Chapter 4

Natural Resources of the Arafura and Timor Seas

As a maritime nation, the natural resources in Indonesian waters are impressive by any standards, including both renewable and non-renewable resources. As an illustration of renewable natural resources, 20,000 species of mollusc, 2,000 crustacean species, six marine turtle species and 8,500 fish species have been recorded. The maximum sustainable yield of marine fish resources is estimated at around 6.4 million metric tons per year with an allowable catch of around 5.1 million metric tons or around 80% of the maximum sustainable yield. Non-renewable resources include oil, natural gas, lead, mangan and gold.

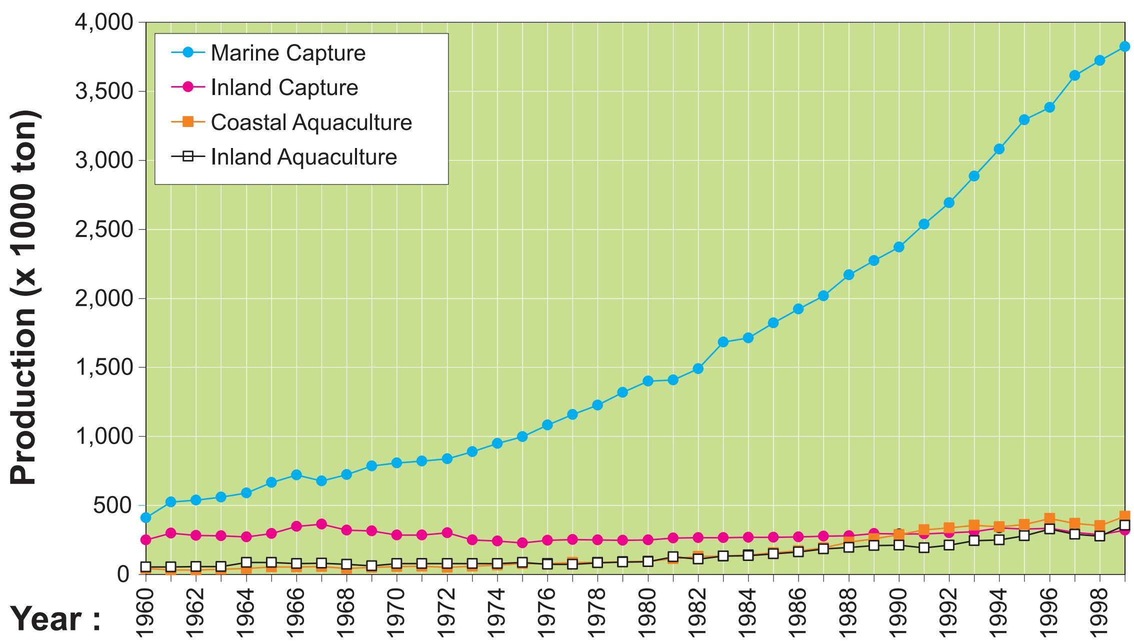
As a country which is categorised as a developing nation, the process of extracting these rich living resources has provided opportunities for many levels of the community, ranging from small scale use to industrial scale exploitation, in the coastal zone, along the coastline, in near-shore and off-shore waters. The form of these living resources is closely linked to the extent of the waters associated with coral reefs, seagrass beds, mangrove forests and the many species which can be found there. From the socio-economic viewpoint, marine biodiversity is a one of the substantial contributors to the national balance of payments.

In 1997 the exploitation of marine resources contributed around 25% to 30% of Indonesian GDP and provided job for 20 million people employed in marine and coastal activities, which is around 10% of the total Indonesian population (Fig. 4.1). Most of these activities were in conventional sectors such as capture fisheries and the harvest of seaweed. These activities are now being added to by research into bioactive substances for medical and pharmaceutical purposes.

The marine and fisheries sector is still the largest contributor to national non-tax income (*Pendapatan Nasional Bukan Pajak* [PNB]). Until now the capture fisheries have held a position as one of the most important sub-systems in marine and fisheries sector development. The significant ongoing increase is one reason for this. Whereas in 2001 national non-tax insome from marine capture fisheries was only Rp 4,033 billion, in 2002 it had reached 207,520 billion. Thereafter in 2003 the contribution to PNBP reached 211,746 billion with Rp 208,205 billion from fisheries retributions, and Rp 3,541 billion of income from port facilities. In the 3 years prior to 2004 there was an average increase in production of 5.53% per year, an average increase in export volume of 21.42% per year, a rise in foreign exchange earnings of 1,59% per year and the number of fishers rose by 7,59% per year (Tabel 3), *(Source: Ministry of Marine Affaires and Fisheries).*

Production from Indonesian marine capture fisheries in 2000 was 3,764.479 metric tons and 3,897.270 metric tons in 2001, placing Indonesia as the 5th largest producer, whereas China is the largest marine fisheries producer in the world. Foreign exchange earning from the marine biodiversity in Indonesian seas was around US$ 1,655 (Fisheries Export Statistics, 2000). It is worth noting that the total volume of fisheries catch in 2001 was 487,116 metric tons, with an export value of US$ 1,631,899. In 2002 the total catch was 565,739 metric tons with an export value of US$ 1,570,353. In 2003, production reached 696,290 metric tons with an export value of US$ 2,004,067 (Source: Ministry of Marine Affairs and Fisheries 02/02/05).

Fig. 4.1
Production of Indonensian Fishery from four components of Fishery activities *(Source: Ministry of Marine Affairs and Fisheries)*



Fishery Management Zone	Resource Potential (x1.000 ton)	Production (x1.000 ton)	Exploitation Status (%)
Malacca Straits	276.03	389.28	Overfishing (>100%)
South China Sea	1,057.05	379.90	Underfishing (35,94%)
Java Sea	796.64	1,094.41	Overfishing (>100%)
Makassar Straits and Flores Sea	929.72	655.45	Underfishing (70,50%)
Banda Sea	277.99	228.48	Underfishing (82,19%)
Seram Sea and the Gulf of Tomini	590.82	197.64	Underfishing (33,46%)
Sulawesi Sea and the Pacific Ocean	632.72	237.11	Underfishing (37,47%)
Arafura Sea	771.55	263.37	Underfishing (34,14%)
Indian Ocean	1,076.89	623.78	Underfishing (57,92%)
National Total	6,409.21	4,069.42	Underfishing (63,49%)

Table 4.1
Resource Potential, Production and Exploitation Status
(Source: Ministry of Marine Affairs and Fisheries)

Fisheries produce entering the international marketplace consists of several main groups which are: shrimp, tuna, skipjack tuna and longtail tuna and others (miscellaneous). Coral reefs, seagrass beds, mangrove forests and several of the species which live there constitute marine biodiversity resources which have made a substantial contribution to the process of development in Indonesia especially in respect of coastal community development.

Based on data from GEF/UNDP/IMO (1999), the economic value of Indonesian coral reefs is US$ 567 million, the direct use and indirect value of Indonesian mangroves is U$ 2.3 billion. The economic benefit value of Indonesia marine fisheries resources is estimated at US$ 15.1 billion (Dahuri, 2002).

The Arafura and Timor Seas is one centre of tropical marine biodiversity including fisheries resources. A complex interaction with the atmosphere takes place in this area and the Arafura Sea is the largest carbon sink in Asia, with carbon sequestration way above the normal (average) for seawater. The productivity of the Arafura Sea is high, with a value of around 12 g C cm^2 d^{-1} (Fig. 4.2). However, data and information regarding this area is lacking in many respects.

4.1 The known

Several international expeditions in Indonesian waters such as the Challenger Expedition (1873-1876), Siboga Expedition (1899-1900), Snellius Expedition (1929, 1984), Danish Expedition to the Kei Island (1922), Galathea Expedition (1950-1952), Mariel King Memorial Expedition (1970), Alpha Helix Expedition (1975), Corindon Expedition (1980), Karubar Expedition (1991) included the Arafura Timor Seas in their voyages have made many contributions to the body of knowledge regarding marine organisms.

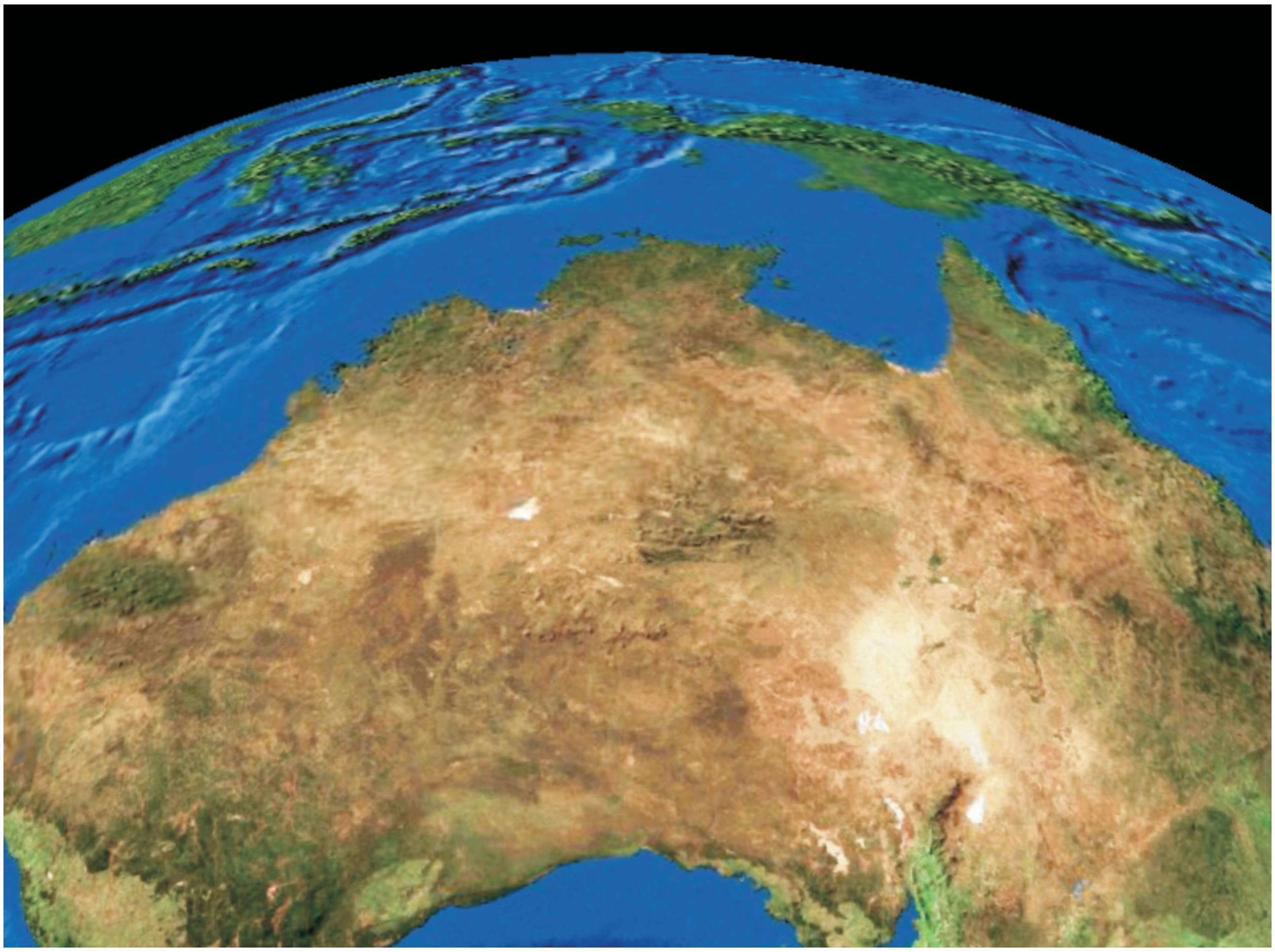


Fig. 4.2
Marine productivity *(Source: adapted by the ATSEF team from AIMS)*

These expeditions as well as a number of other research activities in the Arafura and Timor Seas have found that many of the marine organisms found in the Indo West Pacific can be found in the Arafura and Timor Seas, apart from which there are several species which so far have been found only in the Arafura and Timor Seas.

As a general rule, marine organisms can be divided based on their habitat, into those living in coastal waters (the coastline to the edge of the continental shelf at depths of around 200 m) and those living in oceanic waters (Perry and McKinnel, *PICES-CoML Report*). The Arafura Sea and Timor Seas are renowned for the diversity of deep sea organisms, especially since a number of expeditions such as the Danish Expedition to the Kei Island (1922) and Karubar Expedition (1991) discovered several species new to science (Baba and de Saint Laurent, 1996; Chan, 1997; Chen, 1996; Cleva, 1997; Crosnier, 1994; Forest, 1995; Guinot, 1995; Guinot and Richer de Forges, 1995; Macpherson, 1997; McLaughlin, 1997, 2004; Lemaitre, 1997; Rahayu, 2005, 2006). Shallow water species do not pale in comparison, especially those collected by the Snellius Expedition (1929), Rumphius Expedition (1975-1980), and Alpha Helix Expedition (1975) (Buitendijk, 1937, 1960; Haig, 1979; Haig and Ball, 1988), and the results of research in the mangrove ecosystems (Ng and Rahayu, 2002; Rahayu, 2003; Rahayu and Davie, 2002, 2006; Rahayu and Hortle, 2002; Rahayu and Ng, 2003, 2004, 2005) as well as several research activities by the Balitbang Sumberdaya Laut, Puslit Oseanografi (Marine Resource Research Division of the Oceanographic Research Centre) in Ambon.

4.1.1. Plankton

Marine plankton communities consist of phytoplankton (planktonic plants) which can photosynthesize and zooplankton which comprises many types of larvae and adult organisms from almost every animal phylum. In the food chain phytoplankton will be eaten by herbivorous zooplankton (copepods) which are classified as secondary producers and will in turn be eaten by larger carnivorous animals referred to as tertiary producers. In the marine environment one role of copepods is to control the density of phytoplankton populations. Research has shown that the greatest proportion of primary production occurs not in the cells of phytoplankton but inside the bodies of herbivorous copepods.

Copepods can be found in many aquatic habitats from fresh water to the open oceans, and from the surface layer down to the deepest bathypelagic layers. They are spread from the sub-zero waters of the polar regions to the tropical and equatorial regions, and their vertical distribution ranges from 9,995-10,002 m below sea level in the Mariana Trench to elevations of 5,540 m in the Himalaya Mountains. This is around ¾ of the maximum possible vertical distribution on earth, from the deepest point in the Mariana Trench to the summit of Mount Everest (20,372 m). Because of this, they play a key role in the marine habitat, and several extremely interesting publications have been published, however data is still very limited. Recently, the importance of copepods in the marine ecosystem has been recognised by marine biologists, for example their contribution to fisheries. Copepods are important not only as food for many commercially important fishery species and their larvae, but also as bio-indicators which can help explain many phenomena in marine dynamics.

4.1.1.1 Zooplankton productivity

The results of research in the Arafura Sea reveal that zooplankton biomass is generally twice as high during the East Monsoon as during the West Monsoon. Fisheries resources increase by around 2/3 (21% and 56%). The vertical zooplankton density profile for August shows that in the 0-50 m layer density over the Sahul Shelf is greater (0.94 ml/m^3) than in the Aru Basin (0.41 ml/m^3), but in February the density is almost equal (0.19 and 0.16 ml/m^3). The greatest abundance of zooplankton occurs in August and can reach levels 2-4 times greater than in February and is dominated by copepods.

Over the shallow Sahul Shelf, copepods account for around 57% (February) and 70% (August) of the zooplankton caught whereas in the deeper waters the percentage stays almost the same with values of 77% (February) and 83% (August). The copepod species *Calanoides philippinensis* and *Rhincalanus nasutus* can be found in huge numbers during the upwelling period with densities reaching 4, 000 ind/m^3 (Baars *et al.,*1990), whereas during downwelling periods these two species of copepod are very rarely found in the surface layers (Mulyadi, 2004). These two copepod species are bio-indicators of upwelling events in the Eastern Indonesian Seas (Fleminger, 1986). *Subeucalanus dentatus* is also frequently found during the 'fertile season' but is rarely or hardly ever found during the 'poor' season. The dominant copepod species during these two seasons are *Euchaeta marina* and *Scolecithrix danae.*

The copepod biodiversity of the Arafura Sea and Timor Sea can be seen in Appendix 3. It is estimated that annual secondary production in the Eastern Banda Sea and Aru Basin is around 24 g C m^{-2} or 5% of primary production (Baars *et al.,* 1990).

4.1.1.2 Copepod biodiversity in Indonesia

The development of knowledge regarding zooplankton in Indonesian waters is mainly based on monographs and papers from large expeditions covering the seas of the world. Brady (1883) was the first scientist to study the copepods of the Buru Sea, Banda Sea and Sulawesi. Copepod from the Eastern Indonesian Seas were collected by the Snellius (1929) and Alpha Helix (1979) Expeditions in the Buru-Ambon Archipelago, by Früchtl (1923) in the Aru Archipelago and by Carl (1907) in the Gulf of Ambon. The most important monograph to date regarding copepods in Indonesian waters is that written by A. Scott (1909). A. Scott (1909) reported 338 species of copepods from Indonesian waters and nearby areas which is the largest collection in the history of expeditions world-wide. The dominant copepod species in almost all areas of Indonesia seas are those belonging to the Acartiidae, Paracalanidae, Pontellidae, and Pseudodiaptomidae families. The number of copepod species which have been fully described from Indonesian waters so far is 400 species or less than 3.5% of the total number of copepod species known world-wide (11,500 species) (Humes, 1993). However with this number of species Indonesia is a global mega-biodiversity centre for marine copepods. Mulyadi (2002) reported data regarding the diversity and distribution of copepods from the Pontellidae Family which are represented in all parts of the Indonesian Seas. During this research, 45 species of Pontellidae were found from 5 genera, of which 24 species had been reported previously by other researchers, 15 species were new records for Indonesia and 10 were species new to science. From a bio-geographic viewpoint, the greater part of the species found 62.5% (25 species) were species with an Indo-Pacific distribution, 4.4% (*Pontellopis perspicax* and *P. villosa*) were cosmopolitan species. Species previously only reported from the Indian or Pacific Oceans comprised 8.9% (four species) and 2.2% (one species) respectively. Of the remaining species, *Pontella forcicula* which was originally thought to be endemic to the Philippines was also found in Eastern Indonesia and the remainder (15 species) were species new to science.

Based on their habitat in the horizontal plane, over 66.6% (32 species) of Indonesian pontellid copepods are neritic, five species are estuarine-neritic and nine species are oceanic-neritic.

The species of *Calanopia*, *Labidocera* and *Pontella* found in Indonesian waters can be grouped into four groups of *Calanopia* species, 5 groups of *Labidocera* species and six groups of *Pontella* species. Whereas species from the genus *Pontellopsis* and genus *Pontellina* cannot be placed in species groups because they have very varied individual characteristics (Mulyadi, 2002).

Mulyadi (2004) reported 99 species of calanoid copepods (excluding the Family Pontellidae) collected across the entire Indonesian sea area. Almost all of the species recorded can be found in the waters of Eastern Indonesia. Two calanoid species which still pose problems from a taxonomic point of view are *Undinula vulgaris* and *Cosmocalanus darwini*. Three sub-specific forms of the female *U. vulgaris* have been previously reported from the Indo-Pacific (Vervoort, 1946; Fleminger, 1986). In the Eastern Indonesian Seas in addition to these three sub-specific forms, four new sub-specific forms were also found. The subspecies *typica* was previously reported as limited to the neritic waters of the Eastern Pacific Ocean. The habitat of the subspecies *zeylanica* was considered to be around the shores of oceanic islands, whereas the subspecies *giesbrechti* is thought to be concentrated in the waters of Eastern Indonesia (Fleminger, 1986; Mulyadi, 2004). Three further subspecies of *Cosmocalanus darwini* were also found in the Eastern Indonesian Seas, these being *C.d. typica*, *C.d. symmetrica*, and *C.d. intermedia* (Mulyadi, 2004).

4.1.1.3 Plankton as food for marine organisms

Among marine animals, the zooplankton group with the greatest biomass is the copepods. The important contribution made by copepods to marine fisheries has been proven by marine biologists across the world. Copepods are not only important as a food source for many commercially valuable fishery species and their larvae but are also used as bio-indicators in the study of several marine phenomena. In several countries, data regarding copepod distribution and hydrology are used to determine fishing grounds. This is because copepods produce organic material which can be used by animals at higher trophic levels in various *pellet* sizes. Copepods from the Order Calanoida occupy the prime position in the marine ecosystem, because most of them are herbivorous and have a direct relationship with herrings, sardines, and several whale species (sei, bowhead, right whales and fin whales). The results of scientific research regarding many fish species across the world have proved that many pelagic fish species and the larva of almost all fish world-wide use plankton as a source of food. The greater part of world capture fishery production (74%) consists of pelagic fish. Based on their food source, 63% are plankton eaters, 24% are predators and 8% are demersal (Martinsen, 1966). In Indonesian waters, the biomass of the small plankton-eating pelagic fish species (scads, anchovies, sardines, *Sardinella* sp., *Sardinella lemuru* and mackerel) is around 3,244,000 metric tons or almost 53% of the total maximum sustainable yield (excluding ornamental fish, swimmer and mud-crabs, molluscs, teripang, small shrimp and jellyfish) (Merta *et al*. 1998). In England mackerel catches peak in May, in line with the peak in copepod abundance. Copepods eat phytoplankton and these planktonic plants start to grow and reproduce when the power of the rays of sunlight start to become stronger in early spring (February-March). There is a positive correlation also between herring catches and copepod abundance (Lucas, 1956). In the waters around Bombay and the Gulf of Manaar in India, many of the juvenile and adult fish caught are plankton feeders (Chacko, 1949).

Anchovies in turn are the main food source of the Spanish (*Scomberomorus* spp.). The three most commonly caught sardinella species (*Sardinella perforata*, *S. fimbriata* and *S. dispilonotus*) are plankton feeders. Anchovies and sardinella species are the main prey of wolf herrings (*Chirocentrus* spp.), while zooplankton and anchovies are the main prey of squid (*Loligo* spp.).

