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MARINE BIODIVERSITY IN SOUTHEAST ASIAN AND ADJACENT SEAS

Part 1

Fisheries Centre, University of British Columbia, Canada

Marine Biodiversity in Southeast Asian and Adjacent Seas
Part 1.

edited by
Maria Lourdes D. Palomares and Daniel Pauly

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DIRECTOR'S FOREWORD

I was informed by the authors of this report that this contribution is part one of a two-part final report of the results of a SeaLifeBase mini-project funded by the ASEAN Center for Biodiversity (Los Baños, Philippines) whose goals were to improve the coverage of marine biodiversity, notably of invertebrates, of Southeast Asia. Also, this project was to make the assembled data on nomenclature, geography, biology and ecology available online through the SeaLifeBase website (www.sealifebase.org) and the ASEAN Center for Biodiversity's information sharing service (www.aseanbiodiversity.org/biss). The latter is a regional node of the Ocean Biogeographic Information System, devoted to repatriating biodiversity data to Southeast Asia. Part 1 of this final report includes 4 contributions on national and regional biodiversity accounts, 2 papers on life history and a paper on tourism and management of the biodiversity it depends on and affects. Part 2 of this series will include 4 additional regional biodiversity accounts (on the South China Sea) and 2 contributions on biology.

In the process of performing this task, the SeaLifeBase team unearthed a trove of information which comprises important studies of invertebrate groups, and which, as part of SeaLifeBase, contributes to a comprehensive picture of marine biodiversity of Southeast Asia and, in particular, the South China Sea. In addition, a few 'relict' manuscripts were unearthed, e.g., on the flatfishes of the Philippines (Cabanban *et al*., this volume), which had not found their way into the scientific literature, and merited being included in this two-part series.

SeaLifeBase's focus on this region, the world's center of marine biodiversity, also identified important information gaps, concerning groups which had not been studied adequately, e.g., the smaller species of cuttlefishes, which are usually lumped with the larger species when reported in fisheries catch statistics and are therefore not properly studied (Palomares and Dar, this volume). Other, apparent, information is created when Southeast Asian scientists publish in their own languages, e.g., Thai, Vietnamese, Bahasa Indonesia/Malaysia or Chinese. Biodiversity databases such as SeaLifeBase (and FishBase for that matter) are limited in the capture of data published in non-English languages. However, this can be overcome, as exemplified by the work of Huang *et al.* (this volume) for the marine biodiversity of China.

I congratulate the editors and authors of this report for their efforts in helping to overcome the various obstacles which have so far prevented the emergence of a full account of marine biodiversity in Southeast Asia.

Ussif Rashid Sumaila

Director and Associate Professor, The Fisheries Centre

BIODIVERSITY

TOWARD AN ACCOUNT OF THE BIODIVERSITY IN CHINESE SHELF WATERS: THE ROLES OF SEALIFEBASE AND FISHBASE[1], [2]

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ABSTRACT

Global online databases exist, in the form of FishBase (www.fishbase.org) and SeaLifeBase (www.sealifebase.org) which can be used to make a huge amount of marine biodiversity information available for all maritime countries of the world. This applies also to China. For that country, however, most of data sources used are non-Chinese, which may lead to the impression that these databases were designed with non-Chinese sources in mind. This is not the case, and to correct this impression, this account presents an overview of the marine biodiversity of China based predominantly on Chinese sources.

It is then planned to use the documents cited here as our sources to complement the present coverage of Chinese waters by FishBase and SeaLifeBase, following standardization of the sources' nomenclature. This will not only lead to a nearly complete coverage of the marine biodiversity for China and some neighbouring countries, but also highlight the role of FishBase and SeaLifeBase and of global species databases in general in building bridges between cultures and languages, in particular among marine biologists, and people who love the oceans and the species living therein.

INTRODUCTION

Assembling a comprehensive list of the biodiversity occurring along the coast of a major country such as China requires a huge amount of work, ranging from identifying and locating compilations of species accounts and validating the species names and identifications they contain, to creating databases that organize this information and make it accessible to a wide range of users. Global online databases exist, in the form of FishBase (www.fishbase.org) and SeaLifeBase (www.sealifebase.org), which can be used to

[1] Cite as: Huang, B., Cheung, W., Lam, V.W.Y., Palomares, M.L.D., Sorongon, P.M.E., Pauly, D. 2010. Toward an account of the biodiversity in Chinese shelf waters: the roles of SeaLifeBase and FishBase. *In*: Palomares, M.L.D., Pauly, D. (eds.), *Marine Biodiversity of Southeast Asian and Adjacent Seas*. Fisheries Centre Research Reports 18(3), p. 2-14. Fisheries Centre, University of British Columbia [ISSN 1198-6727].
[2] Presented at the FishBase Mini-Symposium, Innovation Building, YSFRI, Qingdao, China, September 1, 2008.

make marine biodiversity information available for all maritime countries of the world, and which already contain a huge amount of data, including on China. However, most of data sources used for that country are non-Chinese, which may lead to the impression that these databases were designed with non-Chinese sources in mind. This is not the case, and to correct this impression, we have assembled an overview of the marine biodiversity of China based mainly on Chinese sources.

The living marine resources of China and the state of marine biodiversity have been reviewed by Huang (2000) and Zhou *et al.* (2005). In this contribution, we briefly review the status of that biodiversity in terms of functional groups, i.e., groups of species with similar functions within the marine ecosystem.

The ecosystem structure we used follows roughly that of a food web model of the Southern China Sea (Figure 1c), the most biodiverse part of the Chinese coast, constructed and documented by Cheung (2007) and consisting of 31 functional groups, of which 10 are fishes (Figure 2). For each of the non-fish functional groups, we present, so far available the number of species; the habitat requirements and other key biological information; IUCN Status of component species; treaties and/or protection measures relevant to these species; sources of additional information on these species.

Our list is incomplete, and biased towards fishes, bivalves and crustaceans, which are commercially important and thus well studied. However, this list may serve as an example of what we believe is the minimum database each country should create and maintain to document its marine biodiversity (see also Palomares and Pauly, 2004; Pan *et al.*, 2008).

BRIEF REVIEW OF THE CHINESE COASTAL (INCLUDING SHELF) ECOSYSTEMS

The marine ecosystems of China are extensive, with latitudinal range extending from around 4° to 41° N and include the continental shelf, slope and the abyssal plains of the Northwest and West Pacific. These ecosystems consist of three marginal seas: the Yellow Sea (Figure 1a), the East China Sea (Figure 1b) and the South China Sea (Figure 1c), each of which a Large Marine Ecosystem (LME; Sherman *et al.*, 2003) with well-defined physical features, fauna, and patterns of human exploitation (see also www.seaaroundus.org). Major rivers discharging into these systems include the Yalu River in the North, and the Yangtze, Qiantang and Min Rivers to the South, the Yangtze River estuary representing the transition from the Yellow to the East China Sea (Jin *et al.*, 2003).

The Yellow Sea and East China Sea ecosystems are semi-enclosed temperate (32°-42°N) and sub-tropical (23°-33°N) seas, respectively. The relatively small and shallow Yellow Sea has an area of 380,000 km² and average depth at 44 m. Northwest of Yellow Sea is an inner sea, the Bohai Sea, covering an area of 80,000 km² (Tang *et al.*, 2000). The East China Sea has an area of 770,000 km², with average and maximum water depth of 370 m and 2,719 m, respectively. Plankton diversity is high in both the Yellow Sea and the East China Sea, with

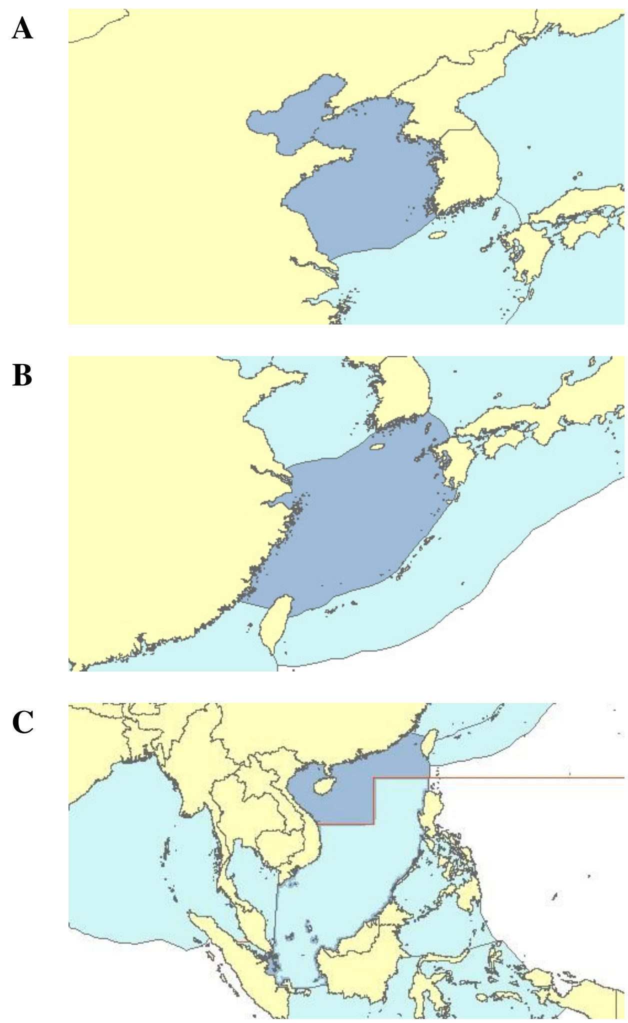

Figure 1. The three Chinese Large Marine Ecosystems in the Northwest Pacific (dark blue): (A) Yellow Sea, with the Bohai Sea in the northeast; (B) East China Sea and (C) South China Sea (in part). This paper focuses on the northern part of the South China Sea, roughly corresponding to the area north of the straight (or red) line in (c), and representing the southern boundary of FAO area 61, i.e., the Northwest Pacific.

over 400 recorded phyto- and zooplankton species. Patterns of fisheries exploitation and the status of fisheries resources parallel those in the South China Sea, i.e., many resource species have strongly declined, and are threatened by overfishing, pollution and coastal development, which we described in detail in the following paragraphs.

The South China Sea is a tropical system that includes diverse habitats ranging from mangrove forests, seagrass beds, estuaries and coastal and offshore coral reefs (Morton and Blackmore, 2001). It lies within the Tropic of Cancer, and has an area of approximately 3.5 x 10^6 km^2 (Caihua *et al.*, 2008), of which 30% of the region is deep sea, with average depth at 1,400 m. It is heavily influenced by monsoonal climate with Southwest Monsoon in summer and Northeast Monsoon in winter. The complexity of the surface current patterns greatly influences the structure and distribution of marine species. For example, the Kuroshio Current brings warm and high salinity water to the northern margin of the South China Sea such as the area around Taiwan and Hong Kong, there allowing for a mixture of tropic and subtropical biological communities (Morton and Blackmore, 2001). Major rivers discharging into the South China Sea includes the Pearl and Mekong Rivers. The South China Sea exhibits a diverse fauna and flora, with over 2,300 species of fishes (Caihua *et al.*, 2008), 58 species of cephalopods and many other invertebrates (Jia *et al.*, 2004). Fishery resources are exploited mainly by trawlers (demersal, pelagic and shrimp), gillnets, hook and line, purse seine and other fishing gears such as traps.

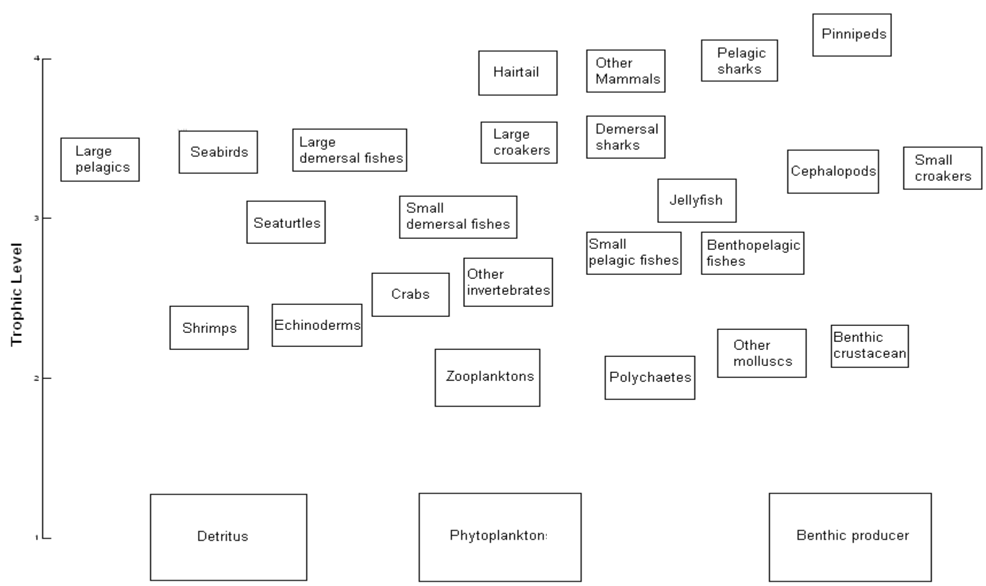

Figure 2. A modified version of the food web model of the South China Sea based on which we summarized marine biodiversity in the 3 Chinese marine ecosystems (Cheung, 2007). The figure shows the trophic level of each functional group only, while the linkages between groups are not displayed. The model consists of 27 functional groups, including 2 mammal groups, 1 reptile group, 1 bird group, 10 fish groups, 10 invertebrates groups, 2 primary producer groups and 1 group representing detritus.

The fisheries of the South China Sea have suffered dramatic depletion over the past five decades (Cheung and Pitcher, 2008). After the founding of the People's Republic of China (PRC) in 1949, there was a rapid growth of the marine capture fisheries. This growth slowed down towards the 1970s, but increased again after the end of 1978, with a large increase in the number of fishing boats and improvement in fishing technology (Pang and Pauly, 2001). The dramatic expansion of fishing fleets resulted in over-exploitation of near-shore, and later, offshore fisheries resources (Shindo, 1973; Cheung and Sadovy, 2004) – a change that is similar to most other fisheries globally (Pauly *et al.*, 2002). A range of species with high vulnerability to exploitation were extirpated locally or regionally by fishing (Sadovy and Cornish, 2000; Sadovy and Cheung, 2003; Cheung and Sadovy, 2004). For instance, the large yellow croaker (*Larimichthys crocea*), now at an all-time low, was once one of the most important fishery resource species in the East and South China Sea (Liu and Sadovy, 2008).

In addition, critical habitats for marine species such as coral reefs and seagrass beds have been damaged or degraded as a result of the use of destructive fishing methods and coastal development (Hutchings and Wu, 1987; Morton and Blackmore, 2001). Overall, over-exploitation in the South China Sea raises serious fishery management and biodiversity conservation concerns, and this also applies to the Yellow and East China Seas.

PROTECTION OF MARINE BIODIVERSITY IN CHINA

International Legislation

China ratified and joined a number of international treaties and conventions to protect its marine biodiversity and environment. They include (Wang *et al*., 2000; Chen and Uitto, 2003):

1) Conventions for conserving biodiversity:
   a) Convention on Biological Diversity (1992);
   b) RAMSAR Convention;
   c) Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES);
   d) Migratory Bird Convention; and,
   e) National Biodiversity Action Plan (1994).
2) Conventions for controlling marine pollution from various sources:
   a) International Convention for the Prevention of Pollution from Ships (1973);
   b) Convention on the Prevention of Marine Pollution of Wastes and Other Matter (1985); and,
   c) UN Convention on Law of the Sea (1996).

After participating in successive UN environmental summits since 1972, China created the China Ocean Agenda 21 based on the model of the global Agenda 21 formulated at the 1992 Earth summit in Rio de Janeiro. The China Ocean Agenda 21 proposed a sustainable development strategy for China's marine waters, emphasizing the involvement of all levels of government for coordinating the development and protection of marine resources (Chen and Uitto, 2003).

China also cooperated with many international organizations such as WWF, IUCN and the World Bank, etc., on conserving marine biodiversity. The Biodiversity Working Group (BWG) of the China Council for International Cooperation on Environment and Development (CCICED), a high level non-governmental advisory body established in 1992 for enhancing international cooperation on environment and development, has a particular focus on biodiversity.

Domestic Legislation

The State Council of China started to draft legislation for specific environmental issues since 1973 (Chen and Uitto, 2003), and earlier legislations included the 1994 Provisional Regulations on the Prevention of Pollution of Coastal Waters (Palmer, 1998). Several studies (e.g., Palmer, 1998; Li *et al*., 1999; Wang *et al*., 2000; Chen and Uitto, 2003) provide a comprehensive overview of the development and implementation of environmental and biodiversity conservation legislation in China. The major laws, measures and regulations in China for conserving marine biodiversity were extracted from these reviews. The laws and regulations for conserving marine and coastal biodiversity and environment include:

1) Laws
   a) Marine Environmental Protection Law (1982, revised in 1999);
   b) Water Pollution Prevention and Control Law (1984, revised in 1996);
   c) Fishery Law (1986);
   d) Wildlife Protection Law (1988);
   e) Environmental Protection Law (1988);
   f) Water and Soil Conservation Law (1991);
   g) Prevention and Control of Water Pollution Law (1996).

2) Administrative Regulations
   a) Regulations about Aquatic Resources Conservation (1979);
   b) State Council's General Order of Strictly Protecting Rare Wild Animals (1983);
   c) Regulations of the PRC on the Control over Prevention of Pollution by Vessels in Sea Waters (1983);
   d) Administrative Regulations about Prevention of Pollution and Damage of Marine Environment by Seashore Construction Projects (1983);
   e) Regulations on the Control over Dumping Wastes into Sea Waters (1985);
   f) Provisional Regulations on Environment Control for Economic Zones Open to Foreigners (1986);
   g) Regulations for the Implementation of the Fishery Law (1987);
   h) Regulations on Protection and Administration of Wild Medicinal Material Resources (1987);
   i) Regulations on the Implementation of the Law on the Prevention and Control of Water Pollution (1989);
   j) Administrative Regulations on the Prevention and Control of the Pollution and Damage Caused to the Marine Environment by Coastal Construction Projects (1990);
   k) Regulations for the Protection of Aquatic Wild Animals (1993).

Central Government Institutions

There are two main institutions in the central government of China that are in charge of marine environment protection: the State Commission on Environmental and Natural Resources Protection and the State Council Committee for Environmental Protection. These institutions are responsible for general environmental policy maters such as drafting legislation, regulations and guidelines on the environmental welfare issues. They also supervise and coordinate other provincial environmental agencies and activities in protecting the environment (Chen and Uitto, 2003). Five other central institutions are also working complementary to each other for protecting the marine environment under the 1999 Marine Environmental Protection Law. Their responsibilities are listed in Table 1.

Table 1. Responsibilities of some central institutions on protecting marine environment (adapted from Chen and Uitto, 2003; www.novexcn.com, 2008).

Institutions	Responsibilities
State Environmental Protection Administration (SEPA)	Coordinating, supervising and providing guidelines for the country's marine environment protection. Conducting scientific research. Prevention of marine pollution caused by land-based sources and coastal construction projects.
State Oceanic Administration (SOA)	Monitoring and managing the marine environment, organizing marine environment surveys, and conducting scientific research. Prevention and control of pollution from offshore construction projects and marine dumping.
State Harbor Superintendence Administration (SHSA)	Managing and monitoring pollution from non-fishing and non-military vessels.
State Fishery Administration (SFA)	Managing and supervising pollution from fishing vessels, and protecting ecosystems in fishing areas.
Environmental Protection Department of the Peoples' Liberation Army	Monitoring pollution by naval vessels

Problems

Although China has participated in international treaties, developed comprehensive environmental policies, laws and regulations for protecting its marine resources, the marine environments and biodiversity in China continue their downward spiral (Palmer, 1998). Liu and Diamond (2005) suggested that these policies, laws and regulations listed above, which seem to be adequate, actually do not do the job, because their enforcement is usually ineffective to non-existent. In fact, at least at the local level, economic development has a far higher priority than biodiversity and environmental conservation.

SOURCES FOR REVIEWING THE MARINE BIODIVERSITY OF CHINA

In the following, we describe the data sources we tapped to assemble the biodiversity lists presented further below.

The list of marine species of China by Huang (2000) was used as starting point, while Zhou *et al.* (2005) supplied a great amount of additional information on marine biodiversity in China. Li (1990) and Wang (1999) contributed to the species diversity of seabirds and marine mammals. Dai and Yang (1991), Zheng *et al.* (1999), Wang *et al.* (2000) and Hong (2002) provided a considerable part of the marine invertebrate list. The list of marine mammals was improved with additional information from Zhu *et al.* (2002). Birdlife International (2008; see www.birdlife.net) supplied information and data on seabirds as well. Information on fish groups was obtained from Jiao and Chen (1997), Li and Luo (2004), Ma *et al.* (2006) and Caihua *et al.* (2008).

The list of threatened species was obtained from the Internet version of IUCN (2007; see www.redlist.org); the list of internationally protected species was obtained from CITES (2007).

Our presentation of Chinese marine biodiversity is organized by ecosystem functional groups. We adopted the functional group structure of an ecosystem model of the South China Sea (Cheung, 2007), slightly modified, based on the ecosystem model of Tang *et al.* (2000), to make it applicable to the three Large Marine Ecosystems in China (Figure 2).

RESULTS

Group-specific results

The following describe in some detail results obtained for each of the groups for which information is available (see Figure 3). Note that viruses, microflagellates, bacteria, macroalgae and phytoplankton species are not discussed.

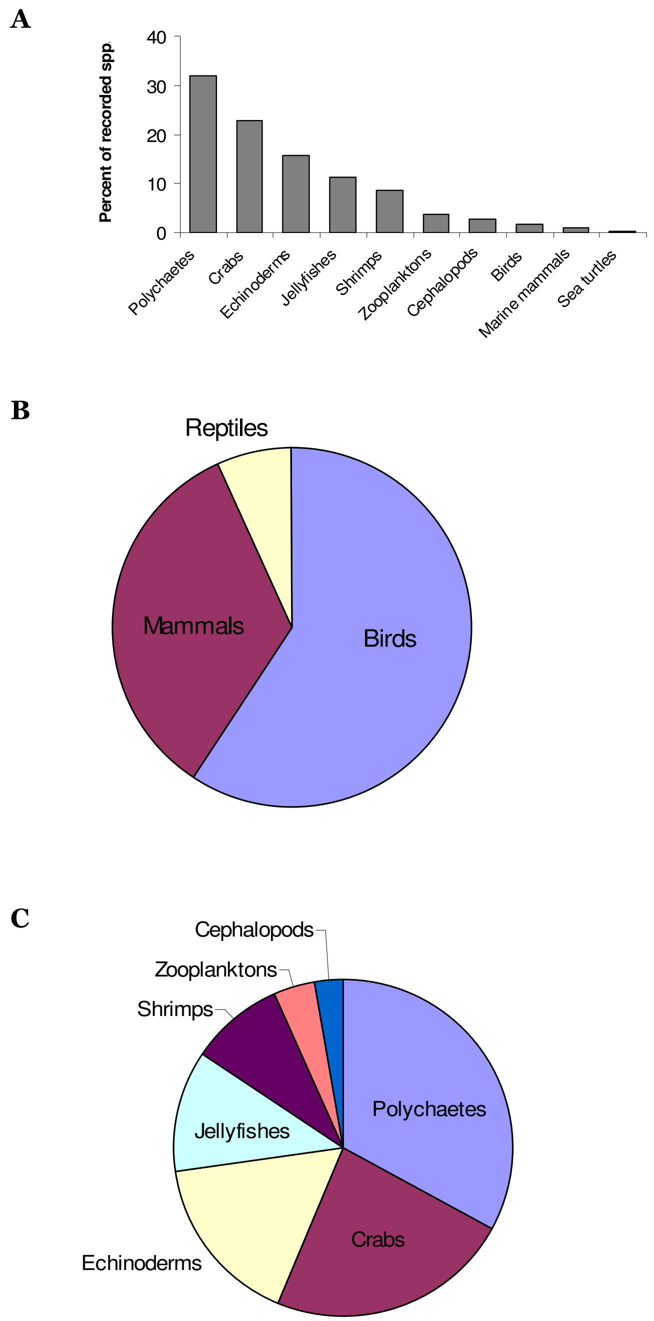

Figure 3. Composition of species richness by major functional groups in Chinese marine ecosystems: (A) percentage of species number of all recorded non-fish species, (B) percentage of species of higher marine vertebrates, and (C) percentage of species of marine invertebrates.

Birds

A total of 62 species of seabirds, including 13 endangered species, were recorded by Li (1990). He lists 35 coastal birds and also provides detailed morphological, distributional and behavioral information for the following species: Short-tailed albatross (*Phoebastria albatrus*), Streaked shearwater (*Calonectris leucomelas*), Swinhoe's storm-petrel (*Oceanodroma monorhis*), Red-billed tropicbird (*Phaethon aethereus*), Spot-billed pelican (*Pelecanus philippensis*), Red-footed booby (*Sula sula*), Pelagic cormorant

(*Phalacrocorax pelagicus*), Christmas Island frigatebird (*Fregata andrewsi*), Pomarine jaeger (*Stercorarius pomarinus*), Black-tailed gull (*Larus crassirostris*), Indian skimmer (*Rynchops albicollis*) and Ancient murrelet (*Synthliboramphus antiquus*). Fifteen endangered bird species are listed in the Birdlife International species database for the Chinese mainland, including three seabirds: Black-footed albatross (*Phoebastria nigripes*), Chinese crested tern (*Sterna bernsteini*) and Christmas frigatebird (*Fregata andrewsi*).

Li (1990) and Birdlife International also list three commercially important guano producing species: White pelican (*Pelecanus onocrotalus*), Great cormorant (*Phalacrocorax carbo*) and Red-footed booby (*Sula sula*). Christmas frigatebird (*Fregata andrewsi*) is the only species included in the IUCN Red List species of seabirds in China. Only 16 of those listed in the Birdlife database are listed by CITES (2007).

Marine mammals

Wang (1999) reports 36 species of cetaceans (eight baleen whales and 28 toothed whales, dolphins and porpoises) occurring in Chinese waters, with detailed information on morphology, distribution, migration, biology, and ecology. A new species of cetaceans, *Sousa huangi*, found in South China Sea, 21°31'N, 109°10'E, was recorded for the first time by Wang (1999). Zhu *et al.* (2002) reports 35 species of cetaceans (eight baleen whales and 27 toothed whales, dolphins and porpoises) as well as five pinnipeds and one sirenian (*Dugong dugong*). The number of cetaceans in Chinese waters represents a considerable 41% of the total number of species worldwide. Of these, only one is endemic, Baiji (*Lipotes vexillifer*), found in freshwater, particularly in the middle and lower reaches of the Yangtze River (Wang, 1999), but which is now considered functionally extinct (Guo, 2006; Reeves and Gales, 2006). Two otter species, Eurasian river otter (*Lutra lutra*) and Smooth-coated otter (*Lutrogale perspicillata*) also appear to be occurring in China (see www.sealifebase.org).

The use of stranded cetaceans can be traced back to thousands of years ago (Wang, 1999). Zhu *et al.* (2000) concluded that the human-induced threat to the cetaceans and other marine mammals in Chinese waters has been reduced by the late 1970s ban on whaling. However, a number of species are currently threatened by human activities such as fisheries, where marine mammals occur as by-catch, coastal development and aquatic pollution. Moreover, despite of the protection of marine mammals through national and international programmes, many of the once heavily exploited species are still vulnerable and rare. Also, as a result of the development and expansion of commercial fisheries, fish populations also consumed by marine mammals have declined tremendously in terms of their size and quality, while pollution and habitat destruction also contribute to population declines (Zhu *et al.*, 2000).

Sea turtles

Of the seven species of sea turtles known worldwide, five occur in Chinese waters: Green sea turtle (*Chelonia mydas*), Loggerhead turtle (*Caretta caretta*), Olive ridley turtle (*Lepidochelys olivacea*), Hawksbill turtle (*Eretmochelys imbricate*) and Leatherback turtle (*Dermochelys coriacea*) (Cheng, 1998). Of these five species, only Green sea turtles, Loggerhead and Hawksbill turtles nest along the east coast of China, with most individuals found in the South China Sea, especially around the Xisha and Nansha Islands. From 16,800 to 46,300 sea turtles are thought to occur in China, of which Green sea turtle is thought to contribute about 87% (Zhou *et al.,* 2005).

All five species are listed as endangered species in the 2007 IUCN Red List, with the Hawksbill and the Leatherback turtle being critically endangered. However, none of them are listed in the CITES database. According to

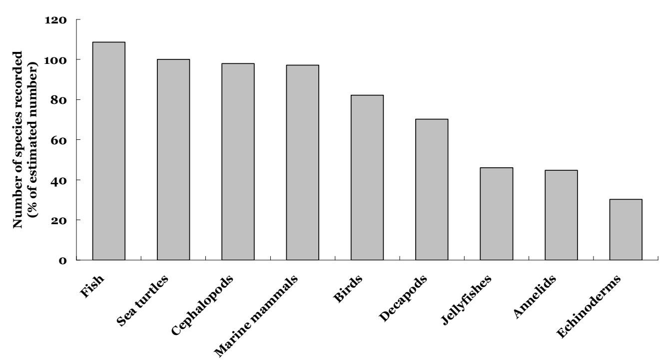

Figure 4. Current coverage of global species databases as %of reported estimates of Chinese marine biodiversity recorded in this study. FishBase accounted for 3,421 fish species, i.e., more than the 3,048 species reported by Jiao and Chen (1977), which explains the above 100% record in this figure. SeaLifeBase accounted for 4,831 species across the non-fish groups and is almost complete for marine mammals, sea turtles and cephalopods (see Discussion).

Cheng (1998), at least 30,000 sea turtles were slaughtered between 1959 and 1989 in the South China Sea. Although nominally protected by Chinese regulation and international programmes, sea turtles in China are under critical threat from habitat destruction and illegal hunting.

Fishes

The diversity of fish in Chinese waters is high and shows a clear latitudinal gradient. Overall, 3,048 species of marine fish, belonging to 288 families, have been recorded in China (Jiao and Chen, 1997). This represents over 20% of fish species in the world. Species richness is lowest in the Bohai and Yellow Sea, with 327 species (Jiao and Chen, 1997). The East China Sea has a total of 760 fish species belonging to 173 families (Li and Luo, 2004). Fish diversity is highest in the South China Sea, with 2,321 species belonging to 236 families (Ma *et al*., 2006; Caihua *et al*., 2008). However, this figure includes fish that are recorded from areas of the South China Sea far away from Chinese territories, including offshore reefs. Shelf diversity in the northern part of the South China Sea (as defined in Figure 1) is currently 1,066 species. The present coverage of FishBase relative to these numbers is discussed further below (see also Figure 4).

Cephalopods

Zheng *et al*. (1999) reported 95 species of cephalopods occurring in Chinese waters, representing 18% of the total number of cephalopod species worldwide. Of these, 78 species, over 21 families and 6 classes, occur in the South China Sea. The most abundant species are in the Family Sepiidae and Octopodidae, which are all included in SeaLifeBase (see www.sealifebase.org). None of the cephalopod species are listed in the IUCN or in the CITES Appendices I-III.

Cephalopods are abundant in the South China Sea where 89 species have been reported (Guo and Chen, 2000). In the South China Sea, 78 species of cephalopods have been reported (Zheng *et al*., 1999) with 21 species, including Japanese flying squid (*Todarodes pacificus*), Mitre squid (*Uroteuthis chinensis*), Swordtip squid (*Uroteuthis edulis*), Whiparm octopus (*Octopus variabilis*) and Common octopus (*Octopus vulgaris*), that are commercially important or potentially important species (Cheng and Zhu, 1997; Guo and Chen, 2000; Zheng *et al*., 2003). From the 1950s to the 1970s, Spineless cuttlefish (*Sepiella inermis*) was one of the four main fisheries in China; the Golden cuttlefish (*Sepia esculenta*) was first exploited in the Yellow Sea prior to the 1970s; later became a primary target of fisheries in the East China Sea in 1990s (Zheng *et al*., 2003).

Shrimps

There are more than 300 species of shrimps (free swimming and benthic decapods) reported by Wang *et al*. (2000) in Chinese waters, including 135 species in the South China Sea (Zhang, 2002). The common commercially important shrimps include Fleshy prawn (*Fenneropenaeus chinensis*), Southern rough shrimp (*Trachysalambria curvirostris*), Japanese sand shrimp (*Crangon affinis*), Kishi velvet shrimp (*Metapenaeopsis dalei*) and Chinese ditch prawn (*Palaemon gravieri*) (Cheng and Zhu, 1997).

Crabs

Dai and Yang (1991) report over 800 species of marine crabs occurring in Chinese waters, including a list of 604 species with description of morphological characteristics, ecology and geographical distributions.

In the East China Sea, 324 species, over 22 families, have been found. Fifty species belong to the Family Majidae, and 37 species belong to the Leucosiidae (Yu *et al*., 2003). Despite this diversity, only about 20 species are considered edible. Among these, 8-9 are commercially important species, such as Horse crab (*Portunus trituberculatus*), Three-spot swimming crab (*Portunus sanguinolentus*), Sand crab (*Ovalipes punctatus*), Crucifix crab (*Charybdis feriatus*) and Japanese swimming crab (*Charybdis japonica*) (Yu *et al*., 2004). Usually found at depths 20-120 m, Horse crabs have been overexploited since 1980s; Sand crabs, meanwhile, have become the most abundant species with the highest exploitation potential (Yu *et al*., 2004).

Jellyfishes

About 400 species of jellyfishes are know from Chinese waters, about 40% of the total number of species worldwide (Hong, 2002): 250 species of Hydromedusa, 100 species of Siphonophora, 50 species of Scyphomedusae and 10 species of ctenophores. The South China Sea alone has 270 species of jellyfish, of which 160 are Hydromedusa. Five edible jellyfish species have been reported from China, i.e., *Rhopilema esculentum*, *Rhopilema hispidum*, *Stomolophus meleagris* (Cannonball jelly), *Lobonema smithi* and *Lobonemoides gracilis* (Hong, 2002). Some species, such as *Rhopilema esculentum* have been used as traditional Chinese medicine since the Ming dynasty (1368-1644 AD), for the treatment of asthma, the flu and other ailments (Hong, 2002).

Recently, jellyfish blooms in the East China Sea, mainly caused by large jellyfishes such as *Stomolophus meleagris* and *Aequorea* sp., have resulted in negative impacts on populations of fishes and commercial invertebrates. Because these jellyfishes, as part of their zooplankton diet, consume fish eggs and shrimp and fish larvae, the populations of commercial fishes and shrimps exposed to such blooms have declined (Cheng *et al.*, 2005).

Echinoderms

According to Zhou *et al.* (2005), 553 species of echinoderms have been reported from Chinese waters. Echinoderms are most diverse in the South China, which harbors 76% of the species reported from Chinese waters. Over 100 species of sea urchins are reported in China, of which only 10 are deemed edible. Catches of sea urchins are composed mainly of *Anthocidaris crassispina*, *Hemicentrotus pulcherrimus* and *Strongylocentrotus nudus*. In 1989, *Strongylocentrotus intermedius* was introduced to China from Japan, and has since become a major commercial species. *Glyptocidaris crenularis* has recently become an important farmed species (Liu, 2000). More than 100 species of sea cucumbers are reported from China, of which 20 are edible, and 10 commercially important, such as *Apostichopus japonicus* (Liao, 2001). Sea stars, or starfishes, widely distributed worldwide, especially in the Northern Pacific Ocean, and are found at depths ranging from 0 to 6,000 m (Wang *et al.*, 1999). More than 1,000 species of sea stars are known worldwide, of which over 100 occur in Chinese waters. The most common sea stars in the Bohai and Yellow Seas are *Luidia quinaria*, *Asterias rolleston* and *Solaster dawsoni* (Zhou *et al.*, 2005). Other common echinoderms include *Amphioplus japonicus* and *Amphioplus lucidus* (Sun and Liu, 1991).

Polychaetes

Zhou *et al.* (2005) report 1,123 species of marine annelids in China, including more than 900 species of polychaetes (see also Figure 3); of these 404 were reported from the western Taiwan Strait, 213 from the Bohai and the Yellow Seas region (Wu, 1993; Bi and Sun 1998). Common species include *Sthenolepis japonica*, *Ophiodromus angustifrons*, *Nephtys oligobranchia*, *Lumbrineris latreilli* and *Sternaspis scutata* (Sun and Liu, 1991). Xu (2008) also lists 20 species of pelagic polychaetes from the East China Sea, the most abundant being *Pelagobia longicirrata*, *Tomopteris elegans* and *Sagitella kowalevskii*.

Benthic invertebrates

Sun and Liu (1991) and Hu *et al.* (2000) reported 338 benthic species, including 71 species of crustaceans, 75 species of mollusks, 115 species of polychaetes, 23 species of echinoderms, 9 species of coelenterates and 7 species of others benthic organisms from the Bohai and Yellow Seas The dominant species include *Scapharca suberenata*, *Bullacta exarata*, Horse crab (*Portunus trituberculatus*), *Palaemon gravieri, Ophiopholis mirabilis* and *Acila mirabilis*.

Zheng *et al.* (2003) reported 855 of benthic species occurring in the East China Sea, i.e., 268 species of polychaetes, 283 of mollusks, 171 of crustaceans, 68 of echinoderms and 65 of other groups. Jia *et al.* (2004) reported on 851 benthic species from the South China Sea, mostly benthic fish, but also including 154 species of crustaceans and 42 species of cephalopods. More than 230 species of crustaceans are known from the South China Sea, about half of them benthic (Zhang, 2002).

About 150 species of benthic crustaceans appear in commercial fisheries catches in the East China Sea, but they do not contribute more than about 3% of the catch in weight. Shrimps, especially *Parapenaeus fissuroides*, are dominant (Jia *et al.*, 2004). Other commercially important crustaceans include *Tellina* *emarginata*, *Atrina pectinata*, *Cultellus scalprum*, *Macoma candida*, *Solenocera koelbeli* and *Metapenaeopsis lata* (Zheng *et al*., 2003).

Zooplankton

Meng *et al*. (1993) listed 133 species of zooplankton in the Bohai and Yellow Seas, including 36 species of hydromedusae and 69 species of copepods. *Aidanosagitta crasssa* and *Labidocera euchaeta* are the two species that tend to dominate the zooplankton for the whole year. Other dominant species include *Acartia pacifica*, *Calanus sinicus* and *Euphausia pacifica*. Xu (2004) reported 316 species of zooplankton from the East China Sea, belonging to more than seven phyla. The dominant group was the crustaceans, consisting of 208 species; among these, the copepods were dominant (36.7%) with regard to the total number of species, followed by the Hyperiidea (11.1%).

In the Taiwan Strait, 1,329 species of zooplankton were reported by Li *et al*. (2001), with two dominant groups, copepods and jellyfishes, consisting of 298 and 232 species, respectively. The dominant species included *Temora turbinata*, *Canthocalanus pauper*, *Pseudophausia sinica*, Akiami paste shrimp (*Acetes japonicus*), *Euphausia diomedeae*, *Flaccisagitta enflata* and *Calanoides carinatus*, which occurred below 200 m. Li *et al*. (2004) reported 709 zooplankton species from the South China Sea, in over eight phyla. The crustaceans, the dominant group, consisted of 470 species. The dominant species included *Temora discaudata*, *Undinula vulgaris*, *Canthocalanus pauper*, *Centropages furcatus*, *Eucalanus subcrassus*, *Euchaeta concinna*, *Flaccisagitta enflata* and *Lucifer intermedius*.

Discussion

China is one of the mega-centers of biodiversity (Hicks, 2008) with probably over 20,000 marine species. We, however, located sources for only about 15,000 of them. It is clear, however, that Chinese marine biodiversity increases from North to South, with species being reported in the hundreds from the Yellow Sea and Bohai Seas, while over 4,000 metazoans species are reported from the East China Sea and nearly 6,000 from the South China Sea (Huang 2000; Zhou *et al*. 2005).

Another clear result is that unwary Internet users would be misled by many of the biodiversity databases available online. To illustrate this, we performed a search for 'China' through the IUCN (www.iucn.org) species search. This resulted in a list of 218 marine species, 32 of which were marine mammals, 56 fish (sharks) and 5 marine turtles. A similar search for species listed in the UNEP-WCMC database for 'China' yielded 364 amphibians, 1,232 birds, 515 fishes, 659 invertebrates, 650 mammals, 431 reptiles and 131 other species. Also, since habitats were not provided, we examined the list for distinctions by habitat. This yielded 22 species (17 reptiles, four corals and one bird species) listed in CITES Appendices I-III, ratified July 1st 2008, and which are protected by the Chinese government.

It is thus obvious that FishBase and SeaLifeBase, which, jointly, are meant to cover all marine metazoans of the world, including those of China, have a big task ahead. The most difficult, but necessary, task is the identification of valid (*versus* synonymous) scientific names, which will help establish the actual number of valid species per functional group.

Preliminary comparisons of the results of this study with what is currently available in FishBase (Figure 4) resulted to a total count of 3,421 fish species, which is more than the number of species reported by Jiao and Chen (1997). FishBase accounts 50.1% of this total to the South China Sea, 25.1% to the East China Sea, 34.2% to the Yellow Sea and 8.0% to the Sea of Japan. Ray-finned fishes are dominant in all of these large marine ecosystems followed by sharks and rays. This shows that FishBase already has a very good coverage of the marine fishes of China and can be used as a reliable online biodiversity resource for China. SeaLifeBase, has almost 50% coverage of the marine non-fish metazoans occurring in China (including Taiwan; see Figure 4), with data for 4,831 species. Of these, 62% are assigned to the South China Sea, 26% to the East China Sea and 5.5% in the Yellow Sea. This is heavily biased towards i) mollusks, which makes up 40.2% of the species distribution; ii) crustaceans, 29.2%; and iii) annelids, 10.4%. If we accept the estimate of 20,000 species for Chinese marine areas, these two global databases together already account for more than 41% of China's marine biodiversity.

We intend to use the documents cited here to complement the present coverage of Chinese waters by FishBase and SeaLifeBase, following standardization of their nomenclature. This will not only lead to a nearly complete coverage of biodiversity for China and some neighboring countries, but also highlight the role of FishBase and SeaLifeBase in building bridges between cultures and languages, in particular among marine biologists, and people who love the oceans and the species living therein.

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REFERENCES

Bi, H., Sun, D., 1998. The ecological characteristics of polychaetes in Jiaozhou Bay. *Acta Ecologica Sinica* 18(1), 63-70. [In Chinese with English abstract].

Birdlife International, 2008. Birdlife's online world bird database: the site for bird conservation. Version 1.0 Cambridge, UK: Birdlife International. Available: http://www.birdlife.net (accessed on August 18, 2008).

Caihua, M.A., Kui, Y., Meizhao, Z., Fengqi, L., Dagang, C., 2008. A preliminary study on the diversity of fish species and marine fish faunas of the South China Sea. *Oceanic and Coastal Sea Research* 7(2), 210-214.

Chen, Q., 1997. Current status and prospects of marine biodiversity in China. *Chinese Biodiversity* 5(2), 142-146. [In Chinese with English abstract].

Chen, S., Uitto, J.I., 2003. Governing marine and coastal environment in China: building local government capacity through international cooperation. *China Environment Series* 6, 67-80.

Chen, S., Zhu, M., Ma, Y., 1999. The research and international plans on global large marine ecosystems. *Journal of Oceanography of Huanghai and Bohai Seas* 17(4), 103-109. [In Chinese with English abstract].

Cheng, J., Zhu, J., 1997. A study on the diet characteristics and the trophic levels of primary commercial invertebrates in the Yellow Sea. *Acta Oceanologica* 19(6), 102-108. [In Chinese with English abstract].

Cheng, J., Ding, F., Li, S., Yan, L., Lin, J., Li, J., Liu, Y., 2005. A study on the quantity and distribution of macro-jellyfish and its relationship to seawater temperature and salinity in the East China Sea Region. *Acta Ecologica Sinica* 25(3), 440-445. [In Chinese with English abstract].

Cheng, Y., 1998. The problems of sea turtle conservation in China. *Sichuan Journal of Zoology* 17(2), 74-75. [In Chinese with English abstract].

Cheung, W.W.L., 2007. Vulnerability of Marine Fishes to Fishing: from Global Overview to the Northern South China Sea. The University of British Columbia, Vancouver, Canada. 354 p.

Cheung, W.W.L., Pitcher, T., 2008. Evaluating the status of exploited taxa in the northern South China Sea using intrinsic vulnerability and spatially explicit catch-per-unit-effort data. *Fisheries Research* 92, 28-40.

Cheung, W.W.L., Sadovy, Y., 2004 Retrospective evaluation of data-limited fisheries: a case from Hong Kong. *Reviews in Fish Biology and Fisheries* 14, 181-206.

CITES, 2007. www.unep-wcmc.org/index.html?http://www.unep-wcmc.org/CITES/redirect.htm~main.

Dai, A., Yang, S., 1991. Crabs of the China Seas. China Ocean Press, Beijing; Springer Verlag, Berlin. 682 p.

Guo, J., 2006. River dolphins down for the count, and perhaps out. *Science* 314: 1860.

Guo, J., Chen, P., 2000. A study on exploitation of Cephalopoda stock in the South China Sea. *Tropic Oceanology* 19(4), 51-58 [In Chinese with English abstract].

Hicks, C., 2008. Countdown 2010 in China: communicating the importance of biodiversity. *Living Forests* (14), 29-36.

Hong, H., 2002. [Medusa and jellyfishes]. *Bulletin of Biology* 37(2), 13-16. [In Chinese]

Hu, H., Huang, B., Tang, J., Ren, S., Shao, X., 2000. Studies on benthic ecology in coastal waters of Bohai and Yellow Seas. *Donghai Marine Science* 18(4), 39-46. [In Chinese with English abstract]

Huang, Z., 2000. The biodiversity and sustainable utilization of Chinese marine biological resources. In: *Proceedings of the Symposium on Biodiversity*. Museum of Natural Science, Taipei, Taiwan p. 179-189.

Hutchings, P.A., Wu, B.L., 1987 Coral reefs of Hainan Island, South China Sea. *Marine Pollution Bulletin* 18(1), 25-26.

Jia, X., Li, Z., Li, C., Qiu, Y., Gan, J., 2004. [*The Ecosystem and Fisheries Resources in the Commercial Zone and the Continental Shelf of the South China Sea*]. Science Press, Beijing. 647 p. [In Chinese].

Jiao, Y., Chen, D., 1997. [Study of the marine fish diversity in China]. *Shan-tong Fisheries* 14(2), 18-20.

Jin, X., Xu, B., Tang, Q., 2003. Fish assemblage structure in the East China Sea and southern Yellow Sea during autumn and spring. *Journal of Fish Biology* 62(5), 1194-1205.

Li, C., Jia, X., Cai, W., 2004. Diversity of marine zooplankton in the north of South China Sea. *Journal of Fishery Sciences of China* 11(2), 139-146. [In Chinese with English abstract].

Li, G., Lu, J., 2004. [Status and analysis of fish diversity in the continental shelf of East China Sea] In: *Proceedings of the Fifth National Symposium on the Conservation and Sustainable Use of Biodiversity in China* [Climate Press], Beijing, p. 56-57 [In Chinese].

Li, W., Tang, Y., Huang, L., 1999. Comparison and research on the fishery laws and regulations of China and Japan. *Transactions of Oceanology and Limnology* 4, 69-76. [In Chinese with English abstract]

Li, X., 1990. [Seabirds in China]. *Bulletin of Biology* 4, 8-11. [In Chinese].

Liao, Y., 2001. [Sea cucumbers in China]. *Bulletin of Biology* 35(9), 1-5. [In Chinese].

Liu, H., 2001. Review on the world sea urchin fishery. *Marine Sciences* 25(3), 38-41. [In Chinese with English abstract].

Liu, J., Diamond, J., 2005. China's environment in a globalizing world. *Nature* 435, 1179-1186.

Liu, M., Sadovy, Y., 2008. Profile of a fishery collapse: why mariculture failed to save the large yellow croaker. *Fish and Fisheries* 9(3), 219-242.

Luo, H., 2003. [How many marine species are there in China's waters?]. Available at http://www.bjkp.gov.cn/bjkpzc/kjqy/hykx/7183.shtml. (accessed on August 18, 2008). [in Chinese].

Ma, C., You, K., Li, F., Zhang, M., 2006. A study on the relationship of the fish biodiversity and the faunal distribution in the South China Sea. *Periodical of Ocean University of China* 36(4), 665-670.

