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Indonesian marine and coastal biodiversity: Present status

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Indonesia is an archipelagic state, its territory stretches from 6º N to 10º S and from 95º E to 142º E, comprises about 18,110 islands with a coastline of about 108,920 km. About 78 % of the Indonesian territory is covered by waters with shallow seas in the western and eastern parts, the Sunda and Sahul plates, separated by the deep Banda Sea. The diversity of Indonesian marine life is hard to be precisely reported, new species are still being described and many more are still unknown. The Indonesian coastal zone is rich in tropical marine ecosystems such as estuarial beaches, mangroves, coral reefs, seagrass, algal beds and small island ecosystems which are homes of different varieties of living communities with various types of association as well as richness in species diversity. Other coastal habitats such as sandy and muddy shores, sand or mud flats, although hosting relatively poorer biodiversity but they are scientifically interesting. Each of these marine ecosystems, with their associated habitats, supports a wealth of marine biodiversity which are not well explored and very poorly documented. The data of marine organisms herewith presented shows that information on many marine taxa, especially animals, are very poor.

[Key words: Marine biodiversity, marine ecosystems, Indonesian waters]

Introduction

The marine biogeographic realm was divided by Ekman[1] into two main regions: the Indo-West Pacific and Atlanto-East Pacific. The Indo-West Pacific Province is very vast, comprising thousands of islands, mostly coral islands. The South East Asian and New Guinean waters are the main regions of the Indo-West Pacific Province which have the richest marine life. The exploitation of marine biota, animals as well as plants for human consumption or other needs was known far back in the history of mankind.

Scientists know very little about the loss of genetic and species resources from the marine environments. Marine species, or even populations, have disappeared in historical times while in some areas marine ecosystems have been disturbed or eliminated that could lead to the lost of genetic diversity. Marine, especially coastal areas which could be directly or indirectly affected by human land based activity, should therefore be protected from increasing pressure which could weaken or even lost its capacity as potential genetic resources for the future generations.

Historical Perspective

The study on the Indonesian marine biodiversity was dated far back before Linnaeus' *Systema Naturae 10th Edition, 1758*.

The diversity of the Indonesian marine life is hard to be precisely reported. The results of some expeditions are sometimes reported as parts of other works or published several decades after the expedition ended. For example, the work of Griffin & Tranter[2] on majid crabs collected by the Siboga in 1929-1930 was published in 1982 adding the specimens collected by the Mariel King Memorial Expedition in the Moluccas, 1970. Forest[3] cited specimens of pagurid crabs collected in the Makassar Strait during the Corindon II Expedition in his work on the Polychelidae which covers specimens from other parts of the world. The list of selected marine organisms presented by Soegiarto & Polunin[4] which is amended by Moosa[5] shows that information on many marine taxa, especially animals, are very poor or even lacking (Table 1). Therefore, tedious work and patience on literature study of the various marine biota are challenging the keen taxonomists to record the diversity of the Indonesian marine life.

State of the Present Knowledge

The Indonesian archipelago is stretching from 6º N to 10º S and from 95º E to 142º E comprises of about 18,110 islands and has a coastline of about 108,920 km (Fig. 1). About 78 % of the Indonesian territory is covered by waters with shallow seas in the western

Figure 1—. Map of Indonesia showing the main islands and the vast coastal area.

and eastern parts, the Sunda and Sahul plates, separated by the deep Banda Sea connected with other deep seas such as Sulawesi and Maluku Seas in the north and Bali and Flores Seas in the south. The northern seas are connected to the Pacific Ocean while the southern seas are connected to the Indian Ocean. Indonesia therefore, probably has the most diverse assemblage of marine habitats in the world.

The Indonesian marine environments can be divided into two main components i.e. the coastal and offshore waters, the latter can be further divided into shallow and deep water habitats. Each of these components or ecosystems is home for different types of biodiversity assemblages which can have some species in common.