Analysis of the stomach contents of *Sardinella longiceps* in the Bali Straits revealed that their diet consisted of phytoplankton and zooplankton with copepods accounting for around 85-95% (Soerjodinoto, 1960). The main food source of anchovies in Jakarta Bay is also zooplankton, mainly copepods and other crustacea (Burhanuddin *et al*. 1975) whereas *Sardinella fimbriata* consume phytoplankton and zooplankton with a preference for copepods (Hutomo and Martosewojo, 1975). In the Seribu Island (Panggang Island), the species *Sardinella lemuru* was found to consume mainly zooplankton with copepods as the main diet. In the waters around Maluku, fish used as bait for skipjack tuna also feed on zooplankton with copepods and decapod larva as their main prey (Sutomo and Arinardi, 1978). Copepods used as feed for the larvae of groupers and snappers have proven to give good results in terms of growth and survival rates. This is due to their high unsaturated fat content, especially *Eicosa Pentatonic Acid* (EPA) and *Diocosa Hexaenoic Acid* (DHA).

As yet there has been limited scientific research into the relationship between plankton abundance and the quantity of fish caught in Indonesia, however the results of research carried out in the Bali Straits indicates that when the density of copepods is low, the catch of *Sardinella lemuru* is also low. When copepods are abundant, the catch of *Sardinella lemuru* increases by up to 70% (Arinardi, 1989). A positive relationship was also found between zooplankton abundance and catch of the Indian mackerel *Rastrelliger kanagurta* in the waters of Ujung Watu, Jepara.

4.1.1.4 Plankton as a bio-indicator of marine phenomena

a. Upwelling phenomena

There are at least seven known upwelling sites in Indonesian waters. Most of these upwellings are found in the Wallacea area, a sea area which is bounded by an imaginary line drawn by Wallace to the west (through the Makassar Straits) and the line drawn by Lydekker to the east (down the west side of Papua). This area is renowned as an area with high biodiversity and abundance of marine organisms, several of which are unique in nature and endemic, and which makes a major contribution to global biodiversity. Apart from the Makassar Straits and Banda Sea, upwellings are also found in the Seram Sea, Maluku Sea, Arafura Sea as well as the waters around the bird head of West Papua. The only upwelling outside the Wallacea area is in the waters from South Java to Sumbawa. Information regarding upwellings in Western Indonesia is still very limited, especially in connection with fish recruitment to the area. Upwelling areas are believed to be fertile and provide ideal feeding areas for small pelagic fish which in turn will become the prey of larger fish. This ongoing mutual relationship has made upwelling areas well-known as excellent fishing grounds. There is a large body of research which has proven that during upwelling events the fertility of sea waters can increase up to 10 fold compared to normal conditions. Upwellings occurring in the offshore waters of California have long been known as a good area for catching sardinopsis fish. It is similar with the waters off Peru which has been a prime fishing ground for anchovies. In West Africa, *Sardinella* sp. forms the major portion of the catch.

In order to clarify the processes involved in upwellings both at micro and macro scales and their relationship with the many organisms linked to the processes requires additional research which is more focused and serious. One bio-indicator which can be put forward as a candidate for investigating upwelling phenomena is the copepods. Copepods are known to be associated with the upwelling mechanism and have a very specific life-cycle strategy which can adapt to normal or extreme conditions. *Calanus pacificus* and *C. marshallae* is an upwelling bio-indicator in the offshore waters of California and Oregon. During upwelling events the abundance of offspring (copepodite V) of these two Calanoid species in surface waters reaches 26 millions individuals/m^3, whereas the phosphate level reaches 2µg/L. *Calanus carmatus* is generally associated with upwellings in North African waters. Several other copepod species are associated with upwelling mechanisms including *Acartia clausi, A. longiremis* and *Oithona similis*.

Calanoides philippinensis and *Rhincalanus nasutus* are two deep water Calanoid species used as bio-indicators for the occurrence of upwellings in Eastern Indonesian waters, especially in the Arafura Sea (Fleminger, 1986). During the upwelling period, generally beginning with the East Monsoon (March-September) copepodites of these two species of copepod are very abundant in the surface layer. Conversely, their adult form is very rarely encountered (Mulyadi, 2004). These copepodites will store as much fat as possible by consuming phytoplankton, nauplii and detritus for their growth and as food reserves in preparation for the downwelling. Towards the end of the upwelling period, when the food resources in the surface layer are becoming scarce, most of the juvenile copepods (copepodite V) from these two species will dive to depths of 300-500 m or more. In these deeper layers, the stage V copepodites will go into a resting state resembling hibernation, reducing their metabolism and activity rates and remain in the copepodite V stage without eating (fasting) for around 5-6 months while awaiting the next upwelling. When the upwelling begins, these stage V copepodites will swim up again to the surface layers and become adults (the majority become females), mate and lay eggs. The highest concentration of upwelling species, the highest zooplankton biomass and the lowest water temperatures are found in the Western and Northern parts of the Aru Archipelago.

b. Red tide phenomena

The systematic division of phytoplankton includes there main groups which are the Diatomae, Dinoflagellata and Cyanophyta. Populations of species from the latter two groups often increase dramatically (blooming phenomena) causing red tides. Basically, phytoplankton can be considered to be a bio-indicator of the fertility of a water body, but their overabundance can have negative impacts on the environment and other aquatic organisms. Red tides are a phenomena cause by population explosion (blooming) of a phytoplankton species achieving a density of tens of millions of cells per litre. This mass reproduction causes the water to change colour becoming brownish or yellowish green. This coloured layer caused by the concentration of algal cells will cover the water surface to a depth of 2-5 m. The population explosion of plankton which reaches the red tide condition will only last for around 30 days at most, depending on the availability of nutrients in the water. In addition to reducing water quality, red tides can cause mass kills of fish, shrimp and other organisms, coral bleaching and the destruction of coral reefs, poisoning and even mass deaths of human beings. Cases of mass fish kills in many water bodies have been linked to red tide phenomena. Negative effects on fisheries include mass kills of fishery resources both in brackish-water ponds (tambak) and in the natural aquatic environment.

Red tide events usually occur in coastal waters or over continental shelves but can also occur in the open ocean. Factors which trigger red tide events include the effects of eutrophication (nutrient enrichment), the reduction of herbivorous organisms (zooplankton) who eat the poisonous plankton, large-scale changes in hydro-meteorological parameters, the occurrence of upwellings which raise nutrients from the sea bed, heavy rain and the influx of large volumes of fresh water.

Based on available data, 20 plankton species have been recorded as potentially capable of causing red tides in Indonesian waters. *Pyrodinium bahamense* var *compressum* is known to occur in Eastern Indonesian waters, but has only caused red tides in Kao Bay and the Gulf of Ambon. In Kao Bay this plankton species causes red tides almost every year which cover an area of tens of km^2. In addition to this species, another red tide causing plankton in the Gulf of Ambon is *Alexandrium effine*, whereas *Alexandrium* sp. is frequently found in the waters of Manokwari and Elpaputih Bay. A *red tide* event which killed cultured pearl oysters in Dobo (Southeast Maluku) occurred in 1995, and mass fish kills occurred in Waigeo, Raja Ampat Island in 1996. The toxin produced (saxitoxin) can be accumulated in shellfish with concentrations up to 1000 µg/100g of flesh, where as the safe level for human consumption is below 80 µg/100g of shellfish flesh. Cases of human deaths caused by the consumption of shellfish contaminated with this poison occurred in the Lewotobi Straits (East Flores) in 1984 and Ambon in 1996.

4.1.1.5 Benefits of plankton for humans

The variety of marine plankton has been known to mankind through witnessing the ability of whales to live on a diet of zooplankton alone. The idea of exploiting plankton for human benefit was first put forward in 1940 (Omori, 1975). Zooplankton has the greatest biomass of all marine organisms and is dominated by copepods. Although copepods are recognised as an ideal food for fish, up to now their harvest has relied on the exploitation of wild populations. The main obstacles to the use of zooplankton are their small size and the fact that they are distributed throughout a very large volume of water. In addition, their capture is time-consuming and the volume depends on environmental conditions such as seasons, currents, and weather. Zooplankton samples are usually collected using NORPAC plankton net with a diameter of 0.45 m, length of 1.8 m and mesh size of 0.33 mm. Another method is to suck up water using a pump, then filter this water using a filter or net with a given mesh size (0.1; 0.2 or 0.3 mm). Effective and economically viable harvesting requires a zooplankton biomass which is sufficiently large and localised. Zooplankton harvesting will be economically viable when mass culture techniques have been developed or a new cheap capture method has been invented.

Zooplankton can be used to produce food for human consumption which contains several essential amino acids, minerals, vitamins, as well as fat and carbohydrate. In addition to use as food, zooplankton can also be used as bait. Actually people living in Asia generally and Indonesia in particular have long been consuming zooplankton as a source of protein.

There are around 20 zooplankton species which are commercially caught for a variety of uses (Table 4.2). Zooplankton consisting of crustacea measuring less than 20 mm is known as *rebon* shrimp. *Rebon* consists of a mix of small shrimp species which is dominated by *Acetes* sp., *Sergia* and other small crustacea such as *Neomysis* and the larvae of Penaeidae (10-40 mm in size) which can be caught in huge numbers. These creatures are one of the economically valuable marine resources in the waters of Asia and East Africa. These 20 or so species of zooplankton have a global market potential as food or as bait.

In addition to *rebon*, other zooplankton with economic potential are the larger jelly fish, such as *Rhopilema esculenta* (diameter 25-30 cm) and *Stomolophus* sp. which are frequently found in the waters of the Timor Sea and Arafura Sea. Several of the larger jellyfish from the Order Rhizostomeae are an important source of food in China and are exploited all along the Chinese coast. Since 1970, over eight species of jellyfish have become important export commodities in Southeast Asia. Japan now imports around 5,400-10,000 metric tons of jellyfish per year, with a value of around 25.5 million US$/year from the Philippines, Vietnam, Thailand, Malaysia, Indonesia, Singapore and Myanmar. At the global level, at least 11 jellyfish species are known to be edible, these are *Cephea cephea* (Cepheidae), *Catostylus maosaicus*, *Crambione mastigophora*, *Crombionella orsinii (*Catostylidae), *Lobonema smithii*, *Lobonemoides gracilis* (Lobonematidae), *Rhizostoma pulmo, Rhopilema esculentum, R. hispidum, Nemopilema nomurai* (Rhizostomatidae) and *Stomolophus meleagris* (Stomolophidae).

The distribution of *Catostylus mosaicus* includes the Philippines, New Guinea, the West Coast of Australia and New South Wales. *Crambione mastigophora* can be found in the Malay Archipelago, Java and Truk Island.

The distribution of *Lobonema smithii* and *Lobonemoides gracilis* is limited to the tropical waters of the Indo-West Pacific. The most expensive species on the market, *Rhopilema esculentum,* has a distribution covering Western Japan, Po Hai, the Yellow Sea, the East China Sea and South China Sea (Hon *et al.,* 1978). Whereas *R. hispidum* can be found in the warmer areas of the Indo-Pacific, from Southern Japan, Southern China, the Philippines, Malaysia and Indonesia to the Indian Ocean and Red Sea. It is suspected that the jellyfish species mentioned above may also be found in the waters of the Timor Sea and the Arafura Sea. The list of Indo-Pacific jellyfish species which are likely to be found in the Timor Sea and the Arafura Sea can be seen in Appendix 4.

Table 4.2
Zooplankton with commercial value from various parts of the (world)

Species Name	Country (Location)	Exploitation (Commercial)
I. Decapods		
1. *Acetes americanus americanus* Ortman	Suriname	+
2. *A. chinensis* Hansen	Korea, China, Taiwan	++++
3. *A. erythraeus* Nobili	China, Southeast Asia, India, East Africa	+++
4. *A. indicus* Edwards	Southeast Asia, India	++++
5. *A. intermedius* Omori	Philippines, Taiwan	+
6. *A. japonicus* Kishinouye	China, Korea, Japan	++
7. *A. serrulatus* (Kroyer)	China	+
8. *A. sibogae sibogae* Hansen	Southeast Asia	++
9. *A. vulgaris* Hansen	Southeast Asia	+++
10. *Sergia lucens* (Hansen)	Japan	+++
11. *Cervimunida johni* Porter	Chile	++++
12. *Pleurocodes monodon* (Edwards)	Chile	++++
II. Mysidacea		
1. *Neomysis intermedia* (Czerniavsky)	Japan	+++
2. *N. japonicus* Nakabawa	Japan	+++
3. *Achantomysis mitsukurii* Nakabawa	Japan	+++
4. *A. Ijimae* Nakabawa*	Japan	+++
III. Euphausiacea		
1. *Euphasia pasifica* Hansen*	Korea, Japan, Canada	+++
2. *E. superba* Dana	Antarctic	++++
3. *Meganictiphanes norvegica* (Sars)*	France, Monaco, Norway	++
IV. Copepods		
1. *Calanus plumchrus* Marukawa*	Japan, Canada	+
V. Syphomedusae		
1. *Ropilema esculenta* Kishinouye	Southeast Asia, China, Japan	+++
2. *Stomolophus nomurai* (Kishinouye)	China, Japan	++

Notes:
+ = , 100 metric tonnes/year; ++ = 100-1.00 metric tonnes/year; +++ = 1.000-10.000 metric tonnes/year;
++++ = > 10.000 metric tonnes/year; * = mainly for bait *(Source: Omori, 1975).*

From the graphical representation of the Calanoid Order shows that the members of the Pontellidae Family dominate the zooplankton composition (61 species), and are represented by the *Calanopia, Labidocera, Pontella, Pontellopsis* and *Pontellina* Genera (Fig. 4.3). Mulyadi (2002) described seven new species belonging to the Pontellidae Family which were collected from several areas within Indonesian waters which are *Calanopia asymmetrica, Labidocera javaensis, L. muranoi, Pontella labuanensis, P. bonei, P. kleini and P. vervoorti*. Indonesia is the country with the richest fauna from the Pontellidae Family in terms of species and species-groups. At least 15 of the 20 known marine species-groups world-wide are found in Indonesia.

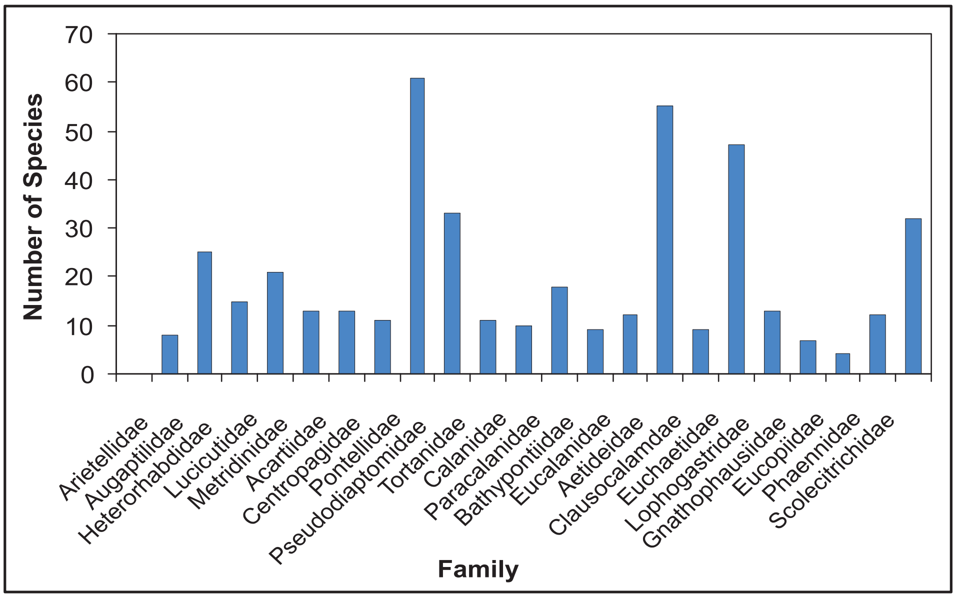


Fig. 4.3
The diversity of Calanoida in Eastern Indonesian Seas

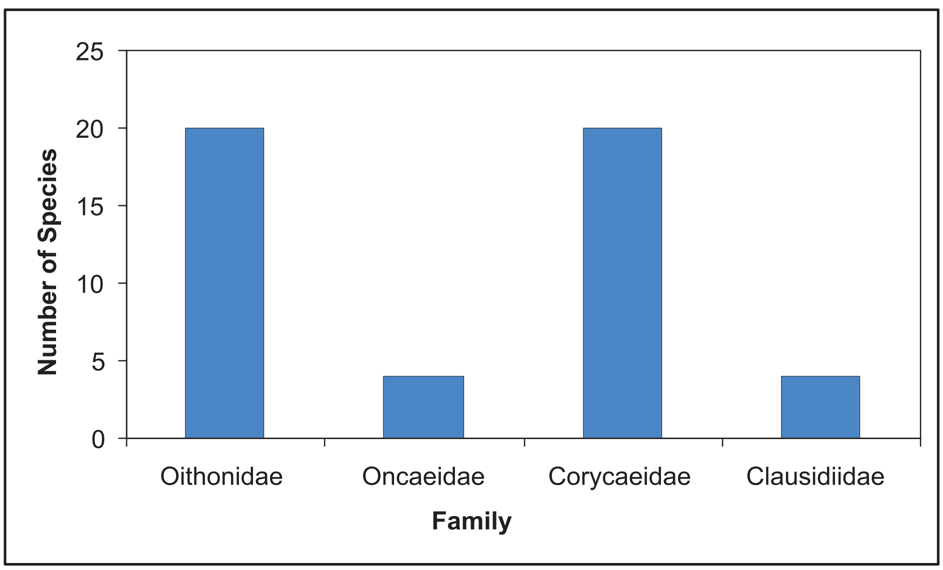


Fig. 4.4
The Cyclopoida and Poecilostomatoida Orders found in Eastern Indonesian Seas

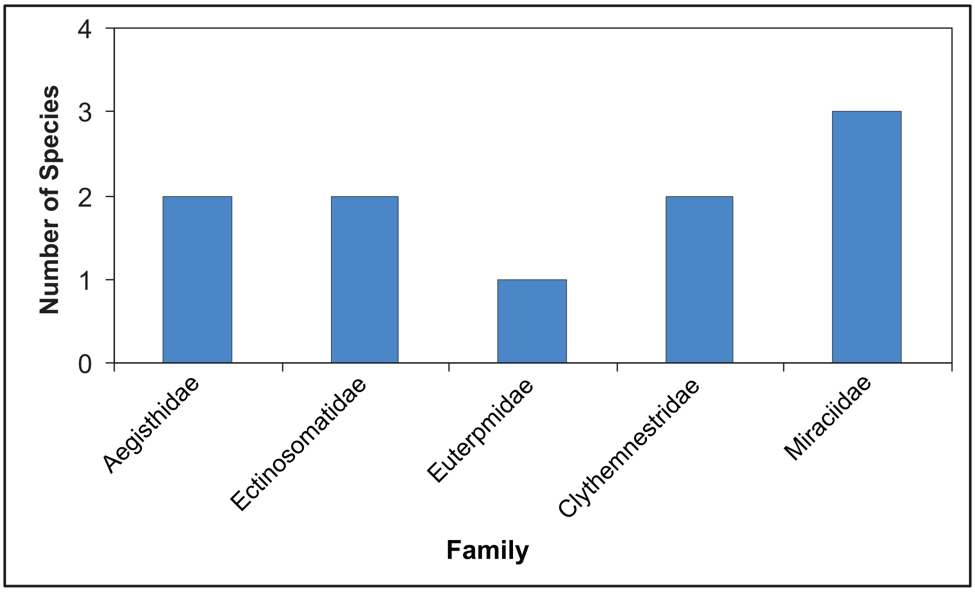


Fig. 4.5
The Harpacticoid Order found in Eastern Indonesian Seas

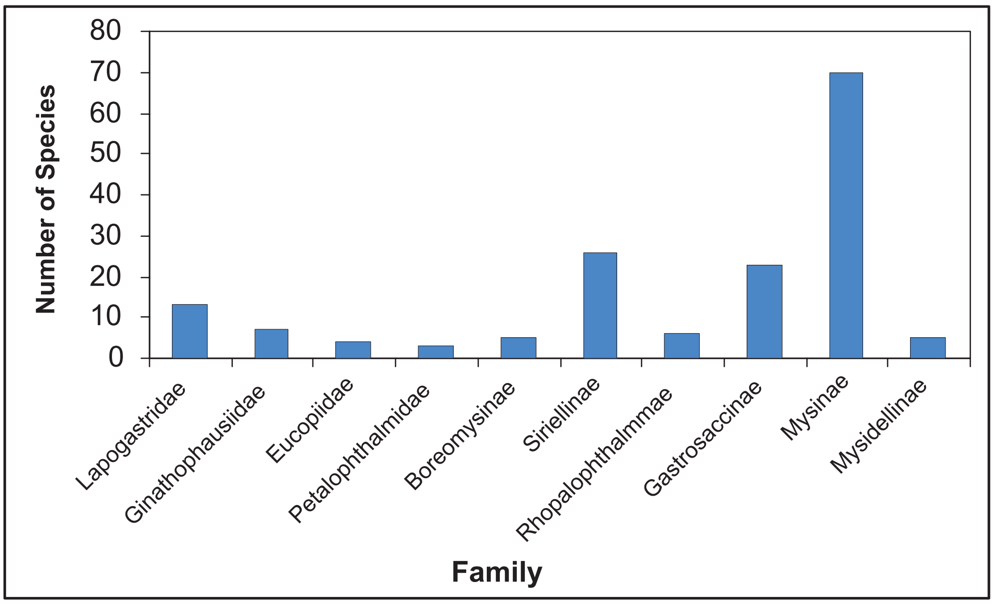


Fig. 35
The diversity of Mysidaceae in Eastern Indonesian Seas

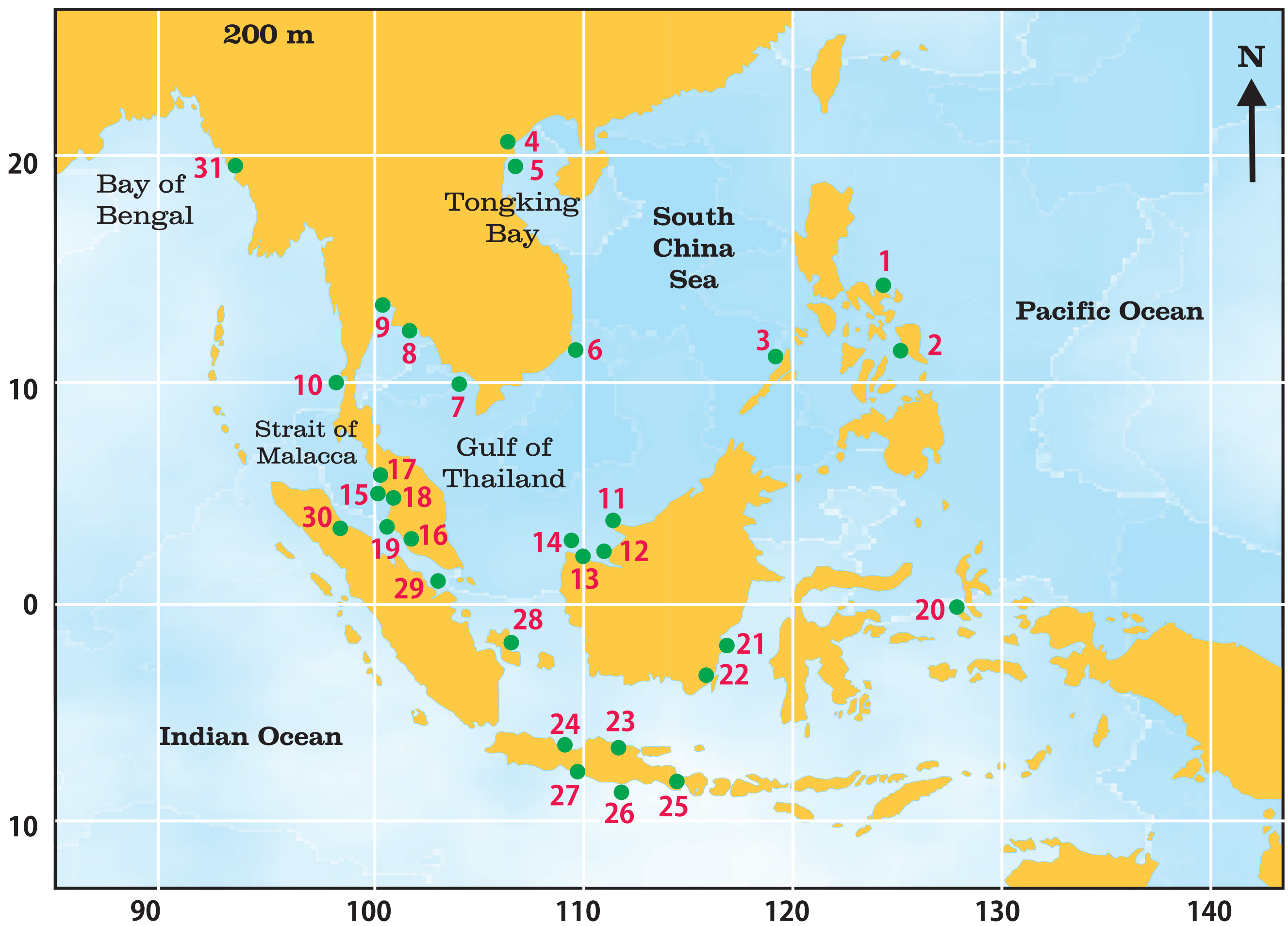
Another taxonomic group with high diversity is the Aetideidae Family with 55 species, whereas the family with the fewest number of species is the Eucopiidae. The Cyclopoida and Poecilostomatoida Orders are each represented by 20 species, followed by the Corycaeidae and Clausidiidae Families with four species each (Fig. 4.4). There are very few members of the Harpacticoid Order found in Eastern Indonesian Seas, they are represented by only five Families of which the Miraciidae are the most dominant (there species), followed by the Aegisthiidae, Ectonostomatoida and Clytemnestridae Families which are each represented by two species. Finally, the Euterpinidae Family has only one species, *Euterpina acutifrons* (Fig. 4.5).