Meng, F., Qiu, J., Wu, B., 1993. Zooplankton of the Yellow Sea large marine ecosystem. *Journal of Oceanography of Huanghai and Bohai Seas* 11(3), 30-37. [In Chinese with English abstract].

Morton, B., Blackmore, G., 2001 South China Sea. *Marine Pollution Bulletin* 42(12), 1236-1263.

Nie, Z., Li, X., 2006. Study on the regeneration of sea cucumber. *Marine Sciences* 30(5), 78-82. [In Chinese with English abstract].

Novexcn, 2008. The marine environmental protection law of the People's Republic of China. Available at http://www.novexcn.com/marine_environemental_prot.html (accessed on August 13, 2008).

Palmer, M., 1998. Environmental regulation in the People's Republic of China: the face of domestic law. *China Quarterly* 156, 788-808.

Palomares, M.L.D., Pauly, D., 2004. Biodiversity of the Namibian Exclusive Economic Zone: a brief review with emphasis on online databases. *In:* Sumaila, U.R., Boyer, D., Skogen, M.D., Steinshamm, S.I. (eds.) *Namibia's fisheries: ecological, economic and social aspects*. Eburon Academic Publishers, Amsterdam, p. 53-74.

Pan, M., Bailly, N., Conejar, J., Coronado, C., Dar, C., Froese, R., Garilao, C.V., Guerzon, L.I., Laxamana, E., Paglinawan, L., Pauly, D., Sorongon, P.M., Tabaranza, G.K., Palomares, M.L.D. 2008. Philippine marine biodiversity thru SeaLifeBase: current progress and gaps. UPV Journal of Natural Sciences 13 Supplement, 123-192.

Pang, L., Pauly, D., 2001. Chinese marine capture fisheries from 1950 to the late 1990s: the hopes, the plans and the data. *In:* Watson, R., Pang, L., Pauly, D. (eds.), *The Marine Fisheries of China: Development and Reported Catches*. Fisheries Centre Research Report 9(2), p. 1-27.

Pauly, D. Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R., Zeller, D., 2002. Towards sustainability in world fisheries. *Nature* 418, 689-695.

Reeves, R.R., Gales, N.J., 2006. Realities of baiji conservation. Conservation Biology 20(3): 626-628.

Sadovy, Y., Cheung, W.L., 2003 Near extinction of a highly fecund fish: the one that nearly got away. *Fish and Fisheries* 4, 86-99.

Sadovy, Y.J., Cornish, A.S., 2000 Reef Fishes of Hong Kong. Hong Kong University Press, Hong Kong.

Sherman, K., Ajayi, T., Anang, E., Cury, P., Diaz-de-Leon, A.J., Fréon, P., Hardman-Mountford, N.J., Ibe, C.A., Koranteng, K.A., McGlade, J., Nauen, C.E.C., Pauly, D., Scheren, P.A.G.M., Skjodal, H.R., Tang, Q., Zabi, S.G., 2003. Suitability of the Large Marine Ecosystem concept. *Fisheries Research* 64, 197-204.

Shindo, S., 1973 General review of the trawl fishery and the demersal fish stocks of the South China Sea. FAO Fish. Tech. Pap. 120. Rome, 49 p.

Sun, D., Liu, Y.. 1991. Species composition and quantitative distributions of biomass and density of the macrobenthic infauna in the Bohai Sea. *Journal of Oceanography of Huanghai and Bohai Seas* 9(1), 42-50. [In Chinese with English abstract].

Tang, Tong Ling, Tang Qisheng, Pauly, D., 2000. A preliminary approach on mass-balance Ecopath model of the Bohai Sea. *Chinese Journal of Applied Ecology* 11(3), 435-440.

Wang, A., Wang, W., Hu, J., Liu, B., Sun, R., 2000. Study on marine organism diversity in China. *Journal of Hebei University* 20(2), 204-208. [In Chinese with English abstract]

Wang, C., Gu, Q., Zhou, P., 1999. Starfish *Asterias amurensis* - a potential seafood resource. *Journal of Fishery Science of China* 6(4), 67-71. [In Chinese with English abstract].

Wang, D., Wang, Z., Tian, H., Shao, X., Wei, L., 2006. Study on sea urchin and its utilization. *Chinese Journal of Marine Drugs* 25(4), 52-54. [In Chinese with English abstract].

Wang, P., 1999. Chinese Cetaceans. Ocean Enterprises Ltd, Hong Kong. 325 p.

Wang, S., Wang, X., Xie, Y.at2000. Developing and implementing national biodiversity strategy and action plan: lesson from China. Available: http://bpsp-neca.brim.ac.cn/calendars/workshop-1/9.html (accessed on August 13, 2008).

Wu, Q., 1993. Polychaete ecology in soft-bottom in western Taiwan Strait. *Journal of Oceanography in Taiwan Strait* 12(4), 324-334. [In Chinese with English abstract].

Xu, Z., 2004. Relationship between red tide occurrence and zooplankton communities structure in the coastal sea of East China. *China Environmental Science* 24(3), 257-260. [In Chinese with English abstract].

Xu, Z., 2008. Environmental adaptation of pelagic Polychaeta in the East China Sea. *Chinese Journal of Applicable Environmental Biology* 14(1), 53-58. [In Chinese with English abstract].

Yu, C., Song, H., Yao, G., 2003. Geographical distribution and faunal analysis of crab resources in the East China Sea. *Journal of Zhejiang Ocean University (Natural Science)* 22(2), 108-113. [In Chinese with English abstract].

Yu, C., Song, H., Yao, G., 2004. Assessment of the crab stock biomass in the continental shelf Waters of the East China Sea. *Journal of Fisheries of China* 28(1), 41-46. [In Chinese with English abstract].

Zhang, L., 2002. Study on the characteristics and its exploitation strategy of South China Sea resources. *Journal of Zhanjiang Ocean University* 22(2), 13-17. [In Chinese with English abstract].

Zheng, Y., Chen, X., Cheng, J., Wang, Y., Shen, X., Chen, W., Li, C., 2003. [Resources and the environment in the continental shelf of the East China Sea]. Scientific and Technical Publishers, Shanghai. 835 p. [In Chinese].

Zheng, Y., Lin, J., Yan, L., Zhou, J., Shen, J., 1999. Cephalopod resources and rational utilization in East China Sea. *Journal of Fishery Sciences of China* 6(2), 52-56. [In Chinese with English abstract].

Zhou, J., Zou, X., Ji, Y., 2005. Review on the study of marine medicinal starfish. *Chinese Journal of Current Practical Medicine* 4(2), 34-38. [In Chinese with English abstract].

Zhou, L., Yang, S., Chen, B., 2005. Studies on marine biodiversity in China. *Science and Technology Review* 23(2), 12-16. [In Chinese with English abstract].

Zhu, Q., Jiang, B., Tang, T., 2000. Species, distribution and protection of marine mammals in the Chinese coastal Waters. *Marine Sciences* 24(9), 35-39. [In Chinese with English abstract].

AN ANNOTATED CHECKLIST OF PHILIPPINE FLATFISHES: ECOLOGICAL IMPLICATIONS[1]

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ABSTRACT

An annotated list of the flatfishes of the Philippines was assembled, covering 108 species (vs. 74 in the entire North Atlantic), and thus highlighting this country's feature of being at the center of the world's marine biodiversity. More than 80 recent references relating to Philippine flatfish are assembled. Various biological inferences are drawn from the small sizes typical of Philippine (and tropical) flatfish, and pertinent to the "systems dynamics of flatfish". This was facilitated by FishBase, which documents all data presented here, and which was used to generate the graphs supporting these biological inferences.

INTRODUCTION

Taxonomy, in its widest sense, is at the root of every scientific discipline, which must first define the objects it studies. Then, the attributes of these objects can be used for various classificatory and/or interpretive schemes; for example, the table of elements in chemistry or evolutionary trees in biology. Fisheries science is no different; here the object of study is a fishery, the interaction between species and certain gears, deployed at certain times in certain places. This interaction determines some of the characteristics of the resource (e.g., recruitment to the exploited stock), and generates catches.

For conventional fisheries research to work, however, the underlying taxonomy must have been done: the species caught must be known, and catch statistics must be available, at least at species level. Without these, state-of-the art methods of fisheries research cannot be used, and emphasis must then be given, to various indirect methods and to inferences by analogy. This, indeed, is the reason for the renaissance of comparative methods in fishery research (Bakun, 1985).

Flatfish (Order Pleuronectiformes) support substantial single-species fisheries in the North Atlantic and North Pacific, besides forming a sizeable by-catch in various medium-latitude trawl fisheries. On the other hand, the many species of flatfish occurring in the inter-tropical belt do not support directed fishery, nor

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do they contribute much to the by-catch of the multispecies (trawl) fisheries common in tropical shelves (Pauly, 1994). Thus, studying the fishery biology of tropical flatfish cannot proceed as does the study of flatfish resource species in temperate waters, and comparative approaches must make use of the facts that are known about the distribution and occurrence, the morphology and other features of the fish under study, in an attempt to compensate as far as possible for the unavailability of abundance data and of catch time series.

Relational databases are ideal for assembling, recombining and analyzing such facts, and this report relied heavily on the FishBase 96 CD-ROM (Froese and Pauly, 1996), and subsequent updates[2] which anticipates the release of FishBase 97. The usefulness of FishBase for the comparative study of flatfish in general (and by extension, of any other fish group) was highlighted in Froese and Pauly (1994). Hence this contribution focuses on the narrower issue of its use for generating inferences on the ecology of flatfishes (here taken as representing any other group of teleosts) in data-sparse, but species-rich tropical areas, here represented by the waters within the Philippine EEZ.

Materials and Methods

The first task was to complete the FishBase coverage of Philippine flatfish; this was achieved by (1) scanning the Philippines (Evermann and Scale, 1907; Fowler, 1934; Herre, 1953) and regional taxonomic literature (e.g., Weber and de Beaufort, 1929; Menon and Monkolprasit, 1974; Amaoka and Hensley, 2001; Hensley and Amaoka, 2001), and (2) interacting with taxonomists, notably at the FAO/ICL ARM/MS I workshop held on 1 - 10 October 1995 for the production of an FAO Identification Guide to Living Marine Resources of the Western Central Pacific, and at the Smithsonian Institution, Washington, D.C. The pleuronectids in Herre (1953) were checked against Menon's (1977) revision of the Cynoglossidae and revisions of *Engyprosopon* (Amaoka *et al.*, 1993) and *Paraplagiisia* (Chapleau and Renaud, 1993), while Eschmeyer (1990) was consulted for the validity of the generic names. Distribution records were taken from Herre (1953), from revisions, redescriptions (e.g., *Pseudorhombus megalops;* Hensley and Amaoka 1989), museum records, and the general scientific literature on Philippine demersal fish and fisheries.

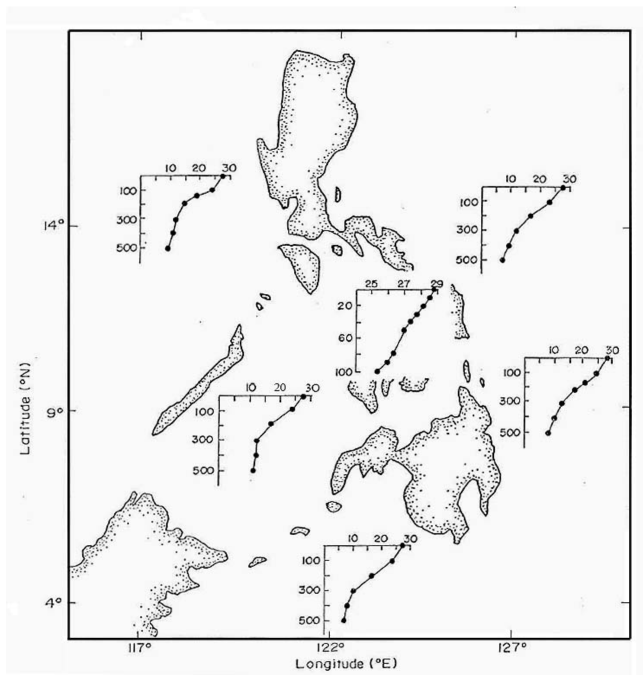

Figure 1. Relationship between mean annual sea temperature (in °C) and depth (in m) for various locations in the Philippines. Source: Dalzell and Ganaden (1987) based on Selga (1931) and Labao (1980).

Biological and ecological information on Philippine flatfish were gleaned mainly from the *Philippine Journal of Fisheries,* the *Philippine Journal of Science,* and the *Philippine Scientist*. Also, various bibliographies were examined for entries on flatfish (Blanco and Montalban, 1951; Gomez, 1980; Aprieto *et al.*, 1986; Pauly *et al.*, 1986), complemented by a search of the Aquatic Sciences and Fisheries Abstracts CD-ROM, and of the personal reprint collections of colleagues both at ICLARM[3], Manila and the Smithsonian Institution, Washington, D.C.

The second task was to create, for each species of flatfish reported from the Philippines at least one georeferenced occurrence record with sampling depth and environmental temperature. The plot of

[2] The original version of this, now slightly updated, paper was presented at the Symposium on System Dynamics of Flatfish, held 2-8 November 1996 at the Netherlands Institute for Sea Research, Texel, The Netherlands and was previously available from http://filaman.uni-kiel.de/geomar/rfroese/Philippines%20Flatfish.pdf. The coverage of flatfishes by FishBase now includes the data therein and additional information.
[3] Now the WorldFish Center, Penang, Malaysia.

temperature *vs*. depth in Figure 1 was used to infer temperature from position and depth in cases where the temperatures had been missing from an original record. Our major source of occurrence records was a printout from the Smithsonian Institution listing all Philippine flatfish in their collection (courtesy of Dr. Leslie W. Knapp), the results of the MUSORSTOM Expedition to the Philippines (Fourmanoir, 1976 in Fourmanoir, 1981), and the definitions of the type locality for the species described (mainly by Fowler, 1934).

Biological characteristics (catch data and derived features do not exist for Philippine flatfish) were entered into the appropriate fields of FishBase, which also documents their sources. Also, the FishBase coverage of non-Philippine flatfish was boosted such as to provide sufficient contrast to Philippine species. The various graphing and reporting routines of FishBase were then evoked, and used to generate the exhibits presented below.

RESULTS AND DISCUSSION

There are at least 108 species of flatfish in the Philippines, distributed in 8 families and 36 genera (Appendix 1). The type locality of 22 nominal flatfish species is in the Philippines (W.N. Eschmeyer, pers. comm.). As predicted by Pauly (1994) for tropical species in general, Philippine flatfish tend to remain small, ranging from 6 to 80 cm in standard length (SL) with most species reaching 15 cm (SL) or less.

Table 1. List of flatfishes surveyed during the October 1995 FAO-ICLARM workshop.

Family	Species	Length (cm)
Bothidae	*Arnoglossus aspilos*	–
	Arnoglossus taenio	–
	Bothus pantherinus	15.4 SL
	Chascanopsetta micrognathus	–
	Engyprosopon grandisquama	–
Citharidae	*Citharoides macrolepidotus*	–
Cynoglossidae	*Cynoglossus cynoglossus*	10.4 SL
	Cynoglossus kopsii	–
	Pseudorhombus arsius	24.5 SL
	Pseudorhombus arsius	25.2 SL
	Pseudorhombus dupliciocellatus	29.0 SL
Psettodidae	*Psettodes erumei*	25.5 SL
	Psettodes sp.	–
Soleidae	*Aseraggodes* sp.	–
	Dexillichthys muelleri	21.0 SL
	Euryglossa sp.	23.8 TL
	Pardachirus pavoninus	13.2 SL
	Synaptura orientalis	–
	Synaptura sorsogonensis	20.5 SL

During the October 1995 FAO-ICLARM workshop for the testing of the FAO Western Central Pacific Field Guide, the fish markets of Cebu, Manila, and Bolinao were sampled by groups of taxonomists, and specimens were bought for identification and collection purposes. The relatively few flatfish found by that survey consisted of 19 flatfish species with an average maximum size of about 21 cm SL (Table 1), thus confirming the low abundance, high diversity, small size, and low economic importance of Philippine flatfish.

Figure 2 compares the maximum size distribution of Philippine flatfish with that of North Atlantic species (FAO areas 21 and 27). Two ecological implications of this are that Philippine flatfish are limited to smaller prey than their North Atlantic counterpart, while simultaneously being susceptible to (numerous) smaller predators. The implications of reduced size and increased temperature for population dynamics are faster turnover rates, i.e., the asymptotic size is approached rapidly due to high values of the parameter K of the von Bertalanffy growth function (Pauly, 1980, 2010). This leads to reduced longevity (Figure 3), and high natural mortality (Figure 4).

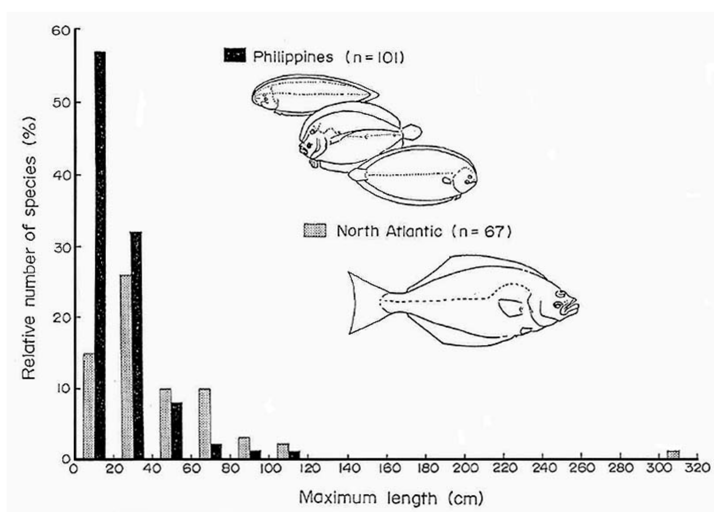

Figure 2. Frequency distribution of maximum reported lengths in Philippine and North Atlantic flatfish, highlighting small sizes of Philippine species (data from FishBase, August 1996).

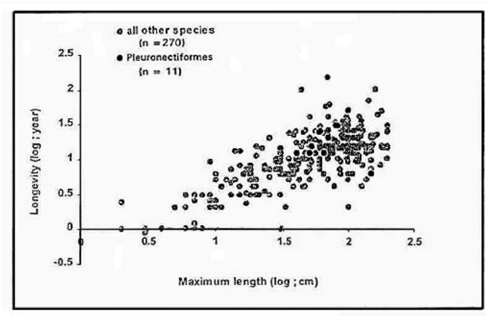

Figure 3. Longevity is in most organisms related to size, and neither the fish nor the Pleuronectiformes are an exception (data from FishBase, August 1996).

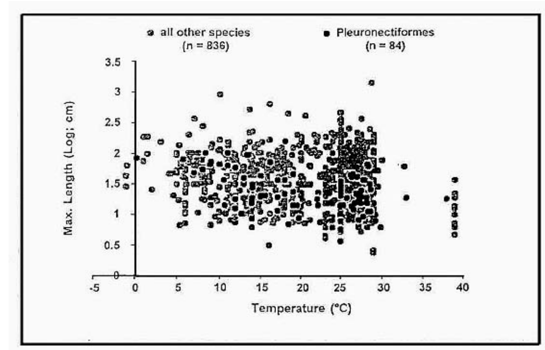

Figure 5. Within groups of similar fishes (here in the Pleuronectiformes), the maximum size reached by different species decreases with environmental temperature, although this effect is not seen when data for all orders of fish are pooled.

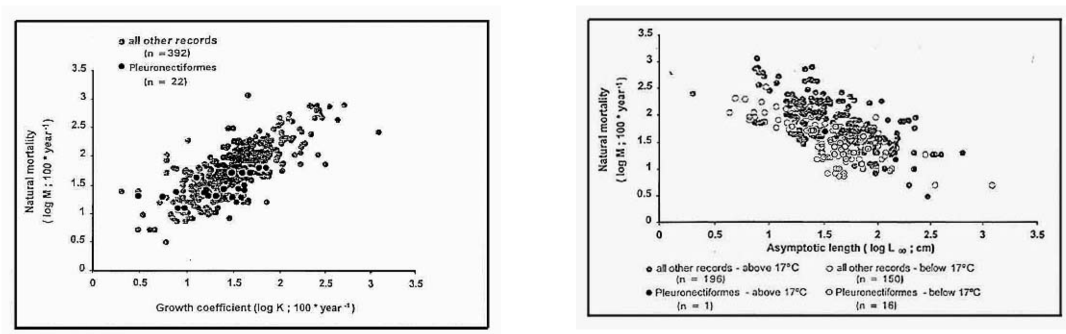

Figure 4. In Pleuronectiformes, as in other fishes, natural mortality (M) is strongly related to the parameters of the von Bertalanffy growth equation, K and L_∞. The plot in the right panel also shows the effect of temperature.

The maximum size that can be reached by fish of various taxa is largely independent of temperature; there are small and large fish at almost all temperatures. However, within groups, the size reduction of maximum size imposed by environmental temperature (for which Pauly, 1994 suggests a mechanism) does show, and this is confirmed by Figure 5 for the Pleuronectiformes.

Tropical demersal environments are usually characterized by high fish diversity (Aprieto and Villoso, 1979; Gloerfelt-Tarp and Kailola, 1984; Sainsbury *et al.*, 1985; Dredge, 1989a, 1989b; Kulbicki and Wantiez, 1990; Cabanban, 1991). Several surveys of demersal fishes were conducted in the Philippines (Warfel and Manacop, 1950; Ronquillo *et al.*, 1960; Villoso and Hermosa, 1982) which provided checklists of fishes and their relative abundances (Aprieto and Villoso, 1979; Villoso and Aprieto, 1983). Furthermore, catch rate data are available for several decades but have tended to remain underutilized (Silvestre *et al.* 1986b). These data allow rough assessments of the status of the demersal stocks (Silvestre *et al.* 1986a, 1986b) and inference on growth, mortality and recruitment patterns based on analysis of lengthfrequency data (Ingles and Pauly, 1984), though inferences on Pleuronectiformes are few, due to their scarcity.

The flatfish of the Philippines are diverse but compose a small percentage of the total catch of demersal fisheries. To date, there is a lack of scientific investigation on the systematics, biology, population ecology, and fisheries of Philippine flatfish. The high diversity and low abundance of flatfish in the tropics [e.g., Sunda Shelf (see contributions in Pauly and Martosubroto, 1996); North Western Australia (Sainsbury *et al.*, 1985); northern part of Australia (Rainer and Munro, 1982; Rainer, 1984); Cleveland Bay, Australia (Cabanban, 1991)) has been highlighted by Pauly (1994), who argued that the low biomass and recruitment rates of flatfish in the tropics are primarily based on environmental physiology (temperature-mediated difference of metabolic rate) and diet. He also suggests that flatfish are overadapted to feeding on zoobenthic epi- and infauna such that low availability of food limits the production of biomass and recruitment.

Flatfish are considered 'trashfish' (Saila, 1983; Dredge, 1989a, 1989b) in most warm water developed countries, e.g., in Australia (Rainer, 1984), but enter markets in the Philippines, often as dried packs of juveniles of various species used for snacks. As for the adults, their small sizes reduce their value, substantially, except for *Psettodes erumei, a* high "quality" fish (Aprieto and Villoso, 1979). Flatfish in Southeast Asia generally feed on benthic invertebrates (Chan and Liew, 1986). In turn, these fish form part of the prey items of medium-sized *(Saurida* spp.; Cabanban, 1991) and large-sized carnivores. As such they may form a significant link in those demersal ecosystems where terrigenous input of nutrients leads to high benthos biomasses (Belperio, 1983).

We conclude by pointing out that there is a need to revise the systematics of the Philippine Pleuronectiformes, many species of which have not been reported since they were originally described. Also there is a need to study their spatial and temporal distribution and abundances in various habitats. Furthermore, studies on the diet, growth, reproduction, and recruitment of these fish are required if understanding of their population dynamics is to improve. Except for taxonomic studies, dedicated work on flatfish may not be of high priority in the Philippines. However, it is hoped that Philippine Pleuronectiformes will be studied further, at least in the context of their relationships in multispecies assemblages.

References

Amaoka K., Hensley, D.A., 2001. Paralichthyidae. Sand flounders. *In*: Carpenter, K.E., Niem, V. (eds.), *The Living Marine Resources of the Western Central Pacific. Volume 6: Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals*, p. 3842-3862. FAO identification guide for fishery purposes. FAO, Rome.

Amaoka, K., Yamamoto, E., 1984. Review of the genus *Chascanopsetta*, with the description of a new species. *Bulletin of the Faculty of Fisheries, Hokkaido University* 35(4), 201-224.

Amaoka, K., Mihara, E., Rivaton, J., 1993. Pisces, Pleuronectiformes: Flatfishes from the waters around New Caledonia. A revision of the genus *Engyprosopon*. *In*: Crosnier, A. (ed.), *Resultats des Campagnes MUSORSTOM* 11(158), p. 377-426. Memoire du Muséum national d'Histoire naturelle, Paris.

Anon., 1994. Printout of all Philippine flatfish in the collection of the Smithsonian, courtesy of Dr. Leslie Knapp (personal communication).

Aprieto, V.L., Villoso, E.P., 1979. Catch composition and relative abundance of trawl-caught fishes in the Visayan Sea. *Fisheries Research Journal of the Philippines* 4(1), 9-18.

Aprieto, V., Saeger, J., Pauly, D., Editors, 1986. Selected Papers on Philippine Marine Fisheries Resources (1947-1986). Department of Marine Fisheries, University of the Philippines, Visayas, Tech. Rep. No. 9, 435 p.

Bakun, A., 1985. Comparative studies and the recruitment problem: searching for generalization. CalCOFI Report 26, 30-40.

Bawazeer, A.S., 1987. Stock assessment of the large toothed flounder (khoffah, *Pseudorhombus arsius*) in Kuwait waters. *Kuwait Bulletin of Marine Science* 9, 207-214.

Belperio, A.P., 1983. Terrigenous sedimentation in the central Great Barrier Reef Lagoon: a model from the Burdekin region. *BMR Journal of Australian Geology and Geophysics* 8, 179-190.

Blaber, S.J.M., 1980. Fish of the Trinity Inlet System of North Queensland with notes on the ecology of fish faunas of tropical Indo-Pacific estuaries. *Australian Journal of Marine and Freshwater Research* 31, 137-46.

Blanco, G.J., Montalban, H.R., 1951. A bibliography of Philippine fishes and fisheries. *Philippine Journal of Fisheries* 1(2), 107-130.

Cabanban, A.S., 1991. The dynamics of the Leiognathidae in a tropical demersal ichthyofaunal community. James Cook University of North Queensland, Australia, 262 p. Ph. D. dissertation.

Chan, E.H., Liew, H.C., 1986. A study on tropical demersal species (Malaysia). International Development Research Centre, IDRC/3-A-83-1905, Singapore, 64 p.

Chapleau, F., Renaud, C.B., 1993. *Paraplagusia sinerama* (Pleuronectiformes: Cynoglossidae), a new Indo-Pacific tongue sole with a revised key to species of the genus. *Copeia* 3, 798-807.

Conlu, P.V., 1979. *Guide to Philippine Flora and Fauna*. Volume III, Fishes. Natural Science Research Centre, Quezon City.

Dalzell, P., Ganaden, R., 1987. A review of the fisheries for small pelagic fishes in Philippine waters. Bureau of Fisheries and Aquatic Resources Technical Paper Seriea 10(1), 58 p.

Devadoss, P., Pillai, P.K.M., Natarajan, P., Muniyandi, K., 1977. Observations on some aspects of the biology and fishery of *Psettodes erumei* (Bloch) at Porto Novo. *Indian Journal of Fisheries* 24(1/2), 62-68.

Dou, S., 1992. Feeding habit and seasonal variation of food constituents of left-eyed flounder, *Paralichthys olivaceus*, of the Bohai Sea. *Marine Science* 4(4), 277-281.

Dredge, M.C.L., 1989a. By-catch from the Central Queensland prawn fisheries. The prawn fisheries, species composition, site associations from the by-catch. Fisheries Research Branch, Queensland Primary Industries. Technical Report FRB 88/04.

Dredge, M.C.L., 1989b. By-catch from the Central Queensland prawn fisheries. Part 2. Spatial and temporal changes in by-catch composition and community assemblages. Fisheries Branch, Queensland Department of Primary Industries, Brisbane. 37 p.

Edwards, R.R.C., Shaher, S., 1991. The biometrics of marine fishes from the Gulf of Aden. *Fishbyte* 9(2), 27-29.

Erzini, K., 1991. A compilation of data on variability in length-age in marine fishes. Working Paper 77. Fisheries Stock Assessment, Title XII, Collaborative Research Support Program, University of Rhode Island.

Eschmeyer, W.N., 1990. *Catalog of the Genera of Recent Fishes*. California Academy of Sciences, U.S.A. 697 p. 10

Evermann, B.W., Scale, A., 1907. Fishes of the Philippine Islands. Bulletin of the United States Bureau of Fisheries 26(1906), 49-110.

Fischer, W., Whitehead, P.J.P., Editors, 1974. FAO species identification sheets: eastern Indian Ocean (Fishing Area 57), Western Central Pacific (Fishing Area 71). Volumes 1- 4. FAO, Rome, pag.var.

Fourmanoir, P., 1981. Poissons (première liste). *In*: Forest, J. (ed.), *Results of the MUSORSTOM Expeditions to the Philippine Islands (18-28 mars 1976)*, p. 85-102. Éditions de l'Office de la Recherche Scientifique et Technique Outre-Mer avec le concours du Muséum National d'Histoire Naturelle, Paris.

Fowler, H.W., 1934. Descriptions of new species obtained 1907 to 1910, chiefly in the Philippine Islands and adjacent seas. *Proceedings of the Academy of Natural Sciences, Philadelphia* 85, 233-367.

Froese, R., Pauly, D., 1994. FishBase as tool for comparing the life history patterns of flatfish. *Netherlands Journal of Sea Research* 32(3/4), 235-239.

Froese, R., Pauly, D., Editors, 1996. *FishBase 96: Concepts, Design and Data Sources*. ICLARM, Manila. 179 p.

Gloerfelt-Tarp, T., Kailola, P.J., 1984. *Trawled fishes of Southern Indonesia and Northwestern Australia*. Australian International Development Assistance Bureau, Australia, The Directorate General of Fisheries, Indonesia, and The German Agency for Technical Cooperation. 406 p.

Gomez, E.D., 1980. *Bibliography of Philippine Marine Science 1978*. Filipinas Foundation, Inc., Makati, Metro Manila. 178 p.

Heemstra, P.C., 1986a. Cynoglossidae. *In*: Smith, M.M., Heemstra, P.C. (eds.), *Smiths' Sea Fishes*, p. 865-868. Springer-Verlag, Berlin.

Heemstra, P.C. 1986b. Pleuronectidae. *In*: Smith, M.M., Heemstra, P.C. (eds.), *Smiths' Sea Fishes*, p. 863-865. Springer-Verlag, Berlin.

Hensley, D.A., 2001. Citharidae. Largescale flounders. *In*: Carpenter, K.E., Niem, V. (eds.), *The Living Marine Resources of the Western Central Pacific. Volume 6: Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals*, p. 3794-3798. FAO identification guide for fishery purposes. FAO, Rome.

Hensley D.A., Amaoka, K., 2001. Bothidae. Lefteye flounders. *In*: Carpenter, K.E., Niem, V. (eds.), *The Living Marine Resources of the Western Central Pacific. Volume 6: Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals*, p. 3799-3814. FAO identification guide for fishery purposes. FAO, Rome.

Hensley, D.A., Amaoka, K., 1989. A redescription of *Pseudorhombus megalops*, with comments on *Cephalopsetta ventrocellota* (Osteichthyes: Pleuronectiformes: Paralichthyidae). *Proceedings of the Biological Society of Washington* 102(3), 577-585. 11

Hensley, D.A., Randall, J.E., 1990. A redescription of *Engyprosopon macrolepis* (Teleostei: Bothidae). *Copeia* (3), 674-6SO.

Herre, A.W., 1953. Checklist of Philippine fishes. Research Report 20, 977 p. Fish and Wildlife Service and United State Department of the Interior, U.S.A.

Ingles, J., Pauly, D., 1984. An atlas of the growth, mortality and recruitment of Philippines fishes. ICLARM Technical Report 13, 127 p.

Kimura, S., 1995. A checklist of the marine fishes collected around northern Palawan and Calauit islands, Philippines. *In*: Pawikan Conservation Project-PAWB, DENR, Philippines and Toba Aquarium, Japan, *Dugongs* Dugong dugong *(Miiller 1776) of the Philippines*, p. 158-167. A report of the Joint Dugong Research and Conservation Program. PANB, DENR, Philippines and Toba Aquarium, Japan.

Kottelat, M., 1993. Technical report on the fishes from fresh and brackish waters of Leyte, Philippines. Technical Report prepared for the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and ViSCA-GTZ Ecology Program, Visayan State College of Agriculture, Philippines. 54 p.

Kulbicki, M., Wantiez, L., 1990. Variations in the fish catch composition in the Bay of St. Vincent, New Caledonia, as determined by experimental trawling. *Journal of Marine and Freshwater Research* 41, 121-144.

Kuronuma, K., Abe, Y., 1986. *Fishes of the Arabian Gulf*. Kuwait Institute for Scientific Research, State of Kuwait, 356 p.

Labao, E., 1980. Oceanographic survey of Samar Sea. Marine Demersal Fisheries Resources and Management Project and Mid-water Trawl Exploration. University of the Philippines, College of Fisheries, Dept. of Marine Fisheries, Technical Report No. 3. Mimeo, pag. var.

Livingston, P.A., 1993. Importance of predation by groundfish, marine mammals and birds on walleye pollock *Theragra chalcogramma* and Pacific herring *Clupea pallasi* in the eastern Bering Sea. *Marine Ecology (Progress Series)* 102, 205-215.

Masuda, H., Amaoka, K., Araga, C., Uyeno, T., Yoshino, T. 1984a. *The Fishes of the Japanese Archipelago*. Vol. 1 (text). Tokai University Press, Tokyo, Japan. 437 p.

Masuda, H., Amaoka, K., Araga, C., Uyeno, T., Yoshino, T., 1984b. *The Fishes of the Japanese Archipelago*, (plates) Tokai University Press, Shinjuku Tokai Building. Tokyo, Japan. 437 p.

Matsuura, S., 1961. Age and growth of flatfish Ganzobriame, *Pseudorhombus cinamoneus* (Temminck & Schlegel). *Records of Oceanographic Works in Japan Sp*. (5), 103-110.

McManus, J.W., Nanola, Jr., C.L., Reyes, Jr., R.B., Kesner, K.N., 1992. Resource ecology of the Bolinao coral reef system. ICLARM Studies and Reviews 22, 117 p.

Menon, A.O.K., 1977. A systematic monograph of the tongue soles of the genus *Cynoglossus* Hamilton-Buchanan (Pisces: Cynoglossidae). Smithsonian Contributions to Zoology 238, 129 p.

Menon, A.O.K., 1984. Soleidae, *In*: Fischer, W., Bianchi, G. (eds.), *FAO Species Identification Sheets for Fishery Purposes. Western Indian Ocean (Fishing Area 51)*. Volume 4. FAO, Rome. pag. var.

Menon, A.O.K., Monkolprasit, S., 1974. Cynoglossidae. *In*: Fischer, W., Whitehead, P.J.P. (eds.), *FAO Species Identification Sheets for Fishery Purposes. Eastern Indian Ocean (fishing area 57) and Western Central Pacific (fishing area 71)*. Volume II. FAO, Rome, pag. var.

Munroe, T., 2001a. Cynoglossidae. Tongue soles. *In*: Carpenter, K.E., Niem, V. (eds.), *The Living Marine Resources of the Western Central Pacific. Volume 6: Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals*, p. 3890-3901. FAO identification guide for fishery purposes. FAO, Rome.

Munroe, T., 2001b. Soleidae. Soles. *In*: Carpenter, K.E., Niem, V. (eds.), *The Living Marine Resources of the Western Central Pacific. Volume 6: Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals*, p. 3878-3889. FAO identification guide for fishery purposes. FAO, Rome.

Myers, R.F., 1991. *Micronesian Reef Fishes*. 2nd ed. Coral Graphics, Barrigada, Guam. 298 p.

Nielsen, J., 1984a. Bothidae. *In*: Fischer, W., Bianchi, G. (eds.), *FAO Species Identification Sheets for Fishery Purposes. Western Indian Ocean Fishing Area 51*. Volume 1. FAO, Rome. pag. var.

Nielsen, J., 1984b. Psettodidae. *In*: Fischer, W., Bianchi, G. (eds.), *FAO Species Identification Sheets for Fishery Purposes. Western Indian Ocean Fishing Area 51*. Volume 3. FAO, Rome.

Pauly, D., 1978. A preliminary compilation of fish length growth parameters. *Ber. Inst. Meereskd. Christian-Albrechts Univ. Kiel*, 55, 200 p.

Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil International sur l'Exploration de la Mer* 39(3), 175-192.

Pauly, D., 1994. A framework for latitudinal comparisons of flatfish recruitment. *Netherlands Journal of Sea Research* 32(2), 107-118.

Pauly, D., 2010. *Gasping Fish and Panting Squids: Oxygen, Temperature and the Growth of Water-Breathing Animals*. Excellence in Ecology (22), International Ecology Institute, Oldendorf/Luhe, Germany, xxviii + 216 p.

Pauly, D., Martosubroto, P., Editors, 1996. Baseline studies of biodiversity: the fish resources of Western Indonesia. ICLARM Studies and Reviews 23, 312 p.

Pauly, D., Saeger, J., Silvestre, G., Editors, 1986. Resources management and socioeconomics of Philippine marine fisheries. University of the Philippines in the Visayas, College of Fisheries, Technical Report of the Department of Marine Fisheries 10, 217 p.

Pradhan, M.J., 1969. Fishery biology of *Psettodes erumei* (Schneider) - an Indian Ocean flatfish. III. The fishery of *Psettodes erumei*. *Bulletin of the National Institute of Science, India* (38), 906-926.

Rainer, S.F., 1984. Temporal changes in a demersal fish and cephalopod communities of an unexploited coastal environment in northern Australia. *Australian Journal of Marine and Freshwater Research* 35, 747-768.

Rainer, S.F., Munro, I.S.R., 1982. Demersal fish and cephalopod communities of an unexploited coastal environment in northern Australia. *Australian Journal of Marine and Freshwater Research* 33, 1039-1055.

Rajaguru. A., 1992. Biology of two co-occurring tonguefishes, *Cynoglossus arel* and *C. lida* (Pleuronectiformes: Cynoglossidae), from Indian waters. *United States Fishery Bulletin* 90, 328-367.

Ramanathan, N., Natarajan, R., 1979. Breeding biology of *Psettodes erumei* (Bloch & Schn.) and *Pseudorhombus arsius* (Hamilton-Buchanan). Pisces: Pleuronectiformes along Porto Novo coast (S. India). *Aquaculture* 18(3), 269-282.

Randall, J.E., 1985. *Guide to Hawaiian Reef Fishes*. Harrowood Books, Pennsylvania.

Randall, J.E., 1995. *Coastal Fishes of Oman*. University of Hawaii Press, Honolulu, Hawaii. 439 p.

Randall, J.E., Allen, G.R., Steene, R.C., 1990. *Fishes of the Great Barrier Reef and Coral Sea*. University of Hawaii Press, Honolulu, Hawaii. 506 p.

Ronquillo, I.A., Caces-Borja, P., Mines, A.N., 1960. Preliminary observations on the otter trawl fishery of Manila Bay. *Philippine Journal of Fisheries* 8(l), 47-56.

Saila, S.B., 1983. The importance and assessment of discards in commercial fisheries. FAO Fisheries Circular No. 765, 62 p.

Sainsbury, K.J., Kailola, P.J., Leyland, G.G., 1985. *Continental Shelf Fishes of Northern and North-western Australia*. Clouston and Hall and Peter Pownall Fisheries Information Service, Australia. 375 p.

Sano, M., Shimizu, M., Nose, Y., 1984. *Food Habits of Teleostean Reef Fishes in Okinawa Island, Southern Japan*. University of Tokyo Press, Tokyo, Japan. 128 p.

Seigel, J., Adamson, T.A., 1985. First record of the genus *Zebrias* (Pisces: Pleuronectiformes: Soleidae) from the Philippine Islands, with the description of a new species. *Proceedings of the Biological Society of Washington* 98(1), 13-1 6.

Selga, M., 1931. *Sea Surface Temperature in the Philippines*. Publications of the Manila Observatory, Manila, Philippines.

Silvestre, G., Regalado, R., Pauly, D., 1986a. Status of Philippine demersal stocks inferences from underutilized catch rate data. *In*: Pauly, D., Saeger, J., Silvestre, G. (eds.), *Resources, Management and Socio-economics of Philippine Marine Fisheries*, p. 47-96. Department of Marine Fisheries Technical Report 10.

Silvestre. G., Hammer, C., Sambilay, Jr., V., Torres, Jr., F., 1986b. Size selection and related morphometrics of trawl-caught fish species from the Samar Sea. *In*: Pauly, D., Saeger, J., Silvestre, G. (eds.), *Resources, Management and Socio-economics of Philippine Marine Fisheries*, p. 107-138. Department of Marine Fisheries Technical Report 10.

Villoso, E.P., Hermosa, Jr., G.V., 1982. Demersal trawl fish resources of Samar Sea and Carigara Bay, Philippines. *Fisheries Research Journal of the Philippines* 7(2), 59-68.

Villoso, E.P., Aprieto, V.L., 1983. On the relative abundance and distribution of slipmouths (Pisces: Leiognathidae) in Lingayen Gulf, Philippines. *Fisheries Research Journal of the Philippines* 8(1), 26-43.

Warfel, E., Manacop, P.R., 1950. Otter trawl explorations in Philippine waters. Research Report 25, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C.

Weber, M., de Beaufort, L.F., 1929. *The Fishes of the Indo-Australian Archipelago. V. Anacanthini, Allotriognathi, Heterostomata, Berycomorphi, Percomorphi: Kuhliidae, Apogonidae, Plesiopidae, Pseudoplesiopidae, Priacanthidae, Centropomidae*. E.J. Brill Ltd., Leiden. 458 p.

Winterbottom, R., 1993. *Philippine Fishes*. Computerized catalog of the fish collection in the Royal Ontario Museum, Toronto, Canada.

APPENDIX 1. ANNOTATED CHECKLIST OF THE FLATFISHES OF THE PHILIPPINES

Bothidae

Arnoglossus aspilos (Bleeker 1851) Max. length: 19 cm TL; Museum: Eastern Luzon, 4.9 miles off Caringo I., in 11 fathoms (20 m), R/V *Albatross* collection, Stn. 5461, USNM 137659 (Anon. 1994). Sold in dried form called *palad*. See also Kuronuma and Abe (1996).

Arnoglossus brunneus (Fowler 1934) Max. length: 18.3 cm TL; Museum: R/V *Albatross* collections, as *Bothus bnmneus'*. east coast of Luzon, in 146 fathoms (267 m), Stn. D. 5453, USNM 93074 (holotype, 18.3 cm) (Fowler, 1934); Sombrero I., Batangas, 118 fathoms (216 m), USNM 93543, and Uanivan I., Batanes, USNM 93544 (paratypes) (Anon., 1994). See also Herre (1953) and Hensley and Amaoka (2001).

Arnoglossus elongatus Weber 1913 Max. length: 11 cm TL; Inhabits coral-sand bottoms from depths of 100-224 m (Hensley and Amaoka, 2001).

Arnoglossus polyspilus (Günther 1880) Max. length: 24 cm TL; Museum: East coast of Luzon, in 195 fathoms (357 m), R/V *Albatross* collection, Stn. 5475, USNM 93076 (as *Bothus tchangi,* 21 cm) (Fowler, 1934). See also Hensley and Amaoka (2001). Additional reference: Morphology in Masuda *et al.* (1984a).

Arnoglossus tapeinosoma (Bleeker 1865) Max. length: 13 cm TL; Museum: R/V *Albatross* collections: western coast of Luzon, off San Fernando Pt., 45 fathoms (82.4 m), USNM 138709; Sulu Sea, off western Mindanao I., off Panabutan Pt., USNM 138712 (Anon., 1994).

Asterorhombus fijiensis (Norman 1931) Max. length: 15 cm TL; Museum: Palawan, Putic I., 0-15 ft (0-4.6 m), USNM 260364. Ajong, Negros I., 0-8 ft (0-2.4 m), USNM 260365. Balicasag I., 0-80 ft (0-24.4 m), USNM 260366. Siquijor I., 0-35 ft (0-11 m), USNM 260367 (Anon., 1994). See also Hensley and Amaoka (2001).

Asterorhombus intermedius (Bleeker 1865) Max. length: 15 cm TL; Museum: Bais Bay, Negros I., 0-120 ft (0-36.6 m), USNM 260363 (Anon., 1994). Additional reference: Morphology in Myers (1991).

Bothus mancus (Broussonet 1782) Max. length: 42 cm SL; Museum: Tagburos, Puerto Princesa, USNM 227085. West of Engano Point, Barrio Anqib., Santa Ana, Cagayan Prov., USNM 309422. Fuga I. (Babuyan Is.) USNM 318329. Maybag I., (Babuyan Is.), USNM 318330 (Anon., 1994). See also Herre (1953) and Randall *et al.* (1990). Additional references: Morphology in Myers (1991). Diet in Randall (1985).

Bothus myriaster (Temminck & Schlegel 1846) Max. length: 27 cm TL; A rare species found in sand and mudd bottoms of continental shelves (Hensley and Amaoka, 2001). See also Conlu (1979). Additional reference: Morphology in Masuda *et al.* (1984a).

Bothus pantherinus (Rüppell 1830) Max. length: 30 cm TL; Reported from southern to western Luzon to Cagayan Prov., Palawan, the Visayas (Panay, Negros, Cebu, Bohol), and northern Mindanao. Museum: ANSP 63543, 63483; LACM 347416, 42485-7; USNM 260373, 260471. Two specimens, 5.2 and 6 in (13 and 15 cm), were collected from Bacon, Sorsogon (Evermann and Scale, 1907). See also Herre (1953), Randall *et al.* (1990), Myers (1991), and Anon. (1994). Additional reference: Morphology in Myers (1991).

Chascanopsetta lugubris Alcock 1894 Max. length: 38 cm SL; Museum: Balayan Bay, Luzon, USNM 138016. Gulf of Davao, Dumalag I. USNM 138017. Northern Mindanao, USNM 138018. Luzon coast, USNM 138019-20 (Anon. 1994). See also Masuda *et al.* (1984a, 1984b). Additional reference: Morphology in Masuda *et al.* (1984a).

Chascanopsetta micrognatha Amaoka & Yamamoto 1984 Max. length: 27.4 cm. Reported by Kunio Amaoka (pers. comm.) using samples collected by him during the WCP Workshop 1995.

Crossorhombus valderostratus (Alcock 1890) Max. length: 14 cm TL; Museum: China Sea, vicinity s. Luzon, Malavatuan I., 80 fathoms (146 m), R/V *Albatross* collection, Stn. 5277, USNM 137391 (Anon., 1994).

Engyprosopon grandisquama (Temminck & Schlegel 1846) Max. length: 15 cm TL; Reported from Sulu archipelago to Corregidor I., Manila Bay. Museum: USNM 137924-41 (Anon., 1994). Sold in the market in dried form called *palad*. See also Herre (1953). Additional reference: Morphology in Masuda *et al.* (1984a).

Engyprosopon latifrons (Regan 1908) Max. length: 8 cm SL. Inhabits sandy bottoms at depths of 37-68 m (Hensley and Amaoka, 2001).

Engyprosopon macrolepis (Regan 1908) Max. length: 5.9 cm SL. Inhabits sandy and muddy bottoms (Hensley and Amaoka, 2001). Museum: BPBM 26860; USNM 260378; CAS-SU 33678. Species redescribed by Hensley and Randall (1990). Additional reference: Morphology in Hensley and Randall (1990).

Engyprosopon maldivensis (Regan 1908) Max. length: 12.7 cm SL. Museum: R/V *Albatross* collections, as *Arnoglossus maculipinnis:* vicinity of Jolo, in 20 to 76 fathoms (37-139 m), Stn. D. 5140, USNM 93098 (10.1 cm) (Fowler, 1934); between Samar and Leyte, vicinity of Surigao Strait, Tabuc Pt., (Leyte), 62 fathoms (113.5 m), Stn. 5480, USNM 93570 (Anon., 1994). See also Amaoka *et al.* (1993) and Hensley and Amaoka (2001). Additional reference: Morphology in Masuda *et al.* (1984a).

