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Sarawak Coastal Biodiversity: A Current Status

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Abstract

Sarawak lies within the Indo-Malay-Philippine archipelago, which is part of the Indo-West Pacific region. The Sarawak coastline is about 1035 kilometers long, with its coastal marine habitats consisting of sandy beaches, mudflats and rocky shores. Sarawak is one of the megadiversity regions in the world. The main objectives of this review are to report on the recorded species diversity of flora and fauna in the Sarawak coastal waters and to identify the threats to management of the coastal biodiversity. Mangrove forest is dominant along the coastal region of Sarawak. The mangrove forests occupy approximately 60% of the total coastline. Sarawak reefs can be divided into those of northeast and southwest Sarawak regions. The northeast region reefs support rich assemblages of marine life while the southwest region reefs are sparse and undeveloped, lying in heavily silted waters. The most comprehensive species diversity studies are available for phytoplankton, seaweeds, seagrasses, nematodes, marine fish, reptiles and marine mammal communities. Detailed study on other organisms along Sarawak coastal waters is still lacking, especially for meio-and macroinvertebrates. Major threats to Sarawak coastal biodiversity are the clearing of the coastal mangrove forest for developmental purposes, the overexploitation of marine resources, anthropogenic pollution, habitat destruction and habitat loss. The effort to manage Sarawak's biodiversity is reflected in the formation of several acts and policies by the Malaysian government. The formation of universities and research centers to educate people on the importance of biodiversity conservation is the proper strategy for tackling the issues of sustainable management of marine coastal resources in Sarawak.

Key words: Sarawak, flora, fauna, threats, management.

1. Introduction

Malaysia, in particular Sarawak, is one of the megadiversity regions of the world. Carpenter and Niem (1998) noted that marine tropical shore fauna diversity centered in South-East Asia is 'greater than any on earth'. Fifty-three percent of the world's coral reefs are found in this region. Sarawak lies within the Indo-Malay-Philippine archipelago, which is part of the Indo-West Pacific region. Sarawak is located at latitude 0° 50´ and 5° N and longitude 109° 36´ and 115° 40´ E (Fig. 1). The Sarawak coastline is about 1035 km long. It contains an extensive continental shelf area, areas of high biological productivity, a high marine coastal biodiversity and a dense human population along the coast.

2. General Overview of Sarawak Coastal Marine Habitats

Sandy beaches, mudflast and rocky shores

Sandy beaches and mudflats occur along the coastal area of Sarawak. Sandy beaches are usually exposed directly to wave action whereas mudflats are located close to river mouths, are sheltered and receive less wave action. The organisms inhabiting both habitats are exposed to high temperature and desiccation. Both habitats contain fauna that can adapt to the wave action and instability of the area. Most of the fauna such as burrowing polychaetes, oligochaetes, sipunculans, bivalves and echinoderms are living at the middle and lower zones of the beach. Some middle and lower zone areas harbor a seagrass bed, for example, Sampadi Island and Engriting beach, Lawas. The seagrass bed is believed to serve as a habitat and nursery for a variety of invertebrates and fish, and also provides food for turtles and dugongs. Sandy beaches at islands such as Satang Besar and Talang-

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Fig. 1: Map shows the location of Sarawak, Malaysia (Source: Google)

talang Islands are recorded as areas for marine turtle nests.

Rocky shores can be seen along the Sarawak coastal waters. Boulder formations and smaller rocky outcrops are common along the Sarawak coast. The horizontal distribution (zonation) of organisms on rocky shores is based on three major tide levels: high-tide, mid-tide and low-tide. Each tide level is characterized by certain organisms such as gastropods (high-tide level), barnacles (mid-tide levels) and algae (low-tide level). Most of the organisms are found at the low tide level where the environment is less extreme. Rock pools on Sarawak's rocky shore support minimal flora and fauna due to a high fluctuation of water parameters such as salinity, temperature and dissolved oxygen.

Mangrove forests

Mangrove is dominant in the environment along the Sarawak coastline. The mangrove forests of Sarawak occupy about 60% of the 1035 km long coastline (Chai 1982; Pang 1989; Rahim 2000) and cover about 1.4% of the total land area (Chai 1982). The total mangrove forest areas in Sarawak are estimated at 127,736 hectares (Say 1999). The mangrove ecosystem is located in the sheltered areas along the Sarawak coast within the major bays of Rajang River Delta, Limbang, Kuching and Sri Aman divisions (Chai 1982, Say 1999). Forty species of mangrove area plants including trees, shrubs, palms, ferns and epiphytes are reported in Sarawak (Chai 1972, 1975a, 1975b, 1982; Othman 1981, 1999; Murofushi *et al*. 1999; Rahim 2000); Ashton and Macintosh 2002). The mangrove forest in Sarawak has suffered from human expansion and human activities such as reclamation for housing and industrial estates, conversion for agriculture land and aquaculture ponds and pollution through industrialization and urbanization.

Coral reefs

Sarawak's reefs can be divided into those in northeast and southwest Sarawak regions (Pilcher and Cabanban 2000). Coral reefs in Southwest Sarawak are located around three small islands (Satang, Talang-Talang Besar, Talang-Talang kecil) and Tanjung Datu. In

the northeast, the reefs are located at Luconia shoals off Bintulu and off the coast of Miri (Pilcher and Cabanban 2000). The northeast region's reefs support a rich assemblage of marine life that includes fish, mollusks and crustaceans (Pilcher and Cabanban 2000; Ferner 2013). The southwest region's reefs are sparse and undeveloped, lying in the heavily silted waters that flow from big rivers such as the Batang Lupar, Batang Sadong, Batang Kayan, and Sarawak rivers and several other smaller rivers such as the Sematan, Samunsam, and Sibu Laut. The major causes of concern in regard to destruction of Sarawak's reefs are sedimentation and sand mining activities. Increased sediment loads from runoff in upstream areas of many rivers in Sarawak have increased sediment output by several orders of magnitude over the last three decades (Pilcher and Cabanban 2000). The anthropogenic pollution and sediments from the rivers could be threatening the nearshore reefs.

3. Previous studies

Studies on Sarawak coastal biodiversity were initiated by British scientists during Rajah James Brook's time when Alfred Russel Wallace collected thousands of biological specimens ranging from invertebrates to Orangutans. Wallace visited Sarawak from November 1854 to January 1856 and did his sampling along the Sarawak River valley from the foothills of Mount Santubong to the peat swamps of Simunjan (Tuen and Das 2005). This collecting was then followed by other studies on various organisms. Table 1 shows the number of species recorded in Sarawak coastal waters together with their sources. The phytoplankton and nematode groups in Sarawak appear to have a high number of recorded species when compared with Peninsular Malaysia but are still far below the number of known species in the world (phytoplankton: 5400; nematode: 5000) (Mazlan *et al*. 2005). There are still many groups of organisms that need to be studied, in particular the small invertebrates such as meio- and macroinvertebrates. The meio- and macroinvertebrates contain huge number of animals and further research should be done to inventory the species in Sarawak's coastal waters. However, the lack of taxonomists working on various invertebrates' taxa is the major drawback to achieving these objectives.