In the Mysidacea group, the most diverse Family is the Mysinae (70 species), followed by the Siriellinae Family (26 species), and Gastrosacchinae (Fig. 35). There are 200 jellyfish species which have been reported from the Indo-Pacific which are dominated by the Anthomedusae with 91 species (45, 5%), followed by the Leptomedusae with 80 species (40%). The Laggiomedusae Family has the lowest diversity being represented by only two species. Up to the present time data regarding jellyfish diversity in the Arafura Sea and Timor Sea is still very limited. However considering that the environmental conditions (temperature and salinity) of the Arafura Sea and Timor Sea closely resemble that of the Indo-Pacific, it is very likely that most of the Indo-Pacific species will be found in these two sea areas (Fig. 4.7).

Fig. 4.7

Main fishing grounds of jelly fish in Southeast Asia.

(1). San Miguel Bay, (2). Carigara Bay, (3). Malampaya Sound, (4). Haiphon, (5). Tongking Bay, (6). Cam Ranh, (7). Phu Quoc Island, (8. Rayong, (9). Samut Sakhon, (10). Ranong, (11). Ulu Kuala Mutu, (12). Kabong, (13). Kuching, (14). Sematan, (15). Ipoh, (16). Kuala Lumpur, (17). Penang, (18). Pangkor, (19). Telok Anson, (20). Bacan Island, (21). Balikpapan, (22). Kotabalu, (23). Tuban, (24). Cirebon, (25). Muncar, (26). Prigi, (27). Cilacap, (28). Bangka Island, (29). Tanjung Balai, (30). Medan, (31). Sitrwe



Country	Fishing Ground	No. in Figure	Type	Fishing Season
Philippines	San Miguel Bay (Luzon) Carigara Bay (Samar and Layte) Malampaya Sound and Port Barton (Palawan)	1 2 3	White White White	Feb - May Feb - May Apr - May
Vietnam	Haiphon and Tongking Bay Cam Ranh (South China Sea) Phu Quoc Island (Gulf of Thailand)	4. 5 6 7	Sand White White	July - Sept Feb - Apr & July - Oct Oct - Mar
Thailand	Rayong and Samul Sakhon (Gulf of Thailand) Ranong (Andaman Sea)	8. 9 10	White & Sand White	May - July Dec - Mar
Malaysia	Matu (Sarawak) Kabong, Kuching, and Sematan (South China Sea) Ipoh and Kuala Lumpur (Strait of Malacca) Penang, Pangkor, and Telok Anson (Strait of Malacca)	11 12. 13.14 15. 16 17. 18. 19	Red White White, Red & River Semi-China	Feb - Apr & Aug - Dec Mar - Oct July - Sept July - Sept
Indonesia	Bacan Island (Halmahera) Balikpepan and Kotabalu (East Kalimantan, Makassar Strait) Tuban (East Java, Java Sea) Cirebon (West Java, Indian Ocean) Muncar and Prigi (West Java, Indian Ocean) Cilacap (West Java, Indian Ocean) Bangka Island (South Sumatra, Java Sea) Tanjung Balai and southern coasts (Strait of Malacca) Medan (North Sumatra)	20 21. 22 23 24 25. 26 27 28 29 30	Semi-China White White & Sand Sand Prigi Cilacap White River White	July - Aug Aug - Nov Mar - May & Sept - Nov Aug - Nov July - Nov Aug - Nov May - Nov May - Aug June - Dec
Myanmar	Sittwe (Arakan, Bay of Bengal)	31	White & Ball	Mar - May & June - Sept

Table 4.3
Main Fishing grounds and fishing seasons for various types of jellyfish in Southeast Asia

4.1.2 Crustacea

The crustacea are a group of marine organisms which vary greatly in body shape and size, live in the water column (pelagic) or on the sea bed (benthic), in fresh water (rivers, lakes), and salt water (estuaries, the inter-tidal zone, mangrove forests, seagrass beds, coral reefs) and down to depths of thousands of metres. There are at least 60,000 crustacean species in the world. Many Crustaceans such as shrimps and crabs are much prized as a delicious food. From an economic point of view, shrimps and crabs are important as earners of foreign exchange for the Nation. Ecologically, crustacea are an important food source for fish and other predators, conversely crustacea are often predators of other small creatures. Crustacean larvae form the major zooplankton component and are extremely important in the fish food chain.

Indonesia has a reputation as the centre of species richness of marine organisms or the centre of marine biodiversity so that many biologists are attracted to explore Indonesian waters. Several world-wide marine exploration expeditions made sure that Indonesia was included in the route of their voyages in order to investigate her marine biodiversity. In spite of this, it is still very hard to give an accurate estimate of the number of species which can be found in Indonesian waters.

A number of international expeditions such as the Challenger Expedition (1873-1876), Siboga Expedition (1899-1900), Snellius Expedition (1929, 1984), Danish Expedition to the Kei Island

SPECIES NAME:
Mastigias Papua
COMMON NAME:
Papuan Jellyfish
DISTRIBUTION:
Papua - Indonesia

SPECIES NAME:
Aurelia aurita
COMMON NAME:
Moon Jellyfish
DISTRIBUTION:
Atlantic Ocean - Indian Ocean

SPECIES NAME:
Cephea cephea
COMMON NAME:
Crown Jellyfish
DISTRIBUTION:
Indo - West Pasific

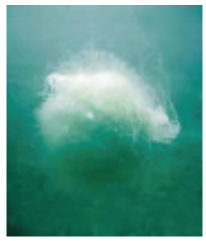
SPECIES NAME:
-
COMMON NAME:
-
DISTRIBUTION:
Kakaban Kalimantan

SPECIES NAME:
Catostylus mosaicus
COMMON NAME:
Blubber Jellyfish
DISTRIBUTION:
Philiphina, New Guina, West Coast

SPECIES NAME:
Crambionella orsini
COMMON NAME:
-
DISTRIBUTION:
Red Sea, Bengal Bay, Iranian Gulf

SPECIES NAME:
Crambione mastigopora
COMMON NAME:
-
DISTRIBUTION:
Malay Achipelago, Java, Truk Island

SPECIES NAME:
Rhizostoma pulmo
COMMON NAME:
shiff arms Jellyfish
DISTRIBUTION:
Meditranian, Bay of Biscay, North Sea and Black Sea



SPECIES NAME:
Lobonema smithii
COMMON NAME:
white Jellyfish
DISTRIBUTION:
Tropical water in the Indo -West Pasific

Fig. 4.8
Jellyfish species which have been reported from the Indo-Pacific

(1922), Galathea Expedition (1950-1952) Mariel King Memorial Expedition (1970), Alpha Helix Expedition (1975), Corindon Expedition (1980) and Karubar Expedition (1991) which were undertaken in Indonesian seas including the Arafura and Timor Seas have made important contributions to the body of knowledge regarding marine biota found in Indonesia. These expeditions and several other research activities in the Arafura and Timor Seas revealed that many species found in the Indo West Pacific are also found in the Arafura and Timor Seas, and in addition there are several species which so far have only been found in the Arafura and Timor Seas.

As a general rule, marine organisms can be classified based on their habitat, either coastal waters (from the coastline to the edge of the continental shelf at depths of around 200 m) or oceanic waters. The Arafura Sea and Timor Sea re renowned for the diversity of deep water species, especially following a number of expeditions such as the "Danish Expedition to the Kei Island (1922)" and Karubar Expedition (1991) which discovered many species new to science (Baba and de Saint Laurent, 1996; Chan, 1997; Chen, 1996; Cleva, 1997; Crosnier, 1994; Forest, 1995; Guinot, 1995; Guinot and Richer de Forges, 1995; Macpherson, 1997; McLaughlin, 1997, 2004; Lemaitre, 1997; Rahayu, 2005, 2006). Shallow-water species are also not lacking in diversity, especially those collected by the Snellius (1929), Rumphius (1975-1980), and Alpha Helix (1975) Expeditions (Buitendijk, 1937, 1960; Haig, 1979; Haig and Ball, 1988), and during research in the mangrove forests (Ng and Rahayu, 2002;

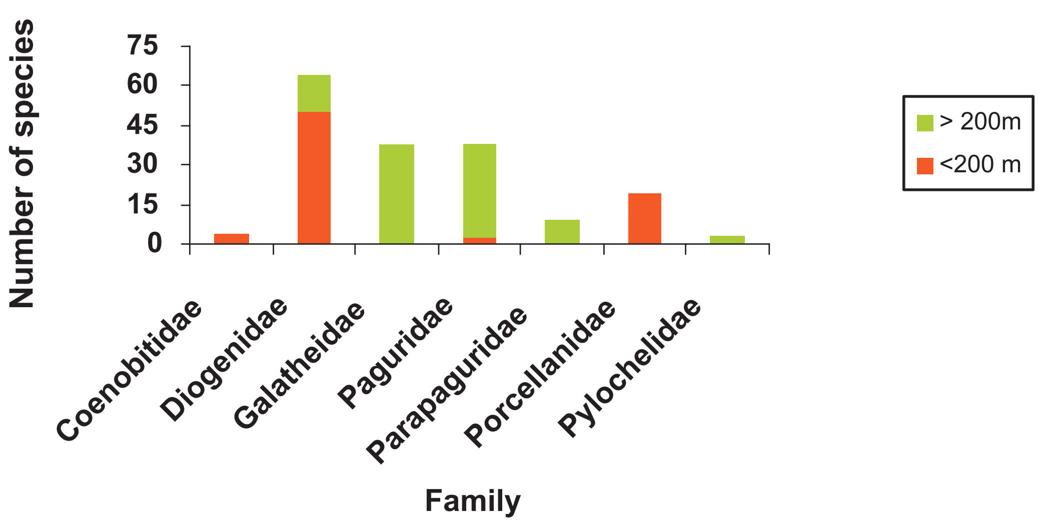
Rahayu, 2003; Rahayu and Davie, 2002, 2006; Rahayu and Hortle, 2002; Rahayu and Ng, 2003, 2004, 2005) as well as during research activities by the Ambon Balitbang Sumberdaya Laut, Puslit Oseanografi (Sub-centre for Marine Resources, Centre for Oceanographic Research).

In the past 50 years there has been a significant increase in the species list for Southeast Asia, not only for crabs (brachyura), but also shrimps and Anomura, with many new discoveries. A desk study revealed a total of 607 Crustacean species reported from the Arafura and Timor Seas. This is a surprisingly small number in view of the fact that the Arafura and Timor Seas are part of the Indo Malaysia area which is the global mega-biodiversity centre.

Based on a number of publications and collections which are available in the Centres for Oceanographic Research (Puslit Oseanografi) in Jakarta and Ambon, there are 607 species of decapod crustacea which have been found in the Arafura Sea and Timor Sea. In this report, crustacea are grouped into the Anomura which comprise hermit crabs and porcelain crabs, Brachyura comprising many crab species, and shrimps are divided into the Dendrobranchiata, Caridea and "other shrimps" category. This grouping is not based on phylogenetic principles.

There are 175 species of Anomura from seven families which have been found in the Arafura and Timor Seas (Appendix 5). Most of the members of the Coenobitidae, Diogenidae and Porcellanidae Families live in coastal (beach) and shallow-water habitats, whereas members of the Paguridae and Galatheidae Families are most often found in deep waters (Fig. 4.9). Two other families, the Parapaguridae and Pylochelidae, are only found in deep waters. Of these Anomura species, 15% (26 species) are endemic to the Arafura and Timor Seas based on the current state of knowledge (Fig. 4.10).

Fig. 4.9
Anomura species found in the Arafura and Timor Seas.

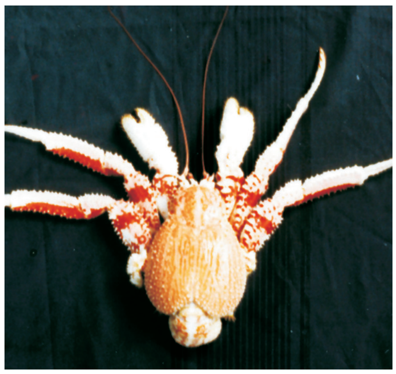


Clibanarius harisi:
For this moment this species is found only in Arafura sea (Timika coast).

Clibanarius rubroviria.
For this moment this species is found only in East Timor Island.

Parasesarma sp.
Unidentified sesarmid crab, found only in mangrove area in Arafura.(Photo taken by Agung Darmawan)

Perisesarma sp.
Unidentified sesarmid crab, found only in mangrove area in Arafura (Photo taken by Abdul Haris)



Tisea grandis.
A large hermit crab, found only in Timor Sea

Uca sp.
(Photo taken by Agung Darmawan)

Fig. 4.10
Anomura endemic species in the Arafura and Timor Seas.

Worldwide, there are at present 6,793 species of brachyura crustaceans (crabs) know to science, which are divided into 93 Families (Ng *et al.,* 2008). By the year 1964 around 2,500 brachyuran species had been found in Southeast Asia of which 1,000 species live in the Indo Malaysia area (Serène, 1964). In New Caledonia 352 species from 24 families of Brachyura have been identified (McLaughlin, unpublished data). Up to the present time, 306 species of Brachyuran crabs (Appendix 6) from 28 families have been identified from the Arafura and Timor Seas (Fig. 4.11 and 4.12).

Of this number the vast majority are species living along the shoreline and in shallow waters. In view of the extent and ecosystem diversity of the Arafura and Timor Seas (Laporan ATSEF, 2006) the number of species which has been found is considered to be low. Of the Brachyuran species found to date, 7 % (21 species) are currently considered to be endemic. The Majidae Family (96 species) is the most diverse, followed by the Xanthidae Family (30 species).

There are 122 shrimp species (Appendix 7) belonging to 21 families which have been found to date in the Arafura and Timor Seas (Fig. 4.13). In

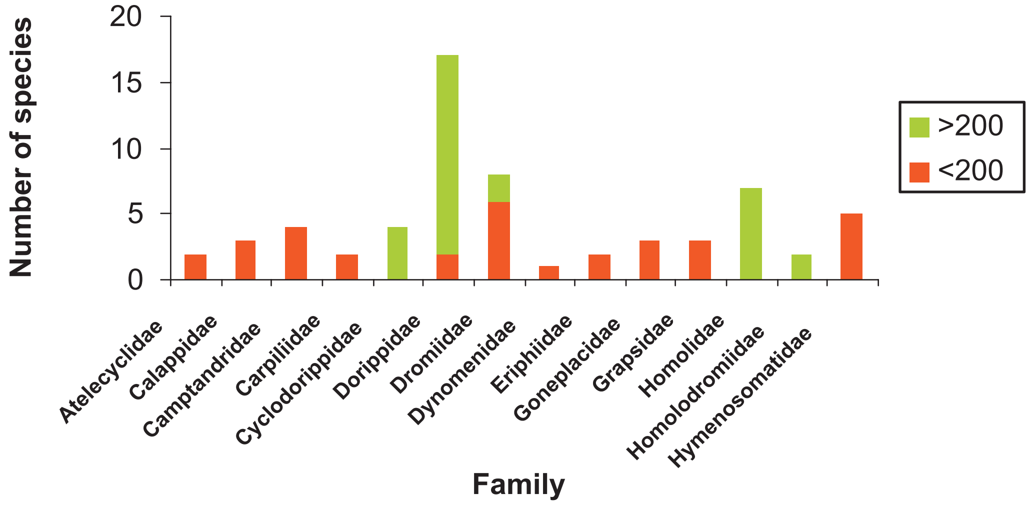


Fig. 4.11
Species of Brachyura crabs found in the Arafura and Timor Seas.

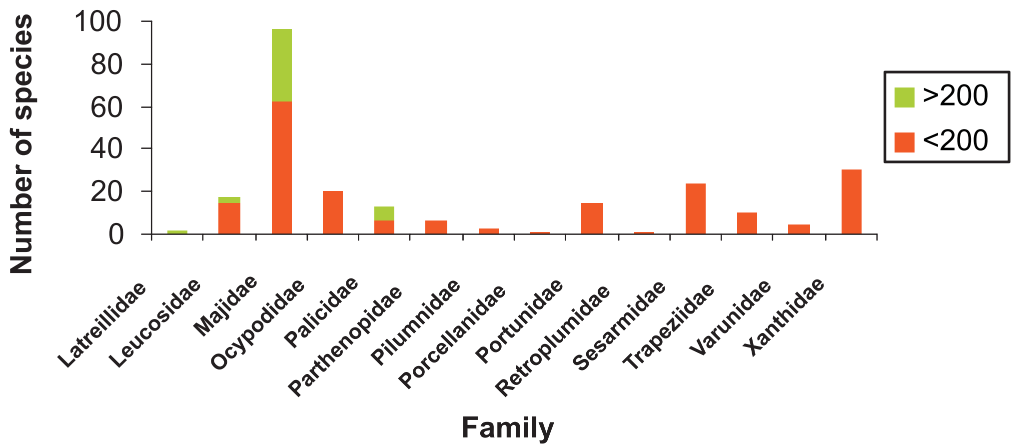


Fig. 4.12
Species of Brachyura found in the Arafura and Timor Seas.

this report shrimps are divided into theree groups. The first group comprise the shrimp species belonging to the Infra-Order Dendrobranchiata, the second group comprises shrimps belonging to the Infra-Order Caridea and the third category comprises shrimps belonging to other Infra-Orders (Astacidea, Thalassinidea, Palinurae, and Stenopodidae). Of the species in the Infra-Order Dendrobranchiata, only the commercially important Penaeidae Family of shrimps are found at depths of less than 200 meters. From the Infra-Order Caridea only species from the Alpheidae, Atyidae and Palaeomonidae Families are to be found in coastal waters.