Engyprosopon mogkii (Bleeker 1854) Max. length: 11 cm SL. Known from Mindanao, southern Negros, Palawan, to southern Luzon. Museum: USNM 137960-81, 260468 (Anon., 1994). Based on records, this species occurs in estuarines, reef sand flats, and embayments.

Engyprosopon obliquioculatum (Fowler 1934) Max. length: 7.6 cm. Museum: collected most likely from deep water, R/V *Albatross* collection, as *Bothus obliquioculatits,* USNM 93077 (holotype, 7.6 cm); USNM 93078 (4 paratypes) (Anon., 1994).

Grammatobothus polyophthalmus (Bleeker 1865) Max. length: 21 cm TL. Reported from southern Negros to Masbate Is. and off entrance to Manila Bay (Herre, 1953). Museum: USNM 260448, 160480-1 (Anon., 1994). See also Weber and de Beaufort (1929).

Kamoharaia megastoma (Kamohara 1936) Max. length: 22.5 cm TL. Inhabits sandy and muddy bottoms (Hensley and Amaoka, 2001). Additional reference: Morphology in Masuda *et al.* (1984a).

Laeops clarus Fowler 1934 Max. length: 15.5 cm TL. Museum: R/V *Albatross* collections: between Cebu and Bohol, in 162 fathoms (296.5 m), Stn. D. 5412, USNM 93083 (holotype, 15.5 cm) (Fowler, 1934); east coast of Luzon, San Bernadino Strait to San Miguel Bay; Atulayan I., 0-560 fathoms (1025 m), USNM 93560 (paratype) (Anon., 1994). See also Herre (1953) and Hensley and Amaoka (2001).

Laeops cypho Fowler 1934 Max. length: 14.9 cm. Museum: R/V *Albatross* collections: off northern Mindanao, in 182 fathoms (333 m), Stn. D. 5519, USNM 93085 (holotype, 14.9 cm) (Fowler, 1934); Sombrero I., Batangas, 118 fathoms (216 m), USNM 93567 (paratype) (Anon., 1994). Type locality identified as off Point Tagolo, Zamboanga (Herre, 1953).

Laeops gracilis Fowler 1934 Max. length: 16.5 cm TL. Museum: East of Masbate, in 108 fathoms (197 m), R/V *Albatross* collection, Stn. D. 5212, USNM 93084 (holotype, 16.5 cm) (Fowler, 1934). See also Herre (1953) and Hensley and Amaoka (2001).

Laeops guentheri Alcock 1890 Max. length: 14 cm TL. Museum: West coast of Luzon, from Manila Bay to Lingayen Gulf, S. Fernando Pt., in 45 fathoms (82.4 m), R/V *Albatross* collection, Stn. 5442, USNM 137394 (Anon., 1994).

Laeops parviceps Günther 1880 Max. length: 14 cm TL. Museum: R/V *Albatross* collections: east coast of Luzon, San Bernardino Strait to San Miguel Bay, Legaspi, 146 fathoms (267 m), Stn. 5453, USNM 137395; west coast of Luzon, Manila Bay to Lingayen Gulf, San Fernando Pt., 45 fathoms (82.4 m), Stn. 5442, USNM 137396; Visayan Sea between northern Negros and Masbate Is., se. Tanguingui I., 0-69.5 m, USNM 260451 (Anon., 1994).

Neolaeops microphthalmus (von Bonde 1922) Max. length: 21 cm SL. Inhabits sandy and muddy bottoms (Hensley and Amaoka, 2001). Additional reference: Morphology in Masuda *et al.* (1984a).

Psettina brevirictis (Alcock 1890) Max. length: 8 cm SL. Museum: R/V *Albatross* collections: western Samar, Taratara I., 20 fathoms (37 m), Stn. D.5209, USNM 137389; off eastern Panay, Antonia I., 24 fathoms (44 m), Stn. 5182, USNM 137390 (Anon., 1994).

Psettina gigantea Amaoka 1963 Max. length: 13 cm SL. Museum: Visayan Sea between northern Negros and Masbate Is. northwest Guintacan I., 0-80.5 m, USNM 260446; southwest of Caduruan Point, 0-78.7 m, USNM 260482 (Anon., 1994). Additional reference: Morphology in Masuda *et al.* (1984a).

Psettina variegata (Fowler 1934) Max. length: 9.2 cm SL. Museum: between Samar and Leyte Islands in 61 fathoms (112 m), R/V *Albatross* collection Stn. D. 5481, USNM 93091 (as *Bothus variegatus,* holotype, 9.2 cm) (Fowler, 1934; Herre, 1953). See also Hensley and Amaoka (2001).

Taeniopsetta ocellata (Günther 1880) Max. length: 11.4 cm. Specimens 6.9 to 11.4 cm were trawled from Stn. 16, at depth of 150 to 164 m during the R/V *Vauban* expedition (Fourmanoir, 1976 in Fourmanoir, 1981). Additional reference: Morphology in Masuda *et al.* (1984a).

Citharidae

Brachypleura novaezeelandiae Günther 1862 Max. length: 14 cm TL. Museum: Marinduque and vicinity, USNM 137708. Off Luzon, Sueste Pt., USNM 137709-10. Manila Bay, Corregidor Lt., USNM 137711. S. Mindanao, eastern Illana Bay, USNM 137712. E. Mindanao, Nagubat I., USNM 137714. Visayan Sea, between northern Negros and Masbate I., USNM 261361, 261363-4, 261526. Carigara Bay, Samar Sea, USNM 228536-9 (Anon., 1994). See also Herre (1953) and Kuronuma and Abe (1986).

Citharoides axillaris (Fowler 1934) Max. length: 19.5 cm. Museum: *Albatross* collections, as *Erachyphurops axillaris:* Balayan Bay and Verde Island Passage, in 118 fathoms (216 m), R/V, Stn. D. 5117, USNM 93080 (holotype, 19.5 cm) (Fowler, 1934; Herre, 1953); China Sea, vicinity of southern Luzon, Malavatuan I., USNM 93545; Balabac Strait, Cape Melville, USNM 93547 (Anon., 1994).

Citharoides macrolepidotus Hubbs 1915 Max. length: 29 cm TL. A rare species found at depths of 121-240 m (Hensley, 2001).

Lepidoblepharon ophthalmolepis Weber 1913 Max. length: 36 cm TL. Museum: Balanja Pt., Mindoro Is., in 234 fathoms (428 m), R/V *Albatross* collection, Stn. 5260, USNM 137408 (Anon., 1994).

Cynoglossidae

Cynoglossus arel (Bloch & Schneider 1801) Max. length: 40 cm TL. Inhabits muddy and sandy bottoms of the continental shelf down to 125 m (Munroe, 2001). Additional references: Growth in Pauly (1980). Food, Diet, Reproduction, and Spawning in Rajaguru (1992).

Cynoglossus bilineatus (Lacepède, 1802) Max. length: 44 cm SL. Museum: R/V *Albatross* collections: Cavite Mkt., USNM 137616; Manila Mkt., USNM 137617, 137652; Palawan, Verde del Sur, reef sand flat, USNM 137618; Manila Bay, USNM 137620; Limbones Cove, USNM 286919 (removed from 113179 and recatalogued) (Anon., 1994). See also Herre (1953) and Menon (1977). Additional reference: Food in Blaber (1980).

Cynoglossus cynoglossus (Hamilton 1822) Max. length: 20 cm TL. Museum: ANSP 49038-9; NHV 43826. See also Herre (1953) and Menon (1977).

Cynoglossus kopsii (Bleeker 1851) Max. length: 17.7 cm SL. Museum: Iloilo, U.S.N. Eclipse Expedition USNM 112872-4. collections: Pt.Tagalo, 102 fathoms (187 m), Stn. 5520, USNM 113186; Lingayen Gulf, e. of Pt. Guecet, Stn. 5442, USNM 113187; Marinduque and vicinity, Tayabas, Stn. 5371, USNM 113188; Tawi Tawi, 34 fathoms (62.6 m), Stn. D.5152, USNM 137653; Cotabato, USNM 137656; Off San Fernando, 45 fathoms (82 m), Stn. D.5442, USNM 137657; Corregidor, 12 fathoms (22 m), Stn. 5360, USNM 137658; Panay, Iloilo, USNM 148586 (Anon., 1994). See also Herre (1953) and Menon (1977).

Cynoglossus lida (Bleeker 1851) Max. length: 21.3 cm SL. Museum: R/V *Albatross* collections: Davao, USNM 137952; Abuyog, Leyte, USNM 137953, 137957; Hinunangan B., USNM 137954; Iloilo Mkt., USNM 137955; offcast coast of Leyte I., Tacloban Anchorage, USNM 137956; Palawan, Mantaquin B., USNM 137958; Cotabato, below river mouth, USNM 137959 (Anon., 1994). BMNH 1872.4.6.96 (Menon, 1977). See also Herre (1953) and Heemstra (1986a). Additional references: Growth, Food, Diet, Reproduction, and Spawning in Rajaguru (1992).

Cynoglossus lingua Hamilton 1822 Max. length: 45 cm TL. Museum: China Sea, off s. Luzon, 17.5 miles from Malavatuan I., 525 fathoms (961 m), Stn. D.5274, USNM 137410 (Anon., 1994).

Cynoglossus monopus (Bleeker 1849) Max. length: 18.8 cm SL. Found on muddy substrates from 13-18.3 m (Menon, 1977). Museum: AMNH 19645.

Cynoglossus puncticeps (Richardson 1846) Max. length: 18 cm TL. Specimens were collected during the U.S.N. Eclipse Expedition and R/V *Albatross* from Cotabato, Mindanao, central and eastern Visayas to southern Philippines (Anon., 1994). Museum: ANSP 63524, 82548; LACM 42475-47. See also Herre (1953) and Menon and Monkolprasit (1974). Additional references: Morphology in Fischer and Whitehead (1974). Growth in Pauly (1994).

Cynoglossus suyeni Fowler 1934 Max. length: 27.5 cm SL. Museum: R/V *Albatross* collections: off southern Luzon, China Sea (Verde I. Passage, off Escarceo Light, Mindoro), in 173 fathoms (317 m), Stn. D. 5291, USNM 93086 (holotype, 15.5 cm) (Fowler, 1934); USNM 113189-113194, 137941-8,- 137950 (Anon., 1994). See also Herre (1953) and Menon (1977).

Paraplagusia bilineata (Bloch 1787) Max. length: 60 cm TL. Museum: R/V *Albatross* collections: Iloilo Mkt., USNM 138070, 138071; Manila Mkt, USNM 138072; Chase Head Endeavor St., Palawan, USNM 138073; Paluan Bay, Mindoro, USNM 138074; Mansalay Bay, southeastern Mindoro, USNM 138075; Lingayen Gulf, USNM 138076; Siquijor I., Santa Maria, USNM 138077; Abuyog, Leyte, USNM 138079; Subig Bay, USNM 138080; Port San Pio Quinto, Camiguin I., 1-6 m, USNM 138082; Panabutan Bay, Mindanao, USNM 138083; Cotabato, USNM 138084; Davao, USNM 138085; Balayan Bay, Luzon, Taal Anchorage, USNM 138086; Bolinao lagoon, Pangasinan, USNM 228535; northeastern side of Siquijor, tidal lagoon, USNM 273773; USNM 138081 (Anon., 1994). See also Herre (1953) and Heemstra (1986a). Additional references: Growth in Pauly (1978) and Erzini (1991). Food in Livingston (1993).

Paraplagusia blochii (Bleeker 1851) Max. length: 20 cm SL. Museum: R/V *Albatross* collections: Philippine Sea, off Daet, Luzon, 15 June 1909, USNM 138087 (7, 11.6-22 cm) (Chapleau and Renaud, 1993); Limbones Cove, USNM 113179. Iloilo, U.S.N. Eclipse Expedition, USNM 112870 (Anon., 1994). ANSP 77427. Also known from Dumaguete, Negros Oriental (Herre, 1953). See also Winterbottom (1993) and Randall (1995).

Symphurus gilesii (Alcock 1889) Max. length: 14 cm. Two specimens collected between 70 to 215 m during the R/V *Vauban* expedition (Fourmanoir, 1976 in Fourmanoir, 1981).

Symphurus marmoratus Fowler 1934 Max. length: 9.8 cm. Museum: Jolo I. and vicinity, in 10 fathoms (18.3 m), R/V *Albatross* collection, Stn. D. 5561, USNM 93092 (holotype, 9.8 cm) (Fowler, 1934).

Symphurus regani Weber & Beaufort 1929 Max. length: 12 cm. Museum: Between Siquijor and Bohol Is., Balicasag I., 805 fathoms (1473 m), R/V *Albatross* collection, Stn. 5526, USNM 138045 (Anon., 1994).

Symphurus septemstriatus (Alcock 1891) Max. length: 10 cm TL. Museum: R/V *Albatross* collections: Verde I. Passage and Batangas Bay, Matocot Pt., 135 fathoms (247 m), Stn. 5265, USNM 138023 and in 170 fathoms (311 m), Stn. 5268, USNM 163654; between Burias and Luzon, Anima Sola I., 215 fathoms (393 m), Stn. 5216, USNM 138026; China Sea, vicinity s. Luzon, Matocot Pt., 140 fathoms (256 m), Stn. 5298, USNM 138028; between Samar and Masbate, Tubig Pt., Destacado I., 118 fathoms (216 m), Stn. 5391 and in 135 fathoms (247 m), Stn. 5392, USNM 138032; between Cebu and Bohol, Lauis Pt., 145 fathoms (265 m), Stn. 5411, USNM 138037; off n. Luzon, Hermanos I., 230 fathoms (421 m), Stn. 5326, USNM 138040; between Burias and Luzon, Bagatao I., 226 fathoms (414 m), Stn. 5388, USNM 138041 and in 209 fathoms (382 m), Stn. 5387, USNM 138042; Camp Overton Lt, Iligan Bay, Stn. 5508, USNM 163655; Dupon Bay (Leyte) and vicinity, Ponson I., 262 fathoms (479 m), Stn. 5405, USNM 163657 (Anon., 1994).

Symphurus strictus Gilbert 1905 Max. length: 14 cm. Museum: R/V *Albatross* collections: Verde I. Passage and Batangas Bay, Matocot Pt., 220 fathoms (402 m), Stn. 5269, USNM 138024; China Sea, vicinity s. Luzon, Matocot, 214 fathoms (392 m), Stn. 5290, USNM 138027 and, Escarceo, 244 fathoms (446 m), Stn. 5294, USNM 138030 (Anon., 1994).

Symphurus woodmasoni (Alcock 1889). Known in the Visayan and Mindanao area, R/V *Albatross* collections (Anon., 1994).

Paralichthyidae

Paralichthys olivaceus (Temminck & Schlegel 1846) Max. length: 80 cm SL. Inhabits muddy and sandy bottoms of shallow waters (Amaoka and Hensley, 2001). Additional reference: Diet in Dou (1992).

Pseudorhombus argus Weber 1913 Max. length: 25 cm SL. Museum: Buton Strait, Kalono Pt., in 39 fathoms (71.4 m), R/V *Albatross* collection, Stn. 5641, USNM 137393 (Anon., 1994). Additional reference: Morphology Amaoka and Hensley (2001).

Pseudorhombus arsius (Hamilton 1822) Max. length: 45 cm TL. Known from northwestern Mindanao to southern and western Luzon, R/V *Albatross* collections. Museum: Davao, USNM 137985. Malabang, USNM 137986. Cavite Mkt, USNM 137987. Manila Mkt., USNM 137988, 137993, 137996. North of Malampaya R., USNM 137989. Mantaquin B., Palawan, USNM 137990. Endeavor Pt., in 14-25 fathoms (26-46 m), Stn. 5342, USNM 137991. Abuyog, Leyte, USNM 137992] Outside Harbor of Manila Bay, USNM 137994. Iloilo Mkt, USNM 137995, 138000. Ragay R., tidewater, USNM 137998. Samar I., Catbalogan, USNM 137999. Cuyo Is., USNM 138001 (Anon., 1994). LACM 42475-33. See also Weber and de Beaufort (1929) and Herre (1953). Additional references: Morphology in Amaoka and Hensley (2001). Growth in Bawazeer (1987). Food in Blaber (1980).

Pseudorhombus cinnamoneus (Temminck & Schlegel 1846) Max. length: 35 cm SL. A 17.7 cm specimen was caught between 150 to 164 m during the 1976 R/V *Vauban* expedition (Fourmanoir, 1976 in Fourmanoir, 1981). Museum: Puerto Princesa Market, USNM 227078 (Anon., 1994). See also Herre (1953) and Masuda *et al.* (1984a). Additional references: Morphology in Amaoka and Hensley (2001). Growth in Matsuura (1961).

Pseudorhombus diplospilus Norman 1926 Max. length: 40 cm SL. Museum: Visayan Sea between northern Negros and Masbate Is., southwest of Caduruan Point, in 75 m, USNM 260477 (Anon., 1994). Additional reference: Morphology in Amaoka and Hensley (2001).

Pseudorhombus dupliciocellatus Regan 1905 Max. length: 40 cm SL. Museum: Visayan Sea, between northern Negros and Masbate I., southwest of Caduruan Pt., 0-75 m, USNM 260478; north of Tanguingui I., USNM 260479; northwest Guintacan I., USNM 260687 (Anon., 1994). One large sample collected from Bulan, Sorsogon, USNM 55898 (as *Platophrys palad,* holotype, 15.5 in (39 cm)) (Evermann and Scale, 1907). Additional reference: Morphology in Amaoka and Hensley (2001).

Pseudorhombus javanicus (Bleeker 1853) Max. length: 35 cm SL. Museum: Bulan, USNM 55967. Panabutan Bay, Mindanao, USNM 138714. Buena Vista, Guimaras I. (Iloilo Strait), USNM 138715. Manila Bay, Corregidor Lt., USNM 138716. Visayan Sea between northern Negros and Masbate Is., southeast south Gigante, USNM 260447 (Anon., 1994). ANSP 49030, 49272. One specimen, 8.25 in. (21 cm), collected from Bulan, Sorsogon (Evermann and Scale, 1907). See also Herre (1953) and Nielsen (1984a). Additional references: Morphology in Amaoka and Hensley (2001). Growth in Chan and Liew (1986).

Pseudorhombus malayanus Bleeker 1865 Max. length: 35 cm SL. Museum: R/V *Albatross* collections: off east coast of Leyte I., Mariquitdaquit I., 15 fathoms (27 m), Stn. 5204, USNM 137420; Manila Bay, Corregidor Lt., 12 fathoms (22 m), Stn. 5361, USNM 137421; Bacoor Beach, USNM 137422; Manila Mkt., USNM 137423; Western Samar, Taratara I., 20 fathoms (37 m), Stn. D.5209, USNM 137424 (Anon., 1994). LACM 35964-9, 35957-15. Additional reference: Morphology in Amaoka and Hensley (2001).

Pseudorhombus megalops Fowler 1934. Max. length: 22 cm SL. Museum: Between Samar and Masbate in 135 fathoms (247 m), R/V *Albatross* collection, Stn D.5392, USNM 93082 (holotype, 22 cm) (Fowler, 1934). USNM 93548-51 (paratypes). Morphological information found also in Hensley and Amaoka (1989).

Pseudorhombus micrognathus Norman 1927. Museum: R/V *Albatross* collections: Balayan Bay, Luzon, C. Santiago Lt, 214 fathoms (392 m), Stn. 5365, USNM 137654; Sulu Archipelago, Tawi-tawi group, Tinakta I., 18 fathoms (33 m), Stn. 5157, USNM 137655 (Anon., 1994).

Pseudorhombus neglectus Bleeker 1865 Max. length: 25 cm SL. Museum: Bulan I., USNM 55968. Panay I., Iloilo, Naval Eclipse Expedition, USNM 102648 (Anon., 1994). Three specimens collected from San Fabian, Pangasinan, 3.5-6.75 in (9-17 cm) (Evermann and Seale, 1907). Also known from Dumaguete, Negros Oriental. Additional reference: Morphology in Amaoka and Hensley (2001).

Pseudorhombus oligodon (Bleeker 1854) Max. length: 30 cm SL. Inhabits muddy and sandy bottoms of continental shelves. Morphological information found also in Amaoka and Hensley (2001). See also Weber and de Beaufort (1929).

Pseudorhombus pentophthalmus Günther 1862 Max. length: 18 cm SL. Museum: Samar I., Catbalogan, USNM 137923. Visayan Sea between northern Negros and Masbate, southeast south Gigante, USNM 260384. Visayan Sea, east of Sicogon I., USNM 260385 (Anon., 1994). See also Masuda *et al.* (1984a, 1984b). Additional reference: Morphology in Amaoka and Hensley (2001).

Pseudorhombus polyspilos (Bleeker 1853) Max. length: 27 cm. Inhabits muddy and sandy bottoms of shallow waters (Amaoka and Hensley, 2001). See also Weber and de Beaufort (1929).

Pseudorhombus russellii (Gray 1834) Max. length: 23 cm. Museum: ANSP 63710, 63544 (12.81 and 16.34 cm). One specimen, 23 cm, was also collected from Bulan, Sorsogon (Evermann and Seale, 1907).

Pleuronectidae

Nematops macrochirus Norman 1931 Max. length: 8.2 cm TL. Museum: China Sea, off southern Luzon at 135 fathoms (247 m), R/V *Albatross* collection, D. 5110, USNM 93087 (holotype, 8.2 cm) (Fowler, 1934). Type locality described as near Corregidor I. See also Herre (1953) and Hensley (2001).

Poecilopsetta colorata Günther 1880 Max. length: 17 cm TL. Museum: Vicinity of southern Luzon, Malavatuan I., 117 fathoms (214 m), R/V *Albatross* collection, Stn. 5275, USNM 137392 (Anon., 1994).

Poecilopsetta megalepis Fowler 1934 Max. length: I8 cm TL. Museum: R/V *Albatross* collections: Balayan Bay and Verde I. Passage, in 118 fathoms (216 m), Stn. D. 5117, USNM 93094 (holotype, 12.8 cm) (Fowler, 1934; Herre, 1953). Balabac Strait: Cape Melville, 148 fathoms (271 m), USNM 93576 (Anon., 1994).

Poecilopsetta plinthus (Jordan & Starks 1904) Max. length: 19 cm TL. Fourmanoir (1976 in Fourmanoir, 1981) reported two specimens (9.6 and 9.9 cm) caught between 185 and 200 m during the R/V *Vauban* expedition. See also Herre (1953).

Poecilopsetta praelonga Alcock 1894 Max. length: 17.5 cm TL. Reported from Davao, Mindanao, central Visayas to the west coast of Luzon; specimens caught between 247-511 m, USNM 138004-138015 (Anon., 1994).

Psettodidae

Psettodes erumei (Bloch & Schneider 1801) Max. length: 64 cm. Known from Iloilo, west to Palawan, and north to western Luzon (Herre, 1953). Occurs from shallow waters to over 300 m deep; most abundant between 22 to 40 m (Warfel and Manacop, 1950). Museum: LACM 35957-12. Off El Nido, gill net, FRLM 11761 (Kimura, 1995). Additional references: Morphology in Nielsen (1984b). Growth in Pradhan (1969), Pauly (1978), and Edwards and Shaher (1991). Food in Devadoss *et al.* (1977) and Cabanban (1991). Diet and Reproduction in Devadoss *et al.* (1977). Spawning in Devadoss *et al.* (1977) and Ramanathan and Natarajan (1979).

Samaridae

Plagiopsetta glossa Franz 1910 Max. length: 19 cm TL. Specimens were collected between 150 and 164 m (Fourmanoir, 1976 in Fourmanoir, 1981).

Samaris cristatus Gray 1831 Max. length: 22 cm TL. Museum: R/V *Albatross* collections: Between Samar and Leyte, vicinity of Surigao Strait, Tabuc Ft., 62 fathoms (114 m), Stn. 5480, USNM 00137649; Buton Strait, Kalono Ft., 39 fathoms (71 m), Stn. 5641, USNM 137650. Samar Sea collection, Carigara Bay, USNM 228532 (Anon., 1994). A specimen, 12 cm, was caught between 70 and 76 m. See also Herre (1953) and Heemstra (1986b). Additional reference: Morphology in Hensley (2001).

Samariscus huysmani Weber 1913 Max. length: 11.5 cm TL. Museum: Samar Sea, Carigara Bay, 0-65 m, USNM 27534 (Anon., 1994).

Samariscus longimanus Norman 1927 Max. length: 12 cm TL. Museum: R/V *Albatross* collection: Between Cebu and Bohol, Lauis Ft., 145-162 fathoms (265-297 m), Stns. 5411, 5412, 5418, USNM 137384-6; Ft. Tagolo, 182 fathoms (333 m), Stn. 5519, USNM 137387; Balayan Bay and Verde I. Passage, Sombrero I., 118 fathoms (216 m), Stn. 5117, USNM 137388 (Anon., 1994).

Samariscus luzonensis Fowler 1934 Max. length: 7.6 cm TL. Museum: West coast of Luzon, in 45 fathoms (82.4 m), R/V *Albatross* collection, Stn. D. 5442, USNM 93089 (holotype, 7.6 cm) (Fowler, 1934). Type locality identified as off San Fernando, La Union, Luzon. See also Herre (1953), Anon. (1994), and Hensley (2001).

Samariscus macrognathus Fowler 1934 Max. length: 5.5 cm TL. Museum: West coast of Luzon, in 45 fathoms (82.4 m), R/V *Albatross* collection, Stn. D. 5442, USNM 93088 (holotype, 5.4 cm) (Fowler, 1934). Type locality identified as San Fernando, La Union, Luzon (Anon., 1994). See also (Hensley, 2001).

Samariscus triocellatus Woods 1960 Max. length: 9 cm TL. Museum: Siquijor L, 80-100 ft (24-30 m), USNM 273792. White Beach, past Mahatae, Batan I., Batanes, 50-70 ft (15-21 m), USNM 298212 (Anon., 1994). Additional reference: Morphology in Myers (1991).

Soleidae

Aesopia cornuta Kaup 1858 Max. length: 20 cm SL. Caught by trawl in the seagrass beds of Bolinao (McManus *et al.*, 1992).

Aesopia heterorhinos (Bleeker 1856) Max. length: 11 cm SL. Museum: As *Soleichthys heterorhinos:* Bacon, USNM 55963; R/V *Albatross* collections-Cebu Mkt. USNM 137412 and Batan I., Caracaran Bay, USNM 137413; Sombrero I., Batangas, USNM 28550; west side of Solino (Selinog) I., Zamboanga del Norte, Mindanao, 0-15 ft (4.6 m), USNM 273795; near Tonga Pt., Siquijor I., 0-1.2 m, USNM 273796; tidal lagoon, northeastern side of Siquijor, 0-1 m, USNM 273800 (Anon., 1994). A 4.2 in (11 cm) specimen was collected from Bacon, Sorsogon (Evermann and Scale, 1907). See also Weber and de Beaufort (1929). Additional reference: Morphology in Myers (1991).

Aseraggodes cyaneus (Alcock 1890) Max. length: 8.3 cm SL. Museum: R/V *Albatross* collections: Balayan Bay and Verde I. Passage, Sombrero I., 340 fathoms (622.2 m), Stn. 5114, USNM 137674; China Sea, vicinity of southern Luzon, Corregidor, in 114 fathoms (208.6 m), USNM 137675 and in 118 fathoms (216 m), USNM 137676; east coast of Luzon, Legaspi, USNM 137678 (Anon., 1994). LACM 42475-47.

Aseraggodes dubius Weber 1913 Max. length: 8.5 cm. Museum: R/V *Albatross* collections: Davao, USNM 137667; China Sea, off s. Luzon, Sueste Pt., 25 fathoms (46 m), Stn. 5105, USNM 137668; Verde I. Passage and Batangas Bay, Matocot Pt., 100 fathoms (183 m), Stn. 5266, USNM 137669; Marinduque I. and vicinity, Tayabas, 90 fathoms (165 m), Stn. 5376, USNM 137671 and in 83 fathoms (152 m), Stn. 5371, USNM 137672; Batangas River, Luzon, USNM 137673 (Anon., 1994).

Aseraggodes filiger Weber 1913 Max. length: 11 cm. Collected from Manila Bay, 8 miles from Corregidor Is. in 15-25 fathoms (27-46 m) (Herre, 1953).

Aseraggodes kaianus (Günther 1880) Max. length: 11.3 cm. Forty specimens, ranging from 7.2-9 cm, were collected between 150-164 m, during the R/V *Vauban* expedition (Fourmanoir, 1976 in Fourmanoir, 1981).

Brachirus aspilos (Bleeker 1852) Max. length: 38 cm. Museum: Ulugan Bay near mouth of Baheli River, USNM 137679; Cebu Mkt., USNM 137680-1; Nasugbu Bay, Luzon, USNM 137682 (Anon., 1994).

Brachirus muelleri (Steindachner 1879) Max. length: 18 cm. Museum: Carigara Bay, Samar Sea, 50-70 m, USNM 228530. Sorsogon Mkt., USNM 286939 and 291084 (Anon., 1994).

Brachirus orientalis (Bloch & Schneider 1801) Max. length: 30 cm SL. Inhabits shallow sand and muddy bottoms of coastal waters (Menon and Monkolprasit, 1974).

Brachirus sorsogonensis Evermann & Seale 1907. Max. length: 23 cm. Museum: Bacon, Sorsogon, USNM 55916 (holotype, 9 in. (23 cm)) (Evermann and Seale, 1907). Cuyo Is., USNM 72194 (Anon., 1994).

Heteromycteris hartzfeldii (Bleeker, 1853) Max. length: 11.4 cm; Museum: R/V *Albatross* collections: Leyte, Hinunangan B., USNM 137718; Mindanao, Davao, USNM 137719; Cotabato, USNM 137720; Palawan, Verde del Sur, USNM 137721; Port Bais, eastern Negros, USNM 137722; Mantaquin Bay, Palawan, USNM 137723; Subic Bay, Olongapo, USNM 137724 (Anon. 1994). A 4.5 in (11.4 cm) specimen was collected from the country (Evermann and Seale 1907). See also Herre (1953).

Liachirus melanospilus (Bleeker 1854) Max. length: 7.5 cm SL. Reported from Manila Bay (Herre, 1953).

Pardachirus pavoninus (Lacepède 1802) Max. length: 25 cm TL. Museum: Cebu Mkt., USNM 137624-29. Bacon, USNM 55966. Zamboanga, USNM 84258. Jolo Mkt. USNM 137622. Bolinao Bay, USNM 137623. Pagapas Bay, Santiago R., USNM 137630. Senora Ascion, n. of Dumaguete, Negros O., USNM 273799. Tagburos, Puerto Princesa City Mkt., USNM 286974 (Anon., 1994). LACM 37398-9, 37397-2, 37398-9, 42471-4. Marketable in Jolo, Sulu, and Cebu. A specimen, 5.5 in (14 cm) in length, was collected from Bacon, Sorsogon (Evermann and Scale, 1907). See also Herre (1953) and Randall *et al.* (1990). Additional references: Morphology in Myers (1991). Food in Sano *et al.* (1984).

Pardachirus poropterus (Bleeker 1851) Max. length: 6.6 cm TL. Museum: Rio Grande, Mindanao, USNM 56164 (Anon., 1994). Three specimens were caught at depths between 122 and 205 m during the 1976 R/V *Vauban* expedition (Fourmanoir, 1976 in Fourmanoir, 1981). See also Herre (1953) and Kottelat (1993).

Solea humilis Cantor 1849 Max. length: 8.9 cm. Considered a commercial fish in the country (Warfel and Manacop, 1950). See also Weber and de Beaufort (1929).

Solea ovata Richardson 1846 Max. length: 10 cm TL. Museum: R/V *Albatross* collections: Manila Mkt. USNM 137397, 137399-404; Sorsogon Mkt., USNM 137405 (Anon., 1994). See also Munroe (2001).

Synaptura marginata Boulenger 1900 Max. length: 50 cm TL. Caught in seagrass beds. Museum: Tagburos, Puerto Princesa City Mkt., USNM 226832 (Anon., 1994).

Synaptura megalepidoura (Fowler 1934) Max. length: 24.3 cm. Museum: R/V *Albatross* collections, as *Brachirus megalepidoura:* offcast coast of Leyte, 15 fathoms (27 m), Stn. D. 5204, USNM 93081 (holotype, 24.3 cm) (Fowler, 1934); western Samar, Taratara I., 20 fathoms (37 m), Stn. D.5209, USNM 93554 (Anon., 1994). See also Herre (1953).

Zebrias lucapensis Seigel & Adamson 1985 Max. length: 8.4 cm SL. Museum: Lingayen Gulf, LACM 37436-6 (holotype); LACM 37436-8 (paratype). Morphological information found also in Seigel and Adamson (1985).

Zebrias quagga (Kaup 1858) Max. length: 15 cm TL. Inhabits shallow coastal waters (Menon 1984).

Zebrias zebra (Bloch 1787) Max. length: 19 cm TL. Museum: Tigbauan, Panay, USNM 106828 (Anon., 1994).

NON-FISH VERTEBRATES OF THE SOUTH CHINA SEA[1]

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ABSTRACT

A preliminary checklist of the non-fish vertebrates of the South China Sea, recently identified as a hotspot of marine biodiversity, was assembled using SeaLifeBase (www.sealifebase.org), a global information system on non-fish marine organisms of the world. The current checklist covers 102 non-fish vertebrates, i.e., 36% marine mammals, 36% seabirds and 27% reptiles. Data were assembled from books, reports, and journal articles identified through targeted searches, complemented and checked by experts collaborating with SeaLifeBase. Vertebrates, sitting at the top of the food chain, are a resource heavily exploited by humans and highly 'visible'. However, the International Union for the Conservation of Nature lists only a few of these in their assessments, leaving 35% marine mammals, 8% seabirds, 78% reptiles with a 'not evaluated' or 'data deficient' assessment. A strategy to fill-in gaps and to store information in SeaLifeBase that may be of use to such assessments is discussed.

INTRODUCTION

The South China Sea (2-23°N, 107-119°E) is bordered by ten countries (China, including Hong Kong and Taiwan, Vietnam, Thailand, Cambodia, Indonesia, Malaysia, Singapore, Brunei and the Philippines), spread over 3.8 million km² including the Gulf of Thailand and Gulf of Tonkin with depths to 5,377 m (Morton and Blackmore, 2001). A recent meeting of the Coral Triangle Initiative in the Philippines identified the South China Sea as a region of interest by virtue of its proximity to the Coral Triangle and of conservation concerns notably of heavily exploited resources. At the top of the marine food chain, vertebrates maintain the balance of the ecosystem (ACCOBAMS and CMS, 2004). However, these slow growing, long-lived and large species are, in most cases and certainly so in the South China Sea, the target of various fisheries.

The absence of a complete census of non-fish vertebrates hinders conservation efforts on this group of marine organisms (Morton and Blackmore, 2001; Perrin, 2002), and even more pertinent in areas like the South China Sea which is managed by 10 different administrations and cultures. Thus, to contribute to conservation efforts of South China Sea non-fish vertebrates, this study assembled the scattered bits of data in the scientific literature on country and ecosystem distribution, IUCN status, and treaties governing the protection of tetrapods in the South China through SeaLifeBase (www.sealifebase.org), an information system on all non-fish marine organisms of the world. This permitted the identification of information gaps which might help colleagues in the region in deciding the direction towards which future research might be channelled.

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MATERIALS AND METHODS

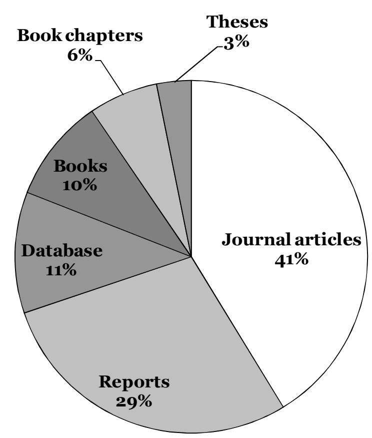
A target search per group was conducted with search engines Google Scholar, ISI Web of Knowledge and Aquatic Science and Fisheries Abstract (ASFA). The keywords applied were based on functional groups, e.g., 'marine mammal', 'seabird' and 'reptile', or by ecosystem, e.g., 'South China Sea', 'Gulf of Thailand' or 'Gulf of Tonkin', and coupled with theme or topic, e.g., distribution, ecology, growth, diet, food, etc. In addition, targetted country searches were performed, i.e., keyword search by country, e.g., 'Thailand' and 'checklist', etc. We also asked the help of some SeaLifeBase collaborators, who took part in providing species lists, distribution, diet and ecological information as well as translations for non-English references. These references provided data on nomenclature, distribution, and ecological information.

Taxonomic global system databases like the Catalogue of Life (www.catalogueoflife.org), the World Register of Marine Species (www.marinespecies.org), and AviBase – The World Bird Database (www.avibase.bsc-eoc.org) were used to check the validity of scientific names obtained from published checklists. Country and ecosystem distribution records were extracted from checklists, species accounts with maps, and references reporting the occurrence of a species in a given locality, e.g., water body or country. Depth distribution, maximum sizes, habitat preference, trophic ecology were obtained from English language books, reports, scientific journal and popular science articles. IUCN (www.iucnredlist.org) 2009 assessments, integrated in the SeaLifeBase information system (www.sealifebase.org) used as the repository of the above gathered information, were used to list species with 'data defficient' or 'not evaluated' assessments. The categories on which the IUCN bases its assessment on the status of a listed species requires data on ecology, distribution, maturity, population size/trends, population dynamics (length-weight relationships, maximum sizes, and growth), threats, and conservation measures. The availability of such data in SeaLifeBase was used to establish which species currently in the IUCN 'data deficient' or 'not evaluated' list might be recommended for re-assessment. In the same manner, gaps in information required to assess other species listed in the IUCN were identified. An additional search for laws, protection and conservation efforts of IUCN listed species was performed to complement the SeaLifeBase data.

RESULTS

A total of 63 references (Appendix 1) were exhausted for marine mammals (36), seabirds (11) and reptiles (16) listed for the South China Sea. The reference search with keywords 'South China Sea' and 'tetrapod' identified 37% of these, while the search by country and keyword 'tetrapod' identified 63%. These are mostly species accounts (60%) and country lists (35%) and a few are ecosystem lists (5%), i.e., checklist of functional groups for the South China Sea. The earliest publications are reports dating back to 1956 while the more recent ones are species accounts and checklists per country or ecosystem in connection to their conservation status. Journal articles and reports provided the most coverage for non-fish vertebrates (see Figure 1, upper panel).

These publications accounted for 102 non-fish vertebrate species specifically listed in a country,



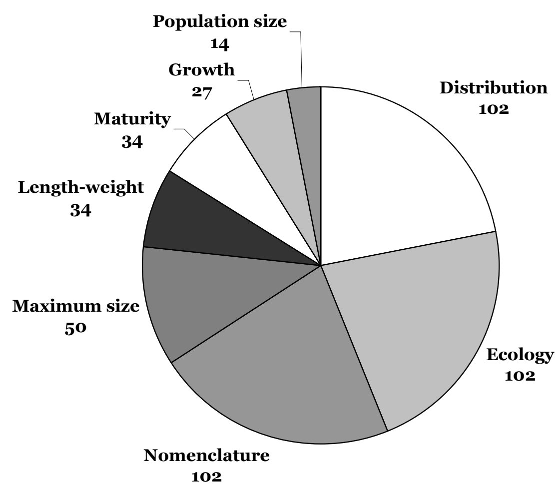


Figure 1. Upper piechart: Distribution of references by type (%; n=63) obtained from reference searches for non-fish vertebrate species occurring in the South China Sea. Lower piechart: Data coverage, i.e., number of species for which data is available, of non-fish vertebrate species in the South China Sea assembled in SeaLifeBase.

locality within or in the South China Sea (Figure 2). All these species have information on their synonyms, ecology and distribution within the South China Sea. Abundance data was obtained for only 14% of these species, usually through the population size of the functional group. Maturity data was obtained for 33% of these species while data on population dynamics were obtained for 26-49% (see Figure 1, lower panel). IUCN listed species which are not evaluated due to lack of available information ('not evaluated' category) include 8% seabirds and 3% marine mammals, and a large number of reptiles (78%; see Figure 2, right panel). Species with 'data defficient' IUCN category make up 32% (see Figure 2, right middle panel).

Table 1. Number of non-fish vertebrates species occurring in countries bordering the South China Sea obtained from target reference searches and assembled in SeaLifeBase (www.sealifebase.org; see Palomares and Pauly, 2010) as compared to country estimates from published literature (values in brackets) only available for marine mammals and marine reptiles. SCS=South China Sea; BrD=Brunei Darusalaam; Cam=Cambodia; MCh= Mainland China; HK=Hong Kong; Tai=Taiwan; In=Indonesia; Mal=Malaysia; Phi=Philippines; Sin=Singapore; Tha=Thailand; VN=Viet Nam.

Class	Countries in the South China Sea												Sources
	SCS	BrD	Cam	MCh	HK	Tai	In	Mal	Phi	Sin	Tha	VN	
Aves	37	6	11	29	17	15	10	7	10	7	13	16	Karpouzi (2005)
Mammalia	37	29 (12)	30 (10)	33 (40)	27 (16)	26 (31)	32 (30)	32 (29)	31 (26)	31 (6)	32 (15)	31 (19)	Beasley and Davidson, (2007; BrD, Cam, In, Mal, Phi, Sin, Tha, Vie); Chou (2002; Ta); Jefferson and Hung (2007; HK); Mazlan, *et al.* (2005; Mal); Sabater (2005; Phi); Zhou (2002; Ch).
Reptilia	28	5	20	17	2	23	24 (38)	24 (40)	17	8	22	24	Hutomo and Moosa (2005; In); Mazlan, *et al.* (2005; Mal).
Totals	102	40	61	79	46	64	66	63	58	46	67	71	–

There is very little coverage of seabirds and marine reptiles on a per country basis, the only checklists of marine organisms available are for Indonesia (Hutomo and Moosa, 2005) and Malaysia (Mazlan, *et al.*, 2005) and the only large marine ecosystem checklist available is that for sea snakes of the Gulf of Thailand (Murphy, *et al.*, 1999), which listed 24 species, increasing SeaLifeBase's previous count by 2. Based on the results of this study, the number of species listed in SeaLifeBase as occurring in the countries bordering the South China Sea is, on the average, higher by 20% than those of published estimates (Table 1). Also, marine mammals are the most studied of the three non-fish vertebrate groups considered here.

Discussion

The fact that there are more studies on marine mammals and turtles and less on marine reptiles is quite understandable, i.e., snakes and crocodiles are known threats to humans, snakes for their deadly venom and crocodiles for their monstrous bite. On the other hand, dugongs, dolphins, whales, turtles and seabirds are charismatic species listed by the IUCN as threatened animals, no doubt because they (particularly marine mammals and turtles) are also the target of traditional fisheries (Chang *et al.*, 1981; Liang *et al.*, 1990; Dolar *et al.*, 1994) with high commercial values (Beasley and Davidson, 2007; Hines, *et al.*, 2008) which encourage fishers in the mostly poor countries bordering the South China Sea to catch and trade them (Beasley and Davidson, 2007). Misidentified as fish, they are caught as by-catch by unmonitored fishing gear, e.g., nylon nets and monofilament line gillnets with varying mesh sizes particularly in Cambodia (Beasley and Davidson, 2007), Sabah and Sarawak, Malaysia (Jaaman, *et al.*, 2009) and Philippines (Dolar, 2004) and other fishing gears, e.g., trawls, fish stakes, driftnets and purse seines (Perrin, 2002; Dolar, 2004; Jaaman, *et al.*, 2009). In addition, marine mammals are caught as show animals in oceanariums, e.g., in Thailand, Jakarta, Indonesia and Japan (Perrin, *et al.*, 1996; Stacey and Leatherwood, 1997; Perrin, 2002).

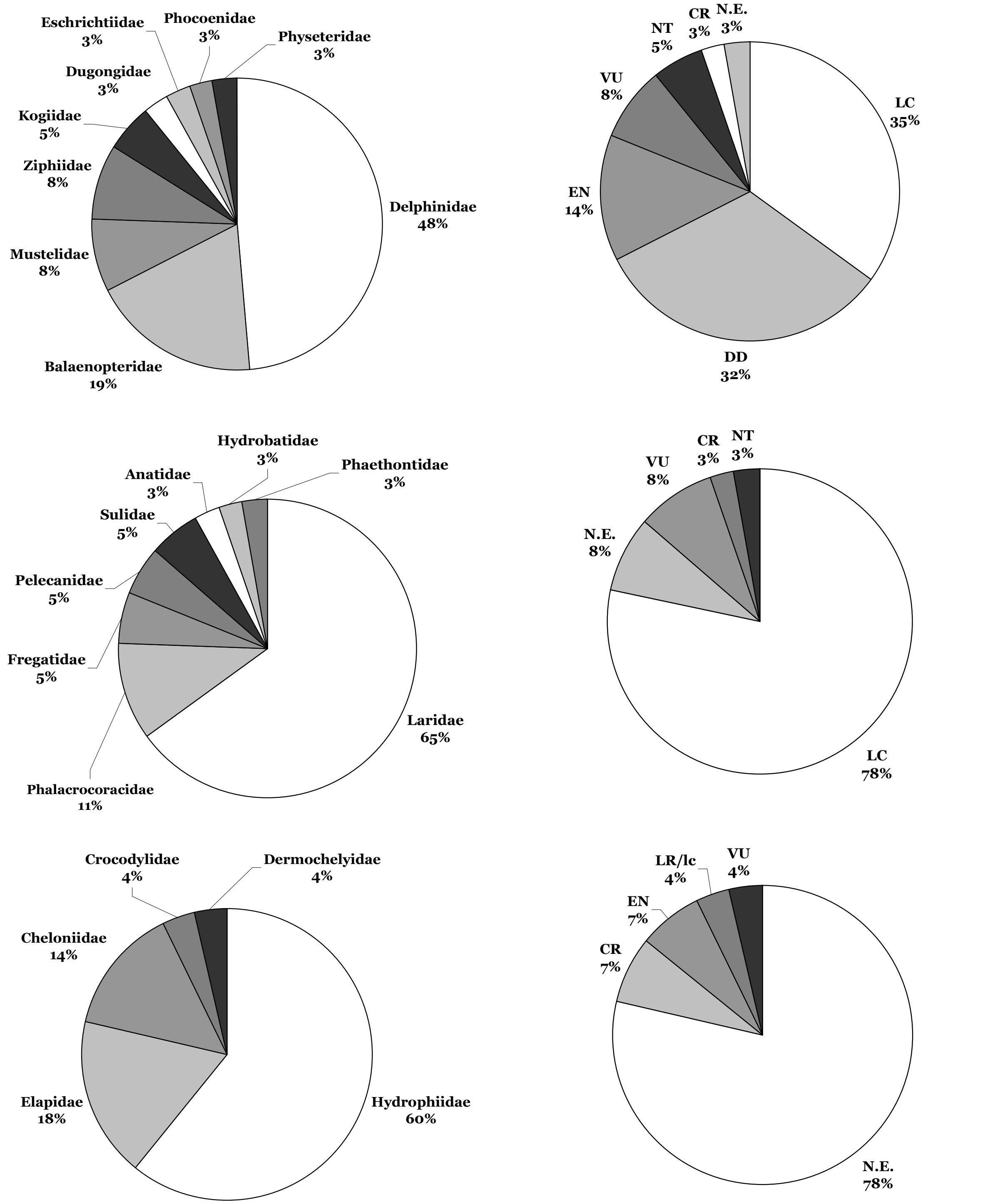


Figure 2. Non-fish vertebrates of the South China Sea listed in SeaLifeBase (www.sealifebase.org). the piecharts on the left show the distribution by family of 37 species of marine mammals (upper), 37 seabirds (middle) and 28 marine reptiles (lower). The piecharts on the right show the distribution by IUCN Red List status of marine mammals (upper), seabirds (middle) and marine reptiles (lower). CR: critically endangered; EN: endangered; LC: least concern; LR/lc: lower risk, least concern; N.E.: not evaluated; NT: near threatened; VU: vulnerable.