Up until the present day, the majority of comprehensive species diversity studies in Sarawak were for phytoplankton (Boonyapiwat 1998), seaweeds (Phang 2007; Anon 2013), seagrasses (Japar Sidek and Muta Harah 2011), nematodes (Shabdin *et al*. 2013), marine fishes (Vidthayanon 1998), reptiles (De Rooij 1915; Musters 1983; Leh 1985; Stuebing 1991; Das and Charles 1993; Denzer 1996; Tisen and Bali 2002; Das 2004, 2006; Jensen and Das 2006; Das *et al*. 2013) and marine mammals (Beasley and Jefferson 1997). Detailed study on other organisms along the Sarawak coastal waters are still lacking especially in regard to the meio- and macroinvertebrates.

Table 1. Sarawak coastal biodiversity checklist. Species recorded in Sarawak and estimated species in Malaysia (in parenthesis).

Organism	species number	Sources
Phytoplankton	291 (100) *	Boonyapiwat (1998)
Seaweeds	104 (209) *	Phang (2007); Anon (2013)
Seagrasses	8 (14) *	Japar Sidek and Muta Harah (2011)
Mangroves	40 (104) *	Chai, (1972, 1975a,1975b, 1982); Othman (1989,1991); Murofushi et al. (1999); Rahim (2000); Ashton and Macintosh (2002).
Hard coral	203 (480) ***	Ferner (2013).
Mollusc: Gastropods	78 (300) *	Ashton et al. (2003), Shabdin and Rosniza (2010); Hamli et al. (2013)
Mollusc: Bivalves	31 (100) *	Ashton et al. (2003), Shabdin and Rosniza (2010); Hamli et al. (2012)
Crustacea – Decapods	54 (1100) *	Bejie (1985); Ashton et al. (2003), Ashton and Macintoch (2002); Ikhwanuddin et al. (2011).
Crustacea - Copepods	18 (100) *	Agatha (2005).
Nematodes	111 (20) *	Shabdin et al. (2013).
Marine fish	518 (1500) *	Vidthayanon (1998)
Sea horses	4 (50) **	Kuang and Chark (2004)
Reptiles	19 (40) *	De Rooij (1915), Musters (1983), Leh (1985), Stuebing (1991), Das and Charles (1993), Denzer (1996), Tisen and Bali (2002), Das (2004, 2006), Jensen and Das (2006), Tisen and Ahmad (2010), Das et al. (2013).
Migratory birds	29(41) #	Mizutani et al., (2006); Edward and Parish (1986).
Marine mammals	15 (29) *	Beasley and Jefferson (1997), Minton et al. (2011)

* Mazlan et al. (2005). ** Lim et al. (2011). *** Affendi and Faedzul (2011). # Bamford et al. 2008.

Phytoplankton

Boonyapiwat (1998) reported 291 phytoplankton species in her study from the South China Sea area II which includes the state of Sarawak. Out of 310 species, 2 species of blue green algae, 139 species of diatoms and 150 species of dinopflagellates were recorded (Table 2). The frequently predominant species found on the surface layer of the South China Sea were *Ocillatoria erythraea, Thalassionema frauenfeldii and Pseudosolenia calcar-avis*.

Table 2. Summary of the coastal phytoplankton reported by Boonyapiwat (1998).

Phylum	Common name	Species number
Cyanophyceae	Blue Green Algae	2
Bacillariophyceae	Diatom	139
Dinophyceae	Dinoflagellate	150
	TOTAL	291

Seaweeds

Sarawak has a variety of ecosystems such as rocky shores, sandy bays, mudflats, mangroves and coral reefs. All these provide habitats for the variety of seaweed species found in Sarawak coastal waters. Phang (2007) reported twenty-six species of seaweed that only exist in Sarawak coastal waters. A comprehensive study was carried out by the Fisheries Research Institute, Sarawak Branch, from 1996 to 1998 along Sarawak coastal waters (Anon 2013). This study recorded 36, 27, and 41 species of seaweeds from Chlorophyta, Phaeophyta and Rhodophyta Division respectively (Table 3). One hundred and four species of seaweed were identified and kept in herbariums of the Fisheries Research Institute, Sarawak Branch, Bintawa, Kuching (Anon 2013).

Table 3. Seaweed species in Sarawak coastal waters (Anon, 2013).

Division	Family	Species
CHLOROPHYTA	Acetabulariaceae	*Acetabularia major* *Acetabularia sp.*
	Dasycladaceae	*Bornetella sp.* *Neomeris annulaia*
	Anadyomenaceae	*Anadyomene plicata* *Anadyomene stellata*
	Cladophoraceae	*Chaetomorpha minima* *Chaetomorpha linum* *Cladophora fascicularis* *Cladophora patentiramea*
	Ulvaceae	*Enteromorpha intestinalis* *Enteromorpha tubulosa*
	Valoniaceae	*Valonia utricularis*
	Boodleaceae	*Cladophoropsis membranaceae*
	Bryopsidaceae	*Bryopsis hypnoides* *Bryopsis pennata*
	Caulerpaceae	*Caulerpa lentillifera* *C. microphysa* *C. peltata* *C. serrulata* *C. sertularioides* *C. taxifolia* *C. verticillata*
	Udoteaceae	*Avrainvillea erecta* *Avrainvillea sp.* *Halimeda discoidea* *Halimeda opuntia var minor* *Halimeda tuna* *Halimeda macroloba* *Halimeda simulan* *Halimeda* sp. *Halimeda* sp. 1 *Halimeda* sp. 2 *Udotea flabellum* *Udotea javensis* *Udotea* sp.
PHAEOPHYTA	Dictyotaceae	*Dictyopteris delicatula* *Dictyota dichotoma* *Dictyota friabilis* *Dictyota mertensii* *Dictyota sp.* *Lobophora variegata* *Padina australis* *Padina boryana* *Padina minor* *Padina* sp. *Padina* sp. 1 *Padina* sp. 2 *Padina* sp. 3 *Padina* sp. 4 *Padina tenuis* *Padina tetrastromatica* *Zonaria* sp.
	Sargassaceae	*Sargassum crassifolium Sargassum ilicifolium* *Sargassum polycystum* *Sargassum siliquosum* *Sargassum spathulaefolium* *Sargassum* sp. *Spatoglossum* sp. *Spatoglossum* sp. 1
	Scytosiphonaceae	*Rosenvingea orientalis Colpomenia sinuosa*