Coastal Ecosystems

The Indonesian coastal zone is rich in tropical marine ecosystems such as estuarial beaches, mangroves, coral reefs, seagrass and algal beds and small island ecosystems which are homes of different varieties of living communities with various types of mode of association as well as richness in species diversity. Other coastal habitats such as sandy and muddy shores, sand or mud flats, have relatively poorer biodiversity. Each of these marine ecosystems, with its associated habitats, supports a wealth of marine resources which are not well explored and documented.

Beaches

As the boundary between land and sea, beaches show a tight zonation of communities and sources of productivity, and they constitute a distinct system which is an important component of the Indonesian coastal zone.

In the upper zones of the beach the dominant organisms are the strand plants, where the beach is tending to acreate the outer fringe of vegetation most commonly comprises a '*pes-caprae*' community of totally 17 species. The plants in this community are low sand-binding herbs, grasses and sedge. *Ipomoea pes-caprae* often predominates in the seaward pioneering fringe, while the grasses and sedges such as species of *Cyperus*, *Fimbristylis* and *Ischaemum* occur behind. Other beaches plants are the *Barringtonia* and associated community comprises of 36 species.

Exposed beaches represent a particularly hostile environment (due to physical instability, and wide variations in temperature, salinity and humidity), but a number of animals have adapted to the conditions. The large animals occurring on the beach generally show a well developed zonation; the ocypodid crabs of the genus *Ocypode* often accompanied by the scopimerid crabs in more compact sand and amphipod crustacean of the family Talitridae are generally characteristic of the upper zones, the middle zones are usually colonized by the mollusc *Donax* and some

isopod crustaceans, while the lower zone is characterized by some gastropod species, hippid crabs and the sea urchin *Echinodiscus* or starfish, *Archaster typicus*. Beaches are also important as a nesting habitat for sea-turtle and for megapode birds in the eastern part of Indonesia.

Mudflats

Invertebrates are commonly found as epibenthos or in mobile epibenthic form such as gastropod mollusc, starfish, and nudibranchs and the infauna. Other invertebrates may consist of representatives from crustaceans, polychaetes and sipunculid, bivalve molluscs, coelenterates, and echinoderms. Several gastropods and bivalves are commonly found burrowing in the substrate, such as *Pinna* sp., *Anadara* spp., and *Paphia* sp., while the crabs are mostly the genera of the family Ocypodidae and Grapsidae which live in crevices or burrows on the mudflats.

Fish community which were found during high tide in the mudflats area associated with estuaries and rivers vary in species, consisting of both freshwater and marine species. Several fish species like mudskippers (Gobiidae) and rays (Dasyatidae) are well adapted with soft substrate. Most mudskippers occupy deeper burrows in the mudflats. All their activities centre on these burrows which are entered briefly throughout the day to moisten the skin and replace water in the gill pouches. Mudskippers are commonly found in the mangroves of Sumatra, Java, Kalimantan and Irian Jaya. Snakes such as *Enhydris* sp. and *Cerberus rhynchops* are sometimes encountered in mudflats. Mudflats in Indonesian coastal area support the population of vulnerable species, *Mycteria cinerea* (Milky stork) and endangered *Limnodromus semipalmatus* (Asian dowitcher) and other birds.

Estuary

The flora-fauna found in the Indonesia's coastal estuarine zone are very diverse. The flora found mainly consists of mangrove plants such as *Rhizophora mucronata, R. apiculata, Avicennia alba, A. marina, A. acida, Sonneratia alba, Ceriops tagal, Candelia candoleana* and *Xylocarpus* sp.