Destructive fishing practices, e.g., blast or dynamite fishing in Hong Kong and Hainan Island (Morton and Blackmore, 2001), Indonesia (Pet-Soede and Erdmann, 1998) and the Philippines (Alcala and Gomez, 1979) and cyanide fishing in the Philippines, Singapore, Taiwan, China, and in Hong Kong (Morton and Blackmore, 2001), though mainly targeting fishes, are known to have indirect effects on non-fish marine vertebrates. These, in addition to small and big-scale non-selective trawlers, pollution, and run-off which destroy habitats, e.g., coral reefs, and thus the prey organisms that depend on these habitats (Perrin, 2002; Beasley and Davidson, 2007; Hines, *et al*., 2008; Chan, 2010). Seabirds in particular are affected by pollution from heavy metals and exploitation and disturbance due to egg gathering and unprotected breeding areas, e.g., the Chinese crested tern (*Thalasseus bernsteini*) now considered at high risk of extinction (Chan, 2010).

These threats and the recorded decline, notably in seabird and marine mammal populations, initiated a wave of legislation and conventions for the protection and conservation of this group of marine animals (Table 2). Global conventions treating all tetrapods (i.e., marine vertebrates including fish) include the Convention on Migratory Species of Wild Animals (CMS), The RAMSAR Convention on Wetlands (RAMSAR), Convention on Biological Diversity (CBD), IUCN and CITES (Karpouzi and Pauly, 2008; IUCN, 2009; CITES, 2010). These conventions establish regional agreements covering large marine ecosystems dealing with habitat conservation, research, sustainable use of resources, threat reduction, e.g., by-catch and pollution. They also provide platforms for capacity building, trainings and incentives for public participation (Perrin, 2002; CBD, 2005; CBD, 2009). The Law of the Sea, an international agreement on the protection of the marine environment, provides a framework for the sustainable management of fish stocks and conservation of marine mammals (Borgerson, 2009). In Southeast Asia, turtles are being conserved through the Indian Ocean – Southeast Asia Marine Turtle Memorandum of Understanding (IOSEA) ratified by 5 ASEAN countries bordering the South China Sea (see Table 2). It aims to protect and conserve sea turtles by reducing causes of mortality, rehabilitating habitats, promoting awareness through information dissemination, and encouraging public participation through international efforts (IOSEA, 2010). National conservation and protection of marine resources platforms are also in place. In Eastern Malaysia, a structure of regulations and laws governing fisheries management, protection of aquatic animals and turtles, and establishment of MPA and reserves are in place, in addition to laws governing trade regulations with Cambodia. Malaysians, unfortunately and in spite of this well-structured platform of marine resources protection, ignore the implemented ban on the fishing of marine mammals (Perrin, *et al*., 2005; Jaaman, *et al*., 2009). Cambodians, on the other hand, have not gotten around to establishing such laws, but, they follow the Mininstry of Agriculture Forestry and Fisheries Fisheries Law, i.e., against hunting, trade, confiscation, captive breeding, import and export of rare and endangered species (Beasley and Davidson, 2007; Hines, *et al*., 2008). In Vietnam, existing laws are mainly to protect the welfare of dugongs and turtles (Hines, *et al*., 2008). China, a top consumer of marine vertebrates, has in addition to the national laws already in place (Huang *et al*., this volume), implements province-wide regulations (Hong Kong and Taiwan; Chan *et al*., 2007). Non-government organizations help implement these laws and regulations, e.g., Taiwan Cetacean Stranding Network (TCSN) and Taiwan Cetacean Society (TCS) responds to strandings on the Taiwanese coast.

In spite of the already long list of conventions summarized in Table 2, there is an overlying concern that enforcement is weak. In addition, the lack of a structured monitoring and documentation system hinders assessment as would benefit, e.g., the IUCN (Beasley and Davidson, 2007; Perrin, 2002; Jaaman, *et al*., 2009). Transboundary cooperation between countries surrounding the South China Sea, e.g., a set of unified laws and conventions implemented by all countries in the South China Sea, may help mitigate threats on these animals. And to support these conventions, the setting-up of information and education campaigns may help nationals of each country understand the need to conserve these animals and thus increase compliance and/or encourage: 1) monitoring through log books, photographs or video documentations (Beasley and Davidson, 2007; Jaaman, *et al*., 2009); and 2) monitoring of by-catch from fishing gear, landings, marine protected areas, and habitats (Perrin, 2002).

As most of the species in this group are migratory and are not easy research subjects, i.e., observation and field work require expensive equipment and trained personnel, the knowledge base available through searchable online global information systems like FishBase (www.fishbase.org) and SeaLifeBase (www.sealifebase.org) present a formidable tool most helpful in the assessment of the status of threat of species in this group. By working with national experts and institutions, these information systems endeavour to provide platforms for conservation assessments; FishBase was used for national assessments for Philippine fresh water fishes (22 April 2009, A session under the 2nd National Training Course on

Freshwater Fish Identification and Conservation c/o Philippine Council for Aquatic and Marine Research and Development-Zonal Center 2, UPLB & WorldFish) and with SeaLifeBase for national assessments of marine mammal species of the Philippines (13-14 August 2009, Conservation International in collaboration with the Bureau of Fisheries and Aquatic Resources). Extending such collaborations to the other 9 countries bordering the South China Sea seems to be a logical 'next step' in the conservation of these much appreciated animal group.

Table 2. Treaties and conventions as well as laws and regulations ratified and implemented in the countries bordering the South China Sea.

Convention/Law	Country	Group	Sources
Government Regulations of the Republic of Indonesia Number 07 (1999)	In	A	Chan, *et al.*, 2007
Protection of Wildlife Act (1972)	Ma	A	Chan, *et al.*, 2007
The RAMSAR Convention on Wetlands (RAMSAR)	Ca, TCh, In, Ma, Ph, Th, Vi	A	Karpouzi and Pauly, 2008; RAMSAR, 2010
International Union for Conservation of Nature (IUCN)	Ca, TCh, In, Ma, Ph, Si, Th, Vi	A, M, R	Chan, *et al.*, 2007; IUCN, 2009
Convention on International Trade In Endangered Species of Wild Fauna and Flora (CITES)	Br, Ca, TCh, In, Ma, Ph, Si, Th, Vi	A, M, R	CITES, 2010
Law of the People's Republic of China on the Protection of Wildlife	MCh, HK	A, M, R	Sharma, 2005
Convention on Biological Diversity (CBD)	Br, Ca, TCh, In, Ma, Ph, Si, Th, Vi	A, M, R	Karpouzi and Pauly, 2008; CBD, 2009
Fishery Law of PRC	MCh, HK	M	Zhou, 2002
Wildlife Protection Law of PRC	MCh, HK	M	Zhou, 2002
Marine Environment Protection Law of PRC	MCh, HK	M	Zhou, 2002
Wildlife Conservation Law 1989	Ta	M	Chou, 2002
Fisheries Act 1985	Ma	M	Jaaman, *et al.*, 2009
Wildlife Conservation Enactment 1997	Ma	M	Jaaman, *et al.*, 2009
Wild Life Protection Ordinance 1998	Ma	M	Jaaman, *et al.*, 2009
Fisheries Department Law	Vi	M, R	Hines, *et al.*, 2008
Convention on Migratory Species of Wild Animals (CMS)	Ph	M, R	Karpouzi and Pauly, 2008; CMS, 2010
MAFF Fisheries Law	Ca	M, R	Hines, *et al.*, 2008
Indian Ocean – Southeast Asia Marine Turtle Memorandum of Understanding (IOSEA)	Ca, In, Ph, Th, Vi	R	IOSEA, 2010

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References

ACCOBAMS and CMS, 2004. Investigating the role of cetaceans in marine ecosystems. *CIESM Workshop Monographs*. 16 p.

Alcala, A.C., Gomez, E.D., 1979. Recolonization and growth of hermatypic corals in dynamite blasted coral reefs in the Central Visayas, Philippines. In: *Proceedings of the International Symposium on Marine Biogeography and Evolution in the Southern Hemisphere*, Auckland, New Zealand, 1978. DSIR Information Services 137(2).

Beasley, I.L., Davidson, P.J.A., 2007. Conservation status of marine mammals in Cambodian waters, including seven new cetacean records of occurrence. *Aquatic Mammals* 33(3), 368-379.

Borgerson, S.G., 2009. Council on Foreign Relations: *The National Interest and the Law of the Sea*. Council Special Report 46, 82 p.

Chan, S., Chen, S.H., Yuan, H.W., 2010. International single species action plan for the conservation of the Chinese crested tern (*Sterna bernsteini*). Tokyo: Japan. BirdLife International Asia Division, Technical Report Series 21, 1-22.

Chang, K.-H., Jan, R.-Q., Hua, C.-S., 1981. Scientific note inshore fishes at Tai-pin Island (South China Sea). *Bulletin of the Institute of Zoology Academia Sinica* 20, 87-93.

Chou, L.-S., 2002. Progress report of cetacean research and conservation in Taiwan. Department of Zoology, National Taiwan University, pp. 248-251.

Convention on Biological Diversity, 2005. Indicators for assessing progress towards the 2010 target: trends in abundance and distribution of selected species. 10th Meeting, Bangkok, Thailand, 7-11 February 2005. http://www.cbd.int/doc/meetings/sbstta/sbstta-10/information/sbstta-10-inf-11-en.pdf [Accessed 03/08/2010].

Convention on Biological Diversity, 2009. Country profiles. http://www.cbd.int/countries/profile.shtml [Accessed 03/08/2010].

Convention on International Trade In Endangered Species of Wild Fauna and Flora, 2010. List of Contracting Parties. http://www.cites.org/eng/disc/parties/alphabet.shtml [Accessed 05/08/2010].

Convention on Migratory Species of Wild Animals, 2010. National Participation in Convention on the Conservation Migratory Species of Wild Animals and its Agreements at 1 August 2010: List of all countries in the World indicating their participation in CMS and its Agreements and MOUs. http://www.cms.int/about/all_countries_eng.pdf [Accessed 05/08/2010].

Dolar, M.L.L., 2004. Incidental takes of small cetaceans in fisheries in Palawan, central Visayas and northern Mindanao in the Philippines. *Reports of the International Whaling Commission* (special issue) 15, 355-363.

Dolar, M.L.L., Leatherwood, S.J., Wood, C.J., Alava, M.N.R., Hill, C.L., Aragones, L.V., 1994. Directed fisheries for cetaceans in the Philippines. *Reports of the International Whaling Commission* 44, 439-449.

Hines, E., Adulyanukosol, K., Somany, P., Ath, L.S., Cox, N., Boonyanate, P., Hoa, N.X., 2008. Conservation needs of the dugong *Dugong dugon* in Cambodia and Phu Quoc Island, Vietnam. *Oryx* 42(1), 113-121.

Hutomo, M., Moosa, M.K., 2005. Indonesian marine and coastal biodiversity: present status. *Indian J. of Marine Sciences* 34(1), 88-97.

IUCN, 2009. Members database. http://www.iucn.org/about/union/members/network/members_database/ [Accessed 05/08/2010].

Jaaman, S.A., Lah-Anyi, Y.U., Pierce, G.J., 2009. The magnitude and sustainability of marine mammal by-catch in fisheries in East Malaysia. *J. of the Marine Biological Association of the United Kingdom* 89(5), 907-920.

Karpouzi, V.S., Pauly, D., 2008. A framework for evaluating national seabird conservation efforts. In: Alder, J., Pauly, D. (eds.), *A Comparative Assessment of Biodiversity, Fisheries, and Aquaculture in 53 Countries' Exclusive Economic Zones*, p. 62-70. Fisheries Centre Research Reports 16(7), 90 p.

Kharin, V.E., 2006. An annotated checklist of sea snakes of Vietnam, with notes on a new record of the yellow-lipped sea krait, *Laticauda colubrine* (Schneider, 1799) (Laticaudidae, Hydrophiidae). *Russian J. of Marine Biology* 32(4), 223-228.

Kideys, A.E., 2002. Fall and rise of the Black Sea ecosystem. *Science*, New York, 297, 1482–1484.

Liang, W.-L., Jwang, W.-S., Liu, C.-W., Liu, W.-S., Sung, J.-S., Chen, T.-T., Chen, I.-Z., Shu, Y.-K., Lu, S.-J., Chang, Z.-S., Chang, C.-Z., Lin, J.-Z., 1990. The investigation of sea turtle resources in the South China Sea, and the development of artificial hatching techniques of the sea turtles. *Report of the Conservation Stations of Southsea Turtle Resources, Gangdong Province, China, PRC.*, 37 pp.

Mazlan. A.G., Zaidi, C.C., Wan-Lotfi, W.M., Othman, B.H.R., 2005. On the current status of coastal marine biodiversity in Malaysia. *Indian J. of Marine Sciences* 34(1), 76-87.

Ministry of Agriculture Forestry and Fisheries: Fisheries Administration, 2007. Law on Fisheries: (Unofficial Translation supported by ADB/FAO TA Project on Improving the Regulatory and Management Framework for Inland Fisheries). http://faolex.fao.org/docs/pdf/cam82001.pdf [Accessed 03/08/2010].

Morton, B., Blackmore, G., 2001. South China Sea. *Marine Pollution Bulletin* 42(12), 1236-1263.

Murphy, J.C., Cox, M.J., Voris, H.K., 1999. A key to the sea snakes in the Gulf of Thailand. *Natural Histoy Bulletin of the Siam Society* 47, 95-108.

Perrin, W.F., 2002. Problems of marine mammal conservation in Southeast Asia. *Fisheries Science* 68(Supplement 1), 238-243.

Perrin, W.F., Dolar, M.L.L., Alava, M.N.R., 1996. *Report of the workshop on the biology and conservation of small cetaceans and dugongs of Southeast Asia*. Dumaguete: United Nations Environment Programme.

Pet-Soede, L., Erdmann, M.V., 1998. Blast fishing in southwest Sulawesi, Indonesia. *NAGA* 21, 4-9.

Sharma, C., 2005. Chinese endangered species at the brink of extinction: a critical look at the current law and policy in China. *Animal Law* 11, 215-254.

Stacy, P.J., Leatherwood, S., 1997. The Irrawaddy dolphin *Orcaella brevirostris*: A summary of current knowledge and recommendations for conservation action. *Asian Marine Biology* 14, 195-214.

The RAMSAR Convention on Wetlands, 2010. Contracting Parties to the Ramsar Convention on Wetlands 30/07/2010. http://www.ramsar.org/cda/en/ramsar-about-parties-contracting-parties-to-23808/main/ramsar/1-36-123%5E23808_4000_0__ [Accessed 05/08/2010].

Zhou, K. 2002. Marine mammal research and conservation in China. *Fisheries Science* 68(Supplement 1), 244-247.

APPENDIX 1. LIST OF REFERENCES FOR TETRAPODS OF THE SOUTH CHINA SEA USED IN SEALIFEBASE

Acebes, J.M.V., Lesaca, L.A.R., 2003. Research and conservation of humpback whales (*Megaptera novaeangliae*) and other cetacean species in the Babuyan Islands, Cagayan Province, northern Luzon, Philippines. pp, 34-42. In: Van der Ploeg, J., Masipiquena, A., Bernardo, E.C. (eds), The Sierra Madre Mountain Range: Global relevance, local realities, Papers presented at the 4th Regional Conference on Environment and Development. Cagayan Valley Program on Environment and Development, Golden Press, Tuguegarao City.

Argeloo, M., 1993. Black-headed gulls wintering in Sulawesi (and notes on their occurrence elsewhere in the Indo-Australia region). *Kukila, Bulletin of the Indonesian Ornithological Society* 6(2), 110-114.

Beasley, I., Robertson, K.M., Arnold, P., 2005. Description of a new dolphin, the Australian snubfin dolphin *Orcaella heinsohni* sp. n. (Cetacea, Delphinidae). *Marine Mammal Science* 21(3), 365-400.

Beasley, I.L., Davidson, P.J.A., 2007. Conservation status of marine mammals in Cambodian waters, including seven new cetacean records of occurrence. *Aquatic Mammals* 33(3), 368-379.

BirdLife International, 2008. BirdLife Internationalhttp://www.birdlife.org/index.html

Bishop, K.D., 1992. New and interesting records of birds in Wallacea. *Kukila, Bulletin of the Indonesian Ornithological Society* 6(1), 8-34.

Cao, L., Pan, Y.L., Liu, N.F., 2007. Waterbirds of the Xisha Archipelago, South China Sea. *Waterbirds* 30(2), 296-300.

Chan, E.H., Liew, H.C., 1999. Decline of the leatherback population in Terengganu, Malaysia, 1956-1995. *Chelonian Conservation and Biology* 2, 196-203.

Cogger, H.G., 1975. Sea snakes of Australia and New Guinea. In: Dunson, W.A. (ed.), *The biology of sea snakes*. Baltimore, University Park Press. Chapter 4, 59-139.

Dunson, W.A., Minton, S.A., 1978. Diversity, distribution and ecology of Philippine marine snakes (Reptilia, Serpentes). *J. of Herpetology* 12(3), 281-286.

Foster-Turley, P., 1992. Conservation aspects of the ecology of Asian small-clawed and smooth otters on the Malay Peninsula. *IUCN Otter Species Group Bulletin* 7, 26-29.

Golden Forests, Landscapes and Seascapes: Governance and Local Development for Endangered Forests, Landscapes and Seascapes Projects, 2050. Green sea turtle. Haribon Foundation for the Conservation of Natural Resources. http://www.haribon.org.ph.

Handley, G.O.J., 1966. A synopsis of the genus *Kogia* (pygmy sperm whales). In: Norris, K.S. (ed.), *Whales, Dolphins and Porpoises*. University of California Press, 62-69.

Hin, H.K., Stuebing, R.B., Voris, H.K., 1991. Population structure and reproduction in the marine snake, *Lapemis hardwickii* Gray, from the west coast of Sabah. *Sarawak Museum J.* 42, 463-475.

Hulsman, K., 1988. The structure of seabird communities: an example from Australian waters. In Burger, J. (ed.), *Seabirds and other marine vertebrates. Competition, predation, and other interactions*. Columbia University Press, New York, USA, 59-91.

Hung, S.K., 2003. Monitoring of Chinese white dolphins (*Sousa chinensis*) in Hong Kong waters - data collection: final report (2002-03). Unpublished report to the Hong Kong Agriculture, Fisheries and Conservation Department, 74 pp.

Hung, S.K., 2004. Monitoring of Chinese white dolphins (*Sousa chinensis*) in Hong Kong waters - data collection: final report (2003-04). Unpublished report to the Hong Kong Agriculture, Fisheries and Conservation Department, 87 pp.

Hung, S.K., 2005. Monitoring of Chinese white dolphins (*Sousa chinensis*) in Hong Kong waters - data collection: final report (2004-05). Unpublished report to the Hong Kong Agriculture, Fisheries and Conservation Department, 107 pp.

Hung, S.K., 2005. Monitoring of finless porpoise (*Neophocaena phocaenoides*) in Hong Kong waters - data collection: final report (2003-05). Unpublished report to the Hong Kong Agriculture, Fisheries and Conservation Department, 95 pp.

Hussain, S.A., Kanchanasakha, B., de Silva, P.K., Olson, A., 2008. *Lutra sumatrana*. In: IUCN 2010. *IUCN Red List of Threatened Species*. Version 2010.1. <www.iucnredlist.org>. [Accessed 26/03/2010].

Ineich, I., Laboute, P., 2002. Sea snakes of New Caledonia. IRD Éditions. Institut de Recherche pour le Développement. Muséum national d'histoire naturelle. *Collection Faune et Flore Tropicales* 39, 302 pp.

IOSEA Marine Turtle MoU Secretariat. 2010. Online National Report Viewer: results of species/habitat searchIOSEA Marine Turtle - Online Reporting Facility (Version 3.0 - Beta). www.ioseaturtles.org; Retrieved Jan 27, 2010.

IUCN, 2006. 2006 IUCN Red List of Threatened Species.www.iucnredlist.org [Accessed 04/07/2007].

Jefferson, T.A., Leatherwood, S., Webber, M.A., 1993. FAO Species Identification Guide: *Marine Mammals of the World*. Rome, FAO, 320 p. + 587 figures.

Jefferson, T.A., Hung, S.K., 2004. *Neophocaena phocaenoides*. *Mammalian Species* 746, 1-12.

Jefferson, T.A., Hung, S.K., 2007. An updated, annotated checklist of the marine mammals of Hong Kong. *Mammalia* 71(3), 105-114.

Kahn, B., 2005. Indonesia oceanic cetacean program activity report: January - February 2005. The Nature Conservancy, 22 pp.

Kanda, N., Goto, M., Kato, H., McPhee, M.V., Pastene, L.A., 2007. Population genetic structure of Bryde's whales (*Balaenoptera brydei*) at the inter-oceanic and trans-equatorial levels. *Conservation Genetics* 8, 853-864.

Karpouzi, V.S., 2005. Modelling and mapping trophic overlap between fisheries and the world's seabirds.MSc thesis, Department of Zoology, University of British Columbia, Vancouver, BC, Canada.

Kasuya, T., Miyashita, T., Kasamatsu, F., 1988. Segregation of two forms of the short-finned pilot whales off the Pacific coast of Japan. *Scientific Report of the Whale Research Institute* 39, 77-90.

Kasuya, T., Nishiwaki, M., 1971. First record of *Mesoplodon densirostris* from Formosa. *Scientific Report of the Whale Research Institute* 23, 129-137.

Kasuya, T., 1976. Reconsideration of life hisotry parameters of the spotted and striped dolphins off the Pacific coast of Japan. *Scientific Report of the Whale Research Institute* 28, 73-106.

Kasuya, T., 1985. Effect of exploitation on reproductive parameters of the spotted and striped dolphins off the Pacific coast of Japan. *Scientific Report of the Whale Research Institute* 29, 1-20.

Kharin, V.E., 2006. An annotated checklist of sea snakes of Vietnam, with notes on a new record of the yellow-lipped sea krait, *Laticauda colubrine* (Schneider, 1799) (Laticaudidae, Hydrophiidae). *Russian J. of Marine Biology* 32(4), 223-228.

Kreb, D., Budiono, 2005. Cetacean diversity and habitat preferences in tropical waters of East Kalimantan, Indonesia. *The Raffles Bulletin of Zoology* 53(1), 149-155.

Lepage, D., 2007. Avibase - the World Bird Database. http://www.bsc-eoc.org/avibase/avibase.jsp [Accessed 09/07/2007].

Li, X., 1990. Seabirds in China. *Bulletin of Biology* 4, 8-11.

Lobo, A.S., Vasudevan, K., Pandav, B., 2005. Trophic ecology of *Lapemis curtus* (Hydrophiinae) along the western coast of India. *Copeia* 3, 637-641.

Mahakunlayanakul, S., 1996. Species distribution and status of dolphins in the inner Gulf of Thailand. Chulalongkorn University, Thailand. MS thesis, 130 p.

Mao, S., Chen, B., 1980. Sea Snakes of Taiwan: A natural history of sea snakes. The National Science Council. NSC Publication 4, v-57pp.

Márquez, M.R., 1990. FAO species catalogue. *Sea Turtles of the World. An annotated and illustrated catalogue of sea turtle species known to date*. FAO Fisheries Synopsis. Rome, FAO. 11(125), 81 p.

McKean, J.L., 1987. A first record of Christmas Island frigatebird *Fregata andrewsi* on Timor. *Kukila, Bulletin of the Indonesian Ornithological Society* 3(1-2), 47.

Minton, S.A., 1975. Geographic distribution of sea snakes. In: Dunson, W.A. (ed.), *The Biology of Sea Snakes*. University Park Press, Baltimore, Maryland, USA. p. 21-31.

Miyazaki, N., 1977. Growth and reproduction of *Stenella coeruleoalba* off the Pacific coast of Japan. *Scientific Report of the Whale Research Institute* 29, 21-48.

Miyazaki, N., 1984. Further analyses of reproduction in the striped dolphin, *Stenella coeruleoalba* off the Pacific coast of Japan. *Reports of the International Whaling Commission* (special issue 6), 343-353.

Murphy, J.C., Cox, M.J., Voris, H.K., 1999. A key to the sea snakes in the Gulf of Thailand. *Natural History Bulletin of the Siam Society* 47, 95-108.

Parsons, E.C.M., Felley, M.L., Porter, L.J., 1995. An annotated checklist of cetaceans recorded from Hong Kong's territorial waters. *Asian Marine Biology* 12, 79-100.

Porter, L., Morton, B., 2003. A description of the first intact dwarf sperm whale from the South China Sea and a review of documented specimens of Kogiidae (Cetacea) from Hong Kong. *Systematics and Biodiversity* 1, 127-135.

Rasmussen, A.R., 2001. Sea Snakes. pp. 3987-4008, In: Carpenter, K.E., Niem, V.H. (eds.), FAO species identification guide for fishery purposes. *The living marine resources of the Western Central Pacific*. Volume 6. Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals. Rome, FAO. pp. 3381-4218.

Rice, D.W., 1998. Marine Mammals of the World Systematics and Distribution. Special Publication number 4: *The Society for Marine Mammalogy*, 231 p.

Ross, G.J.B., 1979. Records of pygmy and dwarf sperm whales, genus *Kogia*, from Southern Africa, with biological notes and some comparisions. *Annals of the Cape Provincial Museum of Natural History* 11, 259-327.

Sah, S.A.M., Stuebing, R.B., 1996. Diet, growth and movements of juvenile crocodiles *Crocodylus porosus* Schneider in the Klias River, Sabah, Malaysia. *J. of Tropical Ecology* 12, 651-662.

Sea Around Us Database, 2006. The *Sea Around Us* Database. www.seaaroundus.org.

Stuebing, R., Shahrul, A.M.S., 1992. Population characteristics of the Indo-Pacific crocodile (*Crocodylus porosus* Schneider) in the Klias River, Sabah. Paper presented at the 2nd Regional Conference of the IUCN-SSC, Crocodile Specialist Group, 12-19 March 1993, Darwin, Northern Territory, Australia.

Tan, J.M.L., 1995. *A Field Guide to the Whales and Dolphins in the Philippines*. Makati City: Bookmark, 125 p.

Tu, A.T., Stringer, J.M., 1973. Three species of sea snake not previously reported in the Strait of Formosa. *J. of Herpetology* 7, 384-386.

Wang, M.C., Walker, W.A., Shao, K.-T., Chou, L.S., 2003. Feeding habits of the pantropical spotted dolphin, *Stenella attenuata*, off the eastern coast of Taiwan. *Zoological Studies* 42(2), 368-378.

Wang, P., 1956. Small-type whaling. *Technology of Fisheries Monthly* 25(5), 13-16.

Wang, P., 1956. Small-type whaling. *Technology of Fisheries Monthly* 25(6), 11-13.

Wang, P., 1956. Small-type whaling. *Technology of Fisheries Monthly* 26(1), 1-3.

Wang, P., 1976. Offshore whaling in China. *J. of Fisheries Technology* 4, 14-31.

Wang, P., 1978. Analysis of Mysticeti in the Yellow Sea. *Zoology Report* 24(3), 269-277.

Wang, P., 1999. *Chinese Cetaceans*. Ocean Enterprises Ltd. Hong Kong, 325 p.

Ward, T.M., 2001. Age structures and reproductive patterns of two species of sea snake, *Lapemis hardwickii* (Grey, 1836) and *Hydrophis elegans* (Grey, 1842), incidentally captured by prawn trawlers in northern Australia. *Marine and Freshwater Research* 52, 193-203.

Zuo Wei, D.L., Mundkur, T., 2004. Numbers and distribution of waterbirds and wetlands in the Asia-Pacific region. Results of the Asian Waterbird Census: 1997-2001. Wetlands International. CG Print, Selangor, Malaysia, 166 pp.

CRUSTACEAN DIVERSITY OF THE SOUTH CHINA SEA[1]

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ABSTRACT

An update on the status of the crustacean diversity in the South China Sea, ca. 1,766 crustacean species in 216 families and 649 genera is presented through SeaLifeBase (www.sealifebase.org), a FishBase-like biodiversity information system that records data, information and knowledge on non-fish marine organisms of the world. An estimation of the potential number of crustaceans by higher taxa from a review of the literature is presented and a gap analysis of potential missing information is obtained from what is already encoded in SeaLifeBase. A discussion on how SeaLifeBase can help to complete such inventories and how this can be turned into a tool for assessing national and regional marine biodiversity is included.

INTRODUCTION

The Subphylum Crustacea is one of the most speciose taxa in the Kingdom Animalia with 47,000 described species (Chapman, 2009), 44,950 of which are marine (Bouchet, 2006). These species are well-represented in all marine habitats, at all depths. Thus, many crustacean species are expected to be thriving in the biologically rich waters of the South China Sea.

Ng and Tan (2000) reported the status of marine biodiversity of the South China Sea (SCS) as part of an on-going effort to understand the rich biodiversity of SCS. Along with this status report are checklists of different crustacean groups, i.e., Cirripedia (Jones *et al*., 2000), Thalassinidea and Anomura (Decapoda; Komai, 2000) and Stomatopoda (Lowry, 2000). However, a comprehensive report on SCS crustacean diversity is yet to be published. In 2009, the SeaLifeBase Project made an effort to assemble lists of species reportedly occurring in the SCS, from published literature (including reports, theses, and other gray literature), i.e., faunal lists, country lists, new species reports and occurrence records from survey reports. SeaLifeBase (www.sealifebase.org) is an online FishBase-like global information system that provides nomenclatural and biological information for all non-fish marine species of the world, like FishBase does for fishes. The SeaLifeBase SCS initiative came in response to a need for data to feed into ecosystem models such as those published by Cheung *et al*. (2009) and in response to the Sea Around Us project's need for species lists for large marine ecosystems.

This work made use of an intensive review of available literature on crustacean diversity in SCS and published estimates of numbers of species by taxa in the SCS. It demonstrates how such disaggregated and disparate data can be assembled, standardized and made available through SeaLifeBase as congruent lists of species by country and region, e.g., the SCS.

MATERIALS AND METHODS

Reference searching primarily targeted published checklists, i.e., species lists for countries bounding the SCS as well as large and small ecosystems (including oceanic islands falling within the SCS). Searches were done using the ISI Web of Knowledge, Aquatic Sciences and Fisheries Abstract (ASFA) and Google Scholar with the keywords "Crustacea" and "South China Sea" occurring specifically in the title field. This search scheme did not identify published checklists for all crustacean groups, i.e., only the most (commercially) important crustacean groups (e.g., decapods) were inventoried. In order to fill this evident gap, a more detailed reference search was performed targetting all other publications mentioning anywhere in their text the SCS, i.e., new species descriptions and taxa revisions with mention of distribution in countries or

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ecosystems within the SCS, other country and ecosystem checklists with mention of SCS and related countries and ecosystems in their distribution information. Thus, the same keywords were used to search in the subject or topic field and any part of the text. In addition, reports dating as early as the 1950s, e.g., reports for the Albatross Expedition as well as reports of the Smithsonian Museum of Natural History obtained from previous initiatives were scanned for species occurring in the SCS. All references identified in this process were analyzed for taxonomy and nomenclature, distribution, ecology and biology. All pertinent data were extracted and standardized in the SeaLifeBase platform, following this process: 1) taxonomic validity was checked against the SeaLifeBase taxonomic backbone, the Catalogue of Life (www.catalogueoflife.org), against the World Register of Marine Species (www.marinespecies.org), Integrated Taxonomic System (www.itis.gov) and a crustacean taxonomic expert if the name was not found in any of these global databases; 2) the distribution was checked against known distribution sources; 3) additional reference searches were made on a per species basis to identify habitat, ecology and life history data.

RESULTS

A total of 123 references (Appendix 1) were identified. The first reference search scheme identified 19% of these publications from species lists for countries surrounding the SCS and 16% on large and small ecosystems including islands. The second search scheme resulted in 54% of these publications from species accounts and revisions mainly from *The Raffles Bulletin of Zoology* dating back to the 1970s. The earliest publications were of a collection of crabs from Aor Island by Tweedie (1950) and a collection of copepods from the Albatross Expedition by Wilson (1950). The most recent publication was that of Poltarukha (2010) on deep-sea barnacles of Southern Vietnam. Most of the SCS crustaceans (68%) were extracted from published journals, notably, *Crustaceana*, *Smithsonian Contributions to Zoology* and *The Raffles Bulletin of Zoology*. Others came from books (18%), reports (12%) and global species and other online databases (2%; see Figure 1).

These publications resulted in a list of 1,766 crustacean species reportedly occurring in the SCS in comparison with 144 listed by the World Register of Marine Species and the 406 by the Catalogue of Life. Decapoda, as the most speciose and probably best-studied order of Crustacea is, expectedly, well documented. Of these 1,766 species, 42% have synonyms (Figure 2, upper left panel), 35% have depth information (Figure 2, upper right panel), 70% have common names (Figure 2, lower left panel) and 98% have ecological information (Figure 2, lower right panel). With photos, being also of major importance in such online information systems, SeaLifeBase strived to provide these for each SCS species. However, not all species are well documented and not many photos were gathered, i.e., only 196 species portraits were obtained for the SCS, 58% of which belong to Decapoda, 38% are Stomatopoda and the rest belonging to Sessilia and Pedunculata.

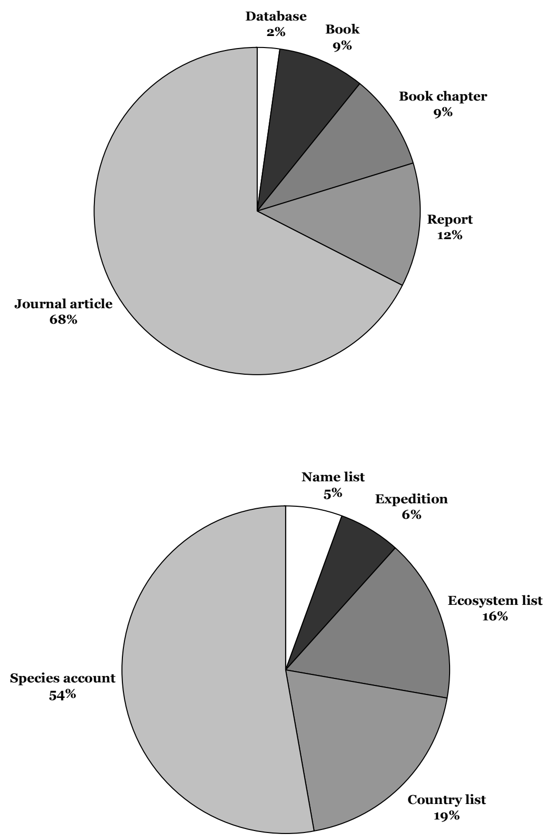

Figure 1. Distribution of 129 references by type obtained from reference search schemes (see text) to identify crustacean species occurring in the South China Sea and used in SeaLifeBase (www.sealifebase.org).

List of crustacean species along with other species in South China Sea can be viewed in the SeaLifeBase website through this link: http://sealifebase.org/trophiceco/FishEcoList.php?ve_code=11.

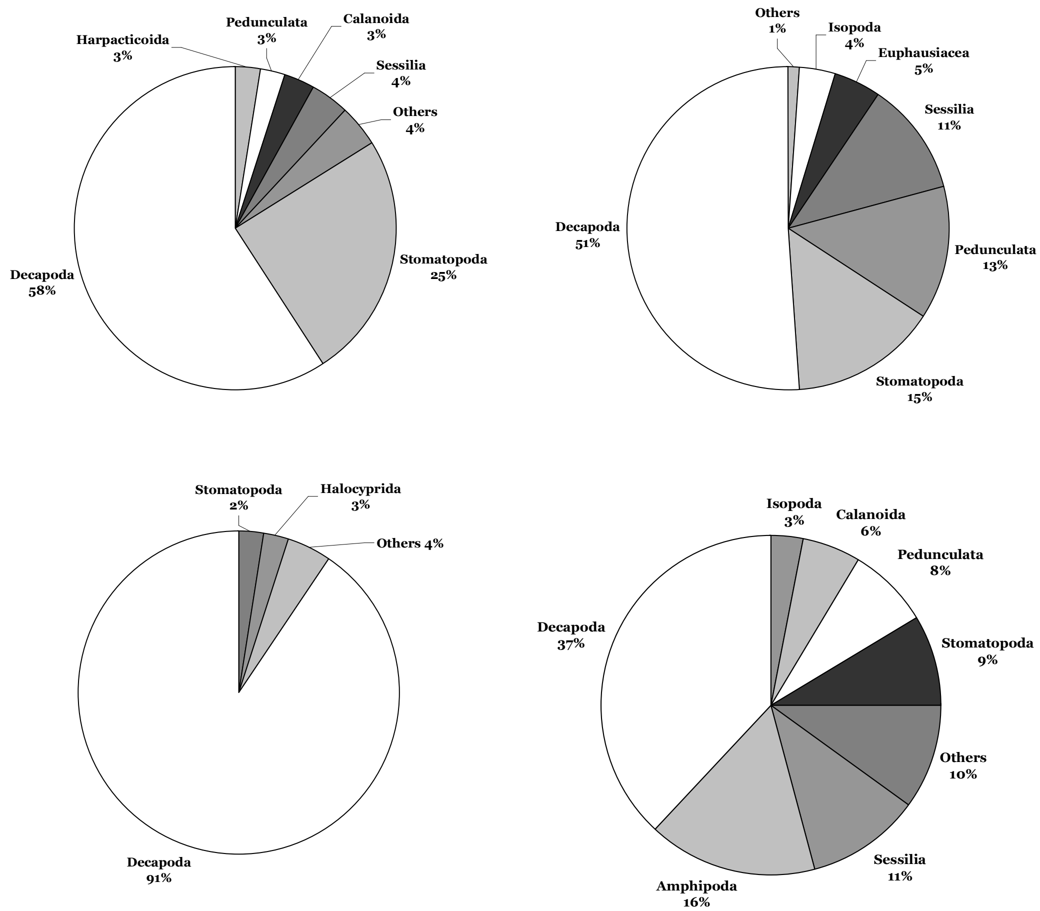

Figure 2. Distribution of information for 1,766 South China Sea crustacean species accounted for in SeaLifeBase. Upper left panel: 745 species have synonyms ('Others' include Euphausiacea, Mysida, Akentrogonida, Arguloida, Cyclopoida, Siphonostomatoida, Halocyprida, Tanaidacea, Poecilostomatoida, Isopoda and Amphipoda). Upper right panel: 622 species have depth information (Others include Amphipoda and Tanaidacea). Lower left panel: 1,244 species have common names (Others include Calanoida, Myodocopida, Pedunculata, Amphipoda, Sessilia, Poecilostomatoida, Mysida and Isopoda). Lower right panel: 1,739 species have ecological information (Others include Mydocopa, Siphonostomatoida, Mysida, Diplostraca, Arguloida, Platycopoda, Halocyprida, Kentrogonida, Podocopida, Akentrogonida, Cyclopoida, Tanaidacea, Cumacea, Poecilostomatoida, Euphausiacea and Harpacticoida). Note that those grouped in the 'Others' category are groups with only 3-5% of required data inputs filled in.

DISCUSSION

Revisions, species accounts and scientific reports of expeditions provided valuable complementary data completing publications of species lists and online checklists for crustaceans occurring in the SCS. Noteworthy are those extracted from reports of scientific expeditions (6%) because these reported species sampled in the SCS whose occurrence were not reported again in recent publications, e.g., *Alpheus bidens*, an alpheid shrimp reported from the Albatross Expedition during 1907-1910 (Chace, 1988). Though no published estimate of overall number of crustacean species exists for the SCS, SeaLifeBase's coverage of Amphipoda (95%), Stomatopoda (>100%), Cirripedia (95%), and Harpacticoida (58%; see Table 1) provides some basis of comparison to determine the extent of its coverage, i.e., an average of 88% for the four cited groups. Though not complete, this checklist of crustaceans of the SCS is probably the first of its kind assembled, especially since no global species database exists for crustaceans anywhere else in the world. By continuing to assemble data from new publications, SeaLifeBase might one day provide a nearly complete list of crustaceans described as occurring in the SCS.

In addition to knowing which species of crustaceans occur in the SCS, SeaLifeBase also endeavoured to provide life history parameters for the better documented species. Figure 2 illustrates what SeaLifeBase has assembled so far from the publications gathered in this exercise, showing quite large chunks of information gaps, notably, depth data (an essential parameter for the generation of Aquamaps in order to model a species' probable distribution) as well as photo portraits of species. Evidently, the work we describe here is just the beginning. SeaLifeBase continues to actively seek collaborations with crustacean experts worldwide, in addition to current collaborations already in place, e.g., with Dr. P.K.L. Ng and Dr. Tim-Yan Chan, to provide quality checks of assembled data in SeaLifeBase.

Table 1. Number of species, genus and families of crustaceans occurring in the South China Sea obtained from targeted references searches and encoded in SeaLifeBase (www.sealifebase.org) compared to species estimates published in the literature, i.e., available only for Amphipoda (95% coverage), Stomatopoda (>100%), Cirripedia (95%), and Harpacticoida (58%).

Class	Order	SeaLifeBase			Other sources			Sources
		Fam.	Gen.	Sp.	Fam.	Gen.	Sp.	
Branchiopoda	Diplostraca	1	1	1	–	–	–	–
Malacostraca	Amphipoda	47	111	259	48	113	272	Lowry (2000)
Malacostraca	Cumacea	4	12	22	–	–	–	–
Malacostraca	Decapoda	65	219	663	–	–	–	Komai (2000; Thalassinidea, Anomura)
Malacostraca	Euphausiacea	2	6	34	–	–	–	–
Malacostraca	Isopoda	4	31	50	–	–	–	Kussakin and Malyutina (1993; Sphaeromatidae)
Malacostraca	Mysida	1	5	6	–	–	–	–
Malacostraca	Stomatopoda	12	54	141	13	52	120	Moosa (2000)
Malacostraca	Tanaidacea	4	9	11	–	–	–	–
Maxillopoda; Cirripedia		23	90	299	21	76	315	Jones *et al.* (2000; Cirripedia)
Maxillopoda; Cirripedia	Akentrogonida	1	2	4	–	–	–	–
Maxillopoda; Cirripedia	Arguloida	1	1	1	–	–	–	–
Maxillopoda; Cirripedia	Kentrogonida	1	1	3	–	–	–	–
Maxillopoda; Cirripedia	Pedunculata	9	35	122	–	–	–	–
Maxillopoda; Cirripedia	Sessilia	11	51	169	–	–	–	–
Maxillopoda; Copepoda		–	–	–	–	–	467	Razouls *et al.* (2010)
Maxillopoda; Copepoda	Calanoida	24	56	141	–	–	–	–
Maxillopoda; Copepoda	Cyclopoida	1	1	9	–	–	–	–
Maxillopoda; Copepoda	Harpacticoida	18	32	45	19	57	77	Chertoprud *et al.* (2010)
Maxillopoda; Copepoda	Poecilostomatoida	4	5	33	–	–	–	–
Maxillopoda; Copepoda	Siphonostomatoida	1	1	1	–	–	–	–
Ostracoda	Halocyprida	1	7	34	–	–	–	–
Ostracoda	Myodocopida	2	6	13	–	–	–	–
Ostracoda	Platycopida	1	1	1	–	–	–	–
Ostracoda	Podocopida	1	2	3	–	–	–	–
Totals		216	649	1766	?	?	?	–

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REFERENCES

Appeltans, W., Bouchet, P., Boxshall, G.A., Fauchald, K., Gordon, D.P., Hoeksema, B.W., Poore, G.C.B., van Soest, R.W.M., Stöhr, S., Walter, T.C., Costello, M.J., Editors, 2010. World Register of Marine Species. Accessed at http://www.marinespecies.org/aphia.php?p=checklist on 2010-06-23.

Bisby, F.A., Roskov, Y.R., Orrell, T.M., Nicolson, D., Paglinawan, L.E., Bailly, N., Kirk, P.M., Bourgoin, T., Baillargeon, G., Editors, 2010. Species 2000 & ITIS Catalogue of Life: 2010 Annual Checklist. Accessed digital resource at http://www.catalogueoflife.org/annual-checklist/2010 on 2010-06-23. Species 2000, Reading, UK.

Bouchet, P., 2006. The magnitude of marine biodiversity. In: Duarte, C.M. (ed.), *The Exploration of Marine Biodiversity: Scientific and Technological Challenges*, p. 31-64. Fundación BBVA, Bilbao, Spain.

Chace, F.A., 1988. The caridean shrimps (Crustacea--Decapoda) of the Albatross Philippine Expedition, 1907-1910. Part 5, Family Alpheidae. *Smithsonian Contributions to Zoology,* 466, 99 p. Smithsonian Institution Press, Washington, D.C.

Chapman, A.D., 2009. *Numbers of living species in Australia and the world*. Report for the Australian Biological Resource Study. Commonwealth of Australia. 80 p.

Chertoprud, E.S., Gheerardyn, H., Gómez, S., 2010. Harpacticoida (Crustacea: Copepoda) of the South China Sea: faunistic and biogeographical analysis. *Hydrobiologia* (in press).

Cheung, W.W.L., Lam, V.W.Y., Sarmiento, J.L., Kearney, K., Watson, R. and Pauly, D., 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* 10, 235-251.

Jones, D.S., Hewitt, M.A., Sampey, A., 2000. A checklist of the Cirripedia of the South China Sea. *The Raffles Bulletin of Zoology*, Suppl. 8, 233-307.

Komai, T., 2000. A checklist of Thalassinidea and Anomura (Crustacea: Decapoda) from the South China Sea. *The Raffles Bulletin of Zoology*, Suppl. 8, 343-376.

Kussakin, O.G., Malyutina, M.V., 1993. Sphaeromtidae (Crustacea: Isopoda: Flabellifera) from the South China Sea. *Invertebrate Taxonomy* 7, 1167-1203.

Lowry, J.K. 2000. Taxonomic status of amphipod crustaceans in the South China Sea with a checklist of known species. *The Raffles Bulletin of Zoology* 8, 309-342.

Moosa, M.K., 2000. Marine biodiversity of the South China Sea: a checklist of stomatopod Crustacea. *The Raffles Bulletin of Zoology*. Suppl. 8, 405-457.

Ng, P.K.L., Tan, K.S., 2000. The state of marine biodiversity in the South China Sea. *The Raffles Bulletin of Zoology*, Suppl. 8, 3-7.

Poltarukha, O.P., 2010. Deep-sea barnacles (Cirripedia: Thoracica) of Southern Vietnam. *Russian Journal of Marine Biology* 36(1), 16-25.

Razouls, C., de Bovée, F., Kouwenberg, J., Desreumaux, N., 2005-2010. Diversity and geographic distribution of marine planktonic copepods. Accessed at http://copepodes.obs-banyuls.fr/en/subloc.php?loc=21&subloc=1 on 2010-06-23.

APPENDIX 1. LIST OF REFERENCES FOR SOUTH CHINA SEA CRUSTACEANS USED IN SEALIFEBASE

Achituv, Y., 2004. Coral-inhabiting barnacles (Cirripedia: Balanomorpha: Pyrgomatinae) from the Kermadec Islands and Niue Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 38, 43-49.

Ahyong, S.T., 2001. Revision of the Australian stomatopod Crustacea. *Records of the Australian Museum*, Supplement 26, 326 p.

Ahyong, S.T., 2004. New species and new records of stomatopod Crustacea from the Philippines. *Zootaxa* 793, 1-28.

Ahyong, S.T., Moosa, M.K., 2004. Stomatopod Crustacea from Anambas and Natuna Islands, South China Sea, Indonesia. *The Raffles Bulletin of Zoology*, Supplement 11, 61-66.

Ahyong, S.T., Erdmann, M.V. 2003. The stomatopod Crustacea of Guam. *Micronesica* 35-36, 315-352.

Ahyong, S.T., Naiyanetr, P., 2000. Revision of the Clorida latreillei species complex with description of a new species (Stomatopoda: Squillidae). *The Raffles Bulletin of Zoology* 48(2), 313-325.

Ahyong, S.T., Chu, K.H., Chan, T.Y., Chen, Q.C., 1999. Stomatopoda of the Zhujiang Estuary between Hong Kong and Macau. *Crustaceana* 72(1), 37-54.

Alves Coelho Filho, P. 2004. Análise do macrobentos na plataforma continental externa e bancos oceânicos do nordeste do Brasil no âmbito do programa REVIZEE. Grupo de estudo do Bentos (Oceanografia Biológica), Programa REVIZEE. 81 p.

An, J., Yu, H., Li, X., 2006. Description of a new genus and two new species of Ioninae (Isopoda: Epicaridea: Bopyridae) parasites of Leucosiidae (Decapoda: Brachyura) from Beibu Gulf. *Zootaxa* 1186, 57-68.

Anker, A., 2003. Alpheid shrimps from the mangroves and mudflats of Singapore. Part I. Genera Salmoneus, Athanas and Potamalpheops, with the description of two new species. *The Raffles Bulletin of Zoology* 51(2), 283-314.