RHODOPHYTA	Chaetangiaceae	*Galaxaura oblongata* *Scinaia boergesenni* *Scinaia* sp.
	Delesseriaceae	*Martensia* sp.
	Gelidiaceae	*Gelidiella acerosa*
	Rhodomelaceae	*Bostrychia binderi*
	Corallinaceae	*Amphiroa anceps* *Amphiroa foliacea* *Amphiroa fragilis-sima* *Jania capillacea* *Jania decussato-dichotoma* *Jania* sp. *Corallina* sp.
	Halymeniaceae	*Halymenia dilatata* *Halymenia maculata* *Halymenia* sp.
	Caulacanthaceae	*Catenella nipae*
	Gracilariaceae	*Gracilaria changii* *G. coronopifolia* *G. blodgettii* *G. edulis* *G. salicornia* *G. arcuata* *Gracilaria* sp. *Gracilaria* sp. 1 *Gracilaria* sp. 2
	Hypneaceae	*Halymenia dilatata* *Halymenia maculata* *Halymenia* sp.
	Caulacanthaceae	*Catenella nipae*
	Gracilariaceae	*Gracilaria changii* *G. coronopifolia* *G. blodgettii* *G. edulis* *G. salicornia* *G. arcuata* *Gracilaria* sp. *Gracilaria* sp. 1 *Gracilaria* sp. 2
	Hypneaceae	*Hypnea esperi* *Hypnea spinella* *Hypnea* sp. *Hypnea* sp. 1
	Squamariaceae / Rhizophyllidaceae	*Peyssonelia rubra*
	Rhodymeniaceae	*Chrysymenia* sp.
	Solieriaceae	*Solieria* sp.
	Ceramiaceae	*Spyridia filamentosa*
	Rhodomelaceae	*Acanthophora spic-ifera* *Laurencia lageni-formis* *Laurencia majuscula* *Laurencia obtusa* *Laurencia papillosa* *Laurencia perforata* *Laurencia cartilag-inea*

Seagrass

Japar Sidek and Muta Harah (2011) listed 8 species of seagrasses found in Sarawak coastal waters (Table 4). The number of species found in Sarawak represent 57 percent of the total species recorded from Sabah and Peninsular Malaysia. The seagrass species in Sarawak were collected from the Bintulu River, the Simalajau estuary, Talang-Talang Island and Punang-Sari, Lawas. Seven species were recorded in Punang-Sari, Lawas, and and it is the place that harbors the highest species number of seagrassess in Sarawak (Japar Sidek and Muta Harah 2011). Recent study has recorded one species, *Halodule pinifolia*, in the intertidal to 5 meter depth which forms seagrass meadows and covers almost 50 ha on the west part at Sampadi Island (Jaaman *et al*. 2011).

Table 4. Summary of coastal seagrass species reported by Japar Sidek and Muta Harah (2011).

Family	**Species**
Hydrocharitaceae	*Enhalus acoroides* (L.*f*.) Royle
	Thalassia hemprichii (Ehrenb.) Aschers.
	Halophila beccarii Aschers.
	Halophila decipiens Ostenfeld
	Halophila ovalis (R.Br.) Hook.*f*.
Cymodoceaceae	*Cymodocea rotundata* Ehrenb. & Hempr. Ex Aschers.
	Halodule pinifolia (Miki) den Hartog
	Halodule uninervis (Forssk.) Aschers.

Coral reefs

Ferner (2013) reported 203 coral species and 66 genera of hard corals recorded from the Miri area (Northeast, Sarawak). Ferner (2013) noted that the high number of coral species indicates that the Miri reefs, Sarawak, are on the edge of the 'Coral Triangle's area of highest diversity of coral and this is consistent with its geographic position near the Philippines and Indonesia, which are known to be in the 'Coral Triangle'. The genera *Acropora, Montipora, Fungia, Leptoseris* and *Pavona* were recorded as having the highest number of species in Miri reef (Table 5)(Ferner 2013). Coral in the Miri reefs appeared healthy, although sedimentation of some of the reefs closest to shore appears to periodically heavy (Ferner 2013). Coral reefs closest to river mouths are likely to be near the limits of their tolerance for water turbidity and die-off due to the high sedimentation rate in the reef area (Ferner 2013). The southwest reefs are sparse and undeveloped, lying in the heavily silted waters that flow from big and small rivers that are located along the southwest coast of Sarawak (Pilcher and Cabanban

2000).

Table 5. Summary of corals genera with the greatest number of species from Miri, Sarawak (Ferner, 2013).

Genus	Species Number
Acropora	21
Montipora	14
Fungia	9
Leptoseris	8
Porites	7
Pavona	7
Acanthastrea	6
Euphyllia	6
Favia	6
Lobophyllia	6
Psammocora	6

Free-living Nematode

One hundred and eleven species of free-living nematodes representing forty seven (47) genera and twenty (20) families are reported from estuarine and marine habitats along the Sarawak coastal waters (Table 6)(Shabdin *et al*. 2013). Though the number of species recorded in Sarawak waters is higher than reported in Malaysia as a whole, it is far below the total number of species in the world (5000 species). Very few studies have been conducted in Sarawak on marine and estuarine free-living nematode species. Considering Sarawak is located in a centre of biodiversity, more efforts should be made in recording the nematode species in Sarawak waters.

Table 6. Summary of free-living nematodes from Sarawak coastal waters as reported by Shabdin et al. (2013).

Order	Family	Species
Enoplida	Anoplostomatidae	*Anoplostoma viviparum* *Chaetonema canellatum* *Chaetonema cf. longisetum*
	Enchelididae	*Belbolla assuplementata* *Belbolla teissieri* *Calyptronema maxweberi* *Calyptronema cf. pulchrum* *Polygastrophora heptabulba*
	Ironidae	*Thalassironus jungi* *Trissonchulus cf. obtusus*
	Oncholaimidae	*Oncholaimus oxyuris* *Viscosia cf. antarctica* *Viscosia coomansi* *Viscosia erasmi* *Viscosia separabilis* *Viscosia stenolaima* *Viscosia cf. tumidula*
	Oxystominidae	*Oxystomina alpha* *Oxystomina elongata* *Oxystomina pulchella*
	Thoracostomopsidae	*Enoplolaimus cf. denticulatus* *Oxyonchus australis* *Trileptium otti* *Trileptium cf. parisetum*
	Tripyloididae	*Bathylaimus capacosus*
Chromadorida	Chromadoridae	*Euchromadora arctica* *Neochromadora appiana* *Neochromadora bilineata* *Neochromadora cf. munita* *Parapinnanema harveyi* *Spilophorella papillata* *Spilophorella paradoxa* *Steineridora adriatica*
	Comesomatidae	*Hopperia australis* *Paracomesoma dubium* *Pierrickia aequalis* *Sabatieria cf. alata* *Sabatieria celtica* *Sabatieria cf. granifer* *Sabatieria pulchra* *Sabatieria cf. splendens* *Setosabatieria hilarula*
	Cyatholaimidae	*Paracanthonchus spec* *Paracanthonchus cf. multitubifer* *Pomponema ammophilum* *Pomponema astrodes* *Pomponema compactum* *Pomponema coomansi* *Pomponema cyatholaimoides* *Pomponema elegans* *Pomponema polydonta* *Pomponema syltense*
	Selachinematidae	*Gammanema cf. polydonta* *Halichoanolaimus cf. consimilis* *Halichoanolaimus macrophallus* *Halichoanolaimus cf. ovalis* *Synonchiella riemanni*
	Desmodoridae	*Metachromadora chandleri* *Metachromadora clavata*

