CHAPTER ONE

GENERAL INTRODUCTION

1.1 ANIMAL DISTRIBUTION AND ABUNDANCE

Animal distribution is determined by a complex series of responses to the physical and biological characteristics of their environment (Odum and Heald, 1972). Thus individuals select habitats that offer the best combination of a high potential for growth and reproduction with the lowest risk of mortality. Many species move from one habitat to another during various phases of their life histories. Furthermore, habitats themselves do not remain constant but vary on a daily and seasonal basis. In coastal waters, aquatic species are subject to additional environmental changes caused by the tides. Species inhabiting such regions employ numerous strategies to deal with tidally phased fluctuations (Brown and McLachlan, 1991).

The distribution and abundance of fishes in estuaries and coastal area are effected by physical and chemical factors, such as temperature, salinity and dissolved oxygen (Moyle and Cech., 1982). The principal movements of the ichthyofauna appear to be primarily in response to changes in physical and chemical factors (Moyle and Cech., 1982), and biological factors including interspecific competition and predation which are of secondary importance.

Biologists often use patterns of distribution and abundance of organisms to detect environmental changes. They infer the cause of the change by associating fluctuations in biological variables with corresponding fluctuations in physiochemical variables (Norris and Georges, 1986; Barmuta, 1987). Ecologists have recognized topographical heterogeneity as a major factor regulating species distribution and abundance within a community (Emson and Faller-Fritsch, 1976, Menge *et al.*, 1985; Bourget *et al.*, 1994). Animals are associated with characteristic habitats or microhabitats whose presence or absence may specifically influence marine species composition and abundance (Odum and Heald, 1972). The ecology of populations and communities determines which factors or processes limit or generate changes to population size. Some workers have suggested that fluctuating abiotic conditions were most important in determining population size (Andrewartha and Birch, 1954; Cushing, 1975; Sinclair *et al.*, 1985). Others advocated density-dependent biotic processes such as competition (Lack, 1954; Cushing, 1990) or predation (Errington, 1946; Johannes, 1978; Bailey and Houde, 1989) as the predominant factor affecting populations.

Sediment characteristics are the prime factors in structuring benthic assemblages (Schlacher *et al.*, 1998). High spatial heterogeneity in community structure is a key feature of the benthic biota at the soft-sediment area.

Measures of community structure (species richness and diversity) are often used as indicators of environmental stress (Menge and Sutherland, 1976; Day, 1977). The assumption is usually made that biological accommodation is most important in communities subject to minimal levels of environmental stress, and that physical factors are most important in communities subject to a high degree of stress (Day, 1977). Subsequently Margalef (1968) suggested that high diversities result from biological accommodation, while low diversity results from physical stresses.

However, this assumption could appear as an oversimplification. Indeed while biological accommodation often increases diversity (Margalef, 1968; Whittaker, 1969), predation and competition may also lead to a decrease of diversity (Menge and Sutherland, 1976; Day, 1977) in the same way as environmental stresses. Biological accommodation is usually associated with a stable community structure while physical control is linked to unstable community structure. In most benthic communities, however, it is likely that community structure is determined by a combination of biological accommodation and physical control (Boesch, 1974; Menge and Sutherland, 1976; Day, 1977).

One of the fundamental importance question for ecologists is whether communities are limited by a lack of food resources, as would inevitably occur if other processes do not intervene (Malthus, 1966), or whether recruitment failure, predation, competition for non-food resources or environmental-induced catastrophes occur with such frequency that communities rarely reach their food resource limits. Marine biologists discuss the importance of food limitation to fish assemblages. Correlation between fish production and nutrient enrichment seems so pervasive at meso-scales to fishery biologists and modellers dealing with pelagic stocks that a causal relationship between fish production and food production is widely assumed (Mann, 1993; Branch *et al.*, 1987). In other fields, competition for food resources is neglected because of the widespread perception that it is of trivial importance in structuring fish assemblages compared with recruitment, stochastic events and behavioral interactions. For example, in a review of studies dealing with the factors influencing fish populations, Doherty and Williams (1988) found little evidence for competition amongst settling fishes, leading them to suggest that competition is not a strong structuring force; they neglected to consider whether exploitative competition for food is important. Thus major differences may exist in the importance of food limitation to fishes in pelagic, reef and soft-sediment habitats, as suggested by the different approaches of workers in these systems.

Generally estuarine environments are believed to be important nursery area for many fishes. Joseph (1973) characterized these nursery grounds as areas that are physiologically suitable in terms of chemical and physical features, provide an abundant food supply and provide some degree of protection from predators. The estuarine fish faunas of the tropical Indo-Pacific from the coast of Africa to the South Pacific generally have similar species compositions. This similarity has been described and discussed in relation to zoogeography (Blaber and Milton, 1990), the biological roles of estuaries in the life cycles of fishes (Whitfield and Bruton, 1989; Robertson and Duke, 1990) and the question of estuarine dependence (Longhurst and Pauly, 1987). Little is known about how tropical estuarine fish communities may be structured or influenced by the effects of prevailing physical factors and habitat diversity. Some of these factors will be discussed later.

Mangrove, a special type of estuarine ecosystem, is ecologically important as a habitat as well as a nursery area for many marine organisms (Wells, 1990; and Chong *et al.*, 1990). In addition, it has a stabilizing effect and acts as a barrier on marginal beaches. The interaction between mangrove ecosystem and fish resources has been explained by Odum and Heald (1972)., as follows: the organic matter produced by mangroves, particularly in the form of fallen leaves, is transformed into detritus particles by bacteria, microalgae, protozoans and permeated fungi, which are eventually transported into the surrounding waters by tidal flushing. The detritus particles, including various organisms found on them are utilized as food by large consumer organisms such as fish, shrimps and crabs. More recent studies show that in tropical Indo-Pacific waters, this classical detrital food chain may be modified as follows: mangrove leaf litter sesarmid crabs → detritus → saprophytes → detritus consumers→ lower carnivores → higher carnivores, since mangrove crabs are abundant and play an important role in removing the litter fall (Robertson, 1988; Robertson and Duke, 1987). Many studies suggested that the mangrove forest serves as a major food source for the local benthos (Zieman *et al.*, 1984; Alongi, 1990; Fleming *et al.*, 1990; Kristensen *et al.*, 1991; Alongi and Christofferson, 1992).

Little is however known about the ecological roles of invertebrates in the mangrove ecosystem (Wells, 1990). Molluscs as well as crustaceans are important animals in mangrove areas, playing important ecological roles including serving as major food items for fish and birds.