Anker, A. and I.N. Marin 2006. New records and species of Alpheidae (Crustacea: Decapoda) from Vietnam. Part I. Genus Salmoneus Holthuis, 1955. The Raffles Bulletin of Zoology 54(2):295-319.

Anker, A., Marin, I.N., 2007. Athanas anatidactylus sp. Nov., a new alpheid shrimp (Crustacea: Decapoda) associated with crinoids in the tropical western pacific. *Zoological Studies* 46(2), 162-167.

Anker, A., Marin, I.N., 2009. The alpheid shrimp genus Leptalpheus Williams, 1965, in the tropical Western Pacific, with descriptions of two new species (Crustacea: Decapoda: Caridea). *The Raffles Bulletin of Zoology* 57(1), 91-107.

Anker, A., Jeng, M.-S., Chan, T.-Y., 2001. Two unusual species of Alpheidae (Decapoda: Caridea) associated with upogebiid mudshrimps in the mudflats of Taiwan and Vietnam. *Journal of Crustacean Biology* 21(4), 1049-1061.

Baba, K., 1988. Chirostylid and galatheid crustaceans (Decapoda: Anomura) of the "Albatross" Philippine Expedition, 1907-1910. *Researches on Crustacea* Special Number 2, 1-203.

Bamber, R.N., 1998. Tanaidaceans (Crustacea, Peracarida) from the southeast of the South China Sea. *Asian Marine Biology* 15, 171-199.

Bamber, R.N., Sheader, M., 2005. Apseudomorph Tanaidacea (Crustacea: Malacostraca: Pericarida) from shallow waters off Sabah, Malaysia. *Systematics and Biodiversity* 2(3), 281-303.

Banner, A.H., Banner, D.M., 1966. The alpheid shrimp of Thailand: the alpheid shrimps of the Gulf of Thailand and adjacent waters. *The Siam Society Monograph* Series 3, 1-168.

Banner, A.H., Banner, D.M., 1968. Three new species of the genus Alpheus (Decapoda, Alpheidae) from the International Indian Ocean Expedition. *Crustaceana* 15(2), 141-148.

Banner, A.H., Banner, D.M., 1976. Decapod Crustacea: Alpheidae Results of the Musorstom Expeditions I. *Hawaii Institute of Marine Biology* Contribution Number 591, 217-235.

Bernard, F.R., Cai, Y.Y., Morton, B., 1993. *Catalogue of the living marine bivalve molluscs of China*. Hong Kong University Press, Hong Kong. 121 p.

Bisby, F.A., Ruggiero, M.A., Wilson, K.L., Cachuela-Palacio, M., Kimani, S.W., Roskov, Y.R., Soulier-Perkins, A., van Hertum, J., 2005. *Species 2000 and ITIS Catalogue of Life: 2005 Annual Checklist*. CD-ROM; Species 2000: Reading, U.K.

Blackmore, G., 2001. Interspecific variation in heavy metal body concentrations in Hong Kong marine invertebrates. *Environmental Pollution* 114, 303-311.

Blumstein, R., 1970. New stomatopod crustaceans from the Gulf of Tonkin, South China Sea. *Crustaceana* 18(2), 218-224.

Boden, B.P., Johnson, M.W., Brinton, E., 1955. The Euphausiacea (Crustacea) of the north Pacific. *In*: Zobell, C.E., Arthur, R.S., Fox, D.L. (eds.), *Contribution from the Scripps Institution of Oceanography* No. 796, 6(8), 287-400. Bulletin of the Scripps Institution of Oceanography of the University of California. University of California Press. California.

Boyko, C.B., Williams, J.D., 2003. A revision of Anathelges and Stegophryxus (Isopoda: Bopyridae: Athelginae) with descriptions of two new genera and one new species. *Journal of Crustacean Biology* 23(4), 795-813.

Brinton, E., 1962. The distribution of Pacific euphausiids. *In*: Fox, D.L., Arrhenius, G.O.S., Phleger, F.B. (eds.), *Contribution from the Scripps Institution of Oceanography*, 8(2), 51-270. Bulletin of the Scripps Institution of Oceanography of the Univeristy of California. University of California Press. California.

Bruce, A.J., 2004. A new pontoniine shrimp from Tahiti, French Polynesia (Crustacea, Decapoda, Palaemonidae). *Zoosystema* 26(2), 279-289.

Bruce, A.J., 2004. A partial revision of the genus Periclimenes Costa, 1884 (Crustacea: Decapoda: Palaemonidae). *Zootaxa* 582, 1-26.

Bruce, A.J., 2005. Pontoniine shrimps from Papua New Guinea, with designation of two new genera, Cainonia and Colemonia (Crustacea: Decapoda: Palaemonidae). *Memoirs of the Queensland Museum* 51(2), 333-383.

Buckeridge, J.S., Newman, W.A., 1992. A reexamination of Waikalasma (Cirripedia: Thoracica) and its significance in Balanomorph phylogeny. *Journal of Paleontology* 66(2), 341-345.

Chace, Jr., F.A., 1985. The caridean shrimps (Crustacea: Decapoda) of the Albatross Philippine Expedition, 1907-1910, Part 3: Families Thalassocarididae and Pandalidae. *Smithsonian Contributions to Zoology* (411), 1-143.

Chace, Jr., F.A., 1988. The caridean shrimps (Crustacea – Decapoda) of the Albatross Philippine Expedition, 1907-1910. Part 5, Family Alpheidae. *Smithsonian Contributions to Zoology* 466(vi), 99 p. Smithsonian Institution Press, Washington, D.C.

Chan, B.K.K., 2004. First record of the parasitic barnacle Sacculina scabra Boschma, 1931 (Crustacea: Cirripedia: Rhizocephala) infecting the shallow water swimming crab Charybdis truncata. *The Raffles Bulletin of Zoology* 52(2), 449-453.

Chan, T.Y., 1998. Shrimps and prawns. 851-971. *In*: Carpenter, K.E., Niem, V.H. (eds), *The living marine resources of the Western Central Pacific. Vol. 2. Cephalopods, crustaceans, holothurians and sharks*, p. 687-1396. FAO species identification guide for fishery purposes. Rome, FAO.

Chen, H., 1989. Leucosiidae (Crustacea: Brachyura). *In*: Forest, J. (ed.), *Résultats de Campagnes MUSORSTOM*, Volume 5(A)144, p. 181-263. Mémoires du Muséum national d'Histoire naturelle, Paris.

Chen, H.L., 1975. Studies on the crabs of Xisha Islands I. Guangdong Province, China. *Studia Marina Sinica* 10, 157-179.

Chen, Q.C., Zhang, G.X., Gao, Q.Z., Yin, J.J., 1989. *Zooplankton*. Research Reports of the Multidisciplinary Investigation of Nansha Islands and its Adjacent Seas. Science Press, Beijing. p. 659-707.

Chertoprud, E.S., Gómez, S., Gheerardyn, H., 2009. Harpacticoida (Copepoda) fauna and the taxocene diversity of the South China Sea. *Oceanology* 49(4), 488-498.

Clark, P.F., Ng, P.K.L., Fransen, C.H.J.M., McLaughlin, P.A., Dworschak, P.C., Baba, K., 2008. A checklist of Crustacea Decapoda collected from Conic Island Cave and adjacent areas of Hong Kong. *Journal of Natural History* 42(9), 913-926.

Coles, S.L., DeFelice, R.C., Eldredge, L.G., Carlton, J.T., 1999. Historical and recent introductions of non-indigenous marine species into Pearl Harbor, Oahu, Hawaiian Islands. *Marine Biology* 135, 147-158.

Davie, P.J.F., 2002. Crustacea: Malacostraca: Eucarida (Part 2): Decapoda - Anomura, Brachyura. *In*: Wells, A., Houston, W.W.K. (eds.), *Zoological Catalogue of Australia*. Vol. 19.3B. CSIRO Publishing, Melbourne. 641 p.

de Saint Laurent, M., 1972. Sur la famille des Parapaguridae Smith, 1882. Description de Typhlopagurus foresti gen. nov., sp. nov., et de quinze espèces ou sous espèces nouvelles de Parapagurus Smith (Crustacea, Decapoda). *Bijdr. Dierk.* 42(2), 97-123.

Deevey, G.B., 1968. *Pelagic Ostracods of the Sargasso Sea off Bermuda*. Peabody Museum of Natural History, Yale University. Bulletin 26. New Haven, Connecticut. 125 p.

del Mundo, C.M., 2000. *Philippine decapod crustacea. An illustrated handbook on the commercially important decapod crustacea of the Philippines*. Fisheries Resources Evaluation and Environmental Services Division, Bureau of Fisheries and Aquatic Resources. Quezon City, Philippines. 83 p.

Faiz, N.N., Omar, R., 2009. Ostrakod baharu di dalam sedimen luar pantai di sekitar Pulau Tioman, Pahang. Sains Malaysiana 38(1), 9-20.

Fize, A., Serène, R., 1955. Les Pagures du Vietnam. *Hai Hoc Viên. Institut Océanographique Nhatrang* 45, 1-228.

Flegel, T.W., 2006. Detection of major penaeid shrimp viruses in Asia, a historical perspective with emphasis on Thailand. *Aquaculture* 258(1-4), 1-33.

Forest, J., 1995. Crustacea Decapoda Anomura: Révision du genre Trizopagurus Forest, 1952 (Diogenidae) avec l'éstablissement de deux genres nouveaux. *In*: Crosnier, A. (ed.), *Résultates des Campagnes Musorstrom 13*. Mém. Mus. Natn. Hist. nat., Paris 163, 9-149.

Galil, B.S., 2001. A revision of Myra Leach, 1817 (Crustacea: Decapoda: Leucosioidea). *Zool. Med. Leiden* 75 (24), 409-446, figs. 1-19.

Galil, B.S., 2001. A revision of the genus Arcania Leach, 1817 (Crusatcea: Decapoda: Leucosioidea). *Zoologische Mededelingen* 75(11), 169-206.

Galil, B.S., 2003. Contribution to the knowledge of Leucosiidae II. Euclosia gen. nov., (Crustacea: Brachyura). *Zoologische Mededelingen, Leiden* 77(20), 331-347.

Galil, B.S., Ng, P.K.L., 2007. Leucosiid crabs from Panglao, Philippines, with descriptions of three new species (Crustacea: Decapoda: Brachyura). *The Raffles Bulletin of Zoology* Supplement 16, 79-94.

Gómez, S., Chertoprud, E.S., 2009. Sentiropsis vietnamensis n. sp., a new pseudotachidid (Copepoda: Harpacticoida) from the South China Sea. *Journal of Crustacean Biology* 29(4), 568-578.

Haig, J., 1992. Hong Kong's porcellanid crabs. *In*: Morton, B. (ed.), *The marine flora and fauna of Hong Kong and southern China III*, 303-327. Proceedings of the fourth International Marine Biological Workshop, 11-29 April 1989. Hong Kong: Hong Kong University Press.

Han, Q., Li, X., Chan, T., 2007. On the Crangonidae (Crustacea: Decapoda: Caridea) of the Philippines from the Panglao 2004 and Panglao 2005 expeditions. *The Raffles Bulletin of Zoology* Supplement 16, 7-14.

Høeg, J.T., Rybakov, A.V., 1992. Revision of the Rhizocephala Akentrogonida (Cirripedia), with a list of all the species and a key to the identification of families. *Journal of Crustacean Biology* 12(4), 600-609.

Hoeg, J.T., Lützen, J., 1993. Comparative morphology and phylogeny of the family Thompsoniidae (Cirripedia, Rhizocephala, Akentrogonida) with descriptions of three new genera and seven new species. *Zoologica Scripta* 22(4), 363-386.

Holthuis, L.B., 1980. *Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries*. FAO Fisheries Synopsis 1(125). FAO. Rome. 271 p.

Holthuis, L.B., 1991. *Marine lobsters of the world. An annotated and illustrated catalogue of species of interest to fisheries known to date*. FAO Fisheries Synopsis 13(125). FAO, Rome. 292 p.

Huang, J.F., Lützen, J., 1998. Rhizocephalans (Crustacea: Cirripedia) from Taiwan. *Journal of Natural History* 32, 1319-1337.

Huang, Z.G., 1994. *Marine species and their distributions in China's sea*s. China Ocean Press, Beijing. 764 p.

Hwang, J.-S., Dahms, H.-U., Tseng, L.-C., Chen, Q.-C., 2007. Intrusions of the Kuroshio current in the northern South China Sea affect copepod assemblages of the Luzon Strait. *Journal of Experimental Marine Biology and Ecology* 352, 12-27.

Jia, X., Li, Z., Li,, C. Qiu, Y., Gan, J., 2004. *Studies on the ecosystem and commerical fisheries in South China Sea*. Science Publishing, Beijing. 647 p.

Jones, D.S., Hewitt, M.A., Sampey, A., 2000. A checklist of the Cirripedia of the South China Sea. *The Raffles Bulletin of Zoology* 8, 233-307.

Kensley, B., Schotte, M., 2002. New species and records of Asellota from the Indian Ocean (Crustacea: Pericarida: Isopoda). *Journal of Natural History* 36, 1421-1461.

Komai, T., 2000. A check list of Thalassinidea and Anomura (Crustacea: Decapoda) from the South China Sea. *The Raffles Bulletin of Zoology* Supplement 8, 343-376.

Kussakin, O.G., Malyutina, M.V., 1993. Sphaeromatidae (Crustacea: Isopoda: Flabellifera) from the South China Sea. *Invertebrate Taxonomy* 7, 1167-1203.

Lemaitre, R., 1993. A new genus of Parapaguridae (Decapoda: Anomura). *Crus. Res.* 22, 11-20.

Lemaitre, R., 1996. Hermit crabs of the family Parapaguridae (Crustacea: Decapoda: Anomura) from Australia: species of Strobopagurus Lemaitre, 1989, Sympagurus Smith, 1883 and two new genera. *Rec. Aust. Mus.* 48, 163-221.

Leung, S.F., 1994. The population dynamics of Exoplalaemon styliferus H. Milne-Edwards (Palaemonidae) in a traditional tidal shrimp pond at the Mai Po Marshes Nature Reserve, Hong Kong. *Asian Marine Biology* 11, 55-78.

Li, L., 2000. A new species of Dynoides (Crustacea: Isopoda: Sphaeromatidae) from the Cape d' Aguilar Reserve, Hong Kong. *Records of the Australian Museum* 52, 137-149.

Li, X., 2004. The Pontiniine shrimps (Crustacea: Decapoda: Palaemonidae) from Anambas and Natuna Islands, Indonesia, collected by Anambas Expedition, 2002. *The Raffles Bulletin of Zoology* 11, 67-72.

Li, X., 2006. Additional pandaloid shrimps from the South China Sea (Crustacea: Decapoda: Caridea), with descriptions of one new species. *The Raffles Bulletin of Zoology* 54(2), 361-372.

Li, X., Liu, J.Y., 2004. Report of Pontoniinae shrimps (Crustacea: Decapoda) collected by joint Chinese-German Marine Biology Expeditions to Hainan Island, South China Sea. III. Periclimenes. *Chinese Journal of Oceanology and Limnology* 22(1), 89-100.

Li, X., Komai, T., 2003. Pandaloid shrimps from the Northern south China Sea, with description of a new species of Plesionika (Crustacea: Decapoda: Caridea). *The Raffles Bulletin of Zoology* 51(2), 257-275.

Li, X., Bruce, A.J., Manning, R.B., 2004. Some Palaemonid shrimps (Crustacea: Decapoda) from northern South China Sea, with descriptions of two new species. *The Raffles Bulletin of Zoology* 52(2), 513-553.

Li, X., Liu, D., Liang, X., 2003. The zoogeography of Chinese Palaemonoidea fauna. *Biodiversity Science* 11(5), 393-406.

Liu, J.-Y., Wang, Y., 1978. Description of a new genus and two new species of stomatopod Crustacea from the South China Sea. *Oceanologia et Limnologia Sinica* 9(1), 89-92 (Chinese text), 93-94 (English text).

Liu, J.-Y., Wang, Y., 1998. On two new species of the Squillidae and Harpiosquillidae (Crustacea: Stomatopoda) from the South China Sea. *Oceanologia Limnologia Sinica* 29, 588-296.

Lowry, J.K., 2000. Taxonomic status of amphipod crustaceans in the South China Sea with a checklist of known species. *The Raffles Bulletin of Zoology* 8, 309-342.

Lowry, J.K., Dempsey, K., 2006. The giant deep-sea scavenger genus Bathynomus (Crustacea, Isopoda, Cirolanidae) in the Indo-West Pacific. *In*: Richer de Forges, B., Justine, J.-L. (eds.), *Tropical deep-sea benthos*, p. 163-192. Mémoires du Muséum national d'Histoire naturelle 24(193).

Lowry, J.K., Springthorpe, R.T., 2005. New and little-known melitid amphipods from Australian waters (Crustacea: Amphipoda: Melitidae). *Records of the Australian Museum* 57, 237-302.

Lützen, J., Jespersen, A., 1990. Records of Thompsonia (Crustacea: Cirripedia: Rhizocephala) from Singapore, including description of two new species, T. littoralis and T. pilodiae. *The Raffles Bulletin of Zoology* 38(2), 241-249.

Makarov, R.R., 1978. New data on crustaceans of the families Lysosquillidae and Gonodactylidae (Crustacea, Stomatopoda) from the Tonkin Bay (Vietnam). *Zoologicheskij zhurnal*, Moscow 57, 176-189.

Manning, R.B., 1995. Stomatopod Crustacea of Vietnam: the legacy of Raoul Serène. *Crustacean Research* Special No. 4, 1-339.

Manning, R.B., 1998. Stomatopods. *In*: Carpenter, K.E., Niem, V.H. (eds.), *FAO Species Identifidication Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Vol. 2. Cephalopods, crustaceans, holothurians and sharks*, p. 827-849. FAO Rome.

Markham, J.C., 1982. Bopyrid isopods parasitic on decapod crustaceans in Hong Kong and southern China. *In*: Morton, B.S., Cheng, C.K. (eds.), *Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of hong Kong and Southern China* 1, 325-391. Hong Kong University Press: Hong Kong.

Markham, J.C., 2003. A worldwide list of hermit crabs and their relatives (Anomura: Paguroidea) reported as hosts of Isopoda Bopyridae. *In*: Lemaitre, R., Tudge, C.C. (eds.), *Biology of Anomura. Proceedings of a symposium at the Fifth International Crustacean Congress, Melbourne, Australia, 9-13 July 2001*. Memoirs of Museum Victoria 60(1), 71-77.

Mathew, K.J., Sivan, G., Krishnakumar, P.K., Kuriakose, S., 2003. *Euphausiids of the west coast of India*. CMFRI Special Publication No. 78. 155 p.

McLay, C.L., 2001. Dynomenidae and Dromiidae (Decapoda, Brachyura) from Guam, Philippine Islands, Tonga and Samoa. *Zoosystema* 23(4), 807-856.

Moosa, M.K., 2000. Marine biodiversity of the South China Sea: A checklist of stomatopod crustacea. *The Raffles Bulletin of Zoology* Supplement No. 8, 405-457.

Naiyanetr, P., 1987. Two new stomatopod crustaceans from Thailand with a key to the genus Manningia Serène, 1962. *Crustaceana* 53(3), 237-242.

Naiyanetr, P., Ahyong, S.T., Ng, P.K.L., 2000. Reinstatement of Carinosquilla thailandensis Naiyanetr, 1983, with a first record of Alima orientalis Manning, 1978, from the Gulf of Thailand, and notes on Clorodina pelamidae (Blumstein, 1970) (Stomatopoda: Squillidae). *Crustaceana* 73(10), 1291-1295.

Ng, P.K.L., 1998. Crabs. *In*: Carpenter, K.E., Niem, V.H. (eds.), *FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 2. Cephalopods, crustaceans, holothurians and sharks*, p. 1045-1155. Rome, FAO.

Pérez Farfante, I., Kensley, B., 1997. Penaeoid and Sergestoid shrimps and prawns of the world: keys and diagnoses for the families and genera. *Mémoires du Muséum National d'Histoire Naturelle* 175, 1-233.

Poltarukha, L.P., 2010. Deep-sea Barnacles (Cirripedia: Thoracica) of Southern Vietnam. *Russian Journal of Marine Biology* 36(1), 16-25.

Poltarukha, O.P., 2004. An addition to the fauna of coral-inhabiting barnacles (Cirripedia: Balanomorpha) of Vietnam. *Russian Journal of Marine Biology* 30(4), 278-282.

Poupin, J., 1998. Crustacea Decapoda and Stomatopoda of French Polynesia. *Atoll Research Bulletin* 451, 62 p.

Rahayu, D.L., 2000. Hermit crabs from the South China Sea (Crustacea: Decapoda: Anomura: Diogenidae, Paguridae, Parapaguridae). *The Raffles Bulletin of Zoology* 8, 377-404.

Rahayu, D.L., Ng, P.K.L., 2003. The Capmtandriidae of Irian Jaya, Indonesia, including the descriptions of two new species (Decapoda: Brachyura). *Journal of Crustacean Biology* 23(4), 951-962.

Ren, X., 1991. Five species of Gammaridea (Amphipoda) from Nansha Islands. Selected Research Papers on Nansha Islands. *Marine Life of Nansha Islands and the surrounding area*, p. 181-188, China Ocean Press.

Rottman, M., 1978. Ecology of recurrent groups of pteropods, euphausiids, and chaetognaths in the Gulf of Thailand and the South China Sea. *Marine Biology* 48, 63-78.

Rushton-Mellor, S.K., 1991. Argulus papuensis n. sp., a new fish louse (Crustacea: Branchiura) from Papua New Guinea. *Systematic Parasitology* 18, 67-75.

Sakai, K., 1993. On a collection Upogebiidae (Crustacea, Thalassinidea) from the Northern Territory Museum, Australia, with the descriptions of two new species. *Beagle, Rec. North. Terr. Mus. Arts Sci.* 10(1), 87-114.

Schotte, M., Kensley, B.F., Shilling, S., 1995. World list of marine, freshwater and terrestrial crustacea isopoda. National Museum of Natural History Smithsonian Institution: Washington D.C., USA. http://www.nmnh.si.edu/iz/isopod/ on 2007-03-01.

Shen, C., 1931. The crabs of Hong Kong. Part I. *The Hong Kong Naturalist* 2, 92-110.

Shih, C., Chen, Q., 1995. The Hyperiidea (Crustacea: Amphipoda). *Zooplankton of China Seas* 2, 1-295.

Shin, P.K.S., Huang, Z.G., Wu, R.S.S., 2004. An updated baseline of subtropical macrobenthic communities in Hong Kong. *Marine Pollution Bulletin* 49, 128-135.

Soong, K., 1992. Occurrence of the giant isopod Bathynomus giganteus A. Milne Edwards, 1879 (Isopoda, Flabellifera, Cirolanidae) in the West Pacific. *Crustaceana* 63, 291-295.

Tirmizi, N.M., Manning, R.B., 1968. Stomatopod Crustacea from West Pakistan. *Proc. US Natn. Mus.* 125(3666), 1-48.

Tweedie, M.W.F., 1950. A collection of crabs from Aor Island, South China Sea. *Bulletin of the Raffles Museum* 21, 83-96.

Vacelet, J., 1987. Eponges. *In*: Fischer, W., Bauchot, M. L., Schneider, M. (eds.), *Fiches FAO d' identification des espèces pour les besoins de la pêche. (Revision 1). Méditerranée et mer Noire. Zone de pêche 37.* Volume I, 137-148. Végëtaux et Invertébrés. Publication préparée par.

Wang, F., Dong, Y., 1977. Two new species of hermit crabs (Crustacea, Anomura) from China. *Acta Zoologica Sinica* 23(1), 109-112.

Wang, F.Z., 1994. Crustacea: Decapoda: Anomura. *In*: Huang, Z.G. (ed.), *Marine species and their distribution in China Seas*, p. 568-576. China Ocean Press, Beijing.

Watling, L., 2005. Cumacea World database. http://www.marinespecies.org/cumacea on 2007-09-26.

Williams, A.B., Abele, L.G., Felder, D.L., Hobbs, Jr., H.H., Manning, R.B., McLaughlin, P.A., Pérez Farfante, I., 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *American Fisheries Society Special Publication* 17, 77 pp.

Williams, J.D., Schuerlein, L.M., 2005. Two new species of branchial parasitic isopods (Crustacea: Isopoda: Bopyridae: Pseudioninae) from hermit crabs collected in Singapore. *Proceedings of the Biological Society of Washington* 118(1), 96-107.

Wilson, C.B., 1950. Copepods gathered by the United States fisheries steamer "Albatross" from 1887 to 1909, chiefly in the Pacific Ocean: contributions to the biology of the Philippine Archipelago and adjacent regions. *In*: *United States Museum. Papers on Echinoidea, fishes and Copepoda: contributions to the biology of the Philippine Archipelago and adjacent regions*. Smithsonian Institution United States National Museum Bulletin 100(14) Part 4, 141-441.

Wong, C.K., Chan, A.L.C., Chen, Q.C. 1993. Planktonic copepods of Tolo harbour, Hong Kong. *Crustaceana* 64(1), 76-84.

Yan, Y., Chan, B.K.K., 2004. A new barnacle species from Hong Kong: Chthamalus neglectus sp. nov. (Cirripedia: Thoracica: Chthamalidae). *Journal of the Marine Biological Association of the United Kingdom* 84, 133-138.

Yang, S.-L., 1983. Preliminary report on the Porcellanidae (Crustacea, Anomura) of Xisha Islands, Guandong Province, China. *Mem. Beijing Nat. Hist. Mus.* 24, 1-9.

Yang, S.-L., 1996. New species and new records of porcellanid crabs (Crustacea: Decapoda: Brachyura) from Nansha Islands, China. *In*: *Studies on marine fauna and flora and biogeography of the Nansha Islands and neighboring waters*, II, 2, 258-269. China Ocean Press, Beijing.

Yang, S.-L., Xu, Z.-X., 1994. Study on the Porcellanidae (Crustacea, Anomura) from Nansha Islands and its adjacent waters. *Researches on the geography, flora and fauna of the Nansha Islands and its adjacent waters*, Beijing 1, 112-124. China Ocean Press, Beijing.

Ye, S.-Z., Zhang, Z.-L., Ye, Q.-T., 2006. Species composition and charactereistics of crab distribuiton in south East China Sea. *Journal of Oceanography in Taiwan Strait* 25(3), 381-387.

Yeo, D.C.J., Ng, P.K.L., 1996. A new species of freshwater snapping shrimp, Alpheus cyanoteles (Decapoda: Caridea: Alpheidae) from Peninsular Malaysia and a rediscription of Alpheus paludicola Kemp, 1915. *The Raffles Bulletin of Zoology* 44(1), 37-63.

Yu, H. and X. Li 2001. Some marine isopods (Crustacea) from Hainan Island, South China Sea. In Matsuura, K. (ed). Marine Fauna of Shallow Waters around Hainan Island, South China Sea. National Science Museum Monographs 21:45-51.

Zhao, Q., Wang, P., Zhang, Q., 1985. Ostracoda in bottom sediments of the South China Sea, off Guangdong Province, China: their taxonomy and distribution. *In*: Wang, P., *et al.* (eds.), *Marine Paleontology of China*, p. 196-317. Beijng: China Ocean Press.

Zheng, Y., Chen, X., Chen, J., Wang, Y., Shen, X., Chen, W., Li, C., 2003. *Biological resources and the environment in East China Sea*. Scientific Technology Publishing of Shanghai. 835 p.

BIOLOGY

LIFE HISTORY OF *SEPIA RECURVIROSTRA* IN PHILIPPINE WATERS [1]

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ABSTRACT

Life history parameters of the curvespine cuttlefish, *Sepia recurvirostra* Steenstrup, 1875 (Mollusca, Cephalopoda, Sepiidae) were assembled from population-based studies within its known native range. Length-weight, fecundity, reproductive load and maturity parameters were estimated from results of an unpublished study of the Visayan Sea and Guimaras Strait (Philippines) populations. There are no known estimates of growth parameters for Philippine populations of this species and, the literature being very scarce, does not offer analogous data for comparisons. Thus, growth estimates were obtained using observed maximum lengths and the growth coefficient (θ') obtained for other *Sepia* species occurring in the region. Comparisons of the growth of Atlantic and Pacific/Indian Ocean populations are discussed.

INTRODUCTION

The curvespine cuttlefish *Sepia* (*Acanthosepion*) *recurvirostra* Steenstrup, 1875 (Nateewathana, 1997) belongs to the Family Sepiidae Keferstein, 1866, Class Cephalopoda, Phylum Mollusca and is also known under the name *Sepia singaporensis* Pfeffer, 1884 (Rooper *et al*., 1984). It is native to the tropical western Pacific (Okutani, 2005), occurring between Burma to the Philippines including the East and South China Sea (Norman and Lu, 2000; see Figure 1) and is a common composite of commercial Southeast Asian trawl fisheries catches, notably those from Hong Kong (Chikuni, 1985; Chullasorn and Martosubroto, 1986).

S. recurvirostra can be identified from other sepiid species by the following characteristics: the club protecting membrane is fused in the carpal part; the sucker-carrying surface is separated from the stalk; 5-6 median suckers of the club are slightly enlarged (Jereb and Roper, 2005). Newly fertilized eggs, white and coated with a sticky, gelatinous material, are usually found hanging from a substrate in dense clusters (Jereb and Roper, 2005). Cuttlefish eggs hatch 4 months after fertilization to 25 mm long larvae with all parental traits (Boyle, 1983, 1987; Wood, 2004). Predation rates on larvae are high and very few of the newly hatched cuttlefish survive past their first few hours (Wood, 2004; Boyle and Rodhouse, 2005). Those that survive grow quickly, make their way to and live in deeper waters (Nixon and Young, 2003; Wood, 2004). Mature *S. recurvirostra* with gravid ovaries are found all year round, with possibly two spawning peaks, November to February and June to September (Jereb *et al*., 2005). Age at first maturity is between 1.5-2.0 years, with spawners mating head to head, locking their tentacles together and the male placing a sealed sperm packet into the pouch just below the female's mouth (Wood, 2004). The female retreats into a den (usually a deep crack or fissure in the rocks or a small cave) where it draws each egg

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individually (which may count to 200 or more) out of its mantle passing it over the sperm; then it becomes lethargic and dies off (Pierce and Guerra, 1994; Jereb and Rooper, 2005).

Cephalopods are an important commodity and cephalopod fisheries have increased over time leading to overfished populations notably in Taiwan (Lu, 2002), Thailand (Nootmorn and Chotiyaputta, 2002) and European waters (Payne *et al.*, 2006). Threats to cephalopod populations worldwide (overfishing, pollution, etc.) become even more serious because they are short-lived and spawn only once in their short lifetime (Boyle, 1990; Pierce and Guerra, 1994).

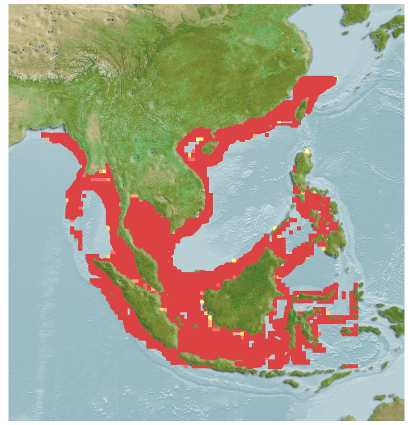

Figure 1. Distribution map of *Sepia (Acanthosepion) recurvirostra* shown using AquaMaps which includes Andaman Islands (India), Brunei Darussalam, Cambodia, China (High Seas), Hong Kong (China) , Indonesia , Korea (South), Macau (China), Malaysia (East Peninsula), Malaysia (Sabah), Malaysia (Sarawak) , Malaysia (West Peninsula), Myanmar, Singapore, Taiwan, Ryukyu Islands (Japan), Philippines and Thailand (Jereb and Roper, 2005).

Biological studies on the curvespine cuttlefish are scarce. A Google Scholar search using "*Sepia recurvirostra*" anywhere in the article returned only 17 results (searching in the title of articles returned zero results) while a Web of Science search using the same keyword in the topic or in the title of the article returned only 1 result. On the other hand, a Google search using the same keyword in PDF format returned 47 results (a search for "any format" returned 3,310 results, mostly images). All of these 47 documents were checklists of species where the curvespine cuttlefish is included, i.e., none of the identified articles contained life-history information for this species. Another literature search, this time using the list of references of the 17 documents identified in the Google Scholar search came up with 10 documents half of which are on the fisheries of Thailand (Chikuni, 1985; Chullasorn *et al.*, 1986, Chotiyaputta *et al.*, 2002; Nootmorn *et al.*, 2002; Jindalit *et al.*, 2005), the rest on biodiversity reviews (Norman, 2000; Okutani, 2005; Tan *et al.*, 2010), predators of cephalopods (Barros *et al.*, 2002) and effects of cooking on cephalopods (Intajarurnsan, 2003). Thus, we can truly state that very little is known on this species and very little is available in the scientific literature.

This contribution extends knowledge on this species with a field study on fecundity, length-weight relationship, and maximum size of Philippine populations and an assemblage of growth parameters for other species of the genus *Sepia*.

MATERIALS AND METHODS

Field sampling

Sepia recurvirostra females were caught 30 June and 15 September 2004 from fishing grounds in the Visayan Sea and Guimaras Strait (Figure 2). Individuals were weighed (g) and measured (mantle length, cm). Ovaries were carefully removed, weighed and preserved in 10% formalin until hardened (making counting easier), and the total number of eggs per ovary were counted under a microscope and using a grid and mechanical counter. Preserved ovaries were dehydrated, cleared, infiltrated with and embedded in paraffin, dissected and mounted in slides for further microscopic examination.

Figure 2. Sampling sites (Visayan sea and Guimaras strait) were samples where collected.

Life-history parameters

Fecundity was estimated as the total number of maturing ova (with striations) and mature ova (large smooth ova) in the ovary and oviducal glands (proximal and distal glands; see definition by Gabr *et al.*, 1997). The relationship between ovary weight and total number of eggs is expressed as W_o = a + b*number of eggs, where W_o is expressed in grams. The relationship between total egg count with total body weight and with mantle length was also investigated using Total egg count=a+b*W and Total egg count=a+b*ML. Gonado-somatic indices were estimated for the September 15 sample using the relationship GSI=100*W_o/W (Pauly and Munro, 1984, Rodhouse *et al.*, 1994).

Assuming isometric growth, condition factors were calculated for the September sample using the relationship, c.f.=W*100/L^3. The average c.f. was used as the variable a in the equation W=aL^b, where W, the total body weight, is expressed in grams and L, the mantle length, is expressed in centimeters, a=c.f./100 and where b is set equal to 3 (see Pauly, 1984). This was performed in lieu of the log-log regression analysis of weight *vs.* length because the September sample (for which length-weight pairs were available) is not representative of the population as it is composed mainly of gravid females. Length-weight relationships for other species of the genus *Sepia* were assembled for comparison.

Von Bertalanffy growth parameters for species of the genus *Sepia* were obtained from the literature in order to obtain estimates of the growth efficiency coefficient θ' using the relationship θ'=logK+2*logL_∞ (see Pauly and Munro, 1984), where K is the growth coefficient expressed in years and L_∞ is the asymptotic length expressed in mantle length centimeters of the von Bertalanffy growth equation, i.e., $L_t = L_\infty(1-e^{-K(t-t_o)})$ (Pauly, 1984). The growth parameters of sepiids (in the Western Central Pacific and the Indian Ocean) were used to compute a mean value of θ', which was then used with an estimate of L_∞ (=L_{max}/0.95; Taylor, 1958) to estimate a value of K applicable to Southeast Asia.

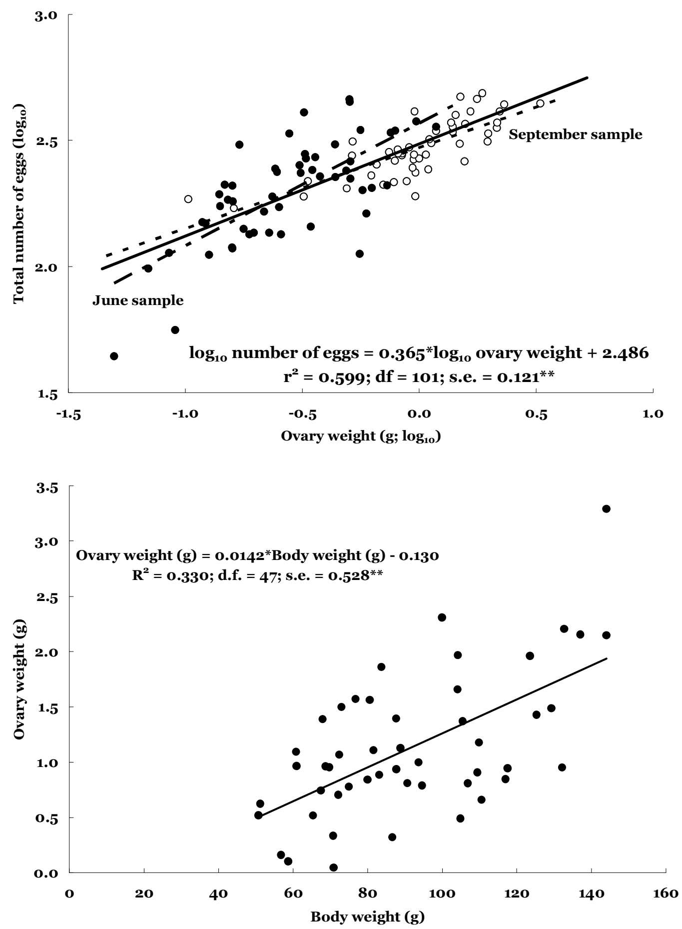

Figure 3. Upper panel: relationship between number of eggs and ovary weight (g) of curvespine cuttlefish, *Sepia recurvirostra*, sampled in the Visayan Sea and Guimaras Strait, Philippines in June (black dots) and in September (white dots) of 2004 (solid line). Each sample separately regressed resulted in only slightly different regression curves: log_{10} number of eggs = 0.486·log_{10} ovary weight + 2.568 (June sample, dashed line; r^2=0.504, d.f.=52) and log_{10} number of eggs = 0.3209·log_{10} ovary weight + 2.471 (September sample, dotted line; r^2 = 0.6066, d.f.=47), the main difference being that the September sample contained individuals with heavier ovaries. Lower panel: relationship between ovary weight and body weight of cuttlefishes from the September sample.

RESULTS

A total of 103 curvespine cuttlefishes were sampled (54 in June and 49 in September), with mantle length range of 7-11 cm (valid only for the September sample); body weight range of 50-144 g (all gravid females, except for 2 in the June and 1 in the September samples); ovary weights ranged between 0.05-3.3 g (GSI range of 0.065-2.55); while egg count ranged between 44-486 eggs. Plotting the number of eggs *vs.* ovary weight for the two samples separately resulted in only slightly different regression curvess, i.e., log_{10} number of eggs = 0.486·log_{10} ovary weight + 2.568 (June sample, dashed line in Figure 3; r^2=0.504, d.f.=52) and log_{10} number of eggs = 0.3209·log_{10} ovary weight + 2.471 (September sample, dotted line in Figure 3; r^2 = 0.6066, d.f.=47), the main difference being that the September sample contained individuals with heavier ovaries. This justifies pooling the two samples and expressing this in one regression relationship as:

$\log_{10}$number eggs=0.3654·$\log_{10}$ovary weight+2.486; r^2=0.599, d.f.=101 and s.e.=0.121, significant to P=0.01 (solid line in Figure 3, upper panel).

Heavier ovaries here might also imply bigger individuals. This could only be tested for the September sample since the June sample did not include total body weights. The September sample contained individuals with mantle lengths of 7-11 cm, body weights of 50-144 g, ovary weights of 0.05-3.3 g and egg numbers of 170-486 for gravid females. Ovary weight increased proportionally with body weight, i.e., ovary weight (g) = 0.0142*Body weight (g) - 0.130, r^2=0.330 for d.f.=47 and an s.e.=0.528 significant at the 0.01 level (see Figure 3 lower panel). This result confirms that the September sample is also composed of larger individuals.

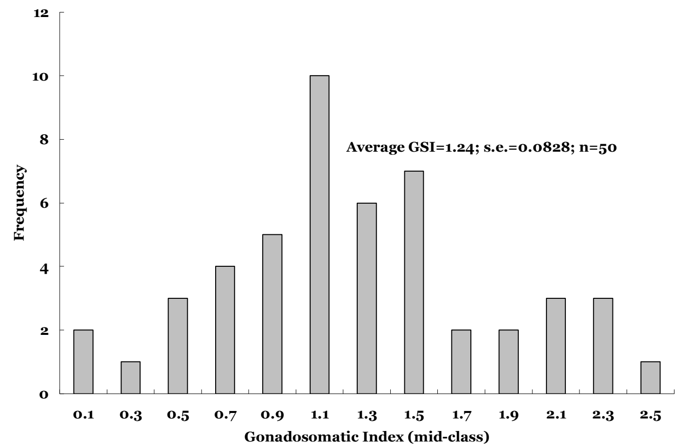

Figure 4. Frequency histogram of gonadosomatic indices for *Sepia recurvirostra* sampled in September 2004 in the Visayan Sea and Guimaras Strait, Philippines showing median GSI value peaks at 1.1, 1.5 and 2.1-2.3.

An analysis of the GSI indicates, however, that though the September sample is composed of larger individuals, not all of these mature females had full ovaries. The frequency histogram presented in Figure 4 shows a high GSI peak at 1.1 and a smaller peak at 2.1-2.3 with an intermediate peak at 1.5, implying at least two classes of gravid female cuttlefishes, probably as part of continued spawning from the June sample. The mean GSI value is 1.24 (s.e.=0.0828, n=50).

The average condition factor of 14.38 obtained for the September sample of gravid females was applied to obtain the length-weight equation of $W=0.1438*L^3$. This equation gives estimates of body weights about twice as heavy as the length-weight relationship for female curvespine cuttlefish from Thailand reported in Supongpan and Kongmuag (1976; see Table 1) and may therefore be biased. Length-weight relationships for other species of the genus *Sepia* were assembled in Table 1 for comparison.

The smallest mature ovary weighing 0.05 g, i.e., for a 4 g individual (obtained using the average GSI above), and, given the length-weight equation for gravid females, may have a mantle length of around 3 cm. Similarly, for an average mature ovary weight of 1.7 g, the average size at maturity is 135 g or 9.75 cm.

Roper *et al.* (1984) reported a maximum length of 17 cm (with maximum reported weight of 400 g) for the curvespine cuttlefish leading to an estimate of L_∞=17.9 cm. The mean growth performance index (θ') of Indian Ocean species of *Sepia* is 2.76 (see Table 2); with the estimate of L_∞=17.9 cm, this suggests a K value of 1.81 $year^{-1}$. Assuming that the growth parameters we obtained here correctly represent the Visayan Sea population, then the reproductive load (i.e., L_m/L_∞, Cushing, 1981) is 0.545, meaning that this population reaches maturity at a size halfway through the largest size it can attain and hence conforms to what is known for fishes (Froese and Binohlan, 2000).

Discussion

Supongpan and Kongmuag (1976) reported that spawning of the curvespine cuttlefish in Thailand occurs throughout the year with peaks in February-March and in June-October. The results of this study fall within the second peak observed for Thailand. The smallest size at first maturity recorded in this study is twice smaller than the reported 6.7 cm by Supongpan and Kongmuag (1976) and the 6.0 cm by Jindalikit *et al.* (2005) and may imply that the Visayan Sea population is maturing at an earlier age/size. However, Jindalikit *et al.* (2005) reported most mature individuals in their study to measure 8.0 cm, which corroborates with the average size at maturity obtained in this study.

Fecundity of the Thailand population is much higher (egg count range of 310-1,370) than that of the Visayan Sea population, implying that these maturing females are in a better condition. Note that the

Visayan Sea study was conducted about 30 years after the Thailand study, i.e., this population may have evolved in response to high exploitation rates.

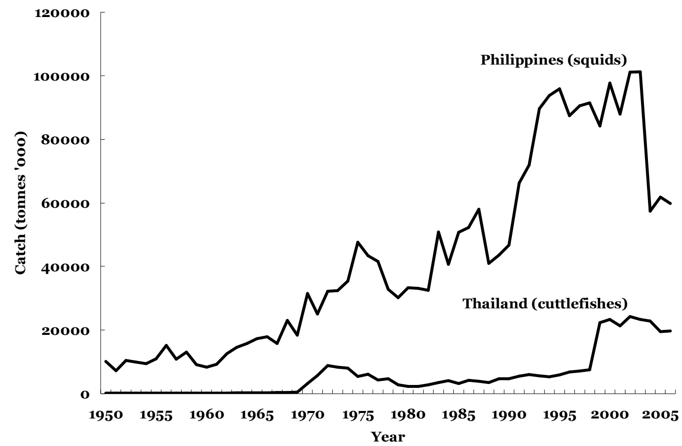

Figure 5. Cephalopod catch statistics obtained for the Philippines (mostly of loliginid squids) and for Thailand (mostly of sepiid cuttlefishes) from the Sea Around Us database (www.seaaroundus.org, accessed 11 August 2010).

Fisheries statistics for the curvespine cuttlefish does not exist for the Philippines, since cuttlefishes are aggregated with squids, so we cannot directly measure the effect of exploitation on size at maturity of these cuttlefishes. Catch statistics for Philippine 'Loligo' obtained from the *Sea Around* Us website (www.seaaroundus.org; see Figure 5), showed an increase in cephalopod catches from 1950-2006. Note that 'Loligo' represents, on the average, 3.0% of total Philippine catches, ranging from 3.9% in 1950, peaking in 1995 to 5.5% and decreasing again in 2006 to 2.7%. Cuttlefish catch statistics in Thailand, on the other hand, are reported only since the early 1960s, and on the average, represent 1.3% of the total catch, e.g., in the Adang-Rawi Archipelago (Thailand), this cuttlefish accounted for 2.10% of 1998-1999 cephalopod catches of 321 t (Nootmorn *et al*., 2002). A 2002 survey, however, reported this cuttlefish to represent about 28% of the 0.0425 t survey catch from the upper Gulf of Thailand (abundant in and spawning in offshore waters; Jindalikit *et al*., 2005). Figure 5 indicates that catches peaked in the early 1970s, sustained over the 1980s and 1990s and in spite of reports of overexploitation, started picking up again in the last decade, mostly as a result of fishery expansion (Chotiyaputta *et al*., 2002). Philippine 'Loligo' catches are 7-fold higher than the cuttlefish catches for Thailand (Figure 5), suggesting equally strong or stronger exploitation pressures on all cephalopod species and most likely as well on the curvespine cuttlefish. Such high exploitation rates may contribute to earlier maturity suggested by our results, similar to studies on fishes, e.g., *Salvelinus fontinalis* (Hutchings, 1993; Magnan *et al.,* 2005) and *Lepomis gibbosus* (Fox and Keast, 1991; Fox, 1994). Note also that maturity at smaller sizes can be brought on by higher temperatures, i.e., gonad development is accelerated and thus stimulates maturity as already reported for *Sepia* by Richard (1966a, 1966b) and for *Octopus* by van Heukelem (1979). With the increase in ocean water temperatures brought about by El Niño events and the escalating climate change, our results might well be a record of this effect caused by two factors, increased water temperatures and fisheries expansion to offshore waters.

The length-weight relationship reported here from the average condition factors of 49 gravid females cannot be used in predicting weights from lengths in general, even though isometry is assumed for the Philippine population. There are only two independent length-weight relationships for the curvespine cuttlefish, i.e., for the male and female populations of the Gulf of Thailand reported by Supongpan and Kongmuag (1976; see Table 1). Using these relationships and assuming that the estimate of L_∞ from L_{max} is acceptable (see above), the W_∞ for the curvespine cuttlefish would be 447 g and 405 g for females and males, respectively. These values match with the reported 400 g maximum weight of this cuttlefish by Roper *et al.* (1984).

The paucity of growth data on the curvespine cuttlefish prompted us to find analogous data for other species of *Sepia* (see Tables 2) in order to obtain informed estimates on its growth. SeaLifeBase (www.sealifebase.org; Palomares and Pauly, 2010) lists 77 species of *Sepia* worldwide, 65% of which are found in the Pacific (mostly with L_{max} <20 cm), 31% in the Atlantic and the rest in the Mediterranean (Figure 6). The curvespine cuttlefish is a medium-sized species, in the same maximum mantle length range as 16 other Indo-Pacific sepiids (Table 3), none of which have available growth parameter estimates.

