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INAUGURAL LECTURE

"Mangrove Conservation - A Fisheye View"

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"CONSERVATION OF MANGROVES - A FISHEYE VIEW"

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by
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Original painting by Xavier Cortada "Mangroves at Sunset"

"If there are no mangroves, then the sea will have no meaning.
It is like having a tree without roots, for the mangroves are the roots of the sea..."

Words of an Andaman Thai fisher

BRIEF PROFILE

Professor Chong had his early education in Sekolah Rendah Sultan Iskandar and Kolej Sultan Abdul Hamid in Alor Star, Kedah. He then graduated from the University of Malaya with a BSc(Hons) in 1976 before joining UM as a career tutor in 1977. He obtained his MSc in 1980 and then his PhD in 1994. Before working on his PhD, he pursued his keen interest and training in marine science for one semester at the Graduate School of Oceanography, University of Rhode Island (USA). He then participated and trained in an oceanographic research cruise on-board the *R/V Hakuho-Maru* - a prestigious research *cum* training vessel of the Ocean Research Institute, University of Tokyo. Prof. Chong became UM lecturer from 1989-1999, Associate Professor from 1999-2003, and then a full professor in 2004.

He is currently serving as the Programme Head for Ecology and Biodiversity, Institute of Biological Sciences, as well as Unit Head for Marine Biodiversity, Ecology and Biotechnology, of the Institute of Ocean & Earth Sciences, UM. He had successfully supervised 4 PhD and 16 Master's students, and is currently supervising another 9 PhD and 7 Master's students.

Professor Chong has successfully carried out many marine research and consultancy projects. He has formed an active Mangrove Ecology Group currently involved in studies ranging from sediment and water quality of mangrove and coastal waters, fisheries, zooplankton, macrobenthos, biofouling to aquaculture. He co-founded the Mangrove Research Centre in Carey Island – a centre dedicated to mangrove and estuarine research, in collaboration with Sime Darby Plantations Bhd.

He had received several international study awards, among which a Sea Grant award and UNDP/UNESCO award which had enabled his early training in marine science. Other international awards supporting his mangrove research work includes US-AID, AUS-AID, IBM and JIRCAS. These awards and those granted locally by MOSTI, NRE, UM, FRIM and NOD have allowed him to forge successful research linkages with various marine scientists from the University Putra Malaysia (UPM), University Science Malaysia (USM), University of Malaysia Sabah (UMS), Fisheries Research Institute (FRI) and Forestry Research Institute of Malaysia (FRIM), NUS, Singapore, AIMS and CSIRO (Australia), University of Rhode Island (USA), University of Maryland (USA), University of York (Great Britain) and the Japanese International Research Center for Agricultural Sciences (JIRCAS).

Prof. Chong has produced 111 scientific writings, including 10 edited books, 11 book chapters, 57 refereed journal papers, and 33 refereed full proceeding papers. His publications are well cited with over 450 ISI-citations and an h-index of 9.

In recognition of his research works in mangrove and fisheries research, Prof. Chong had served as a member of the Working Group 105: Estuaries and Coastal Waters, Scientific Committee of Oceanographic Research (or SCOR) in 1998. He was awarded the Excellent Scientists Award 2005, by Ministry of Higher Education, for his co-researching work in aquaculture feed and bioremediation using bacteria. He has served in several national experts committee in the country, including MRDCS for marine science under MOSTI, R&D Prioritized Reseach or Top-Down Projects, Core Group for R&D in Coastal Mangrove Replanting, and recently the Bay of Bengal Large Marine Ecosystem Project.

Synopsis

Mangroves of South and Southeast Asia account for 41.4% of the world's mangroves of over 18 million ha. Malaysia's total mangrove forests cover 566,856 ha and ranks the sixth highest in the world. Scientists believed that Malaysia is the centre of origin of mangrove evolution and dispersal. In fact, the origin of the word mangrove itself is also Malaysian, coming from the root word "manggi-manggi". Mangrove therefore has a very special meaning to us. Arguments for the conservation of mangrove wetlands have strongly rested on the premise (of food security) that these ecosystems provide the nursery, feeding or spawning areas for marine fishes, and therefore, sustain our coastal fisheries. One of the most striking features of the Malaysian fishing scene is that even after 50 years of fishery development, there is always more fish/prawns caught in the west than in the east coast of Peninsular Malaysia. Equally striking is that there are more mangrove forests on the west coast than east coast. Not surprisingly, one scientist had put it very strongly in a maxim "No mangroves, no prawns" when he showed that major prawn fisheries only occur near mangroves. Unfortunately, mangrove wetlands world-wide are increasingly being reclaimed or converted to farming, industrial and urban lands. They are further degraded by unsustainable timber exploitation, pollution, siltation and mining activity. One recent report estimates that one-third of the world's mangrove forests have been lost to coastal development over the past 50 years. At home, we have lost 16% of our total mangrove area amounting to about 110,000 ha. If we take a more restrictive area, say the more developed west coast of peninsular Malaysia, the loss becomes 23% (25,000 ha), while at the state level, some states have lost >30% or up to 85% of their reserves! So, what impact has this on our fisheries catches? While the quantified relationships predict that the more mangroves you have - the more prawns you'll get, by the same token, the more mangroves you destroy – the less prawns you'll get. The prognosis and the present fishing scenario provide compelling evidence.

It is clear that the traditional concept of fishery management based on the regulation of fish catch and catch effort is no longer effective in the New Millennium which sees the increasing loss of our coastal ecosystems which play vital ecological roles as essential fish habitats (ESH). In many developed countries, habitat conservation has now become an integral fisheries management objective. Fisheries managers need to identify ESH in order to minimize adverse fishing and developmental effects on such habitats, as well as to seek actions to encourage the conservation and enhancement of ESHs. The prevailing trends of coastal resources exploitation and development have highlighted the need for holistic ecosystem-based management. What it ultimately means is that fisheries and coastal resource managers must acquire greater scientific understanding of the complex interactions among species as well as between species and their environment. As marine scientists, we have the daunting task to provide clear, unequivocal evidence of the role played by mangroves in sustaining the vital coastal ecological processes, maintaining a continuous supply of seafood and beneficial materials, and protecting human settlement and property. Innovative research is urgently required to provide solid reasons why mangrove and other critical coastal habitats should be protected and conserved.

1. Introduction

Ladies and Gentlemen, this year is 2010 International Year of Biodiversity. We celebrate the rich biological diversity and its value for Earth. Exactly one month ago we celebrated the World Ocean Day, with the theme "Oceans of Life". WOD is the day that we honour the ocean for the products and the services that it provides us. Three days before WOD was the World Environment Day (WED), when we celebrated the incredible diversity of life on Earth with the theme "Many Species, One Planet, One Future". WED is the day to stimulate awareness of environmental issues and to encourage political and public actions.

Today is an important day because today is another voice to speak for the conservation of one of the most unlikeable if not misunderstood places on Earth. You will understand why because it is a place that few can walk without sinking deep into foul smelling mud, or rub on one's favorite sun-tan lotion without *Tabard* or OFF!. It is perhaps for this reason that one-third of the world's mangrove forests have been lost to development over the past 50 years. Yet, mangrove touches our lives and provides us in so many ways.

In the spirit and purpose of the International Year of Biodiversity, to raise awareness and increase understanding of the vital role that biodiversity plays in sustaining life on Earth, I shall take you through a story of one of the most enigmatic swamplands on our Earth.

1.1 What is a mangrove?

In term of semantics, the word mangrove dates back to the 17th Century from the Portuguese or Senegalese word "mangue", and might have been combined with the Arabic word 'el gurm' to give "mang-gurm", or with the English word "grove", to give its present form. The Spanish called it "manglar" while the French, "manglier". "Mangro" is used in Surinam. However, all these words are believed to have originated from the Malay word 'manggi-manggi' which is however no more in use, except in Indonesia where it is refers to a species of mangrove (*Avicennia*).

Botanically, true mangrove has been defined as any "tree, shrub or fern, of greater than 0.5 m height and lying above the mean sea level or the intertidal zone" (Duke, 1992). The true mangrove species, or those species found exclusively in saline and muddy environment, number 69 species, while the remaining called non-exclusive or mangrove associates, or those also found in other habitats, numbered 699 species (Duke, 1992). True mangrove plants are characterized by a number of distinctive features like their aerial root systems (e.g. pneumatophores, prop roots, cable roots, knee roots, etc), leaves that secrete salts, and seeds that germinate while still on the tree (called vivipary).

Ecologically, mangrove also refers to a type of riverine or coastal habitat which is more inclusive; it is represented by the abiotic environment containing the complex group of plant community as described above, the various fauna and other living organisms. My subsequent discussion will refer to mangroves in the ecological context.

1.2 Where are our mangroves?

Malaysia is well endowed with at least four of the world's most prominent estuarine and coastal ecosystems that include mangroves, tidal flats, coral reefs, kelp beds, salt marshes and seagrass meadows. Mangrove wetlands currently occupy a total area of 566,856 ha in Malaysia (Shaharuddin et al., 2005) or 3% of the world's mangroves of 18 million ha (Spalding et al., 1997), being largely (457,000 ha) located in East Malaysia (Figure 1). In various localities in Malaysia, combinations of mangroves and other coastal habitats provide intriguing examples of conjoint habitats, as for examples, mangroves and seagrass beds (e.g. Sg. Pulai in Johor; Salut-Mengkabong area in Sabah), mangroves and coral reefs (e.g. northeast Langkawi), and mangroves, seagrass beds and coral reefs (e.g. Pulau Banggi in Sabah).

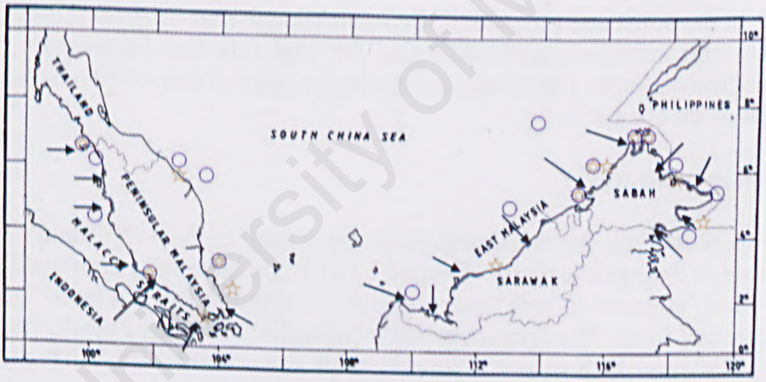


Figure 1. Mangrove and other major coastal habitats of Malaysia.

