	-	-	-	-	-	-	-	-
Harmothoe sp.	-	-	-	-	5	-	-	-	-
Sigalionidae									
Labiosthenolepis sp.	-	-	-	-	8	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	5	-	-	-	-
Aphroditidae									
Aphroditidae UI	3	-	-	-	-	-	-	-	-
Chrysopetalidae									
Paleanotus chrysolepis	-	-	-	-	-	-	-	-	-
Amphinomidae									
Chloeia sp.	-	-	-	-	-	-	-	-	3
Eurythoe sp. 1	-	-	-	-	-	-	-	-	-
Linopherus sp.	-	-	-	-	-	-	-	8	-
Amphinomidae UI	3	-	-	-	-	-	-	-	-
Phyllodocidae									
Eulalia sp.	-	-	-	-	-	-	-	-	-
Eumida sanguinea	-	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	-	-	-	-	-	-	-	-
Alciopidae									
Alciopidae UI	-	-	-	-	-	-	-	-	-
Pilargidae									
Ancistrosyllis sp.	-	-	-	-	-	3	-	-	-
Sigambra constricta	-	-	-	-	-	3	5	-	-
Sigambra parva	-	3	-	-	3	5	-	3	-
Pilargis sp.	-	-	-	-	-	-	-	-	-
Hesionidae									
Kefersteinia cirrata	-	-	-	-	-	3	-	-	3
Leocrates claparedii	-	-	-	-	-	-	-	-	-
Podarke angustifrons	-	-	-	-	-	-	-	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-	-
Syllidae									
Syllis cornuta	-	3	-	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	-	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-	-
Syllis sp. 1	-	-	-	-	-	-	-	-	-
Syllidae UI	-	-	-	-	-	-	-	-	-
Nereididae									
Ceratonereis sp.	-	3	-	-	-	-	-	-	-
Leonnates indicus	-	-	-	-	-	-	-	-	-
Alitta succinea	-	-	-	-	-	-	-	-	-
Nereis sp. 1	-	8	5	3	5	5	3	3	-
Nereis sp. 2	-	-	3	3	-	-	3	3	10
Platynereis sp.	-	-	-	-	-	-	-	-	-
Tylonereis sp.	-	-	-	-	-	-	-	-	-
Nereididae UI	5	3	-	-	-	-	-	-	-

TABLE VI

Polychaete species abundance at 1000m depth during Survey II (FORVSS 228 & 233)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Nephtyidae									
Micronephthys sphaerocirrata	-	-	-	-	5	-	-	-	-
Aglaophamus dibranchis	-	-	3	-	-	3	-	-	-
Nephtys polybranchia	-	-	-	-	10	5	-	3	-
Nephtys sp.	-	-	-	-	-	-	-	-	-
Paralacydoniidae									
Paralacydonia paradoxa	-	-	5	-	-	-	-	-	-
Glyceridae									
Glycera convoluta	-	-	-	-	-	-	-	-	-
Glycera longipinnis	8	-	-	-	-	3	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-	-
Glycera unicornis	-	-	-	-	-	-	-	-	-
Glycera sp. 1	-	-	-	-	-	-	-	-	-
Glycera sp. 2	-	3	-	-	-	-	-	-	-
Glycera spp.	-	5	-	-	-	-	-	-	-
Goniadidae									
Ophioglycera sp.	-	-	-	-	-	-	-	-	-
Glycinde kameruniana	-	-	-	-	-	-	-	-	-
Goniada emerita	8	-	-	-	3	-	-	-	-
Eunicidae									
Eunice indica	-	-	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-	-
Onuphidae									
Diopatra neapolitana	13	-	-	-	-	-	-	-	-
Hyalinoecia tubicola	3	5	-	-	-	-	-	3	-
Kinbergonuphis investigatoris	-	-	-	-	3	-	-	5	-
Onuphis emerita	-	-	-	-	-	-	-	-	-
Onuphis holobranchiata	5	5	-	-	-	-	-	-	-
Onuphis sp. 2	5	3	-	-	-	-	-	-	-
Onuphis spp.	-	-	-	-	-	-	-	-	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-	-
Lumbrineridae									
Lumbrineris aberrans	-	-	-	-	-	-	3	-	-
Lumbrineris heteropoda	10	-	3	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 1	-	-	3	-	-	-	-	-	-
Lumbrineris sp. 2	-	13	-	-	-	-	-	-	-
Lumbrineris spp.	10	3	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	5	8	5	-	-	3
Oenonidae									
Arabella iricolor iricolor	3	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	-	-	-	-
Dorvilleidae									
Schistomeringos rudolphii	-	3	5	-	-	8	-	5	-
Spionidae									
Aonides spp.	-	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	-	-	-	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-	-
Laonice cirrata	13	-	15	-	-	-	3	-	-
Laonice sp.	-	-	-	-	-	23	5	-	-

TABLE VI

Polychaete species abundance at 1000m depth during Survey II (FORVSS 228 & 233)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Malacoceros indicus	-	-	-	-	-	-	-	-	-
Paraprionospio pinnata	-	-	-	3	-	5	-	-	-
Polydora sp.	-	-	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	-	-	-	-	-	5	-
Prionospio (Prionospio) ehlersi	-	-	-	-	10	-	3	-	-
Prionospio polybranchiata	-	-	3	-	-	-	-	-	-
Prionospio sp. 1	-	-	-	-	-	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-	-
Prionospio sp. 4	-	-	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-	-
Prionospio spp.	-	-	5	3	-	-	3	-	3
Pseudomalacoceros gilchristi	3	-	-	-	-	-	-	-	-
Pygospio elegans	3	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	3	-	-	-	-	-	-	-	-
Spiophanes bombyx	-	-	3	-	-	-	-	8	3
Spiophanes sp. 1	40	-	-	3	3	3	8	-	-
Spiophanes sp. 2	-	-	-	-	-	-	-	-	-
Spionidae UI	-	3	5	-	-	-	-	-	3
Heterospionidae									
Heterospio sp.	-	-	-	-	5	-	-	-	-
Magelonidae									
Magelona cincta	28	3	10	-	-	-	-	-	-
Cirratulidae									
Aphelochaeta filiformis	-	13	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-	-
Caulleriella capensis	-	-	-	-	-	-	-	-	8
Caulleriella sp.	-	-	10	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	-	-	-	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-	-
Cirratulus spp.	3	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	-	-	-	5	-	-	-
Tharyx annulosus	-	-	-	-	-	-	-	-	-
Tharyx dorsobranchialis	-	-	5	-	8	8	15	-	10
Tharyx filibranchia	-	-	-	-	-	-	-	-	-
Tharyx marioni	15	5	-	-	-	15	-	-	-
Cirratulidae UI	-	-	-	-	3	-	-	-	-
Poecilochaetidae									
Poecilochaetus serpens	-	-	-	-	-	-	-	-	-
Chaetopteridae									
Chaetopterus sp.	-	-	-	3	-	-	-	-	-
Spiochaetopterus sp.	-	-	-	-	-	-	-	-	-
Orbiniidae									
Haploscoloplos kerguelensis	3	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-	-
Paraonidae									
Aricidea fauveli	-	-	-	-	13	8	3	5	-
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-	-

