MACROBENTHIC COMMUNITY AND ITS RELATIONS WITH ENVIRONMENTAL FACTORS IN COASTAL WATERS OF PENANG NATIONAL PARK, MALAYSIA

by

MOHAMMAD GHOLIZADEH

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And finally, ***IT IS ACCOMPLISHED***! Praise be to GOD for seeing me through it all.

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LIST OF ABBREVIATION

ANN	Artificial Neural Network
ANOVA	Analysis of variance
CEMACS	Centre for Marine and Coastal Studies
DF	Deposit Feeder
DO	Dissolved Oxygen
GIS	Geographic Information System
GPS	Global Positioning System
nMDS	Non-metric Multidimensional scaling
NH4	Ammonia
NO2	Nitrite
NO3	Nitrate
PA	Pantai Acheh
PNP	Penang National Park
PO3	Orthophosphate
SF	Suspension Feeder
SOM	Self-Organizing Map
TA	Teluk Aling
TB	Teluk Bahang
TK	Teluk Ketapang
TSS	Total Suspended Solid

LIST OF PUBLICATIONS AND SEMINARS

Appendix 1: Gholizadeh, M., Yahya, K., Talib, A., & Ahmad, O. (2012.) Effects of environmental factors on polychaete assemblage in Penang National Park, Malaysia. International Journal of Environmental, Ecological, Geological and Mining Engineering Vol: 6 No: 12, 2012.

Appendix 2: Gholizadeh, M., Yahya, K., Talib, A., & Ahmad, O. (2012.) Distribution of Macrobenthic Polychaete Families in Relation to Environmental Parameters in North West Penang, Malaysia. International Journal of Environmental, Ecological, Geological and Mining Engineering Vol: 6 No: 12, 2012.

KOMUNITI MAKROBENTIK DAN HUBUNGANNYA DENGAN FAKTOR-FAKTOR PERSEKITARAN DI PERSISIRAN PANTAI TAMAN NEGARA PULAU PINANG, MALAYSIA

ABSTRAK

Satu kajian mengenai taburan dan kelimpahan komuniti bentik telah dijalankan di sepanjang persisiran pantai yang terletak di bahagian barat laut Pulau Pinang, Malaysia. Empat lokasi (Teluk Bahang, Teluk Aling, Teluk Ketapang dan Pantai Acheh) telah dipilih berdasarkan kepada tahap aktiviti antropogeniknya. Sebanyak 432 sampel sedimen dikutip dua bulan sekali iaitu antara Jun 2010 dan April 2011. Di setiap lokasi, makrobentos, sedimen dan sampel air, telah dikutip bermula pada jarak 200 m berhampiran pinggir subtidal sehingga 400 m, 600 m, 800m, 1000 m dan 1200 m kearah laut di sepanjang persisiran pantai. Sejumlah 68 famili daripada empat taksa yang tertinggi iaitu (Polychaeta, Moluska, Krustasea dan Echinodermata) telah direkodkan. Moluska merupakan kumpulan utama dan diikuti dengan Krustasea, Polychaeta dan Echinodermata. Terdapat 18 famili yang dominan telah dikenalpasti melalui kajian ini iaitu Mytilidae, Nuculidae, Veneridae (kelas Bivalvia), Trochidae, Rentusidae, Ringiculidae, Rissoidae (kelas Gastropoda), Dentaliidae (kelas Scaphopoda), Corophiidae, Oedicerotidae (order Amphipoda), Bodotriidae (order Cumacea), Orbiniidae, Nephtylidae, Glyceridae, Nereidae, Hesionidae, Spionidae (kelas Polychaeta) and Ophiuridae (kelas Ophiuroidea). Jumlah tertinggi kelimpahan makrobentos adalah sebanyak (7676.8 ind /m^2) yang ditemui di Teluk Bahang manakala yang paling rendah (4491.32 ind /m^2) telah direkodkan di Pantai Acheh. Kandungan bahan organik yang tinggi (16.43%) dicatatkan pada transek T1. Parameter kualiti air (suhu, oksigen terlarut, konduktiviti, saliniti, nitrit, nitrat, ammonia, ortofosfat, jumlah pepejal terampai (TSS)) menunjukkan tiada perbezaan yang ketara antara empat lokasi kajian (ANOVA, $p > 0.05$). Analisis Komponen Utama (PCA) menggunakan jarak Euclidean menunjukkan kehadiran tiga komponen utama berdasarkan kepada kualiti air dan kualiti sedimen serta taburan dan kelimpahan makrobentos. Kelimpahan makrobentos ($r = 0.73$), Moluska ($r = 0.69$), Polychaete ($r = 0.67$), Krustasea ($r = 0.3$) dan Echinodermata ($r = 0.6$) mempunyai hubungan yang signifikan dengan komponen pertama(termasuklah, kedalaman, bahan organik dan saiz partikel sedimen). Kajian ini menunjukkan bahawa saiz partikel di sepanjang lokasi kajian mempengaruhi taburan makrobentos. Kebanyakan kawasan iaitu lebih daripada 90% pantai dipenuhi dengan kelodak dan tanah liat. Kelimpahan krustasea juga dikaitkan dengan komponen kedua (suhu, oksigen terlarut, salinity dan jumlah pepejal terampai) ($r = 0.27$). Taburan makrobentos berbeza antara transek dan lokasi kajian yang dapat dilihat menggunakan analisis bukan metrik pelbagai dimensi scaling (nMDS). Diet makrobentos ini terdiri daripada karnivor (40.83%), pemakan deposit (38.26%), pemangsa (6.63%) dan pemakan jenis penggantungan (14.28 %). Algoritma ANN telah membahagikan Status Kualiti Ekologi perairan pantai di Taman Negara Pulau Pinang kepada dua kelompok iaitu sedikit tercemar (transek 200m di Teluk Bahang) dan tidak tercemar (di kebanyakan lokasi kajian).