Mangrove forests (green) with examples of major forest reserves in Peninsular Malaysia - northeast Langkawi, Merbok, Matang, Klang, Sepang, Sg. Pulai and Sungai Johor; Sarawak – Samatan, Sg.Sarawak, Rajang, K.Sibuti; Sabah – Menumbok, Kudat & Marudu Bay, Sg. Sugut-Sg. Paitan, Trusan Kinabatangan , K. Segama & K. Maruap, Segarong & Semporna, Umas-Umas &Tawau (arrowed from left to right). Coral reefs (blue circle, from left to right): Peninsular Malaysia - Langkawi, Pulau Payar, Pulau Sembilan, Port Dickson, Pulau Tioman, Pulau Redang, Pulau Perhentian; Sarawak – Pulau Talang-Talang, Off Miri: Patinggi Ali & Dang Ajar Is.; Labuan; Sabah – Pulau Gaya, Layang-Layang, Kudat, Pulau Banggi, Linkabo, Tambisan, Sipadan. Seagrass beds (orange star, from left to right: Langkawi, Port Dickson, Sg. Pulai, Pulau Tinggi, K. Setiu; Sarawak - Bintulu; Labuan; Sabah - Pulau Gaya, Sg. Sugut- Sg. Mengkabong, Tg. Mengayau, Pulau Banggi, Sandakan, Semporna. (from Chong, 2007).

2.0 Conservation of mangroves – A fisheries perspective

2.1 The mangrove – fisheries connection

If you look at Figure 2 which shows the mangrove distribution in Southeast Asia as well as the main fishing (prawn) areas, you'll find that the main fishing grounds are very closely associated to the mangrove wetlands. Also very striking, is that the west coast of peninsular Malaysia has richer fishing grounds (515,866 tonnes fish; 35,947 tonnes prawns) as compared to its east coast (281,266 tonnes fish; 5,080 tonnes prawns), while mangroves respectively cover 90,041 ha and 7,739 ha of these coasts. We therefore ask are these coincidences by design, or is there a relationship between the occurrence of mangroves and productive fisheries?

For prawn fisheries, at least in several countries, namely, USA, Australia, Indonesia and Malaysia (Sasekumar & Chong, 1987; Baran & Hambrey, 1998), there is empirical evidence that the greater the mangrove area or coastline, the higher is the prawn catch (Figure 3). More recent analysis employing multivariate techniques (e.g. Chong & Ooi, 2001) and multiple regression analyses (e.g. Manson et al., 2005) further strengthen this contention of connectivity

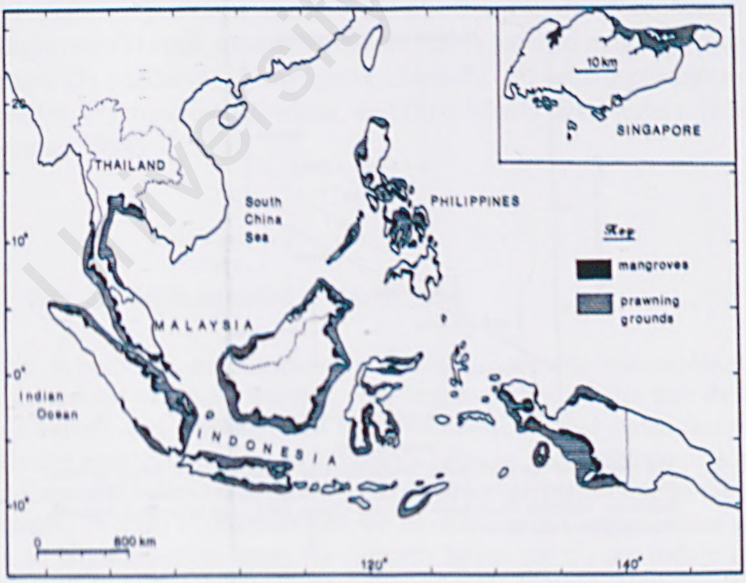


Figure 2. Major fishing grounds of prawns in relation to mangrove distribution in southeast Asia (from Chong et al. 1994).

The life-history of various fishes, prawns, crabs, etc. are strongly coupled to the mangrove habitat (Chong & Sasekumar, 1981; Chong & Sasekumar, 1994; see Figure 4). Many of these species are commercially important such as the sea perch (*siakap*), banana prawn (*udang putih*) and mangrove mud-crab (*ketam batu*). Our studies of the Matang mangroves (Perak) and Klang mangroves (Selangor) indicate that 50-70% of the fish and more than 95% of the prawn species caught commercially depend on mangroves during their young/juvenile stages (Chong, 1977; Chong et al., 1990; Sasekumar et al., 1992). Thus, the evidence of a mangrove-fisheries connection as based on biogeography, the quantified relationships and fish nursery habitat is compelling.

In the following, I would like to discuss why mangroves are so attractive to marine fishes and thus sustain the coastal fisheries.

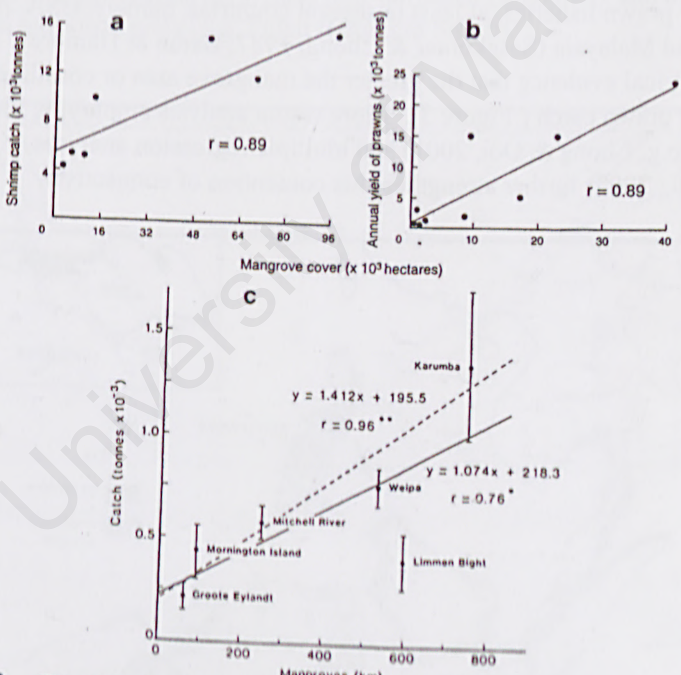


Figure 3 The relationship between prawn production and mangrove areal extent in three geographical regions; (a) Indonesia (from Martosubroto and Naamin, 1977); (b) Peninsular Malaysia (from Sasekumar and Chong, 1987); and (c) tropical Australia (from Staples et al., 1985).

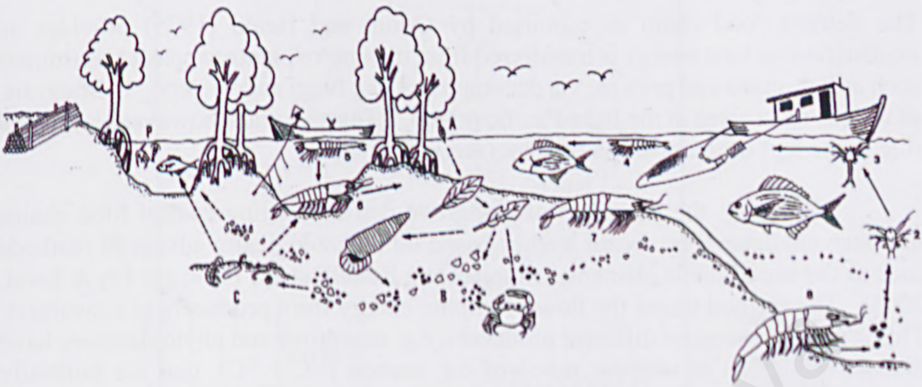


Figure 4. Composite picture of the ecology and benefits of mangroves (not drawn to scale). Mangrove leaf fall (A) contributes to a leaf litter which is broken down into fragments or consumed by macrofauna like crabs and snails. These fragments and the faeces (B) of macrofauna are further broken down by microorganisms like fungi and bacteria, or are consumed by prawns, fish, shellfish and very small benthic animals (C). These animals are themselves consumed by larger fish. Zooplankton (D) comprising of small fauna including the larvae of fish, prawns, crabs, etc. are also food sources for juvenile fish in the mangrove. The life cycle of an economically important species of prawn (udang putih) is illustrated showing its close association with mangroves; (1) eggs spawned offshore, (2-4) hatched nauplius, protozoeal to mysis stage, (5) postlarvae in mangrove channels, (6) settled postlarvae growing into juveniles, (7) maturing subadults, and (8) adults in deep waters. (from Chong & Sasekumar, 1994)

2.2 Why are fishes attracted to mangroves?

Two main hypotheses, not necessarily exclusive, provide the explanations why fishes are attracted to coastal habitats. The first hypothesis states that these habitats provide a variety and abundance of food, while the second states that young fish especially are protected from their predators because such habitats provide refugia space in terms of shallow and turbid water, and hiding places due to their complex root systems. A third hypothesis that we have advanced suggests that mangroves function as large retention areas for (prawn) larvae for a time before they are or ready to settle down in suitable coastal nursery areas (Chong, 1996).

2.2.1 Food supply

The detritus food chain as espoused by Odum and Heald (1975) provides an explanation on how energy is transferred from mangrove plants to coastal consumers such as fish, crabs and prawns, via decomposers like fungi and bacteria. In Malaysia, as well as most areas in the Indo-Pacific region, mangrove crabs however play a vital role in the leaf decomposition process (see Figure 4).

However, the paradigm of mangrove detritus fueling coastal food chains has been challenged by recent studies based on technologically advanced methods such as the use of stable elemental isotopes (e.g Rodelli et al., 1984; see Fry & Ewel, 2003). The method traces the flow of trophic energy from producers to consumers. This is possible because different producers, e.g. mangrove and phytoplankton, have distinctive signals of isotopic ratios of e.g. carbon (^{13}C / ^{12}C), that are faithfully reproduced in consumers at higher trophic levels without being biased due to isotopic fractionation after assimilation. Direct evidence of the incorporation of mangrove carbon into the tissues of prawns, crabs and fish residing inside the mangrove swamp have been obtained through studies based on the tissue ratios of stable isotopes (C,N,S) (e.g. Rodelli et al., 1984; Newell et al., 1995; Chong et al., 2001).

Rodelli et al. (1984) showed that juvenile banana prawns (*Penaeus merguiensis)* feeding in the Klang mangrove creeks derived on average 65% of their total carbon assimilated from mangrove plants, and the remainder from phytoplankton and benthic microalgae. Their results concur with the results obtained from stomach contents analysis (e.g. Chong & Sasekumar, 1981). On the other hand, Chong et al. (2001) found that prawns in the Matang mangrove creeks assimilated as much as 85% mangrove carbon, but this dependency decreases in the offshore direction, with more assimilation of carbon from phytoplankton and benthic microflora. Newell et al. (1995) showed shifts in tissue $\delta^{13}C$ ratios of migratory banana prawns, from -22.4 $^{o}/_{oo}$ to -15.16 $^{o}/_{oo}$ as they moved from mangrove creeks to offshore waters, suggesting that benthic microflora in coastal mudflats became more important to secondary production than mangrove detritus outside the swamp.

Our recent studies, both from stomach content and stable isotope analyses (see Figure 5), show that two main trophic pathways exist in large mangrove estuaries (e.g. Matang), one via the mangrove detritus food chain and the other, the phytoplankton food chain. In the water column, feeding of larval fish and prawn is at the phytoplankton pathway, but as they grow larger into juveniles their trophic energy is largely derived via the mangrove detritus pathway (Chong et al., 2003, Chew et al. 2006; Chong, 2007). The main food intermediaries for young fishes are zooplankton, the most important being copepods which comprised the largest zooplankton component (Chew & Chong, 2010; Then & Chong, 2010).