The fauna ranges from small crustaceans and polychaetes up to crocodiles. The crustacean species commonly found in such areas are palaemonid shrimps such as *Macrobrachium* spp., penaeid shrimps such as *Penaeus* spp., *Metapenaeus* spp., *Parapenaeopsis stylifera, P. sculptilis,* and others such as *Acetes erythraeus*, Stomatopoda, Brachyura, Paguridae, Cirripedia, Isopoda, portunid crab such as *Scylla serrata*. Mammalia such as: Otter *(Lutra lutra*). Primates: *Macaca fascicularis, M. nemestrina, Presbytis cristata, Hylobates syndactylus, H. agilis, H. lar*. Reptiles: *Crocodylus porosus, Tomistoma schlegelii, Hydrosaurus amboinensis, Phyton* spp., *Trionix* spp.

Lagoon

In coastal waters where barrier reef exists, lagoon occurs between the barrier reef and the coast. In Indonesia, the biggest atoll is the Taka Bone Rate Atoll. Organisms living in estuarine lagoon have specific characteristics since the lagoon condition is commonly influenced by freshwater from the river and saltwater from the sea as well. Estuarine lagoon is rich of flora and fauna. Benthic organisms mostly depend on their type of substrates. Muddy or sandy substrates are common in lagoon influenced by river with high deposit materials. The bottom surface, influenced by tidal movements, several gastropod and bivalve molluscs were found buried in muddy or sandy substrates. Other benthic organisms are polychaets, ocypodid crabs, gammarid amphipods, and other crustaceans.

An estuarine lagoon is very rich in fish diversity. Cartilaginous fishes such as requiem sharks and stingrays are often occurred in the lagoon. Stingrays are bottom dwellers and commonly found hiding on a sandy or muddy substrates. Bony fishes could find suitable habitat in the lagoon for their feeding and nursery ground.

Muddy substrate at the bank of a lagoon is suitable for mangroves to grow. Mangrove genera such as *Avicennia, Rhizophora,* and *Bruguiera* are well adapted with muddy substrate. The presence of mangrove ecosystem adjacent to estuarine lagoon will enrich the flora and fauna.

Lagoons surrounded by a coral reef may have similiar benthic biota to a coral reef ecosystem. At the leeward side, corals may grow on a hard substrate with a variety of lifeforms comprising branching corals, table corals of the genus *Acropora*, and foliose corals as well as massive corals. Mushroom corals like *Fungia* which are well adapted in water with high sedimentation occur as well [6].

Mangroves

The mangroves of Southeast Asia are extremely diverse. The Indonesian mangrove forest accounts for

76 % of the total mangroves in the Southeast Asian Region. Indonesia has the greatest area of mangrove where it forms the dominant coastal community in Sumatra, Borneo, and Irian Jaya. The forest of Irian Jaya covers about 77 %, while the rest of the islands contribute relatively smaller percentage, for example Sumatra accounts for 10.5 % of the total mangrove area; Sulawesi accounts for 1.4 %; Kalimantan 7.2 %; Maluku 2.6 % and Java & Nusa Tenggara 1.2 % of the total mangroves in Indonesia.

The complexity of the mangrove ecosystem in Indonesia is different from one place to another, depending on the coastal physiography and the tidal dynamics. Along with the straight coastal area, the mangrove growth is relatively narrow, i.e. 25 to 50 m, while in the deltas where the river flows bring some materials, the mangrove can grow very well and spread out widely through out the coast.

The most valuable mangrove-related species in Indonesia are the penaeid shrimps. The landing catch of penaeid shrimps in Indonesian coastal waters is positively correlated with the associated area of mangroves [7].

Seagrass beds

Sandy reef flat in the shelter area of low tidal range may be the best environment for the seagrass to develop. The seagrass forms dense beds that cover a very wide area of Indonesian coastal waters and perform a wide spectrum of biological and physical functions serving as habitat, feeding and nursery ground for fish, invertebrates, turtles and dugong. The most important area for seagrasses is the lower intertidal and upper subtidal zone, where complex vegetation may occur in which of 7 to 8 species grow together. The intertidal zone is characterized by pioneer (colonizer) vegetation, dominated by *Halophila ovalis*, *Cymodocea rotundata* and *Halodule pinifolia* and the lower subtidal zone is dominated by *Thalassodendron ciliatum*.