1.1.1 Fish

Fishes are the most ancient and numerous of the vertebrates (Cohen, 1986). Over 20,000 species are known, the majority of which live in the warm waters of the world. About 8,000 species (40%) live on the continental shelves of warm seas in water less than 200m deep, while about 1,130 species (5%) live in similar habitats in the cold seas. A total close to 8,500 species (40%) are found in freshwater with a majority of species present in the vast river systems and lakes of the tropics (Cohen, 1986). The richest fish faunas of the world are in the Indonesian area of the Indo-Pacific; waters around New Guinea include over 1,000 species belonging to 241 fish families (Springer, 1982). Fish families are more numerous in the sea than in freshwater. Fishes may be classified according to their way of life; pelagic fishes usually in schools in the water column, while benthic (demersal) fishes live on or near the bottom.

Nelson (1984) estimated that of the almost 22,000 species of fishes, about 8,500 (39%) are freshwater species, perhaps 10,200 (47%) are coastal or littoral, leaving fewer than 14% from the open, oceanic seas. Nelson's data present powerful evidence that the land-sea interactions of the coastal zone have resulted in the greatest proliferation of fish diversity.

Many species of reef and demersal fishes occur in a wide range of habitats. Settlement and post-settlement demography of these species may be affected by structural characteristics of the habitat (Carr, 1994; Connell and Jones, 1991; Levin, 1991). Many studies have shown that the distribution and abundance of fishes are correlated to the amount and type of available habitats (Connell and Jones, 1991; Levin, 1993; Sogard, 1992; Carr, 1994; Tupper and Boutilier, 1995).

Distribution of fishes is determined by a range of interactions between fishes and their environment. For example, fish distribution varies with respect to local topographic complexity (Roberts and Ormond, 1987; Grigg, 1994), current flow and exposure (Thresher, 1983). Many studies on the relationships between habitat characteristics and fish communities have sought to determine whether fish saturate their habitat, and thereby resolve the relative importance of habitat in determining the structure of the fish communities (Kaufman and Ebersole, 1984). It has been suggested that fish have spawning periods adapted to seasonal variations of food and abundance (Cushing, 1990). More and more evidences show that habitat is one of the factors affecting community structure, although the apparent degree of order or chaos in fish distributions will depend on the scale of examination (Sale, 1991). The understanding of habitat effects also helps to narrow down the eventual causes of variations in fish distribution and biomass. This is particularly useful with regards to increasing concern of overfishing and pollution (Russ, 1991; Grigg, 1994).

The ecology of pelagic fish, distribution and abundance, has been linked to topographic, bathymetric and biotic factors. The study by Maravelias (1999) has concluded that depth is one of the significant factors which affect the presence and abundance of a pelagic species.

Fish populations are affected by shrimp trawlers in at least two ways. First, trawls catch adults and juveniles of commercially important species (Villoso and Hermosa, 1982; Chong, 1984; Poiner and Harris, 1986). Secondly, the shrimp trawlers affect benthic organisms that form part of the fish habitat (Poiner and Harris, 1986; Sainsbury, 1987). This disturbance of the biotope is believed to be one of the causes of long-term species changes such as have been observed in the Gulf of Thailand and the north-western shelf of Australia (Pauly, 1979; Sainsbury, 1987).

The coastal zone is a distinctive portion of the Earth. Since the vast majority of the world fisheries is coastal, it becomes essential to examine how this great diversity and productivity may be related to human-caused alterations of coastal ecosystem dynamics (Nelson, 1984). Estuaries are prominent coastal ecosystems. As estuaries play essential role in fish ecology and fisheries, it is important to analyze the relationships of fishes to estuaries and to conserve fishes and fisheries by halting the alarming degradation of coastal ecosystems.

Young growth is a critical factor influencing juveniles and adults demography (Forrester, 1990; Connell and Jones, 1991; Sogard, 1992). Growth may influence adult population size directly, by affecting the number of individuals reaching reproductive maturity (Jones, 1991) or indirectly, through the effects of size-selective mortality on juveniles (Forrester, 1990; Sogard, 1992). Furthermore a more complex habitat may offer more shelter, resulting in reduced predation pressure (Connell and Jones, 1991; Tupper and Boutilier, 1995). Habitat complexity may also influence growth and survival through increased prey density and diversity (Connell and Jones, 1991; Sogard, 1992). Predation by fishes can play a major role in structuring aquatic communities (Carpenter, 1988; Ebenman and Persson, 1988). For example, fishes can directly affect mortality, size structure and size distribution of the prey populations (Kerfot and Sih, 1987; Stein *et al.*, 1988; Wilbur, 1988). The survival of the fishes through the estuarine phase of their life history depends on the factors that affect growth and survival within the estuary such as food availability, diseases and predation (Currin *et al.*, 1984).

Many environmental factors may explain spatial and temporal variability of fish assemblages. Habitat structure in the form of habitat complexity and /or heterogeneity (McCoy and Bell, 1991) is often related to fish population size and assemblage structure (Luckhurst and Luckhurst, 1978; Bell and Galizin, 1984;

Roberts and Ormond, 1987; Fowler, 1990; Norton, 1991; Anderson, 1994; Grigg, 1994; McGehee, 1994; McCormick, 1994).

A diversity of nektonic organisms occurs in estuaries from cuttlefish, swimming crabs, penaeid prawns and fishes (Day *et al.*, 1981). Because of their exceptional productivity, estuaries support high abundance and biomass of fishes, which is the largest faunal group present. Their great mobility confers them significant advantages over sessile organisms that are able to avoid unfavorable environmental conditions and predator attacks (Day *et al.*, 1981; Claridge and Petter, 1986).

Estuarine populations display some degree of temperature tolerance and osmoregulatory ability. The ichthyofauna of estuaries is characterized by the numerical dominance of a few species which tend to be widespread, thus reflecting a broad tolerance forwards environmental conditions (Day *et al.*, 1981). The structure of an estuarine fish community depends on abiotic and biotic factors. Among the abiotic factors, both chemical and physical conditions especially salinity, temperature and dissolved oxygen, strongly influence species composition, abundance and distribution (Kennish, 1990).

Fish distribution and abundance in estuarine and coastal habitats are determined firstly by physical and chemical factors including salinity, temperature, transparency, tide, waves and wind (Mann, 1993), and secondly by biological functions such as migration, reproduction, feeding and habitate selection (Blaber and Blaber, 1980; Whitfield and Bruton, 1989). Estuarine environments are especially important as nursery areas for juvenile marine and anadromous fishes (Claridge and Petter, 1986).