MACROBENTHIC COMMUNITY AND ITS RELATIONS WITH ENVIRONMENTAL FACTORS IN COASTAL WATERS OF PENANG NATIONAL PARK, MALAYSIA

ABSTRACT

A study on the distribution and abundance of macrobenthic communities was conducted along the coastal waters of northwestern part of Penang Island, Malaysia. Four selected locations (Teluk Bahang, Teluk Aling, Teluk Ketapang and Pantai Acheh) were chosen based on the degree of anthropogenic activities. A total of 432 sediment samples were collected bimonthly between June 2010 and April 2011. At each location, macrobenthos, sediment and water samples, were collected starting at an intervals of 200 m near the edge of the subtidal and extending 400 m, 600 m, 800m, 1000 m and 1200 m toward the sea along the coastal waters. A total of 68 families from four higher taxa (Polychaeta, Mollusca, Crustacea and Echinodermata) were recorded. Mollusca was the major group followed by Crustaceans, Polychaetes and Echinodermata. The 18 dominant families observed in the present study were Mytilidae, Nuculidae, Veneridae (class Bivalvia), Trochidae, Rentusidae, Ringiculidae, Rissoidae (class Gastropoda), Dentaliidae (class Scaphopoda), Corophiidae, Oedicerotidae (order Amphipoda), Bodotriidae (order Cumacea), Orbiniidae, Nephtylidae, Glyceridae, Nereidae, Hesionidae, Spionidae (class Polychaeta) and Ophiuridae (class Ophiuroidea). The highest total abundance of macrobenthos (7676.8 ind/m^2) was found at Teluk Bahang, while the lowest (4491.32 ind/m^2) was observed at Pantai Acheh. High organic matter (16.43%) was recorded at 200 m distance from the shore. The measured water quality parameters (temperature, dissolved oxygen, conductivity, salinity, nitrite, nitrate, ammonia, orthophosphate and total suspended solids (TSS) did not differ significantly among the 4 sampling locations (ANOVA, $p > 0.05$). Principal

Component Analysis (PCA) using the Euclidean distance showed the presence of 3 main components based on water quality and sediment quality, and distribution and abundance of macrobenthos. The macrobenthic abundance (r=0.73), Mollusca (r=0.69), Polychaete (r=0.67), Crustacean (r=0.3) and Echinodermata (r=0.6) were significantly correlated with the first component (including: transect, organic matter and sediment particle size). This study indicated that particle size along the sampling locations affected the distribution of the macrobenthos. Most of the coastal region was covered with silt and clay (more than 90%). The crustacean abundance was also correlated with the second component (temperature, dissolved oxygen, salinity and total suspended solid) (r=0.27). Macrobenthic assemblages differed among transects and between sampling locations, which were clearly explained by non-metric multi-dimensional scaling (nMDS). The macrobenthic feeding guild comprised of 40.83 % carnivorous, 38.26 % deposit feeders, 6.63 % predator and 14.28 % suspension feeders. The non-supervised ANN algorithm has separated Ecological Quality Status of coastal waters of Penang National Park into two cluster visualized, slightly polluted (at T1of Teluk Bahang) and unpolluted (most of sampling transects).

CHAPTER 1.0-INTRODUCTION

The assemblage structure of existing organisms differs in space and time in response to many physical and biotic parameters. Researchers have long recognized how human actions have changed terrestrial environments. It is now being acknowledged that human activities have drastically changed marine ecological system (Jackson et al. 2001).

Nearly 71% of the earth's surface area is covered by the marine ecosystem. The effects of human activities could lead to constant changes in land use, and these changes in land use can affect the aquatic ecosystems. The coastal area ecosystem, which is an interface region between land and sea, are considerably affected by these effects. The coastal area ecosystem is not only are a small region of the global's oceans but also is important ecologically and economically. Presently, the habitat and resources of the coastal area ecosystem is exposed to excessive exploitation for different development projects (Matias et al., 2001).

The most important parameter of changes in majority of the global's coastal area is anthropogenic activities. The increase of population growth along with request for development is endangering these areas. Various types of pollutants for example oil, petroleum product, manufactured organics, etc. could cause changes in the biological, as well as chemical water quality (GESAMP, 1990).

Malaysia is situated in one of the biodiversity epicenter hotspots of the world (Myers et al., 2000). The marine biodiversity in Malaysia is part of the imaginary area of Coral Triangle, which is considered the highest in the world (Veron et al., 2009). Hence, Malaysia is rich in terms of its biodiversity treasure. However, diversity of many marine taxa remains unknown including macrobenthos.