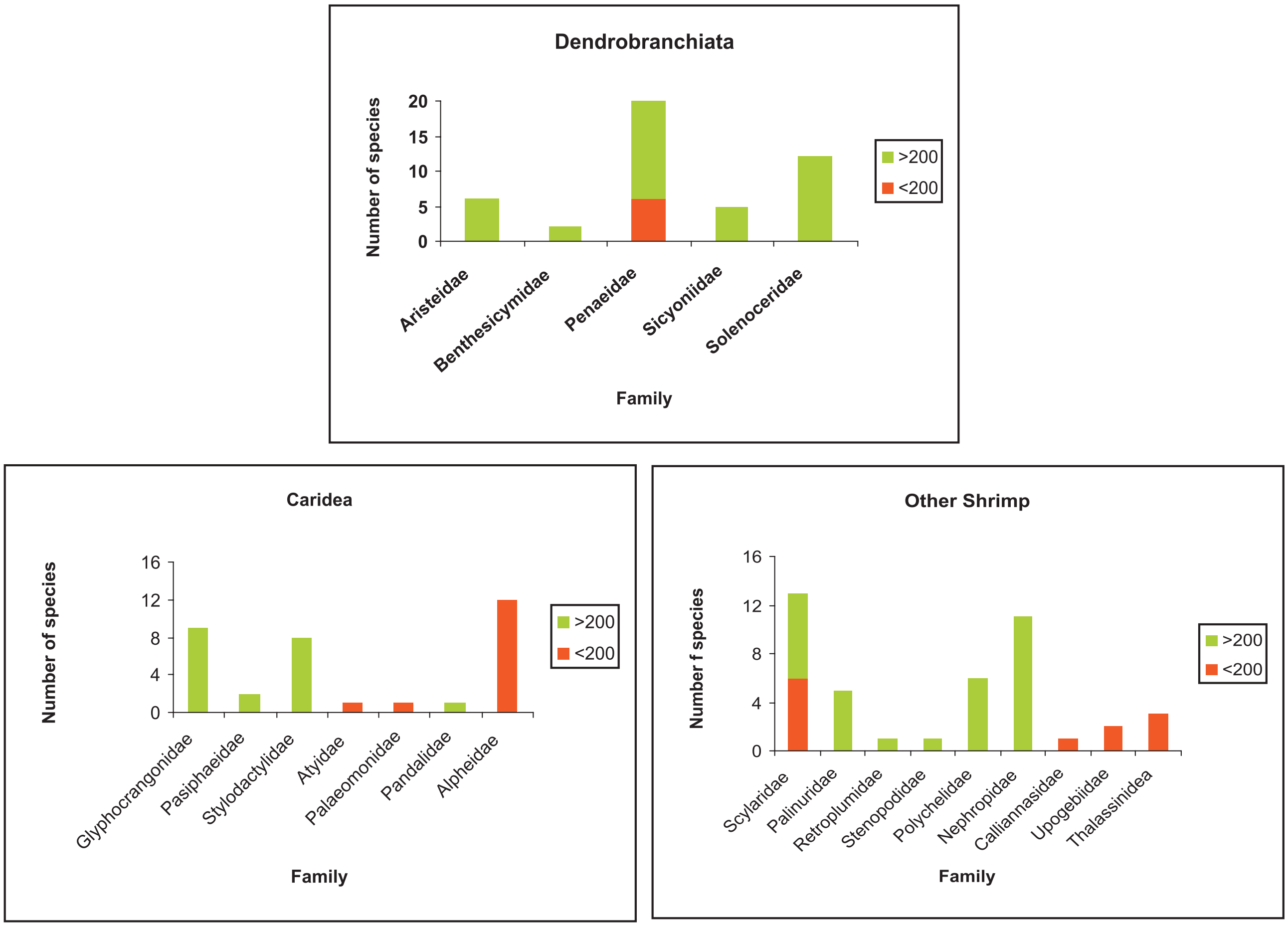


Fig. 4.13
Shrimp species found in the Arafura and Timor Seas.

Neoglyphea inopinata Forest and de Saint Laurent, 1975 (Fig. 4.14), is a living fossil which was first discovered in the Philippines, and has now also been found in the Timor Sea (Bruce, 1988) and the Arafura Sea (Sumiyono, 1994). Schram and Ahyong (2002) stated that "One of the more interesting crustacean discoveries of the last centuries was the recognition and description of *Neoglyphea inopinata* Forest and de Saint Laurent, 1975, a living member

Fig. 4.14
Neoglyphea inopinata Forest and de Saint Laurent, 1975), a living fossil which has been found in the Timor Sea (Bruce, 1988) and the Arafura Sea *(Source: Sumiyono, 1994)*

of a group long thought to be extinct since the Mesozoic". The finding of this living fossil was a very important discovery for both biologists and palaeontologists in terms of determining phylogenetic relationships within the crustacea.

One of the marine organisms which until now is still considered endemic to the Timor Sea is *Tisea grandis* Morgan and Forest (1991), a hermit crab species living at depth around 250 m. This species is very large so that it cannot find gastropod shells which are large enough to protect its body (Fig. 4.15). The soft body is folded below a shell which is hard and spiny. The Karubar Expedition in 1991 found two specimens of *T. grandis* which were still quite small and still making use of gastropod shells for protection and one specimen without a gastropod shell relative which spend much of it's life on land, which during the juvenile stage uses gastropod shells for protection while still small, and once it has grown larger cannot find gastropod shells of suitable size so that as a replacement the carapace hardens in order to protect the soft body.

Several shrimp species such as tiger shrimp species (*P. monodon, Penaeus semisulcatus*, *P. merguiensis*), metapenaeid shrimps (*Metapenaeus spp.*), and the shrimps known in Indonesia as *krosok* (*Metapenaeopsis spp.*) as well as crabs are a food which is considered delicious and much sought after. Fisheries for these species are a source of foreign exchange for the Nation.

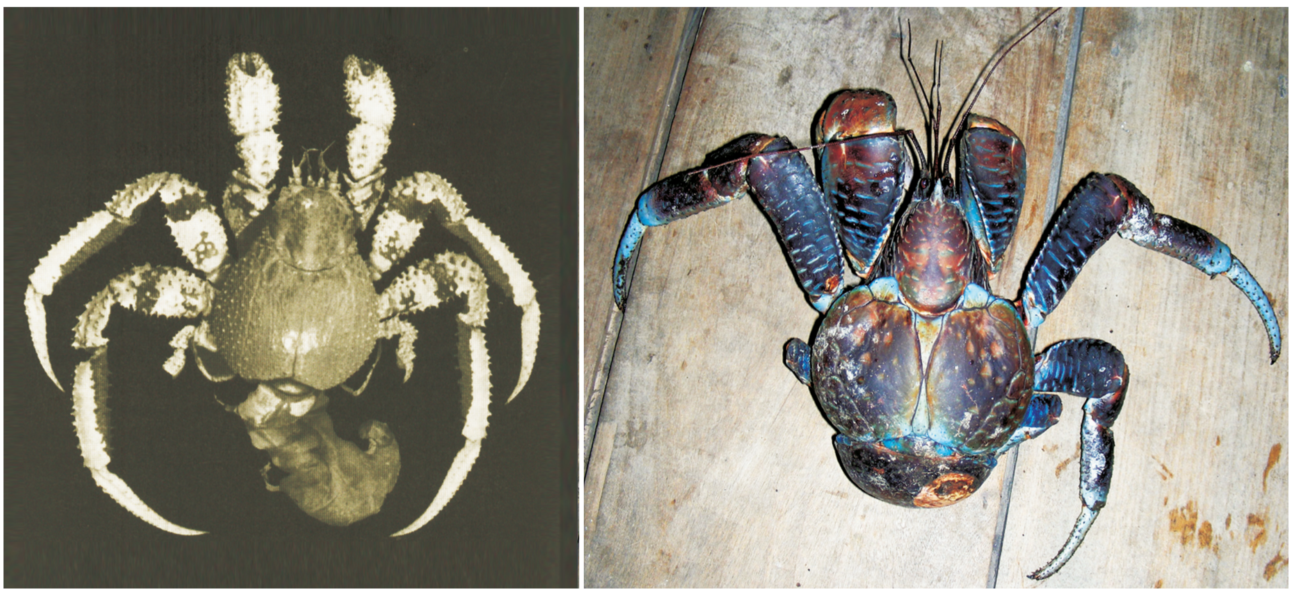


Fig. 4.15
Another interesting species found in Timor Sea is a large hermit crab, *Tisea grandis* Morgan and Forest, 1991 (named after Timor Sea "Tisea") that live in the deep sea (about 250 m).

(unpublished data). As stated by Morgan and Forest (1991), the hardened carapace is a form of adaptation to protect the body when gastropod shells of sufficient size cannot be found.

This hermit crab lives in similar manner to the coconut crab, *Birgus latro*, a hermit crab

Based on fisheries data for **shrimps** in the Arafura Sea from 1970-1978 which was the period in which industrial scale commercial exploitation of shrimps began by joint-venture Indonesian-Japanese companies, there are several interesting aspects which show up when this data is compared with exploitation data for the 1991-2002 period (Table 4.4).

For the period 1991-2002 there are two data sets available for establishing catch per-unit of effort, CPUE). The first is in the format 'tonnes/vessel/year' and the second is in the format 'tonnes/vessel/day' both of which indicate a relatively low annual variation, as is reflected in the coefficient of variance with values of 9.3% and 11.1% respectively, even though fishing effort was relatively similar. Conversely data for the period 1970-1978 shows quite high annual variations of 25.1% and 33.0% respectively. This can be interpreted as meaning that during the 1970-1978 there was a high fluctuation or wide range of CPUE. This phenomenon is normal during the early growth or development stage of a fishery, where there will sometimes be high catch levels and subsequently catches tend to be lower (Table 4.4).

It can be seen that during the early stages of exploitation CPUE was variable but relatively high. However during the period 1991-2002 the CPUE was relatively stable, so that the management status of shrimp resources in the Arafura Sea was considered to be in the "management phase." In this condition or management phase, it is necessary to carry out regular and strict monitoring of fishing activities. For example, the number of fishing vessels operating and the number of effective fishing days require serious attention which needs to be accompanied by monitoring to detect changes in the composition of the shrimp catch. These activities are very important remembering that production levels and/or MSY are often relatively constant form one year to the next, however the shrimp catch may become dominated by species or groups of shrimp which are smaller and have a lower economic value.

4.1.3 Sea cucumbers of the Arafura and Timor Seas

In Indonesia, the expression *teripang* is more popular than that of seacucumber. However, it is often not understood that the name *teripang* only refers to about 26 species out of over >350 seacucumber species which are known to live in Indonesian waters. Properly speaking, *teripang* are those seacucumber species which are traded in a dried form. In many national (Indonesian) scientific papers, the use of the expression *teripang* often gives rise to confusion because there is a lack of information regarding the taxonomy and biodiversity of seacucumbers in this country.

Table 4.4
Comparison between catch and effort figures for the periods 1991-2002 and 1970-1978.

Parameters	Unit of Effort 1991-2002		Unit of Effort 1970-1978 (Unar and Naamin, 1984)	
	Vessel	Day	Vessel	Day
Mean CPUE (tonnes)	73,5	0,28	57,5	0,29
Standard deviation	6,9	0,03	14,4	0,10
Coef. of variation (%)	9,3	11,1	25,1	33,0
Total No. of vessels	**1033**		**767**	

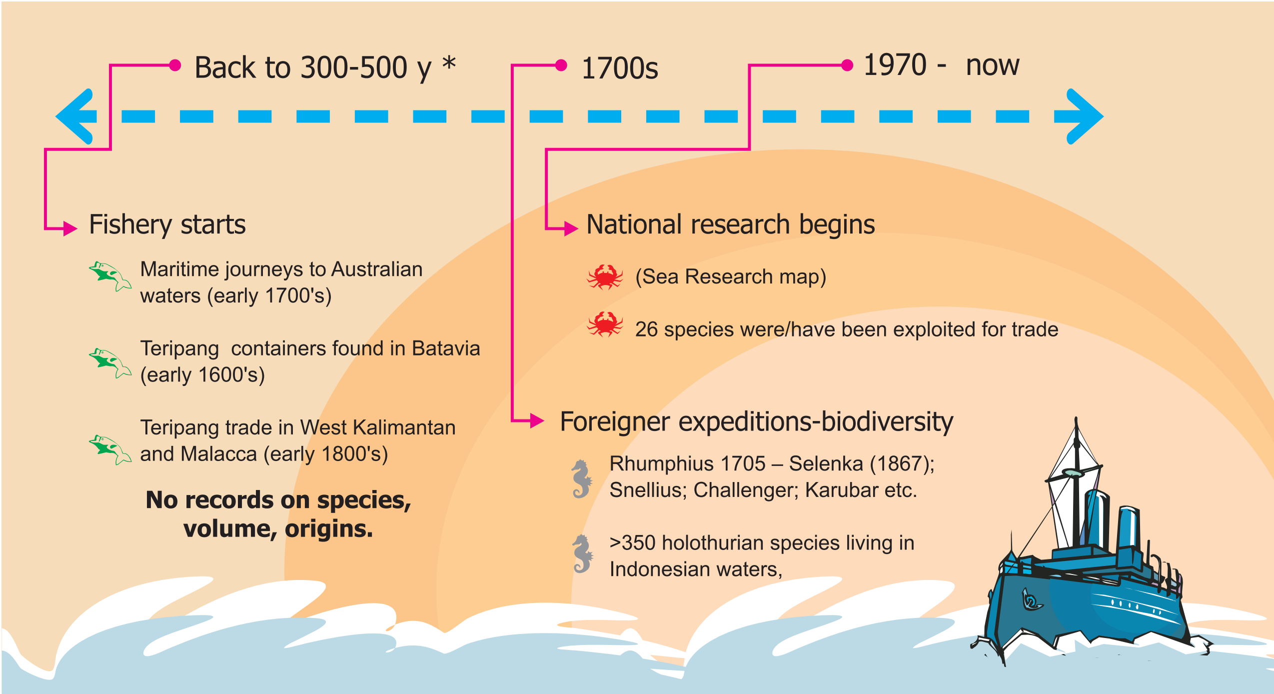


Fig. 4.16
History of Indonesian holothurians

In Indonesia seacucumber exploitation activities are much more intensive than research activities. Seacucumbers have indeed long been caught for sale outside the country. This fishery was well-known 500 years ago, and began as a trading link with the Chinese nation, who require seacucumbers for medicinal and health related uses (Macknight, 1978; Dwyer, 2000; Fox, 2000; Tagliacozzo, 2004). Research in the form of identification and naming species of seacucumbers by several nations who collected specimens in the Indonesian Archipelago only began during the late 1800's, whereas national publications only began to appear in the 1970's. (Fig. 4.16).

4.1.3.1 Seacucumber biodiversity

Investigations into Indonesian seacucumber biodiversity have mainly concentrated on the eastern waters. G.E. Rumpf began the process of inventory during the Rhumphius I Expedition in 1705, which was followed by a number of other foreign expeditions such as the Siboga Expedition (Sluiter, 1900), Snellius Expedition (1929-1930) right up to the Rhumphius IV Expedition (1990). Massin (1996) outlined the key researchers involved in determining the seacucumber biodiversity of Indonesia, including Linnaeus (1753), Selenka (1867), Semper (1868), Ludwig (1882, 1888), Theel (1886), Sluiter (1890,1894,1895,1901), Koehler (1895), Heidy (1828), and Rowe (1883).

Many seacucumber species were first known to science based on specimens from the waters of Eastern Indonesia. For example, the Siboga Expedition in 1899-1900 which explored the Timor, Banda, Flores, Maluku and Halmahera Seas, the Makassar Straits and the waters around Sulawesi from shallow areas down to depths of 3000 meters (Sluiter, 1900) recorded 184 species and of these, 46 were species new to science, found for the first time, consisting of six Holothuriidae, 28 Cucumariidae, six Molpadidae and six Synaptidae species.

The waters around Sulawesi and Maluku are an area where many species of tropical seacucumber were found for the first time (type localities), including species which were subsequently found to have wide distributions including *Actinopyga lecanora* Jaeger 1833, *Holothuria scabra* Jaeger 1833, and *H. atra* Jaeger 1833 (Massin, 1996). The collection activities by the Rhumphius II Expedition produced 93 seacucumber species of which 32 are considered endemic (Aziz, 1978).

During the 1990's, 2 more species were announced to the world after Massin (1996) identified seacucumbers collected from the waters around Ambon. Before this, the waters around Ambon were known to have 59 species. These two new species were *H. cavans* Massin and Tomascik (1996) and *Synaptula spinifera* Massin and Tomascik (1996) from Pulau Kakaban in the Sulawesi Strait (Massin and Tomascek, 1996), 10 new species were found from the Spermonde Archipelago, South Sulawesi (Massin, 1999) and *T. rubralineata* from the Alor Sea (Massin and Lane, 1991). The majority of seacucumber collection including the 'holotypes' of most species are kept in a number of Natural History Museums in Europe, especially in France, Holland and Belgium.

Worldwide around 1,200 species of seacucumber or Holothuroidea are known to science and have been grouped into 18 families. Of this number, 150 are shallow-water species

Table 4.5
Publications relating to Indonesian seacucumber

Topics	Authors	Remarks
Holothurians collected during Expedition Siboga in eastern Indonesia 1899-1900	Sluiter, C.P (1901).	46 new species out of 184 Holothurian species
Monograph of The Indo-west Pacific echinoderms	Clark, (2000)	Many species are potentially found in Indonesia
Species check list of Echinoderms of Banda Islands	Aziz, A. (1999)	32 endemic species out of 93 Holothurian species
Species list of holothuroids, echinoids and asteroids (Echinodermata) collected by the expedition Snellius II	Jangoux et al., (1989)	40 species including those collected from >700 m depth. (10 new species, 3 new records for Indo Malaysia
A new species Thelenota rubralineata	Massin, C., and. Lane, D.J.W (1991).	Lane (1999) describes the distribution in Indonesian waters
Description of Holothuroidea collected from Ambon during Rhumphius Expedition 1990	Massin, 1996	59 species (2 new species, 2 species new for Indonesia, 2 species new for Ambon)
Two new species from Kakaban Island, East Kalimantan	Massin, C., and T. Tomascek (1996).	Holothuria (Lessonothuria) cavans and Synaptula spinifera
Description of Holothuroidea collected from Spermonde Is.	Massin, (1999)	10 new species amongst 59 Holothurian species
Stichopodidae collection RC Oceanography-LIPI	Wirawaty et al. (2007)	7 species

and 114 are members of the Genus Holothuria (Clark, 2000; Rowe, 1969). At least one member of each family can be found in Indonesian waters. The Snellius II Expedition (1984-1985) recorded 40 species from a depth of 730 m. Of these, 10 species were new to science, and 3 were species found for the first time in Indo Malaysian waters (Jangoux *et al.,* 1989). At the present time, at least 350 species have been identified from Indonesian waters (some of which were collected by the Siboga Expedition and later identified and published by Sluiter in 1901). Sadly, in Indonesia we do not yet have sufficient material proof of this wealth of seacucumber species, including the results of systematic studies.

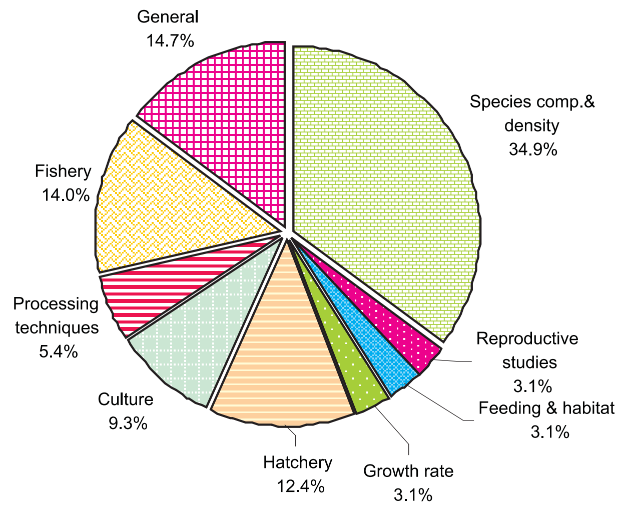


Fig. 4.17.
Trends in Indonesian seacucumber research, based on national publications *(Source: Purwati and Darsono (2007)*

Table 4.6
State of knowledge regarding seacucumbers in Indonesia and the Arafura and Timor Seas

Status Indicator	Indonesia	Arafura and Timor Sea	Notes
Number of species	>350	at least 54	Sluiter 1901, Massin and Lane 1999, Purwati (unpublished report)
Number of endemic species	Several in the Banda Sea and around Maluku	Not yet known	
Species of commercial value	26	at least 14	For the AT Seas: species have been confirmed, production trends are downwards, *H. nobilis* and *H. scabra* are threatened with extinction
Regulations	absent	absent	
Abundance, local distribution	Already estimated for species	Not yet known	(compilation, unpublished report)
Reproduction	*Holothuria scabra* in Ambon, Makassar, Lampung	Maybe the same	(Purwati, 2006)
Breeding	Ambon, Lampung, Bali	Not yet	Purwati and Darsono (2007)
Research into habitat preference	Research in West Lombok	Not yet	Purwati et al.(2006)

Although reports/publications regarding seacucumber biodiversity and abundance form around 1/3 of national seacucumber publications (Fig. 4.17), taxonomic studies are not included. Just recently (Wirawati *et al.,* 2007) began by identifying members of the Stichopodidae Family which had been kept in the collection of the LIPI Puslit Oseanografi (Centre for Oceanographic Research) in Jakarta. Further collections are now being prepared, from the waters of Western Lombok (Nusa Tenggara Barat) and South Timor as well as from Rote. The national collection kept by this Institute consists of specimens collected over the past 30 years and has yet to reach 500 specimens, very few of which originate from the Arafura and Timor Seas. It is clear that there needs to be a continuing push for further surveys and sample collection in order to prove the high seacucumber biodiversity of Indonesia, which is also a rich part of the world heritage.

Information on the distribution and abundance of seacucumbers based on the ecological reports which are available include several commercially exploited species such as *T. ananas, H. nobilis, H. atra,* and *H. scabra* (Fig. 4.18).