In estuarine waters, physicochemical gradients are again conspicuous and either directly or indirectly influence species assemblages.

A number of parameters tend to correlate with salinity and form gradients across the freshwater and marine interface, and these in turn influence species distributions and local abundances (Weinstein *et al.*, 1980; Felley, 1987; Rozas and Odum, 1987; Odum, 1988). Some species are directly limited by narrow physiological salinity tolerance, whereas other species having broad tolerances may be restricted from certain locations by other physical or biotic factors (e.g. productivity, nutrients, habitat structural heterogeneity).

Zoogeography also plays a major role in determining which species are available for recruitment into a particular estuary (Blaber, 1981). The ichthyofauna of estuaries throughout the world may be characterized by the numerical dominance of only a few species (Kennish, 1990).

Tropical estuaries usually have a greater diversity of fishes than temperate systems (Saila, 1975). The most abundant fish are juveniles that use the estuarine environment as a nursery area (Odum and Heald, 1972; Bell and Galizin, 1984; Pinto, 1987; Little *et al.*, 1988; Chong *et al.*, 1990; Kennish, 1990). Many of these belong to coastal populations which are short-lived and euryhaline (Sheridan and Livingston, 1979). Although a few permanent residents can be found in estuaries, most of the fish populations are seasonal migrants, moving into and out of these shallow ecosystems from the near shore ocean.

Estuarine nursery areas play a key role in maintaining commercial offshore stocks of fishes. There are numerous species of fishes whose juveniles have managed to adapt to estuarine conditions, since many occur in greatest abundance in these areas. One of the most abundant groups of fishes utilizing U.S. Atlantic and Gulf Coast estuarine environments is the family Sciaenidae (Joseph, 1972). Most species of mullets are found in brackish water habitats where the salinity is not too high, i.e. generally less than 28 ppt. Areas such as mangrove swamps, estuaries and bays are excellent habitats for mullets if the bottom is sandy mud or mud in nature. Mullets constitute an important fishery in Malaysia where one of the most common species is *Valamugil cunnensis*.

Sciaenid fish represents another important group of fish inhabiting the estuarine environment. Ten species were found in the Matang mangrove waters in Perak, Malaysia (Yap, 1995). The most abundant species occurring in the mangrove channels and coastal mudflats were *Johnius carouna* and *Johnius weberi*. Three species *Johnius trachycephalus, Nibea soldado* and *Otolithes ruber* were common, while *Pennahia macrophthalmus, Johnius belangerii, Dendrophysa russelli* and *Panna microdon* occurred in considerable numbers. These species of Sciaenidae are known to be abundant in inshore coastal waters especially estuaries. Yap (1995) suggested that Sciaenidae colonization of mangrove waters is partially due to the abundance of juvenile prawns which are important prey items. The ability of *J. carouna, J. weberi* and *D. russelli* to survive in low salinity waters is however prerequisite to estuarine colonization.

Mangroves serve as important feeding, breeding and nursery grounds as well as a habitat for many fish species (Odum and Heald, 1972; Bell and Galizin., 1984; Pinto, 1987; Little *et al.*, 1988; Chong *et al.*, 1990). Many fish species which are mangrove-dependent however have low commercial value, such as the Leiognathidae found in Australia and most South-East Asian countries (Robertson and Duke, 1987; 1990a).

Temperate estuarie are often used as temporary nursery areas by many juvenile species. Many studies have pointed out that there are more fish diversity in tropical and subtropical waters as compared to temperate waters (Moore, 1978 and Yanez-Arancibia *et al.*, 1985). A total of 119 species were recorded in the Selangor (Malaysia) mangroves (Chong *et al.*, 1990). In the subtidal zone in mudflats of Selangor, the fish populations were co-dominated by the Sciaenidae, Clupeidae, Leiognathidae and Engraulididae. Ambassidae, Engraulididae and Clupeidae were caught in high numbers in the mangrove estuary at Sungai Sementa Kecil, Selangor, Matang (Sasekumar *et al.*, 1989). Fish community in other tropical mangroves also shows a large number of species, eg. Embley Estuary, Australia with 197 species (Blaber *et al.*, 1989), Pagbilao mangroves in Philippines with 129 species (Pinto, 1988) and Pichavaram mangroves in south India with 195 species (Krishnamurthy and Jeyaseelan, 1981).

Many studies show that information on soft-bottom fish assemblages are urgently required in the Indo-Pacific tropical region, where demersal fish are heavily exploited as principal targets or as by-catch components (Aoyama 1973; Pauly, 1979; Poiner and Harris, 1986). Fish population effected by the use of shrimp trawlers includes adults and juveniles of commercially important species (Villoso and Hermosa, 1982;

Chong, 1984; Poiner and Harris, 1986). Trawling also affects benthic organisms (Poiner and Harris, 1986; Sainbury, 1987; Hutchings, 1990). The use of trawling gears creates disturbance of benthic environment, which in the long term will be one of the major causes responsible for changes in the species composition of the community.

According to a study by Jennings *et al.* (1999), fishing has greater effects on slow growing, large species with delayed maturity and lower rates of potential population increase. The intensive exploitation of marine fish has led to substantial reductions of some species abundance (Myers *et al.*, 1996) and to changes in the structure and species composition of fish communities (Greenstreet and Hall, 1996; Fresse. *et al.*, 1999).

1.1.2 Macroinvertebrates

Distribution of macroinvertebrates in the world varies highly among species, with some macroinvertebrates being widely spread whereas others are more restricted to specific areas. Furthermore, species composition and abundance in estuaries also markedly vary temporally. In general, diversity is a useful parameter for assessing the stability of macrobenthic communities (Kennish, 1990). A combination of seabed imaging and catches of towed gear has been proposed to be most adequate for examining the epibenthic fauna (Rice *et al.*, 1982; Schneider *et al.*, 1987).

Marine invertebrates form an important linkage between the primary detritus at the base of the food web and consumers in higher trophic levels. However, little is known about invertebrates in mangrove ecosystem although molluscs and crustaceans are known to populate these areas (Wells, 1990).

Studies on the structure of macrobenthic communities show that the abundance, biomass and diversity of macrobenthic communities decreased with depth and shallow water. Sedimentary characteristics such as grain size play an important role (Ioannis and Anastasios, 1997; Karakassi and Eleftherious, 1997; Cyr, 1998) and affect chemical exchanges within the water column (Cyr, 1998).