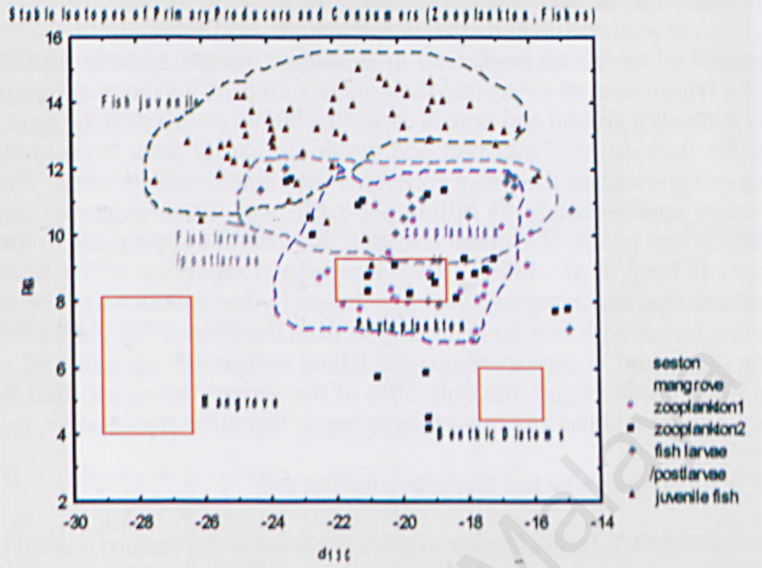


Figure 5. $\delta^{13}C$ and $\delta^{15}N$ values of producers and consumers in the Matang estuary, Matang Mangrove Forest Reserve, Perak, Malaysia. Arrow indicates shift from phytoplankton-based carbon (fish larvae) to mangrove carbon (juvenile fish). From Chong (2007b), data from Chew, Ooi and Then (*pers. comm.*).

2.2.2 Refuge function

Shallow water and habitat complexity as present in many coastal habitats are ideal nursery places for young fish and shrimps seeking refuge from predators so that they could quickly grow in a relatively safe environment. Banana prawns, being diurnal foragers, rely on turbid spring tide waters to avoid predation. In less turbid neap tide conditions they show a preference for shallow water at the fringes of mangrove forests. An interesting study of prawn ingress and distribution inside the Matang mangrove forest of different age stands (5, 17, 24 and >45 years), showed that prawns penetrated as far as 56m inside the forest during high tides, but all 10 species preferred older age stands with higher root structural complexity; the highest mean catch occurred in the 24-yr old forest (3.55 prawns/pot/hr) and the lowest (0.28 prawn/pot/hr) occurred in a clear felled area (Affendy & Chong, 2007). Prawn catch also increased with increasing distance from the river bank (i.e. more shallow water), and more prawns were caught amongst the mangrove prop roots than in the open spaces between trees. Vertical structure as exemplified by the mangrove roots appears important for shelter as also shown in other studies.

2.2.3 Larval retention

The process of larval accumulation in nearshore waters appears critical to the successful recruitment of larvae into their nursery areas. This requires recognition of the right spawning ground and time in order that larvae could catch the most suitable currents for their onshore transport and yet do not suffer from over-dispersal, i.e. by being swept away by the water currents to unsuitable nursery areas. The Klang Strait retains approximately 65 billion pre-settlement larvae of prawn annually, a phenomenon that results from tidal transport and lateral trapping due to the coastal mangroves (Chong et al., 1996). Two-dimensional modeling of the Klang Strait demonstrated that the mangrove swamps due to hydrodynamics had the ability to trap passing larvae with very little larval loss from the system (see animation demo). Based on the model, it appears that if the Klang mangroves are removed, not only will the Klang Strait silt up, but only 50% of the shrimp larvae will find their way close to the shore and the loss rate of these larvae thereafter may double.

2.3 Fish diversity and mangrove habitat use

That marine and even freshwater species are attracted to the various coastal habitats, usually at one point in their life cycle, is attested by the large diversity of fishes and invertebrates found in them (Table 1). These include (1) marine migrants from the sea that spawn in more saline offshore waters but their young migrate into estuarine waters to nurture or feed for varying periods (e.g. threadfins, carangids, stingrays, penaeid prawns); (2) anadromous species which spend time inside estuaries or coastal waters, but adults migrate upstream to spawn (eg. 'Terubuk' shads); (3) freshwater species that usually spawn in freshwater but move down into estuaries (e.g. poecilids, tilapias), sometimes to spawn (e.g. eleotrids, giant freshwater prawn); (4) estuarine species that can complete their life cycle inside the estuarine habitat (e.g. mudskippers, mullets, catfishes) (Blaber, 2000).

From the lists of fish species so far recorded from peninsular Malaysia's mangroves, a total of not less than 250 species are expected (see Table 1). In a recent review of the Malaysian fishes, the total number of mangrove fishes is put at 296 species (Chong et al., 2010). In the Matang mangroves, of the 122 fish species reported in waterways, 60% are marine migrants and 40% are estuarine species, while all 15 penaeid prawn species are marine migrants (Chong, 2005). Also, 87% of the fishes in Matang mangrove waterways and 83% in the adjacent coastal mudflats were juveniles (Sasekumar et al., 1994). The major marine migrant fish species of economic importance here include threadfins, trevallies, queenfish, grunters, snappers and groupers. Estuarine species of economic importance include most of the sciaenids, gizzard shads, catfish eels and gray mullets.

Most of the migrant fish species (>35 families) moved into the mangroves as postlarvae or early juveniles, while only 15 families were found inside the mangroves as fish larvae (Ooi et al., 2005). For instance, young mangrove snappers or *jenahak* of mostly 10-15 cm SL (young juveniles), continuously recruited into their mangrove nursery area, staying in for about a year, before they start to migrate back to the open sea at about 25cm SL (Then et al., 2006).

Table 1. Species richness of fishes, shrimps, crabs and stomatopods of selected coastal habitats in Malaysia. No. in parenthesis are unidentified species. Examples from other countries in region are given where there is lack of data.

* subtidal only.
(source: Chong , 2007a)

Type of coastal habitat	State/ Country	Fish	Shrimp	Crab*	Stomatopod	Authority
Mangrove	Malaysia	244(32)	25(3)			
N.E. Langkawi	Kedah	91	10	18(10)	3	Chong et al.(2005)
Merbok	Kedah	86(1)				Khoo (1989)
Matang	Perak	122	21(1)	9(7)	1	Chong (2004)
Klang	Selangor	114(4)	12(1)			Sasekumar et al. (1992)
Sg. Pulai	Johor	121(12)	13			Chong & Sasekumar (2002)
Sg. Johor	Johor	118(13)	19	13	2	Chong & Sasekumar (2002)
Mudflat	Malaysia	150	17			
Matang	Perak	85	17	11*	6#	Chong (2004); * Teh (2006); # Ng (pers. comm)
Klang	Selangor	132	16	19	5	Chong et al.(2005)
Seagrass beds	Phi/Thai/ Indon	172/67/301				Poovachiranon et al. (1994); Kiswara et al. (1994)
Cape Bolinao	Phillippines	103				Fortes (1994)
Calauag Bay	Phillippines	41				Fortes (1994)
Gulf of Thailand	Thailand	38				Sudara et al. (1992)
Burung Island	Indonesia	78				Hutomo & Martosewojo (1977)
Banten Bay	Indonesia		23			Kiswara et al. (1992)
K. Setiu	Malaysia	15				Rajuddin (1992)
Coral Reefs	Malaysia	>600				Cabanban et al. (2004)
Pulau Payar	Kedah	233				Yusuf and Ali (2002)
Pulau Singa	Kedah	180				Yusuf and Ali (2002)
Pulau Redang	Terengganu	209				Harborne et al. (2000)
Pulau Tioman	Pahang	233				Harborne et al. (2000)
Pulau Tinggi	Johor	219				Harborne et al. (2000)
Pulau Banggi	Sabah	228				Harding et al. (2000)
TAR National Park	Sabah	364				Allen (1992)
Sipadan Island	Sabah	409				Allen (1992)
Bodgaya Island	Sabah	528				Allen (1992)

Matang mangrove and its adjacent mudflats are the major nursery areas of penaeid prawns whose populations comprised of 70-90% and 40-90% juveniles respectively (Chong et al., 1994). Prawn postlarvae mainly of the genera Penaeus and Metapenaeus recruit into the Matang mangrove nursery areas throughout the year (Low et al., 1999), while Parapenaeopsis have their main nursery areas in the coastal mudflats with a few species (P. sculptilis and P. coromandelica) even breeding just off the coastal mudflat. Unlike the Matang mangrove, the Klang mangrove with a total of 114 fish species and 12 prawn species, appears to function more as feeding rather than nursery areas for fish, this being due to its small but abundant waterways (Chong et al., 1990). This view is further supported by the fact that half of the fish species present in mangroves were common to the 132 species recorded over the Klang mudflats and nearshore waters.

While about 50% of the commercially exploited fishes of Perak are likely mangrove-dependent (Sasekumar et al., 1994), the percentages were higher in Johor waters. 70% of the 130 fish species recorded from Sg. Johor mangrove and 64% of the 67 fish species from Sg. Pulai mangrove are commercially exploited in inshore waters (Chong & Sasekumar, 2002). For penaeid prawns, all are commercially exploited and are either dependent on mangroves or coastal mudflats as nursery habitats. One resident species of caridean prawn, Exopalaemon styliferus, has a seasonal nearshore fishery.

A total of 91 species of fish has been recorded from the north eastern coast of Langkawi Island, where mixed habitats of mangrove and coral/rocky reefs (near offshore islands) are found (Chong et al., 2005). Common mangrove fishes with reefal fishes such as sparids, labrids, haemulids and monacanthids are found inside the mangrove swamps. Apparently these species utilize the high salinity mangrove estuaries (21-34 ppt) as their living and feeding area. The Sg. Pulai estuary is yet another of such unique mixed habitats, in this case, mangroves with seagrass beds (Sasekumar et al., 1990). It may well be mentioned that the northeast Langkawi mangroves are unique, representing probably Malaysia's only Type VI mangrove setting (Thom, 1982) where the mangrove trees grow on sandy peat substrates trapped amongst limestone karsts.

I am not aware of any studies on habitat connectivity for fishes in Malaysia, for example, the role of each habitat in the life cycle of particular fish species. Nevertheless, an understanding of inter-habitat linkages, whether in terms of fish life cycles or the exchange of inorganic and organic materials, has important implication for joint management of these connected habitats.