In Malaysia, the rapid changes in the natural environment are mainly driven by the continued eco-social growth and industrialization whereby the coastal zone is the most affected area. The coastal region of Malaysia experiences the most intense anthropogenic activity, where a large percentage of population, tourism, ports, industries, constructions as well as agriculture, aquaculture, fisheries and sewage discharge concentrated in that area. This wide range of activities may be contributing to the release of pollutants to the coastal region (Shumilin and Chudaeva, 1991).

Some parts of the coastal zones of Penang Island are directly exposed to the waste discharge from various pollutants such as domestic, industrial and animal wastes (Kadir, 1998). According to the Penang State Government (1997), the island suffers from diverse sources of pollution, and therefore the coastlines are no larger clean, except those which have been used for tourists attraction. Environmental quality in terms of the levels of water pollution in rivers and coastal waters has declined. Furthermore, most of the coastal waters of Penang Island are not safe for swimming because of high bacteria levels and high turbidity of the water (Yasser, 2003).

One of the critical steps for appropriate environmental management is monitoring. Bio-monitoring is an important type of monitoring because pollutant materials that are directly and indirectly affect resident organisms at individual, community and ecosystem levels can be measured (Stewart, 1995). Bio-monitoring is useful for monitoring of contaminant and assessment of water quality status (Spellerberg, 1991).

An index for bio-monitoring in the open sea and coastal region can be calculated by using marine organisms. The changes in water quality and contaminant effect on environmental index can be measured using macrobenthic population, abundance and species composition due to sensitivity of these organisms to environmental changes (APHA, 1992).

One of the most significant human impacts on marine macrobenthic environments is commercial fishing. Fishing activities lead to differences in the structure of marine environments and influence the diversity, composition, biomass and productivity of associated biota. Certain fishing techniques have destructive effect on aquatic environment, including dynamiting and fish poisoning (Jennings & Kaiser, 1998).

Benthic habitats are being disturbed due to fishing pressure around the coastal regions in Penang National Park. For example, the coastal of Teluk Bahang has some aquaculture activities. The fishes are fed and kept in floating cages along the shoreline. The increase of food supply encourages the growth of various benthos communities and some of the benthic organisms feed on fish feed or fish waste as well (Goldberg, 2003).

Benthic marine assemblages are characterized by spatial heterogeneity in species composition and abundance due to the interplay of various abiotic and biotic processes operating at different spatial scales and depths. Spatial heterogeneity is particularly evident among marine benthic assemblages associated to shallow water habitats, since they commonly experience fluctuation of key environmental factors such as temperature, salinity, wave action, etc. (Witman & Dayton, 2001).

Marine macrobenthos are organisms that use sea bottom either for feeding, breeding or resting. The term ´benthos´ is derived from the Greek word meaning, ´depths of the sea´ and first used by Haeckel in 1890. Approximately 98% of all marine species belong to the benthos (Peres, 1982). They include a wide variety of flora, fauna and microorganisms. The term "phytobenthos" used to denote plant community whereas "zoobenthos" for animal community. They are also ubiquitously distributed and highly diverse in marine sediments.

Benthos are classified into three habitat groups which are infauna, epifauna and hyper-fauna, i.e, referring to organisms living within the substratum, on the surface of the substratum and just above it respectively (Hickman, 2006). Based on the habitat, benthos are classified into soft-bottom and hard-bottom benthos. Benthic communities comprise of species differing in terms of their ecology, life strategies and body size. Thus another arbitrary classification based on the size of the benthos is macrofauna, meiofauna and microfauna, having a size range more than 0.5mm, between 0.5mm and 0.063mm and less than 0.063mm respectively. This division reflects differences in sampling techniques for the three groups. Macrobenthos are organisms larger than 500µm, which are visible by naked eyes, mainly invertebrate animals such as mollusks, polychaetes, crustacean, echinoderms etc.

Benthos are important in the energy cycle of the sea by consuming the organic matter draining down from the surface waters. They are important in the recycling of nutrients and oxygenation of sediment substratum. The benthic organisms are depending upon the nature of the substratum and hydrographic conditions overlying it. They sustain the demersal fishery resources of the region by offering trophic support. They inevitably enrich the planktonic community by the supply of meroplankton. Benthic organisms link the primary producers, with higher trophic levels, such as fishes, by consuming phytoplankton and then being consumed by larger organisms. Thus, they provide the key linkage between primary producers and higher tropic level animals, in the marine food web. So, benthic productivity of the adjacent seas of any maritime country is of fundamental interest to access the total fishery potential pertaining to that area (Nisha, 2008).

Some benthic organisms are sessile, or attached to substrates such as sponges, barnacles, mussels, oyster, crab and seaweeds. Others are creepers that move around such as crabs, lobsters, burrowing copepods, amphipods, snail and fishes. Some benthic organisms are burrowers such as clams, worms, echinoderms and polychaetes. Species from different macroinfauna taxa such as mollusks (McLachlan and Dorvlo, 2005), polychaetes (Dean, 2008), and crustaceans (Nel et al., 1999) vary considerably in their burrowing ability. The burrowing execution of individual species can have pronounced effect on sediment characteristic by creating local hydrodynamic change which may also provide larval settlement (Hutchings et al., 2002) and they are often affected by a variety of parameters, including body sizes (McLachlan and Jaramillo, 1995), sediment grain size (Nel et al., 1999), and water temperature (McLachlan and Jaramillo, 1995).