The spatial distribution and abundance of benthic macroinvertebrates within estuarine habitats have also been related to other physical factors, notably waves and currents (Ioannis and Anastasios, 1997). Biological factors (e.g. predation and competition) and chemical factors (e.g. oxygen concentration) also influence the distribution of the benthic macrofauna (Kennish, 1990; Ioannis and Anastasios, 1997). The sediment type and more particularly the concentration of organic matter in sediments are known to influence benthic communities structure and compositions (Kennish, 1990).

The distribution of benthic macroinvertebrates throughout an estuary is also a function of larval dispersal and recruitment. Many benthic faunal populations have a planktonic larval stage, during which the larvae experience high mortality rates due to predation and vagaries of environmental conditions. The degree of larvae dispersal is not only contingent upon the duration of the pelagic stages, but also upon the behavior of the larvae and, perhaps most importantly, upon the hydrodynamic processes in the estuary (Kennish, 1990).

The patchy distribution of benthic organisms in marine soft sediments has been recognized for a long time (Barry and Dayton, 1991). The distributions of other sediment related variables, such as pollutants and sediment particle size is likely to be heterogeneous. Physical environmental factors, such as water depth, currents and sediment types, are believed to determine large scale patterns of distribution (Gray, 1974; Warwick and Uncles, 1980; Barry and Dayton, 1991).

The impact of commercial fishing on the marine environment has been a matter of concern since at least the 14th century (De Groot, 1984). More recently the world-wide increase in environmental awareness has resulted in further concern as heavier fishing gears are towed by large and more powerful vessels (Hall, 1994). But few impacts of fishing have been well-documented and biological impacts are particularly difficult to investigate because of the complexity of benthic communities and our limited knowledge of its natural variability (Messieh *et al.*, 1991; Gislason, 1994).

Many studies have suggested that as long as mobile fishing gears are used, there will be harmful effects on benthic habitats. Gears can affect the sea bed in many ways such as scarping or ploughing, sediment resuspension, physical destruction of bed forms, and removal or scattering of non-target benthos (De Groot, 1984). Delayed effects on the seabed include post-fishing mortality of organisms and long-term changes of the benthic community structure (Jones, 1992). A committee of the U.S. National Research Council identified fishing as the most ubiquitous agent of change in marine biodiversity (NRC, 1995). Although the effect of one passage of a fishing net is relatively minor, the cumulative effects and the intensity of trawling and dredging may generate long-term changes in benthic communities. The effects of

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In India many studies suggested that most of the penaeid shrimp species have a similar life history pattern. Adults spawn in deep waters, and post larvae and juveniles use inshore estuarine and coastal waters as nursery habitats for their early development. Furthermore, the use of mangroves as nursery grounds for penaeid prawns in many parts of the world has been reasonably well studied (de Freitas, 1986; Rao, 1990; Stoner & Zimmerman, 1988; Vance *et al.*, 1990).

A positive correlation between commercial yields of shrimp and extent of mangrove forests has been well established (Staples *et al.*, 1985; Chong *et al.*, 1990). High abundance of juveniles in tropical estuaries and success of the shrimp fishery in the tropical inshore areas have been attributed to high concentrations of mangrove-derived detritus in the nearshore ecosystems (Longhurst and Pauly, 1987; Stoner and Zimmerman, 1988). The offshore commercial catch of adult *Peneaus merguiensis* was significantly correlated with catches of prawns emigrating from the Embley River, Australia during the wet season (Vance *et al.*, 1998). Jansson *et al.*, (1988) suggested that the inshore areas constitute a crucial part of the life support system of offshore populations by providing nursery and feeding areas.

The juveniles of some prawn species such as *Penaeus merguiensis*, is mangrove-dependent during the first 3-6 months of their life. Macnae (1974) suggested the correlation between offshore prawn catches and a real extent of mangroves can be the indicator of the dependence of juvenile prawns on mangroves. The juvenile of *Penaeus merguiensis* and *Metapenaeus ensis* were both significantly more abundant in mangrove habitats compared to other nearshore habitats in tropical Australia (Robertson and Duke, 1987). Several hypotheses may explain the preference of juvenile banana prawns for mangrove regions. The first suggests that mangrove trees root penumatophores and fallen timber provide protective habitat from predator fish which consume juvenile banana prawns (Robertson and Duke, 1987). The second suggests that because of the high productivity of mangrove systems there is likely to be more food available to juvenile banana prawns in mangroves as compared to other coastal habitats (Robertson, 1988b; Chong *et al.*, 1990). The third hypothesis suggests that postlarval prawn are attracted to estuaries by a chemical cue, in which case the distribution pattern of juveniles reflects settling choice at the larval and postlarval phase. The banana prawn *Penaeus merguiensis* has been studied extensively in Australia because of its commercial importance (Rothlisberg *et al.*, 1985a; Haywood and Staples, 1993).

Crabs species distribution and abundance were associated with a higher variability in sediment pH, and a homogeneous distribution of organic matter (Brazeiro, A., and Omar, D.1999). Only five species of Stomatopoda belonging to the family Squillidae, viz. *Oratosquilla perpensa, O. interrupta, Harpiosquilla harpax, Cloridopsis scorpio* and *Anchisquilla* sp., were recorded in Angsa Bank (Selangor) (Addyanis, 1995). *O. interrupta* was found to be the most abundant species followed by *H. harpax* and *O. perpensa* in the coastal waters off Bukit Jeram and Kuala Selangor (Selangor, Malaysia).

Shallow benthic octopi are found commonly throughout the world, and are likely to be an important component of many ecological communities. Several researches on octopus distribution suggest that many species were characterized by marked density fluctuations at particular sites (Hartwick and Thorarinsson, 1978; Ambrose, 1982) and strong site selection (Mather and O`Dor, 1991). The abundance of octopus species varies temporally (Mangold, 1983; Ambrose, 1988). Both ontogenetic and migratory mechanisms have been suggested to be responsible for these patterns. Octopus may exert considerable choice in food and shelter (Yarnell, 1969; Wells, 1978; Aronson, 1986; Voight, 1988). A number of habitat factors have been suggested to influence octopus distribution and abundance. One study by Anderson (1997) suggested that octopus were more abundant near the reef edge, and in areas with high numbers of small boulders. No relationships between octopus and potential reefal predator eels or crayfish species were found. Soft sediment bivalves occurred in the majority of shelter middens, suggesting that octopi were foraging over adjacent soft sediments rather than on the rocky reef itself. In soft sediment habitats, which are generally featureless, small octopus was often associated with shells which comprise a large portion of the heterogeneity of the habitat (Mather and O`Dor, 1991; Voight, 1992). On rocky reefs, octopus occupy naturally occurring shelters to avoid predation (Hartwick and Thorarinsson, 1978; Ambrose, 1982; Aronson, 1986; Hartwick *et al.*, 1988; Mather and O'Dor, 1991). Shelter types utilized by octopi are variable and often opportunistic ranging from naturally occurring holes and crevices (Hartwick *et al.*, 1984b) to artificial shelter within discarded car tyres, pipes and railway iron. Many of these shelters are likely to limit the size of the occupant (Hartwick *et al.*, 1984b).