Growth parameter estimates (Table 2) are available only for three Indian Ocean species, i.e., *S. aculeata* (third most important cuttlefish resource worldwide), *S. inermis* (main commercial species in Thailand, India and Sri Lanka), *S. pharaonis* (major industrial and artisanal target species) and one Atlantic species, i.e., *S. officinalis* (traded worldwide) all of which are in the >20 cm L_{max} categories. The availability of studies on these 4 species is very likely directly related to their high commercial values. The growth curves of these species were compared by regressing K *vs*. L_∞, i.e., in an auximetric plot (Figure 7). Only the growth parameters for S. officinalis and *S. pharaonis* could be used in this analysis because, a) growth parameters of *S. aculeata* exhibited a positive trend and thus did not follow the assumptions of this analysis (i.e., growth coefficient K, is negatively related to asymptotic length); and b) *Sepiella inermis*, is a smaller sepiid which is not in the genus *Sepia* and does not follow the expected trends, i.e., small species grow faster and therefore should have higher K values. Figure 6 shows that the pair of L_∞ and K for *S. recurvirostra* estimated from maximum size and the mean θ' follows snugly along the regression line for *S. pharaonis*, and suggests that *S. recurvirostra* grows similarly to populations of *S. pharaonis* with small mantle sizes. Figure 6 also suggests that at similar mantle lengths, the Atlantic species (common at depths of 100 m; Roper *et al.*, 1994) grows faster than the Indian Ocean species (common at depths of 40 m; see Roper *et al.*, 1994).

Though this study extended what we know of this species, the knowledge base on it is still appalingly poor. As cephapolopod resources are continually being exploited, and in some cases, the target of fisheries expansion, notably in offshore waters, it is important that further studies be made on smaller species such as *S. recurvirostra* before it is too late to save them from being listed as threatened by the IUCN. We therefore recommend that, e.g., fisheries departments of universities in the Philippines make these small species of cephalopods the subject of M. Sc. theses in order to gather data that can be used in their assessment.

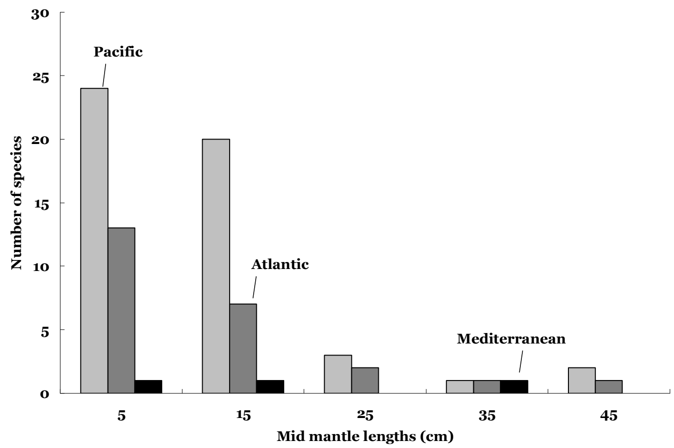

Figure 6. Maximum mantle length frequency distribution of 77 species of *Sepia* listed in SeaLifeBase (www.sealifebase.org; Palomares and Pauly, 2010).

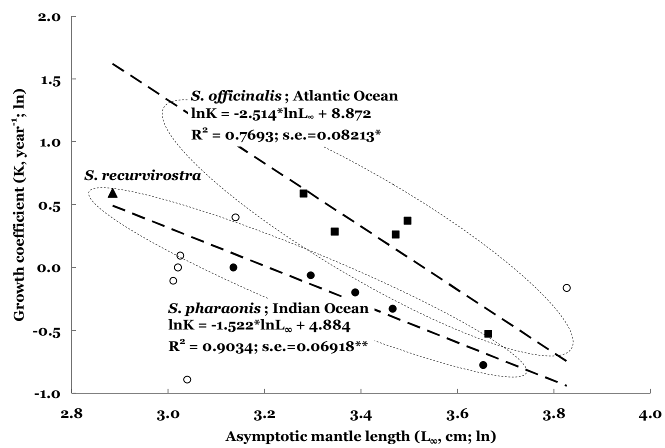

Figure 7. Relationship between the von Bertalanffy growth coefficients (K) with asymptotic mantle lengths (L_∞) for *Sepia officinalis* (black squares) from the Atlantic Ocean and *S. pharaonis* (black dots) from the Indian Ocean. White dots are data not included in this analysis, pertaining to *S. aculeata* and *Sepiella inermis*. Note position of the growth parameters obtained from this study, along the regression line for *S. pharaonis*, suggesting that *S. recurvirostra* (black triangle) grows similarly to *S. pharaonis*.

Table 1. Length-weight relationships of 9 species of the genus *Sepia* assembled from published sources. Note that c.f.=W*100/L³ and denotes condition factor, which is used to obtain the parameter 'a' using a=c.f./100. Sex: F=females; IF=immature females; M=males; IM=immature males; U=unsexed; B=mixed. These parameters are available for the species in **www.sealifebase.org** (see Palomares and Pauly, 2009).

Species	N	Sex	a	b	r^2	Remarks
Sepia aculeata		M	0.2090	2.6671		1985-1989; east coast, India; Indian Ocean; Rao *et al.* (1993)
		F	0.1913	2.7427		1985-1989; east coast, India; Indian Ocean; Rao *et al.* (1993)
		M	0.1457	2.6070		Gulf of Thailand, Pacific Ocean; Supongpan and Kongmuag (1976, 1976a; in Chullasorn and Martosubroto, 1986)
		F	0.2320	2.6770		Gulf of Thailand, Pacific Ocean; Supongpan and Kongmuag (1976, 1976a; in Chullasorn and Martosubroto, 1986)
	281	M	0.4838	2.3852	0.937	Apr. 1982-Mar. 1986 Mangalore, Kartanaka, India; Indian Ocean; Rao (1997)
	396	F	0.1950	2.5033	0.967	Apr. 1982-Mar. 1987; Mangalore, Kartanaka, India; Indian Ocean; Rao (1997)
	82	IM	0.1402	2.9119	0.890	Apr. 1982-Mar. 1988; Mangalore, Kartanaka, India; Indian Ocean; Rao (1997)
	66	IF	0.1064	3.2075	0.930	Apr. 1982-Mar. 1989; Mangalore, Kartanaka, India; Indian Ocean; Rao (1997)
		M	0.2752	2.5974		1985-1989; west coast, India; Indian Ocean; Rao *et al.* (1993)
		F	0.3145	2.5562		1985-1989; west coast, India; Indian Ocean; Rao *et al.* (1993)
Sepia brevimana		M	0.2411	2.5990		Gulf of Thailand; Pacific Ocean; Chotiyaputta (1982; in Chullasorn and Martosubroto, 1986)
		F	0.2705	2.5490		Gulf of Thailand; Pacific Ocean; Chotiyaputta (1982; in Chullasorn and Martosubroto, 1986)
Sepia dollfusi	960	B	0.1886	3.0000		a from mean cf; lengths 5-14 cm; weights 36.4-405 g; Oct 1994-Apr 1996; Suez Canal, Indian Ocean; Gabr *et al.* (1998)
	700	M	0.5100	2.4200	0.960	lengths 1-14 cm; Suez Canal Indian Ocean; Gabr *et al.* (1999b)
	900	F	0.3600	2.6300	0.980	lengths 1-14 cm; Suez Canal Indian Ocean; Gabr *et al.* (1999b)
Sepia elegans	63	M	0.2680	2.3440		lengths 2.33-5.42 cm; weights 1.9-13.1 g; May 1999; Mola di Bari, Itally, Adriatic Sea; Bello (2006)
	65	F	0.2360	2.5140		lengths 3.07-6.37 cm; weights 3.9-27.4 g; May 1999; Mola di Bari, Itally, Adriatic Sea; Bello (2006)
Sepia officinalis		F	0.1235	3.0000		a from mean cf; lengths 8-247 cm; weights 100-1908 g; Jan 17-Feb 2, 2002; Aegean Sea; Laptikhovsky *et al.* (2003)
Sepia officinalis	246	U	0.1304	3.0000		a from mean cf; lengths 6-18 cm; weights 43-652.3 g; Sept 2002-Mar 2004; Antalya Bay, Turkey from Guven *et al.* (2007)
		U	0.2204	2.7730		Baltic Sea; Manfrin Piccinetti and Giovanardi (1984)
	512	M	0.3049	2.6390		Apr. 1994-Mar. 1996; English Channel; Atlantic Ocean; Dunn (1999)
	519	F	0.2427	2.7830		Apr. 1994-Mar. 1996; English Channel; Atlantic Ocean; Dunn (1999)
	1031	B	0.0010	2.5640		Apr. 1994-Mar. 1996; English Channel; Atlantic Ocean; Dunn (1999)
	89	M	0.4656	2.3466	0.954	lengths 2.8-15.6 cm; Sado Estuary, Portugal; Atlantic Ocean; Neves *et al.* (2009)
	106	F	0.0692	3.1547	0.988	lengths 2.8-16.5 cm; Sado Estuary, Portugal; Atlantic Ocean; Neves *et al.* (2009)

Table 1. (Continued).

Sepia orbignyana	61	M	0.2320	2.5200		lengths 1.76-8.1 cm; weights 1.2-44.9 g; May 1999; Mola di Bari, Italy, Adriatic Sea; Bello (2006)
	63	F	0.2200	2.5940		lengths 2.51-9.25 cm; weights 2.5-70.3 g; May 1999; Mola di Bari, Italy, Adriatic Sea; Bello (2006)
Sepia pharaonis		M	0.2427	2.6000		lengths 9-15 cm; east coast, India; Indian Ocean; Nair *et al.* (1993)
		F	0.2384	2.6286		lengths 9-17 cm; east coast, India; Indian Oceanl; Nair *et al.* (1993)
		M	0.2571	2.6290		Gulf of Thailand; Pacific Ocean; Chotiyaputta (1982; in Chullasorn and Martosubroto, 1986).
		F	0.2869	2.6090		Gulf of Thailand; Pacific Ocean; Chotiyaputta (1982; in Chullasorn and Martosubroto, 1986).
		B	0.1058	3.0000		a from mean cf; lengths 9-24 cm; weights 100-1216 g; Oct. 1994-Apr. 1996; Suez Canal; Indian Ocean; Gabr *et al.* (1998)
	966	F	0.2700	2.6500	0.990	Sept. 1994-Apr. 1996; Suez Canal; Indian Ocean; Gabr *et al.* (1999a)
	723	M	0.2800	2.6000	0.990	Sept. 1994-Apr. 1996; Suez Canal; Indian Ocean; Gabr *et al.* (1999a)
		M	0.3166	2.5058		lengths 13-21 cm; west coast, India; Indian Ocean; Silas *et al.* (1986)
		F	0.2563	2.5478		lengths 15-23 cm; west coast, India; Indian Ocean; Silas *et al.* (1986)
		U	0.2777	2.6930		Jun-Nov 1979; Yemen; Indian Ocean; Ayoma *et al.* (1989)
Sepia recurvirostra		M	0.4357	2.3690		lengths 3.2-12.3 cm; Gulf of Thailand; Pacific Ocean; Supongpan and Kongmuag, (1976, 1976a); Chotiyaputta (1982); in Chullasorn and Martosubroto (1986)
		F	0.3613	2.4680		lengths 3.2-12.3 cm; Gulf of Thailand; Pacific Ocean; Supongpan and Kongmuag, (1976, 1976a); Chotiyaputta (1982); in Chullasorn and Martosubroto (1986)
Sepiella inermis	42	M	0.9372	1.9320		lengths 2.1-11.2 cm;.Mandapam and Rameswaram, India; Indian Ocean; Unnithan (1982)
	92	F	0.5909	2.3080		lengths 6.9-7.1 cm, Mandapam and Rameswaram, India; Indian Ocean; Unnithan (1982)

Table 2. Growth parameters (L_∞, K), total mortality (expressed as Z/K; resulting from the Powell-Wetherall method of estimating L_∞), reproduction load, length at first maturity, spawning season and fecundity data for 10 species of *Sepia* from 79 populations from the Pacific, Indian and Atlantic Oceans. Length types: mDML=mid-dorsal mantle length; DML: dorsal mantle length; ML= mantle length. All lengths are expressed in cm. Sex: F=females; M=males; U=unsexed; B=mixed. Rn is the score obtained by fitting growth curves to monthly length-frequency data using the ELEFANI software (Pauly and David, 1981) while r is the regression coefficient of the Powell-Wetherall routine (Wetherall *et al.*, 1987). 'Repro. load' is the reproductive load (Cushing, 1982), here estimated as L_m/L_∞. Θ' is the growth performance index from $\log K+2*\log L_\infty$ (Pauly and Munro, 1984). L_m is the mantle length at first maturity and may be given as a range. These parameters are available for the species in **www.sealifebase.org** (see Palomares and Pauly, 2009).

Species	N	Type	Sex	L_∞	K (Z/K)	Rn (r)	Θ'	Repro. load	L_m (range)	Spawning season (month)	Fecundity	Remarks
Sepia aculeata		mDML	F						13			1985-1989; Cochin and Bombay, India; Silas *et al.* (1986)
		mDML	M						12.4			Cochin, India ; Silas *et al.* (1986)
		mDML	B	20.30	0.90		2.57	0.96	19.5 (18-21)	All year round		east coast, India; VBGF parameters from Rao *et al.* (1993)
		mDML	U						19.5 (7-19)			east coast, India; Silas *et al.* (1986)
		mDML	M						7			east coast, India; Silas *et al.* (1986)
		mDML	B						8.1	All year round; Mar.-Apr., Jul.-Sept.	650-3900	Gulf of Thailand; Supongpan and Komgung (1976, 1976a)
		mDML	M	12.37	(1.68)	(-0.909)		0.57	7			Jan., Apr., Jul., Oct., 2002; Gulf of Thailand; L_∞ from length frequency analysis of data from Jindalikit *et al.* (2005; Fig. 5, p. 280)
	132	mDML	F	16.91	(2.83)	(-0.989)		0.35	6			Jan., Apr., Jul., Oct., 2002; Gulf of Thailand; L_∞ from length frequency analysis of data Jindalikit *et al.* (2005; Fig. 5, p. 280)
	220	mDML	B	16.10	(0.98)	(-0.988)						Jan., Apr., Jul., Oct., 2002; Gulf of Thailand; L_∞ from length frequency analysis of data Jindalikit *et al.* (2005; Fig. 5, p. 280)
		mDML	B						8.5 (8-9)			1986-1988 ; Kakinada, India; Silas *et al.* (1986)
		mDML	M						10			Madras, India; Silas *et al.* (1986).
		mDML	F						11.8			Madras, India; Silas *et al.* (1986).
		mDML	M						8.3			Mandapan, India; Silas *et al.* (1986).
		mDML	F						11			Mandapan, India; Silas *et al.* (1986).
		mDML	B						8.5 (8-9)			1982-1986; Mangalore, Kartanaka, India; Silas *et al.* (1986)
	825	DML	B	23.10	1.49		2.90	0.37	8.6			Apr. 1982-Mar. 1986; Mangalore, Kartanaka, India; VBGF parameters from Rao (1997; Fig. 8, p. 252)
	396	DML	F							Oct.-Mar.	206-1568	Apr. 1982-Mar. 1986; Mangalore, Kartanaka, India; Rao (1997)
		DML	U									southeast coast, India; Silas *et al.* (1986)

Table 2. (Continued).

Sepia aculeata		DML	M						7.7			Visakhapatnam, India; Silas *et al.* (1986)
		DML	F						10.2			Visakhapatnam, India; Silas *et al.* (1986)
		mDML	M	20.60	1.10		2.67	1.06	21.8 (19-24.5)	All year round		1985-1989; west coast, India; VBGF parameters from Rao *et al.* (1993)
		mDML	F	20.50	1.00		2.62	1.09	22.3 (20-24.5)	All year round		1985-1989; west coast, India; VBGF parameters from Rao *et al.* (1993)
		mDML	U						14.5 (9-20)			west coast, India; VBGF parameters from Rao *et al.* (1993)
Sepia bertheloti			U								50-100	Roper *et al.* (1984; in Caddy 1996)
Sepia brevimana		mDML	M									Gulf of Thailand; Chotiyaputta (1982).
		mDML	F									Gulf of Thailand; Chotiyaputta (1982).
		mDML	B								3312-6565	Gulf of Thailand; Chotiyaputta (1982).
Sepia dollfusi	459	ML	M	14.00	(0.99)	(-1)		0.54	9.5 (5-14)			Oct. 1994-Apr. 1996; Suez Canal, Indian Ocean; L_∞ from length frequency analysis of data from Gabr *et al.* (1998; Fig. 4, p. 106)
	501	ML	F	14.99	(0.98)	(-1)		0.56	8.5 (8-9)	Jan.-Apr.	30-273	Oct. 1994-Apr. 1996; Suez Canal, Indian Ocean; L_∞ from length frequency analysis of data from Gabr *et al.* (1998; Fig. 4, p. 106)
	960	ML	B	14.76	(0.95)	(-0.998)			9.5 (5-14)			Oct. 1994-Apr. 1996; Suez Canal, Indian Ocean; L_∞ from length frequency analysis of data from Gabr *et al.* (1998; Fig. 4, p. 106)
	900	DML	F							Dec.-Apr.		Nov. 1994-Apr. 1996; Suez Canal, Indian Ocean; Gabr *et al.* (1999b).
Sepia hierredda		DML	F								250-1400	Rao (1997)
Sepia officinalis			U								200-550	Mature ova only; Mangold-Wirz (1963)
		ML	F								99-543	Jan. 17-Feb. 2, 2002; Aegean Sea; mean L_m from Laptikhovsky *et al.* (2003)
	246	ML	U	14.60	(1.79)	(-0.994)						Sept. 2002-Mar. 2004; Antalya Bay, Turkey; L_∞ from length frequency analysis of data from Guven *et al.* (2007; Fig. 1, p. 494)
	244	ML	F	14.53	(1.59)	(-0.991)						Sept. 2002-Mar. 2004; Antalya Bay, Turkey; L_∞ from length frequency analysis of data from Guven *et al.* (2007; Fig. 1, p. 494)
	244	ML	M	14.10	(1.49)	(-0.977)						Sept. 2002-Mar. 2004; Antalya Bay, Turkey; L_∞ from length frequency analysis of data from Guven *et al.* (2007; Fig. 1, p. 494)

Table 2. (Continued).

Sepia officinalis	1002	DML	B	39.00	0.59	0.53	2.95					Jun. 1988-Jun. 1990; Bay of Biscay, France; L∞ and K from length frequency analysis of data from Gauvrit *et al.* (1997; Fig. 2, p. 21)
	512	ML	M	33.00	1.45	0.30	3.20	0.20	6.7 (8.1-17)	Feb.-Mar. (2nd year)		Apr. 1994-Mar. 1996; English Channel; L∞ and K from length frequency analysis of data from Dunn (1999; Fig. 7, p. 285)
	519	ML	F	28.38	1.33	0.64	3.03		18.6 (14.2-23)	May-Oct. (2nd year)		Apr. 1994-Mar. 1996; English Channel; L∞ and K from length frequency analysis of data from Dunn (1999; Fig. 8, p. 286)
	1031	ML	B	32.20	1.30	0.34	3.13					Apr. 1994-Mar. 1996; English Channel; L∞ and K from length frequency analysis of data from Dunn (1999; Fig. 7 & 8, p. 285-6)
	326	DML	IU	8.21	0.09		0.76					2000; English Channel; VBGF parameters of juveniles from Challier *et al.* (2005; Tab. 4, p. 1678); hatching length=0.3 mm
	374	DML	IU	9.21	0.06		0.71					2002; English Channel; VBGF parameters of juveniles from Challier *et al.* (2005; Tab. 4, p. 1678); hatching length=1.5
	2232	DML	U	35.63	(1.12)	(-0.809)						Jul. 1998-Jun. 1999; Kavala, Greece; L∞ from length frequency analysis of data from Belcari *et al.* (2002; Fig. 4, p. 193)
	7246	DML	U	21.70	(4.67)	(-0.967)						Jul. 1998-Jun. 1999; Livorno, Italy; L∞ from length frequency analysis of data from Belcari *et al.* (2002; Fig. 4, p. 193)
	89	ML	M						5.9	All year round		May 2001-Apr. 2002; Sado estuary, Portugal; Neves *et al.* (2009)
	106	ML	F						8	Feb.-Jun.		May 2001-Apr. 2002; Sado estuary, Portugal; Neves *et al.* (2009)
	195	ML	B	26.60	1.80		3.11					May 2001-Apr. 2002; Sado estuary, Portugal; L∞ and K from length frequency analysis of data from Neves *et al.* (2009; Tab. 2, p. 583)
			U								252-676	Senegal; large maturing and mature ova; Bakhayokho (1983; in Gabr *et al.* 1998)
	3475	DML	U	34.36	(7.69)	(-0.982)						Jul. 1998-Jun. 1999; Villanova, Spain; L∞ from length frequency analysis of data from Belcari *et al.* (2002; Fig. 4, p. 193)

Table 2. (Continued).

Sepia officinalis hierredda			U									150-500	English Channel; mature ova only; Richard (1971;in Gabr *et al.* 1998)
Sepia pharaonis		ML	U									1000-2000	Boletzky (1975, 1987; in Gabr *et al.* 1998)
		ML	U	38.60	0.46		2.84						Mar.-Apr. 2003; Aden-Abyan area, Yemen; L_∞ and K from length frequency analysis of data from Abdul-Wahab (2003; Fig. 4, p. 12)
		mDML	M	32.00									Cochin, India; Silas *et al.* (1986; in Nair *et al.* 1993).
		mDML	F	29.60									Cochin, India; Silas *et al.* (1986); M=1.08-1.8 year^{-1}; F=1.65-2.9 year^{-1} for 17 cm
		DML	M	27.00	0.94		2.84		12				East coast, India; VBGF parameters from Nair *et al.* (1993) ; M=1.08-1.8 year^{-1}; F=1.65-2.9 year^{-1} for 17 cm
		DML	F	23.00	1.00		2.72		12.9 (11.9-12.1)				East coast, India; VBGF parameters from Nair *et al.* (1993); M=1.08-1.8 year^{-1}; F=1.65-2.9 year^{-1} for 17 cm
			B						14.3	All year round; Jan., Jul.		780-2500	Gulf of Thailand; Chotiyaputta (1982).
			U							Mar.-May			Hong Kong; Voss and William (1971, in Nair *et al.* 1993)
		mDML	M	27.00									Madras, India ; Silas *et al.* (1986, in Nair *et al.* 1993)
		mDML	F	23.00									Madras, India ; Silas *et al.* (1986, in Nair *et al.* 1993)
			U							Aug.-Oct.			Red Sea; Sanders (1981, in Nair *et al.* 1993)
	1096	ML	M	24.95	(1.72)	(-0.964)		0.24	6.1 (4-20)	Mar.-Jun.			Oct. 1994-Apr. 1996; Suez Canal, Indian Ocean;L_∞ from length frequency analysis of data from Gabr *et al.* (1998; Fig. 4, p. 106)
	1329	ML	F	21.55	(1.09)	(-1.087)		0.57	12.2 (5-24)			517-1525	Oct. 1994-Apr. 1996; Suez Canal, Indian Ocean; L_∞ from length frequency analysis of data from Gabr *et al.* (1998; Fig. 4, p. 106)
		ML	B	26.52	(3.07)	(-0.831)							Oct. 1994-Apr. 1996; Suez Canal, Indian Ocean; L_∞ from length frequency analysis of data from Gabr *et al.* (1998; Fig. 4, p. 106).
		mDML	M										Visakhapatnam, India ; Silas *et al.* (1986, in Nair *et al.* 1993).
		mDML	M	36.50									Vizhinjam, India, Silas *et al.* (1986, in Nair *et al.* 1993).
		mDML	F	34.20									Vizhinjam, India ; Silas *et al.* (1986)
		DML	U							Oct.-Apr. (may extend to Aug.)			West and east coast, India; Silas *et al.* (1986).

Table 2. (Continued).

Sepia pharaonis		DML	M	32.00	0.72		2.87					West coast, India; VBGF parameters from Nair *et al.* (1993).
		DML	F	29.60	0.82		2.86	0.54	15.9 (15.7-16)			West coast, India; VBGF parameters from Nair *et al.* (1993)
		ML	B	45.90	0.85	0.32	3.25					Jun.-Nov. 1979; Yemen; L_∞ and K from length frequency analysis of data from Ayomana *et al.* (1989; Fig. 10, p. 70)
Sepia recurvirostra	141	DML	B	14.65	(0.11)	(-0.998)						2002; Cochin, India; L_∞ from length frequency analysis of data from Jindalikit *et al.* (2005; Fig. 5, p. 280)
		DML	B						6.7	All year round; Feb.-Mar., Jun.-Oct.	310-1370	Gulf of Thailand; Supongpan and Kongmuag (1976, 1976a) and Chotiyaputta (1982)
	141	DML	F						6			Jan., Apr., Jul., Oct. 2002; Gulf of Thailand; Jindalikit *et al.* (2005)
Sepiella inermis	69	DML	B						5			Jan., Apr., Jul., Oct. 2002; Gulf of Thailand; Jindalikit *et al.* (2005)
	69	DML	B	14.61	(0.05)	(-0.998)						2002; Madras, India; L_∞ from length frequency analysis of data from Jindalikit *et al.* (2005; Fig. 5, p. 280).
	42	mDML	M	20.90	0.41	0.35	2.25	0.24	5			Jan. 1973-May 1974; Mandapam and Rameswaram, India; L_∞ and K from length frequency analysis of data from Unnithan (1982; Fig. 2, p. 104).
	92	mDML	F						3.1		470-850	Jan. 1973-May 1974; Mandapam and Rameswaram, India; Unnithan (1982).

Table 3. Indo-Pacific species of *Sepia* with length ranges of 10-20 cm. Data assembled from SeaLifeBase (www.sealifebase.org; Palomares and Pauly 2010).

Species	Mantle length (cm)	Distribution	Source
S. andreana	12.0	Western Pacific Ocean: Philippines, China and Japan	Roper *et al.* (1984)
S. aureomaculata	16.0	Northwest Pacific: Japan	Jereb and Roper (2005)
S. brevimana	11.0	Indo-West Pacific: Southern India to Anaman Sea, Gulf of Tonkin, Java, Sulu and Celebes seas	Roper *et al.* (1984); Jereb and Roper (2005)
S. cultrata	12.0	Indo-West Pacific: Australia	Jereb and Roper (2005)
S. elliptica	17.5	Indo-West Pacific: Austalia, New Guinea, South China Sea and possibly the Philippines	Jereb and Roper (2005)
S. esculenta	18.0	Western Pacific: South and East China seas, Japan to Philippines and Indonesia	Roper *et al.* (1984)
S. foliopeza	11.0	Northwest Pacific: East China Sea and Taiwan	Jereb and Roper (2005)
S. opipara	15.0	Eastern Indian Ocean and Western Pacific: Australia	Jereb and Roper (2005)
S. papuensis	11.0	Indo-West Pacific: Australia to Philippines	Jereb and Roper (2005)
S. peterseni	12.0	Southwest Pacific: Japan to South Korea	Jereb and Roper (2005)
S. plangon	13.5	Western Pacific: Australia and Papua New Guinea	Jereb and Roper (2005)
S. recurvirostra	17.0	Indo-West Pacific: China to the Philippines, Indonesia and Pakistan	Roper *et al.* (1984)
S. rozella	14.0	Southwest Pacific: Australia	Jereb and Roper (2005)
S. smithi	14.0	Indo-Pacific: Northern Australia	Jereb and Roper (2005)
S. stellifera	12.0	Indo-West Pacific: Arabian Sea and west coast of India to Viet Nam	Jereb and Roper (2005)
S. tenuipes	10.5	Northwest Pacific: Japan and Korea to East China Sea	Jereb and Roper (2005)
S. whitleyana	17.4	Western Central Pacific; Southwest Pacific: Australia	Jereb and Roper (2005)

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REFERENCES

Abdul-Wahab, M.M., 2003. A study on stock assessment and fisheries management of invertebrates in Yemen waters. The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden progress report, Marine Science and Resources Research Center Aden, Republic of Yemen, 22 pp.

Alves, D.M., Cristo, M., Sendão, J., Borges, T.C., 2003. Diet of the cuttlefish *Sepia officinalis* (Cephalopoda: Sepiidae) off the south coast of Portugal (eastern Algarve). *J. of the Marine Biological Association of the United Kingdom* 86, 429-436.

Amir, O.A., Berggren, P., Ndaro, S.G.M., Jiddawi, N.S., 2005. Feeding ecology of the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) incidentally caught in the gillnet fisheries off Zanzibar, Tanzania. *Estuarine, Coastal and Shelf Science* 63(3), 429-437.

Ayomana, T., Nguyen, T., 1989. Stock assessment of cuttlefish off the coast of the people's democratic republic of Yemen. *Shimonoseki Univ. of Fisheries* 37(2-3), 61-112.

Bakhayokho, M., 1983. Biology of the cuttlefish *Sepia officinalis* hierradda off the Sengalese coast. *In:* Caddy, F.D. (ed.), *Advances in Assessment of World Cephalopod Resource*. FAO Fish. Tech. 231, 204-263.

Barros, N.B., Jefferson, T.A., Parsons, E.C.M., 2002. Food habits of finless porpoises (*Neophocaena phocaenoides)* in Hong Kong waters. *The Raffles Bulletin of Zoology* Supp. 10, 115-123.

Belcari, P., Sartor, P., Sanchez, P., Demestre, M., Tsangridis, A., Leondarakis, P., Lefkaditou, E., Papaconstantinou, C., 2002. Exploitation patterns of the cutllefish, *Sepia officinalis* (Cephalopoda, Sepiidae), in the Mediterranean Sea. *Bulletin of Marine Science* 71(1), 187-196.

Belo, G., 2006. Tentcle club length and body condition in the cuttlefishes *Sepia elegans* Blainville, 1827 and *Sepia orbignyana* Férussac, 1826 (Cephalopoda: Sepiidae) *Zoologischer Anzeiger* 244, 187-192.

Blaber, S.J.M., Wassenberg, T.J., 1989. Feeding ecology of the piscivorous birds *Phalacrocorax variu*, *P. melanoleucos* and *Sterna bergii* in Moreton Bay, Australia. *Marine Biology* 101, 1-10.

Blanc, A., Daguzan, J., 2000. Size selectivity in the diet of the young cuttlefish *Sepia officinalis* (Mollusca: Sepiidae). *J. of Marine Biological Association of the United Kingdom* 80, 1137-1138.

Boletsky, S.V., 1987. Fecundity variation in relation to intermittent or chronic spawning in the cuttlefish, *Sepia officinalis* L. (Mollusca, Cephalopoda). *Bulletin of Marine Science* 40(2), 382-387.

Boletzky, S.V., 1975. The reproductive cycle of Sepiolidae (Mollusca, Cephalopoda). *Pubble. Staz. Zool., Napoli* 39 Supplement, 84-95.

Boyle, P.R., 1990. Cephalopod biology in the Fisheries context. *Fisheries Research* 8, 303-321.

Boyle, P.R., Rodhouse, P.R., 2005. Cephalopods: ecology and fisheries. Oxford: Blackwell Science. 452 p.

Bozzano, A., Recasens, l., Sartor, P., 1997. Diet of the european hake *Merliccius merluccius* (Pisces: Merluciidae) in the western Mediterranean (Gulf of Lions). *Scientia Marina* 61(1), 1-8.

Challier, L., Dunn, M.R., Robin, J.-P., 2005. Trends in age-at recruitment and juvenile growth of cuttlefish, *Sepia officinalis*, from the English Channel. *ICES Journal of Marine Science* 62, 1671-1682.

Chikuni, S., 1985. The fish resources of the northwest Pacific. FAO Fish. Tech. Pap. 266, 190p.

Chotiyaputta, C., 1992. Squid fishery of Thailand. FAO Fish. Rep. 275, 124-34.

Chotiyaputta, C., Nootmorn, P., Jirapunpipat, K., 2002. Review of cephalopod fishery production and long term changes in fish communities in the Gulf of Thailand. *Bulletin of Marine Science* 71(1), 223-238.

Chullasorn, S., Martosubroto, P., 1986. Distribution and important biological features of coastal fish resources in Southeast Asia. FAO fisheries technical paper 278, 84 p.

Croxall, J.P., Prince, P.A., 1996. Cephalopods as prey. I. Seabirds. Philosophical Transactions, *Biological Sciences 351(1346), 1023-1043.*

Cushing, D.H., 1981. Fisheries Biology: A Study in Population Dynamics. 2nd Ed. University of Wisconsin Press, Madison. 295 p.

Domingues, P., Sykes, A., Sommerfield, A., Almansa, E., Lorenzo, A., Andrade, J.P., 2004. Growth and survival of cuttlefish (*Sepia officinalis*) of different ages fed crustaceans and fish. Effects of frozen and live prey. *Aquaculture* 229, 239-254.

Dunn, M.R., 1999. Aspects of the stock dynamics and exploitation of cuttlefish, *Sepia officinalis* (Linnaeus, 1758), in the English Channel. *Fisheries Research* 40, 277-293.

Fox, M.G. 1994. Growth, density, and interspecific influences on pumpkinseed sunfish life histories. *Ecology*, 75, 1157–1171.

Fox, M.G., and Keast, A. 1991. Effect of overwinter mortality on reproductive life history characteristics of pumpkinseed (*Lepomis gibbosus*) populations. *Canadian J. of Fisheries and Aquatic Science* 48, 1792–1799.

Froese, R., Binohlan, C., 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *J. of Fish Biology* 56:758-773.

Froese, R., Palomares, M.L.D., Pauly, D., 2000. Estimation of life history key facts of fishes. Available at http//www.fishbase.org/download/keyfacts.zip Version of 14.2.2000 (accessed on June 30, 2010)

Gabr, H.R., Hanlon, R.T., Hanafy, M.H., El-Etreby, S.G., 1999. Reproductive versus somatic tissue allocation in the cuttlefish *Sepia dollfusi* Adam (1941). *Bulletin of Marine Science* 65, 159-73.

Gabr, H.R., Hanlon, R.T., Hanafy, M.H., El-Etreby, S.G., 1998. Maturation, fecundity and seasonality of reproduction of two commercially valuable cuttlefish, *Sepia pharaonis* and *S. dollfusi*, in the Suez Canal. *Fisheries Research* 36, 99-115.

Gauvrit, E., Le Goff, R., Daguzan, J., 1997. Reproductive cycle of the cuttlefish, *Sepia officinalis* (L.) in the northern part of the Bay of Biscay. *J. of Molluscan Studies* 63, 19-28.

Grigoriou, P., Richardson, C.A., 2004. Aspects if the growth of cultured cuttlefish *Sepia officinalis* (Linnaeus, 1758). *Aquaculture Research* 35, 1141-1148.

Guven, O., Özbaş, M., 2007. Reproduction of comon cuttlefish (*Sepia officinalis* L., 1758) in Antalya Bay. *Rapports de la Commission Internationale sur la Mer Médit.*, 38, 494.

Hutchings, J.A., 1993. Adaptive life histories affected by age-specific survival and growth rate. *Ecology* 74**,** 673–684.

Hylleberg, J., Nateewathana, A., 1991. Morphological, internal anatomy, and biometrics of the cephalopod *Idiosepius biserialis* Voss, 1962, a new record for the Andaman Sea. *Phuket Marine Biological Center Research Bulletin* 56, 1-9.

Hylleberg, J., Nateewathana, A., 1991. Redescription of *Idiosepius pygmaeus* Steenstrup,1881. (Cephalopoda : Idiosepiidae), with mention of additional morphological characters. *Phuket Marine Biological Center Research Bulletin* 55, 33-42.

Ikeda, Y., Arai, N., Sakarnoto, W., Nateewathana, A., Muruyama, T., Yatsu, A., Yoshida, K., 1996. Trace element analysis of squid statolith-a comparison between Ommastrephidae and Loligonidae. Presented at PIXE Symposium, Kyoto, October 1996.

Intajarurnsan, J., 2003. Effects of cooking on cholesterol content of various cephalopod and a survey of cephalopod consumption. M.Sc. thesis, Mahidol University, 160 p.

Jereb, P., Roper, C.F.E. (Eds.), 2005. *Cephalopods of the world. An annotated and illustrated catalogue of species known to date. Volume 1. Chambered nautiluses and sepioids (Nautilidae, Sepiidae, Sepiolidae, Sepiadariidae, Idiosepiidae and Spirulidae).* FAO Species Catalogue for Fishery Purposes 1(4) Rome, FAO, 262 p.

Jindalikit, J., Sereeruk, K., 2005. Distribution and spawning grounds of cuttlefish in the upper Gulf of Thailand. *Phuket Marine Biological Center Research Bulletin* 66, 275-282.

Laptikhovsky, V., Salman, A., Onsoy, B., Katagan, T., 2003. Fecundity of the common cuttlefish, *Sepia officinalis* L. (Cephalopoda, Sepiidae): a new look at an old problem. *Scientia Marina* 67(3), 279-284.

Lefkaditou, E., Mytilineou, Ch. Maiorano, P., D'Onghia, G., 2003. Cephalopod species captured by deep-water exploratory trawling in the northeastern Ionian Sea. *J. of the Northwest Atlantic Fisheries Science* 31, 431-440.

Luther, G., 1985. Food and feeding habits of the two species of *Chirocentrus* from Mandapam. *Indian J. of Fisheries* 32(4), 439-446.

Magnan, P., Proulx, R., Plante, M., 2005. Integrating the effects od fish exploitation and interspecific competition into current life history theories: an example with lacustrine brook trout (*Salvelinus fontalis)* populations. *Canadian J. of Fisheries and Aquatic Science* 62, 747-757.

Manfrin Piccinetti, G., Giovanardi, O., 1984. Données sur la biologie de *Sepia officinalis* L. dans l'Adriatique obtenues lors de expéditions pipeta. In: *Technical Consultation on Stock Assessment in the Adriatic*, 3, Fano (Italy), 6 Jun 1983. FAO Fisheries Report 290, pp. 135-138. Fishery Policy and Planning Div. FAO, Rome, Italy.

Mangold, K., Boletzky, S.V., 1987. Céphalopodes. *In:* Fischer, W., Bauchot, M.L., Schneider, M. (eds), *Fiches d'identification des especes pour les besoins de la pêche : Méditerranèe et Mer Noire*. V. 2. Vertebrés, pp. 633-714. FAO, Rome, Italy.

Mangold-Wirz, K., 1963. Biologie des céphalopodes benthiques et nectoniques de la Mer Catalane. *Vie Millieu*, 13 Supplement, 1-285.

Muthiah, C. , 1982. Study on the biology of *Johnieops vogleri* (Bleeker) of Bombay waters. *Indian J. of Fisheries*. 29(1 & 2), 118-133.

Nair, K.P., Srinath, M., Meiyappan, M.M., Rao, K.S., Sarvesan, R., Vidyasagar, K., Sundaram, K.S., Rao, G.S., Lipton, A.P., Natarajan, P., Radhakrishnan, G., Mohamed, K.S., Narasimham, K.A., Balan, K., Kripa, V., Sathianandan, T.V., 1993. Stock assessment of the pharaoh cuttlefish *Sepia pharaonis*. *Indian J. of Fisheries* 40 (1&2), 85-94.

Nateewathana, A., 1996. The Sepiidae (Cephalopoda) of the Andaman Sea, Thailand. *Phuket Marine Biological Center Special Publication* 16, pp. 145-176.

Nateewathana, A., Hylleberg, J., 1989. First record of oceanic squid *Thysanoteuthis rhombus* Troschel, 1857 (Cephalopoda:Teuthoidea) in Thai waters. *The Natural History Bulletin of the Siam Society* 37(2), 227-233.

Neves, A., Cabral, H., Sequeira, V., Figueiredo, I., Moura, T., Gordo, L.S., 2009. Distribution patterns and reproduction of the cuttlefish, *Sepia officinalis* in the Sado estuary (Portugal). *J. of the Marine Biological Association of the United Kingdom* 89(3), 579-584.

Nootmorn, P., Chotiyaputta, C., 2002. Species diversity, biomass and community structure of cephalopods off Adang-rawi archipelago, Thailand. *Bulletin of Marine Science* 71(2) 591-600.

Norman, M.D., Lu, C.C., 2000. Preliminary checklist of the cephalopods of the South China Sea. *The Raffles Bulletin of Zoology* Supp. 8: 539-567.

Okutani, T., 2001. Ika World (Cuttlefish and Squids of the world in color). Available at http, //www.zen-ika.com/zukan/01-10/p05.html (accessed on October 2004).

Okutani, T., 2005. Past, present, and future studies on cephalopod diversity in tropical west Pacific. *Phuket Marine Biological Center Research Bulletin* 66, 39-50.

Pauly, D., 1984. *Fish population dynamics in tropical waters: A manual for use with programmable calculators*. ICLARM Studies and Reviews 8. ICLARM, Manila, Philippines. 325 pp.

Pauly, D., 1979. Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. Ber. Inst. Meereskd. Christian-Albrechts Univ. Kiel 63, 156 p.

Pauly, D., David, N., 1981. ELEFAN I, a BASIC program for the objective extraction of growth parameters from length-frequencies data. *Meeresforschung* 28(4): 205-211.

Pauly, D., Munro, J.L., 1984. Once more on growth comparison in fish and invertebrates. *Fishbyte* 2(1):21.

Pierce, G.J., Guerra, A., 1994. Stock assessment methods used for cephalopod fisheries. *Fisheries Research* 21, 255-285.

Rao, G.S., 1997. Aspects of biology and exploitation of *Sepia aculeata* Orbigny from Mangalore area, Karnataka. *Indian J. of Fisheries* 44(3), 247-254.

Rao, K.V., 1981. Food and feeding of lizard fishes (*Saurida* spp.) from the northwestern part of Bay of Bengal. *Indian J. of Fisheries* 28(1&2), 47-64.

Rao, K.S., Srinath, M., Meiyappan, M.M.. Nair, K.P., Sarvesan, R., Rao, G.S., Natarajan, P., Vidyasagar, K., Sundaram, K.S., Upton, A.P., Radhakrishnan, O., Narasimha, K.A., Mohamed, K.S., Balan, k., Kripa, V. and Sathianandan, T.V., 1993. Stock assessment of the needdle cuttlefish *Sepia aculeate* Orbigny. *Indian J. of Fisheries* 40(1), 95-103.

Richard, A. 1966a, La temperature, facteur externe essential de croissance pour le céphalopode *Sepia officinalis* L. *Conte Rendue de l'Académie de Science Paris* 263(D), 1138-1141.

Richard, A. 1966b. Action de la temperature sur l'évolution génitale de *Sepia officinalis* L. *Conte Rendue de l'Académie de Science Paris* 263(t), 1998-2001.

Richard, A., 1971. Contribution à l'étude experiméntale de la croissance et de la maturation sexuelle de *Sepia officinalis* L. (Mollusque Céphalopode). Thèse de Doctorat Nat., Univ. Lille, 264 p.

Rodhouse, P.G., Robinson, K., Gajdatsy, S.B. Daly, H.I., Ashmore, M.J.S., 1994. Growth, age structure and environmental historu in the cephalopod *Martialia hyadesi* (Teuthoidea: Ommastrephidae) at the Antarctic Polar Frontal Zone and on the Patagonian Shelf Edge. *Antarctic Science* 6, 259-267.

Roper, C. F. E., Sweeney, M.J., Nauen, C.E., 1984. Species Catalogue. Vol 3 Cephalopods of the World. An annotated and illustrated catalogue of species of interest to fisheries. FAO Fisheries Synopsis 123(3). FAO, Rome, Italy, 127 p.

Sanders, M.J., 1981. Revised stock assessment for the cuttlefish *Sepia pharaonis*, taken off the coast of the People's Democratic Republic of Yemen. Project for the development of fisheries in areas of the Red Sea and Gulf of Aden, Cairo, Egypt. RAB/77/008/13, 44 p.

Silas, E.G., Satyanarayana, R.K., Sarvesan, R., Prabhakaran N.K., Vidyasagar, K., Meiyappan, M.M., Appanna S.Y. and Narayana, R.B., 1986. Some aspects of the biology of cuttlefishes. *Bulletin Central Marine Fisheries Research Institute* 37, 49-70.

Sivashanthini, K. Charles, G.A., Thulasitha, W.S., 2009. Length-weight relationship and growth pattern of *Sepioteuthis lessoniana* Lesson, 1830 (Cephalopoda:Teuthida) from the Jaffna Lagoon. *Sri Lanka J. of Biological Sciences* 9(4), 357-361.

Supongpan, M., Kongmuag, K., 1976a. Study on the length-weight relationship of the squids and cuttlefish in the Gulf of Thailand. Annu. Rep. Invertebr. Fish. Unit Mar. Fish. Div. Bangkok, 18p. [In Thai]

Supongpan, M., Kongmuag, K., 1976b. Study on the sex ratio of the squids and cuttlefish in the Gulf of Thailand. Annu. Rep. Invertebr. Fish. Unit Mar. Fish. Div. Bangkok, 42 p. [In Thai]

Tan, S.K., Woo, H.P.M., 2010. A preliminary checklist of the molluscs of Singapore. Raffles Museum of Biodiversity Research, 82 p.

Taniuchi, T., 1988. Aspects of reproduction and food habits of the Japanese swell shark *Cephaloscyllium umbratile* from Choshi, Japan. *Nippon Suisan Gakkaishi* 54(4), 627-633.

Unnithan, K.A., 1982. Observations on the biology of cuttlefish *Sepiella inermis* at Mandapam. *Indian J.of Fisheries 29 (1&2), 101-111.*

Van Heukelem, W.F., 1979. Environmental control of reproduction and life span in octopus, an hypothesis. In: Stancyk, S.E. (ed.) *Reproductive Ecology of Marine Invertebrates,* 123-133. Columbia, University of Carolina Press.

Voss, G.L., Williamson, G.R., 1971. *Cephalopods of Hongkong*. Government Press, HongKong, 138 p.

Wood, J., 2004. Cephalopod Page. Available at http, //is.dal.ca/~ceph/TCP/index.html#intro (accessed on October 2004).

Wetherall, J.A., Polovina, J.J., Ralston, S., 1987. Estimating growth and mortality in steady-state fish stocks from length-frequency data. In: Pauly, D., Morgan, G.R. (eds.), *Length-based Methods in Fisheries Research*, p. 53-74. ICLARM Conference Proceedings 13, Manila, Philippines.

SIZE STRUCTURE OF *ACANTHASTER PLANCI* POPULATIONS IN TUBBATAHA REEFS NATURAL PARKS, SULU SEA, PHILIPPINES[1]

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ABSTRACT

Since 2007, *Acanthaster planci* (crown-of-thorns or COT) outbreaks in Tubbataha Reefs Natural Park (TRNP, Sulu Sea, Philippines), one of UNESCO's World Heritage Site, has prompted the Tubbataha Marine Office (TMO) to conduct COT clean-up activities and invite initiatives on COT studies. This study, invited by the TMO, attempts to identify outbreak areas within the TRNP, measure the density of COTs within these areas and conduct size-frequency surveys using bucket view and SCUBA methods in three islets, i.e., North Atoll, South Atoll and Jessie Beazeley Reef. Six sites were identified where outbreaks have been reported. Total diameter and number of arms for 425 COTs were measured from 18 belt transects (30x5 m) and a COT clean-up activity. The largest individuals measured had a total diameter of 56 cm (with 15 arms) while a 43 cm individual had the most number of arms at 20 arms. Asymptotic length (L_∞=52.6 cm) and growth coefficient (K=0.0367) was estimated using the Powell-Wetherall Plot and the average growth performance index (θ') from growth parameters of COT populations in the Western Pacific region. Crown-of thorns starfishes were not widespread in the area but were observed to aggregate, average density being 0.011 ind·m^{-2} (maximum observed density of 0.547 ind·m^{-2}). This is lower compared to reported densities in similar ecosystems but is higher than the maximum sustainable density of 0.002 ind·m^{-2} estimated for a Panamian coral reef ecosystem, notably since most individuals sampled (98%) were adults, and may be enough to produce another outbreak within 2-4 years. Therefore, further monitoring of COT populations in the area is highly recommended.