		Metachromadora pneumatica *Metachromadora cf. vivipara* *Metachromadora vulgaris* *Onyx perfectus* *Onyx rugata* *Perspiria cf. papillata* *Pseudochromadora quadripapillata* *Spirinia gerlachi* *Spirinia megamphida* *Spirinia cf. parasitifera* *Spirinia septentrionalis*
	Monoposthiidae	*Nudora nuda* *Nudora omercooperi* *Nudora steineri*
	Aegialoalaimidae	*Southernia zosterae*
	Ceramonematidae	*Dasynemoides cf. riemanni*
	Desmoscolecidae	*Desmoscolex longisetosus* *Quadricoma cf. suecica*
Monhysterida	Xyalidae	*Cobbia dentata* *Cobbia truncata* *Daptonema articulatum* *Daptonema buelkiensis* *Daptonema cf. dentatum* *Daptonema exutum* *Daptonema fimbriatus* *Daptonema hirsutum* *Daptonema laxum* *Daptonema normandicum* *Daptonema polaris* *Daptonema tenuispiculum* *Daptonema cf. trabeculosum* *Daptonema vicinum* *Metadesmolaimus aduncus* *Rhynchonema cf. brevituba* *Rhynchonema impar* *Rhynchonema cf. ornatum*
	Sphaerolaimidae	*Sphaerolaimus balticus* *Sphaerolaimus cf. islandicus* *Sphaerolaimus lodosus* *Sphaerolaimus macrocirculus* *Sphaerolaimus cf. megamphis* *Sphaerolaimus cf. pacificus*
	Axonolaimidae	*Parodontophora brevamphida* *Parodontophora breviseta* *Parodontophora danka* *Parodontophora pacifica* *Parodontophora polita* *Parodontophora quadristicha* *Parodontophora xenotricha* *Pseudolella cf. bangalensis* *Pseudolella cf. granulifera*
	Linhomoeidae	*Terschellingia longicaudata*

Coastal Marine fishes

A comprehensive survey on marine fishes of the coastal area of Sarawak was reported by Vidthayanon (1998). A total of 518 species from 24 orders and 111 families were recorded through research cruise and market surveys from various coastal towns in Sarawak (Table 7). Order Perciformes is dominant as compared to the other orders. The study also reported 103 and 106 economic species noted in both trawling and market surveys, respectively.

Table 7. Summary of marine fish species reported by Vidthayanon (1998).

Order	Family number	Species number
Orectolobiformes	1	2
Carcharhiniformes	3	12
Rhinobatiformes	1	1
Torpediniformes	1	2
Rajiformes	1	2
Myliobatiformes	5	10
Anguilliformes	4	11
Clupeiformes	3	20
Aulopiformes	1	7
Ophiiformes	2	4
Siluriformes	2	9
Osmeriformes	1	1
Zeiformes	1	1
Myctophiformes	1	1
Gadiformes	2	2
Beloniformes	3	8
Atheriniformes	1	1
Beryciformes	2	3
Gasterosteiformes	5	9
Lophiiformes	4	9
Scorpaeniformes	4	25
Perciformes	50	309
Pleuronectiformes	7	27
Tetraodontiformes	6	42
TOTAL	111	518

Coastal reptiles

Twenty one species of reptiles are found in Sarawak coastal waters. Out of that sixteen are species recorded in mangrove ecosystem such as crocodiles, terrapins, lizards, geckos, skinks, monitors and snakes (De Rooij 1915; Musters 1983; Stuebing 1991; Das and Charles 1993; Denzer 1996; Das 2004; 2006; Jensen and Das 2006; Das *et al*. 2013) (Table 8). Five species of turtles are recorded along the Sarawak coast (Leh 1985). Leh (1985) noted that only three species are commonly found in Sarawak waters, namely *Chelonia mydas, Eretmochelys imbricata* and *Caretta caretta*. Leh (1985) noted that Dermochelys coriacea (Leatherback turtle) is seldom seen in Sarawak waters. However, lately *Dermochelys coriacea* is also reported in Sarawak waters and are included in the conservation program held by the Sarawak Forestry Corporation (Tisen and Bali 2002). Turtle are reported to lay their eggs on Talang-Talang and Satang Islands, Sarawak.

Table 8. Reptiles found in Sarawak mangrove forests and adjacent waters.

Species	Common name
Crocodylus porosus	Estuarine crocodile *
Batagur borneoensis	Painted terrapin **
Draco cornutus	Flying lizard ***
Gekko smithii	Smith's (green-eyed) gecko #
Hemiphyllodactylus typus	Indopacific tree gecko #
Apterygodon vittatum	Borneo skink ##
Emoia atrocostata	Mangrove skink ###
Varanus salvator	Common water monitor @
Boiga dendrophila	Mangrove snake @@
Cerberus rynchops	Dog-faced water snake @@
Gerarda prevostiana	Gerard's water snake @@@
Fordonia leucobalia	Crab-eating water snake @@
Acrochordus granulatus	Little filesnake @@
Xenelaphis hexagonotus	Malaysian brown snake @@
Enhydrina schistosa	Beaked sea snake @@
Ophiophagus hannah	King cobra +
Chelonia mydas	Green turtle ++
Eretmochelys imbricata	Hawksbill turtle ++
Caretta caretta	Loggerhead turtle ++
Dermochelys coriacea	Leatherback turtle +++
Lepidochelys olivacea	Olive Ridley turtle +++

* Tisen, and Ahmad (2010), ** Jensen and Das (2006), *** Musters (1983), # Das and Charles (1993), ## Denzer (1996), ### Das (2004), @ De Rooij (1915), @@ Stuebing (1991), @@@ Das et al. (2013),+ Das (2006), ++ Leh (1985), +++ Tisen and Bali (2002).