Gonzalez *et al.* (1997) suggested that squid are short-lived and populations are likely to be able to respond rapidly to environmental change. However, it is not clear at what stage in the life cycle of the squid these oceanographic events exert their effect.

Variation in sea urchins recruitment and many marine organisms has been attributed to numerous physical processes that influence larval supply (Gaines and Roughgarden, 1985; Roughgarden *et al.*, 1988; Shanks, 1995). In particular, the influence of nearshore currents on larval supply has been investigated in numerous studies (Banse, 1986; Farrell *et al.*, 1991; Roughgarden *et al.*, 1991; Wing *et al.*, 1995a, 1995b). Studies by Ebert *et al.* (1994) and Wing *et al.* (1995b) suggested that spatial and temporal patterns of sea urchin settlement may be closely linked to patterns of onshore and offshore transport of coastal waters. Sea urchins are important grazers, eroders of substrate and compete with fishes (Carpenter, 1986; Birkeland, 1988; McClanahan and Shafir, 1990; McClanahan and Kurtis, 1991). Although numerous factors such as diseases and planktonic settlement play a role in the abundance of sea urchins, many studies suggest that predation is frequently a dominant force controlling their populations, behavior and coexistence (McClanahan and Shafir, 1990; McClanahan, 1992).

Starfish distribution can be affected by the abundance of coarse sediments since these latter are known to provide abundant food (Kurihara, 1999).

1.2 RAINFALL

The Klang Strait forms part of the Malacca Straits. The latter is strongly influenced by the monsoons which directly or indirectly affect the water circulation and its physical, chemical and biological characteristics (Chua *et al.*, 1997). In Malaysia, the winter or northeast (NE) monsoon generally brings more rain and lasts from November – March. Most of the onsets of the winter monsoon occur during the period 11-20 November where heavy rainfall is experienced during the early part of the monsoon, and dry spells during the later part (Cheng, 1988a). The summer or southwest (SW) monsoon prevails from May to October, but does not bring heavy rains until the months of June – September when easterlies or southeasterlies converged with the southwesterly winds over the Bay of Bengal and Sumatran regions (Cheng, 1988b; and Uktolseya, 1988). Generally, two peak rainfall periods occur in a year, which corresponds roughly to the intermonsoon periods (Leyu and Ling, 1988); in the Klang Strait, Chong (1993) observed one large peak in November and the other smaller peak in April.

Many studies suggested that primary production in tropical nearshore waters is elevated during the wet monsoon season due to nutrient enrichment of the euphotic zone caused by land run-off (Qasim, 1974; Longhurst and Pauly, 1987; Robertson *et al.*, 1988). Chong (1993) found significant correlations between phytoplankton abundance and the rainfall, surface salinity and surface water temperature in the

Klang Strait. Two peaks of phytoplankton abundance were observed in November-December and May, which appeared to be related to increased rainfall and riverine discharge, and depressed salinity and temperature. Zooplankton abundance was also generally matched to the phytoplankton peaks although with time lags. Chong (1993) alluded to the importance of nutrient enrichment from land as a contributing factor to the plankton blooms.

1.3 CURRENTS AND TIDES

According to the Malacca Strait Pilot (1946) and Soeriaatmadja (1956), the prevailing surface drift in the Malacca Straits is generally in the northwest direction which may vary in intensity seasonally as a result of the monsoon winds. The influence of tides is however more significant; tides in Malacca Straits are mainly semidiurnal, with two high and two low tides during each day. As the flood currents set to the southeast and ebb currents to the northwest, the northwesterly flow in Malacca Straits is enhanced so that ebb flow is slightly longer and stronger than flood flow. The British Admiralty (cited in Coleman *et al.*, 1970) recorded maximum ebb and flood current velocities of 1.5 ms^{-1} and 1.0 ms^{-1}, respectively, in the Malacca Straits (25 km west of the Klang Strait). However, within Klang Strait, flood tide velocities increased from 0.9 ms^{-1} at its mouth to 1.5 ms^{-1} at the coast, whereas ebb flow decreased from 1.3 ms^{-1} to 0.8 ms^{-1} in the opposite direction.

Within Klang Straits, high water at spring tide could reach 5 meters above chart datum (Kamaruzaman, 1995).

1.4 WATER PARAMETERS

Water quality variables such as temperature, dissolved oxygen, pH, salinity and turbidity are important parameters that often interact and thus determine the suitability of habitat to marine life (Hynes, 1970). Physical and chemical factors largely control the abundance and distribution of fishes in estuaries (Moyle and Cech, 1982). Biological factors, including interspecific competition and predation, are of secondary importance and may play a role in the seasonality of estuarine fish population (Moyle and Cech, 1982).

1.4.1 Temperature

Temperature, is a key physical factor, because of its influence on the biochemistry, physiology, and behavior of fishes (Magnuson *et al.* 1979). Temperature influences metabolism and growth rate of aquatic organisms, photosynthesis, solubility in water, organism sensitivity to diseases caused by parasites, and accumulation of toxic materials (Whitefield and Bruton, 1989; Longley, 1994). Temperature gradients are known to affect the species composition, abundance, and distribution of fishes (Magnuson *et al.*, 1979). The temperature limits of a species correspond to its critical thermal minimum and critical thermal maximum (Matthews and Maness, 1979). Individuals exhibit temperature preference that allows them an optimal growth (Jobling, 1981). The densities of benthic community decrease concomitantly with temperature (Brandimarte and Shimizu, 1996).