The Indonesian seagrasses, however, are the least studied coastal ecosystem compared to mangrove and coral reefs. There is still no information of seagrass ecosystem from Sumatra, Kalimantan and Irian Jaya.

Seagrass beds are important to finfish communities worldwide. In the tropics, many nearshore and offshore fisheries (finfish and shellfish) are closely linked to seagrass and to adjacent mangrove and coral reef as well. Subsistence fishing in seagrass occurs widely throughout Indonesia. Early work of Hutomo & Martosewojo[23] demonstrated that many finfish species are associated with seagrass. The fish community consisted of permanent residents, occasional residents and some residents are juvenile only. The last category includes some commercial species.

Invertebrates such as shrimps, sea cucumbers and molluscs are harvested directly from seagrass meadows throughout Indonesia. In some areas the seeds of *Enhalus acoroides* and the rhizomes of *Cymodocea* spp. are harvested for human food. These widespread Indonesian fisheries are poorly documented and their contribution to subsistence economy is unquantified. Therefore, the linkage between Indonesian seagrass ecosystem and the fisheries production is poorly understood.

In general, cyclones, typhoons, tidal waves and volcanic eruptions, pests and diseases, and population and community interactions (grazing and competition) constitute natural stresses to tropical coastal zone including seagrasses [8].

Coral reefs

It is estimated that Indonesia has approximately 75,000 km^2 of coral reef ecosystem which are distributed throughout the archipelago[9]. All types of coral reef including fringing reefs, barrier reefs, atolls, and patch reefs occur in Indonesian marine waters.

Throughout the Indonesian coastal waters fringing reefs are most common and are present around most small to medium-size islands especially in the eastern part, while on the eastern coast of mainland Sumatra, West and South Kalimantan and the southern part of Irian Jaya coral reefs are not remarkable.

Reef fringes the island in the shallow littoral that is free from sediment load coming from the river mouth. Coasts facing the inner basin of Sunda or Sahul continental shelf is devoid of coral reefs (east coast of Sumatra, west and south coast of Kalimantan, north coast of Java and south coast of Irian Jaya), but small islands at a distance from the river siltation, are fringed by healthy coral reef as seen in Seribu Islands and some other places. Reef also develops in the zone of the rough sea that faces to the open ocean.

Factors having impacts on the Indonesian coral reef are: climate, tidal and geological events; coral predators and human impact on reefs. It has been estimated that 41,39 % of the Indonesian reefs have now been lost or seriously damaged. Coral reef condition monitored indicates that about 70 % of the reefs are either fair or badly damaged and only 6.69 % was in excellent condition[10].

Table 1. — List of marine fauna and flora known from Indonesian waters[4,5]

Main taxa	Group	Region	Number	Source
Plants	Green Algae	1	196 spp.	Bosse[12]
	Brown Algae	1	134 spp.	Bosse [12]
	Red Algae	1	452 spp.	Bosse [12]
	Seagrass	1	13 spp.	Hartog [13]
	Mangrove	1	38 spp.	Soegiarto & Polunin[4]
Corals	Hard Corals	1	590 spp.	Suharsono[10]
	Soft Corals	1	210 spp.	Moosa [14]
	Gorgonians	1	350 spp.	Moosa [14]
Sponges	Desmospongia	1	830 spp.	Soest [15]
Mollusc	Gastropoda	1	1,500 spp.	Moosa [14]
	Bivalve	2	1,000 spp.	Valentine [16]
Crustasea	Stomatopoda	1	112 spp.	Moosa [14]
	Brachyura	1	1,400 spp.	Moosa [14]
Echinoderms	Crinoids	2	91 spp.	Clark & Rowe[17]
	Asteroids	2	87 spp.	Clark & Rowe[17]
	Ophiuroids	2	142 spp.	Clark & Rowe[17]
	Echinoids	2	284 spp.	Clark & Rowe[17]
	Holothuroids	2	141 spp.	Clark & Rowe[17]
Fishes	Marine Fishes	1	3,215 spp.	Fishbase[18]
Reptiles	Turtles	1	6 spp.	René Marquez [19]
	Crocodiles	1	1 sp.	Soegiarto & Polunin[4]
	Sea Snakes	1	31 spp.	Tomascik *et al.*[9]
Mammals	Whales & Dolphins	1	29 spp.	Tomascik *et al.*[9]
	Dugong	2	1 sp.	Soegiarto & Polunin[4]