Marine mammals

Studies on marine mammals in Sarawak coastal waters were started in 1901 when Lydekker (1901) published his work 'Notice of an apparently new estuarine dolphin from Borneo'. In later years, several historical records were put together by scientists on the marine mammals of Sarawak coastal waters (Gibson-Hill 1950; Beasly and Jefferson 1997). More recent studies focus on the distribution of cetaceans in Sarawak coastal waters (Jaaman 2006; Bali *et al*. 2008; Minton *et al*. 2011). Fourteen species were reported by Beasly and Jefferson (1997) and one species (*Tursiops aduncus*) was recorded by Minton et al. (2011) in Sarawak coastal waters (Table 9). Three species of dolphins are common in Sarawak waters, namely *Tursiops aduncus, Sousa chinensis* and *Orcaella brevirostris* (Minton *et al*. 2011). *Dugong dugon* (sea cow) was first reported present in Cape Datu, Lawas and Limbang, Sarawak (Jaaman *et al*. 2011) and was also reported in Teluk Serabang, near Samunsam Wildlife Sanctuary, Sarawak prior to the 1960s (Jaaman *et al*. 2000). Fourteen individuals of *Dugong dugon* were reported seen in Limbang Division Sarawak and Brunei Bay, Sabah during a 2007 aerial survey (Jaaman *et al*. 2011). *Dugong dugon* is an endangered species due to hunting and habitat destruction (seagrass). Previous studies on marine mammals were focused on the taxonomies of the groups. A recent study by Minton et al. (2011) deals with the distribution and populations of small cetaceans. A more comprehensive study should be carried out to see the relationship of the marine mammals and their interaction within and between ecosystems (Mazlan *et al*. 2005).

Table 9. Summary of marine mammals reported by Beasly and Jefferson (1997).

Species name	Common name
Balaenoptera musculus	Blue whale
Balaenoptera physalus	Fin whale
Balaenoptera edeni	Bryde's whale
Megaptera novaeangliae	Humpback whale
Physeter macrocephalus	Sperm whale
Kogia breviceps	Pygmy sperm whale
Orcinus orca	Killer whale
Globicephala macrorhynchus	Short-finned pilot whale
Grampus griseus	Risso's dolphin
Tursiops aduncus	Bottlenose dolphin *
Lagenodelphis hosei	Fraser's dolphin
Sousa chinensis	Indo-Pacific humpback dolphin
Orcaella brevirostris	Irrawaddy dolphin
Neophocaena phocaenoides	Finless porpoise
Dugong dugon	Dugong

* Species recorded by Minton et al. (2011).

4. Threats to Sarawak Coastal Biodiversity Resources

Mangrove ecosystem

Development of the coastal mangrove forest is a major threat to mangrove ecosystems in Sarawak. These include the conversions of mangrove ecosystems into aquaculture pond and eco-tourism industries, reclamation of mangrove forest into housing estates, and industrial complex and commercial ports which lead to habitat losses. The reclamation and conversions of mangrove forest will cause habitat degradation along the Sarawak coastal waters and deprived them of the functions performed by the mangrove ecosystem in coastal protection and serving as a nursery ground for aquatic fauna.

Commercial fisheries

An increase of the population density will lead to continuing pressures on the Sarawak coastal marine ecosystems. An increase in the demand for commercially important fishes will lead to over exploitation of the marine fish resources due to uncontrolled use of trawling gears. The continuing exploitation of fishery resources above the levels of maximum sustainable yield will result in the disruption of species composition through the increase in trash fish landing (by catch yield) and recruitment failure of the commercially important marine species (Mazlan *et al*. 2011). Invasiveness of introduced species in the natural environment is another important issue to be addressed in protecting the Sarawak coastal marine species. *Tilapia mosambica* is a freshwater species in its native country but can adapt well tp the brackish water habitat and its presence will affect the survival of the local resident species.

Coral reefs ecosystem

The coral reefs ecosystem in Sarawak has long been under threat due to natural hazards and anthropogenic pollution in the coastal waters. The coral reefs near Miri and Simalajau are suffering coral bleaching due to environmental and human factors (The Star 2010). Coral death is also caused by the corallivores species such as *Acanthaster planci*. However, this mortality is relatively minor assuming there is no population outbreak of the crown-of-thorns starfish.

The major threats to coral reefs in Sarawak are anthropogenic pollution such as sedimentation and sand mining (Pilcher and Cabanban 2000). The increase in sediment load due to runoff in upstream areas of many rivers in Sarawak could be a threat to the nearshore reefs. Most of the reefs in Miri lie within 8-9 km of the Miri and Baram River mouths (Pilcher and Cabanban 2000). The primary threat to the reefs of Talang-Talang Islands comes from sediment loading in the water which originated from the Kayan and Sematan Rivers (Pilcher and Cabanban 2000), whereas sedimentation at Satang Island reefs is transported by currents from Sibu Laut, Rambungan and Sampadi Rivers. High sediment loads in many rivers of Sarawak are related to forest removal and land development. Most of the dead corals in those islands are covered with sediment and macroalgae (Pilcher and Cabanban 2000).

Reptiles

The clearing and reclamation of mangrove forest in the coastal areas will lead to habitat loss for many reptiles species found in Sarawak. Conservation efforts by government agencies such as the Sarawak Forestry Corporation are focusing on the sea turtles rather than on other reptile species in the mangrove forests. Sea turtles in Sarawak are highly endangered species due to their slow reproduction rate and habitat destruction (Anon 2009). The major threats to turtles in Sarawak waters are incidental capture by fishermen's fishing gear, over harvesting for meat and eggs, and natural predators of the newly hatched turtles. All turtle species in Sarawak are fully protected species and included in the state's conservation program.

Marine mammals

Marine mammals such as *Dugong dugon* are currently facing threats due to seagrass degradation and habitat loss. Seagrass degradation is due to sedimentation and pollution from coastal development and palm oil plantations (Jaaman *et al*. 2011). Though seagrass is known as hardy and robustly pioneering, it cannot tolerate highly silty and turbid water. The murky water along the Sarawak coast is possibly due to the high human population and intensive coastal development activities. The immediate impact from sedimentation and water pollution (untreated waste disposal) may have severely degraded seagrass meadows along the Sarawak coast and consequently directly impacts the dugong feeding grounds. Further threats to dugongs are incidental catches by fishermen, hunting for dugongs as food and unsupervised tourism (Jaaman *et al*. 2011). The

other marine mammals such as dolphins, porpoises and whales are not under critical threat due to the nature of their swimming habits.