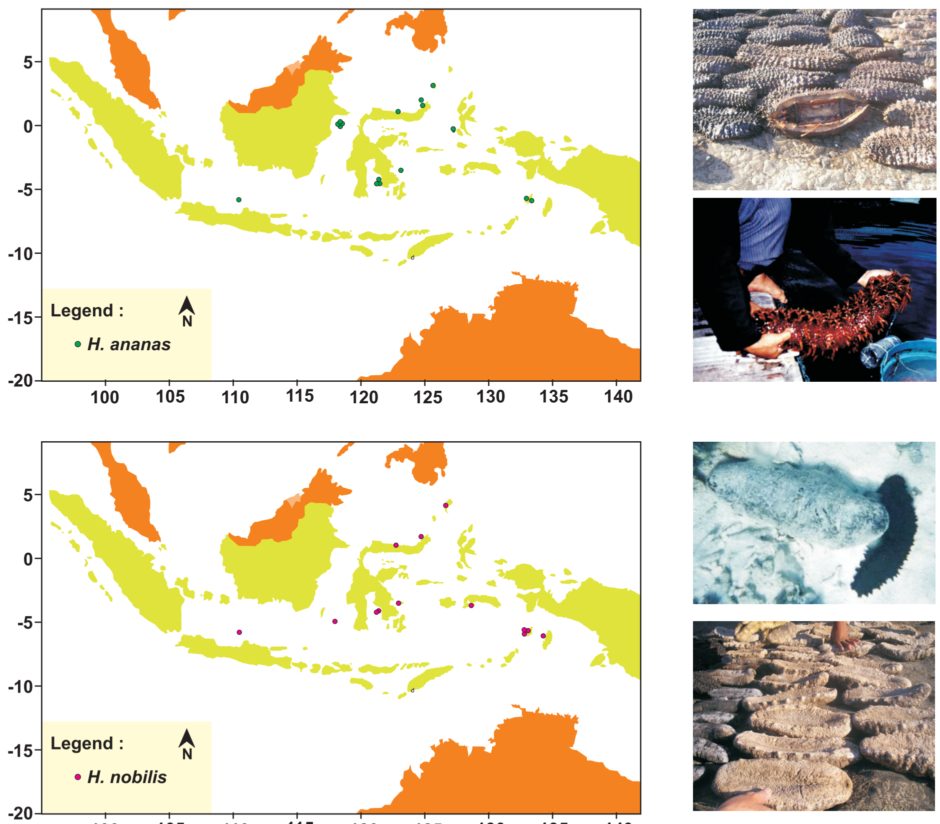
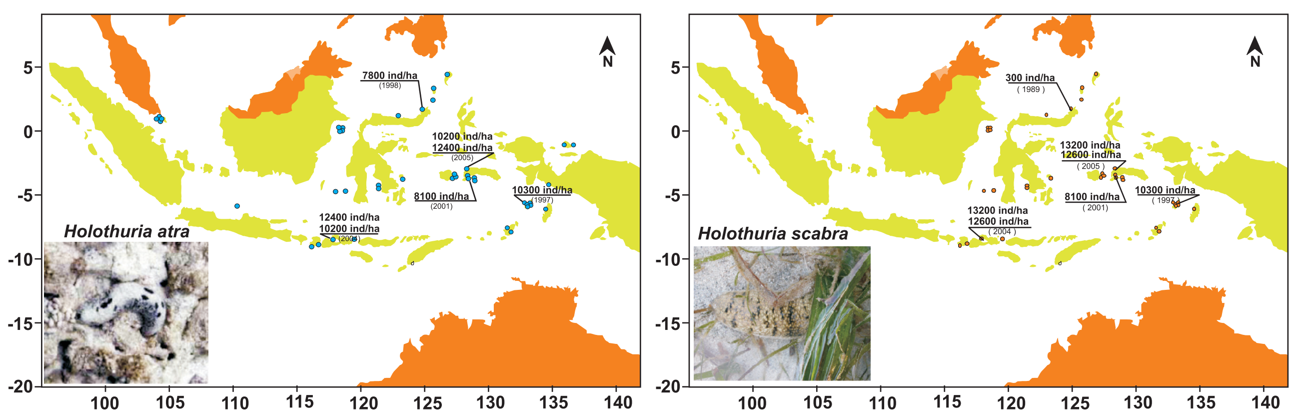


Fig. 4.18
Distribution of *T. Ananas* and *H. Nobilis* (above) and density of *H. Atra* and *H. Scabra* in several areas (Below)



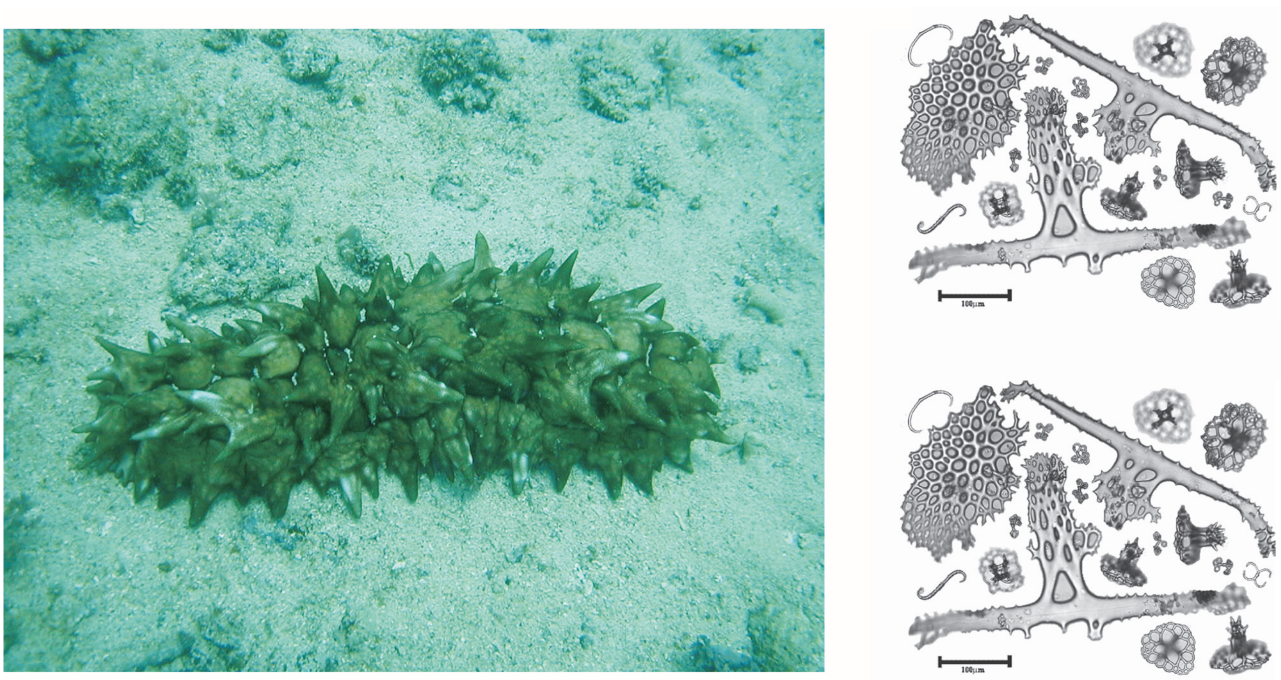
As far as can be determined from available data, at least 53 seacucumber species can be or were once found in the waters of the Arafura and Timor Seas, spreading from Rote, the South side of Timor Island, the Tanimbar and Aru Archipelagos and Timika to Merauke. These seacucumbers were collected at depths ranging from a few metres down to > 2000 m.

Coming back to Sluiter (1901), several species were found for the first time, including 5 species of Cucumaria, *Thyone discolor* and *Colochirus squamatus*. Alor and Timor are the 'type locality' for the large seacucumber *Thelenota rubralineata* Massin and Lane 1990. The distribution of this species includes Komodo Island, the Banda Archipelago, Manado and Bunaken (North Sulawesi) (Lane, 1999; Massin and Lane, 1991).

It is highly likely that many more species will be discovered in the waters of the Arafura and Timor Seas if biodiversity surveys are undertaken more frequently. Compare [the list of known species] with nearby areas such as the seas around Ambon in Central Maluku, where such survey have been undertaken on several occasions (including the Rhumphius I to IV Expeditions), and 59 seacucumber species have already been recorded from this area which is only around 15-25 % as large as the Arafura and Timor Seas.

Just recently, a number of species such as *A. lecanora, S. chloronotus, H. fuscogilva, H. nobilis, T. ananas* and *T. anax* which are species frequently caught by fishers were identified (Purwati, unpublished report). Apart from these, a number of more rarely reported species such as *Actinopyga albonigra* Cherbonier and Feral 1984, *A. bannwarthi* Panning 1944 and *Stichopus pseudohorrens* Cherbonier 1980 are found in the waters around Timor Island at depths of less than 20 m. These three species are very likely new records for Indonesia.

Fig. 4.19
Stichopus psesudohorrens Cherbonnier 1967 from Timor Sea, could be a new species found in Indonesia.



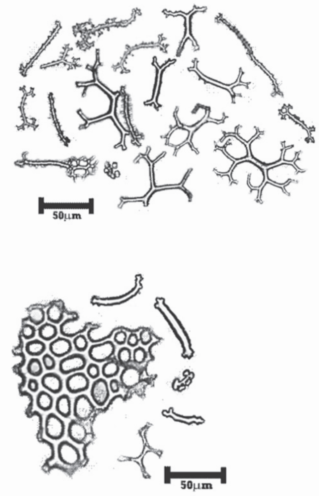


Fig. 4.20
A holothurian Recently found in Timor Sea, *A. Bannwarthy* Panning 1944, possibly new record to Indonesian waters

The extent or abundance of the seacucumber resources in the Arafura and Timor Seas is not yet known, whereas the capture fishery continues apace. Survey and research activities are badly needed not only regarding biodiversity but also the distribution and abundance patterns as a basis for evaluation and monitoring in order to achieve sustainable exploitation.

4.1.3.2 Seacucumber Exploitation

Traditional fishers such as the Makassar, Bajo and Bugis ethnic groups can be said to play a major role in the teripang fishery. Going back to the 17th Century, these fishers sailed South as far as Northern Australia to collect teripang, along with sharks and molluscs, which they traded to Chinese merchants from the Malaysian peninsular (Campbell and Wilson, 1993; Clark, 2000; Dwyer, 2001; Macknight, 1978; Stacey, 2001; Ham, 2002). This long history places Indonesia as the oldest teripang producer in the world (Conand and Byrne, 1993; Fox, 2000; Morgan and Archer, 1999).

When advances in biodiversity and ecological research lag behind exploitative activities, changes in the species composition or falls in the catch volume which often lead to an increase in prices, can be an indicator of a reduction in wild stocks. As with most teripang producing countries in the tropical Pacific, Indonesia does not yet separate teripang produce based on species, so that it is hard to know which species and find out which (fishing ground) areas need special attention as a result of intensive fishing. Ecological studies give an indication that seacucumbers are already scarce in many sea areas, for example the Seribu Archipelago in the waters off Northern Java (Aziz and Darsono, 1997), the Spermonde Archipelago in South Sulawesi (Conand and Tuwo, 1996; Tuwo, 2005; Tuwo and Conand, 1992), and in Nusa Tenggara Timur (Gimin *et al.,* 2005).

International trade statistics show that Indonesia is no longer the largest producer of teripang in recent times, even though national statistics show the reverse. Other noticeable phenomena are a reduction in market price due to poor quality of the product (poor post-harvest treatment) and the capture of seacucumber species which are less favoured by the market, so that fishermen tend to increase the intensity of capture effort, in terms of species and size range, in order to make more cash (Conand, 1990; Conand and Byrne, 1993; Purwati and Yusron, 2007). These factors have meant that pressure on seacucumber resources/diversity is ever increasing.

Of the 26 species which have been reported as species which are fished, all are members of the Order Aspidochirotidae (Purwati, 2005). In comparison with the number of species traded in international markets (43 species) (Toral-Granda, 2006), this list comprises more than half of them. All these seacucumber species are medium or large in size and all are taken from the wild. Several of them are T. ananas, T. anax (large size), H. scabra, H. nobilis, A. lecanora and B. argus (medium sized). H. scabra (known as sandfish/teripang pasir/teripang gosok) and H. nobilis (known as teatfish/teripang susu/koro susu) are the species with the highest market value (Purwati and Yusron, 2007, Gimin *et al.,* 2005).

Teripang are one of the marine commodities which have driven the movement of sea-faring ethnic groups including the Bajo, Makassar, Bugis and Madurese to Nusa Tenggara Timur (NTT) (Pranoto 2007). NTT is the province which bounds and administers a substantial part of the Arafura and Timor Seas, and has long been the last staging post for traditional fishers during their voyages to Australia. Some of these fishers eventually settled in various places along the coastline especially in Rote, where they continued their traditional activities fishing for teripang, shark fin and several molluscan species.

Reports from the NTT Fisheries and Marine Service indicate that in 2004, 16% (or in value

Fig. 4.21
A Trepang from Aceh Singkil (a); sun dried H. scabra in Bintan I. (b); a canoe full of fresh sea cucumbers in Kaimana, West Irian (c) and dried ones in East Nusa Tenggara (d) .

terms 390 million Rupiah per year) of the provincial income came from teripang. Of this teripang harvest, 18% was produced by Kupang District (Gimin *et al.,* 2005).

NO.	Species
1.	*Actinopyga lecanora* (Jaeger, 1833)
2.	*Bohadschia argus* Jaeger, 1833
3.	*Bohadschia marmorata* Jaeger, 1833
4.	*Holothuria (Halodeima) atra* Jaeger, 1833
5.	*H. (Halodeima) edulis* Lesson, 1830
6.	*H. (Metriatyla) scabra* Jaeger, 1833
7.	*H. (Mertensiothuria) leucospilota* Brandt, 1835
8.	*H. (Microtele) nobilis* (Selenka, 1867)
9.	*H. (Microthele) fuscogilva* Cherbonnier, 1980
10.	*H. (Microthele) fuscopunctata* Jaeger, 1833
11.	*Pearsonothuria graeffei* (Semper, 1868)
12.	*Stichopus chloronotus* Brandt, 1835
13.	*Thelenota ananas* (Jaeger, 1833)
14.	*T. anax H.L.* Clark, 1921

Table 4.7
List of seacucumber species caught in Kupang, NTT

Up to 2005, in Kupang and Rote (East Nusa Tenggara), seacucumber fishing expeditions could still earn tens of millions of rupiah per trip (7-14 days). In 2007 and early 2008, the catch was dominated by *T. ananas* and *A. lecanora*, with values of Rp.35,000,-/individual with sizes of 30-50 cm and ± 20 cm respectively (Table 4.7). Seacucumbers are sold to the local collector/trader after salting or in a semi-cooked form. Two species are now very rarely found: *Holothuria scabra* (sandfish, *teripang pasir*) and *H. nobilis* (black teatfish or *teripang susu*), and their populations are most likely threatened with (local) extinction, although these species can still be found quite easily in some other parts of Indonesia.

The capture of seacucumbers in the wild is undertaken down to depths of 20-30 m^2. Below this, exploration activities for seacucumbers are not yet or very rarely undertaken. Surveys are necessary with all the attendant consequences in order to prevent the loss of species whose existence we have never even known (been aware of).

4.1.4 Fish and fisheries

From a social point of view, all capture fishery activities especially the industrial scale fisheries operating in the Arafura Sea and Timor Sea is economic activities which employ a large workforce.

4.1.4.1 Species diversity

Comprehensive information on the fish in the Arafura Sea is still very limited, but the results of several previous research activities regarding the fish fauna Arafura Sea, especially off-shore fish, were compiled and published by Russel and Houston in 1989. In the Arafura Sea, 527 fish species have been recorded, belonging to 141 families, consisting of fish with a wide Indo-Pacific distribution. Most of these fish are caught using bottom trawls (93.2%), and there are 10 dominant families which comprise around 34% of the total fish composition which are the Carangidae, Lutjanidae, Carcharhinidae, Leiognathidae, Nemipteridae, Platycephalidae, Serranidae, Scorpaenidae, Mullidae, and Bothidae (Russel and Houston, 1989).

A collection of the fish species of the Arafura Sea was made from 2000 to 2006 (Haris *et al.,* 2008). This collection consists of 133 species from 50 families. The families with the greatest number of species are the Arridae, Carangidae, Scianeidae, Engraulidae, Leiognathidae, Dasyatidae, Cynoglossidae, Tetraodonthidae, Clupeidae and Soleidae (Haris *et al.,* 2008).

The most up-to-date information on fish in the Arafura Sea was compiled from data which represents off-shore waters (Russel and Houston, 1989) and inshore waters and estuaries (Haris *et al.,* 2008). From the results of this compilation there are 538 species of fish belonging to 133 Families (Appendix 8). All of these species are already listed in *Fishbase* (Froese and Pauly, 2008). The number of Families is somewhat less than that given in the compilation by Russel and Houston (1989), most probably due to changes in classification since 1989.

The fish species known as Red Snapper are high value demersal fish of economic importance which are frequently caught in Indonesian waters. These fish are generally caught in the waters over the continental shelf. Several species of snapper are found in habitats with some coral reef formation (Talbot, 1960). All snappers are members of the family Lutjanidae. A few of the genera which have been found in the waters of the Southern Indian Ocean, NTB and NTT include *Lutjanus, Pristipomoides, Symphorus, Paracaesio, Aphareus, Etelis, Pinjalo,* and *Glabrilutjanus*, all of which are demersal fish of economic value.

Fish from the Genus *Lutjanus* are more frequently found in relatively shallow waters whereas *Pristipomoides*, known as '*deep-sea snapper*' in Australia, is more often caught in deeper waters (Ramm, 1995).

It is well-known that limits have been placed on the exploitation of demersal fish and especially snapper in the waters of the Australian sector of the Sahul Shelf, and that the issue of licences to foreign fishing vessels has been stopped. The results of research by Australian scientists regarding stocks of the deep-sea snapper known in Indonesia as *kurisi bali* (*Pristipomoides multidens*) through examination of mtDNA, provided information that the population in the Indonesian sector is thought to consist of 5 separate genetic stocks based on samples taken from (1) Jimbaran/Bali, (2) Sape/Tj.Luar, (3) Kupang and (4) Probolinggo, whereas the sample from Tual seems to be from the same genetic stock as the samples from Townsville/Northern Queensland.

A survey voyage by the research vessel KAL Baruna Jaya I in the Timor Sea EEZ indicated that snappers (*Lutjanus spp., Etelis spp.* and *Pristipomoides spp.*) and emperors (Lethrinidae) were to be found at depths of over 100 m in this area. (Survey Team, 1993). Ramm (1995) reported that the estimated potential yield of '*deepwater snapper, Pristipomoides*' in the Australian sector was around 2,988-9,516 metric tons, whereas the catch based on the '*limited entry*' system was 1,500 metric tons.

In line with the rise in demand for snapper and similar species on the local, national and world markets, efforts to increase production need to be supported by research regarding stocks and exploitation patterns which can provide an optimal and sustainable catch. If efforts to use the fishery stocks in the Indian Ocean/Timor Sea EEZ are carried out in an optimal fashion which is guaranteed sustainable, this will not only be a use of local resources for human welfare but also fulfil part of the international responsibility (of Indonesia) in strengthening the *Wawasan Nusantara* principle.

The initial results of studies of *L. malabaricus* which have been collected across Indonesia are not genetically different from fish of the same species found in the Australian sector, so that this snapper population is considered a '*shared stock*' (Fig. 4.22).

The catch composition of snapper caught by bottom liners operating in Eastern Indonesia based in Probolinggo as follows: 65% from the family Lutjanidae, 6 % Carangidae, 18 % Carcharhinidae 5 %, Serranidae 3 % and the remainder are from the Ariidae and Lethrinidae. The percentage of each of the Lutjanid species is 16.6 % *L. malabaricus,* 15.9 % *L. erythropterus,* 4.8 % *L. sebae,* 1.5 % *L. bohar,* 1.2 % *L. russelli,* 1.5 % *L. johni,* 3.1 % *L. fulviflama,* 2.5 % *L. lutjanus,* 1.8 *Lutjanus sp.,* 4.0 % *Pristipomoides multidens,* 5.3 % *P. typus,* 1.5 % *P. filamentosus,* 3.1 % *Pinjalo pinjalo* and 1.3% *Aprion virescens.*

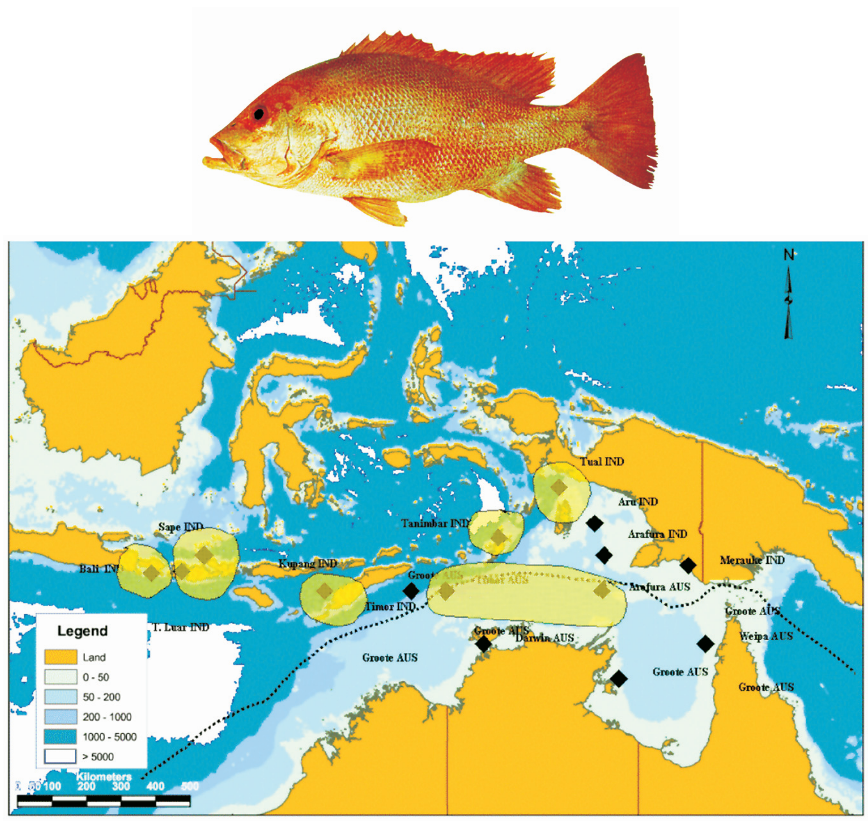


Fig. 4.22
Inferred stock boundaries for *L. malabaricus* (Anonymous, 2003)

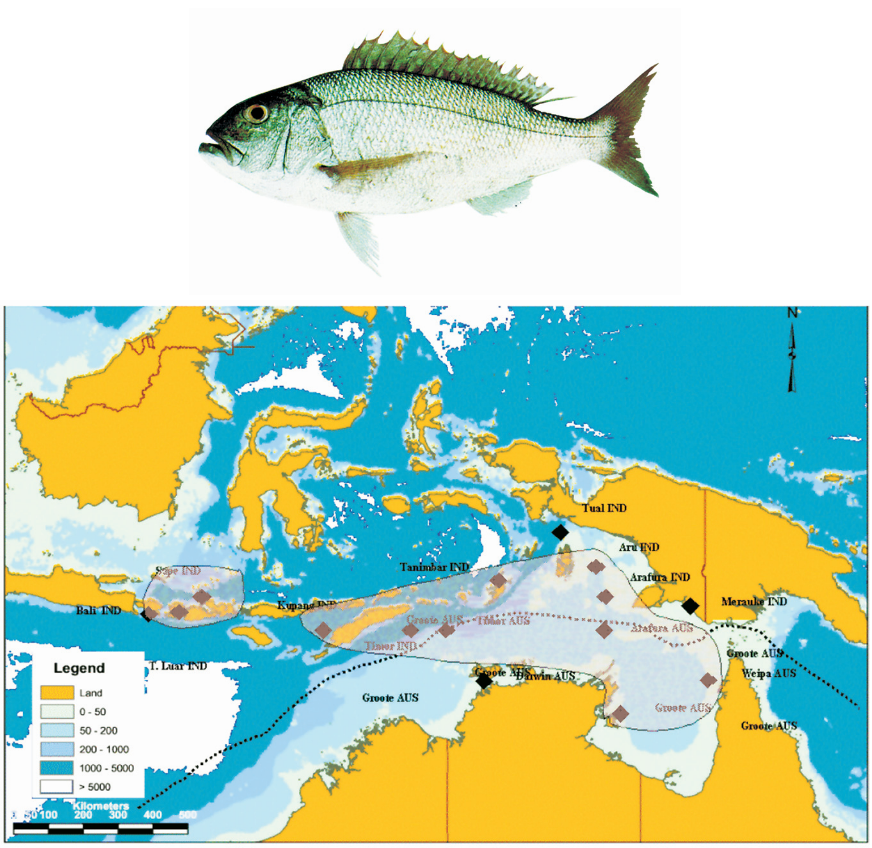


Fig. 4.23
Inferred stock boundaries for *Pristipomoides multidens* (Anonymous, 2003)

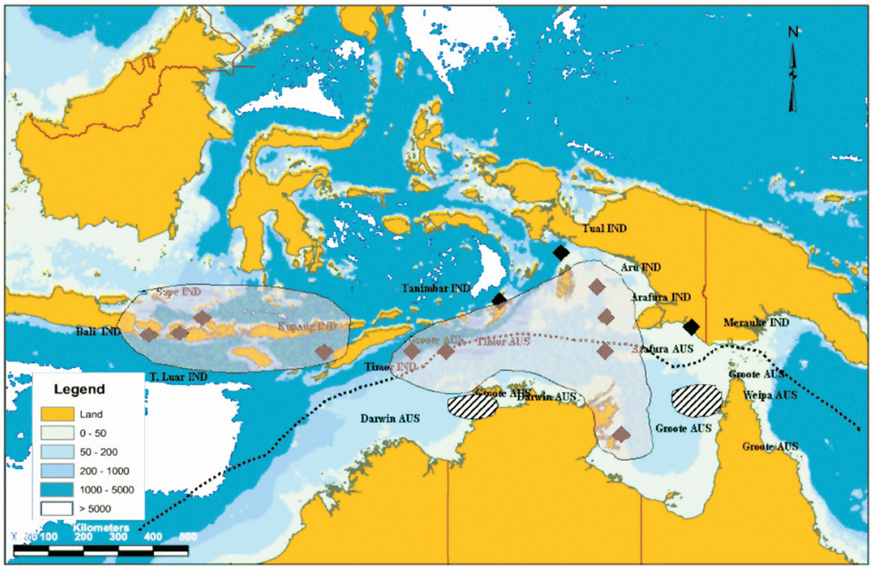


Fig. 4.24
Inferred stock boundaries for *Lutjanus erythropterus* (Anonymous, 2003)

Sharks and rays are known collectively as cartilaginous fish, whereas other fish species are known as bony fish. The difference between these two groups is that bony fish have hard skeletons, whereas cartilaginous fish have skeletons formed of softer cartilage. Other differences which can be readily seen are that the mouths of cartilaginous fish are on the underside of the head, and that male fish have sexual organs called claspers.