TABLE VI

Polychaete species abundance at 1000m depth during Survey II (FORVSS 228 & 233)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Aricidea (Acmira) simplex	33	-	-	-	-	-	-	-	-
Aricidea (Allia) belgicae	3	5	-	-	-	-	-	-	-
Aricidea (Aricidea) capensis	-	-	-	-	-	-	-	-	-
Aricidea sp. 1	10	5	-	-	-	-	-	-	5
Aricidea sp. 2	-	-	-	-	-	-	-	-	-
Aricidea sp. 3	-	-	-	-	-	-	-	-	-
Aricidea spp.	-	-	-	-	5	-	-	-	-
Aricidea (Aedicira) spp.	-	-	20	-	-	-	-	5	-
Cirrophorus branchiatus	5	-	-	8	-	-	13	-	3
Levinsenia oculata	15	-	-	-	-	-	8	-	5
Paraonides lyra	3	-	-	-	-	-	-	-	-
Paraonis gracilis	25	-	10	-	-	-	3	8	-
Paraonidae UI	8	5	-	-	-	-	-	-	-
Opheliidae									
Ophelina sp.	-	-	-	-	-	-	-	-	-
Cossuridae									
Cossura coasta	18	25	18	53	20	25	45	73	15
Capitellidae									
Capitella capitata	3	-	-	-	3	-	-	-	-
Dasybranchus spp.	-	-	-	-	-	-	-	-	-
Leiochrides africanus	-	-	3	-	-	-	-	15	-
Mediomastus sp.	-	-	-	5	-	-	-	-	-
Notomastus aberans	15	20	15	28	3	30	-	5	10
Notomastus fauveli	-	-	-	-	13	-	3	13	8
Notomastus latericeus	-	-	-	-	-	-	-	-	-
Notomastus sp.	-	3	13	-	-	5	-	-	3
Capitellidae UI	-	-	-	-	-	-	-	-	-
Maldanidae									
Euclymene oerstedi	-	-	-	-	-	-	-	3	-
Euclymene santandarensis	-	-	-	-	-	-	-	-	-
Euclymene spp.	13	-	-	-	-	-	-	-	-
Johnstonia sp.	-	-	-	-	-	3	-	-	-
Lumbriclymene spp.	5	-	-	-	-	-	-	-	-
Maldane sarsi	28	8	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	-	-	-	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	3	-	-
Maldanidae UI	-	8	-	-	-	-	3	-	-
Flabelligeridae									
Brada sp.	-	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-	-
Flabelligera sp.	-	-	-	-	-	3	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-	-
Sternaspidae									
Sternaspis scutata	-	-	3	-	-	-	-	3	-
Pectinariidae									
Pectinaria sp.	-	-	-	-	-	-	-	-	-
Ampharetidae									
Ampharete acutifrons	3	-	5	-	-	-	-	-	-
Ampharete sp. 1	5	3	-	-	-	-	-	-	5

TABLE VI

Polychaete species abundance at 1000m depth during Survey II (FORVSS 228 & 233)

Species	Cap 1000	Tvm 1000	Klm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Ampharete sp. 2	-	-	-	-	-	-	-	-	-
Ampharete spp.	-	-	-	-	-	-	-	-	-
Amphicteis gunneri	13	13	3	3	-	-	-	3	3
Isolda pulchella	-	-	-	-	-	-	-	-	-
Sabellides spp.	-	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	3	5	3
Trichobranchidae									
Terebellides stroemii	5	3	-	3	-	5	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-	-
Terebellidae									
Amphitrite cirrata	-	-	-	-	-	-	-	-	-
Amphitrite sp. 1	3	3	-	-	-	-	3	-	-
Pista cristata	-	3	-	-	-	-	-	-	-
Pista fasciata	-	-	3	-	-	-	-	-	-
Pista macrolobata	-	-	-	-	-	-	-	-	-
Pista unibranchia	-	-	-	-	-	-	-	-	3
Pista sp.	-	-	-	-	-	-	-	-	-
Streblosoma persica	3	-	-	-	-	-	-	-	-
Terebellidae UI	-	-	-	-	-	-	-	-	-
Sabellidae									
Chone collaris	-	-	-	-	-	-	-	-	-
Chone letterstedti	-	-	-	-	-	-	-	-	-
Fabricia spp.	-	-	-	-	-	-	-	-	-
Jasmineira elegans	-	-	-	-	-	-	-	-	-
Oriopsis sp.	-	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	-	-	-	-	-
Sabellariidae									
Idanthyrsus macropalea	-	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-	-
Serpulidae									
Hydroides sp.	-	-	-	-	-	-	-	-	-
Metavermilia acanthophora	-	3	-	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	-	-	3	-	-	-

TABLE VII

Polychaete species abundance at 200m depth during Survey III (FORVSS 254)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Pholoidae									
Pholoe minuta	-	-	-	-	-	-	-	-	-
Polynoidae									
Harmothoe profunda	-	-	-	-	-	-	-	-	-
Harmothoe sp.	-	-	-	-	-	-	10	15	-
Sigalionidae									
Labiosthenolepis sp.	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	-	-	-	-
Aphroditidae									
Aphroditidae UI	-	-	-	-	-	-	3	-	-
Chrysopetalidae									
Paleanotus chrysolepis	-	5	-	-	-	-	-	-	-
Amphinomidae									
Chloeia sp.	3	-	-	-	-	-	-	-	-
Eurythoe sp. 1	-	-	-	-	-	-	-	-	-
Linopherus sp.	-	-	-	-	-	-	-	-	-
Amphinomidae UI	-	-	-	-	-	-	-	-	-
Phyllodocidae									
Eulalia sp.	-	-	-	-	-	-	-	-	-
Eumida sanguinea	-	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	10	-	-	-	-	-	-	-
Alciopidae									
Alciopidae UI	-	-	-	-	5	-	-	-	-
Pilargidae									
Ancistrosyllis sp.	-	-	-	-	-	-	-	-	-
Sigambra constricta	-	-	-	-	-	-	-	-	-
Sigambra parva	-	-	-	-	-	13	-	-	-
Pilargis sp.	-	-	-	-	-	-	-	-	-
Hesionidae									
Kefersteinia cirrata	3	5	-	-	-	-	-	-	-
Leocrates claparedii	-	-	-	-	-	-	-	-	-
Podarke angustifrons	-	5	-	-	5	-	-	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-	-
Syllidae									
Syllis cornuta	-	-	-	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	-	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-	-
Syllis sp. 1	-	-	-	-	35	-	-	-	-
Syllidae UI	-	-	-	-	-	-	-	-	-
Nereididae									
Ceratonereis sp.	-	-	-	-	-	-	-	-	-
Leonnates indicus	-	-	-	-	-	-	-	-	-
Alitta succinea	-	-	-	-	-	-	-	-	-
Nereis sp. 1	-	-	-	-	-	-	-	-	-
Nereis sp. 2	-	-	-	-	-	-	-	-	-
Platynereis sp.	-	-	-	-	-	-	-	-	-
Tylonereis sp.	-	-	-	-	-	-	-	-	-
Nereididae UI	-	5	-	-	-	-	-	-	-