The immigration of juvenile fish into the lower-latitude systems usually takes place subsequently to a decrease in temperature. In tropical environments, seasonal temperature changes are little but offshore temperature decreases with water depth. Moreover, temperature fluctuations are greater near the water surface due to wind disturbance (Magnuson *et al.*, 1979; Brandimarte and Shimizu, 1996). Freshwater flows into coastal marine waters affect temperature, salinity, and nutrient regimes (Reddering, 1988; Whitfield & Bruton, 1989; Longley, 1994).

Temperature plays an important role in the distribution of organisms in the mud flats. The major groups of macrobenthos including fish and prawn exhibit population fluctuations both at the species level and at the community level, in response to seasonal changes in temperature (Choudhury *et al.*, 1984).

Surface water temperature in the Straits of Malacca ranged from 28 °C to 30 °C during the SW monsoon, while lower temperatures of 26 °C to 27 °C are recorded during the NE monsoon (Soegiarto, 1985).

In the Klang Strait where the study was carried out, Chong (1993) recorded monthly mean surface and bottom temperatures that ranged from 29.3°C to 30.6° C and 29.2°C to 30.6°C, respectively. He also noted no obvious seasonality of water temperatures, but water temperatures from September to January were generally lower than 30°C which is attributable to the existing cold monsoonal air surges from the northern Asian continent.

1.4.2 Salinity

"Salinity" is defined as the total inorganic materials, approximately 90% sodium chloride (NaCl), dissolved in 1 kg of seawater. Generally, the salinity of the open ocean surface water is 34 ppt to 37 ppt Values are lower in coastal areas with heavy rainfall and higher in subtropical areas where evaporation is high and rainfall is low (Lobban and Harrison, 1994). Day (1981) defined water columns showing slight variation in salinity between surface and bottom waters as partially stratified water bodies.

Undoubtedly salinity is one of the important factors that affect the distribution of marine life since it involves the organism capability to osmoregulate (Cervetto *et al.*, 1999). Composition and abundance of nearshore fish and macroinvertebrate assemblages in the Port River Barker estuary, South Australia, were weakly correlated to water temperature and salinity (Jackson and Jones, 1999).

The distribution of organisms in mangroves has been defined in terms of habitats (Golley *et al.*, 1962) and in terms of environmental gradients within habitats (Macnae, 1968). One of the most limiting factors is salinity, which plays an important role in the distribution of marine invertebrates. Organisms in mangrove habitats acquire a certain degree of euryhalinity that insured them against fluctuating environmental conditions. However, rapid salinity fluctuations can represent a significant stress to certain marine organisms. For fishes, abrupt salinity changes can cause hydromineral imbalance in the blood which tend to become diluted as salinity drops and concentrated as it rises - either of which can be lethal (Mazeaud *et al.*, 1977).

Numerous studies have examined the effects of salinity fluctuation, and / or abrupt salinity changes, on invertebrates (Crisp and Costlow, 1963; Davenport *et al.*, 1975; Drouin *et al.*, 1985; Kumlu and Jones, 1995). The impact of low salinity pulses on tropical and sub-tropical marine invertebrates has received only limited attention (Moore, 1972; Broom, 1982; Montague and Ley, 1993).

The average surface salinity in the open water of Malacca Straits varied from 30.80 to 31.83 ppt while higher average salinity readings of 31.33 to 31.48 ppt., were recorded near the bottom of the Straits (Moosa, 1988). This lower salinity as compared to most open marine waters is due to large freshwater inputs from the many rivers that flow from Peninsular Malaysia and Sumatra (Indonesia).

In the Klang Strait, salinity ranged between 21.0 and 32.0 ppt in coastal mangrove inlets and between 28 to 32 ppt in offshore waters at Pulau Angsa (Chong, 1980). The offshore gradient in salinity change (increase) was small, approximately 1.6 ppt per 10 km (Chong, 1993). The difference in surface and bottom salinity was also small but significant in the Klang Strait, 2.5 ppt at a depth of 20 m (Chong, 1993).

Selvarajah (1961) and Uktolseya, (1988, 1990) showed that the salinity regimes in the Straits of Malacca are related to the seasonal rainfall patterns (see above). Clear seasonal effects on salinity due to heavy rainfall were observed in the Klang Strait. Mean surface salinity was high during the months of July – September (32.1 ppt) but lowest (28.2 ppt) during December (Chong, 1993).

1.4.3 Turbidity

Turbidity is the condition resulting from suspended solids in the water, including silt, clay, industrial wastes, sewage and plankton. Highly turbid water during high tide indicated that turbidity is caused by tidal action. In shallow estuaries there is a stronger interaction between the water column and the bottom (Day *et al,* 1989). Suspended particles absorb heat thus raising water temperature, which in turn lowers dissolved oxygen levels. They also prevent sunlight from reaching submerged plants, thereby decreasing their photosynthetic rate and thus the production of oxygen. Therefore high turbidity may harm fish and their larvae.

The effects of turbidity on marine fish are not well understood. According to the study by Blaber and Blaber (1980), it is found that it is possible to divide marine species into turbid water species, species indifferent to turbidity, and clear water species, species preferring clear water. Juvenile and adult of the same species frequently fall into different categories. Those species found in estuaries are tolerant and/or indifferent to turbid water.

One of the current hypothesis is that high turbidity may help juveniles to avoid predators and these conditions may be associated with shallow, food-rich areas (Boehlert and Morgan, 1985). Turbidity is a ubiquitous feature of estuaries that can reduce visibility.

Feeding success can affect growth in the early life of fishes and influence survival, year-class strength, and recruitment (Folkvord and Hunter, 1986; Houde, 1987).

Many fishes use turbid estuaries as nursery areas (Boehlert and Morgan, 1985). Turbidity negatively affects feeding success by decreasing reactive distance (Barrett *et al.*, 1992. Gregory and Northcote, 1993), and the volume of water searched (Gardner, 1981) by reducing visual range (Vinyard and O'Brien, 1976). Low light resulting from turbid conditions may also reduce foraging (Diehl, 1988) and coupled with turbidity, may reduce feeding by diminishing prey contrast and visibility (Miner and Stein, 1993). Compared with larvae, this effect may be intensified for juveniles which search a large volume of water (Chesney, 1989) or feed on large, more mobile preys capable of escaping the reduced visual field (Hecht and van der Lingen, 1992). It has been suggested that reduced prey contrast associated with turbidity could reduce feeding success for larval fishes (Dendrinos *et al.*, 1984).

High turbidity is observed in areas around the river mouths and in waters off the west coast of Peninsular Malaysia, but in offshore waters turbidity becomes lower (Soegiarto, 1985; Gomez *et al.*, 1990).