Notes: 1 = specifically Indonesia; 2 = Indonesia and closely adjacent waters

The Indonesian Marine and Coastal Biodiversity

Species diversity

Moosa[5] presented a data (Table 1) by showing the known number of Indonesian marine organisms which could be used as a reference to have an idea of the richness of the existing marine organisms inhabiting the Indonesian seas.

Information on sponges, soft corals worms, tunicates, bryozoans and gorgonids are not available. The table also clearly shows that the Indonesian marine biodiversity is not sufficiently documented. As for plankton not much information is available. The phytoplankton information is still based on the work of Allen & Cupp[11], the zooplankton, especially crustaceans, are based on scattered publications. The study of one group of animals such as mantis shrimp shows that contributions of individual collector to the knowledge of Indonesian fauna is very remarkable.

The coastal zone of Indonesia is rich in estuarine zone, mangroves, coral reefs, seagrass and algal beds and many small island ecosystems. Each of these marine ecosystems, with its associated habitats, supports a wealth of marine resources which are not yet explored and documented.

Mangroves

Kartawinata *et al.*[20] listed 88 species of 37 families reported from the Indonesian mangrove forest, this includes the epiphytes and associated vegetations. Rhizophoracea is represented by 10 species belonging to four genera while Sonneratiaceae and Verbenaceae each is represented by three species. The flora and fauna of the mangrove forest facing the South China Sea is presented in the LPP Mangrove[21] which listed 32 mangrove species of 11 families.

Algae

Indonesia has a high variety of marine algae which mostly grow on coral reef ecosystems. In the eastern

part of Indonesia alone Bosse[12] found 782 species of seaweeds which consist of 179 green algae, 134 brown algae, and 452 red algae. Moosa *et al.* [22] presented 101 species of marine algae from Seribu Islands, 50 species from Pangandaran, 43 species from Benoa, Bali, 64 species from South and Southeast Sulawesi, and 88 species from Maluku. The higher species reported from Seribu Islands is due to more intensive collection activity.

Seaweeds are collected or cultured on reef flats. For centuries coastal communities throughout the archipelago have traditionally utilized seaweeds as vegetables.

Seagrass

Indonesian coastal waters are inhabited by 13 species of seagrasses: *Cymodocea rotundata, C. serrulata, Enhalus acoroidesi, Halodule decipiens, H. finifolia, H. minor, H.ovalis, H. spinulosa, H. uninervis, Syringodium isoetifolium, Thalassia hemprichii, Thalassodendron ciliatum* and another species, *Ruppia maritima* which was based on a specimen at Herbarium Bogoriense collected from Jakarta Bay and has never been reported again since. The 14th species, *Halophila beccarii* was thought to exist in Indonesian waters but so far there is no information of its location and therefore is not listed at Table 1. Among the thirteen species, besides *R. maritima*, *Thalassodendron ciliatum* has limited distribution which is only in the eastern part of Indonesia. Two other species, *Halophila spinulosa* and *H. decipiens* were recorded in few locations.

Corals

Indonesia has approximately 18,110 islands which are partly or wholly surrounded by coral reefs. The eastern part of Indonesia is considered to have the richest coral reefs in the world with high diversity of corals, fish, sponges, algae and other groups of organisms. Furthermore, the eastern part of Indonesia is also rich in reef types including more than 50 atolls or pseudo-atolls.