INTRODUCTION

Acanthaster planci outbreaks have, since the late 1940s, devastated coral reefs across the Indo-Pacific (Shirai, 1956). Some think that outbreaks are a natural phenomenon (Vine, 1973), while others think that outbreaks are a response to exogenous factors, e.g., nutrient influx (Brodie *et al.*, 2005) from terrestrial run-off (Birkeland, 1982) and removal of natural predators (Dulvy *et al.*, 2004). The first outbreak of crown of thorns starfish, *A. planci*, in Tubbataha Reefs Natural Park (TRNP) was reported in 2007 (Dr. Theresa Aquino, Tubbataha Management Office, Puerto Princesa, Palawan, Philippines, pers. comm., 20 August 2009), and it continues, the most recent being in June 2009, when Bos (2010) reported up to 8 *A. planci* individuals per coral colony at Amos Rock (8°50.978'N, 119°53.493'E). Moran (1990) reported that the natural density of *A. planci* in a coral reef ecosystem ranges from 6-20 adults km^{-2} and that outbreak

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densities may go up to 20.6 juveniles m^{-2} or more than 1,150 adults counted over a 20-minute swim and may last for 1-5 years depending on reef complexity and food availability (Moran, 1990). In spite of the extent of this seemingly catastrophic problem, nothing is much is known of crown of thorns starfishes in the Philippines.

This study, reports on the spatial distribution and size structure of *Acanthaster planci* (Asteroida: Echinodermata) populations in Tubbataha Reefs Natural Park, Sulu Sea, Philippines and provide an overview of the extent of the most recent COT outbreak and of the size structure of this COT population. Such baseline information is important for the management of this problem, notably since the Tubbataha Reefs Natural Park is a world heritage site.

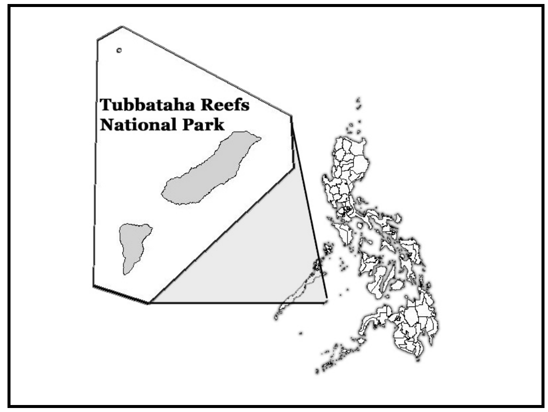

Figure 1. Map of Tubbataha Reefs' South and North atolls and Jessie Beazeley Rock, Philippines where crown of thorns survey was performed. Source of digital data: Conservation International (2008).

METHODOLOGY

Tubbataha Reefs Natural Park (Figure 1) is a 33,200 hectare park that was established under the Philippine government's Proclamation No. 306 and is protected under Presidential Decree No. 705. It is located between 8°41'33" to 9°6'5"N and 119°45'46" to 120°3'20"E in the middle of the Sulu Sea, 175 km southeast of Puerto Princesa City, Palawan Island. It contains more than 10,000 ha of coral reefs, considered by UNESCO as a World Heritage Site of global ecological importance (UNEP-WCMC, 2008).

The history of COT outbreaks within the TRNP was established through park ranger interviews and by going through a series of Tubbataha Marine Office (TMO) internal reports.

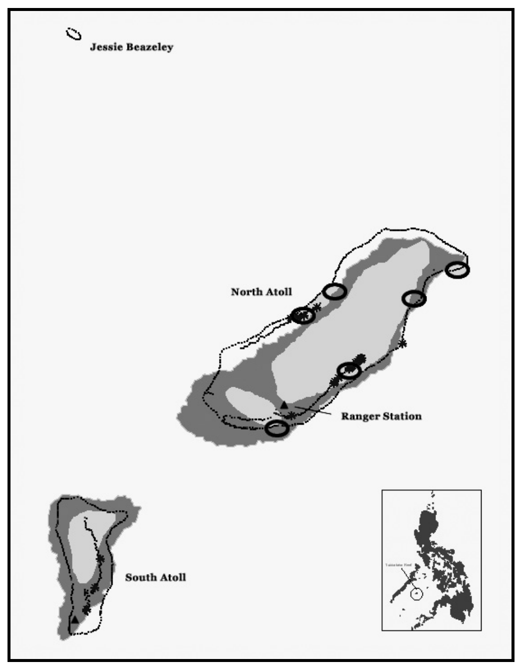

Figure 2. Bucket viewing survey path (dotted lines) and SCUBA survey areas (encircled) of the crown of thorns survey of the Tubbataha Reefs South and North Atolls and Jessie Beazeley Rock, Philippines. Areas where COT individuals were sited were marked with asterisks (*) Source of digital data: Conservation International (2008).

Tubbataha Reefs' North and South atolls and Jessie Beazeley (Figure 2) were surveyed from April 4 to May 1, 2010 using bucket view (acrylic glass bottom buckets handmade for this study) and SCUBA methods, modified from Bass and Miller's (1996) Standard Operating Procedure for COT survey (i.e., bucket view, recommended for reconnaissance, in lieu of manta tow, a method designed for small survey areas already exhibiting outbreaks). Environmental parameters were measured, i.e., temperature (°C); depth (m); wind strength and sea state based on the categories adopted from Bass and Miller (1996; see Table 1). Crown of thorns starfishes were counted along a belt transect as recommended in Hill and Wilkinson (2004), to provide density estimates while diameter and number of arms were measured/counted to provide a preliminary picture of their population structure. Sites for more detailed SCUBA surveys were selected using the bucket viewing method. Two buckets were ballasted with lead weights such that they can be held steadily on both sides of the dinghy when the bottom of the buckets were submerged 30 cm deep on the water surface. The dinghy's path was set parallel to the reef crest, close enough for the observers to see the reef slope, traveling at a speed of 3.4 km h^{-1} or slower to allow observers to see the bottom through the bucket. A Global Positioning System (GPS) receiver was used to mark the start and end of two-minute transects along the entire perimeter of the three islets, i.e., North and South atolls and

Jessie Beazeley, and to keep track of the dinghy's path. Temperature, depth, number of COTs and live hard coral cover estimates (eye-balled, as % of transect) were recorded for each transect.

The bucket view method identified three sampling sites for detailed SCUBA surveys. In addition, three sites with known COT outbreaks were included in the SCUBA survey. For each site, three 30 x 5 m transect belts surveys were performed (see Figure 2). Crown of thorns found within the transect were measured, i.e., diameter from leftmost arm tip to rightmost arm tip in cm, and number of arms were counted. The absence of a weighing scale that could be used underwater prevented the recording of individual weights.

Table 1. Categories of wind strength and sea state adopted from the standard operating procedures for crown of thorns surveys from Bass and Miller (1996, p. 9-10). Note that Bass and Miller (1996) refers to the wind strength scale used here as a modified Beaufort Scale.

Parameter	Category	Description
Wind strength	1	0-5 knots
	2	6-10 knots
	3	11-15 knots
	4	16-20 knots
	5	21-25 knots
Sea state	Calm	Mirror-like to small ripples
	Slight	Small waves, small whitecaps
	Moderate	Moderate waves, many whitecaps
	Rough	Large waves, 2-3 m whitecaps everywhere, some spray

Total diameter of COTs was used to obtain the size-frequency distribution for the surveyed populations. As all observed COTs were measured in the 6 survey sites, we assume that our data is representative of the 'outbreak' population for the TRNP as a whole and thus valid for analysis using the Powell-Wetherall method (Powell, 1979). This method estimates the von Bertalanffy parameters, asymptotic length, L_∞, or the length towards which a population can grow and the ratio of total mortality, Z, to the growth coefficient, K, expressed as Z/K, which provides a measure of how fast the population grows. Under basic assumption that the size-frequency distribution is representative of the population, i.e., sampled the breadth of the population size range, this relationship shows that the mean length of n selected individuals (L_{mean}) is a linear function of the knife-edge selection length (L'), thus, L_i-L_i'=a+b*L_i and where L_∞=a/-b and Z/K=(1+b)/-b (Pauly, 1986).

Because this was a one-time survey, and therefore not valid for length-frequency analyses as required by the ELEFAN software (Pauly, 1987) for von Bertalanffy growth parameter estimations (Bertalanffy, 1938), the value of K was obtained from the growth performance index (θ') using the relationship, θ'=logK+2*logL_∞ as defined by Pauly and Munro (1984), from DL_∞ and K data pairs obtained from other COT populations across Western Pacific Region (see Table 2).

A correlation matrix was used to identify which among the parameters measured significantly affect the number of COTs per transect area observed (defined here forth as COT density). It is expected that coral cover (though eye-balled) will have a direct relationship with the density of COTs since this is their habitat (Moran, 1990). It is also expected that in areas with regular water column exchange (through currents caused by winds and the lunar cycle), i.e., non-eutrophic habitats, will have healthier coral cover and be less prone to COT outbreaks. This follows from Bell's (1992) conclusion that high nanoplankton concentrations characteristic of eutrophic habitats can sustain *A. planci* larvae and thus promote outbreaks.

Once identified, significant independent variables were regressed with COT density to obtain a preliminary predictive equation that can be used to identify possible areas of COT outbreaks within the TRNP.

RESULTS

In his 10 years as a park ranger, Segundo Canales (Tubbataha Management Office, pers. comm., 4 April 2010) recalls observing the first COT outbreak one slow summer evening in 2007 while picking shells in knee-deep water in the lagoon northeast of the ranger station. Patches of bleached branching corals were later observed in the lagoon near the ranger station and further investigations identified COT aggregations scattered in the lagoon and outer reefs throughout the atolls. The rangers reported this to the Tubbataha Management Office (TMO), which started COT 'clean-up' drives within the TRNP. As the COT were immediately blamed for the seemingly rapid and extensive destruction of coral reefs in the TRNP, tourists and dive boat operators also started collecting COTs. Roy Magbanua (Tubbataha Management Office, pers. comm., 4 April 2010), another park ranger who worked in the TRNP for 8 years, added that they were able to collect 12,000 COTs in just three months of collections after the first sighting. The number of COT sightings has since declined (park rangers collected 2,500 in 2008; this study observed 72 with the bucket view survey and measured 425 in the SCUBA surveys), but, park rangers still observe and receive reports of aggregations from time to time.

The entire perimeter of the Tubbataha islets were reconnoitered using the bucket view method for 10 days along the coast at 0-10 m depths with water surface temperatures at 28.5-33.5°C. This reconnaissance exercise sighted 72 COTs and concluded that the COT outbreak was not horizontally spread throughout the park, but rather, form scattered aggregations.

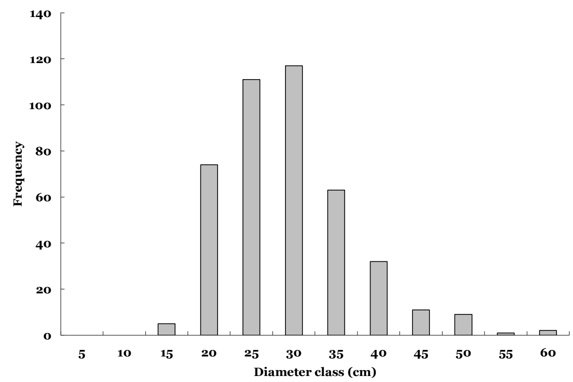

Figure 3. Size structure of crown of thorns starfish (n=425) sampled from the North and South Atolls and Jessie Beazeley islet of the Tubbataha Reefs National Park (Palawan, Philippines) in April and May 2010.

The six SCUBA sampling sites were surveyed for a week. Aggregating COTs had an average density of 0.011 indivudals m^{-2}, with maximum density observed at 0.547 indivudals m^{-2}, which is well above the sustainable density of 0.002 individual·m^{-2} (Glynn, 1973). The majority (98%) of the individuals measured were of adult size (>15 cm) (Figure 3), with diameters ranging from 13-56 cm (average of 27.3 cm +/-0.73; s.e.=0.37) and with 10-20 arms (average of 13.9 arms +/- 0.15; s.e.=0.077). The largest individual measured 56 cm had 15 arms while the individual with most number of arms (20 arms) measured 46 cm.

The diameter-frequency distribution in Figure 3 was run through the FiSAT (Gayanilo and Pauly, 1997) Powell-Wetherall routine to obtain the linear regression correlation coefficients a=13.0 and b=-0.224 (r=0.95) which led to the asymptotic diameter (D_∞) of 58 cm and Z/K=3.46. Growth parameter estimates of other COT populations in the Western Pacific Region assembled in Table 3 provided von Bertalanffy parameters for COTs with D_∞ ranging from 23.7 cm (Guam) to 44.4 cm (Davies Reef, Australia). This puts our estimate of 58 cm beyond the largest asymptotic diameter reported for this species in the Pacific Ocean. The average θ' value obtained from the 6 growth parameter estimates is 2.920 and resulted in a K value of 0.247 for the Tubbataha population.

Table 2. Von Bertalanffy growth parameters for crown of thorns starfish in the Western Pacific Region. The L_∞ estimate for Tubbataha population was obtained from the diameter-frequency distribution described in Figure 3 and K was obtained from the average θ' value of 2.008 from the Australia, Fiji and Guam populations.

Locality	Country	Year	N	D_∞	K	Source
Davies Reef (pre-outbreak cohorts)	Australia	1988-91	106	44.4	0.50	Stump, 1994
Davies Reef (post-outbreak cohorts)	Australia	1988-91	106	42.2	0.61	Stump, 1994
Hospital Point	Guam	1992	40	23.7	1.70	Stump, 1994
South Tumon Bay	Guam	1992	40	29.4	0.76	Stump, 1994
Double Reef	Guam	1992	36	31.1	0.83	Stump, 1994
Suva Reef	Fiji	1992	56	34.2	0.53	Stump, 1994
Tubbataha Reefs	Philippines	2010	425	58.0	0.25	This study

The correlation analysis (Table 3) identified temperature, wind strength and coral cover as possible variables for testing with a regression analysis on COT density. This also identified relationships between sea state and temperature, depth, wind strength and coral cover. Temperature and depth are auto-correlated, i.e., temperature decreases with depth. Similarly, wind strength and sea state are also auto-correlated, i.e., the water column is disturbed or 'shifted' by stronger winds and therefore determines sea state. Thus, we accepted the linear regression results of COT density *vs*. temperature, wind strength and coral cover. This regression, which explained 34% of the variability (r^2=0.341, s.e.=0.117, d.f.=17) is significant at P = 0.11, is expressed as: COT density = -0.7885 + 0.02894*Temp -0.1029*Wind strength +0.005481*Coral cover; where COT density is the number of COTs in a 150 m^{-2} survey area; temperature is in °C; wind strength is a rank based on Bass and Miller's (1996; see Table 1 above); coral cover is an eye-ball estimate of the live hard corals present in the 150-m^{-2} belt transects expressed in percent. The standard errors obtained for the intercept 'a' and each of the slopes (coefficient of regression 'b') of the independent variables included here are: 0.6763, 0.0240, 0.0452 and 0.0036, respectively; these are significant to P levels, 0.26, 0.25, 0.039 and 0.15, respectively.

Given that coral cover is a 'guesstimate', we dropped it from the regression analysis and rerun the analysis with surface temperature and wind strength alone as independent variables. This resulted in the relationship: COT density = -1.386 +0.06756*Temp -0.1571*Wind strength; with r^2=0.339, s.e.=31.0, d.f.=19, significant to P level=0.036 and where the intercept has s.e.=1.179, the slopes have s.e. values of 0.0394 and 0.0614, respectively, and where the intercept and slopes are significant at P levels 0.26, 0.10 and 0.02, respectively. This implies that COT density will be higher in areas with high temperature (i.e., shallow waters) and in calm areas where wind strength is between 0-5 knots.

Table 3. Correlation matrix of crown of thorns density and independent environmental variables of three islets (North and South Atolls and Jessie Beazeley) surveyed within the Tubbataha Reefs National Park (Palawan, Philippines) in April and May 2010. Environmental variables and COT density were obtained from a summary of the 425 crown of thorns in the SCUBA surveys while number of arms and diameter here were obtained from individual measures of these.

	Sea state	Temperature	Depth	Wind strength	Coral cover	COT density
Sea state	1.00					
Temperature (°C)	0.557	1.00				
Depth (m)	0.371	-0.408	1.00			
Wind strength	0.605	0.239	0.343	1.00		
Coral cover (%)	0.588	0.388	0.220	0.573	1.00	
COT density (#·m^{-2})	0.000158	0.303	-0.00337	-0.294	0.1849	1.00
# of Arms	-0.114	-0.138	0.0792	-0.0837	-0.0150	
Diameter (cm)	-0.0522	-0.182	-0.170	0.0509	0.335	

Similarly, we correlated diameter and number of arms with the environmental variables in Table 3 in order to test which of these could have an effect on the size structure shown in Figure 3. The correlation matrix in Table 3 shows that sea state and temperature have testable effects on number of COT arms, while temperature, depth and coral cover may affect the diameter of COTs. We performed several regression analyses to test these as well as to test for a relationship between diameter and number of arms, i.e., larger COTs might have more arms. The best fitting regressions are shown in Table 4, the most interesting and viable being that diameter is a function of depth, sea state and coral cover, i.e., smaller COTs are found in deeper waters, smaller COTs are found in rougher waters and that larger COTs are found in areas of higher coral cover.

Table 4. Summary of multiple linear regression statistics obtained for crown of thorns starfishes sampled in the Tubbataha Reefs National Park, Palawan, Philippines in April-May 2010. Diameter is in cm, depth in m, sea state is a rank category following the standard operating procedures of Bass and Miller (1996; see Table 1), coral cover is an eye-ball estimate in %of live hard coral cover.

Parameter	r^2	s.e.	d.f.	P level	a	b
No. of arms	0.0468	1.549	425	0.0001	12.73	
Depth		0.1149		0.002		0.3578
Sea state		0.1129		0.0001		-0.4728
Coral cover		0.007001		0.007		0.01907
Diameter	0.338	6.234	425	0.0001	19.86	
Depth		0.04626		0.04		-0.9483
Sea state		0.4545		0.0001		-4.707
Coral cover		0.02821		0.0001		0.3959

Discussion

The bucket view method served as an effective and safe method for reconnaissance survey of COT outbreak especially in the TRNP where large pelagics, i.e., barracudas, can easily snap at objects on the water surface. However, in the absence of aggregations, it was difficult to spot COTs because of their cryptic behavior, notably since this survey method only allowed for a two-dimensional view of the reef. Thus, we decided not to complement the SCUBA survey data with the more than 83,000 2-minute transects obtained through the bucket view method in order to discount the method's natural bias.

We showed in Figure 3 that the COTs we sampled at depths of 1-10 m were 98% adults, implying that juveniles do not occur in shallow waters, in line with Black and Moran's (1991) suggestion that juveniles settle in deeper waters at bases of reef slopes where most outbreaks originate. Though the regression results in Table 4 support Black and Moran's (1991) suggestion, there remains the possibility that juveniles were too small, cryptic and nocturnal, e.g., algae-feeding juveniles with diameters <10 cm (Johnson *et al.*, 1991), and were not seen during the sampling period. Note also that 13% of these adults had diameters >40 cm, the largest being 56 cm, implying that the asymptotic diameter (58 cm) we obtained from the Powell-Wetherall relationship is a viable estimate. However, this D_∞ estimate is much larger than any of the 6 populations reported by Stump (1994), whose samples fell in the same size range as those sampled in this study. Assuming that Stump's (1994) results are viable, we plotted ln K *vs.* ln D_∞ in a linear regression analysis, which gave an auximetric relationship significant at P=0.02 (see Figure 4). This indicates that the use of the average θ' obtained in Table 2 to estimate K for the Philippine population is reasonable. Accepting the asymptotic diameter and K values we obtained in this exercise, we estimated ages at diameters for the 425 COTs we sampled (Figure 5), suggesting that the largest individual we sampled may have been 14 years old, the smallest may have been one year old and that the majority (76%) of the individuals we sampled were of 2-3 years of age, about the same age as those sampled by Stump (1994), i.e., spawning adults (CRC Reef Research Center, 2003). These samples, similar to those reported in Stump (1994), were aggregating individuals, which supports Moran's (1990) report that aggregates form to ensure reproductive success, i.e., spawning COTs need to be within at least 1-2 m to ensure the mixing of the eggs and sperms. Thus, logic compels us to think that aggregations such as those observed in the TRNP are effectively spawning swarms of a native population and not an outbreak of 'introduced pests', though others may argue the opposite.

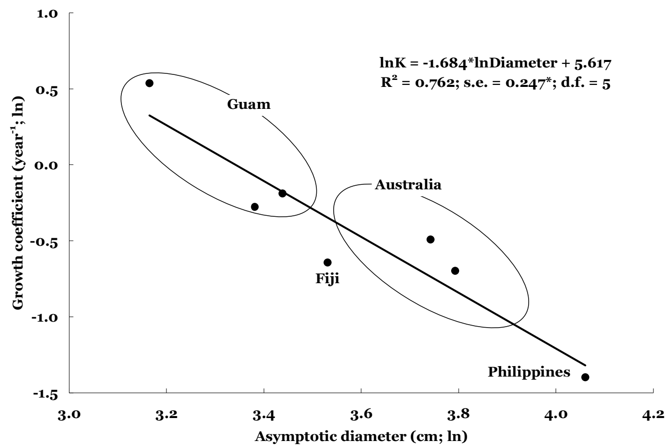

Figure 4. Comparison of von Bertalanffy growth parameters for seven populations of COT across Western Pacific Region (see Table 2 for details).

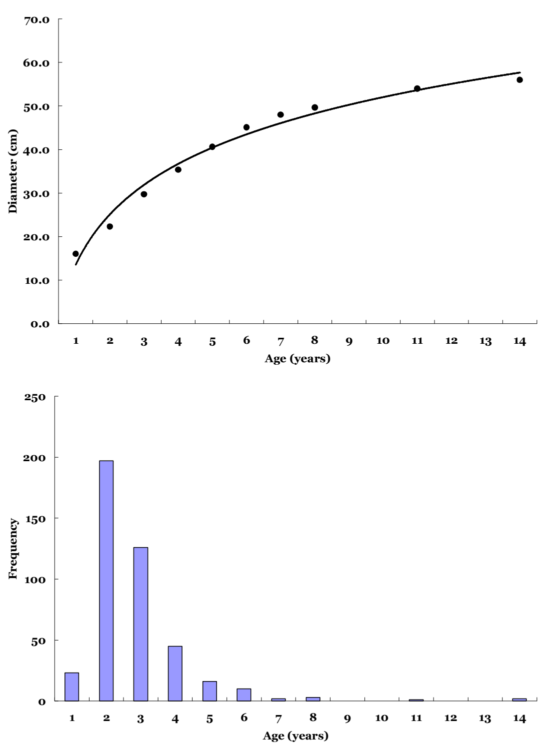

Figure 5. Growth and age composition of crown of thorns starfish from Tubbataha Reefs National Park, Palawan, Philippines sampled by SCUBA in April-May 2010. Upper panel: age at length curve estimated using von Bertalanffy growth parameters D_∞=58 cm and K=0.247years^{-1}. Lower panel: age composition resulting from our samples and the growth curve in the upper panel.

The TRNP outbreak was reported only recently (2007) and is expected to last 3-5 years, though some outbreaks may last longer, e.g., 15 years in the Great Barrier Reefs and 20 years in the Ryukyu Islands, depending on reef complexity, which affects the rate of COT larvae transport (Moran, 1997). There is growing speculation that this population was brought in from a previous outbreak reported from mainland Palawan in the early 2000s through ballast waters of dive-tour boats frequenting the site every summer, similar to Bos's (2010) suspicion of massive influx of larvae from other sites. This predominantly adult population were sampled in shallow areas (0-10 m), dominated by large formations of branching corals, which offer refuge to spawning adults, i.e., COTs have better chances of getting a good grasp of branching corals than of massive coral forms (Chesher, 1969), notably in an area exposed to strong currents, which are favorable to the spreading and transport of pelagic COT larvae (Black *et al.*, 1995). If we accept that this population settled in the three islets sampled in this study because of the favorable environmental conditions, and given that a gravid female can produce up to 65 million eggs (Moran, 1990), we might see another 'outbreak' in this area in the next 2-4 years.

If we accept that our results are indicative of spawning swarms, then the relationship we presented above on COT density as a function of temperature and wind strength may be used by the TMO to predict where COT spawning aggregations may occur in other areas of the TRNP in addition to these three islets. This might be instrumental in preempting aggregations that might threaten coral reef health, but hopefully not in decimating entire cohorts, notably since there is evidence that the cleansing effect of a COT 'outbreak' sweep may enhance reef recovery and promote diversity, i.e., the cleaned surfaces serve as suitable substrates for new hard coral recruits (Colgan, 1987).

As these results were based only on one sampling, and are thus preliminary, we strongly recommend continued monitoring (i.e., regular sampling surveys) of the COT population in Tubbataha Reefs Natural Park.

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References

Bass, D.K., Miller, I.R., 1996. *Crown-of-thorns starfish and coral surveys using the manta tow and scuba search techniques. Long-term Monitoring of the Great Barrier Reef. Standard Operating Procedure No. 1.* Australian Institute of Marine Science, Townsville, 38 p.

Bertalanffy, L. von, 1938. A quantitative theory of organic growth (Inquiries on growth laws. II). *Human Biology* 10, 181-213.

Birkeland, C., 1982. Terrestrial runoff as a cause of outbreaks of *Acanthaster planci* (Echinodermata: Asteroidea). *Marine Biology* 69, 175-185.

Black, K.P., Moran, J.P., 1991. Influence of hydrodynamics on the passive dispersal and initial recruitment of larvae of *Acanthaster planci* on the Great Barrier Reef. *Marine Ecology Progress Series* 69, 55-65.

Black, K., Moran, P., Burrage, D., De'ath, G., 1995. Associations of low-frequency currents and crown-of-thorns starfish outbreaks. *Marine Ecology Progress Series* 125, 185-194.

Bos, A.R., 2010. Crown-of-thorns outbreak at the Tubbataha Reefs UNESCO World Heritage Site. *Zoological Studies* 49(1), 124.

Brodie, J., Fabricius, K., De'ath, G., Okaji, K., 2005. Are nutrient inputs responsible for more outbreaks of crown-of thorns starfish? An appraisal of the evidence. *Marine Pollution Bulletin* 51, 266-278.

Chesher, R.H., 1969. Destruction of Pacific corals by the sea star *Acanthaster planci*. *Science* 165, 280-283.

Dulvy, N.K., Freckleton, R.P., Polunin, N.V.C., 2004. Coral reef cascades and the indirect effects of predator removal by exploitation. *Ecology Letters* 7, 410-416.

Gayanilo, F.C. Jr. and D. Pauly. 1997. FAO-ICLARM Fish Stock Assessment (FiSAT) Reference Manual. FAO Computerized Information Series (Fisheries) 8. Vol. 2. FAO of the United Nations, Rome, Italy. 265p.

Glynn, P. W., 1973. *Acanthaster*: effect on coral reef growth in Panama. *Science* 180, 504–506.

Hill, J., Wilkinson, C., 2004. Methods for ecological monitoring of coral reefs. Version 1. A resource for managers. Australian Institute of Marine Science. 117 p.

Johnson, D.B., Moran, P.J., Baker, V.J., Christie, C.A., Miller, I.R., Miller-Smith, B.A., Thompson, A.A., 1991. Report on field surveys to locate high density populations of juvenile crown-of-thorns starfish (*Acanthaster planci*) within the central Great Barrier Reef. Australian Institute of Marine Science, Townsville, Australia. 17 p.

Moran, P., 1990. *Acanthaster planci* (L.): biographical data. *Coral reefs* 9, 95-96.

Moran, P., 1997. *Crown of thorns starfish: Questions and answers*. Australian Institute of Marine Sciences, Townsville. Accessed at http://www.aims.gov.au/pages/reflib/cot-starfish/pages/cot-000.html on 2009-10-13.

Pan, M., (in progress). Crown of thorns outbreaks: standardizing abundance observations for meta-analyses with a case study in Tubbataha Reefs Natural Park, Sulu Sea, Philippines. MSc thesis, University of the Philippines, Los Baños, Laguna, Philippines.

Pauly, D., 1987. A review of the ELEFAN system analysis of length-frequency data in fish and aquatic invertebrates. p. 7-34. *In* D. Pauly and G.R. Morgan (eds.) Length-based methods in fisheries research. ICLARM Conference Proceedings 13, 468 p. International Center for Living Aquatic Resources Management, Manila, Philippines and Kuwait Institute for Research, Safat, Kuwait.

Pauly, D., Munro, J.L., 1984. Once more on the comparison of growth in fish and invertebrates, *Fishbyte* 2(1), p. 21.

Powell, 1979. Estimation of mortality and growth parameters from the length frequency in the catch. *Rapp. P.-v. Réun. CIEM* 175, 167-169.

Pratchett, M.S., 2005. Dynamics of an outbreak population of *Acanthaster planci* at Lizard Island, northern Great Barrier Reef (1995-1999). *Coral Reefs* 24, 453-462.

Shirai, S., 1956. Ecological notes on the Amami-Oshima (II), Okinawa. *Collecting and Breeding* 18(10),301-307. [in Japanese]

Stump, R.J.W., 1994. Age determination and life-history characteristics of *Acanthaster planci* (L.) (Echinodermata: Asteroidea). PhD dissertation, James Cook University, 405 p.

United Nations Environment Program World Conservation Monitoring Centre (UNEP-WCMC), 2008. Tubbataha Reefs Natural Park, Philippines. 7 p.

Vine, P.J., 1973. Crown of thorns (*Acanthaster planci*) plagues: The natural causes theory. Atoll Research Bulletin 166, 1-10, figs. 1-4.

MANAGEMENT

THE EFFECT OF TOURISM ON CETACEAN POPULATIONS IN SOUTHERN PHILIPPINES[1]

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ABSTRACT

The Bohol Marine Triangle has the highest marine mammal diversity in the Philippines with a total of 13 species. Popularity of cetacean watching among local and international tourists increased by an average of 23 boats annually since the early 2000s, e.g., as seen in number of tour boats in the area, i.e., 40 boats for Pamilacan and about 250 for Panglao. The conduct of tour boats was assessed with observations obtained from a one month survey of different boats from Panglao and Pamilacan during the peak month of cetacean watching. The results of this study aim to: 1) identify where cetacean species are sighted; 2) determine what factors affect cetacean behavior; and 3) document cetacean behavior during human-cetacean interactions. This will provide preliminary information on the compliance of tour boats to the code of conduct legislated by the Philippine government for cetacean watching activities for conservation and management.

INTRODUCTION

Cetacean ecotourism (watching, swimming, and feeding encounters) is an increasingly popular activity among tourists (Scarpaci *et al.*, 2003). The human desire to experience and interact with these animals in their natural habitat has become an income generating activity among local communities and may sometimes contribute to environmental awareness of the public at large (Amante-Helweg, 1996; Scarpaci *et al.*, 2003). However, increase in such activities also alters cetaceans' normal behavior and may bring about death, as in the case of whales colliding with large vessels (30 m or more in length) at speeds of

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18 knots or faster (Weinrich, 2005). Human interactions with cetaceans may cause increased inter-breath intervals, i.e., dive time, and active evading behavior thus affecting their energy expenditure and may impact on their foraging strategies (Williams *et al.*, 2009). If feeding strategies are affected, it follows that reproductive patterns are also altered (Lusseau and Bejder, 2007; Schaffar and Garrigue, 2008).

Due to these observed impacts, codes of conduct to proper whale watching were legislated to protect the welfare of marine mammals exploited by the ecotourism industry (Cunningham-Smith *et al.*, 2006; Lusseau and Bejder, 2007). Garrod and Fennel (2004) reviewed 54 codes of conduct from North and South America, Europe, Asia, Africa, New Zealand, Australia and Micronesia. These codes slightly differ in presentation and in context, i.e., a minority have species specific guidelines while the majority deals mainly on the minimum distance of boat to cetaceans. The biggest challenge in standardizing these codes is the identification of which guideline works best and which is based on sound scientific evidence (Garrod and Fennel, 2004).

In the Philippines, whale watching started in 1996 in Bais City, and was eventually followed by other jurisdictions (Evacitas, 2001). The consistent increase of whale watching in the Philippines prompted a Joint Administrative Order No. 1 (JAO-1; see Sorongon, 2010, Appendix A) between Department of Tourism (DOT) and Department of Agriculture's Bureau of Fisheries and Aquatic Resources (DA-BFAR; signed in 2004) to establish a set of guidelines governing people interacting with whales, dolphins and porpoises. This code complements the existing Fisheries Adminstrative Order 185-1 which prohibits the killing, taking and transporting of dolphins and whales which was used to stop the cetacean fishery in San Francisco, Negros Oriental (Blue Ocean Institute, 2005) and in 2003 by the World Wildlife Fund (WWF) in establishing marine mammal marine protected areas (MPA's) in Negros, Cebu and the Bohol Sea (Alcala et al., 2003). In addition, JAO-1 is being used as a guideline for the protection of humpback whales in Cagayan along with their provincial ordinances (Acebes, personal communication), whales and dolphins in the Bohol Marine Triangle and in other Philippine sites (WWF, 2008).

In spite of the evident importance of validating the applicability of such legislations to help ensure strict enforcement (Hoyt, 2009), an evaluation of the compliance to the different sections of this code and the possible impacts of compliance and non-compliance to cetacean behavior are yet to be studied. In the Philippines, cetacean studies revolve around species identification, distribution and feeding ecology (Dolar *et al.*, 1993; Acebes and Lesaca, 2003; Dolar *et al.*, 2003; 2006) and little is done on evaluating the impact of tourism on exploited populations, e.g., in the Bohol Marine Triangle (BMT) where previously prevalent hunting was replaced with active ecotourism. Mapping local perceptions of inhabitants within the BMT, similar to the initiatives in Shark Bay, Australia (Bejder, *et al.*, 2006), may help in identifying changes in observed species of cetaceans and their abundance. Data on cetacean abundance estimates and shifts from fishing to whale watching and the subsequent effects of livelihood changes on cetaceans may also be inferred from perception mapping.

The aim of this study is to determine which of the parameters in selected sections of JAO-1 significantly influence cetacean response to ecotourism by comparing two locations in close proximity to each other, where guidelines are, on one hand followed, and ignored on the other. This study focuses on Pamilacan and Balicasag Islands in the Bohol Sea, hotpots of cetacean diversity in the Philippines (Calumpong, 2004; Sabater, 2005) and aims to identify factors that may have long-term impacts on marine mammals (Dolar, 1995). This study also aims to help the Municipality of Baclayon and Panglao in creating viable interventions to strongly enforce compliance of tour boat operators for cetacean watching to ensure not only the safety of the tourists but also to protect marine mammal populations.

Cetaceans in the Bohol Marine Triangle

There are 124 marine mammal species worldwide belonging to the three main groups namely: Cetacea (83), Pinnipedia (36), and Sirenia (5). Aside from these, several species of carnivores such as bats, bears, foxes and otters occur in marine waters, thus adding to the list of marine mammals of the world (Rice, 1998). A total 26 species and one subspecies of cetaceans have confirmed Philippine occurrences based on fishery data (Leatherwood *et al.*, 1992; IUCN, 2009), which is similar to the list obtained through SeaLifeBase (www.sealifebase.org; see Palomares and Pauly, 2009), i.e., 28 species listed for the Philippines belonging to Cetacea (27) and Sirenia (1).

The Bohol Marine Triangle (BMT) is home to 13 species of cetaceans out of the 26 confirmed in Philippine waters (Calumpong, 2004; Sabater, 2005; see Table 1). The latest addition to the list is the blue whale, *Balaenoptera musculus* plus one unidentified ziphiid (Sabater, 2005). This constitutes 11% of the total number of marine mammal species known worldwide. The most frequent animals seen in the BMT are *Stenella longirostris* and *Tursiops truncatus*. These are followed by *Lagenodelphis hosei, Grampus griseus, and Peponocephala electra* (Calumpong, 2004).

Table 1. Species composition of cetaceans in the Bohol Marine Triangle (adapted from Sabater, 2005).

Family	Species	Common name
Delphinidae	*Globicephala macrorhynchus*	Shot-finned pilot whale
	Grampus griseus	Risso's dolphin
	Lagenodelphis hosei	Fraser's dolphin
	Peponocephala electra	Melon-headed whale
	Stenella attenuata	Pantropical spotted dolphin
Delphinidae	*Stenella longirostris*	Long-snouted spinner dolphin
	Tursiops truncatus	Bottlenose dolphin
	Feresa attenuata	Pygmy killer whale
Ziphiidae	*Mesoplodon densirostris*	Blainville's beaked whale
Physeteridae	*Physeter catodon = (macrocephalus)*	Sperm whale
Kogiidae	*Kogia sima*	Pygmy sperm whale
Balaenopteridae	*Balaenoptera musculus*	Blue whale
	Balaenoptera edeni	Bryde's whale

Cetacean watching

In the mid-1940's, students of the Scripps Institution of Oceanography (San Diego, CA) observed and counted gray whales (*Eschrichtius robustus)* from boats (Hoyt, 2009). This academic study gave birth to cetacean watching, i.e., a form of nature-based tourism involving tour boats and planes (Bejder *et al*., 2003a), and sometimes swimming (Scarpaci *et al*., 2003). Governments have acknowledged this as a 'sustainable use' of cetaceans, provided that codes of conduct are followed (Evacitas, 2001). Thus, being 'sustainable', whale watching replaced whale hunting (primarily for the products of the hunt, e.g., oil, baleen, meat, ivory) as a source of livelihood, which was practiced worldwide, probably since humans learned to hunt, e.g., in Tonga (Orams, 2001), Newfoundland and Labrador (Lien, 2000), Scotland (Parsons *et al*., 2003), New Zealand and Australia (Lusseau *et al*., 2007), Philippines (Evacitas, 2001), Iceland, North America, and South Africa (Reeves *et al*., 2003), and as part of cultural, ceremonial, and social functions (Renker, 2007). Recreational fishing, diving and whale watching, generate an annual revenue of 47 billion USD (Cisneros-Montemayor *et al*., 2010), with whale watching possibly generating 413 million USD (Cisneros-Montemayor *et al*., 2010) given that in 2006 alone, the industry recorded 12 million whale watchers (Hoyt, 1995; 2009).

Cetacean behavior

Cetacean behavioral states are species or group specific and include feeding, resting, traveling, and communicating or socializing (Shane *et al*., 1986; Fish *et al*., 2006; Lusseau, 2006). Associated with these states are actions such as leaping in the air displayed during feeding and socializing/playing. Socializing actions include spinning, bow riding, tail slaps, and breaching, which are also considered playful behaviors. In the 'resting' state, pods move slowly in the same direction, i.e., slower than boat speed of an observing vessel, with short dive intervals. In the 'traveling' state, pods move steadily but faster than boat speed, with short dive intervals (Lusseau, 2006). 'Spy-hopping', which displays curiosity or orientation behavior, i.e. using signs from the surface to determine their movement, is also observed by cross ocean travelers or when vessels approach an individual or group of cetaceans (Dalheim, 1981; Pryor, 1986). This kind of behavior is commonly seen in whales and is usually followed by evasive behavior (Perryman, 2009).

Being social animals, marine mammals respond to stimuli, whether it is favorable or unfavorable to them. Thus, stimuli injected by whale watching activities, e.g., presence of a significant number of tour boats (Buckstaff, 2004; Mattson *et al*., 2005; Bejder *et al*., 2006b; Lusseau, 2006), are considered as primary causes of altered cetacean behavior (IUCN, 2008). The two main changes in cetacean behavior observed on whale watching tours are avoidance and longer bottom time, e.g., in the tropical Pacific, Fraser dolphins reportedly swam away from tour boats (Wursig, 2000), while melon-headed whales exhibited evasive to curious behavior towards divers and swimmers (Perryman, 2009). This is commonly observed when whale watching is conducted in areas where feeding, mating, and resting occurs and where smaller cetacean populations reside (Hoyt, 2009). Cetaceans in captivity are known to exhibit aggressive behavior, e.g., ramming their heads or biting (Perryman, 2009). With the growing interest in a multi-billion dollar industry, understanding the impact of exogenous activities on natural populations of cetaceans is paramount to making it a truly 'sustainable' industry.

Impacts

Sizes of marine mammal populations have declined since the 1950s (Schneider, 1973; Christensen, 2006). Perceived causes of this decline include whaling, commercial and indigenous fisheries and climate change (Dolar, 1994; Dolar *et al*., 1994). Many studies blame the fisheries sector as the major cause for this decline, thus discounting ecotourism. However, some reports claim that decline in sightings is observed only in areas where there is an increase in whale watching tours (Garrod and Fennell, 2004; Bejder *et al*., 2006b; Hoyt, 2009; Williams *et al*., 2009); and that cetacean behavior changes, such as exhibited in diving, aerial and communication behavior in response to presence of tour boats (Buckstaff, 2004; Mattson *et al*., 2005; Lusseau, 2006) lead to disruptions in their daily activities, e.g., foraging strategies and social/mating relationships, the repeated occurrences of which may change their biological and natural clock to adapt to human presence, thus leading to 'human dependency' (Bryant, 1994).

Such 'forced' adaptation varies depending on the length of time of exposure to the disturbance (Bejder *et al*., 2006a). Persistent and repeated short-term disturbances decrease cetaceans' reproductive fitness (Lien, 2001; Bejder, 2005). Wells and Scott (1997) show that long-term disturbances, i.e., increased exposure to tour boats, may cause population decline, which is confirmed by Bejder *et al*. (2006b) for the dolphin population in Shark Bay, Australia where the increase in number of tour boats in an ecotourism site decreased the population by 14%. In Fiordland, New Zealand, at the peak of the tourist season, high tour boat traffic forced resting resident dolphins, notably pregnant females, to move away, thus increasing their energy expenditure (Lusseau, 2003; 2004). This disruption, repeated over a long period resulted to an area avoidance strategy by the dolphin population, effectively mimicking a population decline (Lusseau, 2004). Displaced cetacean populations may return to their preferred areas once disturbance stops. However, they may also permanently transfer to an area with a lower level of disturbance (Bejder *et al*., 2006a). High boat traffic may also affect foraging behavior, as in the resident killer whales of waters off Vancouver, Canada whose foraging opportunities were decreased because they could not compete for water surface space with the large cargo vessels (including salmon fishing vessels) coming in and going out of the Vancouver harbor, thus again affecting their energy expenditure (Williams *et al*., 2006). In the Bohol Marine Triangle, the observed increase in whale watching tours in both Pamilacan and Balicasag Islands is identified as one of the causes of disturbance affecting resident marine mammal populations.

Code of Conduct

Observing cetaceans in their natural habitat is being promoted as a prime tourist activity in the Philippines. The resulting increase in demand for whale watching boat operators and the absence of a regulating authority nurtured the sprouting of non-registered tour boats and untrained tour boat operators, e.g., in the BMT, a priority marine protected area (MPA) since its declaration as a marine mammal sanctuary in 1998 (Alcala *et al*., 2003). Unregulated cetacean watching activities aroused concerns amongst Philippine marine mammal scientists and conservationists, which initiated the drafting and signing of the JAO-1 between the DOT and DA-BFAR (Evacitas, 2001; see Sorongon, 2010, Appendix A) to govern the code of conduct of people interacting with cetaceans, i.e., to ensure the safety of these animals while they are sustainably exploited (WWF, 2008). This guideline is similar to those implemented in other countries where whale watching has replaced whale hunting as a primary source of fisher's livelihood, e.g., in Canada (Lien, 2000), New Zealand and Australia (Lusseau *et al*., 2007), Scotland (Parsons *et al*., 2003), Tonga (Orams, 2001).

Management

Management, i.e., training of tour boat operators and monitoring of compliance by these operators to JAO-1 is essential for the sustainable use in ecotourism of cetacean populations (Quiros, 2007). The logical implementing bodies of JAO-1 are the Department of Tourism and the Bureau of Fisheries and Aquatic Resources, notably in the apprehension of violators, controlling licensure and boat dispatch schedules, trainings and seminars on the proper conduct in cetacean watching as well as in activating propaganda campaigns to promote incentives to comply with JAO-1 and to encourage inhabitants of the BMT to protect and conserve these animals. Implementation of JAO-1 requires an analysis of the carrying capacity of the tourism area in order to determine the optimal number of tour boat operators and encounter time (Higham and Bejder, 2008), notwithstanding, boat speed, type of approach and pursuit and noise level within sites. These regulations aim to decrease the impact of tourism activities in disruptions of cetacean life processes (Lien, 2001). Thus, effective implementation of JAO-1 requires the identification of critical habitats, i.e., feeding, mating or resting areas, in order to restrict access to cetacean populations when they are within these areas (Lusseau and Higham, 2004). Furthermore, implementing bodies of JAO-1 need to continuously assess its efficiency and should also implement regular evaluations in order to amend the code, e.g., to cater to species specific responses to ecotourism (Lien, 2001; Ritter, 2003). Moreover, educating people as to how the code can be properly implemented (and why) will help disseminate information for boat operators, tourists, resort owners, and other mariners in whale watching areas and motivate them to follow the code. Having a naturalist on board the trips may aid in increasing awareness of tourists in conserving whales and dolphins by treating them with utmost respect (Hoyt, 2009). Finally, emphasis on enforcement of the code and not just on compliance by some should be the utmost goal of JAO-1.

MATERIALS AND METHODS

The study site

The Bohol Marine Triangle (Figure 1), home to 14 species of cetaceans (Sabater, 2005), covers over 1,120 km² (112,000 ha) around Pamilacan (9°29'43.55"N, 123°55'39.40"E, Baclayon municipality) and Balicasag Islands (9°30'57.00"N, 123°41'02.00"E; Panglao municipality), composed of 92% water and 8% land (Calumpong, 2004; BMT, 2006), are the main cetacean watching sites in Bohol. Panglao and Baclayon together are home to 207,573 inhabitants (NSO, 2007), whose main source of livelihood is fishing. Specifically for Pamilacan Island, it also involved hunting whales and dolphins for subsistence. These harvests accelerated at a dangerous scale, i.e., for commercial purposes, in the 1990's (Dolar *et al.*, 1994), which prompted authorities to impose a ban on cetacean harvesting in 2000, and which led to the establishment of nature-based tourism. As cetacean watching developed into an alternative source of livelihood, fishers permanently gave up whale hunting (Edgar Baylon, BRAABO, Baclayon, Bohol, personal communication).

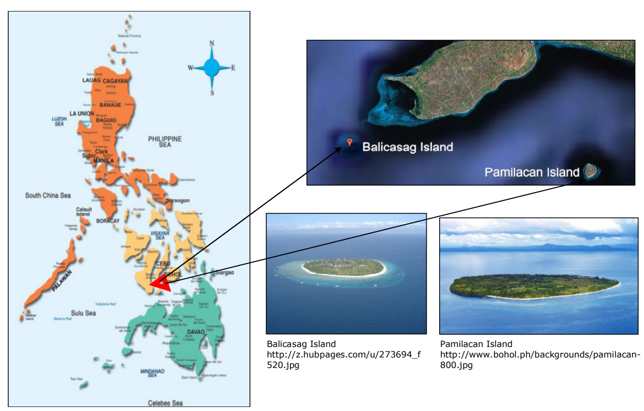

Figure 1. The Bohol Marine Triangle, surface area of 1,120 km², showing Pamilacan (9°29'43.55"N, 123°55'39.40"E, Baclayon municipality) and Balicasag (9°30'57.00"N, 123°41'02.00"E; Panglao municipality) Islands in the southern Philippines.

Evaluation of compliance

A field survey conducted 1 April to 8 May 2009 permitted observation of cetaceans from tour boats over a 30-day period, i.e., 15 boats per island or a total of 30 boats boarded depending on the availability of boats at the docking sites and based on the assumption that tour operators in both islands are composed of those who attended trainings as boat operator, boat mechanic, and spotter, and untrained boat personnel who basically trained themselves. During the study, the code was not yet used as a basis for trainings held in relation to whale watching activities although parts of the code were discussed with different specifications, i.e., allowed distance from the pod based on the training is 20 meters while prescribed distance by JAO-1 is 50-300 m. Boat personnel were informed that the study involved observing cetacean behavior during a whale watching tour operation. Tour boat operators, resort owners, and a member of the BRAABO NGO helped in getting permission from tourists to let observers board during the whale watching tour.

Volunteer observers were trained prior to boarding, i.e., familiarization with cetaceans occurring in the BMT using pictures; familiarization with cetacean behavior as illustrated in Table 2 and using pictures and videos; and familiarization with video documentation equipment (Sony DCR-SR45 video camera with a 40 x optical zoom lens). A list of cetaceans, tour operator and tourist behavior, pictures of confirmed species in the BMT, and an interview sheet (see Sorongon, 2010, Appendix B) for tour boat operators were provided to the observers as reference during the survey.

A test survey conducted on the first day of assessment helped to assess the understanding of observers with respect to the sampling methodology. Daily briefing and de-briefing sessions assessed progress of data gathering and helped adjust the schedule of tasks for the next day.