1.4.4 Dissolved Oxygen

The amount and distribution of dissolved oxygen are affected by physical circulation, as a result of atmospheric exchange and turbulence, water temperature, as well as organic activity such as primary production, decomposition of organic matter and other biological processes (Nelson. *et al.*, 1994). In estuarine waters the concentration of dissolved oxygen is a function of temperature, salinity, and pressure (Wetzel, 1983; Tyson and Pearson, 1991). In addition to these physical factors, biological activities and pollutant can alter dissolved oxygen levels.

Many estuaries receive both organic and nutrient pollutants from domestic and industrial sources, which can lead to major changes in the biological productivity and its associated oxygen demand (Wetzel, 1983). Low dissolved oxygen concentrations are common in aquatic system, especially in the bottom water of lakes, estuaries and coastal marine systems that have high nutrient loading (Wetzel, 1983; Breitburg, 1994; Tyson and Pearson, 1991). Low dissolved oxygen allows microbial degradation of organic matter to deplete further the dissolved oxygen at the bottom layer, and inhibits re-aeration of bottom waters. Low dissolved oxygen can directly affect nearly every aspect of predator-prey interactions (Kramer, 1987; and Breitburg *et al.*, 1994).

In the rivers and estuaries, the dissolved oxygen is an important indicator of water quality. One of the fundamental processes that control dissolved oxygen in an estuary is the neap-spring tidal cycling (Nelson. *et al.*, 1994).

One of the limiting factors affecting growth rates, distribution and predator-prey interactions of aquatic organisms is low dissolved oxygen concentration (Breitburg *et al.*, 1999). Dissolved oxygen levels in tropical seas lying between 0.3-3.0 mg/l is considered too low for marine life; the optimum range should be between 3.5 to 5.0 mg/l (Breitburg *et al.*, 1994). Living organisms need more oxygen up to values of 6.0 mg/l during the spawning season. Increase in decomposition activities may increase dissolved oxygen consumption by microorganisms (Hynes, 1970). Because of the variation in effects on trophic interactions, low dissolved oxygen has the potential to cause major alterations in the estuarine system (Breitburg *et al.*, 1994).

The oxygen concentration is often an important factor regulating benthic community structure (Fraser, 1997). In response to decreasing oxygen concentrations, the abundance and species richness decreases, and the species composition is largely determined by tolerance to oxygen deficiency of the individual species (Fraser, 1997). Fraser (1997) suggested that dissolved oxygen levels below 2 mg/l near the bottom resulted in sharp decreases for relative abundance and number of species present.

In general, in the open water of the Malacca Straits, the surface dissolved oxygen contents show a strong seasonal variation. The variation of the annual average was 4.03 to 4.61 mg/l near the surface and 3.51 to 3.88 mg/l in deep waters near the bottom (Chua *et al.*, 1997). The lowest value of 3.76 mg/l for surface waters was recorded in January 1980 and in January 1979, and the highest value was 5.50 mg/l. The minimum value of 2.03 mg/l was recorded near the bottom in January.

Fluctuations in dissolved oxygen content in nearshore and coastal waters, showed high variation from one place to another due to the influence of land drainage and fresh water run-off from the large rivers on the coasts (Chua *et al.*, 1997). In the Klang Strait, mean surface dissolved oxygen concentrations fluctuated between about 4.2 to 6.4 mg l^{-1}, whereas mean bottom oxygen concentrations fluctuated between 3.7 to 6.2 mg l^{-1} (Chong, 1993).

1.4.5 pH

The pH of water is the measure of how acidic or basic the water is on a scale of 0-14. It is a measure of hydrogen ion concentration. Extremes in pH can make the water body inhospitable to life. Low pH is especially harmful to immature fish (Lobban and Harrison, 1994). Acidic water also speeds up the leaching of heavy metals harmful to fish. The alkalinity of seawater is higher and more stable compared with fresh water (Lobban and Harrison, 1994). Boto and Bunt (1981) emphasized that there is a positive correlation between pH and dissolved oxygen.

The pH of the Malacca Straits is relatively alkaline; mean annual pH values near the surface varied from 7.43 to 8.13 compared to 7.38 to 8.25 near the bottom (Chua et al. 1997). The study by Chong (1993) indicates that both the monthly mean surface and bottom pH values in the Klang Strait fluctuated between 7.85 to 8.25, the surface value being generally higher but the difference was less than 1 pH value. He also found that lower pH values were obtained during periods of high riverine discharge.

1.4.6 Depth

Water depth is considered as one of the limiting factors known to influence fish population size (Thresher, 1983). A study of fish community structure has clearly shown that species richness decreased significantly with depth (Moranta *et al.*, 1998) Other studies indicated that the number of species and individuals of shrimps and crabs were significantly correlated with depth (Ansell *et al.*, 1999). The Klang Strait is a shallow basin, the greater part of it does not exceeds 6 fathoms in depth. However, the depth at its entrance exceeds 10 fathoms (Chong, Sasekumar and Lim, 1994).

1.5 BOTTOM SEDIMENT CHARACTERISTICS

Great variations in faunal densities and species richness in tropical waters have been attributed to the great variety of habitats and environmental conditions. Topographical heterogeneity refers to the variety of physical or structural features found in the habitat. It is the major factor regulating species distribution and abundance within a community (Emson and Faller-Fritsch, 1976; Raffaelli and Hughes, 1978; Genin *et al.*, 1986; Bourget *et al.*, 1994). The characteristics of the community such as diversity and richness are also modified by topographical heterogeneity (MacArthur and Macarthur, 1961; Menge *et al.*, 1985).

1.5.1 Sediment Texture and Characteristics

Sediments rarely consist entirely of one size range. Particle-size analysis is often used in soil science to evaluate soil texture. Sediment texture is based on different combinations of sand, silt and clay that make up the particle-size distribution of a soil sample (Folk, 1974).

Soil particles cover an extreme size range, varying from stones and rocks (exceeding 0.25 m in size) down to submicron clays (< 1 um). Various systems of size classification have been used to define arbitrary limits and ranges of soil particle size. Soil particles smaller than 2,000 um are generally divided into three major size groups: sand, silt and clay (Folk, 1974).