There are currently 3 families (38 species) of Chimaera known to live in the sea, which are often found in the deep seas, over the *continental slope*, and several species also live in shallow near-shore waters.

The main distinguishing traits of Chimaera are the shape of the head, the shape and position of the fins, the relative distance between the first dorsal fin and the hard spines, the dental structure, and colour. Adult fish are around 50 – 200 cm long. All Chimaera species are oviparous and their main prey is invertebrates which live on the sea bed.

Table 4.8
Shark and Ray Families and species found in Australia and the Arafura and Timor Seas.

	Group	Family	Species
Australia	Sharks	27	166
	Rays	16	118
	Chimaera	2	12
	Total	**45**	**296**
Arafura and Timor Seas	Sharks	15	64
	Rays	11	41
	Chimaera	1	2
	Total	**27**	**107**

Group of Fish	Family	Spp.	Species (Latin)	English
Sharks	Carcharhinidae	1	*Gliphis sp. A.*	Speartooth shark
	Scyliorhinidae	2	*Apristurus sp. A*	Freckled catshark
		3	*Atelomycterus sp. A*	Banded catshark
		4	*Galeus sp. A*	Slender sawtail shark
		5	*Halaelurus sp.A*	Dusky catshark
	Triakidae	6	*Mustelus sp.A*	White-spotted gummy shark
Rays	Rhinobatidae	1	*Aptychotrema sp. A*	Spotted shovelnose ray
	Rajidae	2	*Pavoraja sp. B*	Western looseskin skate
		3	*Raja sp. F*	Leyland skate
		4	*Raja sp. I*	Wengs skate
		5	*Raja sp.O*	Sawback skate
	Anacanthobatidae	6	*Anacanthobatis sp.A*	Western leg skate
	Narcinidae	7	*Narcine sp. A*	Ornate numbfish
		8	*Narcine sp. B*	Western numbfish
	Dasyatidae	9	*Himantura sp. A*	Brown whipray
	Chimaeridae	10	*Chimaera sp. E*	Whitefin chimaera

Table 4.9
Species of sharks and rays identified to Genus (level) (Last, P.R. and J.D. Stevens, 1994).

From the results of the inventory in Table 4.9, it can be seen that there is still a possibility that new species will be discovered, with several species of sharks and rays which up until now have only been classified to Genus level.

4.1.4.2 Exploitation

Catch sampling in 2004 using a shrimp trawl revealed 105 demersal species, 24 small pelagic species and 5 large pelagic species of fish. In

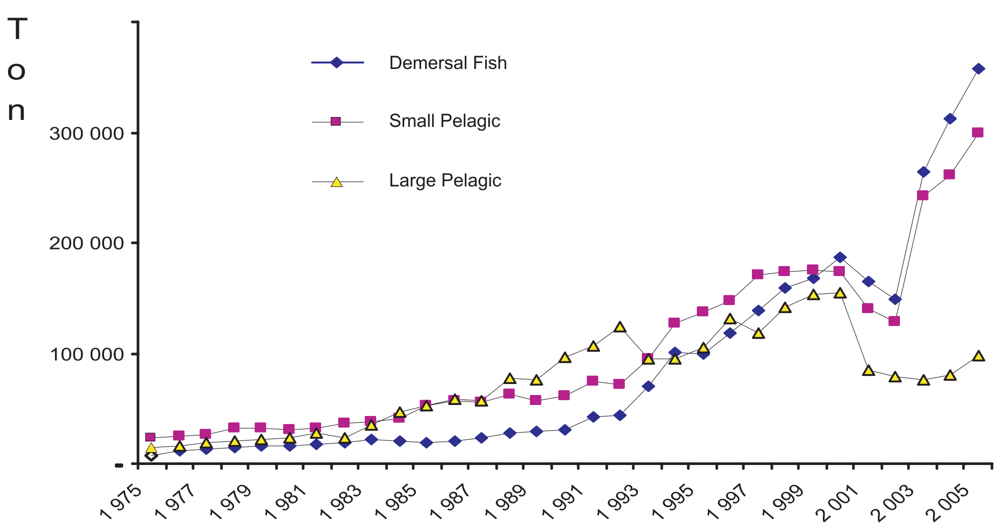


Fig. 4.25
Production trends for demersal fish, small pelagic and large pelagic

addition there were several fish which could not be identified to species level.

Production trends for demersal fish, small pelagic fish, large pelagic fish, shrimp and other organisms are shown in the Fig. 4.25.

The production of demersal, small pelagic and large pelagic fish fell during the period 2000-2003, this is thought to be very much related to the security status which was not conducive in some parts of Eastern Indonesia and affected data recording activities (Fig. 4.26).

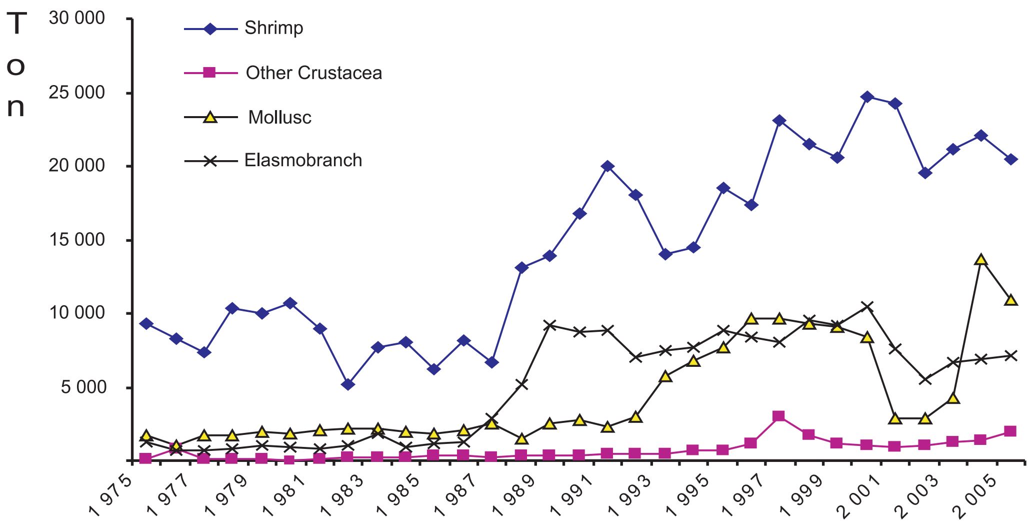


Fig. 4.26
Production trends for shrimp, crustacea, molluscs and elasmobranchs in Maluku – Papua.

Table 4.10
Catch composition (%) based on major (categories)

Commodity	2001	2002	2003	2006
Demersal fish	82.0	55.8	55.6	58.8
Pelagic fish	8.5	15.8	1.4	11.5
Penaeid shrimp	3.2	5.9	3.9	7.8
Rays	1.8	10.2	0.8	3.4
Sharks	2.0	0.8	0.2	0.6
Crabs	1.0	10.2	32.1	9.9
Squid	1.4	1.2	1.6	4.6
Gastropods	0.2	0.0	2.0	0.3
Jellyfish	0.0	0.0	0.0	1.2
Sea urchins	0.0	0.0	0.0	1.0
Others	0.0	0.0	2.5	1.0
	100.0	100.0	100.0	100.0
Total (Kg)	3640	6408	19448	18119
Number of stations	44	15	27	60
Catch rate (kg/hour)	83	427	720	302

The catch rate is basic data which is collected during each research cruise. Fluctuations in the catch rate are one indicator of fish resource community dynamics (Table 4.10).

Using the '*swept area*' method, estimates of the biomass can be calculated following Saeger *et al*. (1976). In 2001, the estimated stock density was around 1.9 metric tons/km^2. In 2002, the estimated stock density was around 9.7 metric tons/km^2, which in 2003 seemed to rise sharply to 16.3 metric tons/km^2, but in 2006 fell again to 6.9 metric tons/km^2 (Table 4.11). Fluctuations in fish stock density in a given sea area is generally closely associated with the schooling behaviour of fish, whereas in turn the behaviour of schools in that area is closely related to the dynamic nature of oceanographical conditions which are constantly changing. These changes are generally linked to changes in the weather due to monthly seasonal or annual cycles or to global changes which occur over long time-scales such as the 'El Nino' phenomena.

4.1.4.3 Catch composition

Information regarding species composition is one of the bases for managing *target species*' fisheries. It is important to remember this fact because the capture of *target species* requires the design of fishing gear which really and truly does not catch non-target fish. In this way by-catch can be kept to an absolute minimum, so that fisheries resources are used in an optimum way (*optimal use of the resources*).

From Table 4.12, the Sciaenidae show up as a group of fish which seem to have a fairly high resistance to fishing pressure. This can be seen from the percentage of fish from this group which are still listed among the 10 (ten) fish species which dominate catch composition. Examples of species thought to have a low resistance to fishing pressure include the silver pomfret (*Formio niger*), mullet (*Mugil sp*) and hairtails (*Trichiurus spp.*), which in 2000 showed up among the 10 dominant species but in following years were eliminated and not listed as dominant species.

From the population dynamics aspect, the flat fish (*Cynoglosus sp.*) is an interesting case, because in 2003 based on numbers of individuals caught this species formed 97% of the catch, however the Table shows that this species only contributed 6.5% to the total catch weight.

The catch rate of red snappers in these waters seems relatively low, although from an economic viewpoint this low catch-rate is still profitable, as the bottom liner vessels in operation can be said to be medium to large scale, with 2,250 hooks per bottom-line unit per-setting. The catch-rate of bluespotted snappers from 15 bottom-line

Parameter	2001	2002	2003	2006
Catch rate (kg/jam)	83	427	720	302
Constant	22,7	22,7	22,7	22,7
Stock Density (metric tons/ km2)	1,9	9,7	16,3	6,9
Biomass (B∞) Area * stock density				

Table 4.11
Estimated annual stock density of demersal fish in the Arafura Sea based on the catch rate of research

Table 4.12
Percentages of the 10 dominant demersal fish groups caught in the Arafura Sea (2000-2006)

NO.	FAMILY	2000	2001	2002	2003	2006
1	Scianidae	29,5	12.0	7.2	38.6	6.7
2	Leiognathidae	10.6	16.1	6.6	-	11.5
3	Mullidae	1.7	3.2	6.6	-	4.0
4	Clupeidae	-	6.6	4.0	1.2	8.2
5	Other fish	-	5.8	-	-	-
6	Penaeidae	-	3.9	-	1.2	6.7
7	Portunidae	-	-	10.2	32.1	9.4
8	Nemipteridae	2.6	2.9	5.4	-	-
9	Carangidae	-	2.9	5.3	-	-
10	Pomadasydae	-	-	11.1	-	3.7
11	Dasyatidae	11.5	-	10.1	-	-
12	Engraulidae	6.4	-	4.4	-	-
13	Plotosidae	1.5	-	-	1.2	-
14	Carcharinidae	-	3.0	-		-
15	Cynoglosus sp.	-	-	-	6.5	-
16	Squillidae	-	-	-	2.7	-
17	Holothuridae	-	-	-	2.5	-
18	Pectinidae	-	-	-	2.0	-
19	Harpadontidae	-	-	-	1.6	-
20	Synodontidae	-	13.7	-	-	-
21	Tetraodontidae	-	-	-	-	4.1
22	Apogonidae	-	-	-	-	4.1
23	Ariidae	-	-	-	-	3.9
24	Formio niger	5.9	-	-	-	-
25	Mugil sp.	5.7	-	-	-	-
26	Trichiuridae	2.6	-	-	-	-

Source: BRPL Survey Reports for the years 2000 - 2006

settings during this research period (2001-2006) was around 3,3%. Based on information from exporters the unit price of *L. malabaricus* which is known as '*scarlet snapper*' in the USA reached USD 20 kg^{-1} in 1999 (Mulyadipers.com.).

The catch-rate as an index of stock abundance for the industrial scale bottom-line industry operating in the waters to the South of Timor Island is around 2.6 % (or 3 fish 100 $hooks^{-1}$ $setting^{-1}$.

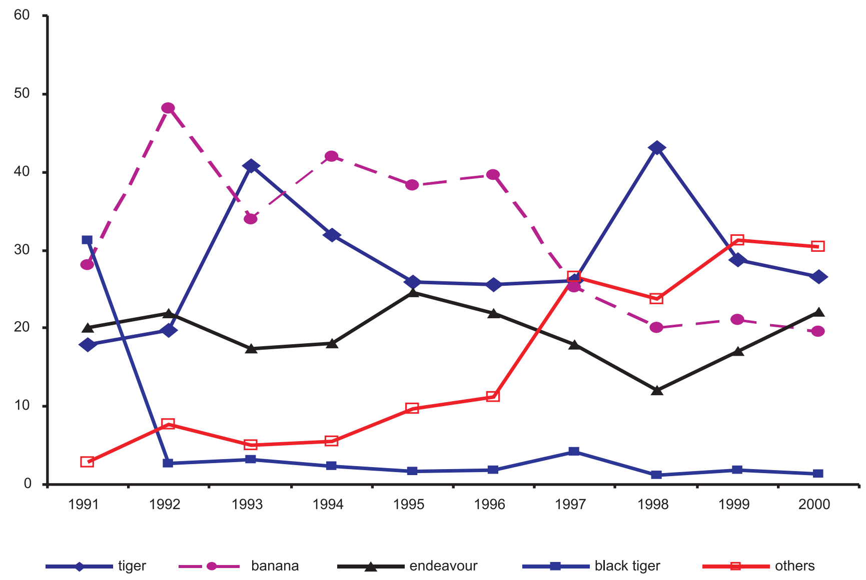


Fig. 4.27
Annual variations in the composition of shrimp catches in the Arafura Sea 1991-2000.

A change in the composition of organisms found in a given area of water is a reaction to a disturbance which affects the community. This can be interpreted as an attempt by the community to maintain a condition of equilibrium. This phenomena tends to occur frequently in the form of inter-specific interaction or in the form of changes in species dominance (species replacement)

This phenomenon has already occurred in the demersal communities of the waters in the Gulf of Thailand where the trend of falling CPUE for several demersal fish species groups was followed by a trend of increasing CPUE for squid (Pope, 1979). This phenomena of changing species dominance has also been reported in the fish communities in the North sea in the early years of the 19th Century (Pitcher and Hart, 1982), where the reduction of demersal fish populations due to over fishing was followed by an increase in the herring population, and the reduction in herring populations was followed by a rise in mackerel populations.

It is suspected that the same phenomena has happened on a smaller scale to the shrimp resources of the Arafura Sea where five groups of shrimp such as the Penaeid 'tiger' shrimps (Penaeus semisulcatus, P. monodon, and P. merguiensis), and metapenaeid shrimps (Metapenaeus spp. and Metapenaeopsis spp.), as well as a number of smaller shrimp species seem to have reacted to fishing pressures differently from one another. This can be seen from the falling catch trend for P. monodon and P. merguiensis over the period 1991-2000, whereas Penaeus semisulcatus and Metapenaeus spp. seem to have a higher resilience, as indicated by continued increasing trends, although in the past three years there have been indications of a dramatic overall decline. As the P. monodon and P. merguiensis catches continue to fall, conversely the Metapenaeus spp. catches continue to rise (Fig. 4.27). The economic value of the metapenaeid groups of shrimp species is lower than that of the Penaeid shrimps P. monodon and P. merguiensis.

4.1.4.4 *Fishery biodiversity*

The number of species and the number of individuals of each species of fish are generally used to calculate the biodiversity index (for fish). Biodiversity is variable between sites, habitats, seasons and can vary also due to a number of other factors including the method used to calculate it. The biodiversity index which has been used in the following calculations is the Shannon Index or 'H' (Ludwig and Reynold, 1988). This Index has been calculated to yield a total biodiversity index (fish and non-fish) and a fish biodiversity index. The rise and fall of these indices is an indication of changes in the fish communities.

total number of individuals caught which was 33,922,710 (almost 34 million), the H value seems extremely low. It turned out that during this research voyage, the catch was dominated by only two species groups which were the flat fish *Cynoglosus sp.* with 97.6% and *Sciaena spp.* which accounted for 2.2%.

The total annual biodiversity index (H total) was H= 3.416 in 2001. After this the values show a downward trend, and in 2006 the value of this index was H = 2.073. This indicates that over the period 2001-2006 the biodiversity was reduced by around 39% ((3.416-2.073)/3.416). The reduction in the fish biodiversity index (H fish) was less than that of the total biodiversity

Year	'H' Total	'H' Fish
2000	1.935	2.827
2001	3.416	3.151
2002	3.088	2.521
2003	0.316	0.130
2004	-	-
2005	-	-
2006	2.073	3.095

Table 4.13
Shannon Index (H) for total catch and fish catch

From Table 4.13 it can be seen that the values of H do not reveal an ordered trend in line with the development of fishing activities. This lack of a clear trend could be caused by the variety of habitats, fishing grounds, uneven/variable fishing pressure at survey sites, limited information for species identification by the researchers, and local changes in (marine) environmental conditions.

The value of H in 2003 needs careful examination. Compared with the relatively high

index. As for the total annual biodiversity index, the highest fish annual biodiversity index of H = 3.151 also occurred in 2001. In 2006, this index had fallen to H = 3.095, indicating a biodiversity loss of around 1,8% or H = 2%.

Both the total and fish annual biodiversity indices 'H total' and (H fish) vary between H: 1,935-3,416 (or H: 2,0 -3,0). From this Table it seems that in general (apart from during 2003), it can be thought that from an ecological point of view the diversity of fish caught in the Arafura

Sea is still quite high despite heavy fishing pressure. One aspect which requires further attention from a fisheries viewpoint is the species composition of the catch which will determine the economic viability of fishing activities. As was mentioned above in that year (2003), the catch was dominated by small fish such as flat fish (*Cynoglosus sp.*) and *Sciaena spp.*

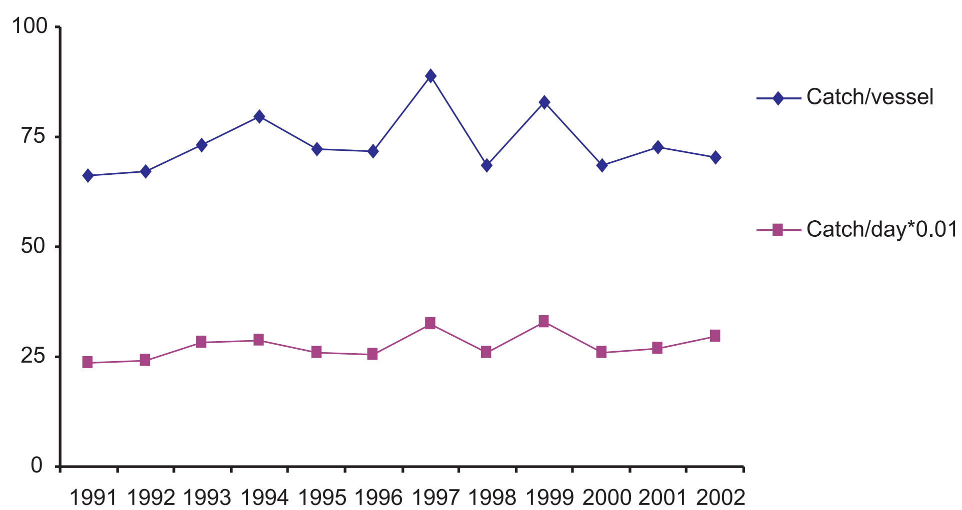
4.1.4.5 Index of stock abundance

The status of exploited fishery resources can be determines through the comparison between stock abundance index values at two points in time. Based on the above, shrimp fishery data for the Arafura Sea on 1970-1978 which was the initial period of exploratory industrial scale exploitation of shrimp by Indonesian-Japanese joint-venture companies shows several interesting differences compared with fishery data for the period 1991-2002.