3.0 What Cause Mangrove Loss?

Traditionally and commercially, mangroves are being used in many ways, whether directly, i.e. use of in-situ organisms or their products, or indirectly, i.e. any form of alienation of the habitat to various human uses, e.g. aquaculture (Table 2). The economic value of coastal habitats can be very substantial (see below). Here I would like to emphasis that not all uses are sustainable. Often such uses lead to over-exploitation of the resources within, or the wide-scale degradation or destruction of mangroves. Although anthropogenic impacts (Table 3) are of real concern but not unmanageable, damage and threats to mangroves and coastal habitats may also result from natural causes such as tropical storms, typhoons, volcanic activity, tsunamis and El Nino events. As can be seen from Table 3, the causes of mangrove degradation and loss are varied, but the main causes are due to agriculture, urbanization and aquaculture, and these threats appear consistently across the ASEAN region. In the 70s, forestry over-exploitation for woodchip and pulpwood production had however caused large scale extirpation of mangrove forests in East Malaysia (85,000 ha).

COASTAL HABITATS	DIRECT USES	INDIRECT USES
Mangroves	Fisheries products	Agriculture
	Fish, shrimps, crabs, molluscs,	Rice, coconut, oil palm
	jellyfishes	Aquaculture
	Forest products	Prawn/fishponds, fish cages,
	Poles, logs, thatchings, firewood,	mussel & cockle farming
	woodchips, charcoal, brown sugar,	Mining
	charcoal, brown sugar, herbal	Tin, bauxite, iron-sand, oil
	medicines.	Salt production
		Ports & harbours
		Urbanization
		Ecotourism
Coral reefs	Fisheries products	Aquaculture
	Fish, shrimps, sea cucumbers,	Fishpens/cages
	molluscs, turtles, seaweeds.	Seaweed farms
	Ornamental products	Coral and sand mining
	Live aquarium fish and invertebrates,	Ecotourism
	collector shell items of molluscs &	
	echinoderms	
	Medicinal products	
	Sea cucumbers (gamat), seahorses	
Seagrass beds	Fisheries products	Seaweed farms
	Fish, shrimps, crabs, molluscs,	Ports & harbours
	turtles	Urbanization
	Agriculture products	Ecotourism
	Composts, fodder	
	Others	
	Packing material, toys	

Table 2. The direct and indirect uses of mangrove and other coastal habitats (from Chong & Sasekumar, 2002).

Table 3. Causes of damage to three types of coastal habitats for six ASEAN countries (m= mangroves; s = seagrass beds; c= coral reefs; x = no clear information). (from Chong & Sasekumar, 2002)

Causes of Damage	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
Forestry (over-exploitation)	m	m			m	m
Illegal cutting	m	m	m		m	m
Agriculture	m	ms	s		ms	m
Fishing	sc	sc	sc	c	sc	sc
Aquarium/live/curio trade	c	c	c	c	c	c
Aquaculture	msc	mc	msc	m	msc	msc
Mining (sand,minerals and oil)	msc	sc	sc		msc	m
Salt pands/ponds	m	m	s		m	m
War (herbicide application)						m
Pollution *	msc	msc	sc	sc	msc	msc
Waste Disposal	mc	ms	s	m	m	m
Airports	s	m	s	s	s	x
Ports and harbours	s	ms	s	s	ms	msc
Boat traffic	ms	m	ms	s	ms	m
Dredging	c	sc	sc	sc	mc	x
Land reclamation	x	msc	x	ms	x	x
Industrialization	sc	ms	ms	ms	m	mc
Settlement/Urbanisation	msc	msc	msc	msc	msc	msc
Recreation/tourism	sc	sc	sc	sc	sc	c

4.0 Mangrove Loss: What Impacts on Fisheries?

4.1 Shrinking mangroves and falling catches

Arguments for the conservation of mangrove forests have largely rest on the premise (of food security) that these ecosystems provide the nursery, feeding or spawning areas for marine fishes, and therefore sustain coastal fisheries (Farnsworth & Ellison, 1997; Chong, 2007). While the quantified relationship essentially predicts that the more mangroves you have the more prawns you'll get, by the same token, the more mangroves you destroy the less prawns you'll get. Is there evidence of this?

Let us look at the former first. There is evidence of 16% loss of mangrove area in Malaysia from 1973 to 2000 or 111,046 hectares as reported by Chong & Sasekumar (2002). A more restrictive area such as the west coast of Peninsular Malaysia lost 24,518 hectares or 23% (1980-2004). At the state level, losses could be much higher, for e.g. four states had lost more than 30% of their mangroves, but up to 85%! (Table 4). Now, let us look at our prawn catch and we pick our west coast again. Figure 5 shows the west coast landings of penaeid prawns and Acetes shrimps (udang baring) over the last 30 years. The analysis shows that the catches of both types of shrimps increased steadily during the early years and appeared to have reached their potential yield by the late 80s. For prawns, the annual potential yield may be 60,000 tonnes. However, the post 90s prawn yields consistently fell below this level reaching 65% of its potential yield by 2003. Similarly, Acetes (or belacan) shrimps catch fell by 50%. This had occurred despite the small change in fishing effort (-4% for trawl units or -15% for total boats) and yet there is no evidence of a shift to greater boat efficiency or larger boats that would suggest severe overfishing. Boats of <10 GRT, 10- <20 GRT, and 20- <40 GRT that normally operated in coastal waters had actually decreased in numbers by 53%, 20.6% and 2.2% respectively, from 1982-2003. Thus there is evidence of a concomitant fall in both mangrove forest area and shrimp catch. The question is: Is there a causal effect? If not, what other factor(s) could have caused such a drastic decline in shrimp catch?

I shall consider the possibilities – over-fishing, pollution and habitat loss/ degradation. As I had stated before, severe overfishing is not likely since fishing effort had in fact decreased slightly at the same time. If excessive overfishing is the main cause, finfish catches should fall too - but this is not so (Figure 6). This is interesting because strong correlations between fish catches and mangrove area have never really been established suggesting other coastal habitats may be equally or more important (see Robertson and Duke, 1987; Blaber, 2006). As for pollution, there has been no evidence of its deleterious effect on shrimp or fish in open waters although the Malacca Straits waters are being increasingly marred by land-based pollution. Localized organic pollution of bays and coastal waters as by agricultural effluents in the early 70s had ceased when the EQA came into effect, and most coastal waters are currently slightly polluted with a water quality index of 60-80. The concentrations of the principal pollutants in Klang Strait from 1995-1996 were within the proposed marine interim standards. Therefore, the loss of mangrove forests is likely the main reason why we are catching less prawns and not more fishes.

Table 4. Area (ha) change and percentage loss/gain of mangrove forest reserves by state (1980-2004). Sources: 1) Chan et al. (1993); 2 = Shaharuddin et al. (2004).

Region	State	Stateland Forests[2]	Forest Reserve 1980[1]	1990[1]	2004[2]	+/-%	No. of Gazetted Reserves[1]
Peninsular Malaysia	Perlis	13	0	0	0	0	0
	Kedah	0	9,037	8,034	8,118	-10.2	11
	Penang	494	406	406	279	-31.3	1
	Perak	1885	40,869	40,869	41,617	1.8	21
	Selangor	4650	28,243	21,983	14,897	-47.3	15
	N.Sembilan	0	1,352	1,061	204	-84.9	3
	Melaka	0	77	314	80	-3.9	2
	Johor	3348	25,619	16,697	17,185	-32.9	10
	Pahang	1850	2,496	2,032	2,416	-3.2	11
	Terengganu	692	2,982	954	1,295	-56.6	1
	Kelantan	744	0	0	0	0	0
East Malaysia	Sarawak	93,200	44,491	36,992	33,200	-25.4	11
	Sabah	23,266	349,773	316,460	317,423	-9.2	26
	Labuan	0	0	0	0	0	0
	Total	130,142	505,345	445,802	436,714	-13.6	112

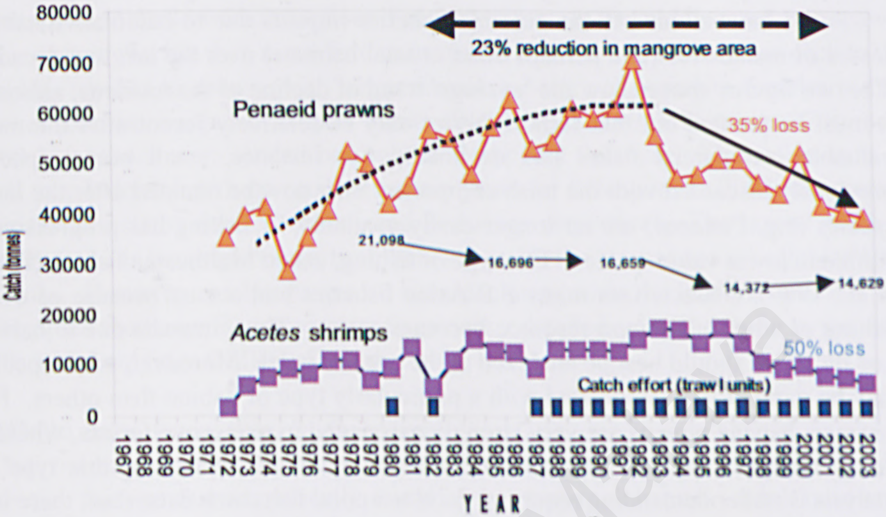
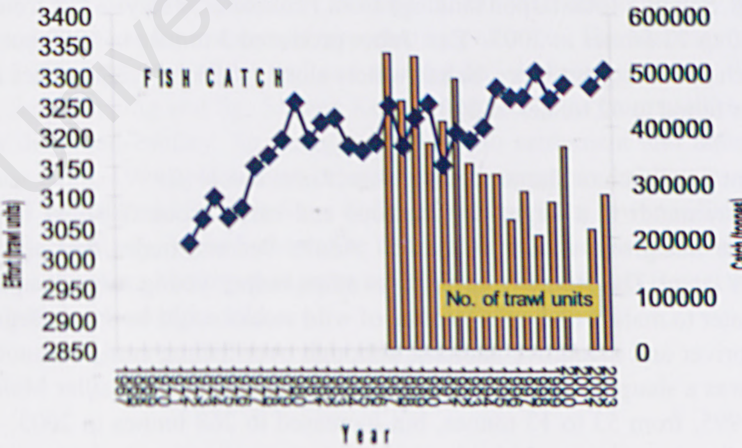


Figure 5. Shrimp catches (penaeids and *Acetes*) from the west coast of peninsular Malaysia, from 1972-2003. Vertical bars indicate number of trawl units while numerals indicate total number of licensed boats (from Chong, 2007).