Fringing reef and patch reef are the most common reef types with scleractinian corals as the most important and dominant groups. The Indonesian waters is the global centre for coral species diversity. Approximately 76 genera of hard coral comprising more than 350 species occur in the vicinity of the Eastern Indonesian seas. Tomascik *et al.*[9] listed 452 species of hermatypic scleractinian coral collected from the Indonesian waters of which some are either mentioned as new species in preparation or mentioned as "sp." or other indication which probably the species could be undetermined. The recent study as presented by Suharsono[10] reveals that the Indonesian sleractinian corals consist of 590 species of 82 genera. The three most important reef-building coral genera in Indonesia are *Acropora*, *Montipora*, and *Porites* represented by 104, 39 and 24 species respectively. The present knowledge on coral genera distribution shows that West Sumatra hosted 49, Java Sea 63, South of Sulawesi 75, Flores and Sumbawa Islands 68, and 63 in the north of Manado, North Sulawesi.

Cairns & Zibrowius[24] listed 173 species of deep-water (ahermatypic) scleractinian species known from Indonesian waters adding 21 new species of which the Karubar Expedition (1991) contributed 15 new species.

Sponges

The shallow sponge species of the Indonesian waters has been collected by several expeditions such as Siboga, Snellius, Rumphius IV besides other collections made individually. Soest[15] speculated that the Desmospongia of the Indonesia is about 830 species (mostly of the Siboga Expedition) and with the more recent collection this number could increase.

Major collections, those made by the Siboga Expedition (3,000 specimens) and the Snellius II Expedition (1,500 specimens), still await description[9]. The deep water sponges of Indonesia collected during the Corindon Mission and Karubar Expedition is still under study.

Echinoderms

There is no addition to the echinoderm fauna in both shallow water and deep sea. The work of Clark & Rowe[17] is one of the most comprehensive to have general impression on the Indonesian echinoderm fauna. Most recently Améziane[25] added one new species, *Saracrinus moosai*. The shallow water echinoderms were reported by Moosa *et al.*[22] comprising 86 species from Seribu Islands, 31 species from Pangandaran, 82 species from South and Southeast Sulawesi, and 145 species from Maluku.

Molluscs

The number of marine molluscs is not precisely known, no list of species ever published. Soegiarto & Polunin[4] mentioned about 1,000 species of bivalves while the gastropod are about 1,500 species[14]. Data on

other molluscan groups is not available. Budiman[26] reported the presence of 303 species of molluscs from mangrove in Asia and Oceania of which 183 species possibly occur in Indonesian mangroves. The shallow water molluscs was reported by Moosa *et al*.[22] comprising 329 species from Jakarta Bay, 392 species from Seribu Islands, 247 species from Java Sea and Madura Strait, 63 from Pangandaran, 125 from South and Southeast Sulawesi, and 913 species from Maluku adding no new species. Recent works which could be added to the list are of Sysoev[27] who adds 19 new species of Conoidea or Turridae; Houart[28] adds one new species, *Leptotrphon kastoroae*; Verhecken[29] adds nine species. Dijkstra & Kastoro[30] add two new species and eight new records for the bivalves.

Crustaceans

The Indonesian marine crustaceans are not sufficiently documented. Table 1 shows only two groups, the stomatopods (102 species) and crabs (1,400 species). These numbers are based on the unpublished data. The contributions of Moosa[31], Erdmann[32], Erdmann & Manning[33] and Ahyong[34] make the number of Indonesian stomatopod fauna become 115 species; while crabs should remain so until more information is gathered. Tomascik *et al.*[9] estimated that the pontoniine shrimps of Indonesia could reach at least 170 species.