The macrobenthos are important in their roles as bio-indicators of habitat changes in aquatic ecosystems and as well as food sources for fishes (Kumar et al., 2010). Understanding the characteristics and life cycle of the fauna living in or near the bottom is needed to acquire a clear picture of the fishery potential of a region (Kundu et al., 2010)

Macrobenthic communities are utilized as primary indicators of environmental status in water, as,

(i) they have restricted movement and so are incapable to keep away from unfavorable conditions.

(ii) their nature of living are in sediment, they are exposed to the stressors for example chemical pollutions.

(iii) they show changes to environmental stress due to their long life span.

(iv) They respond to several types of stresses (such as: pollution, fishing boat) because they are taxonomically diverse (Joydas et al., 2011).

In marine soft-sediments, the hydrodynamics can be considered as a source of natural perturbation that structures organisms' dispensations (Hewitt et al., 2003; Dolbeth et al., 2009). Sediment features are, to a large extent, the direct result of near-bed flow conditions, which influence particle size, sedimentary organic matter, pore-water chemistry, microbial content, larval supply (Snelgrove and Butman, 1994) and availability of food (Incera et al., 2003). These variables can directly or indirectly affect the macrobenthic assemblages' dispersal (Snelgrove and Butman, 1994) and function. Availability of food in the seabed sediments can vary according to the hydrodynamics and morphodynamics (Arruda et al., 2003; Hewitt et al., 2003; Wieking and Kroncke, 2005) and due to man-induced disturbances (Sarda et al., 2000; Chicharo et al., 2002a, b). Differences can be found in the feeding guild composition in relation to the food quality, quantity and the environmental regime (Dolbeth et al., 2009).

One of the remaining questions is how the differences in the physical environment affect the functioning of the macrobenthic subtidal community. Most of the biotic indices are based on the Pearson and Rosenberg (1978) model. According to this model, with increasing organic input there is an increase of abundance in the first step. In fact, Pearson and Rosenberg (1978) pointed out that the relative proportions of four broad trophic groups in marine environments (deposit feeders, suspension feeders, carnivores, and predator) change according to several environmental factors such as sediment type, depth, salinity and organic load.

In stressed environments subjected either to anthropogenic action or natural physical stress, it is expected that the diversity of feeding groups decreases. This decrease is perhaps attributable to changes in dominance of the feeding groups, with the presence of all types or the absence of some types. In communities from locations with good ecological conditions presumably all the feeding groups will occur. In sandy sediments the community will be dominated by suspension feeders and in muddy sediments by detritus feeders. In seagrasses beds, which are very common in healthy coastal waters or estuarine locations, the species richness is usually high and the community might be dominated by detritus feeders, as these locals act as sediment traps, accumulating fine sediments and organic matter (Gamito and Furtado, 2009).

Macrobenthic are being increasingly investigated, because they are omnipresent, relatively sedentary, and reflect site-specific conditions. For example, they react to alterations in water quality that occur at the time of sampling, and also to changes occurring over a longer time period (Roldan, 2003). Moreover, many organisms of macrobenthic display low tolerance to small physic-chemical differences (Seto and Sato, 2003). This is because of their sedimentary living condition, whereby they accumulate contaminants and respond rapidly to any environmental changes caused by sediment pollutants (Blanchet et al., 2007). Therefore, they can be utilized as bio-indicators to prevent further pollution, which could spread to larger, less sensitive animals.

The diversity of macrobenthic assemblages also indicates water quality conditions, with a high diversity usually indicating high water quality. Evaluation of macrobenthic assemblages is thus frequently utilized in biological monitoring, to evaluate the ongoing quality of the ecosystem (Bockelmann et al., 2004).

The distribution of macrobenthic assemblages is significant for maintaining population structures of many animals, and is considered to include interspecific relationships between distribution and abundance. Therefore, the relationship between occupancy and abundance is one of the most extensively surveyed models in macro-ecology (Blackburn et al., 2006).

Ecological researcher use geographical information systems (GIS) as a means for the management, visualization, and analysis of the monitored data. In this study, the ArcGIS geostatistical analyst tool for spatial data exploration, and surface generation using sophisticated statistical methods that permits for the development of a surface from the data measured at discrete points were used. In addition, the geostatistical analyst tool also gives the user the power to fully understand the qualitative and quantitative aspects of the data. By providing the freedom to predict and model spatial phenomena based on statistics using powerful exploration tools, ArcGIS geostatistical analyst effectively bridges the gap between geostatistics and GIS analysis (Kumar et al., 2007).

Generally, spatial interpolation is a technique of estimating parameters at unobserved sites as well as re-estimating parameters at observed sites (Dille et al., 2002). Sample observations should be characterized at an operational scale that adequately captures the spatial variability across the area of attentiveness (Palmer et al., 2009). Ordinary kriging is the most frequently utilized spatial interpolation techniques in academic studies (Li and Heap, 2011).

Kriging is a method of spatial interpolation approaches for assigning a value of a random field to an unsampled site, based on the measured values of the random field at nearby sites (Gu et al., 2012; Li and Heap, 2011; Xie et al., 2011). The kriging tool is well-known as the best unbiased linear estimator for unsampled sites (Kazemi and Hosseini, 2011; Palmer et al., 2009).

Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modeling, creating the surface, and (optionally) exploring a variance surface. Kriging is most appropriate when you know there is a spatially correlated distance or directional bias in the data. Ordinary kriging is the most common and widely utilized of the kriging techniques. (ESRI, 2010; Li and Heap, 2011; Merwade, 2009).

In order to explain the relationship between the macrobenthic communities and Ecological Quality Status, the non-supervised Artificial Neural Network (ANN) is utilized in ecological modeling where the Self Organizing Map (SOM) was practiced to order the data by similarity and to cluster the same input variables into groups of similar input (Gevrey et al., 2006). This application displays a classification on the macrobenthic composition and the relationship of different index of Ecological Quality Status towards macrobenthic distribution. In the present survey, the impacts of human activities on macrobenthic assemblages were considered. Anthropogenic activities can trigger land runoff, waste pollutants, and sediment disturbances, which potentially have a greater influence on shallow water macrobenthic habitations than on deep water areas (Levin et al., 2009).

In the current investigation, the distribution, diversity and abundance of marine macrobenthic was examined in the tropical coastal waters of Penang National Park. Since 2001, Penang has been activity involved in land reclamation, mostly in the northern part of the island (Chung, 2012).

Considering all the above, the purpose of this study is to survey the functional diversity of the macrobenthos in coastal waters of Penang Island subject to anthropogenic stressing conditions. Based on taxonomic, trophic and ecological approaches, this survey intends to reliably estimate the general status of the ecosystem in the Penang National Park and to identify the contribution of the main environmental/ anthropogenic parameters that determine current macrobenthic assemblage organization.

1.1 Study Objectives

The main purpose of this study is to gather a baseline database of the subtidal macrobenthic assemblages and using them as a biological index for coastal water of Penang Island.

Therefore, the objectives of this study were:

(1) To record the density and diversity of macrobenthic communities and its spatial and temporal variation during the sampling period in the coastal waters of northwestern part of Penang Island.

(2) To determine the feeding guild composition of dominate macrobenthos to prepare a map showing the distribution and density of feeding mode using Geographic Information System (GIS)

(3) To evaluate a marine biotic index to establish the ecological quality of macrobenthic community within Penang National Park coastal waters and ordination and clustering using Artificial Neural Network

CHAPTER 2.0- LITERATURE REVIEW

2.1 Macrobenthic Community Studies

Studies on macrobenthic assemblage have a long history. The investigations on benthos dated back to the middle of the eighteenth century. The first benthic investigation was carried out by two Italians, Marsigli and Donati, around the year 1750, by gathering the benthic organisms of shallow waters using a dredge (Murray & Hjort, 1965).

It was John Peterson (Peterson, 1911) who made a quantitative approach to the macrobenthic surveys, where individuals number and organic matter weight was estimated per unit of bottom region. Placing paramount significance on those organisms, which dominated in weight, Peterson developed his assemblage notion (Peterson, 1915 and 1918).

Sanders (1968) early work focused on marine diversity and how it differed with respect to large-scale gradients in depth and latitude, and how environmental conditions along these gradients changed, setting up conditions that promoted either low or high species diversity. This led him to formulate a stability-time hypothesis, in which diversity in benthic communities in northern latitudes and shallow environments was physically controlled whereas at lower latitudes and in the deep sea diversity was biologically accommodated. He noted that the theory of spatial heterogeneity as expressed by Simpson (1964), wherein "the more heterogeneous and complex the physical environment, the more complex and diversity its flora and fauna become″, is controlled by the effects of time and environmental stability.

Fischer (1960) noted that shallow water areas are relatively immature biotically due to their geologic history, a factor that was not often considered in the early diversity debates. Boesch (1973) looked at diversity trends within and among different shallow coastal systems and found a significant degree of variation, which he attributed to a combination of factors including conditions related to estuarine and depth gradients, sediments types, degree of pollution and environmental stability. Buchanan et al., (1978) performed a seasonal survey on the shelf bottom macrobenthic from 20m down to 80m off the coast on Northumberland and found that the seasonal alterations in abundance revealed to be independent of the composition of the community.

Whitlatch (1981) found that both particulate and bulk sedimentary characteristics were related to deposit-feeding species diversity. Richness index was correlated with the amount of surficial sedimentary organic matter, and diversity index with total particulate and food particulate diversity. Bogdanos and Satsmadjis (1985) examined the Greek Gulf of Pagassitikos macrobenthos with a prospect to describe precisely the biocoenosis of the whole range of soft substratum. Gaston (1987) investigated the polychaetes distribution and feeding in Middle Atlantic Bight and observed that the ratio of carnivorous polychaetes highest in coarse sands and diminished meaningfully with water depth across the continental shelf.

Service and Feller (1992) studied the seasonal and annual tendencies in subtidal macrobenthos samples from sandy and muddy locations in North Inlet and revealed large changes in abundance of faunal and high irregularity between replicate samples.

Ecologists have identified topographical heterogeneity as a principal parameter regulating species abundance and distribution within an assemblage (Emson& Faller-Fritsch, 1976; Genin et al., 1986; Bourget et al., 1994; Addy & Johnson 2001; Joshi, 2010). Assemblage attributes such as richness and diversity are also changed by topographical heterogeneity (Menge et al., 1983; Menge et al., 1985). The function of heterogeneity of topographical may alter with scale.