For the period 1991-2002 two stock abundance index (catch per-unit of effort, CPUE) data sets were found (Fig. 4.28). The first Index was in the format '*tonnes/vessel/year*' and the second was in the format '*tonnes/vessel/day*'. Both of these show relatively low inter-annual variation as reflected in the coefficients of variation which were 9.3% and 11.1% respectively. Conversely using data from the period 1970-1978 there is a high inter-annual variation of 25.1% and 33.0% respectively. This can be interpreted as meaning that during the years from 1970-1978 the CPUE varied significantly over a wide range. This phenomena is a normal feature of exploitation during the *early growth and development phase* of a fishery, when there can be relatively high catches or low catches at different times even though the level of fishing effort is relatively constant.

It can be seen that at the start of the exploitation period there were quite large variations in CPUE. But over the period 1991-2002 no significant changes in CPUE were noticeable, as can be seen from the relatively low coefficient of variation. In other words, the CPUE was relatively stable, so that the exploitation status if the shrimp resources in the Arafura Sea is suspected to have entered the *management*

Fig. 4.28
Shrimp stock abundance index trends for the Arafura Sea (1991-2002).



phase. At this stage of exploitation strict monitoring of capture activities is necessary. For example, the number of fishing vessels and number of effective fishing days requires serious attention and must be followed or accompanied by monitoring to detect any changes in the composition of shrimp catches. These activities are extremely important remembering that it has often been found that production figure and/or MSY remain relatively constant from year to year, however the majority of shrimp caught can become dominates by shrimp age groups or species which are smaller in size with lower economic values.

Table 4.14
Comparison between catch and effort figures for the periods 1991-2002 and 1970-1978.

Parameter	Effort Unit 1991-2002		Effort Unit 1970-1978 (Unar and Naamin, 1984)	
	Vessel	Day	Vessel	Day
Mean CPUE (tonnes)	73,5	0,28	57,5	0,29
Standard deviation	6,9	0,03	14,4	0,10
Coef. of variation (%)	9,3	11,1	25,1	33,0
Total No. of vessels	1033		767	

Table 4.15
The biodiversity of snappers caught by bottom long-liners in the Arafura Sea (Maarch 2000)

Taxonomic Group	Species	Sample 1	Sample 2	Number	Percentage
Lutjanidae	*Lutjanus malabaricus*	125	240	365	16,58
	L. erythropterus	216	133	349	15,85
	L. sebae	46	59	105	4,77
	L. bohar	19	15	34	1,54
	L. russelli	13	13	26	1,18
	L. johni	15	19	34	1,54
	L. fulviflama	43	25	68	3,09
	L. lutjanus	26	28	54	2,45
	Lutjanus sp.	18	22	40	1,82
	Pristipomoides multidens	493	388	881	40,00
	P. typus	68	48	116	5,27
	P. filamentosus	14	19	33	1,50
	Pinjalo pinjalo	26	42	68	3,09
	Aprion virescens	-	29	29	1,32
	Sub-total	**1122**	**1080**	**2202**	**64,46**

The large pelagic fish group includes among others; tuna (*Thunnus spp.*), skipjack tuna (*Katsuwonus pelamis*), Eastern little tuna (*Euthynus spp*), spanish mackerel (*Scomberomorus spp.*), sharks (Elasmobranchii), marlin (*Makaira spp.*, and *Tetrapturus spp.*) and sailfish (*Istiophorus spp.*). Tuna are the second most important fisheries export commodity after shrimp.

The demersal fish groups, especially snapper of the Lutjanus and Pristipomoides Genera, which in Australia are known as 'deep-sea snapper' are targeted for the export market and caught with bottom long-line gear (BLL, vessels based in Tanjung Karimun). From information given by exporters the price of *L. malabaricus* which is known as 'scarlet snapper' in the United States of America reached US. $ 20.- / kg in 1999 (Mulyadi pers. comm. PT. Tirta Raya Mina) and Pristipomoides which is known as *anggoli* in Singapore fetched Singapore $ 40,-/kg.

The most common small pelagic fish groups include; scads (Decapterus spp.), mackerel (Rastrelliger spp.), big-eye scad, Sardinella spp., anchovies and flying fish. Almost all the fish from small pelagic and demersal species which are caught with fish nets/fish trawls in the Arafura Sea with a number of legal/illegal fishing methods are transhipped to Thailand, Taiwan, Korea and China, and are unrecorded/ unreported. According to research by the Badan Riset Kelautan and Perikanan (Agency for Marine and Fisheries Research) in partnership with FAO, the figures for unrecorded/unreported catch are around 1.25 million metric tons (2005). Assuming an average price of US $ 1.0 /kg the value would be around Rp. 12.5 trillion (Nurhakim *et al.*, 2008).

A number of uncommon deep sea fish are appearing in the marketplace. In Europe, the deep-sea fish called 'lunglip' is marketed as '*cusk eel'*, a type of eel. In New Zealand, this fish is referred to as '*hung*', in Latin America as '*cangrio*' and in Japan it is called '*kingu*'. This fish is sold on the retail market and can be found in restaurants as a specialty with a unique flesh texture. In Australia the fish species called '*alfonsino*' (*Beryx splendens*) and 'orange roughy' (*Hoplostethus* sp.) are intensively fished and threatened with overfishing.

Analysis of the flesh of 10 deep sea fish species, *Dietmoides pauciradiatus*, *Benthodesmus tenuis*, Beryx *splendens*, *Hoplosthethus crassipinus*, *Hoplothethus* sp., Ophidiidae, *Ostracoberyx dorygenis*, *Godamus colleti*, *Myctophidae* sp., and Hyteroglypne *japonica,* revealed 17 types of amino acid, of which 9 were essential and the remainder non essential amino acids, dominated by leusin and prolin, all of which are required by the human body. Amino acids are important bio-chemical compounds required by the body to produce energy and to stimulate the upper brain. Arginin which can act as an aphrodisiac was also found in substantial quantities; this substance can assist in the recovery of vitality or improve sexual performance/stamina. Arginin acts together with the enzyme Nitrogin oxidase (NO) to expand blood vessels. In addition to amino acids, chemical compounds found in the flesh of deep sea fish include steroids, a type of hormone with a steroid nucleolus, a chemical substance which can act as an aphrodisiac, one of the bio-chemical substances which is used to improve sexual health and function.

4.1.4.6 Economic and social value

The group of shrimp species such as tiger shrimp (*P. monodon, Penaeus semisulcatus*, *P. merguiensis*), metapenaeid shrimps (*Metapenaeus spp.*), and the shrimps known in Indonesia as *krosok* (*Metapenaeopsis spp.*) which are caught in the Arafura Sea by shrimp trawlers or fish nets are all export commodities.

The large pelagic fish group includes among others; tuna (*Thunnus spp*.), skipjack tuna (*Katsuwonus pelamis*), Eastern little tuna (*Euthynus spp*), Spanish mackerel (*Scomberomorus spp*.), sharks (Elasmobranchii), marlin (*Makaira spp*., and *Tetrapturus spp*.) and sailfish (*Istiophorus spp*.). Tuna are the second most important fisheries export commodity after shrimp.

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From a social standpoint, all the capture fisheries activities especially the industrial scale fisheries operating in the Arafura Sea and Timor Sea are economic activities which provide employment for a large workforce.

4.1.5 Marine mammals

Based on sighting information in Indonesia (including anecdotal records) there are an estimated 31 or more species of whales and dolphins in the Indonesian Seas (PHPA, 1984; Rudolph *et al.*, 1997; Kahn *et al.,* 2000, 2002a, b). Several rare and endangered and vulnerable "great whale" species, including the sperm and blue whales, as well as other baleen whales are sighted regularly in the eastern waters of this vast archipelago. However, despite the numerous and major advances in marine science in Australasia, the lack of information on the ecology and conservation status of whales and dolphins is one of the largest 'knowledge gaps' concerning the marine biology of this exceptionally diverse part of the world. All of Indonesia's whale and dolphin populations are data-deficient, and to variable degrees vulnerable to the region's largely unchecked marine resource exploitation (Kahn 2002c, 2003a; Satria and Matsuda, 2004).

4.1.5.1 Taxonomy and systematics

There are two marine mammal orders which are frequently found in Indonesian waters, which are the Cetacea and Sirenia. In Indonesia around 30 species of Cetacea (dolphins and whales) belonging to six families have been recorded, out of the 86 known species worldwide, whereas from the Sirenia only one species is found, the dugong *Dugong dugon* (Appendix 9). The Dugong is an herbivorous mammal, whose basic diet is seagrass and algae.

The six Cetacean Families found in Indonesia (Kahn, 2003; Rudolph *et. al*, 1997) are the Phochoenidae with the species *Neophocaena phocaenoides*, the Delphinidae (*Delphinus capensis*, *D. delphis*, *Feresa attenuata*, *Grampus griseus*, *Globichephala macrorhynchus*, *Logenodelphis hosei*, *Orcaella brevirostris*, *Orcinus orca*, *Peponocephana electra*, *Pseudorca crassidens*, *Steno bredanensis*, *S. coeruleoalba*, *S. attenuata*, *S. longirostris Sousa chinensis*, and *Tursiop truncatus*), the Ziphiidae (*Mesoplodon* spp., *Hyperodon* sp. and *Ziphius cavirostris*), the Physeteridae (*Physeter macrocephalus*), the Kogiidae (*Kogia simus, K. Breviceps*) and Balaenopteridae (*Balaenoptera acutorostrata*, *B. borealis*, *B. edeni*, *B. brydei*, *B. musculus*, *B. physalus* and *Megaptera novaeangliae*).

Fig. 4.29
Stenella longirostris (Photo: P. Borsa/IRD)

Fig. 4.30
Physeter macrocephalus (Photo: P. Borsa/IRD)

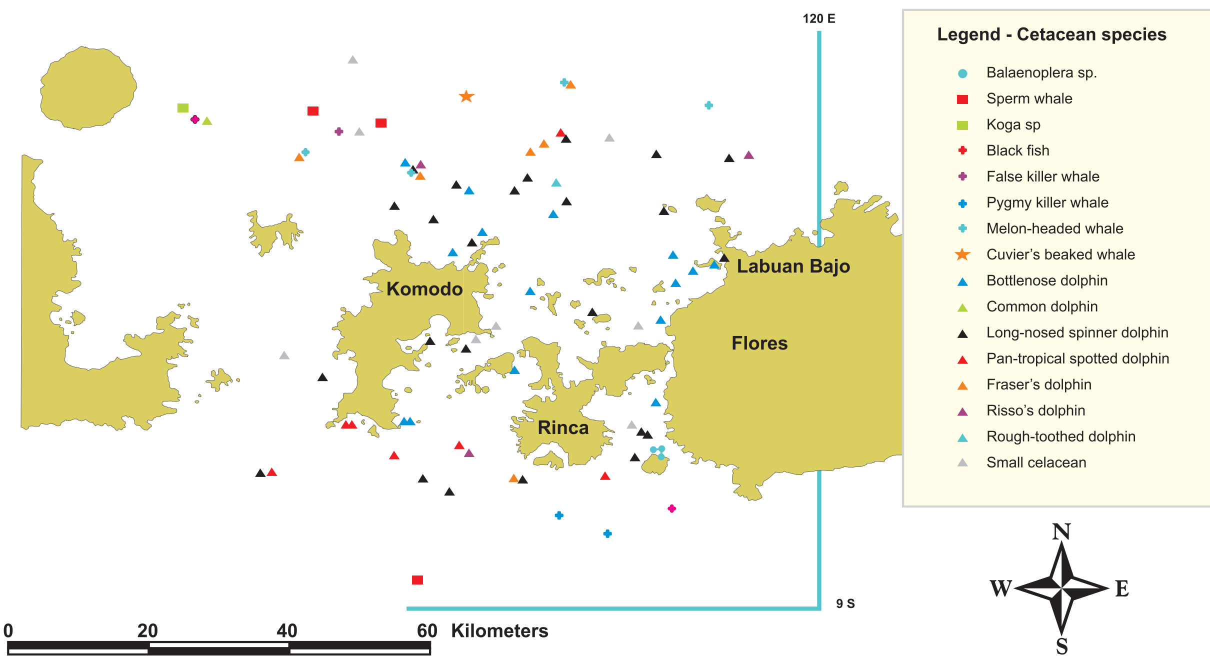

Fig. 4.31
Cetacean species diversity and distribution in Komodo National Park and adjacent waters- 1999 surveys (Kahn et al, 2000).

4.1.5.2 Geographical distribution

Cetacea which were recorded in the Komodo National Park in 1999 (Kahn, 2001) were *Delphinus delphis, Feresa attenuata, Grampus griseus, Lagenodelphis hosei, Peponocephala electra, Pseudorca crassidens, Stenella longirostris, S. attenuata, Tursiops truncatus, Steno bredanensis, Ziphius cavirostris, Kogia* sp*, Balaenoptera edeni* and *Physeter macrocephalus*.

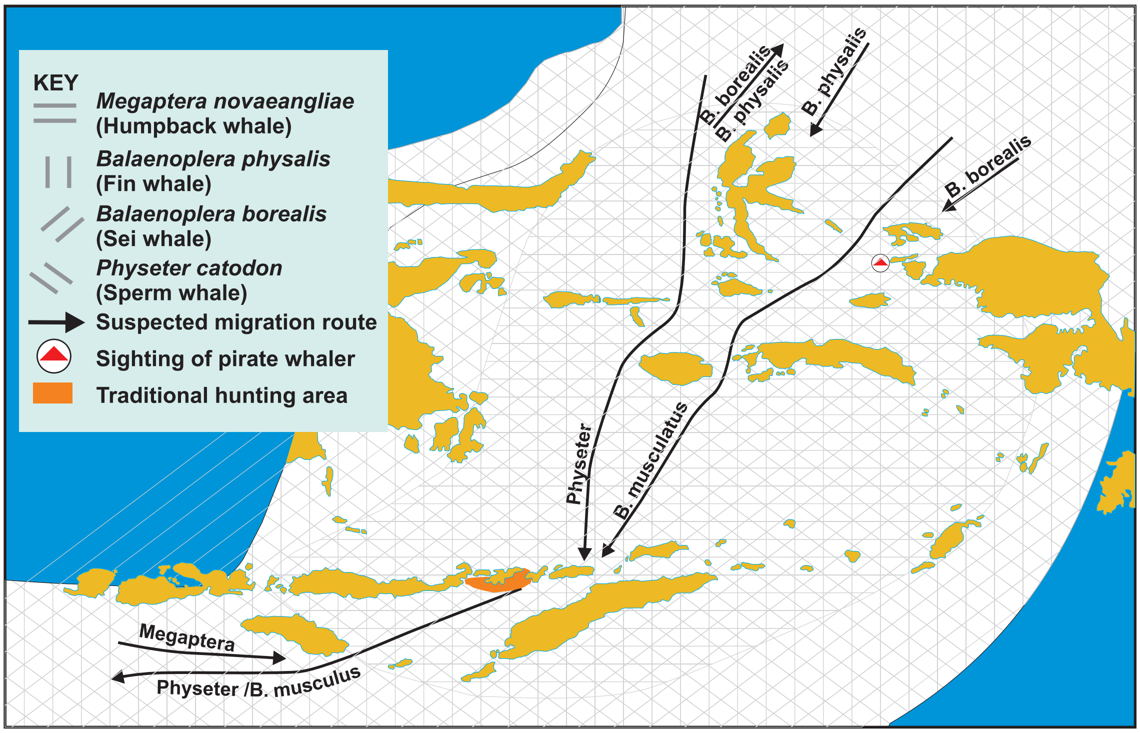

Fig. 4.32
Migration routes and distribution of whales in the waters around Nusa Tenggara and Maluku (Source: Monk et al, 1997)

The Dugong (*Dugong dugon*, Muller 1766) which in Indonesian is called *duyung* is a marine mammal which grazes on seagrass. Dugongs live in waters where seagrasses of the Halodule, Syringodium, Halophila, Cymodocea and Zostera species grow in abundance (de Iongh and Wenno, 1992). At the present time, information regarding the distribution, abundance and behaviour of dugongs in Indonesian waters is still very limited. However based on several research activities in Indonesian waters, it is estimated that in the 1970's the dugong population consisted of around 10,000 individuals. In 1994 the population was estimated at around 1,000 individuals and was in continuous to decline (Marsh *et al*, 2002).

The Dugong is listed as a species *vulnerable to extinction* in the International Union for the Conservation of Nature (IUCN), or World Conservation Union's Red Data Book of Threatened Species (IUCN, 2000). The Dugong is also listed in the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) and in *Appendix I* to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Marsh *et. al*, 2002).

Data from 1979 (de Iongh, 1996) stated that in Kobroor, Aru Timur, as many as 80 - 200 dugong were reported as being caught in shark nets, whereas in 1989 only 20 - 40 individuals were caught. In 1979 and 1980 around 550 – 1000 dugong were caught using *Taiwanese nets* used to catch sharks in several areas around Maluku (de Iongh and Wenno, 1992).

4.1.5.3 Abundance and biomass

In 2003 there was a drop in the number of species observed, which were *Stenella attenuata, S. longirostris, Tursiops truncates, Grampus*

Fig. 4.33
Distribution of dugong in Eastern Indonesia (Marsh *et. al*, 2002).

griseus, Pseudorca crassidens, Kogia simus and Physeter macrocephalus. It was also revealed that the appearance of baby dolphins and whales in the waters of the Komodo National Park means that this is an area where these animals give birth and nurse their offspring.

4.1.5.4 Economic social and cultural values

Solor – Alor Island region is one of the most important habitats for oceanic cetaceans in the Indonesian Seas, and possibly South East Asian waters. Traditional whale hunting in Indonesia is found in two villages which are Desa Lamalera on Lomben Island and Desa Lamakera on Solor Island. Whale hunting was first documented here in the 17th century at which time wooden boats called *peledang* were used. The whale hunting seasons are in May and October.

According to local reports from Lamakera, there are year-round (albeit opportunistic) hunts for small to medium sized baleen whales (named kelaru – see below). This village is located on Solor Island and has a history of traditional whaling specializing in baleen whales (not to be confused with the traditional sperm whaling village of Lamalera on nearby Lembata Island) (Kahn, 2005).

The Savu Sea, and the Solor-Alor region in particular, is an important feeding, breeding, calving and nursery ground for the sperm whale – a vulnerable species under the IUCN's

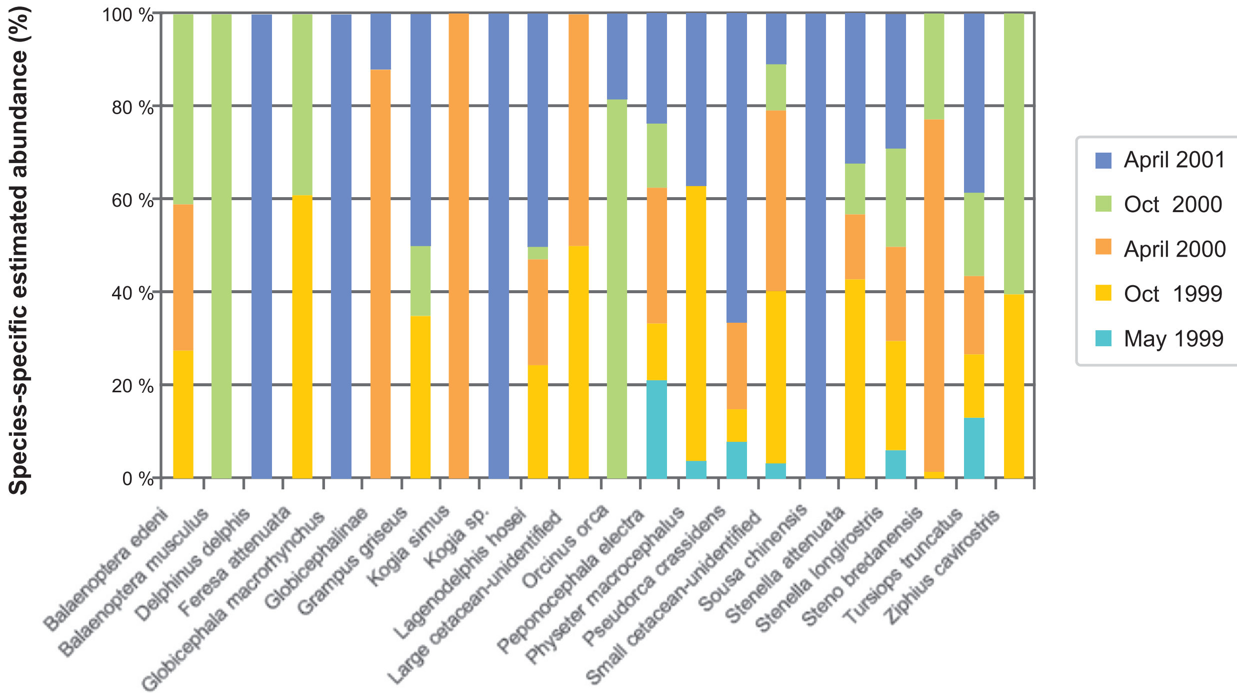

Fig. 4.34
Percentage of species-specific cetacean abundance for each Komodo survey (Khan, 2001).

Red List (IUCN 2004). Sperm whales have a complex social structure which includes nursery groups, bachelor groups and solitary bulls (Rice 1989). The social organization of sperm whale populations may be influenced by ecological conditions and whaling histories (i.e. Whitehead and Kahn,1992). Consistent sightings of sperm whales in Solor-Alor include nursery groups of 12-15 sperm whales (presumably adult females and immatures of both genders, mostly closely related individuals living in pods or 'units' which are stable long-term), numerous juveniles and new-born calves estimated at 3.5-4 m length (Kahn, 2005).

Sperm whales have a thick layer of sub-cutaneous fat which acts as a food reserve during their southwards migration when food is scarce. Sperm whale oil is found in the head in a cavity within the cranium. When the cranium is split open, the liquid oil will spurt out, whereas the fat can be rendered to produce oil. Whale oil is believed to have health benefits, especially for curing internal disorders, and the Lamalera community have a strong belief that whale oil cleans the stomach and digestive system. The role of whale hunting was not only to provide dietary requirements in the form of meat but also as a ceremonial tradition.

Although data from Indonesia's fisheries are fragmentary and sparse, the combined information from various Southeast Asian countries indicates that by catch and targeted catch represent the primary threat to small cetacean populations, both coastal and oceanic, some of which have been drastically reduced.