Marine fishes

Based on the Fishbase[18] 2004 version, the number of Indonesian marine fishes is 3,215 species. Tomascik *et al*.[9] listed 1,133 species of fish from Maumere Bay, Flores and from Komodo Island as many as 736 species of 254 genera based on the unpublished data of G.R. Allen & R. Kuiter. Allen & Adrim[35] reported that the total reef fish are 2057 species of 113 families, of which 97 are Indonesian endemic. The most abundant families in terms of number of species are Gobiidae (272 species), Labridae (178), Pomacentridae (152), Apogonidae (114), Blenniidae (107), Serranidae (102), Muraenidae (61), Syngnathidae (61), Chaetodontidae (59), and Lutjanidae (43). These 10 families collectively account for about 56% of the total reef fauna. Of the 321 species of damselfish[9] known in the world, Indonesian waters hosted about 138 species. Therefore, the number presented by the Fishbase[18] seems to be too small since many of the species reported by the Indonesian scientists are still not included.

Sea turtles

Six sea turtle species occur in Indonesia, including the green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), Olive ridley (*Lepidochelys olivaceae*), and Leatherback turtle (*Dermochelys coriceae*), which do nest, and the loggerhead (*Caretta caretta*) and flatback turtle (*Natator depressa*), which do not nest in Indonesia. It was only since 1984 that the latter species was confirmed to occur in Indonesia. The green turtle is the most abundant species and is valued particularly for its meat, and its eggs. It seems that over 25,000 females are breeding annually in western Indonesia. The hawksbill turtle is also abundant, and is taken mostly for its shell which has long been worked locally. There are some valuable nesting sites for leatherback turtle, although this turtle is rather rare in the enclosed seas of the region and this species is also hunted in several parts of the country; there are important fisheries in the Kai and Aru Islands.

Marine mammals

Among the mammals, Indonesia remains an important refuge for the Dugong in southern Asia. There is little information on its populations, for as everywhere it is an elusive and sensitive animal. Dugongs are exploited not only for their meat, but also for their teeth.

There are approximately 29 species reported of which seven are baleen whales and the rest are dolphin and relatives[9]. They are found in all seas under national jurisdiction of Indonesia.

Threats to Coastal and Marine Biodiversity

The changing development caused by population growth, increasing quality of life, and the national economic restructuring, have forced Indonesia to intensify and diversify the utilization of coastal and marine resources. Substantial opportunities still exist to increase production from under-exploited coastal and marine resources and, at the same time, ensuring their sustainability for use by future generations. For instance, there are large pelagic fish stocks in the eastern part of the country; only a fraction of coastal areas identified as having potential for aquaculture are currently utilized; large oil and gas reserves are believed to occur in the Natuna basin, the Arafura sea, the Sulawesi sea, and the Timor gap, and exploitation of these resources could impact the marine life.

Despite the high potential development that can be offered by marine ecosystems and resources as described above, the threats to the sustainable

capacity of marine ecosystems, to provide resources and environmental services have, in many cases, reached a critical level. Human activities which threaten marine biodiversity can be broadly grouped into five categories:

- overexploitation of living resources,
- physical alteration of coastal and marine habitats,
- coastal and marine pollution,
- introduction of alien species,
- global climatic change.

However, these threats in essence are symptoms of more fundamental forces which are causing the degradation of marine biodiversity.

The sustainable capacity of these coastal ecosystems is being subjected to stresses and degradation from inappropriate development activities within the coastal zone itself as well as in the ocean (open seas) and in the upland areas. The causes to the degradation of these coastal ecosystems are described below.