TABLE VII

Polychaete species abundance at 200m depth during Survey III (FORVSS 254)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Nephtyidae									
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	15	-	-	-	10	35	2	-	-
Nephtys polybranchia	-	-	-	-	-	-	2	-	-
Nephtys sp.	-	-	-	-	-	-	-	-	3
Paralacydoniidae									
Paralacydonia paradoxa	-	-	-	-	-	-	-	-	-
Glyceridae									
Glycera convoluta	-	-	3	-	-	-	-	-	-
Glycera longipinnis	-	-	-	-	-	-	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-	-
Glycera unicornis	3	-	5	-	-	-	-	-	-
Glycera sp. 1	-	-	-	-	-	-	-	-	-
Glycera sp. 2	-	-	-	-	-	-	-	-	-
Glycera spp.	-	-	-	-	-	-	-	-	-
Goniadidae									
Ophioglycera sp.	-	-	-	-	-	-	-	-	-
Glycinde kameruniana	-	-	-	-	-	-	-	-	-
Goniada emerita	13	35	25	-	10	-	-	-	-
Eunicidae									
Eunice indica	-	5	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-	-
Onuphidae									
Diopatra neapolitana	-	-	-	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	-	-
Kinbergonuphis investigatoris	-	-	-	-	-	-	-	-	-
Onuphis emerita	-	-	-	-	-	-	-	-	-
Onuphis holobranchiata	3	15	-	-	-	-	-	-	-
Onuphis sp. 2	-	-	-	-	-	-	-	-	-
Onuphis spp.	-	-	-	-	-	-	-	-	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-	-
Lumbrineridae									
Lumbrineris aberrans	-	-	-	-	-	-	-	-	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	40	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 1	-	-	-	-	-	-	-	-	-
Lumbrineris sp. 2	-	-	-	-	-	-	-	-	-
Lumbrineris spp.	-	5	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	-	-	8	3	-	-
Oenonidae									
Arabella iricolor iricolor	-	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	3	-	-	-
Dorvilleidae									
Schistomeringos rudolphii	-	-	-	-	-	-	-	-	-
Spionidae									
Aonides spp.	-	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	20	25	-	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-	-
Laonice cirrata	18	15	-	-	-	-	-	-	-
Laonice sp.	-	25	-	-	-	-	-	-	-

TABLE VII

Polychaete species abundance at 200m depth during Survey III (FORVSS 254)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Malacoceros indicus	-	-	-	-	-	-	-	-	-
Paraprionospio pinnata	15	20	-	5	510	5	2	-	-
Polydora sp.	-	-	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	-	15	-	58	72	43	70
Prionospio (Prionospio) ehlersi	-	-	-	-	-	-	-	-	-
Prionospio polybranchiata	-	-	-	-	90	140	58	168	-
Prionospio sp. 1	-	-	-	-	210	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-	-
Prionospio sp. 4	-	-	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-	-
Prionospio spp.	3	20	8	-	-	-	-	-	-
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	5	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	3	-	-	-	-	-	-	-	-
Spiophanes bombyx	-	40	5	-	-	-	-	-	-
Spiophanes sp. 1	38	15	-	5	5	18	-	-	-
Spiophanes sp. 2	-	-	-	-	-	-	-	-	-
Spionidae UI	3	-	-	-	-	-	-	-	-
Heterospionidae									
Heterospio sp.	-	-	-	-	-	-	-	-	-
Magelonidae									
Magelona cincta	3	-	48	-	50	-	-	-	-
Cirratulidae									
Aphelochaeta filiformis	-	-	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-	-
Caulleriella capensis	-	-	-	-	-	35	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	-	-	-	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	-	-	-	-	-	-	-
Tharyx annulosus	-	-	3	-	-	-	40	1588	10
Tharyx dorsobranchialis	170	120	695	-	-	68	37	63	65
Tharyx filibranchia	-	-	30	-	-	-	13	175	13
Tharyx marioni	-	15	5	10	20	-	-	-	3
Cirratulidae UI	5	-	-	-	-	-	-	-	-
Poecilochaetidae									
Poecilochaetus serpens	3	5	-	-	-	-	5	8	-
Chaetopteridae									
Chaetopterus sp.	5	-	-	-	-	5	-	-	-
Spiochaetopterus sp.	-	5	-	3	-	-	-	-	-
Orbiniidae									
Haploscoloplos kerguelensis	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-	-
Paraonidae									
Aricidea fauveli	103	-	5	-	-	-	-	-	-
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-	-

TABLE VII

Polychaete species abundance at 200m depth during Survey III (FORVSS 254)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Aricidea (Acmira) simplex	-	-	-	-	-	-	-	-	-
Aricidea (Allia) belgicae	40	-	-	-	-	-	-	-	-
Aricidea (Aricidea) capensis	-	175	-	-	-	-	-	-	-
Aricidea sp. 1	28	-	-	-	-	23	-	-	-
Aricidea sp. 2	-	-	-	-	-	-	-	-	-
Aricidea sp. 3	-	-	-	-	-	-	-	-	-
Aricidea spp.	113	-	-	-	-	-	-	-	-
Aricidea (Aedicira) spp.	-	-	-	-	-	-	-	-	-
Cirrophorus branchiatus	-	5	-	-	-	-	-	-	-
Levinsenia oculata	-	-	-	13	340	-	-	-	-
Paraonides lyra	-	30	-	-	-	-	-	-	-
Paraonis gracilis	265	5	-	-	-	408	57	-	-
Paraonidae UI	-	-	-	-	-	-	-	-	-
Opheliidae									
Ophelina sp.	3	-	-	-	-	-	-	-	-
Cossuridae									
Cossura coasta	-	-	3	8	70	195	22	15	113
Capitellidae									
Capitella capitata	-	-	-	-	-	-	-	-	-
Dasybranchus spp.	-	-	-	-	-	-	-	-	-
Leiochrides africanus	-	-	-	-	-	-	-	-	-
Mediomastus sp.	-	-	-	-	-	-	-	-	-
Notomastus aberans	20	-	38	-	-	-	-	-	-
Notomastus fauveli	-	-	-	-	5	-	-	-	-
Notomastus latericeus	-	-	-	-	5	-	-	-	-
Notomastus sp.	-	15	-	-	-	-	-	-	-
Capitellidae UI	-	-	-	-	-	-	-	-	-
Maldanidae									
Euclymene oerstedi	5	-	10	-	-	-	-	-	-
Euclymene santandarensis	-	-	-	-	-	-	-	-	-
Euclymene spp.	-	20	-	-	30	48	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	-	-	-	-	-
Maldane sarsi	-	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	18	-	-	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	-	-	-
Maldanidae UI	25	-	3	-	-	-	-	-	-
Flabelligeridae									
Brada sp.	-	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-	-
Sternaspidae									
Sternaspis scutata	-	5	-	-	-	5	-	-	-
Pectinariidae									
Pectinaria sp.	3	-	-	-	-	-	-	-	-
Ampharetidae									
Ampharete acutifrons	-	-	-	-	-	-	-	-	-
Ampharete sp. 1	-	-	13	-	-	50	-	-	-