Basford et al., (1989) investigated the macro fauna of the northern North Sea and observed that the principal determinative of macro fauna assemblage composition was granulometry of sediment, with depth being of secondary significance. Alongi& Christofferson (1992) studied macrobenthic fauna and organism-sediment relations in a shallow tropical coastal region. The poor nutritional quality of mangrove detritus and intermittent physical disturbances appear to be the major factors preventing the establishment of equilibrium communities and perpetuating the dominance of pioneering infaunal assemblages in this shallow, tropical inshore area.

Ajmal Khan et al., (2004) studied about a new macrobenthos as indicator of pollution and the utility of graphical tools and diversity indices in pollution monitoring studies. Al-Hakim and Glasby (2004) studied about polychaeta (Phylum: Annelida) of the Natuna islands, South China Sea. One-hundred and twenty-nine polychaete organisms in 38 families are found from continental shelf sediment off the Natuna Islands. About 17 species (33%) occur in both the South China Sea and neighboring Indo-Malaysia peninsula. A few species appeared to have a wider pantropical or cosmopolitan distribution, but these observations essential to be proved. Alcantara and Solis-Weiss (2005) investigated the seasonal changes of the Spionida (Palpata: Canalipalpata) in the sublittoral area of the Golf of California. Cristian et al. (2005) studied the biogeographic provinces of polychaetes along Chile coast. These studies are worthy and would be of vast utilization to the macrobenthic ecologists. Ajmal Khan (2006) focused on environmental effect evaluation using macrobenthos. Analysis of taxonomic groups might more clearly reflect pollution gradients and be less affected by natural nuisance variables than species analysis. Community responses to pollution should be more easily detected above the natural stress at higher taxonomic levels.

The biodiversity and distribution pattern of the deep Southern Ocean macrobenthos was investigated by Brandt et al. (2009). In this study, they characterized the general biodiversity patterns of meio and macrofaunal taxa, based on historical and recent expeditions, and against the background of the geological events and phylogenetic relationships that have influenced the biodiversity and evolution of the investigated taxa. The relationship of the macrobenthos to environmental factors, such as water depth, sediment particle size and food availability, as well as species interrelationships, presumably have shaped present-day biodiversity patterns as much as evolution.

Barnes and Conlan (2007) surveyed about the disturbance, colonization and development of Antarctic communities. Gogina et al (2010) studied distribution of macrobenthic assemblages in the western Baltic Sea with regard to near-bottom environmental factors basis for predictive modeling of species distribution. Species-specific models predicting the probability of occurrence relative to environmental and sedimentological characteristics were developed in this survey for 29 macrobenthic organisms common for our survey region using a logistic regression modelling approach. This way, a good description of the occurrence of species along gradients of single environmental variables was obtained.

Sadeghi et al. (2010) investigated species diversity of macrobenthic assemblages in Salakh area (Qeshm Island, Persian Gulf, Iran) where the fishery efforts have declined in the last few years. Outcomes indicated spatial and temporal heterogeneity in the structure of macrobenthic in this region.

Numerous investigations have documented the links between spatial variation in the environment and/or habitats and spatial change in the macrobenthic assemblage in aquatic systems. For example, Gaston and Nasci (1988), Gray et al. (1988) and Raut et al. (2005) observed the significant correlations among abiotic parameters such as salinity, pH, sediment characteristics and dissolved oxygen with distributional patterns of macrobenthic assemblages. Earlier studies have revealed that benthic communities may be largely affected by human activities. For example, Inglis and Kross (2000) observed the significant changes in macroinvertebrate communities of an estuarine system subjected to urbanization. Accordingly, Mucha et al. (2003) and Courtenay et al. (2005) observed that considerable alterations in macrofauna communities in Douro estuary (Portugal) and Sydney coastal water (Australia), respectively, were due to human activities. The conclusions from their studies indicated that the proper evaluation of sediment pollution and environmental parameters in estuaries and coastal water and their effects on macrobenthic communities and composition is a beneficial method for evaluating the health of these ecosystems.

2-2 Macrobenthos distribution in relation with environmental conditions

Daure et al. (2000) worked on the relationships between benthic community condition, water quality, sediment quality, nutrient loads and land use patterns in Chesapeake Bay.

They estimated benthic community condition by the Benthic Index of Biotic Integrity (B-IBI) and found to be negatively correlated with exposure to low dissolved oxygen, total nitrogen loadings and sediment contaminants. At the total watershed level, benthic community condition was marginally, positively correlated with the percentage forest land area.

Bilkovic et al. (2006) investigated the influence of land use on macrobenthic communities in nearshore subtidal systems, with depths ranging from 0.3 to 1.5 m, from 2002 to 2003. The community was dominated by Mollusca (%85 of biomass). There were significant annual differences between total abundance and biomass for watershed. Macrobenthic index scores decreased with anthropogenic alterations to the landscape. The predominant sediment component was sand (76.9 ± 3.0%).Silt and gravel compositions were significantly different in each year. These changes may be related to differences in the watersheds sampled in a given year or the notable changes in precipitation between the two years.