The extent of the problem in Indonesia is hard to quantify in the absence of relevant fisheries data and of any direct observer programs for the large-scale fleets (considered the only reliable way to obtain quantitative data on by catch). An assessment of cetacean by catch in commercial fisheries within the Indonesian EEZ is urgently needed (Khan., 2002.).

The diel dive patterns as well as the observed proximity to land (<150m) of blue whales in the Solor-Alor region (see above) indicate that these endangered whales are vulnerable to both coastal and pelagic fisheries interactions, in particular gill and drift net entanglements as well as destructive fishing practices such as reef bombing.

In addition to the potential threat from by-catch, blue whales may also be targeted catch by the Lamakera community, who continue to hunt opportunistically for kelaru baleen whales.

4.1.6. Turtles

4.1.6.1 Taxonomy and systematics

There are 250 known turtle and tortoise species in the world, including terrestrial (tortoise) and aquatic (turtle) species; however there are only eight species of marine turtles. Out of these eight marine turtles, six species are found in Indonesian waters. These six marine turtle species belong to two Families, the Cheloniidae and Dermochelidae (Tomascik *et al.* 1997).

The most commonly found marine turtles in Arafura and Timor Sea are the green turtle (*Chelonia mydas*) and hawksbill turtle (*Eretmochelys imbricata*) which live in coral reef habitat. Whereas less is known about the other marine turtle species which are *Lepidochelys olivacea, Caretta caretta, Dermochelys coriacea and Natator depressus*.

Marine turtles in Indonesia which are *C. mydas, E. imbricate, L. olivacea, C. caretta and N. depressus* belong to the Class Reptilia, Order Testudines, Family Cheloniidae except for *Dermochelys coriacea* which belongs to the Dermochelydae Family. *D. coriacea* is a turtle species which can grow to around three metres in length with a weight of 250 to 700 kg, however turtles alive nowadays are generally between one and two metres in length.

4.1.6.2 Geographical distribution

Green turtles are frequently found in the waters off South Java (Pangumbahan), Sangalaki Island in East Kalimantan Timur, West Kalimantan, Bali, Berau Island and Aru Island where there are extensive seagrass meadows.

Fig. 4.35
Distribution of marine turtles in the waters of Nusa Tenggara and Maluku *(Source: Monk et al, 1997)*

4.1.6.3 Economic social and cultural values

Throughout history marine turtles have played an important role in the culture and economy of coastal communities, for example the Bajau (sea gypsy) and Balinese Hindu communities who trade turtles. In the past green turtle populations were protected by traditional laws however in line with rising human populations there has been a decline in the green turtle populations.

Human beings pose the greatest threat to marine turtles in Indonesia, as is the case all over the world. Excessive coastal development has reduced the nesting habitat of marine turtles. The take of turtles for their eggs, flesh, and skin or shell has substantially reduced population levels. In many countries, people still take eggs for human consumption. These eggs can be found for sale on the markets. The green turtle is one of the species which is overexploited by Indonesian people. These turtles are slaughtered for their meat. Bali is the main turtle consuming area. The Balinese use turtles in their traditional rituals. Thousands of turtles are slaughtered to fulfil market demand in Bali.

4.2 The unknown

As a general rule, the exploration of marine biota can help us to answer questions and to anticipate environmental changes in a given habitat. Certain marine organisms can be used as indicators of environmental change. In connection with the issue of global warming, research needs to be supported in order to answer questions such as:

1. Which marine organisms are good candidates as bio-indicators for climate change
2. Can the Arafura Sea be considered a hot-spot or a sensitive area requiring continuous monitoring
3. How will the distribution and abundance of marine species or communities be affected by climate change
4. What is the relationship between marine productivity levels and climate change
5. How can the impact of environmental degradation and pollution be reduced in order to increase the resilience of ecosystems to climate change
6. What are the (likely) social and economic impacts of climate change in relation to marine ecosystems in Indonesia

4.2.1 Mangrove ecosystem of the Arafura and Timor Seas

The mangrove ecosystem of the Arafura and Timor Seas is a living resource which can provide an endless source of knowledge to be uncovered, and on review there is still much information that is not yet known regarding this ecosystem so that it would be interesting to undertake a long-term to obtain the information which is lacking such as abundance, productivity, spatial variability, seasonal variability and inter annual variability.

From another aspect, degradation of this ecosystem due to development pressures over the past two decades has caused the conversion of much of this mangrove area for residential use, brackish-water ponds, and coastal industry. This poses a dilemma, because on the one hand community welfare must be ensured and this requires the destruction of the environment due to changes in land use or as by-products of development such as increase pollution in areas around mangrove forests. It will be a great shame if such a meaningful resource, not only for human beings but for the many associated organisms, is lost from the face of the earth

Environmental rehabilitation is one way to attempt to restore this area or to increase the mangrove area. One interesting area of research which can support rehabilitation efforts is the development of ring-culture of mangrove plants, and it will be even more interesting if research can achieve genetic modification. Genetic modification can be applied not only to plant communities but also to associated organisms which have a high commercial value. Genetic modification and ring culture are steps to apply culture technology to mangrove areas without having to degrade the area.

One interesting field of research is the *screening* of associated organisms for their ability to produce active chemical compounds which can be of benefit to mankind. This exploration is one way in which biotechnology can be applied to mangrove ecosystem areas which up to now have been considered by many people as a smelly mosquito-infested place not suitable to be visited and of little interest for further study.

4.2.2 Seagrass ecosystem of the Arafura and Timor Seas

Up until now, seagrass beds have been considered as a coastal area of little interest to research. This is reflected in the minimal amount of information regarding the abundance, productivity, Taxonomy, distribution, as well as spatial, seasonal and inter annual variability of seagrass communities in the Arafura and Timor Sea areas.

One interesting avenue of research in the seagrass ecosystem which as yet has been little explored, although available technology can readily be adapted, is the exploration for active chemical compounds which have antifouling, antibacterial, antiviral, anticancer or anti-inflammatory properties from the flora and fauna found in the seagrass ecosystem including macro and micro organisms.

4.2.3 Coral reef ecosystem of the Arafura and Timor Seas

One of the most interesting avenues of research in connection with coral reefs in these areas is to increase knowledge of "Deep Sea Reefs". Previously no-one had even imagined that on the deep sea bed there could be found coral animals associated (with other organisms) to form an ecosystem. Advances in science and technology over time have enabled and will further enable researchers to access and compile knowledge regarding life in the ocean depths, so that it is now known that Deep Sea Coral Reefs can be found in several areas. Through the adoption of appropriate methods and technology for reaching and exploring such depths, it is very possible to find out more about life in the depths of the Arafura and Timor Seas, and especially to determine whether deep sea coral reefs can be found there.

Information which could be obtained from a Deep Sea Coral Reef expedition in the Arafura and Timor Seas include the taxonomy, source of energy, abundance, productivity, interaction or community structure, seasonal variations, spatial variability and inter annual variability of these ecosystems.

4.2.4 Deep sea ecosystem of the Timor Sea

Hydrothermal vents, *Oil seeps* and the sea bed in the deep sea ecosystem of the Timor Sea are part of a unique environment which has not yet been touched or explored and is an area offering the chance of finding new sources of biodiversity and biological activity. The microbiological diversity of deep sea bacteria and their genetic diversity could then be linked to biochemical processes which occur in the deep seas.

4.2.5 Plankton

Although several major expeditions have recorded a number of plankton species, especially from Eastern Indonesia, only a few taxa have been reported to date. Indeed, for deep sea plankton, research regarding the genetics, relationships between species and groups within taxonomic groups has not yet been undertaken. There is a need for comprehensive research regarding the diversity and distribution of species/taxa. Analysis of Indonesian plankton Collections kept in several countries is also required.

4.2.6 Invertebrates

4.2.6.1 Crustacea

As was mentioned earlier, crustacea can be found in extremely varied habitats. Up to the present time, the "published record" of crustacea from the Arafura and Timor Seas is the result of deep sea collection (trawl, dredge or grab) and/or collection from the intertidal zone (reef walking, transects). Collection using "skin diving" or "scuba diving" has been very rare so far. Therefore the species of crustacea associated with coral reefs have not yet been reported although almost all the islands in the Arafura and Timor Seas have coral reefs almost all around their coastlines (ATSEF Report, 2006). Many crustacea generally associated with coral reefs such as shrimps from the Palaeomonidae and Alpheidae families, crabs from the Xanthidae Family or hermit crabs from the Diogenidae Family have been recorded from many other parts of Indonesia and the Indo West Pacific. It is very likely that many of these species are also found in the Arafura and Timor Seas. In addition, many of the species which live in other ecosystems such as seagrass beds, mangrove forests and the deep sea which have been found in a number of other parts of Indonesia are probably to be found in the Arafura and Timor Seas.

Species of shrimp which are traded or consumed and are generally caught by commercial trawling vessels are often reported as *Metapenaeus* spp. or *Metapenaeopsis* spp. Up to now only 3 species are recorded to species level: *Penaeus semisulcatus, P. merguiensis and P. monodon*. In view of the ecological conditions of the Arafura Sea which are suitable for many shrimp species, it is thought that other commercially valuable shrimp species can also be found there.

Table 4.16
Comparison of the number of crustacean species found in the Arafura and Timor Seas, other Indonesian waters and in the Indo West Pacific (based on InfraOrder)

Infraorder	Arafura/Timor	Rest of Indonesia	Indo West Pacific
Dendrobranchiata	5	9	32
Stenopodidea	1		
Caridea	12	40	128
Thalassinidea	3	3	5
Palinura	5	7	21
Anomura	142	170	888
Brachyura	306	500	3400

4.2.6.2 *Holothuroidea*

In terms of species diversity, there has been very little work done on sea cucumbers. There are as yet no in-country taxonomists, so that collections of specimens are generally limited to very common sea cucumbers and those with economic value. The waters around Ambon, Central Maluku to the North of the Arafura and Timor Seas are considered to be the area of the Indo Pacific with the highest (sea-cucumber) diversity (Massin 1996). Massin pointed out that over the period 1867 - 1983, 53 species were found in the waters around Ambon. When the Rhumphius Expedition returned to Ambon in 1990, 6 new species were found, making a total of 59 species. Of these 6 new species, 2 species were new discoveries not previously recorded anywhere in the world, 2 were new records for Indonesia and the remainder had not previously been found in Ambon. Meanwhile in the Banda Sea, Aziz (1999) concluded that there were 93 holothurian species, and 32 of these were species endemic to the area. Because of the proximity of Maluku with the Arafura and Timor Seas, it is very likely that species found in Maluku are also found in the Arafura and Timor Seas. The discovery of the species *Actinopyga banwarthii* and *Stichopus pseudohorrens* raises hopes that new species will be found in the future and that some of these may be endemic to the Arafura and Timor Seas.

Intensive fishery activities have the potential to upset the balance of the marine ecosystem and species diversity. Capture not only causes scarcity at the population level, but also impoverishment at the species level. The seacucumber species which are harvested for sale have not yet been confirmed at the taxonomic level, and it is not known how many are still available in the wild. Reliance on local names alone, which often vary between sites, can mean that the information given can give rise to confusion and error. Therefore, there must be an agreed name for each species beforehand, to eliminate confusion during data collection.

The recording of teripang production which so far has been done on a multi-species basis, must in the future be done at species level, so that changes in catch composition in particular can be traced and monitored. These changes in catch composition can be used as an indicator of the availability (population status) in the wild, and the level of market demand for specific species.

Understanding regarding the life cycle, growth and reproduction of sea cucumbers (teripang) will be of great assistance in maintaining variety while capture activities are ongoing Maybe we do not need to worry about the stock levels in the wild. The root cause of most of the problems which have arisen are associated with management strategy. If need be, management tools could be species-based, taking into account the differences in natural habit and current population between species.

4.2.7 Vertebrates

4.2.7.1 Fish

Based on the results of a number of research activities and other sources of information which have been obtained, it is known that there are > 500 species of fish in the Arafura Sea belonging to at least 130 families. If the results of this compilation are compared with the results of a study of fish larvae in the Banda and Arafura Seas (Soewito and Schalk, 1990), during which only 48 families were found in this area, which is 36,1% of the total number of families which are known or suspected to spawn in the Arafura Sea. The spawning grounds of 55 families are not yet known. Conversely, the larvae of 30 families of fish which are not listed as fish found in the Arafura Sea were caught in the Banda / Arafura Seas.

The deep sea fish species of the Arafura and Timor Seas are not yet known. As the Timor Sea is part of the Indian Ocean it is thought likely that the species of deep sea fish in the Timor and Arafura Seas are similar to those found in the Western Indian Ocean.

The abundance of Myctophids, *Diaphus sp.1* is very high, and these species occupy the top position in the zone < 500 m depth in the waters off West Sumatra. The fish known as *ekor tikus macrourid* (mousetail macrourid), *Caelorinchus divergens,* seems to be representative of the most dominant species at depths greater than 500 m. These fish species can be considered '*cosmopolitan*' meaning that they are widely distributed and are quite likely to be found also in the Arafura and Timor Seas. In Australia the fish species called alfonsino (*Beryx splendens*) has been intensively exploited and is close to being considered overfished.

It seems that deep sea fish in the Indian Ocean offer quite good prospects for exploitation. However it is not intended that these resources be used for direct consumption. This is because the flesh of most deep sea fish has specific characteristics, with high protein content and a low fat content. This was proven by analysis of the flesh of 4 deep sea fish: *Dietmoides pauciradiatus*, *Beryx splendens*, *Hoplosthethus crassipinus*, and *Bajacalifornia erimorensis* (Fig. 4.36).

Neoscopelid fish, *Neoscopelus macrolepidotus,* seem to inhabit waters in the southern equatorial region. Spinyfins, *Diretmoides pauciradiatus* seem to be found in deeper water habitat similar to the macrourid group, *Caelorinchus divergens*. The alepocephalid black fish, *Bajacalifornia erimorensis,* also belongs to the deep sea fish group, in the depth zone 750-1000 m, as well as shallower depth

Fig. 4.36
Deep sea fishes (Samples from: Eastern Indian Ocean – Western Sumatra)

Hoplosthethus crassispinus

Diretmoides pauciradiatus

Beryx splendens

Bajacalifornia erimorensis

zones in the northern and southern equatorial region, whereas the slimehead fish, *Hoplostetus crassispinus* are suspected to live in waters to the North of West Sumatra.

In the flesh of these deep sea fish, as many as 17 types of amino-acid have been found, consisting of 9 essential amino acids and the remainder being non essential amino acids, all of which are required by the human body. For example in the species *Diretmoides pauciradiatus* and *Hoplothethus crassispinus* the amino acids present in greatest concentration are leusin and prolin. *Benthodesmus tenuis* and *Beryx splendens* contain the highest proportion of essential amino acids in the form of leusin and phenylalanine, as do *Holoplethus* sp., *Myctophidae* sp., and *Hyteroglypne japonica*, whereas for Ophidiidae and *Ostracoberyu dorygenis* the amino acids present in greatest concentration are glutamate and leusin.

From all the deep sea fish species analysed, it can be seen that leusin is the essential amino acid present in the greatest concentration in the flesh of deep sea fish. Leusin is a ketogenic essential amino acid which is used in the production of keton in the heart. The amino acids in this category are lysine and tripthopan. Amino acids are important which are required by the body in order to produce energy and stimulate the upper part of the brain. Arginin which can function as an *aphrodisiac* is also found in substantial quantity and has the function of restoring vitality or male potency. Arginin together with the enzyme Nitrogin oxidase (NO) plays a role n the widening of blood vessels. In addition to amino acids, steroid chemical compounds are also found in the flesh of deep sea fish. Steroids are a type of hormone which has a steroid nucleolus, and is a biochemical compound which can be used to restore vitality (as an *aphrodisiac*). It is common knowledge that an *aphrodisiac* is a biochemical compound which can be used to improve sexual health and performance.

Based on the potential usefulness of the biochemical content of the flesh of deep sea fish, it is felt to be necessary to recommend that the use of deep sea fish resources should not be directed towards direct consumption, unlike shallow-water fish species. The optimal use of these resources should be directed towards the production of bioactive substances for pharmaceutical use. An extremely interesting biological aspect in the chemical compounds found in the flesh of these fish such as protein, fat and other biochemical compounds which require further laboratory analysis and research. During a research *cruise,* on one occasion none of the ship's crew or the research team could sleep for a whole night after consuming the flesh of the black fish (*Bajacalifornia erimorensis*) which had been steamed. This experience clearly demonstrates the importance of pioneering research to be undertaken in the field of biodiversity use.

4.2.7.2 Mammals

Marine mammals range over relatively extensive territories. Therefore it is necessary to form partnerships with neighbouring countries to preserve their diversity and abundance. In Indonesia, research regarding these two groups of marine animals is still rarely undertaken. Their migration, breeding and nursery grounds are not yet known. In the Arafura and Timor Seas, it is necessary to inventory the turtle nesting habitat, and ensure protection for the habitat, the eggs and the hatchlings. Lack of knowledge regarding the pelagic habitat of turtle hatchlings in their quest for food is one obstacle to conservation.

The traditional hunting of whales doesn't actually have a great effect on whale populations. However, commercial whaling needs to be strictly regulated. In addition to species, the natural capacity to regenerate lost stocks needs to be studied. Breeding grounds and migration paths need to be mapped in order to conserve this group of mammals.

One branch of the Indonesian Throughflow (marine current between the Indian and Pacific Oceans) passes through the Alor Straits, close to the Timor Sea. This area is a migration route for blue whales and sperm whales passing through the Alor Straits towards the Flores/Banda Seas, between Lembata and Pantar and also returning in the opposite direction. The Alor-Solor sea area which is a migration corridor for marine mammals includes the East coast of Flores, the Solor Islands, Lembata, Pantar and Alor. So for there is little research to show that the Timor Sea is a migration corridor, however based on proximity and spatial association, it is quite possible that the Timor Sea is used by marine mammals as a migration route between the Banda Sea and the Indian Ocean. It is highly likely that the marine mammal species frequently encountered in the waters around Komodo Island can also be found in the Timor Sea.

The relatively shallow Arafura Sea is less conducive for encountering whales, which tend to prefer deeper waters, however it is likely that dolphin species are found in this sea area. This is possible because the Arafura Sea is in direct contact with deep sea areas of the Banda Sea. The dolphin species which are likely to be found include *Delphinus delphis, Feresa attenuata, Lagenodelphis hosei, Peponocephala electra, Pseudorca crassidens, Stenella longirostris, S. attenuata, Tursiops truncatus, Steno bredanensis, and Ziphius cavirostris.*

Dugong is also marine mammals with a population which is currently reducing continuously. There is only a limited body of research regarding the distribution of dugong in Indonesia, therefore it is hard to provide current population figures, especially for the coastal areas of the Timor Sea and Arafura Sea. The likelihood of encountering dugong can only be investigated from their feeding trails in seagrass beds which comprise Halodule, Syringodium, Halophila, Cymodocea and Zostera species (de Iongh and Wenno, 1992).

4.2.7.3 Marine turtles

Lack of knowledge regarding the pelagic habitat of turtle hatchlings and juveniles in their search for food means that the accuracy of information regarding marine turtle populations is poor. Most data only covers the status of adult turtles and turtles nests/nesting sites. The increasing capture frequency can affect the status of marine turtles, so that it is likely that population numbers are continuing to fall and in the end extinction is possible.

A number of questions which need to be highlighted in connection with research into the marine aspects of global climate change include:

1. How will the distribution and abundance of marine species or communities be affected by climate change
2. Which marine organisms are good candidates as bio-indicators for climate change
3. Can the Arafura Sea be considered a hot-spot or a sensitive area requiring continuous monitoring
4. What is the relationship between marine productivity levels and climate change
5. How can the impact of environmental degradation and pollution be reduced in order to increase the resilience of ecosystems to climate change
6. What are the (likely) social and economic impacts of climate change in relation to marine ecosystems in Indonesia

4.3 The unknowable

Eastern Indonesian Seas, especially the Arafura and Timor Seas have been explored by a number of major expeditions, but not all the marine organisms present are known.

In 2006 Richer de Forges found a second living fossil species, *Neoglyphea neocaledonica* in New Caledonia. More thorough research in the Arafura and Timor Seas may well find further individuals or new species of living fossil because the Arafura and Timor Seas have environmental conditions suitable for this species.

In addition, research into the phylogenic relationships between groups of marine organisms and "bioprospecting" in the Arafura and Timor Seas using genetic and molecular techniques has not yet been undertaken.

In the Arafura Sea and Timor Sea there are several areas of relatively deep water. It is suspected that more deep sea species would be found if investigations were carried out using high technology equipment and vessels, with large funds, continuous research and high quality professional human resources.

There is good reason to worry about the effects of climate change due to the global trend of increasing air temperatures. This is because the effects can be direct and indirect. The effects also become felt over varying time-scales. Sometimes effects are not detected in the early stages of change. In connection with species diversity and fisheries, research is leading the way in explaining and revealing the symptoms of climate change and the effects on species diversity. However, environmental changes and degradation of habitat quality due to many factors (pollution, fishing pressure etc.) tend to occur faster that the capacity to collect data and understand the phenomena and dynamics which have occurred and are occurring now in the natural environment.

The global increase in air temperatures causes rising water temperatures, and indirectly increases the volume of water in the oceans. The implication of this is that sea levels will rise. If this trend continues, then the extent of mangrove forests, estuaries and coastal wetlands will be reduced, so that the productivity of these waters will also be reduced and will affect the lives of marine organisms associated with coastal ecosystems.

4.3.1 Deep sea ecosystems

4.3.1.1 Life or communities around hydrothermal vents

Based on the assumption that high energy hydrothermal vents can be found in the Arafura and Timor Seas, the hypothesis has been put forward that life or deep sea biotic communities can be found around these hydrothermal vents. Verification is very difficult not to say impossible to undertake because of the vast area of sea bed which would have to be searched in order to find hydrothermal vents on the bed of the Arafura and Timor Seas.

4.3.1.2 Biogas resources

It should be remembered that the mangrove forest is an area with high rates of decomposition at the substrate level, because of the presence of fallen mangrove leaves and many short-lived organisms which decay through anaerobic processes. This anaerobic decomposition process releases methane gas H_2S which has a most unpleasant and pungent smell. The idea has been put forward that this gas H_2S could be a source of biogas to be used as fuel. The difficulty in applying this idea is that so far no effective and efficient technology and methods have been developed for the collection and storage of this gas ■