5. Sarawak Biodiversity Conservation and Management Program

Malaysian commitment to biodiversity is reflected in the formation of several policies, centres and directorates related to environment and biodiversity. Among the policies are the Fisheries Act of 1985, the National Policy on Biological Diversity 1998, and the National Biotechnology Policy 2005. The establishment of centres and directorate to manage the biodiversity such as the National Biodiversity Centre 2012 and the National Oceanography Directorate under the Ministry of Science Technology and Innovation (MOSTI) are spearheading biodiversity management in Malaysia. The National Biodiversity Centre is focusing on the inventory of biodiversity such as flora, fauna and marine biodiversity. In Sarawak, the commitment of the state government to manage the biodiversity is reflected in several ordinances and acts such as the Sarawak Biodiversity Ordinance 1997 and the Sarawak National Parks and Nature Reserves Ordinance 1998 (Chapter 27). Sarawak has several laws and other legislation related to biodiversity and conservation. These include the following: the Sarawak Forestry Corporation Ordinance of 1995, the Wildlife Protection Ordinance 1998, the National Parks and Nature Reserves Ordinance 1998, the Wildlife Protection Rules 1998 and the National Parks and Nature Reserves Rules 1999. Continuous efforts have been made by several state government agencies and universities to discover and gather the latest information on the state of biodiversity in the Sarawak coastal waters. These include scientific expeditions, independent research, seminars and conferences. The Sarawak government through various agencies has taken active responses in addressing various environmental issues. Various policies are formed to tackle different threats posed to the environment and its biodiversity with the specific aims of balancing human demands on biodiversity resources. Following the World Summit on Sustainable Development (WSSD), which was held in Rio de Janeiro, Brazil in 1992, the Sarawak State Government enacted the Natural Resources and Environment (Amendment) Ordinance, 1993; the Natural Resources and Environmental Board (NREB) was established on 1st February 1994. The formation of the NREB of Sarawak under the Ministry of Resource Planning and Environment was purposely to tackle environmental issues. The NREB's main objective is to protect and enhance the environmental quality in Sarawak. The NREB had imposed an Environmental Impact Assessment (EIA) and a Natural Resource Environmental Audit on all development projects in Sarawak coastal waters. The requirement of an EIA for a prescribed coastal development activity in Sarawak is mandatory for all coastal development projects. In Sarawak the management of forests including an inventory of flora is under the jurisdiction of the Sarawak Forestry Department (SFD) while bio-prospecting of natural products is controlled by the Sarawak Biodiversity Centre (SBC). All National Parks (NP) including two marine National Parks (Talang-Satang NP and Miri-Sibuti Coral Reefs NP) are managed by the Sarawak Forestry Corporation (SFC). Sarawak has enough rules and regulations to safeguard its biodiversity and natural resources. However, the enforcement of these rules and regulations can be further improved in the future.

The Sarawak Forestry Corporation (SFC) embarked on a reef ball project in order to protect the inter-nesting habitats and migratory routes of turtles from the traps posed by the trawlers' nets. The formation of Sarawak Reef Balls Working Group (SRBWG) has had tremendous impact on turtle conservation efforts. The use of reef balls as a tool for turtle conservation in Sarawak is the first in Asia. Enforcement against illegal trawlers is not effective because the trawlers can always spot the patrol boat first and flee immediately. Its sharp and rough surface along with its two tonnes weight made the reef ball a suitable tool for ripping the trawler nets that entangled it. This will keep trawlers away from the sea turtle inter-nesting habitats (Tisen and Bali 1999). Reef balls were deployed randomly in areas that were identified as the inter-nesting swimming grounds for turtles during their nesting season through a radio and ultrasonic telemetry study (Tisen and Bali 1999). Since 1998, a total of 2284 reef ball units have been deployed by the Sarawak Reef Balls Working Group (SRBWG) along the Sarawak coast. Prior to 1998, around 70 to 100 dead turtles suspected of having originally been caught in trawler nets were found annually in the area stretching from Sematan to Telaga Air beaches (Tisen and Bali 1999). Following the deployment of reef balls, there has been a marked reduction in the number of dead turtles with only about 20 turtles found each year (Tisen and Bali 1999).

The SFC is also involved in the conservation projects for marine mammals, especially dolphins and dugongs. Aerial and boat surveys of Irrawaddy dolphins were carried out by the SFC in collaboration with

Universiti Malaysia Sabah (UMS) offshore and along the Sarawak's coastal waters. The dolphin population survey also covered four big rivers in Sarawak, namely the Saribas, Lupar, Lassa and Rajang rivers. In recent collaborations between SFC, Universiti Malaysia Sarawak (Unimas) and Sarawak Shell Berhad, Irrawaddy dolphin studies were conducted in the Kuching, Bintulu and Miri coastal areas, which recorded 15 species including one new species, *Tursiops truncates*, along the waters of the Sarawak coast (Bali and Tisen 2013). The SFC also monitors the dugong population and its feeding habitats in seagrass meadows at Kuala Lawas, Sarawak. The strategies of dolphin and dugong conservation projects are to create public awareness to local people and fishermen on the importance of these animals through national and local media. The expected outcome of these conservation projects is the involvement of the local community in conserving the coastal marine resources of Sarawak.

The conservation of coral reefs and seagrasses is another project led by the SFC in collaboration with local universities. Coral reefs in northeast Sarawak include Miri-Sibuti National Park and Simalajau National Park whereas Talang-Satang National Park and Tanjung Datu National Park are located in the southwest of Sarawak. Several coral management activities were conducted in the National Park such as annual reef cleaning with volunteers and other government agencies, reef health monitoring and research collaboration with local universities. Seagrass monitoring is also regularly conducted in Kuala Lawas, Talang-Satang NP, Serabang Bay, Sematan and Sampadi Island, Kuching, Sarawak. Among the activities done were monitoring the seasonal changes in species composition, species density, species distribution and water quality in the seagrass area. An expedition with local universities to explore new seagrass areas was also conducted in the coastal waters. The final aim of all these projects is to create awareness among the local communities and hope that participation from them will materialise in the future.

Education is an effective tool for helping to generate public awareness on the importance of biodiversity to natural resources in Sarawak. In order to tackle the higher education issues, the Universiti Malaysia Sarawak (UNIMAS) was established on 24 December 1992 after the declaration of vision 2020 by Malaysian government. The Faculty of Resource Science and Technology (FRST) was established in July 1993 and become one of the pioneer faculties in UNIMAS with offered academic programmes focusing on science, management, and sustainable utilization of natural resources in Sarawak. Students can specialise in science and management of flora and fauna, aquatic biology, biotechnology, and resource chemistry. In order to enhance the education process in biodiversity, the Institute of Biodiversity and Environmental Conservation (IBEC) was launched by UNIMAS in 1994. The IBEC objectives are to promote an understanding of the ecological principles and the benefits of biodiversity resources to mankind, and to promote the wise management and use of the Sarawak biotic wealth in ways that do not adversely affect the environment. IBEC program are focussing on research at post-graduate level that will promote the acquisition and dissemination of knowledge in environmental science and technology. The overall programmes in FRST and IBEC focus on biodiversity towards establishing highly educated, skilled and dedicated natural resource managers, biological conservationists, environmental educators and teachers capable of contributing and providing leadership for the sustainable development of Sarawak's biotic wealth (Abdullah *et al*. 2005).

The Malaysian government is also in the process of developing a draft of Integrated Coastal Zone Management (ICZM) in order to address problems of pollution, biological diversity, and deterioration and exploitation of fisheries resources. A pledge to develop an Integrated Coastal Zone Management policy is suggested in order to resolve the conflicting uses and ensure sustainability of coastal resources. Though the suggested ICZM policy is still at a drafting stage, pilot projects have been carried out in Pulau Pinang, Sabah and Sarawak from year 1996 to 2000 (CZMU 1996). Therefore it appears that the ICZM is a priority area for policy development in the near future.