As invertebrates are partly suspension or deposit feeders, they form a group of producers dependent directly on the amount of organic matter present within the substratum and in its close vicinity. Studies of benthic communities in various zoogeographic regions showed the dependence of the animal associations of benthos on the physical and chemical composition of the substratum. Parallel communities with the same dominant genera are associated with sandy or muddy beds in distant zoogeographic regions (Longhurst, 1998; Arvanitidis et al., 2009).

Most of the invertebrates in temperate and tropical waters have pelagic larvae. At the end of the pelagic stage the larvae seek an adequate substratum which will fulfill their adult feeding and reproduction needs. Thus the character of the bed has proved to be the most important factor in the qualitative composition of the animal communities (McArthur et al., 2010). Granulometric analysis of the bottom substratum proved that there is a direct correlation between the soil grade and the distribution of polychaetes and mollusks in English water (Pinnion et al., 2007). Similar correlation was also demonstrated in respect of echinoderms in North Sea (Kröncke et al., 2011). The quality of the bed was an important factor in the distribution of decapods off North Carolina (Grabowski et al., 2005).

Marine benthic biology has many applications, one of the most important being in waste disposal. The relative abundance of the organisms and their relation to the environmental factors must be known before important biological and physiological studies can be undertaken on the basis of laboratory experiment (Ellingsen, 2002; Jayaraj et al., 2007; Li et al., 2011).

2.3 Taxonomic groups of Macrobenthos

Several researches have been carried out on various benthic communities in the coastal waters such as phylum Polychaeta.

2.3.1 Phylum: Annelida

Bristleworms (Class: Polychaeta) are segmented worms belonging to Phylum Annelida like the more familiar earthworm. Annelids are segmented worms. They are distinguished by a long ringed body. Most common segmented worms are Polychaeta. As their name implies, polychaete have many setae, usually arranged in bundles on the parapodia, paired appendages on most segment (Hickman, 2006). Some of them burrow into mud and others live in tubes made of a variety of materials. There are two groups of benthic bristle worms which are Sedentaria and Errantia (Chung, 1961). Sedentaria are tube-making or burrow-dewelling worms. Errantia includes the swimming and creeping forms, which are among the most generalized members of the segmented worms.

The most significant ecological role played by annelid is reworking of soil and sediments. They ingest and excrete large quantities of sediments or soils. Annelids are important components of their respective habitats. The feeding habits of many species are important in the decomposition of organic matter and recycling of nutrients in their living environments. Many annelids feed on algae, insects, and other worms (Hickman, 2006).

The polychaetes have long been a choice to act as representative species in the analysis of the health of benthic communities as they are usually the most abundant taxon taken in benthic samples, both in terms of the number of species and numerical abundance. Any long-term changes in the wellbeing of the benthos should be reflected in the polychaete community (Papageorgiou et al., 2006).

2.3.2 Phylum: Mollusca

The phylum Mollusca gets its name from the latin “molluscus” meaning soft. This looks like a strange name for a group that a main character is the existence of a hard calcareous shell (Arnold et al., 1989). Mollusks are soft-bodies animals. Chuang (1961) proposed that they form the largest group of local marine animals. Mollusks are widely used as food because of their soft fleshy bodies. These include snails, slugs, mussels, clams, tusk shells, chitons, oyster, squids and octopuses. The mollusk body plan consists of a head-foot portion and a visceral mass portion (Hickman, 2006).

The three major groups of Mollusca in terms of abundance and divers classes are gastropods (snails), bivalves (mussels and cockles) and scaphopoda (tusk shells). Majority of mollusks have shells made of calcium carbonate (Arnold et al., 1989).

Generally, the mollusks are subdivided into eight classes which are Caudofoveata, Solenogastres, Monoplacophora, Polyplacophora, Scaphopoda, Gastropoda, Bivalve and Cephalopoda. Gastropoda are the largest class of mollusk. Their interesting evolutionary history includes torsion, twisting of the posterior end to the anterior, so that anus and head are at the same end, and coiling, an elongation and spiraling of the visceral mass (Hickman, 2006). Gastropod feeding habits are extremely varied, although most species make use of a radula in some aspect of their feeding behavior. Some graze, some browse, some feed on plankton, some are scavengers or detritivores, and some are active carnivores.

2.3.3 Phylum: Arthropoda

Subphylum Crustacea have two pair of antennae and a pair of mandibles. Crustaceans have two pairs of maxilla on the head, followed by a pair of appendage on each body segment (Chuang, 1961). Class Malacostraca includes isopods, amphipods and order Decapoda which are shrimps, crabs and lobsters. Amphipods are usually compressed laterally, and their gills are in the typical thoracic position. Their thoracic and abdominal limbs are each arranged in two or more groups that differ in form and function. Decapods have three pairs of maxillipeds and five pair of walking legs, of which first are modified in many to form pincers or called chelae (Hickman, 2006).

Among the Malacostraca, Amphipoda especially play an important role in structuring macrobenthic communities (Duffy and Hay, 2000) as secondary and tertiary producers in marine communities (Guerra et al., 2002). Beare and Moore (1996) and de-la-Ossa-Carretero et al., (2010) revealed amphipods to be an important source of food for macrobenthos of commercial interest. Amphipods are also very ecologically sensitive organisms and good indicators of natural or disturbed environmental conditions (Conradi et al., 1997; Afli et al., 2008a).