TABLE VII

Polychaete species abundance at 200m depth during Survey III (FORVSS 254)

Species	Cap 200	Tvm 200	Klm 200	Kch 200	Pon 200	Knr 200	Mng 200	Cnd 200	Kwr 200
Ampharete sp. 2	23	-	13	-	-	-	-	-	-
Ampharete spp.	5	-	-	-	-	-	-	-	-
Amphicteis gunneri	10	20	-	-	-	3	10	15	-
Isolda pulchella	15	15	-	-	-	-	-	-	-
Sabellides spp.	-	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	-	-	-
Trichobranchidae									
Terebellides stroemii	-	-	-	-	-	-	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-	-
Terebellidae									
Amphitrite cirrata	-	-	-	-	-	-	-	-	-
Amphitrite sp. 1	-	-	-	-	-	5	3	-	-
Pista cristata	-	-	-	-	-	-	-	-	-
Pista fasciata	-	-	-	-	-	-	-	-	-
Pista macrolobata	-	5	-	-	-	-	-	-	-
Pista unibranchia	53	-	-	-	-	-	-	-	-
Pista sp.	10	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-	-
Terebellidae UI	-	-	-	-	-	-	-	-	-
Sabellidae									
Chone collaris	-	5	-	-	-	-	-	-	-
Chone letterstedti	-	-	-	-	-	-	-	-	-
Fabricia spp.	-	-	-	-	-	-	-	-	-
Jasmineira elegans	-	5	-	-	-	-	-	-	-
Oriopsis sp.	-	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	-	-	-	-	-
Sabellariidae									
Idanthyrsus macropalea	-	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-	-
Serpulidae									
Hydroides sp.	20	-	-	-	-	-	-	-	-
Metavermilia acanthophora	-	10	-	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	-	-	-	-	-	-

TABLE VIII

Polychaete species abundance at 500m depth during Survey III (FORVSS 254)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Pholoidae									
Pholoe minuta	-	-	-	-	-	-	-	-	-
Polynoidae									
Harmothoe profunda	-	-	-	-	-	-	-	-	-
Harmothoe sp.	-	-	5	-	-	-	-	3	-
Sigalionidae									
Labiosthenolepis sp.	-	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	3	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	-	-	-	-
Aphroditidae									
Aphroditidae UI	-	-	-	-	-	-	-	-	-
Chrysopetalidae									
Paleanotus chrysolepis	-	-	-	-	-	-	-	-	-
Amphinomidae									
Chloeia sp.	-	-	-	-	-	-	-	-	-
Eurythoe sp. 1	-	-	-	-	-	-	-	-	-
Linopherus sp.	-	-	-	-	-	5	-	-	-
Amphinomidae UI	-	-	-	-	-	-	-	-	-
Phyllodocidae									
Eulalia sp.	-	-	-	-	-	-	-	-	-
Eumida sanguinea	-	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	3	-	-	-	-	-	-	-
Alciopidae									
Alciopidae UI	-	-	-	-	-	-	-	-	-
Pilargidae									
Ancistrosyllis sp.	-	-	-	-	-	-	-	-	-
Sigambra constricta	5	5	-	5	-	-	-	-	-
Sigambra parva	5	13	-	-	5	-	-	-	-
Pilargis sp.	-	-	-	-	-	-	-	-	-
Hesionidae									
Kefersteinia cirrata	5	-	55	-	-	-	-	-	-
Leocrates claparedii	-	-	-	-	-	5	-	3	-
Podarke angustifrons	-	3	3	5	10	-	3	-	-
Podarkeopsis capensis	-	3	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	-	-	-	-
Syllidae									
Syllis cornuta	-	-	13	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	3	-	-	-	-	-	-
Syllis vittata	-	-	-	-	-	-	-	-	-
Syllis sp. 1	-	-	-	-	-	-	-	-	-
Syllidae UI	-	-	3	-	-	-	-	-	-
Nereididae									
Ceratonereis sp.	-	-	-	-	-	-	-	-	-
Leonnates indicus	-	-	-	-	-	-	-	-	-
Alitta succinea	-	-	-	-	-	-	-	-	-
Nereis sp. 1	-	-	5	5	-	-	-	-	-
Nereis sp. 2	-	-	-	-	-	-	-	-	-
Platynereis sp.	-	-	-	-	-	-	-	-	-
Tylonereis sp.	-	-	-	-	-	-	-	-	-
Nereididae UI	10	-	-	-	-	-	-	-	-