4.2 Threatened species

I have alluded to the possible fisheries impacts due to cumulative habitat losses of mangroves (and perhaps other coastal habitats) over the last two decades. The two figures above show the 'average' trend of decline of the resource, although it must be pointed out that some fisheries may be relatively recent after the more valuable commercial fishes had declined. For instance, small prawn species previously discarded with the trash component may now be retained after the large species (e.g. *Penaeus*) are no longer easily available, or fishing has progressively shifted to lower value species. This type of fishing, called Malthusian fishing (Pauly et al., 1989), characterizes many S.E Asian fisheries and occurs because of over-fishing or when a common resource becomes scarce. Thus, impacts due to habitat loss on fishes should best be analyzed at the species level. Moreover, some species may be more closely associated with a particularly type of habitat than others. For instance, banana prawns are very strongly associated to mangrove forests, whereas *Parapenaeopsis* spp. are associated to coastal mudflats. However, this type of analysis is rather demanding requiring good temporal fish catch data; thus, there is a dearth of such studies. I shall discuss here some selected species of concern.

a) Indo-Pacific Tarpon, *bulan-bulan*, *Megalops cyprinoides*
The Indo-Pacific tarpon is an estuarine mangrove and coastal fish, often migrating into freshwaters. Adults mate in schools in open marine waters, producing pelagic eggs and leptocephalid larvae. The decline of wild stocks could be due to degradation of estuarine and especially upstream freshwater habitats. This species may require undisturbed and clean habitats; I had observed large schools of tarpons in Pulau Banggi, Sabah. Total tarpon landings from Peninsular Malaysia fell from 53 tonnes in 1980 to 13 tonnes in 2003. East Johor produced 5 tonnes in 1980 but there were no catch in subsequent years. Sabah waters alone produced 1,229 tonnes in 1995 but catches felled to 42 tonnes in 2003.

b) Giant Sea Perch or Barramundi, *siakap*, *Lates calcarifer*
The barramundi is a large, catadromous and carnivorous fish that migrates into estuarine mangrove waters to spawn. Adults become males first and change to females later. The larvae develop in swamps before young migrate upstream into freshwater to mature (3-5 yr). Decline of wild stocks could be due to degradation of both upriver and mangrove habitats, although over-fishing could be another factor. There was a sharp decline in wild caught barramundi for Peninsular Malaysia from 1980-1995, from 53 to 13 tonnes, but increased to 268 tonnes in 2003. However, the recent resurgence could be due to introduction of escaped or released fish from aquaculture.

c) Tropical Shad, *terubuk*, *Tenualosa toli*

The tropical shad is a also protandrous hermaphrodite that lives in large turbid estuaries and shallow coastal waters. Females migrate to the middle reaches to spawn. The ensuing larvae then move further upstream to grow into males, then back to the middle reaches to spawn (with larger females), before changing to females at the lower reaches or adjacent coastal waters (Blaber et al., 1996). In the mid 70s about 200-300 tonnes were landed but only in Perak and Selangor. Thereafter, catches fell tremendously with no catch in certain years for Selangor. In 2003, the catches for the two states were 51 tonnes and 24 tonnes respectively. The largest catch of terubuk shads however comes from Sarawak, with the current annual catch of 1000 tonnes. However, catches have also been declining since the late 70s, and this had prompted the Sarawak government to initiate a detailed scientific study in the early 90s with help from CSIRO, Australia.

d) Mud crabs, *ketam batu*, *Scylla* species.

One common species is *Scylla serrata*, but there are at least 3 similar looking species that are characteristically found in the mangrove habitat. Adult mud crabs are believed to mature and spawn in marine waters, the young develop as plankton but settle and bury in mangrove muds as juveniles. They are highly sought after as seafood and for grow-out in ponds, and as a result are subject to increasing fishing pressure. Over-fishing and mangrove degradation appear to have a detrimental effect on body size and abundance.

4.3 Nursery ground value of mangrove varies and changes with time

The nursery value or carrying capacity of a coastal habitat itself could vary spatially, or change over time as for instance, if impacted by pollution. The Matang mangrove forests in 1992 supported 40 kg ha^{-1} and 47.6 kg ha^{-1} of fish in two less disturbed estuaries, Sg. Selinsing and Sg. Sangga Kecil respectively, as compared to 23.3 kg ha^{-1} for a disturbed estuary, Sg. Sangga Besar, with settlement and aquaculture) (Sasekumar et al., 1994). However, other disturbed mangrove habitats as found in Klang (17.7 kg ha^{-1}) and Sg. Dindings (9.3 kg ha^{-1}) had even lower values (Chong et al., 1990). Similarly, Table 5 shows the changes in prawn densities over a period of 6 years in the same Matang mangrove estuaries. In Sg. Sangga Besar, the prawn densities had declined eight-fold.

Table 5. Comparison of prawn densities (No.ha^{-1}) in two mangrove estuaries in Matang Mangrove Forest Reserve, sampled after a lapse of 6 years (from Chong, 2006).

	Chong et al. (1994)			Low et al. (1999)	
Year	**1990-93**			**1996-97**	
Site	Selinsing	Sangga Besar	Sangga Kecil	Selinsing	Sangga Besar
Mean	4,315	4,677	3,435	1,758	593
SD	7,202	8,663	4,092	1,292	391
Max	7,788	34,082	16,465	4,474	1,372
Min	495	292	334	271	62

4.4 Economic valuation of mangroves: Contribution to fisheries

A total economic valuation study of mangrove and various coastal habitats on the west coast of peninsular Malaysia gave net benefits accruing to market and non-market values that amounted to RM4 billion annually, of which RM386 million came from fisheries that benefited from the presence of various coastal habitats (Table 6). The percentage breakdown of habitat contribution to fisheries in the Malacca Straits are mangroves (45.6%), mudflats (18.0%), coral reefs (1.3%), seagrass beds (0.5%) and seaweed beds (0.4%), with the remaining (33.2%) from outside the coastal ecosystems. Hence, the loss of mangroves will result in the loss of these economic values.

Table 6. Gross and net revenues from fisheries and aquaculture as contributed by coastal habitats in the west coast of Peninsular Malaysia.
Value in USD = RM2.50 (based on Sasekumar et al., 1999).

Habitat	Area (ha)	Gross	Net	Net value per ha	% Contribution
Mangroves	83,259	352,544,077	70,452,989	846	45.6
Mudflats	32,364	49,417,104	27,868,925	861	18.0
Coral Reefs	1,318	10,210,570	2,014,545	1,528	1.3
Seagrass Beds	456	*3,669,064	*723,906	1,588	0.5
Seaweeds Beds	1,421	2,875,737	567,383	399	0.4
From Habitats	118,818	415,047,488	100,903,842		65.3
From outside habitats		271,292,537	53,526,018		34.7
Fisheries		686,340,025	154,429,860		
Aquaculture		97,852,203	38,973,538		

* modified to exclude offshore catches

5. Conservation of mangroves vis-à-vis fisheries

5.1 Forestry legislation and policy

The following national Policies, Acts and Enactments govern, regulate or influence the management of all forests in Malaysia:

1) National Forestry Policy 1978 (revised 1992) (NFP). Aims to ensure that forestry resources are sustainably utilized and managed in an orderly manner, so as to maximize benefits to the people; to create sufficient forest areas called Permanent Forest Estates (PFE) which includes protective forests, productive forests and amenity forests, which will be managed according to sound forest management practices so as to maximize the social, economic and environmental benefits; to ensure that non-PFEs are efficiently utilized for the local industry through wise planning.
2) State Forest Enactments, Rules or Ordinances. Varied for different States.
3) National Forestry Act 1984 (amended 1993). Instituted to ensure that all States prepare and implement proper forestry management plans. In Sabah and Sarawak, forestry activities are regulated separately by several State enactments or ordinances, including protection of national parks and wildlife in the latter case.
4) Land Conservation Act 1960
5) Wildlife Act 1972
6) Environmental Quality Act 1974 (Amended 1985)
7) National Park Act 1980
8) Wood-based Industries Enactment 1985
9) Fisheries Act 1985
10) National Biodiversity Policy 1998
11) National Environmental Policy 2003

Mangrove forests like all other forests come under the jurisdiction of the respective State Governments. Each state is empowered to enact their own forestry laws and to formulate forestry policies independently. The executive authority of the Federal Government (under Ministry of Primary Industries) only extends to the administration of matters relating to research and development, education and training, forestry-based industries development and provision of advice and technical assistance. The National Forestry Council helps to resolve State and Federal matters concerning management.

The NFP was revised in 1992 to improve federal and state levels coordination, increase awareness of biodiversity conservation and sustainable management, and seeks to create sufficient PFE to support rational land use. It also requires all the State Forestry Departments to re-classified their PFEs into one or more of the eleven functional classes.

5.2 Mangrove production and management practices

The best managed mangrove forests on a sustainable basis occurred in the Matang Mangrove Forest Reserve of the state of Perak. It has been systematically managed on a sustained basis for fuelwood and poles since 1908. The silviculture system was initially based on a rotation age varying from 20 to 40 years, with a fixed number of seed trees maintained in the logged-over areas for regeneration. Since 1950 this system was changed to a fixed rotation age of 30 years at the end of which all trees were cleared cut without retention of seed plants. Ten-year working plans were prepared and followed successively. Retention of seed plants was however reintroduced after the first rotation cycle in 1979, but the method was again dropped under after 1990, and clear felling was reintroduced. Matang's Working Plan for mangrove utilization and management has the main objective to maximize production of greenwood for pole and charcoal wood production both for sustained local consumption and export. In maintaining the mangrove forests for this purpose the plan also has the objectives to protect the shoreline from erosion; to protect and conserve the forests as functioning nursery areas and wildlife habitats; to provide forest areas for conservation, research, education and training; and to promote sustainable ecotourism.

In the state of Selangor, mangroves in the Klang Islands are managed solely for economic profits from the production of piling poles, charcoal, woodchips and fishing stakes, and for this reason the bakau (*Rhizophora*) forests are preferred for regeneration (Soo, 1979). There is no proper working plan as for the Matang mangroves, but since 1957 the rotation based on a clear-felling system has been fixed at 25 years. The system does not practice intermediate thinnings and enumeration of stand volume of wood, but there is replanting of blank areas with *Rhizophora* seedlings usually 2 years after felling. Wood production under the system is however low.

The state of Sarawak also has an interesting history of mangrove management that dates back to 1915 when the Sarawak Forest Department was first established and three large tracts of mangrove forests were reserved in the First, Fifth and Sixth Divisions (Chai and Lai, 1984). Mangroves were then also managed for firewood, charcoal and poles, including tannin and nipah sugar production for domestic consumption. Ten-year working plans based on a 15-year (for charcoal) and 20-

year (firewood) cycles were only established since 1953, with the main objectives of orderly exploit and produce mangrove timber to satisfy local demand as well as export, and to ensure regeneration (natural and artificial) and conservation. From 1969 woodchip demand for the pulp and rayon industry in Japan caused large scale exploitation that reached 300,000 tonnes or 20% of the total production in 1976, while demand for fuel wood decreased and licenses to produce it instead converted to woodchip production (Chai and Lai, 1984).

As far as mangrove management in the state of Sabah is concerned, there was no working plan of any sort in the past and in the present. Timber exploitation for charcoal and firewood and its management appears very *ad hoc* with the result that excessive logging and woodcutting had occurred in some forest reserves in the past and which were considered worse off than unmanaged stateland forests (Phillips, 1984). Sabah (as well Sarawak) uses a simple system of clear felling small patches, with retention of seed trees. The state's woodchip industry consumed an estimated 70,000 ha of mangroves over 15 years since 1970 (Chan et al., 1993). Despite an ill-defined management system, Sabah has the highest number of gazetted conservation areas of mangroves.