6. Conclusion

Considering Sarawak as a mega-biodiversity state, more extensive studies of flora and fauna in the coastal waters should be done to explore the unreported species present in the area. Major hurdles in proceeding with the idea of doing more study on biodiversity are the lack of taxonomists, in Sarawak in particular and in Malaysia as a whole. The lack of publications in ecology and basic biology on marine and estuarine organisms also are problematic for enhancing the coastal biodiversity studies. An increase in information on coastal biodiversity, including biology and ecology, are needed in order for Sarawak to have better conservation management for future genera-

tions.

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References

Abdullah MT, Tuen AA and Khan FAA (2005). Universiti Malaysia Sarawak Contribution Towards Biodiversity and Protected Area Management. Proceedings of the Seventh Hornbill Workshop on Protected Areas and Biodiversity Conservation (SarawakForestry),7:1-2.

Affendi YA and Faedzul RR (2011). Current knowledge on Sclerectinian coral diversity of Peninsular Malaysia. In: Malaysia's marine biodiversity: inventory and current status, Department of marine park Malaysia and EKOMAR, pp 21-31.

Agatha A (2005). Impact of coal-fired power station on the community of harpacticoid copepods in estuarine ecosystem at Sarawak River. MSc thesis, Department of Aquatic Science, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia.

Anon (2009). Sea turtle adoption program. Sarawak Forestry Corporation. seaturtle.sarawakforest.com

Anon (2013). Seaweed resources of Sarawak. July, 2013. http://www.fri.gov.my/friswak/eseaweed.htm.

Ashton EC and Macintoch DJ (2002). Preliminary assessment of plant diversity and community ecology of the Sematan mangrove forest, Sarawak, Malaysia. Forest ecology and management 166:111-129.

Ashton EC, Macintosh DJ and Hogarth PJ (2003). A baseline study of the diversity and community ecology of crab and molluscan macrofauna in Sematan mangrove forest, Sarawak, Malaysia. Journal of Tropical Ecology 19: 127-142.

Bali J, Jaaman SA, Tisen OB, Landong WS, Zaini MK, Yee CW, Bakir K and Saimin S (2008). Aerial sighting rate of marine life in Sarawak waters. 7th International Scientific Symposium of the Intergovernmental Oceanographic Commission -Western Pacific (IOC/WESPACT), Sabah, Malaysia, pp 1–13.

Bali J and Tisen OB (2013). Status of marine conservation in Sarawak, Malaysia. http://www.nre.gov.my/Malay/Biodiversiti/documents/STATUS

Bamford M, Watkins D, Bancroft W, Tischler G and Wahl J (2008). Migratory Shorebirds of the East Asian - Australasian Flyway; Population Estimates and Internationally Important Sites. Wetlands International - Oceania. Canberra, Australia.

Beasley I and Jefferson TA (1997). Marine mammals of Borneo: a preliminary checklist. Sarawak Museum Journal 51: 193-216.

Bejie AB (1985). First prawn resources survey along the coast of Sarawak (May-July, 1980). Jabatan Perikanan Kementerian Pertanian Malaysia, Sarawak.

Boonyapiwat S (1998). Distribution, abundance and species composition of phytoplankton in the South China Sea, Area II: Sabah, Sarawak and Brunei Darussalam. Proceedings of the second technical seminar on Marine Fishery Resources Survey in South China Sea, Area II: west coast of Sabah, Sarawak and Brunei Darussalam, Kuala Lumpur, Malaysia, pp 224-242.

Carpenter KE and Niem VH (1998). FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 1. Seaweeds, corals, bivalves and gastropods. Rome, pp. 1-686.

Chai PPK (1972). Field key to the mangrove trees and shrubs occurring in Sarawak, including a brief description of the flora. Forest Department Sarawak.

Chai PPK (1975a). Mangrove forest of Sarawak. The Malaysian Forester 38: 108-134.

Chai PPK (1975b). The mangrove trees and shrubs of Sarawak. The Malaysian Forester 38: 187-206.

Chai PPK (1982). Ecological studies of mangrove in Sarawak. Ph.D Thesis, Universiti Malaya, Malaysia.

Coastal Zone Management Unit (CZMU) (1996). Integrated coastal zone management in the states of Penang, Sabah and Sarawak, Malaysia. Sabah pilot project component. Town and Regional Planning Department, Ministry of Local Government and Housing, Sabah.

Das I and Charles JK. (1993). A contribution to the herpetology of Bako National Park, Sarawak, East Malaysia. Hamadryad 18: 24-27.

Das I (2004). Lizards of Borneo. Kota Kinabalu, Borneo. Natural History Publications.

Das I (2006). A Photographic Guide to Snakes and

Other Reptiles of Borneo. London, New Holland Publishers (UK) Ltd.

Das I, Breuer H and Shonleben S (2013). *Gerarda prevostiana* (Eydoux and Gervais, 1837) (Squamata: Serpentes:Homalopsidae), a New Snake for Borneo. Asian Herpetological Research 4: 76–78.

Denzer W (1996). Reptilien und Amphibien der Santubong Halbinsel (Reptiles and amphibians of the Santubong peninsula), Sarawak, Borneo. Sauria, Berlin 18: 35-42.

De Rooij N (1915). The reptiles of the Indo-Australian Archipelago. Leiden XIV.

Edward P and Parish D (1986). Survey of the western coastline of Sarawak to evaluate the status of wetlands and to identify key sites for migratory waterbirds. Interwader report no.3. World Wildlife Fund Malaysia.

Ferner D (2013). Reef corals of Miri area reefs, Sarawak, Malaysia. ReefBase: A Global Information System for Coral Reefs. July 2013.http://www.reefbase.org

Gibson-Hill CA (1950). The whales, porpoises and dolphins known in Sarawak waters. Sarawak Museum Journal 5: 288-296.

Hamli H, Idris MH, Abu Hena MK and Wong SK (2012). Taxonomic study of edible bivalve from selected division of Sarawak, Malaysia. International Journal of zoological research 8: 52-58.

Hamli H, Idris MH, Abu Hena MK, Wong SK and Arshad A (2013). Checklist of habitat descriptions of edible gastropods from Sarawak, Malaysia. Journal of Fisheries and Aquatic Science 8: 412-418.

Ikhwanuddin M, Azmie G, Juariah HM, Zakaria MZ and Ambak MA (2011). Biological information and population features of mud crab genus Scylla from mangrove areas of Sarawak, Malaysia. Fisheries Research 108:299-306.

Jaaman SA (2006). Marine Mammal Distribution and interactions with fisheries in East Malaysia: Ph.D thesis. University of Aberdeen, United Kingdom.