TABLE VIII

Polychaete species abundance at 500m depth during Survey III (FORVSS 254)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Nephtyidae									
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	-	-	-	-	-	-	-	-	-
Nephtys polybranchia	-	-	-	-	-	-	-	-	5
Nephtys sp.	-	-	-	-	-	-	-	-	-
Paralacydoniidae									
Paralacydonia paradoxa	-	-	-	-	-	-	-	-	-
Glyceridae									
Glycera convoluta	-	-	-	-	-	5	3	-	-
Glycera longipinnis	5	-	5	-	5	-	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-	-
Glycera unicornis	5	-	-	-	-	-	-	-	-
Glycera sp. 1	-	-	5	-	-	-	-	-	-
Glycera sp. 2	-	-	-	-	-	-	-	-	-
Glycera spp.	-	-	-	-	-	-	-	-	-
Goniadidae									
Ophioglycera sp.	-	-	-	-	-	-	-	-	-
Glycinde kameruniana	-	-	-	-	-	-	-	-	-
Goniada emerita	-	3	-	-	-	-	-	-	-
Eunicidae									
Eunice indica	-	-	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-	-
Onuphidae									
Diopatra neapolitana	-	3	-	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	3	-
Kinbergonuphis investigatoris	-	-	-	-	-	-	-	-	-
Onuphis emerita	-	-	-	-	-	-	-	-	-
Onuphis holobranchiata	-	-	8	-	-	-	-	-	-
Onuphis sp. 2	-	-	3	-	-	-	-	-	-
Onuphis spp.	-	-	-	-	-	-	-	3	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-	-
Lumbrineridae									
Lumbrineris aberrans	-	-	-	-	-	-	-	-	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	5	5	-	-	-	5
Lumbrineris sp. 1	5	5	-	10	-	-	3	3	-
Lumbrineris sp. 2	-	23	3	-	-	-	-	-	-
Lumbrineris spp.	-	-	-	-	-	-	-	-	-
Ninoe sp.	-	-	-	15	-	-	5	-	-
Oenonidae									
Arabella iricolor iricolor	-	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	-	-	-	-	-
Dorvilleidae									
Schistomeringos rudolphii	-	-	-	-	-	-	-	-	-
Spionidae									
Aonides spp.	-	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	-	-	3	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-	-
Laonice cirrata	15	-	5	-	-	-	-	-	-
Laonice sp.	-	-	-	-	-	75	-	-	-

TABLE VIII

Polychaete species abundance at 500m depth during Survey III (FORVSS 254)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Malacoceros indicus	-	-	-	-	-	-	-	-	-
Paraprionospio pinnata	5	5	-	45	10	-	-	10	95
Polydora sp.	-	-	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	-	-	-	-	8	8	-
Prionospio (Prionospio) ehlersi	-	68	-	65	-	35	-	-	-
Prionospio polybranchiata	-	3	20	-	-	40	-	-	-
Prionospio sp. 1	-	-	3	-	-	-	-	-	-
Prionospio sp. 2	-	3	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	8	-	-
Prionospio sp. 4	-	-	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	3	-	-
Prionospio spp.	20	68	75	-	-	5	23	-	-
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-	-
Pygospio elegans	-	3	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	-	-	3	-	-	-	-	-	-
Spiophanes bombyx	-	-	-	-	-	10	-	-	-
Spiophanes sp. 1	-	13	18	10	-	-	-	-	-
Spiophanes sp. 2	5	-	-	-	-	-	-	-	-
Spionidae UI	-	18	3	-	-	-	-	-	-
Heterospionidae									
Heterospio sp.	-	-	-	-	-	-	-	-	-
Magelonidae									
Magelona cincta	-	-	18	-	-	-	-	-	-
Cirratulidae									
Aphelochaeta filiformis	-	-	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-	-
Caulleriella capensis	-	-	-	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	-	-	5	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	-	-	-	-	-	-	-
Tharyx annulosus	-	-	-	-	-	-	-	-	-
Tharyx dorsobranchialis	70	3	8	-	5	-	-	5	318
Tharyx filibranchia	-	-	-	-	-	-	-	-	30
Tharyx marioni	-	10	-	-	-	-	-	-	-
Cirratulidae UI	-	-	-	-	-	-	-	-	8
Poecilochaetidae									
Poecilochaetus serpens	-	-	8	5	-	-	-	-	-
Chaetopteridae									
Chaetopterus sp.	-	-	-	-	-	-	-	-	-
Spiochaetopterus sp.	-	-	-	-	-	-	3	-	-
Orbiniidae									
Haploscoloplos kerguelensis	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-	-
Paraonidae									
Aricidea fauveli	-	3	3	-	-	-	3	-	-
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-	-

TABLE VIII

Polychaete species abundance at 500m depth during Survey III (FORVSS 254)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Aricidea (Acmira) simplex	-	-	8	-	-	-	-	-	-
Aricidea (Allia) belgicae	-	-	-	-	-	-	-	-	-
Aricidea (Aricidea) capensis	-	-	-	-	-	-	-	-	-
Aricidea sp. 1	-	-	-	-	-	-	3	-	-
Aricidea sp. 2	-	-	-	-	-	-	-	-	-
Aricidea sp. 3	-	-	-	-	-	-	-	-	-
Aricidea spp.	-	-	-	-	-	-	-	3	-
Aricidea (Aedicira) spp.	-	-	-	-	-	-	-	-	-
Cirrophorus branchiatus	-	-	-	-	-	-	-	-	-
Levinsenia oculata	-	-	-	-	-	-	-	10	-
Paraonides lyra	-	-	-	-	-	10	-	-	-
Paraonis gracilis	-	3	13	-	-	-	-	-	-
Paraonidae UI	-	-	13	-	-	-	-	-	-
Opheliidae									
Ophelina sp.	-	-	-	-	-	-	-	-	-
Cossuridae									
Cossura coasta	-	3	-	-	-	-	8	-	3
Capitellidae									
Capitella capitata	-	5	-	-	-	-	-	-	-
Dasybranchus spp.	-	15	-	-	-	-	-	-	-
Leiochrides africanus	-	-	5	-	-	-	-	-	-
Mediomastus sp.	-	-	-	-	-	-	-	-	-
Notomastus aberans	15	-	-	-	-	10	5	-	-
Notomastus fauveli	-	-	-	5	-	-	-	-	-
Notomastus latericeus	-	-	3	-	-	-	-	-	-
Notomastus sp.	15	5	-	-	-	-	-	-	-
Capitellidae UI	-	-	13	5	-	5	-	-	-
Maldanidae									
Euclymene oerstedi	-	-	-	-	-	-	-	-	-
Euclymene santandarensis	-	-	-	-	-	-	-	-	-
Euclymene spp.	-	5	-	-	-	-	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	-	-	-	-	-
Maldane sarsi	-	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	3	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	-	-	-	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	-	-	-
Maldanidae UI	-	-	3	-	-	-	-	-	-
Flabelligeridae									
Brada sp.	-	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	-	-	-
Sternaspidae									
Sternaspis scutata	-	8	-	-	-	-	-	-	-
Pectinariidae									
Pectinaria sp.	-	-	-	-	-	-	-	-	-
Ampharetidae									
Ampharete acutifrons	-	-	-	-	-	-	-	3	-
Ampharete sp. 1	-	-	5	-	20	-	-	-	-

TABLE VIII

Polychaete species abundance at 500m depth during Survey III (FORVSS 254)