The most important environmental variables considered to control the distribution and abundance of benthic animals in estuaries are several interrelated static sediment

The most important environmental variables considered to control the distribution and abundance of benthic animals in estuaries are several interrelated static sediment variables, such as grain type, size and organic content, which in turn are determined by the hydrodynamic features of the estuary (Brandimarte and Shimizu, 1996). The associated changes in flow-rate, depth and temperature are important both directly and indirectly in their effects on the structure and composition of the sediments. However, hydrodynamics do not only affect benthic animals through their effects on static variables, but also influence the stability of the sediment and the nature of the food supply available to these animals (Warwick & Uncles, 1980).

The near shore sediments of the Selangor coast consist mostly of clay and silt, and a lesser amount of sand (Sagathevan, 1989). The mud is bluish grey in colour and pH is usually near neutral. Sasekumar *et al.* (1984) showed that the benthic invertebrates are important components of the mangrove ecosystem and provide valuable food resources for humans and fish. The muddy substrate is rich in benthic fauna. Except for these studies and that of Broom (1982), there are no studies on sediment characteristics or sediment distribution in the Klang Strait.

1.5.2 Organic Matter Content

Soil organic matter plays an important role in nutrient cycling in tropical ecosystems (Sanchez and Miller, 1986). Brandimarte and Shimizu (1996) suggested that densities of benthic communities decreased due to the decrease of organic matter input from terrestrial ecosystems. This organic matter is useful as an energy source for benthic organisms of the detrital food chain (Efford & Hall, 1975; Terek, 1980). Most freshly deposited organic matter are either utilized by benthic organisms or resuspended and exported during the tidal phase (Kelley *et al.*, 1990). Only a small fraction is buried and lost permanently from the detrital food web (Yoon and Benner, 1992; Zimmerman and Benner, 1994).

According to the study by Springer and Bullis (1954), the Gulf of Mexico pink shrimp were more abundant on calcareous mud and shell sand where white and brown shrimp were more abundant on terrigenous mud. This kind of limited work has been done to relate shrimp abundance and distribution to the nature of the substrate. The results from these studies were further confirmed by Williams (1958) and Grady (1971) who showed a positive association between the catch of *Penaeus* shrimps in the Gulf of Mexico with the organic content of the sediment. High catches of shrimps occurred on substrates with the highest organic matter content. Soft muddy sediments are suitable to the burrowing behavior of shrimps which is a method of escape from predation.

Dauwe *et al.* (1998) suggested that the highest benthic diversity was however found in sediment with intermediate quantity of organic matter. Studies have shown the correlation between organic enrichment and community characteristics that describe the impact of organic disturbance on benthic communities (Pearson and Rosenberg, 1978; Gray, 1989). It is generally believed that organic enrichment will result in a decrease in the species richness and an increase in the number of individuals, as a result of high densities of a few opportunistic species.

According to the study of Sasekumar *et al.*, (1984) and Broom (1982) the organic matter content of the nearshore sediments of the Klang Strait in Selangor was between 6 and 11%.

1.5.3 Fishing Impact

Fish and macroinvertebrate community structure and abundance may be influenced by anthropogenic activities. Modern fishing activities have direct and indirect impacts by way of reducing predators and preys, and modifying topographical heterogeneity. The prawn fishery in the west coast of Peninsular Malaysia is one of he most important components of the coastal capture fishery. Prawns are the main target of commercial trawlers because of its economic value. Because prawns are more abundant in the inshore waters where most fin-fish species are also found as juveniles, the prawn fishery has significant impact on the fin-fish resource since the latter are also captured as by-catch and often discarded (Chong *et al.*, 1990).

Trawling gear affects the environment both directly and indirectly. Research conducted in the Grand Banks of New Foundland by Prena *et al.*(1999) indicates that otter trawling on the sandy bottom ecosystem can produce detectable changes of both benthic habitat and community, in particular, a significant reduction in the biomass of large epibenthic fauna. Long-term trawling that induced changes to the benthos are included among the indirect effects (Jones, 1992). Extensive fishing activities clearly can produce long-term changes in sediment characteristics and benthic community structure (Messieh *et al.*, 1991).

1.6 IMPORTANCE OF THE STUDY

Estuaries are particularly important shoreline features because their sheltered position are often the basis for human settlement, and their shallow brackish waters and muddy sediments, often with mangrove vegetation, are thought to form the nursery grounds for the young of certain commercial fishes and prawns. Human activities have had various effects on estuaries around the world; such impacts include reduced or altered freshwater flow, changes of temperature and dissolved oxygen, nutrient enrichment and hyper-eutrophication, fishing pressure, and many forms of pollution (Livingston, 1990). Many studies suggest that climatic variability may be a more basic causative factor for benthic disturbance compared to other possible factors (Kroncke *et al.*, 1988).

The present study area, the Klang Strait, represents a very important multiuse coastal zone. It is an important fishing as well as an aquaculture area. Selangor's largest mangrove swamps are situated in several offshore deltaic islands including some that remained on the mainland coast. Pulau Tengah one of the deltaic island is the wintering stop-over site for millions of shorebirds that migrated from the cold northern Asiatic continent. At the same time the Klang Strait functions as a conduit for ships traversing the Malacca Strait to Port Klang which is Malaysia's largest port (see Figure 1). Expanding port facilities and industrial parks had removed much of the mangrove forests in Pulau Lumut, an offshore island off Port Klang.

According to the Annual Fisheries Statistics 1997, the annual marine capture fishery production of 515,429 tonnes in the west coast of Peninsular Malaysia were attributable to fish, prawns, crabs, cephalopoda and other macroinvertebrates. The

Selangor wholesale value was RM 321,944,429 million, or 18.4% of the total wholesale value for the west coast of Peninsular Malaysia. This high production of fish and macroinvertebrates are believed to be sustained by the mangroves and their associated mudflats in the Klang Strait (Chong *et al.*, 1990).

1.7 AIMS OF STUDY

A detailed knowledge of the composition, distribution and abundance of the fishes and macroinvertebrates, in relation to the physico-chemical factors of their environment, is vital to the understanding of their habitat requirements and thus is of great value to fisheries management and rehabilitation.

The objectives of this study are to investigate the substrate and ambient water parameters of the Klang Strait, and test the hypothesis that these parameters influence the distribution and abundance of demersal fishes and benthic macroinvertebrates.

To achieve the above objectives, this study carried out the following investigations:

(1) Characterisation of the bottom sediments and their distribution in Klang Strait, and

(2) Elucidating the distribution and abundance of demersal fishes and benthic macroinvertebrates in relation to abiotic factors such as water parameters, bottom sediment texture and organic matter content, by using multivariate analyses.