Jaaman SA, Ahmad-Kamil EI, Bali J, Redzwan K, Rajamani L, Ponnampalam LS, Syed Abdullah SAK, Mohd Lazim MS and Azlina A (2011). Report on UNEP/CMS Southeast Asia Regional meeting on Dugong and workshop on developing standardized analysis protocols for Dugong questionnaire survey project data for Southeast Asia region. Lawas, Sarawak, Malaysia, 26-29 July 2011, pp 57-74.

Jaaman SA, Ali SA, Lah-Anyi YU, Miji CJ, Bali J, Regip JM, Bilang R and Wahed R (2000). Research and Conservation of Marine Mammal in Sarawak: Current Knowledge. In Bennett EL, Chin CLM and Rubis J (eds) Proceedings of the Fourth Annual Workshop of the National Parks and Wildlife Division, Kuching, Sarawak, pp 17-28.

Japar Sidek B and Muta Harah Z (2011). Seagrasses in Malaysia. In: Ogawa H, Japar Sidek B and Muta Harah Z (eds) Seagrasses: Resource status and trends in Indonesia, Japan, Malaysia, Thailand and Vietnam. Seizando-Shoten Publishing Co., Ltd. Shinjyuku-ku, Tokyo, Japan, pp 22-37.

Jensen K and Das I (2006). Biological observations on the Asian soft-shell turtle in Sarawak, Malaysia Borneo, with notes on the Biology and conservation of other non-marine turtles. March, 2014, http://www.britishcheloniagroup.org.uk/testudo/v6/v6n3jensen.htm.

Kuang CC and Chark LH (2004). A record of seahorse species (family Syngnathidae) in East Malaysia with notes on their conservation. Malayan Nature Journal 56:409-420.

Leh C (1985). Marine turtle in Sarawak. Marine turtle news letter 35:1-3.

Lydekker R (1901). Notice of an apparently new estuarine dolphin from Borneo. Proceedings of the Zoological Society of London 1: 88-91.

Lim ACO, Chong VC, Wong CS and Choo CK (2011). Diversity, habitats and conservation threats of syngnathid (syngnathidae) fishes in Malaysia. Tropical Zooplogy 24:193-222.

Mazlan AG, Zaidi CC, Wan-Lotfi WM and Othman BHR (2005). On the current status of marine biodiversity in Malaysia. Indian Journal of Marine Sciences 34: 76-87.

Minton G, Peter C and Tuen AA (2011). Distribution of small cetaceans in the nearshore waters of Sarawak. Raffles Bulletin of Zoology 59: 91-100.

Mizutani A, Kato K, Tanaka K, Ichikawa T, Mawek Z and Ilias A (2006). A report on the study of the wintering waterbirds status along the west coast of Sarawak – Results of AWC 2006 – Sarawak Forestry, Kuching, Sarawak.

Murofushi T, Chiew FCY, Wat Y, Miyagi T, Fujimoto K and Ishihara S (1999). Mangrove forest dynamic in relation to sediment input at the mouth of Sematan River, Sarawak, Malaysia. Tropic 8:207-220.

Musters CJM (1983). Taxonomy of the *genus Draco* L. (Agamidae, Lacertilia, Reptilia). *Zoological*

Verhandelingen, Leiden 199: 1-120.

Othman S (1989). The structure of vegetation and rate of litter production in a mangrove forest at Siar Beach, Lundu, Sarawak, East Malaysia. In: Symposium on mangrove management: its ecological and economic considerations. Biotrop special publication number 37. SEAMEA-BIOTROP, Bogor Indonesia, pp 145-155.

Othman S (1991). Analysis of vegetation and stratification of tree in mangrove forest of Samariang Batu, Kuching, Sarawak, East Malaysia. In: Edlin CD (eds), Proceeding L'Arbe-Biologie et Development. Montpellier, France, pp 658-659.

Pang SC (1989). Traditional fishing activities in the mangrove ecosystems of Sarawak. Department of Fisheries, Ministry of Agriculture, Malaysia.

Phang SM (2007). Seaweed Resources in Malaysia. Current status and future prospects. Aquatic Ecosystem, Health and Management. 9:185-202.

Pilcher NJ and Cabanban A (2000). The status of coral reefs in Sabah, Labuan and Sarawak, East Malaysia. Global Coral Reef Monitoring Network, Clive Wilkinson series editor, Australian Institute of Marine Sciences, Townsville.

Rahim KAA (2000). Vegetation structure, zonation, and seedling establishment in the Asajaya Mangrove forest, Sarawak, Malaysia. MSc thesis, Institute of Biodiversity and Environmental Conservation (IBEC), Universiti Malaysia Sarawak.

Say WCW (1999). Coastal aquaculture planning and management in Sarawak. Regional workshop on integrated management of mangrove/coastal ecosystems for sustainable aquaculture, Kuching Sarawak.

Shabdin ML and Rosniza R (2010). Kekunci siput dan kerang-kerangan perairan pantai Malaysia Timur (Key for identification of gastropod and bivalves in coastal waters of east Malaysia). UMT publishers, Kuala Terengganu, Malaysia.

Shabdin ML, Rosli NM and Chen CA (2013). Free-living nematodes in Sarawak coastal waters. Penerbit UMT, Kuala Terengganu.

Stuebing RB (1991). A check list of the snakes of Borneo. Raffles Bulletin of Zoology 39: 323-362.

The Star 2010. Sarawak reef under stress due to environmental and human factors. September, 19, 2010.

Tisen OB and Bali J (1999). Reef Ball as Marine Turtles Conservation Tool in Sarawak. Malaysian Science & Technology Congress, November 1999, Kuching Hilton, Sarawak. Tisen OB and Bali J (2002). Current Status of Marine Turtle Conservation Program in Sarawak, Malaysia. In: Mosien A, Foley A and Brost B (eds) Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation, pp 12-14.

Tisen OB and Ahmad R (2010). *Crocodylus porosus* in Sarawak : status and management. Paper presented in IUCN-SSC crocodile specialist group (CSG) Workshop on Human-crocodile conflict, Sabah Malaysia.

Tuen AA and Das I (2005). Introduction – A conference to Honour Alfred Russel Wallace. In: Tuen AA and Das I (eds), Wallace in Sarawak – 150 years later, Proceedings of an international conference on biogeography and biodiversity. Institute of Biodiversity and Environmental Conservation Universiti Malaysia Sarawak, pp 1-3.

Vidthayanon C (1998). Species Composition and Diversity of Fishes in the SouthChina Sea, Area II: Sarawak, Sabah and Brunei Darussalam Waters. Proceedings of the second technical seminar on marine fishery resources survey in the South China Sea, Area II: Sarawak, Sabah and Brunei Darussalam Waters. SEAFDEC, Kuala Lumpur, Malaysia.