Species	Cap 500	Tvm 500	Klm 500	Kch 500	Pon 500	Knr 500	Mng 500	Cnd 500	Kwr 500
Ampharete sp. 2	-	-	3	-	-	-	-	-	-
Ampharete spp.	-	-	33	-	-	-	-	-	-
Amphicteis gunneri	-	-	-	-	-	-	3	5	110
Isolda pulchella	-	-	-	-	-	-	-	-	-
Sabellides spp.	-	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	-	-	-
Trichobranchidae									
Terebellides stroemii	-	-	-	-	-	-	-	-	-
Trichobranchus glacialis	-	-	5	-	-	-	-	-	-
Terebellidae									
Amphitrite cirrata	-	-	-	5	-	-	-	-	-
Amphitrite sp. 1	-	-	-	-	-	-	-	-	-
Pista cristata	-	-	-	-	-	-	-	-	-
Pista fasciata	-	-	-	-	-	-	-	-	-
Pista macrolobata	-	-	-	-	-	-	-	-	-
Pista unibranchia	-	-	-	-	-	-	-	-	-
Pista sp.	-	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-	-
Terebellidae UI	-	-	-	-	-	-	-	-	-
Sabellidae									
Chone collaris	-	-	-	-	-	-	-	-	3
Chone letterstedti	-	-	-	-	-	-	-	-	-
Fabricia spp.	-	-	8	-	-	-	-	-	-
Jasmineira elegans	-	-	-	-	-	-	-	3	-
Oriopsis sp.	-	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	13	-	-	-	-	-	-
Sabellariidae									
Idanthyrsus macropalea	-	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	3	-	-
Serpulidae									
Hydroides sp.	-	-	-	-	-	-	-	-	-
Metavermilia acanthophora	-	-	5	-	-	-	-	-	-
Unidentified Polychaetes	-	-	-	-	-	-	-	-	-

TABLE IX

Polychaete species abundance at 1000m depth during Survey III (FORVSS 254)

Species	Cap 1000	Tvm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Pholoidae								
Pholoe minuta	-	-	-	-	-	3	-	-
Polynoidae								
Harmothoe profunda	-	-	-	-	-	-	-	-
Harmothoe sp.	-	-	-	-	-	-	-	-
Sigalionidae								
Labiosthenolepis sp.	-	-	-	-	-	-	-	-
Sthenelais boa	-	-	-	-	-	-	-	-
Sthenolepis japonica	-	-	-	-	-	-	-	-
Aphroditidae								
Aphroditidae UI	-	-	-	-	-	-	-	-
Chrysopetalidae								
Paleanotus chrysolepis	-	-	-	-	-	-	-	-
Amphinomidae								
Chloeia sp.	-	-	-	-	-	-	-	-
Eurythoe sp. 1	-	-	-	5	-	-	-	-
Linopherus sp.	-	-	-	-	-	-	-	-
Amphinomidae UI	-	-	-	-	-	-	-	-
Phyllodocidae								
Eulalia sp.	-	-	-	-	-	-	-	-
Eumida sanguinea	-	-	-	-	-	-	-	-
Phyllodoce malmgreni	-	-	-	-	-	-	-	-
Alciopidae								
Alciopidae UI	-	-	-	-	-	-	-	-
Pilargidae								
Ancistrosyllis sp.	-	-	-	-	-	-	-	-
Sigambra constricta	5	-	3	3	-	-	-	-
Sigambra parva	-	-	3	-	3	-	-	3
Pilargis sp.	-	-	-	-	-	-	-	-
Hesionidae								
Kefersteinia cirrata	-	-	-	-	-	-	-	-
Leocrates claparedii	-	-	-	-	-	-	-	-
Podarke angustifrons	-	-	-	-	3	3	-	-
Podarkeopsis capensis	-	-	-	-	-	-	-	-
Hesionidae UI	-	-	-	-	-	5	5	-
Syllidae								
Syllis cornuta	-	-	-	-	-	-	-	-
Syllis hyalina	-	-	-	-	-	-	-	-
Syllis prolifera	-	-	-	-	-	-	-	-
Syllis vittata	-	-	-	-	3	-	-	-
Syllis sp. 1	-	-	-	-	-	-	-	-
Syllidae UI	-	-	-	-	-	-	-	-
Nereididae								
Ceratonereis sp.	5	-	-	-	-	-	-	-
Leonnates indicus	-	-	-	-	-	-	-	-
Alitta succinea	-	-	-	-	-	-	-	-
Nereis sp. 1	-	-	3	-	-	3	10	3
Nereis sp. 2	-	-	-	-	3	-	-	-
Platynereis sp.	-	-	-	-	-	-	-	-
Tylonereis sp.	-	-	-	-	-	-	-	-
Nereididae UI	10	3	-	-	-	-	-	-

TABLE IX

Polychaete species abundance at 1000m depth during Survey III (FORVSS 254)

Species	Cap 1000	Tvm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Nephtyidae								
Micronephthys sphaerocirrata	-	-	-	-	-	-	-	-
Aglaophamus dibranchis	-	-	-	3	-	-	-	-
Nephtys polybranchia	-	-	-	-	-	-	-	-
Nephtys sp.	-	-	-	-	-	-	-	-
Paralacydoniidae								
Paralacydonia paradoxa	-	-	-	-	-	-	-	-
Glyceridae								
Glycera convoluta	-	-	-	-	-	-	-	-
Glycera longipinnis	-	-	-	3	-	-	-	-
Glycera rouxii	-	-	-	-	-	-	-	-
Glycera unicornis	-	-	-	-	-	-	-	-
Glycera sp. 1	-	-	-	-	-	-	-	-
Glycera sp. 2	-	-	3	-	-	-	-	-
Glycera spp.	-	-	-	-	-	-	-	-
Goniadidae								
Ophioglycera sp.	-	-	-	-	-	-	-	-
Glycinde kameruniana	-	-	-	-	-	-	-	-
Goniada emerita	-	-	-	3	-	-	5	-
Eunicidae								
Eunice indica	-	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	3	-	-
Onuphidae								
Diopatra neapolitana	-	-	-	-	-	-	-	-
Hyalinoecia tubicola	-	-	-	-	-	-	-	-
Kinbergonuphis investigatoris	-	-	-	-	-	-	-	-
Onuphis emerita	-	-	-	-	-	-	-	-
Onuphis holobranchiata	5	-	-	-	-	-	-	-
Onuphis sp. 2	-	5	-	-	-	-	-	-
Onuphis spp.	-	-	3	-	-	-	-	-
Rhamphobrachium sp.	-	-	-	-	-	-	-	-
Lumbrineridae								
Lumbrineris aberrans	-	-	-	-	-	-	5	-
Lumbrineris heteropoda	-	-	-	-	-	-	-	-
Lumbrineris inflata	-	-	-	-	-	-	-	-
Lumbrineris latreilli	-	-	-	-	-	3	-	-
Lumbrineris sp. 1	-	-	-	3	-	3	-	-
Lumbrineris sp. 2	5	5	-	-	-	-	-	-
Lumbrineris spp.	-	-	-	-	5	-	-	-
Ninoe sp.	-	-	-	-	-	-	-	-
Oenonidae								
Arabella iricolor iricolor	-	-	-	-	-	-	-	-
Drilonereis sp.	-	-	-	-	5	-	-	-
Dorvilleidae								
Schistomeringos rudolphii	-	10	-	-	-	-	10	3
Spionidae								
Aonides spp.	-	-	-	-	-	-	-	-
Aonidella cirrobranchiata	-	-	-	-	-	-	-	-
Boccardia polybranchia	-	-	-	-	-	-	-	-
Laonice cirrata	-	-	-	-	-	-	-	-
Laonice sp.	-	-	-	-	-	-	-	-