Pulpwood production in Sarawak and Sabah was unsustainable and subsequently phased out in 1986, being considered wasteful due to extensive debarking and highly destructive to mangroves,

5.3 Reservation and Conservation Issues

5.3.1 Competing jurisdiction and management conflicts

Of the total mangrove forest area, 70% has been gazetted as forest reserves or PFE and the rest are stateland forests (see Table 4). The mangrove forest reserves fall under the country's PFE which are managed mainly for sustainable production of fuel wood, poles and charcoal. There are a total of 112 mangrove forest reserves, of which 75 reserves are located in peninsular Malaysia, 26 reserves in Sabah and 11 reserves in Sarawak (Chan et al., 1993). Recent gazettement of mangrove forests includes the Tanjung Piai mangroves (526 ha) as part of the recently declared Tanjung Piai National Park in Johor, but degazettement includes reserves in Langkawi as well as the Pendas River mangroves in Johor. Stateland forests occur outside forest reserves and are not managed for sustained timber production. These forests are subject to pressures of alienation and conversion for development purposes.

As much as the Federal government wants to see more mangrove forests being assigned as PFE by State Governments, it has no jurisdiction over land matters. Few States would readily give up valuable state lands for conservation purposes without economic returns or revenue that are needed for state development. Indeed, faced with pressures to develop, States often alienate mangrove forest lands, including reserves, for developmental purposes. For instance, degazettement of PFE in Peninsular Malaysia, has seen losses of about 17% from 1980 to 1990, and 4% from 1990 to 2000 (see Table 4). Such are the cases of management conflicts between Federal and State interests, and one obvious result from this is the glaringly, non-uniform or unequally managed mangroves as observed in the different states.

5.3.2 Sectoral-based management

Mangroves is not just a single-commodity resource, it is an ecological resource. It is a habitat for many marine animals and terrestrial wildlife whose well-being hinges on its ecosystem functioning. Although the socioeconomic benefits gained by coastal communities through sustained forestry production are substantial, these direct benefits are in fact much lower in comparison to the indirect benefits provided by fisheries (Salleh and Chan, 1987; Sasekumar et al., 1998). Because fisheries management is under the purview of the Department of Fisheries, any successful policy to protect, manage or enhance juvenile fish stocks in mangrove habitats is dependent upon the Forestry Department to protect these habitats. Nonetheless, neither agencies are responsible for the health of the swamp's waters since management and enforcement of water quality standards is under the Department of Environment. Often the sectoral division of management responsibilities does not add up to effective management of the mangrove ecosystem (Figure 7). Clearly, an integrated coastal resources management plan is needed which should be implemented in sensitive, resources-rich, multiple-use coastal zones.

5.3.3 Threat from aquaculture development

The New Agriculture Policy (1991-2010) or NAP which superceded the previous National Agriculture Policy 1984, targets further expansion of the aquaculture sector for the future. To achieve the goals of the NAP, the Fisheries Department has formulated the Aquaculture Development Action Plan (ADAP) which identifies the major thrust areas for expansion, Suitable areas for aquaculture development called "Aquaculture Development Areas" (ADA) are identified, zoned or demarcated, and presented to state authorities for land alienation. The NAP projects that brackish water aquaculture will use about 20,000 ha of land/water space to fulfill its targetted production of 400,000 tonnes. Although the Fisheries Department has identified some 20,000 ha of aquaculture development areas, mostly former mangrove land that could not be gainfully farmed, resistance from farm owners to part with their land is rather unexpected as in Kerpan, Kedah. If such lands are unavailable, new land including mangroves may be alienated.

With respect to mangrove clearing for aquaculture, an important regulatory and legal instrument is environmental impact assessment (EIA). The EIA Guidelines 1995 use a set of criteria for evaluating various environmental impacts. Mangrove clearing of more than 50 ha requires an EIA under Section 34A of the Environmental Quality Act. In spite of this, there are legal loop-holes as ponds could still be dug in stages to avoid contravening the EQA (see Choo, 1996).

5.3.4 Mangrove (and other habitats) protection for sustaining fisheries

Coastal and estuarine habitat conservation has now become a fishery management objective in several fisheries of the world. For instance, in the USA amendments to the Magnuson-Stevens Fishery Conservation and Management Act as a result of the Sustainable Fisheries Act (1996), require fisheries managers to not only identify Essential Fish Habitats (ESH) to minimize the adverse fishing effects on such habitats but also to identify actions to encourage the conservation and enhancement of such habitats (Duval et al., 2004). Among the high-value ESH are the Habitat Areas of Particular Concern (HAPC) which are designated to protect rare, sensitive and ecologically important areas from large-scale coastal developments. The mandate to designate ESH thus formalizes the need to link coastal land management with fishery management. Another example is the Oslo-Paris Commission (OSPAR) set up to provide an international regulatory framework for human impacts in the Northeast Atlantic, which includes management measures to ensure the Convention of Biological Biodiversity goals are met. OSPAR is in the process of identifying habitats deemed sensitive to human impacts including fishing (Frid et al., 2006).

Our studies have shown that mangroves, seagrass beds and corals may be connected in terms of habitat usage by fishes to complete their life cycle, and exchange of materials. This is one area of habitat conservation and fishery management that needs to be further researched on because of habitat connectivity and interdependency, and the possible disruption of such linkages due to anthropogenic impacts. Similarly, the required size of mangroves and other adjacent habitats (e.g. seagrass beds) in relation to species conservation and fishery benefits are still unknown or little studied.

5.3.5 Multispecies and ecosystem-based management

Fisheries management in the future will not just be for maximizing fish yield but also for the purpose of maintaining a healthy ecosystem. Species and habitat conservation will become important objectives in fishery management because of public and scientific concern over the wider effects of fishing. Killing of non-target species (e.g. dolphins, sea turtles and seabirds) and habitat destruction have been attributed to fishing (Blaber et al., 2000). In fact fishing has often been viewed as a threat to the environment, and this has resulted in a number of international treaties to identify the environmental impacts. Some species of fish, marine mammals, seabirds and invertebrates have been identified as endangered by fishing, and the protection of such species has become a primary management purpose due to public concern. A recent paper has however identified habitat modification as the topmost factor threatening the freshwater, estuarine and marine fishes of Malaysia (Chong et al., 2010), and its effects may have exacerbated the impacts of overfishing.

So what do all these mean? It means that fisheries and coastal resources managers need to have greater scientific understanding of the complex interactions among species as well as between species and their environment. In a few cases, a good understanding of interactions of species has even allowed manipulations to enhance fisheries yield. For instance, mangrove rehabilitations in Java have been shown to increase the coastal prawn yields. Based on our present findings, another interesting question is can one increase the mangrove forest: creek interface (border) to increase fish abundance? Overall, our current understanding of the complex interactions among marine species and environment is still poor, and even in developed countries, studies pertaining to these are lacking. Therefore, more research is warranted here.

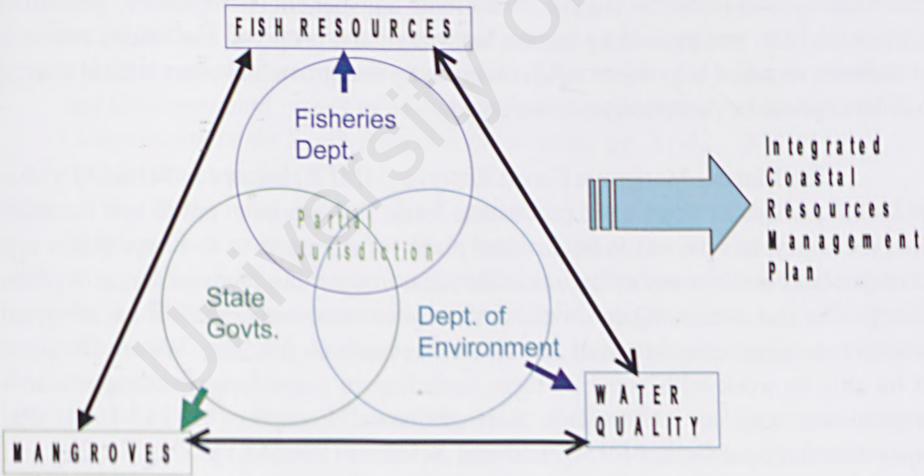


Figure 7. Sectoral-based management of marine resources (fish, mangrove and water) by various governmental agencies has resulted in partial jurisdiction and sub-optimal management of fisheries resources. Outer long arrows show interactions between coastal resources; inner short arrows indicate agency's responsibility. Thick arrow shows the need for an integrated coastal resources management plan. (from Chong, 2007)

6.0 Concluding Remarks

Mangroves are unique irreplaceable ecosystems that play an important role in sustaining coastal productivity. There is strong connection between fisheries production and mangrove wetlands. Food and refuge space are the main reasons why fishes are attracted to mangroves which thus function as nursery, feeding or spawning areas. Unfortunately, both mangroves and fisheries are being depleted despite efforts to manage them independently. The loss or degradation of mangroves (and other coastal habitats) may be a major reason for stagnating or declining fish/ prawn yields. Fishery management in the future will need to consider protection of Essential Fish Habitats, as well as the effects of fishing on ecosystem health.

The prevailing trends of coastal resources exploitation and development, and their multiple-use conflict, have highlighted the need for holistic ecosystem-based management. What it ultimately means is that fisheries and coastal resource managers must acquire greater scientific understanding of the complex interactions among species as well as between species and their environment. As marine scientists, we have the daunting task to provide clear, unequivocal evidence of the role played by mangroves in sustaining the vital coastal ecological processes, maintaining a continuous supply of seafood and beneficial materials, absorbing carbon dioxide, and protecting human settlement and property. Innovative research is urgently required to provide solid reasons why mangrove and other critical coastal habitats should be protected and conserved.

The Matang Mangrove Forest Reserve (MMFR) located in Perak, by virtue of its uniqueness as a managed production forest that has been put to test for more than a century, has proven to be an ideal place for scientists to test hypotheses and to understand better many of the scientific ideas concerning biodiversity, ecosystem functioning and sustainability. I believe this is one reason why MMFR has attracted so many eminent scientists from afar as well as research funding. We are fortunate to be able to work with some of them including in some long standing research programmes such as AUS-AID's "Living Coastal Resources" (1987-1994) and Japan International Center for Agricultural Sciences (JIRCAS)'s "Productivity and Sustainable Utilization of Brackish Water Mangrove Ecosystems" (1996-2011). Nonetheless, MOSTI and UM's generous support in both research funding and facilities have been crucial to the success of our studies.

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(please refer to Prof. Chong's CV for others)

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Rodelli M.R., Gearing J.N., Gearing P.J., Marshall N. and Sasekumar A. (1984). Stable isotope ratio as trace of mangrove carbon in Malaysian ecosystems. Oecologia 61: 326-333.

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Soo, N.P. (1979). Management and harvesting of Klang Mangrove Forests, p. 85-

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Then, A.Y.H and Chong V.C. (2010). Food resource utilization and trophic guild structure of a juvenile-dominated fish community in a tropical estuarine mangrove habitat. Estuarine Coastal Shelf Science (MS submitted).

Thom, B.G. (1982). Mangrove ecology: a geomorphological perspective. In B.F. Clough (ed.), Mangrove ecosystem s in Australia, structure, function and management, pp. 3-17. ANU Press, Canberra.