a) Coral reef damage is mainly due coral mining, the use of explosive (bombing) and poisons to harvest reef fish and other biota, and sedimentation from upland soil erosion can be found almost throughout the archipelago. Based on the percent coverage of living corals, Suharsono[10] reported that 29.16 % of the Indonesian coral reefs is severely damaged, 37.56 % is moderately damaged, 26.59% in good conditions, and only 6.69 % is in excellent condition.
b) The conversion of mangroves for other uses, such as tambak (brackish water shrimp/fish ponds), settlement, and industrial estates, and over-harvesting of mangroves timber has resulted in the reduction of their areal extent and quality. The Indonesian mangrove area has been declining from 4.25×10^6 hectares in 1982 to 3.80×10^6 hectares in 1993.
c) Sedimentation that increases turbidity of marine waters has so far the most deleterious effects on seagrass beds in Indonesia. Heavy coral mining and collection from reef flats, such as on the Seribu Islands and the coast of Bali, have also deteriorated seagrass beds.
d) Beach erosion is mostly due to inappropriate coastal development or construction. This is common phenomena in Indonesia. Other practices that have resulted in beach erosion include: collecting beach sand for construction materials; construction of airports, hotels, and other structures too close to beaches or in offshore waters; and sand mining.

Although the exploitation rate of fisheries resources for the overall Indonesian marine waters is currently estimated at 40 % of its sustainable potential (MSY = Maximum Sustainable Yield), there are some marine areas, particularly those with dense population and high industrialization like the North Coast of Java, the Straits of Malacca, and the Strait of Bali, which have already been overfished[36,37].

Coastal and Marine Pollution

A variety of wastes originated from both land-and marine-based activities eventually enter into the marine environment. Sources of land-based pollutants include: coastal and upstream agriculture which discharge pesticide, fertilizer and sediment runoff; and urban and industrial development leading to discharge of untreated wastes and effluents. Sources of marine-based pollutants include: oil and gas related activities resulting in discharges of drilling wastes, chronic spills and potential major oil spills (tanker accidents, blowouts); and marine traffic accidents resulting in release of waste and toxic materials. The accumulation of wastes in coastal and marine waters, especially in areas with high population density and industrial activities like the north coast of Java and the Malacca Straits, has caused heavy pollution in these areas which, in turn, could threaten the sustainability of marine living resources and the human health. Cases like massive fish kills in Jakarta Bay (1986, 1993, and 1994) and in Bontang Bay of East Kalimantan in 1989, and Minamata alike diseases found in the North Jakarta[38] indicate such a threatened condition.

The ever increasing coastal and marine water pollution is also believed to be one of the most important factors that have brought about harvest failures of brackish water shrimp production in all populated or high industrial development areas including along the north coast of Java, South Sulawesi, and Aceh.

Illegal utilization of coastal and marine resources include: the use of extraction techniques which are forbidden by Indonesian laws and regulation (e.g. coral mining, the use of explosive and poisons to catch fish); and illegal fishing by foreign fishermen.

The aforementioned environmental threats will either directly or indirectly reduce or degrade marine biodiversity at genetic, species, or ecosystem levels.

The most serious and direct threats to coastal and marine biodiversity are the conversion of coastal habitats (e.g. mangroves, seagrass beds, and estuaries) into man-made land uses, such as tambak, industrial estates, and settlement; and harvesting of coastal and marine resources. Indirect threats to marine biodiversity would be in the form of pollution and sedimentation.

Conclusion

Studies on marine biota should also be accompanied by the sufficient knowledge on the ecosystem, habitat, and substrate where the fauna or flora lives. Without sufficient knowledge on these, it will be hard to collect the right biota on its right biotope. Therefore, protection on the marine biota for the future should be guaranteed by sufficient effort to conserve and manage the ecosystems.

The roots of the problems that cause the degradation of marine biodiversity in Indonesia are the following factors:

1. Rapid population growth and poverty in coastal areas,
2. Lack of implementation policy and poor enforcement,
3. Lack of awareness of the strategic importance of coastal and marine resources for sustainable economic development,
4. Lack of political will to apply sustainable development principles in marine resource utilization,
5. Lack of recognition of “adat” (local tradition) rights and indigenous knowledge, community based participation, and empowerment to local government,
6. Lack of integrated approaches in coastal and marine resource development,
7. Lack of capable human resources,
8. Lack of information as a basis for rational and optimal marine resource management, and poor system to access available information,

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