TABLE IX

Polychaete species abundance at 1000m depth during Survey III (FORVSS 254)

Species	Cap 1000	Tvm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Malacoceros indicus	-	-	-	-	-	-	-	-
Paraprionospio pinnata	-	-	-	5	-	3	-	3
Polydora sp.	-	-	-	-	-	-	-	-
Prionospio cirrifera	-	-	-	-	-	-	-	-
Prionospio (Prionospio) ehlersi	-	-	3	-	5	-	-	-
Prionospio polybranchiata	-	10	-	-	-	-	-	-
Prionospio sp. 1	-	-	-	-	-	-	-	-
Prionospio sp. 2	-	-	-	-	-	-	-	-
Prionospio sp. 3	-	-	-	-	-	-	-	-
Prionospio sp. 4	-	-	-	-	-	-	-	-
Prionospio sp. 5	-	-	-	-	-	-	-	-
Prionospio spp.	-	8	-	-	-	-	-	-
Pseudomalacoceros gilchristi	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	-	-	-	-	-	-
Scolelepis lefebvrei	-	-	-	-	-	-	-	-
Scolelepis (Scolelepis) squamata	-	-	-	-	-	-	-	-
Spiophanes bombyx	-	3	-	-	-	-	-	-
Spiophanes sp. 1	-	-	-	-	-	5	5	-
Spiophanes sp. 2	-	-	-	-	-	-	-	-
Spionidae UI	5	3	-	-	-	-	10	3
Heterospionidae								
Heterospio sp.	-	-	-	-	-	-	-	-
Magelonidae								
Magelona cincta	-	-	-	-	-	-	-	-
Cirratulidae								
Aphelochaeta filiformis	-	-	-	-	-	-	-	-
Caulleriella bioculata	-	-	-	-	-	-	-	-
Caulleriella capensis	-	-	-	-	-	-	-	-
Caulleriella sp.	-	-	-	-	-	-	-	-
Chaetozone setosa	-	-	-	-	-	-	-	-
Cirratulus cirratus	-	-	-	-	-	-	-	-
Cirratulus sp. 1	-	-	-	-	-	-	-	-
Cirratulus spp.	-	-	-	-	-	-	-	-
Cirriformia afer	-	-	-	-	-	-	-	-
Tharyx annulosus	-	-	-	-	-	-	10	-
Tharyx dorsobranchialis	-	-	3	-	5	10	-	3
Tharyx filibranchia	-	-	-	-	-	-	-	-
Tharyx marioni	20	-	-	-	3	-	-	-
Cirratulidae UI	10	-	-	-	-	-	-	-
Poecilochaetidae								
Poecilochaetus serpens	-	-	-	3	5	3	-	-
Chaetopteridae								
Chaetopterus sp.	-	-	-	-	-	-	-	3
Spiochaetopterus sp.	-	-	-	-	-	-	5	-
Orbiniidae								
Haploscoloplos kerguelensis	-	-	5	-	-	-	-	-
Scoloplos (Leodamas) latum	-	-	-	-	-	-	-	-
Scoloplos (Leodamas) uniramus	-	-	-	-	-	-	-	-
Paraonidae								
Aricidea fauveli	-	3	-	-	-	-	5	-
Aricidea (Acmira) catherinae	-	-	-	-	-	-	-	-

TABLE IX

Polychaete species abundance at 1000m depth during Survey III (FORVSS 254)

Species	Cap 1000	Tvm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Aricidea (Acmira) simplex	-	-	-	8	-	-	-	-
Aricidea (Allia) belgicae	-	5	-	-	-	-	-	-
Aricidea (Aricidea) capensis	-	-	-	-	-	-	-	-
Aricidea sp. 1	-	-	-	-	-	-	10	-
Aricidea sp. 2	-	-	-	-	-	-	-	-
Aricidea sp. 3	-	-	-	-	-	-	-	-
Aricidea spp.	-	-	-	-	-	-	-	-
Aricidea (Aedicira) spp.	-	-	-	-	-	-	-	-
Cirrophorus branchiatus	-	-	-	-	-	-	-	-
Levinsenia oculata	-	-	-	-	-	-	10	-
Paraonides lyra	-	-	-	-	-	-	-	-
Paraonis gracilis	-	-	-	-	5	-	5	-
Paraonidae UI	-	-	-	-	-	-	-	-
Opheliidae								
Ophelina sp.	-	-	-	-	-	-	-	-
Cossuridae								
Cossura coasta	15	18	3	28	20	18	25	-
Capitellidae								
Capitella capitata	-	3	3	-	-	5	-	-
Dasybranchus spp.	-	-	-	-	-	-	-	-
Leiochrides africanus	-	-	-	-	-	-	-	-
Mediomastus sp.	-	-	-	-	-	-	-	-
Notomastus aberans	-	8	-	10	-	-	40	-
Notomastus fauveli	-	5	8	5	5	15	-	-
Notomastus latericeus	-	-	-	-	-	-	-	-
Notomastus sp.	15	5	-	-	-	-	10	3
Capitellidae UI	-	-	-	-	-	-	-	-
Maldanidae								
Euclymene oerstedi	5	3	-	-	-	-	-	-
Euclymene santandarensis	-	-	-	-	-	-	-	-
Euclymene spp.	5	3	-	-	13	-	-	-
Johnstonia sp.	-	-	-	-	-	-	-	-
Lumbriclymene spp.	-	-	-	-	-	-	-	-
Maldane sarsi	-	-	-	-	-	-	-	-
Nicomache lumbricalis	-	-	-	-	-	-	-	-
Pseudoclymene quadrilobata	-	3	-	-	-	-	-	-
Rhodine sp.	-	-	-	-	-	-	-	-
Maldanidae UI	-	3	3	-	-	3	-	3
Flabelligeridae								
Brada sp.	-	-	-	-	-	-	-	-
Diplocirrus sp.	-	-	-	-	-	-	-	-
Flabelligera sp.	-	5	-	-	-	-	-	-
Pherusa tropica	-	-	-	-	-	-	-	-
Piromis congoense	-	-	-	-	-	-	5	-
Sternaspidae								
Sternaspis scutata	-	-	-	-	-	-	-	-
Pectinariidae								
Pectinaria sp.	-	-	-	-	-	-	-	-
Ampharetidae								
Ampharete acutifrons	-	-	-	-	-	-	-	-
Ampharete sp. 1	-	-	-	-	-	-	-	-