Nevertheless, most studies of macrobenthic assemblages have concentrated on the infauna and little research has been performed on epifaunistic crustaceans. As a member of the epifauna, crustaceans have much higher mobility than do members of the infauna. Hence, during environmental alterations, the assemblage structure not only responds to the disappearance or recruitment of crustacean on the families or species level, but also a much faster response occurs in which individuals may move in or out of an area (Wong et al., 2010).

2.3.4 Phylum: Echinodermata

Sea urchins (Echinodermata: Echinoidea) are a very significant group because they play a major role as cleaners of the ocean bottom. The regular sea urchin has a round, flattened and sometimes globular calcareous test. It has long, sharply pointed spines which have a wide variety of colors (Elmasrya et al, 2013).

Sea urchins are one of the most general components of near-shore marine ecosystem universal, often playing a significant ecological part in shallow subtidal environments (Harrold& Pearse 1987; Satheeshkumar, 2011).

The echinoderms or spiny-skinned animals are exclusively marine animals with radial symmetry and generally spiny or warty appearance. Asteroidea are sea stars or often called starfishes. They are often brightly colored and range in size. Most Asteroidea are predators or scavengers. Some asteroids are suspension feeders. Ophiuridea or brittle stars have a superficial resemblance to starfish. They are called brittle stars because of their tendency to lose parts of their arms when irritated (Chuang, 1961; Sala, 1997; Hereu et al. 2004; Entrambasaguas, 2008).

Echinoidea or sea-urchins have a globular to discoid shape. Echinoids lack arms, but their tests reflect a typical pentamerous plan of echinoderms in their five ambulancral areas (Hickman, 2006). Sea cucumbers or Holothuroidea are the most conspicuous echinoderms. They have an elongated muscular body with the mouth at one end the anus at the other. Most Holothuroidea are suspension or deposit feeders. Holothurians may also eviscerate their digestive and other organs in response to predation or seasonal events (Brusca& Brusca, 2003). The indirect effects of fishing on sea urchin populations and their subsequent effects on the rate of accretion and bioerosion on macrobenthic habitat are one of the few well documented examples of top-down control in marine ecosystem. Sea urchins, if not controlled by predators, may overgraze their habitat. Asteroides have several commensals, including polychaetes that feed on leftovers from the sea star′s prey items (Barnes, 1987). Many echinoderms are easy to culture and maintain in a laboratory setting, and produce a large amount of eggs. Sea urchin eggs are also edible and often served in sushi bars (Brusca& Brusca, 2003).

2-4 Habitats of Benthic Organisms

Habitats are very useful for examining the behavioral and morphological differences between benthic organisms. In subtidal habitats, which tend to be more physically predictable, these habitats are influenced by greater variability in environmental factors such as sediment characteristics, organic matter and water parameters (Burd et al., 2008).

Mud substrates in the shallow subtidal tend to be protected from wave exposure and typically have low tidal currents. These habitats have oxygenated bottom water, with sufficient oxygen for shallow burrowers that are mostly deposit feeders (bivalves and polychaetes), epifauna (scavenging amphipods and bottom shrimp), surface grazers (gastropods) and predators (mud stars, brittle stars, hear urchins, echiurans, drills, and fish) (Burd, 1992). In some habitats, mud-dwelling sea cucumbers such as Molpadia or Chirodota may be found if there is sufficient oxygen in surface sediments (Burd, 1992). About mixed silt and sand habitats (near the coastal) are the input of course material that increases mobility beyond that found in mud substrates (Burd et al., 2008). This is because the inorganic input to these sediments and their tendency to be less sticky and cohesive than mud, and they are usually better oxygenated than marine muds (Burd et al., 2008).

A wide range of habitat types, based on fine-scale structural features, can be found in these substrates, along with a mixture of biotic features of both mud and sand communities. Biota are diverse in terms of richness, type (polychaetes, bivalves, echinoderms, crustaseans, and more) and size spectrum of organisms, as well as feeding types (mixed deposit and/or suspension feeders, scavengers, and predators) (McPherson et al., 2006). Pearson and Rosenberg (1978) suggested that habitat with mixed silt and sand in temperate coastal area tends to have greatest diversity of benthos organisms in soft sediments. In sand habitat, unlike the previous two substrate types (silt and clay), substrates are non-cohesive and highly mobile. Sand habitats are the most extensively bioturbated of all the habitat types, as the sediments tend to be loosely packed, and, thus, are relatively easy to move through (Burd et al., 2008). Tube building polychaetes and amphipods are frequently found in these substrates. Sand substrates tend to have a higher proportion of suspension feeder than deposit feeders, and thus epifaunal predators and scavengers are common. While some families that are found in the mixed silt/sand habitats may also be present in sand habitats, the strictly deposit-feeding families are typically absent or rare. Course sand habitat is usually found in moderate to high energy locations. This substrate can be both mobile and immobile (Burd et al., 2008). These substrate matrials tend to be heavy and can only be moved by high energy waves or storm events, particularly in shallow subtidal areas. Similarly, the coarse materials tend to be a difficult substrate for the burrowing activities of bivalves and other fauna and, as a result, bioturbation may be limited (Burd et al., 2008). The benthic fauna are dominated by suspension feeders and mobile predators, particularly in high current areas (Burd et al., 2008). Studies done by Davidson (1989) and Shimeta et al., (2003) have shown strong correlation between sediment particle size and the benthic community.