Curriculum Vitae of Dr. Chong Ving Ching

PERSONAL PARTICULARS

- Date of Birth: 12 October 1952
- Country and Place of Birth: Malaysia, Alor Star.
- Marital status: Married, 3 children
- Degrees: B.Sc (Hons.) Zoology (*Malaya*), 1977; MSc, 1984 (*Malaya*); PhD, 1994 (*Malaya*)
- Employment record in UM: Career tutor (1977-1988), Lecturer (1989-1999); Assoc. Professor (1999-2003); Full Professor (2004- present).
- Present administrative positions:
    - Unit Head, Marine Living Resources, Biotechnology and Ecosystems Studies, Institute of Ocean and Earth Sciences (IOES), University of Malaya
    - Coordinator, Division of Ecology and Biodiversity, Institute of Biological Sciences, University of Malaya,
- Telephone Nos: 603-77291379 (Home); 603-79674220 (Office); 79674609 (Lab); Fax no: 603-79674178

CURRENT RESEARCH INTERESTS

- Coastal habitats and fisheries ecology
- Biofouling (cage fish nets, mangrove seedlings)
- Aquaculture: Feed enrichment for hatchery culture of fish; bioremediation of aquaculture effluents

MAJOR RESEARCH AWARDS

- Study on the biology, ecology and management of commercially-important fish species in mangrove estuaries and related coastal waters of Malaysia, (Japan International Center for Agricultural Sciences, JIRCAS, 2006-2011)
- Effects and control of biofouling on mangrove seedlings (FRIM – RMK-9 Project, 2008-2010).
- Bioremediation of mariculture effluents using indigenous microbial organisms (National Oceanographic Directorate, 2008-2010)
- Ecology and management of mud lobsters in Carey Island (UM- Golden Hope Biodiversity of Heritage Island Research Projects) 2005-2010
- Linking marine biotopes: Fish diversity-seascape mosaics interrelationships, trophodynamics and life-cycle dependencies. UMRG grant, 2009-2011
- Quantifying nursery value of mangroves for fisheries: A multi-criteria approach, (R&D, 2006-2008).
- Enrichment of live zooplankton feed for aquaculture (FS271/2007C, 2007-8)

- Floristic and faunistic studies of northeast Langkawi (PFF award) 2004-2005; 2006 (continuation)
- Sustainable production systems of aquatic animals in brackish water mangrove areas (Japan International Center for Agricultural Sciences, JIRCAS, 2001-2005)
- Environmental effects of cage culture in mangrove waters (R &D award, 1999-2002).
- Containment and mortality risks of larval fish and prawn in mangrove waters (R&D award, 2002- 2004).
- Productivity and sustainable utilization of brackishwater mangrove ecosystems (JIRCAS, 1995-1999).
- Effects of mangrove species diversity and ecosystem function in the west coast of peninsular Malaysia. Collaborative research with University of York. 1997-1998.
- Production of Indigenous Microbial Feed for Aquaculture (R & D award, in collaboration with leader, S. Vickineswary, 1996-2002)
- Ecology of the Klang Straits (R & D award, 08-02-03-0249, 1996-1998)
- Contribution of mangrove detritus to the production of commercially-important shrimp species. (USAID award, in collaboration with University of Maryland, 1989-1991)
- ASEAN-AUSTRALIA Cooperative Program on Marine Science - Living Resources in Coastal Areas (Phases I & II). (Australian International Development Assistance Bureau (AIDAB) award, in collaboration with leader, A. Sasekumar, 1987-1994).

STUDENTS SUPERVISION

- Had successfully supervised 4 PhD and 16 Master's students,
- Currently supervising 9 PhD and 7 Master's students.

HONOURS AND AWARDS

- Excellent Service Award, University of Malaya (1999, 2007)
- Excellent Service Certificate, University of Malaya (2008)
- Gold Medal: "Rhodobac: For Healthy Fish and Prawns and a Clean Environment" (Leader: Prof. Vikineswary, S.) in "The 33rd International Exhibition of Inventions, New Techniques and Products 2005", Geneva.
- Excellent Scientists Award 2005, awarded by Ministry of Higher Education, in recognition of gold medal award in Invention Exhibition in Geneva.

MAJOR CONSULTANCIES

Major consultancy works for international and local/govt agencies, as fisheries and aquaculture consultant for:

- "Kuala Perlis Dredging Project" (Marine Department) (2006/7)
- "Shoreline Management Plan for Pahang" (DID) (2001)
- "Integrated Management Plan for Sustainable Use of Johor Mangrove Forests (Johor Forestry Dept/DANCED) (1998)
- "Malacca Straits Demonstration: Coastal Resource Mapping and GIS" (GEF/UNDP/IMO) (1997-1998)
- "Lekir Coastal Development Plan" (Perak SEDC) (1996-1997)
- "Environmental Sensitivity Index Mapping of Coastlines (ESSO) (1994)
- "Site Selection and Identification of Power Stations" (TNB) (1991).

PUBLICATIONS

- Edited Books

1. Chong, V.C., Sasekumar, A., Phang, S.M. & Jaafar, M.N. (1998). *Marine and coastal resource mapping for the Straits of Malacca.* GEF/UNDP/IMO Regional Programme for Prevention and Management of Marine Pollution in the East Asian Seas. Malacca Straits Demonstration Project Report.
2. Chong VC & Choo PS. (1999). Productivity and Sustainable Utilization of Brackish Water Mangrove Ecosystems", JIRCAS and University of Malaya.
3. Chong, V.C. (1999). *Mangrove Fisheries of the Sungai Johor Estuarine System.* Preparation of an Integrated Management Plan for Sustainable Use of the Johor Mangrove Forests. Project Document No. 8, Forestry Department Peninsular Malaysia, Danish Cooperation for Environment and Development and Johor State Government.
4. Phang SM, Chong VC, Ho SC, Noraieni Mokhtar & Jillian Ooi LS (2004). Marine Science into the New Millenium: New Perspectives and Challenges, University of Malaya Maritime Research Centre, Kuala Lumpur.
5. Azhar Hussin, Chong VC, Md Yusoff Musa, Md Sofian Azirun, Rosli Hashim, Phang SM. (eds) (2005). Scientific Expedition to Langkawi by the University of Malaya Maritime Research Centre, Special Issue, October 2005, Malaysian Journal of Science 24, University of Malaya.
6. Sasekumar A. & Chong VC. (2006). Ecology of Klang Strait, University of Malaya Press, University of Malaya, Kuala Lumpur.
7. Phang SM, Azhar Hussin, Chong VC, Mary George, Siti Aisyah Alias & Ho SC. (2006). Innovations and Technologies in Oceanography for Sustainable Development, University of Malaya Maritime Research Centre, Kuala Lumpur.
8. Phang SM, Azhar Hussin, Chong VC, Rosli Hashim & Siti Aisyah Alias (2007). Gems in the Straits of Malacca, University of Malaya Maritime Research Centre, Kuala Lumpur.

9. Siti Aisyah Alias, Chong V.C. (eds) (2008). Scientific Expedition to the Seas of Malaysia (SESMA I & II), Institute of Ocean & Earth Sciences, University of Malaya. Malaysian Journal of Science Vol. 27 (special issue), Faculty of Science, University of Malaya.
10. Chong V.C., A. Sasekumar (eds) (2010). Scientific Expedition to the Seas of Malaysia (SESMA IV), Institute of Ocean & Earth Sciences, University of Malaya. Results of the Research Findings on the Scientific Expedition to Bachok's Coastal Environment, Kelantan, 14-20 June 2008, Malaysian Journal of Science 29 (SESMA Special Issue), February 2010.

❖ Book Chapters

1. Chong, V.C and A. Sasekumar (1994): Status of mangroves fisheries in the ASEAN region. In: (Wilkinson, C., ed.) *ASEAN-Australia Symposium on Living Coastal Resources. Consultative Forum. Living coastal resources of South-east Asia: status and management*, pp. 56-61.
2. Chong, V.C. and A. Sasekumar (1990): Fish of inshore waters adjoining mangroves. **In**: *Final Report of the ASEAN Australia Cooperative Program on Marine Science: Coastal Living Resources Project (Phase I)* (B.H.R. Othman, compiler), pp. 235-334.
3. Chong, V.C. (2001). Prawns. In (Ong J.E. & Gong W.K., eds) *Encyclopaedia of Malaysia IV: The Seas*, Vol. 6, pp. 68-69.
4. Chong, V.C. (2004). Chapter 8: Animals with protostomous development. In: SBB13103 Plant and Animal Diversity, Faculty of Science and Foundation Studies, Open University, Malaysia, pp. 126-153.
5. Chong, V.C., King, B. and Wolanski, E. (2005). Physical features and hydrography. In: (Sasekumar, A. & Chong, V.C., eds) *Ecology of Klang Strait*, University of Malaya Press, Kuala Lumpur, pp. 1-14.
6. Chong, V.C., Sasekumar, A. and S.W. Zgozi (2005). Ecology of fish and shrimp communities. In: (Sasekumar, A. & Chong, V.C., eds) *Ecology of Klang Strait*, University of Malaya Press, Kuala Lumpur, pp. 174-200.
7. Leong, L.F., Kwan, K.K., Chong, V.C. and A. Sasekumar (2005). Resource valuation of Kuala Selangor mangrove forest. In: (Sasekumar, A. & Chong, V.C., eds) *Ecology of Klang Strait*, University of Malaya Press, Kuala Lumpur, pp. 230-252.
8. Sasekumar, A., Chong, V.C., and S.M. Phang (2005). Economic valuation of coastal resources in the Straits of Malacca. In: (Sasekumar, A. & Chong, V.C., eds) *Ecology of Klang Strait*, University of Malaya Press, Kuala Lumpur, pp. 253-261.

9. Chong, V.C. (2007). Fifteen years of fisheries research in the Matang mangroves – What have we learnt? *In* M.I. Shaharuddin, M. Azahar, U. Razani, A.B. Kamaruzzaman, K.L. Lim, R. Suhaili, M.S. Jalil and A. Latiff, (eds.) Sustainable Management of Matang Mangroves: 100 Years and Beyond. Forest Biodiversity Series 4. Forestry Department Peninsular Malaysia, pp. 411-429. ISBN 983-9269-42-9.
10. Ooi, A.L., Chiew L.L. and Chong, V.C. (2007). Diurnal abundance of zooplankton particularly fish larvae in Sungai Sangga Kecil, Matang. *In* M.I. Shaharuddin, M. Azahar, U. Razani, A.B. Kamaruzzaman, K.L. Lim, R. Suhaili, M.S. Jalil and A. Latiff, eds. Sustainable Management of Matang Mangroves: 100 Years and Beyond. Forest Biodiversity Series 4. Forestry Department Peninsular Malaysia, pp. 443-451
11. Chong, V.C., A. Sasekumar and E.Wolanksi (2007). The role of mangroves in retaining penaeid prawn larvae in Klang Strait, Malaysia. In Y.Mazda, E.Wolanski & P.V.Ridd (eds.) The Role of Physical Processes in Mangrove Environments: manual for the preservation and utilization of mangrove ecosystems, pp. 547-558. TERRAPUB, Tokyo.