TABLE IX

Polychaete species abundance at 1000m depth during Survey III (FORVSS 254)

Species	Cap 1000	Tvm 1000	Kch 1000	Pon 1000	Knr 1000	Mng 1000	Cnd 1000	Kwr 1000
Ampharete sp. 2	-	-	-	-	-	-	-	-
Ampharete spp.	-	-	-	-	-	-	-	-
Amphicteis gunneri	-	3	-	-	-	-	-	-
Isolda pulchella	-	-	-	-	-	-	-	-
Sabellides spp.	-	-	-	-	-	-	-	-
Ampharetidae UI	-	-	-	-	-	-	-	-
Trichobranchidae								
Terebellides stroemii	-	-	-	-	-	-	-	-
Trichobranchus glacialis	-	-	-	-	-	-	-	-
Terebellidae								
Amphitrite cirrata	-	-	-	-	-	-	-	-
Amphitrite sp. 1	-	-	-	-	3	-	-	-
Pista cristata	-	-	-	-	-	-	-	-
Pista fasciata	-	-	-	-	-	-	-	-
Pista macrolobata	-	-	-	-	-	-	-	-
Pista unibranchia	-	-	-	-	-	-	-	-
Pista sp.	-	-	-	-	-	-	-	-
Streblosoma persica	-	-	-	-	-	-	-	-
Terebellidae UI	-	-	-	-	-	-	-	-
Sabellidae								
Chone collaris	-	-	-	-	-	-	5	-
Chone letterstedti	-	-	-	-	-	-	-	-
Fabricia spp.	-	-	-	-	-	-	-	-
Jasmineira elegans	-	-	-	-	-	-	-	-
Oriopsis sp.	-	-	-	-	-	-	-	-
Sabellidae UI	-	-	-	-	-	-	-	-
Sabellariidae								
Idanthyrsus macropalea	-	-	-	-	-	-	-	-
Sabellaria sp.	-	-	-	-	-	-	-	-
Serpulidae								
Hydroides sp.	-	-	-	-	-	-	-	-
Metavermilia acanthophora	-	-	-	-	-	-	-	-
Unidentified Polychaetes	5	-	-	-	-	-	5	-

PLATE I

Fishery Oceanographic Research Vessel *Sagar Sampada*

Underwater Unit of CTD with rosette sampler

Smith-McIntyre Grab ready for deployment

Smith-McIntyre Grab with full bite of sediment

Sieving of sediment samples

Sediments retained in the sieve

Examination of samples

Preserved sediment samples

PLATE II


Molluscs


Crustaceans


Nemertines


Paraprionospio pinnata


Cossura coasta


Prionospio cirrifera


Paraonis gracilis


Tharyx dorsobranchialis


Aricidea simplex

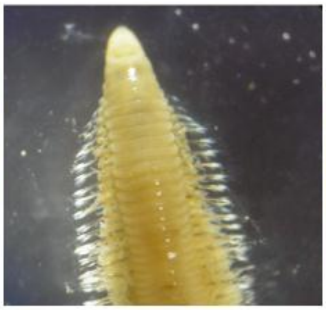

Amphitrite sp. 1


Harmothoe sp.


Pectinaria sp.

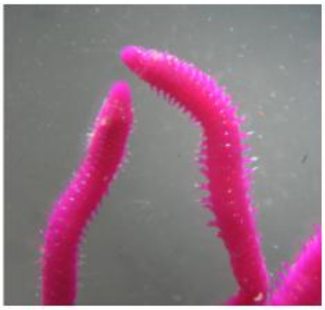
PLATE III

Goniada emerita



Ninoe sp.

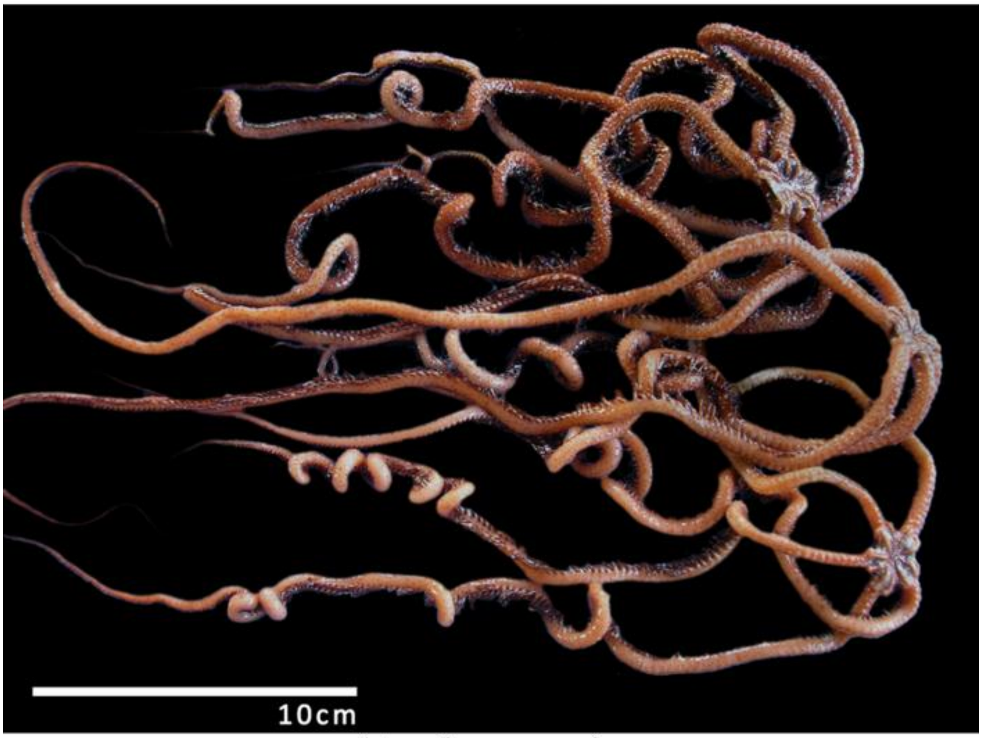
Poecilochaetus serpens



Lumbrineris sp. 1

Pista unibranchia

Limopsid bivalves



Asteroschema sampadae

A new species of ophiuroid from the SEAS margin
(Parameswaran & Jaleel 2012)