❖ Refereed Journal Papers

1. Chong, V.C. (1977): Studies on the small grey mullet *Liza malinoptera* (Valenciennes). *Journal Fish Biology 11*: 293-308
2. Chong, V.C. and A. Sasekumar (1981): Food and feeding habits of the white prawn *Penaeus merguiensis* in the Angsa Bank - Klang Strait wates (Straits of Malacca). *Marine Ecology Progress Series. 5*: 185-191.
3. Chong, V.C. and N. Marshall (1981): A reconsideration of Munro/Chee(1978) interpretation regarding the impact of inshore trawlers on prawn catches. *Pertanika Journal of Tropical Agriculture Science 4(2)*: 200-203.
4. Chong, V.C. and A. Sasekumar (1982): On the identification of three morphospecies of prawns - *Penaeus merguiensis* de Man, *Penaeus indicus* H. Milne-Edwards and *Penaeus penicillatus* Alcock (Crustacea: Penaeidae). *Crustaceana 42(2)*: 127-141.
5. Chong, V.C. (1982): A study of gonadal maturation and sexual maturity in the white prawn *Penaeus merguiensis* de Man. *Malayan Nature Journal 25*: 1-12.
6. Chong, V.C. (1984): Prawn resource management in the west coast of Peninsular Malaysia. *Wallaceana 34*: 3-6.
7. Chong, V.C. (1988): Malaysia's participation in the ASEAN-AUSTRALIA Cooperation Program on Marine Science (AACPMS) - Living Resources in Coastal Areas. *LAUT* (Association of South-east Asian Marine Scientists) *1(5)*:4-6
8. Chong, V.C. (1988): Fish and prawns in mangrove waterways. *LAUT 1(5)*:6-8.

9. Chong, V.C.,A. Sasekumar, M.U.C. Leh and D'Cruz, R. (1990): The fish and prawn communities of a Malaysian coastal mangrove system, with comparisons to adjacent mudflats and inshore waters. *Estuarine, Coastal and Shelf Science 31*: 703-722.
10. Chong, V.C. (1991): The early larval stages of the Malaysian penaeid prawn *Trachypenaeus fulvus* Dall, 1957, reared in the laboratory. *Asian Fisheries Science 4*: 165-187.
11. Sasekumar, A., Chong, V.C., Charles Leh, M.U. and R. D'Cruz (1992): Mangroves as a habitat for fish and prawns. *Hydrobiologia 247*: 195-208.
12. Chong, V.C. and A. Sasekumar (1994): The larval development of the fiddler shrimp, *Metapenaeopsis stridulans* (Alcock, 1905) (Decapoda, Penaeidae) reared in the laboratory. *Journal of Natural History 28*: 1265-1285.
13. Newell, R.I.E., Marshall, N., Sasekumar, A. and V.C. Chong (1995): Relative importance of benthic microalgae, phytoplankton and mangroves as sources of nutrition for penaeid prawns from Malaysia. *Marine Biology 123*: 595-606.
14. Chong, V.C., Sasekumar, A. and E. Wolanski (1996): The role of mangroves in retaining penaeid prawn larvae in Klang Strait, Malaysia. *Mangroves and Salt Marshes 1*: 11-22. (*now Wetlands Ecology and Management*).
15. Chong, V.C. (1996): The prawn-mangrove connection - fact or fallacy? In: *Sustainable Utilization of Coastal Ecosystems* (Suzuki, M., S. Hayase and S. Kawähara, eds), *JIRCAS Working Report* No. 4, pp. 3-20.
16. Sasekumar, A. and V.C. Chong (1998). Faunal diversity in Malaysian mangroves. *Global Ecology & Biogeography Letters* 7 : 57-60.
17. Getha, K., Chong, V.C. and S. Vikineswary (1998): Potential use of the phototrophic bacteria, *Rhodopseudomonas palustris*, as an aquaculture feed. *Asian Fisheries Science* 10: 221-230.
18. Getha, K., Vickineswary, S. and Chong, V.C. (1999). Isolation and growth of the phototrophic bacteria, *Rhodopseudomonas palustris* strain B1 in sago-starch-processing wastewater. *World Journal of Microbiology and Biotechnology* 14(4): 505-512.
19. Sarpedonti, V., Ponton, D. & Chong V.C. (2000). Description and ontogeny of young *Stolephorus baganensis* and *Thryssa kammalensis*, two Engraulididae from Peninsular Malaysia. *Journal of Fish Biology 56:* 1460-1476.
20. Blaber, S.J.M. Blaber, Cyrus, D.P., Albaret, J.J., Chong, V.C., Day J.W., Elliot, M., Fonseca, M.S., Hoss, D.E., Orensanz, J. Potter, I.C. & Silvert W. (2000). Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. *ICES Journal of Marine Science 57*: 590-602.
21. Chong, V.C., Low, C.B. & Ichikawa, T. (2001). Contribution of mangrove detritus to juvenile prawn nutrition: a dual stable isotope study in a Malaysian mangrove forest. *Marine Biology 138*: 77-86.

22. Azad, S.A., Vikiniswary, S. , Ramachandran, K.B. & V.C. Chong (2001). Growth and production of biomass of *Rhodovulum sulfidophilum* in sardine processing wastewater. *Letters in Applied Microbiology* 33: 264-268.
23. Alongi, D.M., V.C. Chong, P. Dixon, A.Sasekumar & F. Tirendi (2002). The influence of fish cage aquaculture on pelagic carbon flow and water chemistry in tidally-dominated estuaries of peninsular Malaysia. *Marine Environmental Research* 55(4):313-333.
24. Chong V.C. & Sasekumar, A. 2002. Coastal habitats (mangroves, coral reefs and seagrass beds) of the ASEAN region: status, utilization and management issues", *Fisheries Science 68(1)* : 566-571.
25. Sujat Al-Azad, Chong V.C & Vickineswary, S. 2002. Phototrophic bacteria as feed supplement on rearing *Penaeus monodon* larvae. *Journal of World Aquaculture Society* 33(3): 158-168.
26. Marsitah, I. & Chong, V.C. (2002). Population and feeding ecology of *Parapenaeopsis sculptilis* (Heller, 1862) in Klang Strait, Peninsular Malaysia. *Malaysian Journal of Science* 21: 61-68.
27. Chong, V.C. & Sasekumar, A. (2002). Fish communities and fisheries of Sungai Johor and Sungai Pulai Estuaries (Johor, Malaysia). *Malayan Nature Journal* 56(3), 279-302.
28. Sujjat Al-Azad; Ramachandran,K.B.; Chong, V.C. and Vikineswary, S. (2003). *Rhodovulvum sulfidophilum* in the treatment and utilisation of sardine processing wastewater. *Letters in Applied Microbiology* 38. 13-18.
29. Azad, S.A., Chong V.C., Vickineswary, S & K.B. Ramachandran (2003). Potential of wastegrown phototrophic bacteria as a feed ingredient in aquafeeds. *Journal of Bioscience* 12(2): 1- 11. (now *Tropical Life Sciences Research*)
30. Singh, H.R., Chong V.C. & M.Zakaria-Ismail (2003). Morphological differentiation among estuarine catfishes of the family Ariidae of the Matang ecosystem, Perak. *Malayan Journal of Science* 22: 7-13.
31. Chong, V.C. , Ooi, A.L., Chew, L.L. & Ogawa, Y. (2003). Mangrove zooplankton of Matang mangrove estuaries: Preliminary assessment of spatio-temporal abundance in relation to environmental parameters, In Ogawa, Y. et al (eds). Sustainable Production Systems of Aquatic Animals in Brackish Mangrove Areas. *JIRCAS Working Report* 35: 21-44.
32. Alongi, D.M., A. Sasekumar, V.C. Chong, J. Pfitzner, L.A. Trott, F. Tirendi, P. Dixon & G.J. Brunskill (2004). Sediment accumulation and organic material flux in a managed mangrove ecosystem: estimates of land-ocean-atmosphere exchange in peninsular Malaysia. *Marine Geology 208:* 383-402.
33. Chong, V.C., Affendy, N., Ooi AL & Chew L.L. (2005). Mangrove fishes of northeastern Langkawi Island. *Malayan Nature Journal* 57(2): 193-208.

34. Chong, V.C., Ng., Y.P., Hairi, B.J., Ooi L.L., Chiew, L.L., Amirah M. and B.N. Affendy (2005). Update of the fishes of mangrove and coastal waters of northeastern Langkawi. *Malaysian Journal of Science* 57(2): 167-184.
35. Noramly, G., Azhar B.H., Chong V.C. & Phang S.M. (2005). The scientific, social, environmental and economic value of N.E.Langkawi: an overview of the present status. *Malaysian Journal of Science* 57(2): 219-235.
36. Chong, V.C. (2006). Sustainable utilization and management of mangrove ecosystems. *Aquatic Ecosystem Health & Management*, 9(2):249-260.
37. Then, A.Y.H., V.C. Chong, H.H. Moh and Y. Hanamura (2006). Size frequency, abundance and feeding habits of young snappers *(Lutjanus* spp.*)* and groupers *(Epinephelus* spp.*)* in the Matang Mangrove Estuary, Malaysia. *JIRCAS Working Report* 44: 1-5 (ISSN 1341-710X).
38. Chew, L.L., A.L. Ooi, V.C. Chong and Y. Ogawa (2006). The diet of five major fish species in Matang mangrove estuaries, Peninsular Malaysia.. JIRCAS Working Report 44: 7-12.
39. Chong, V.C. (2007). Mangroves and fisheries linkages: the Malaysian perspective. *Bulletin Marine Science* 80(3): 755-772.
40. Affendy, N. and V.C.Chong (2006). Shrimp ingress into mangrove forests of different age stands, Matang mangrove forest reserve, Malaysia. *Bulletin Marine Science* 80(3): 915 (ISI abstract).
41. Ogata, H.Y., K. Ahmad., E.S. Garibay, D.R. Chavez, H. Furuita and V.C. Chong (2006). Arachidonic acid distribution in mangrove organisms in the Philippines, Malaysia and Japan. *JIRCAS Working Report* 44: 45-52.
42. Ooi, A.L., Chong, V.C., Hanamura, Y. & Konishi, Y. (2007). Occurrence and recruitment of fish larvae in Matang mangrove estuary, Malaysia. *JIRCAS Working Report* 56: 1-6 (ISSN 1341-710X).
43. Chew, L.L., Chong V.C.& Hanamura, Y. (2007). How important are zooplankton for juvenile fish nutrition in mangrove ecosystems? *JIRCAS Working Report* 56: 7-18.
44. Tarutani, K., Ooi A.L., Chew L.L., Chong, V.C., Chee P.E. & Hanamura, Y. (2007). Biomass and production rates of phytoplankton and zooplankton in the Matang mangrove estuaries of northwestern Peninsular Malaysia. *JIRCAS Working Report* 56: 27-30.
45. Sarpedonti, V. and Chong V.C. (2008). Abundance and distribution of *Stolephorus baganensis* Hardenberg 1933 and *Thryssa kammalensis* (Bleeker 1849) larvae in relation to ontogeny and environmental factors in a Malaysian estuary. *Tropical Zoology* 21(2): 195-208.
46. Chew L.L., Chong V.C. and Ooi A.L. (2008). Zooplankton of the Straits of Malacca, with emphasis on copepods and fish larvae in the vicinities of Jarak, Perak and Sembilan Islands. *Malaysian Journal of Science* 27: 83-104.

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