A binocular (Bushnell Marine 7x50 Waterproof/Fogproof) was used for ease of species identification and estimation of the number of individuals in a pod. The proximity of the boat from the pod being observed was estimated using the binocular's internal rangefinder. This distance was later estimated from the rangefinder reading using the relationship: D=(OH/Mil)*100, where, D is the distance to the object being observed in meters, OH is the observed height, and Mil is the rangefinder reading (1 rangefinder line is equal to 5 Mil). The parameter OH was based on average values of dorsal fin heights, a species-specific trait (Nowak, 2003).

Species identification, GPS (ETREX GPS) readings per sighting and cetacean behavior (see Table 2) in response to JAO-1 criteria (Table 3), e.g., boat proximity and approach, number of boats per encounter, human behavior towards cetaceans and observation (surface) time were documented by the first author while volunteer observers documented human-cetacean encounters with the video camera. Informal interviews of boat personnel were conducted to assess the possible reasons for compliance or non-compliance to the FAO.

Table 2. Types of cetacean behaviour described in marine mammal scientific literature.

Type of behaviour	Action
Resting[a]	The school moves slowly in the same direction, slower than the boat speed of an observing vessel, with short dive intervals
Socializing/Playful[ab]	Leaping in the air and spinning, and those described below for tail slap, breaching and bow riding.
Tail slap/Lobtail[a]	Forcefully slaps the water surface with the tail
Breaching/Side flop[a]	Jumps clearing its entire body out of the water and lands on its side
Bow riding[b]	Positioning themselves near the bow in such a manner as to be lifted up and pushed forward by the circulating water generated to form a bow of pressure wave of an advancing vessel.
Curious[a]	Goes near the vessel advancing in short distances
Spy hop[a]	Lifts its head above water until its eye-out
Avoidance[c]	Diving or swimming away from tour boats from a resting behavior

[a]Lusseau (2006); [b]Hertel (1969); [c]Perrin *et al.* (2009).

Among the behaviors described in Table 2, the main behavior being observed is avoidance behavior, i.e. sudden diving from a resting (logging) position as the vessel approaches and resurfacing to a far distance; this is equivalent to a short surface time, which is gender or species specific (Williams *et al.*, 2002). The initial position of the cetacean(s) and its/their behavior as the vessel approaches was noted for an individual or pod without gender specificity. The estimated number of individuals and species composition per encounter was also noted.

Table 3. Criteria for the evaluation of the code of conduct JAO-1 for cetacean watching tour operators in the Bohol Marine Triangle, Philippines. Illustrations of boat approach types are presented in Figure 2.

Criteria	Specifications	Definition	Sources
Boat approach type	parallel	boat is positioned parallel to the individual or the pod	DA-BFAR (2004)
	back of pod	boat is positioned at the back of the individual or the pod	Scarpaci *et al.* (2003)
	direct	boat crosses the path of the individual or the pod	DA-BFAR (2004)
	j-approach	boat blocks the path as it goes in front of the individual or the pod	DA-BFAR (2004)
Distance to cetacean	50-300 meters		DA-BFAR (2004)
Observation time	maximum of 20 minutes		DA-BFAR (2004)
Interactions	NO touching, feeding, swimming or playing of underwater sounds		DA-BFAR (2004)
No. of boats/encounter	maximum of 4 boats		DA-BFAR (2004)

The initial time, i.e. once cetacean(s) are spotted, and final time (observation time), i.e., once the last individual in the pod dives down and disappears, were recorded for each sighting with a stop watch. The end of each observation time was determined by the tourists, or when the boat moves away to view another pod at a far distance. If a particular pod was still being observed when the tourists decided to end the whale watching activity, that particular sighting was not included in the data analysis.

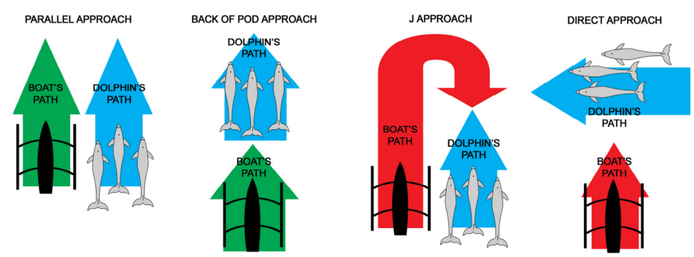

Figure 2. Type of boat approaches during cetacean watching activities.

Observations are on a per sighting basis, i.e., not on a per pod or per individual basis. Thus, the same individual or pod may be the subject of several sightings.

The code recommends a combination of the parallel and back of pod approaches as these avoid forcing an individual or pod to change direction or to disaggregate. Observation time is set to a maximum of 20 minutes per boat per encounter. The number of boats between 50-300 m of the pod is limited to 4 per pod per encounter. Feeding, touching, swimming and playing of sounds underwater are prohibited as these may compete with cetacean echolocation.

Cetacean historical time series perception mapping workshop

A historical time series resource mapping workshop, i.e., a process by which the stakeholders' perceptions of an existing resource is mapped or charted, was held 3-6 August 2009, with 30 key informants from both islands. Marine mammal abundance data and changes in livelihood from 1960 to 2009 were documented and mapped.

Table 4. Age class grouping of perception mapping participants from Pamilacan and Balicasag Islands, Bohol Marine Triangle, Philippines.

Year	Age class (years)
1960	65 to 74
1970	55 to 64
1980	45 to 54
1990	35 to 44
2000	25 to 34
2009	15 to 24

Workshop participants, i.e., five per age class (Table 4) and type of livelihood, e,g., fishing, tourism, etc., were chosen per municipality with the help of BANGON NGO from the municipality of Panglao and the baranggay captain of Pamilacan island. The participants were limited to fishers and those involved in the tourism industry. The oldest age class, i.e., 65 to 74 years old, would have experienced the earlier years of directed fisheries of marine mammals in the Philippines (1974) as active fishermen during that time (Dolar *et al*., 1994). Data on the initiation of cetacean watching in this area and the observed impacts on cetacean populations, particularly their abundance in the BMT through time were gathered. This will measure the shifts in livelihood from whaling to whale watching and decline in sightings through time.

Cetacean species assessment

BMT coast scaled maps labeled per year (Figure 3) were provided along with stickers, i.e., cetacean species in the BMT, qualitative classification of cetacean abundances (choice of ranges, e.g. 0 to 50, 50 to 100, 100 to 500), and types of fishing methods. These were placed on the specific area of observation during the represented year. A 10 minute presentation of results was allotted per group.

Issues and solutions

Issues being faced by each community were discussed per group. Information, i.e. locality, resource, benefits, stakeholders, person/institution responsible, other issues and concerns, were provided by each group. A 10 minute presentation of results was allotted to impart concerns and acquire feedback for proper management strategies; this was used to assess qualitative changes in abundance of cetacean species and their species composition through time. The evolution of fishing methods, i.e., blast fishing, cyanide, etc. were also defined in this exercise and was used to assess the possible causes of shift from fishing and hunting cetaceans in the BMT to conducting nature-based tourism, i.e., cetacean-watching.

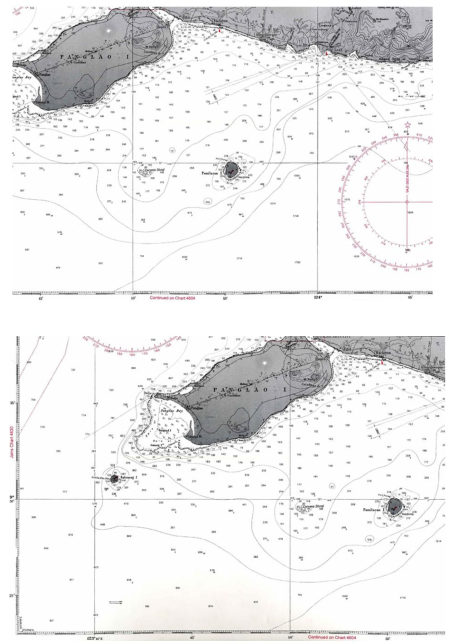

Figure 3. Scale maps of Pamilacan (top) and Panglao (bottom) Islands (Bohol Marine Triangle, Philippines) used for the perception mapping method described in the text.

Field survey results provided information on the compliance to the code of conduct of tour boat operators for cetacean watching, and the probable reasons of their compliance and/or non-compliance was based on the output of the perception mapping workshops.

Statistical Analyses

Hypothesis: The parameters, namely, number of boats, duration of encounter, distance of boat to pod, boat approach and training effect on cetacean behavior during whale watching activities, did not dffer between boat operators who underwent training and those who did not.

Expected relationships: High number of boats induces avoidance behavior (lowest behavior rank). Long surface time is concurrent with resting behavior (highest behavior rank). Short distance of boat to pod induces avoidance behavior. Direct and J-approach generate avoidance and curious behavior, while A combination of the parallel and back of pod approach generate resting and playful behavior. Trained boat operators following JAO-1 code of conduct will use the parallel and back of pod approach, observe at a distance of 50 to 300 m during encounters, encourage longer surface time and thus resting and playful behavior.

Descriptive statistics (i.e., averages and their standard errors for continuous variables, and median, mode, range of values for variables such as boat approaches - 1: direct; 2: J-approach; 3: back of pod; 4: parallel, and behavior - 1: avoidance, 2: playful, 3: resting, based on rankings) are provided for each parameter. A correlation matrix was used to identify possible relationships of these variables, a multiple regression analysis to test the significance of these relationships and principal components analysis to compare the results of the multiple regression analysis and present trends and relationships in the data gathered. Also, compliance between trained and untrained tour boat operators was compared.

These statistical tests aim to produce an output presenting the level or percent of disturbance that each criteria has on cetaceans based on observed behavior during encounters, on the assumption that trained tour boats had the proper training and certifications (see Sorongon, 2010, Appendix C), while untrained tour boat operators did not undergo any training in relation to whale watching. This also showed whether the abovementioned criteria of proper conduct had significant effects on cetaceans and whether these criteria are essential in the conservation of cetaceans.

RESULTS

A total of 26 boats with a total of 23 hours and 22 minutes on-effort (active search for cetaceans), and a total of 10 hours and 36 minutes off-effort (observation time) were evaluated for compliance to JAO-1. There were two days with no sightings due to the rough waters during a storm ('Dante') that affected the tides in Bohol. There was a lag of 8 days with no boats to be evaluated due to the privacy preference of tour guides or guests for their tours. A total of 195 videos were taken for 331 sightings during the survey. Note that not all the sightings displayed the specified boat approaches, thus the statistical analysis includes only 175 sightings where the four approaches described above were observed. The historical perception mapping workshop generated a total of 5 maps (1970s to 2009) from 22 participants for Pamilacan and 6 maps (1960s to 2009) from 25 participants for Panglao. For the detailed attendance sheets of participants, please refer to Sorongon (2010, Appendices D and E).

Table 5. Percentage of occurrence of cetacean species observed in the Bohol Marine Triangle, Philippines.

Scientific name	Common name	% in Pamilacan	% in Balicasag
Stenella longirostris	spinner dolphin	81	60
Tursiops truncatus	bottenose dolphin	12	6
Lagenodelphis hosei	Fraser's dolphin	1	4
Peponocephala electra	melon-headed whale	–	6
Globicephala macrorhynchus	short-finned pilot whale	5	

Table 6. Cetacean species associations in Pamilacan and Balicasag Islands, Bohol Marine Triangle, Philippines. N=Not observed; O=Observed.

Associations	Pamilacan	Panglao
spinner dolphin - bottlenose dolphin	N	O
melon headed whale - bottlenose dolphin	N	O
melon headed whale - Fraser's dolphin	N	O
Fraser's dolphin - bottlenose dolphin	O	O
Fraser's dolphin - spinner dolphin	N	O
bottlenose dolphin - spinner dolphin - Fraser's dolphin	O	N
short-finned pilot whale - bottlenose dolphin	O	N

Species composition

Five cetacean species were observed during the survey (Table 5), but only four were seen in each area, i.e., melon-headed whales were not observed in Pamilacan while short-finned pilot whales were not seen in Balicasag. The percentage of occurrence of the species in each area, i.e., frequency of occurrence of each species divided by the total number of sightings multiplied by 100 is presented in Table 5, while observed intra-specific associations are presented in Table 6.

Table 7. Food preference of marine mammal species observed in the Bohol Marine Triangle; data obtained from SeaLifeBase (**www.sealifebase.org**; see Palomares and Pauly, 2010). N=Not observed; O=Observed.

Species	Food Preference		
	Fish	Cephalopods	Crustaceans
Spinner dolphin	O	O	N
Bottlenose dolphin	O	O	N
Fraser's dolphin	O	O	O
Melon-headed whale	O	O	N
Short-finned pilot whale	O	O	N

There is a high number of pods consisting of spinner and bottlenose dolphins and an equally high number of pods consisting of bottlenose, spinner, and Fraser's dolphins (Figure 4). The least observed associations are between melon-headed whales and Fraser's dolphins, and between melon-headed whales and bottlenose dolphins.

Results of the perception mapping workshops confirm the availability of prey, mainly fish and squid (Table 7; see Sorongon, 2010, Appendix F). Unfortunately, the participants only identified fish species to the species level through pictures. Some fish species were only identified up to the family level or their local/common names validated through FishBase (Froese and Pauly, 2010), making fish identifications incomplete. Fish surveys are needed, to come up with a complete list of fish species caught in BMT and can be validated by locals through their local or common names. Squids were identified as a group and not to the species level. Perception mapping results indicate a general decline in the 'eye-balled' number of individuals of cetacean prey from the 1960s to 2009 (see Sorongon, 2010, Appendices G and H).

Table 8. Descriptive statistics of continuous variables tested in compliance to the proper code of conduct of cetacean watching tour boat operators in the Bohol Marine Triangle, Philippines.

	Number of boats	Surface time (min)	Distance (m)
Untrained			
Mean	4.78	1.52	27.01
Standard Error	0.343	0.127	2.783
Number of samples	76	76	76
Trained			
Mean	1.90	2.71	26.35
Standard Error	0.127	0.335	2.028
Number of samples	99	99	99
Combined			
Mean	3.15	2.20	26.64
Standard Error	0.197	0.202	1.662
Number of samples	175	175	175

GPS readings acquired per sighting were used to map cetacean locations around the two islands (see Sorongon, 2010, Appendix I; Figure 5). Spinner dolphins were found to be dominant, followed by the bottlenose dolphins among the five species in both sites. This was followed by melon-headed whales and then short-finned pilot whales. Fraser dolphins were least sighted during this survey.

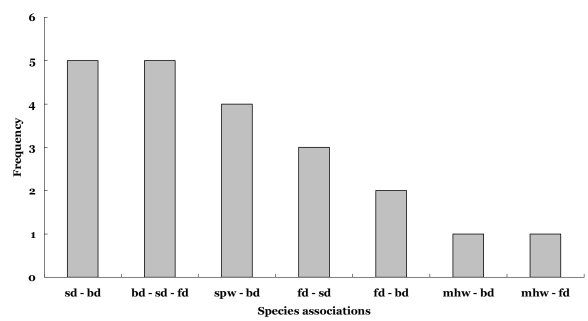

Figure 4. Frequency of species associations in the Bohol Marine Triangle, Philippines (sd: spinner dolphin; bd: bottlenose dolphin; fd: Fraser's dolphin; mhw: melon-headed whale; spw: short-finned pilot whale).

Descriptive statistics

On average, there are 5 untrained and 2 trained (1-16) boat operators per pod (Table 8) per sighting; the regulated maximum number of boats per pod is 4. This implies that the untrained boat operators did not comply with the regulated number of boats required by the code. A total of 13 boats were observed to exceed the regulated number required by the code per sighting. Average surface time is 2 minutes for untrained and 3 minutes for trained boat operators per sighting (Table 8); the regulated maximum duration of encounter per sighting is 20 minutes. However, we cannot conclude from this data that the boat operators complied with the regulated encounter time because the surface time is affected by other factors, e.g., number of boats, distance of boat to pod and boat approach. This will be further discussed below. The average distance of boat to pod is 27 meters for untrained and 26 meters for trained boat operators per sighting (Table 8); the regulated distance of boat to pod ranges from 50 to 300 meters. This implies that there is no compliance with the regulated distance as required by the code in the BMT region as a whole.

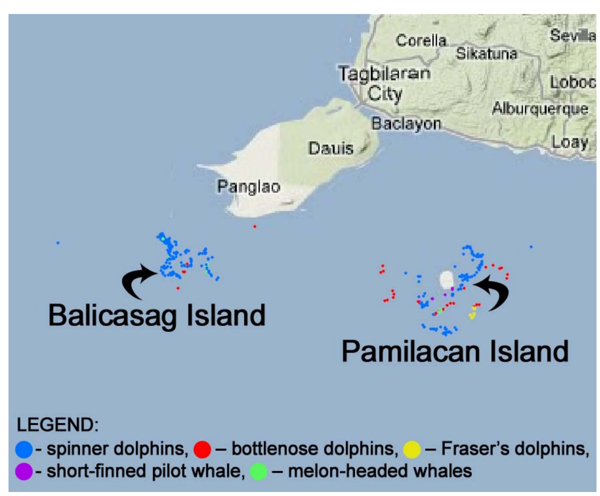

Figure 5. Occurrence points of cetaceans observed in Pamilacan and Balicasag Islands, Bohol Marine Triangle, Philippines.

There is no difference in the median boat approach used by trained and untrained boat operators; boat operators in the area favor the parallel approach when feasible (Table 9). Note that the parallel approach is one of the most desired approaches as regulated by JAO-1, the other one being the back of pod approach. This implies that boat operators of the region comply with JAO-1. On the other hand, avoidance behavior is the observed median response of cetaceans to untrained boat operators approaching a pod while resting behavior is the observed median cetacean response to trained boat operators (Table 9). These median values are affected by several factors which will be discussed below. However, these results already imply that training of boat operators may be an important factor in reducing undesirable actions by ecotourism operations.

The correlation matrix of parameters tested here (Table 10) shows a relatively high negative correlation between number of boats and surface time, number of boats and boat approach, number of boats and training, number of boats and cetacean behavior, distance of boat to pod and cetacean behavior, and relatively high positive correlation between surface time and training, surface time and behavior, boat approach and training, and training and cetacean behavior. The significance of these correlations was tested in the multivariate analysis.

The negative correlation between number of boats and surface time implies that a high number of boats will generate short surface time. The negative correlation between number of boats and boat approach implies that more boats will generate undesirable boat approaches. The negative correlation between number of boats and the dummy variable for training (trained = 1; untrained = 0) implies that higher number of boats were observed among untrained boat operators. The negative correlation between number of boats and behavior implies that high density of boats will generate avoidance behavior. The lower the number of boats, less disturbance is inflicted on cetaceans.

The positive correlation between surface time and training rank implies that longer surface time is observed among trained boat operators. The positive correlation between surface time and behavior implies that cetaceans spend more time on the surface during resting and playful behaviors. This as above corroborates with expected results. Moreover, surface time (as a continuous variable) can be used in lieu of behavior rank (non-continuous qualitative variable) in the multiple regression analysis.

The positive correlation between boat approach and training rank implies that there is a preponderance of favorable boat approaches, e.g. parallel and back of pod approach, among trained boat operators. Recall, however, that the observed median boat approach reported in Table 9 is parallel approach. Figure 6 demonstrates the preponderance of this approach in the region both for trained and untrained boat operators. Thus, it is assumed here that the favored approach is the parallel approach.

Table 9. Descriptive statistics of discontinuous variables tested in compliance to the proper code of conduct of cetacean watching tour boat operators in the Bohol Marine Triangle, Philippines. (Boat approaches - 1: direct; 2: J-approach; 3: back of pod; 4: parallel; Behavior ranks - 1: avoidance, 2: playful, 3: resting)

	Boat approach	Behavior
Untrained		
Median	4	1
Mode	4	1
Minimum	1	1
Maximum	4	3
Number of samples	76	76
Trained		
Median	4	3
Mode	4	3
Minimum	1	1
Maximum	4	3
Number of samples	99	99
Combined		
Median	4	2
Mode	4	3
Minimum	1	1
Maximum	4	3
Number of samples	175	175

The positive correlation between the tour boat operators' training rank and cetacean response behavior implies that resting and playful behaviors are observed when trained boat operators approach the pods. This is clearly reflected in Figure 7 where the frequency of avoidance is high while that of resting is low with untrained boat operators and the reverse trend is true for trained boat operators.

The above results corroborate with the expectations in the methodology section.

The negative correlation between the distance of boat to pod and cetacean behavior implies that the further the boat is from the pod, the more cetaceans avoid them. This deviates from expectations, which assumes that the further the boat is from the pod, the more resting behavior is displayed. This scenario, however, is based on the assumption that boat operators are following JAO-1 to the letter. Thus, this relationship can only be tested for trained boat operators. However, none of the boats observed (even those of trained boat operators) followed the code's regulated distance, which probably led to this result.

Multiple regression analysis

After determining relationships between variables from the correlation matrix, a number of multiple regression analyses were performed. The first regression analysis tested behavior rank against all variables of the correlation matrix discussed above. This resulted in a highly significant overall correlation coefficient for df=174. However, the partial slopes were not all significant (Table 11): the significance of distance to pod was weak at the p=0.05 level, while surface time and boat approach were not significant at all. This maybe because of the following: 1) behavior and surface time maybe auto-correlated as discussed in the preceding section; and 2) boat approach is a qualitative rank variable (non-continuous) and might be auto-correlated with distance from the pod. Boat approach may be affected by the number of boats, notably in small surface areas (36 km^2 and 128 km^2) for Balicasag and Pamilacan Islands, respectively. These values include the surface area where cetacean watching activities were observed during this study. One boat applying one of the regulated approaches would require a distance of at least 50 m from the pod, i.e., a 50 m radius. Several boats in the same area, observing the same pod at the same time, would require least a 300 m radius. As already discussed above, none of the boats applied the regulated distance set by JAO-1, which implies that the high density of boats in one area hindered the application of regulated boat approaches.

Furthermore, the variable being tested, i.e., behavior, is also a qualitative rank variable, which may not be an appropriate variable to test with regression statistics. However, as discussed above, surface time may be used as a surrogate for behavior. Thus, a series of regression analyses were performed plotting surface time against continuous independent variables, i.e., number of boats and distance of boat to pod, and a dummy variable for training rank (trained=1, untrained=0). Results in Table 10 indicate that there might still be underlying relationships that have not been detected using the correlation matrix discussed above, and/or that this relationship is not linear.

Table 10. Correlation matrix of variables tested in compliance to the proper code of conduct of cetacean watching tour boat operators in the Bohol Marine Triangle, Philippines.

	Number of boats	Surface time (mins)	Distance (m)	Boat approach	Training	Behavior
Number of boats	1					
Surface time (mins)	-0.160	1				
Distance (m)	-0.016	-0.098	1			
Boat approach	-0.145	0.095	-0.014	1		
Training	-0.549	0.221	-0.015	0.148	1	
Behavior	-0.377	0.196	-0.146	0.069	0.387	1

Standardizing for linearity, all variables were transformed to their logarithms and the dummy variable was eliminated by expressing number of boats by the surface area of the locality, assuming that untrained boat operators practiced in Balicasag and trained operators practiced in Pamilacan. This last variable was also log-transformed. The resulting regression was highly significant with all coefficients also being highly significant and suggests the possibility of predicting surface time as a function of distance to pod and number of boat per surface. However, the expected trend for the relationship between surface time and distance was a positive instead of the expected negative correlation. A possible reason for this, as already mentioned above, is that the number of boats determines the distance at which boat operators can approach a pod. Thus again, an auto-correlation is suspected.

Table 11. Results of regression analyses testing the effect of several measured parameters (data in Sorongon, 2010, Appendix J) on cetacean behavior and surface time for trained and untrained boat operators in the Bohol Marine Triangle. Surface time is expressed here in minutesa and distance in m.

X		Distance	Locality rank	Number of boats	Surface time	Boat approach
Y	Behavior					
df	174					
R	0.461					
s.e.	0.806					
P-value	1.00E^{-07}					
a	2.25					
b		-0.0055	0.4202	-0.0797	0.0329	-0.008
s.e.	0.297	0.003	0.15	0.028	0.024	0.066
P-value	2.17E^{-12}	0.0521	0.00555	0.00539	0.168	0.904
X		Distance	Locality rank	Number of boats		
Y	Surface time					
df	174					
R	0.245					
s.e.	2.61					
P-value	0.0137					
a	2.126					
b		-0.0117	1.007	-0.0599		
s.e.	0.586	0.00901	0.476	0.0908		
P-value	0.000377	0.196	0.036	0.511		
X		Distance (log_{10})	#boats·km^{-2} (log_{10})			
Y	Surface time (log_{10})					
df	174					
R	0.36					
s.e.	0.359					
P-value	6.43E^{-06}					
a	0.0267					
b		-0.1411	-0.2065			
s.e.	0.0934	0.0441	0.0506			
P-value	0.775	0.00164	6.83E^{-05}			
X		Distance (log_{10})				
Y	Surface time (log_{10})					
df	174					
R	0.213					
s.e.	0.375					
P-value	0.0046					
a	0.326					
b		-0.1321				
s.e.	0.0603	0.046				
P-value	2.01E^{-07}	0.0046				
X		#boats·km^{-2} (log_{10})				
Y	Surface time (log_{10})					
df	174					
R	0.279					
s.e.	0.369					
P-value	0.000182					
a	-0.124					
b		-0.198				
s.e.	0.0827	0.0519				
P-value	0.135	0.000182				

In order to correct for this auto-correlation, regression analyses were performed separately with log-transformed surface time against log-transformed distance and number of boats per surface area. Both regressions, though with low R values, yielded significant F-tests (Table 11). The effect of number of boats per surface area on surface time of cetaceans was higher than that of distance.

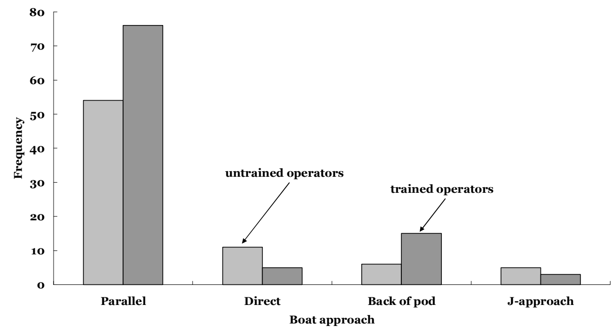

Figure 6. Frequency analysis of boat approaches used in Panglao and Pamilacan Islands, Bohol Marine Triangle, Philippines.

An earlier principal components analysis (PCA) determined that of all the variables being tested here, number of boats and distance of boat to pod was reported to have a high loading value in untrained boat operators (Figure 8, top panel) while boat approach and number of boats was reported for trained boat operators (Figure 8, bottom panel). The PCA results for untrained boat operators showed that avoidance behavior was observed where there were high number of boats represented by the high loading value in Figure 8 (top panel). Distance also showed a high loading value, negative correlation, i.e., avoidance behavior observed as boats are farther from the pod. Surface time was also observed to be longer where cetaceans displayed resting and playful behaviors. Resting behavior also showed an association with the use of the parallel boat approach. The PCA of trained boat operators showed well distributed data among variables, giving no indication as to which variable elicits a particular behavior. Thus, association between the variables tested and behavior was only observed among untrained boat operators specifically the association between high number of boats and increase in avoidance behavior. The results of the suite of regression analyses corroborates with the results of the principal components analysis.

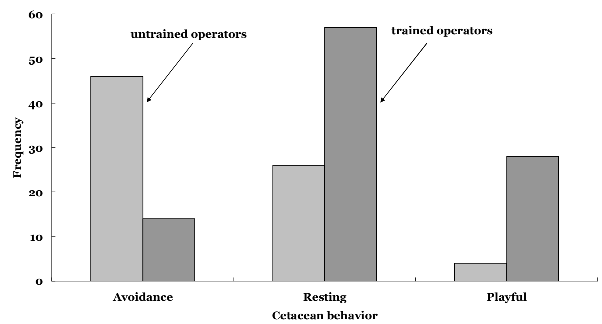

Figure 7. Frequency analysis of cetacean behavior ranks (1: avoidance, 2: playful, 3: resting) observed in Panglao and Pamilacan Islands, Bohol Marine Trinagle, Philippines. Blue bars represent untrained while red are trained boat operators.

Thus, in conclusion, this study proposes that number of boats present at one point in time over the same area or locality expressed as a ratio of surface area of this locality, is the strongest, most visible and easily measurable parameter that can be used to predict the amount of time that cetacean pods will permit encounters with tour boat operators. Such an empirical equation may help monitor and eventually, once more data of this sort is gathered and analyzed, to also manage the cetacean ecotourism trade in the Bohol Marine Triangle.

DISCUSSION

Results from this study confirmed some of the cetacean species observed in the Bohol Marine Triangle (Sabater, 2005), though their residency is still in question. However, this study suggests that species associations among cetaceans in the BMT are directly related to foraging activities. Such species associations are reported in other parts of the world. Melon-headed whales and Fraser's dolphins were reported to travel together in the Gulf of Mexico (Wursig *et al*., 2000). In the Sulu Sea, Fraser's are often seen with short-finned pilot whales (Dolar *et al*., 2006), although the association between these two were not observed in this study. Cetacean interactions such as those reported here can be attributed to foraging and reproductive functions (Rossi-Santos *et al*., 2009) and are also observed in similar situations in the

Bahamas (Herzing *et al.*, 2003), Hawaii (Psarakos *et al.*, 2002) and the Marquesas Islands (Gannier, 2002). The interaction between melon-headed whales, bottlenose dolphins and spinner dolphins reported in Hawaii (Psarakos *et al.*, 2002), is similar to the interaction observed in the BMT, and is assumed due to foraging behavior, particularly on fish species. There may also be competition or collaborative behavior among these three species when they forage since all of them feed on fish and cephalopods (see Table 7). Furthermore, Melon-headed whales, like Spinner dolphins, feed on deep-water myctophid, paralepid and scopelarchid fishes (Jefferson *et al.*, 1993; Brownell *et al.*, 2009) which migrate vertically between depths of 200 to 3,000 m (Clarke, 1973). Bottlenose dolphins feed on a wider variety of fish prey, and like Fraser's dolphins, on a variety of crustaceans (www.sealifebase.org; see Palomares and Pauly 2010). Commonality of prey species among these cetaceans seem to explain the associations observed in this study, although further studies on their food and feeding habits within the BMT are needed.

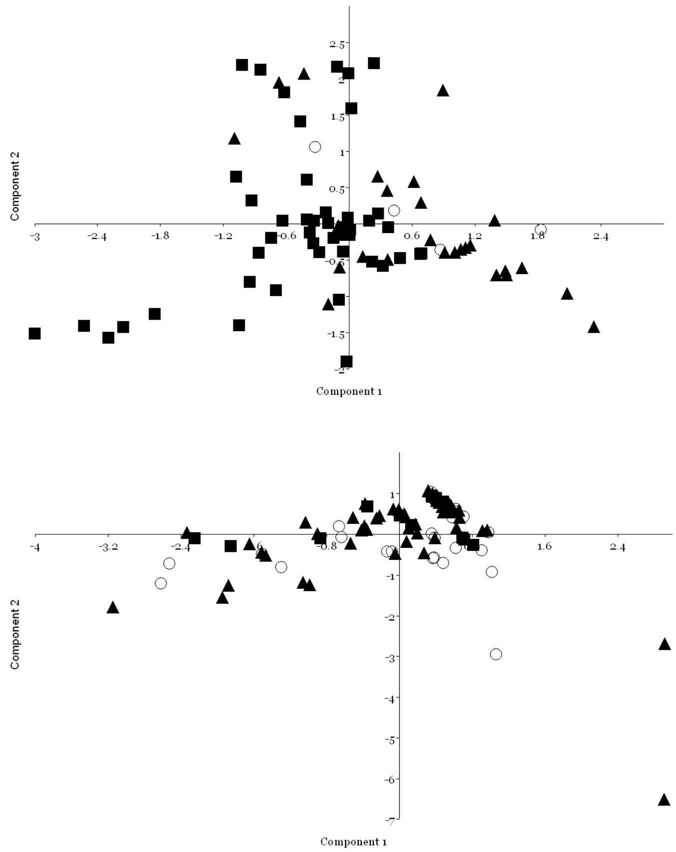

Figure 8. Results of principal components analysis of untrained (top) and trained (bottom) boat operators with cetacean response behavior (black squares: avoidance, white dots: playful, black triangles: resting) in the Bohol Marine Triangle, Philippines.

Results of similar studies based on local ecological knowledge showed that a number of Brazilian fishers identified dolphins as fish and whales as mammals and vice versa (Souza and Begossi, 2007), the misapplication of vernacular names to species coming from the use of unlabeled photographs. It seems that prelabeled pictures (with vernacular and scientific names, if applicable) of the animals being studied facilitates identification by participants in, e.g., perception mapping exercises, though this methodology does not assure identification to the genus or species level, i.e., vernacular names may vary between fisher/ethnic communities. This reiterates the importance of establishing a comprehensive list of marine species occurring in the area being studied, e.g., the BMT. Though this list is indispensable, it does not overshadow the usefulness of knowledge gathered from fisher's notably in providing insights on shifts between past and present species occurrences and predator-prey associations.

The results of our assessment of compliance to the code of conduct applied within the BMT is comparable to those of Scarpaci *et al.* (2003) and Scarpaci *et al.* (2004) for Port Philip Bay, Victoria, Australia, which has a relatively bigger surface area (1,930 km^2) than the BMT (1,120 km^2). The code of conduct in both Port Philip Bay and the BMT limits interaction with pods to two boats at a time applying the parallel boat approach (DSE, 2009). However, Scarpaci *et al.* (2003) reported that, although only 4 tour boats operate in Port Philip Bay, these approached pods with the parallel approach but reposition to the less desirable J-approach as they came closer to the pod, thus generating avoidance behavior from the pods. The parallel approach requires a distance of 50-300 m to be done properly, as can be practiced in Port Philip Bay given its large surface area. In the BMT, where whale watching is restricted sometimes to a surface area of 36 km^2, and given the high boat density, use of the parallel approach requires a widening of the 'watching circle', thus forcing boats to stop at further distances from the pod. In effect, the mere fact that there are many boats circling a pod already generates avoidance behavior (Constantine and Baker, 1997; Nowacek *et al.*, 2001; Constantine *et al.*, 2004; Arcangeli *et al.*, 2008). This may explain why our results showed more avoidance behavior at further distances.

Considering the small population of Port Philip Bay dolphins (80 to 120 individuals), Hale (2002) concludes that an increase in tourism activity may indeed lead to avoidance behavior. Such behavior may in turn cause cetacean populations to migrate to areas with less disturbance levels (Mattson *et al*., 2005), as exhibited by the fast swimming Fraser's dolphins traveling in pods of 100 to 1000 individuals in the eastern tropical Pacific (Dolar, 2009), thus causing a perceived decline in sightings in whale watching areas (Bejder *et al*., 2006b). Such changes in behavioral states imply an increase in energy expenditure and metabolic rate which may affect essential life sustainting acitivities such as feeding and reproduction (Lusseau, 2004; Williams *et al*., 2009). Evading mechanisms, e.g., swimming away from boats or diving, may cause an increase in energy expenditure and may translate to short but frequent breath-intervals (Lusseau, 2003), as observed when untrained boat operators in the BMT approach pods directly.

Our results suggest that, in the BMT, high boat density and untrained boat operators are affecting cetacean populations to a degree that may cause a decrease in sightings possibly due to migrations out of the whale watching zone, not to mention the likely physiological and biological changes which may already occur for resident species. Thus, we highly recommend monitoring studies to be set-up by the concerned municipalities in order to properly assess the state of cetaceans in the BMT.

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REFERENCES

Acebes, J.V., Lesaca, L.A.R., 2003. Research and conservation of humpback whales (*Megaptera novaeangliae*) and other cetacean species in the Babuyan Islands, Cagayan Province, Northern Luzon, Philippines. In: Van der Ploeg, J., Masipiquena, A.B., Bernardo, E.C. (eds.), *The Sierra Madre Mountain Range: Global Relevance, Local Realities. Cagayan Valley. Program on Environment and Development*, pp. 34-42. Golden Press, Tuguegarao City.

Alcala, A., Alava, M., Anglo, E., Aragones, N., Bate, E., Guarin, F., Hermes, R., Lagunzad, D., Montebon, A.R., Miclat, R., Palma, J.A., Pe-Montebon, J., Nacorda, H.M., Perez, T., Trono, G., Jr., Yaptinchay, A.A., 2003. A biophysical assessment of the Philippine territory of the Sulu-Sulawesi marine ecoregion. WWF-Philippines. 240 p.

Arcangeli, A., Crosti, R., 2008. The short-term impact of dolphin-watching on the behavior of bottlenose dolphins (Tursiops truncatus) in western Australia. *J. of Marine Animals and Their Ecology* 2(1), 3-9.

Bejder, L., 2005. Linking short and long-term effects of nature-based tourism on cetaceans. Unpublished PhD, Dalhousie University, Halifax.

Bejder, L., Samuels, A., 2003. Evaluating impacts of nature-based tourism on cetaceans. In: Gales, N., Hindell, M., Kirkwood R. (eds.), *Marine Mammals: Fisheries, Tourism and Management Issues*, pp. 229-256. CSIRO Publishing.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., 2006a. Interpreting short-term behavioral responses to disturbance within a longitudinal perspective. *Animal Behavior* 72, 1149-1158.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C., Krutzen, M., 2006b. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology* 20, 1791–1798.

Blue Ocean Institute, 2005. Project Global: global bycatch assessment of long-lived species, Philippines country profile. Blue Ocean Institute http://bycatch.env.duke.edu/regions/SoutheastAsia/Philippines.pdf. [Accessed 12/02/2010].

BMT Project, 2006. The Bohol Marine Triangle coastal resource management plan: towards a unified and sustainable marine resource conservation and protection. Bohol Marine Triangle Project, 82 p.

Brownell, R.L., Jr., Ralls, K., Baumann-Pickering, S., Poole, M.M., 2009. Behavior of melon-headed whales, *Peponocephala electra*, near oceanic islands. *Marine Mammal Science* 25(3), 639-658.

Bryant, L., 1994. Report to Congress on results of feeding wild dolphins, 1989-1994. Washington, DC: NOAA/National Marine Fisheries Service, Office of Protected Resources, 23 pp.

Buckstaff, K.C., 2004. Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay Florida. *Marine Mammal Science* 20, 709-725.

Calumpong, H.P., (ed.), 2004. Bohol Marine Triangle Project (BMTP): Biodiversity inventory, assessment and monitoring. Foundation for the Philippine Environment, #77 Matahimik St., Teachers' Village, Quezon City 1101, Philippines.

Christensen, L.B., 2006. Marine Mammal Populations: Reconstructing Historical Abundances at the Global Scale. *Fisheries Centre Research Reports* 14(9), 161 pp.

Cisneros-Montemayor, A.M., Sumaila, U.R., Kaschner, K., Pauly, D., 2010. The global potential for whale watching. *Marine Policy* doi:10.1016/j.marpol.2010.05.005.

Clarke, T.A., 1973. Some aspects of the ecology of lanternfishes. (Myctophidae) in the Pacific Ocean near Hawai'i. *Fishery Bulletin* 71, 127-138.

Constantine, R., Baker, C.S., 1997. Monitoring the commercial swim-with-dolphin operations in the Bay of Islands. *Science for Conservation* 56, 1173-2946.

Constantine, R., Brunton, D.H., Dennis, T., 2004. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation* 117, 299-307.

Cunningham-Smith, P., Colbert, D.E., Wells, R.S., Speakman, T., 2006. Evaluation of human interactions with a provisioned wild bottlenose dolphin (*Tursiops truncatus*) near Sarasota Bay, Florida, and efforts to curtail the interactions. *Marine Mammal Science* 32(3), 346-356.

DA-BFAR, 2004. DA and DOT Joint Administrative Order No. 1, series of 2004. Department of Agriculture – Bureau of Fisheries and Aquatic Resources, Philippines.

Dalheim, M.E., 1981. Attraction of gray whales, *Eschrichtius robustus*, to underwater outboard engine noise in Laguna San !gnacio, Baja California Sur, Mexico. In: The 102nd Meeting of the Acoustical Society of America. *J. of the Acoustical Society of America* 70(Suppl. 1), 90 pp.

Department of Sustainability and Environment, 2009. Sustainable dolphin tourism in Port Philip Bay, Australia. The State of Victoria.
http://www.dse.vic.gov.au/DSE/nrenrt.nsf/LinkView/6556E39DB4FEC4ABCA256C91007FE716BB5357677D1317A6CA25725D001DD8F2 . [Accessed 24/05/2010].

Dolar, M.L.L., 1994. Incidental takes of small cetaceans in fisheries in Palawan, Central Visayas and Northern Mindanao in the Philippines. *Report of the International Whaling Commission* (Special Issue 15), 355-363.

Dolar, M.L.L., 1995. Possibilities for coexistence with marine mammals in the Philippines. *IBI Reports* 5, 17-23.

Dolar, M.L.L., 2009. Fraser's dolphin *Lagenodelphis hosei*. In: Perrin, W.F., Wursig, B., Thewissen, J.G.M. (eds.), 2009. *Encyclopedia of Marine Mammals*, 469-471 pp. 2nd edition. Elsevier, USA.

Dolar, M.L.L., Leatherwood, S.J., Wood, C.J., Alava, M.N.R., Hill, C.L., Aragones, L.V., 1994. Directed fisheries for cetaceans in the Philippines. *Report of the International Whaling Commission* 44, 439-449.

Dolar, M.L.L., Perrin, W.F.P., Taylor, B.L., Kooyman, G.L., 2006. Abundance and distributional ecology of cetaceans in the central Philippines. *J. of Cetacean Research and Management* 8, 93-111.

Dolar, M.L.L., Walker, W.A., Kooyman, G.L., Perrin, W.F., 2003. Comparative feeding ecology of spinner dolphins (Stenella longirostris) and Fraser's dolphins (*Lagenodelphis hosei*) in the Sulu Sea. *Marine Mammal Science* 19, 1-19

Dolar, M.L.L., Wood, C.J., 1993. Survey of marine mammals in the central Visayas and northern Mindanao. *Enviroscope* 7(8), 1-6.

Evacitas, F.C., 2001. Impacts of whale watching on the cetaceans and coastal populations in Bais City, Philippines, 1999. Dissertation, University Los Banos, College: Laguna, Philippines, 76 p.

Fish, F.E., Nicastro, A.J., Weihs, D., 2006. Dynamics of the aerial maneuvers of spinner dolphins. *J. of Experimental Biology* 209, 590-598.

Froese, R., Pauly, D., (eds.), 2010. FishBase. www.fishbase.org. version (03/2010).

Gannier, A., 2002. Cetaceans of the Marquesas Islands (French Polynesia): distribution and relative abundance as obtained from a small boat dedicated survey. *Aquatic Mammals* 28, 198–210.

Garrod, B., Fennell, D.A., 2004. An analysis of whalewatching codes of conduct. *Annals of Tourism Research* 31(2), 334-352.

Hale, P., 2002. Interactions between vessels and dolphins. Final Report to the Victoria Department of Natural Resources and Environment, 71 p.

Hertel, H., 1969. Hydrodynamics and swimming of wave-riding dolphins. In: Anderson, H.T. (ed.), *The Biology of Marine Mammals*, 31-63 pp. Academic Press, New York.

Herzing D.L., Moewe, K., Brunnick, B.J., 2003. Interspecies inter-actions between Atlantic spotted dolphins, *Stenella frontalis* and bottlenose dolphins, *Tursiops truncatus*, on Great Bahama Bank, Bahamas. *Aquatic Mammals* 29, 335–341.

Higham, J.E.S., Bejder, L., 2008. Managing wildlife-based tourism: edging slowly towards sustainability? *Current Issues in Tourism* 11(1), 75-83.

Hoyt, E., 1995. The worldwide value and extent of whale watching: 1995. Whale and Dolphin Conservation Society, 1-36 pp. Bath, UK.

Hoyt, E., 2009. Whale watching. In: Perrin, W.F., Wursig, B., Thewissen, J.G.M. (eds.), *Encyclopedia of Marine Mammals*, 1223-1227 pp. Academic Press, San Diego, CA.

IUCN, 2008. The IUCN Red List of threatened species. IUCN, Gland Switzerland.

Jefferson, T.A., Leatherwood, S., Webber, M.A., 1993. FAO species identification guide: marine mammals of the world. Rome, FAO, 320 p.

Leatherwood, S., Dolar, M.L.L., Wood, C.J., Aragones, L.V., Hill, C.L., 1992. Marine mammals confirmed from Philippine waters. *Silliman Journal* 36(1), 65-86.

Lien, J., 2001. The conservation basis for the regulation of whale watching in Canada by the Department of Fisheries and Oceans: a precautionary approach. *Canadian Technical Report of Fisheries and Aquatic Sciences* 2363, vi + 38 pp.

Lusseau, D., 2003. Male and female bottlenose dolphins *Tursiops sp*. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress Series* 257, 267-274.

Lusseau, D., 2004. The hidden cost of tourism: Detecting long-term effects of tourism using behavioural information. *Ecology and Society* 9(1), 15 pp.

Lusseau, D., 2006. Why do dolphins jump? Interpreting the behavioural repertoire of bottlenose dolphins (*Tursiops sp*.) in Doubtful Sound, *New Zealand*. *Behavioural Process* 73, 257-265.

Lusseau, D., Bejder, L., 2007. The long-term consequences of short-term responses to disturbance experiences from whale-watching impact assessment. *International J. of Comparative Psychology* 20, 228-236.

Mattson, M.C., Thomas, J.A., Aubin, D.St., 2005. Effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in waters surrounding Hilton Head Island, South Carolina. *Aquatic Mammals* 31, 33-140.

National Statistics Office (NSO), 2007. 2007 Census of population. http://www.census.gov.ph/data/sectordata/2007/municipality.pdf. [Accessed 16/03/09].

Nowacek, S.M., Wells, R.S., Solow, A.R., 2001. Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science* 17, 673-688.

Nowak, R.M., 2003. Walker's Marine Mammals of the World. John Hopkins University Press, London, 263 pp.

Orams, M.B., 2001. From whale hunting to whale watching in Tonga: A sustainable future? *J. of Sustainable Tourism* 9(2), 128-146.

Palomares, M.L.D., Pauly, D., (eds.), 2009. SeaLifeBase. www.sealifebase.org. version (01/2009).

Palomares, M.L.D., Pauly, D., (eds,), 2010. SeaLifeBase. www.sealifebase.org. version (03/2010).

Parsons, E.C.M., Warburton, C.A., Woods-Ballard, A., Hughes, A., Johnston, P., 2003. The value of conserving whales: the impacts of cetacean-related tourism on the economy of rural West Scotland. *Marine and Freshwater Ecosystems* 13, 397-415.

Perryman, W.L., 2009. Melon-headed whale *Peponocephala electra*. In: Perrin, W.F., Wursig ,B., Thewissen, J.G.M. (eds.), *Encyclopedia of Marine Mammals*, 719-720 pp. 2nd Edition. Elsevier, USA.

Pryor, K., 1986. Non-acoustic communicative behavior of the great whales: origins, comparisons and implications for management. *Report of the International Whaling Commission* (Special issue) 8, 89-96.

Psarakos S., Herzing, D.L., Marten, K., 2003. Mixed-species associ- ations between pantropical spotted dolphins (*Stenella attenuata*) and Hawaiian spinner dolphins (*Stenella longirostris*) off Oahu, Hawaii. *Aquatic Mammals* 29, 390–395.

Quiros, A.L., 2007. Tourist compliance to a code of conduct and the resulting effects on whale shark (*Rhincodon typus*) behavior in Donsol, Philippines. *Fisheries Research* 84, 102-108.

Reeves, R.R., Smith, T.D., 2003. A taxonomy of world whaling: operations, eras, and data sources. *Northeast Fish. Sci. Cent. Ref. Doc.* 03-12, 28 p.

Renker, A.M., 2007. Whale hunting and the Makah Tribe: A needs statement. IWC/59/ASW9, 80 pp.

Ritter, F., 2003. Interactions of cetaceans with whale-watching boats – Implications for the management of whale-watching. A special report from M. E. E. R. e V. based on the findings of research project M. E. E. R. La Gomera (1995-2001), 89 pp.

Rossi-Santos, M.R., Santos-Neto, E., Baracho, C.G., 2009. Interspecific cetacean interactions during the breeding season of humpback whale (*Megaptera novaeangliae*) on the north coast of Bahia State, Brazil. *J. of the Marine Biological Association of the United Kingdom* 89, 961-966.

Sabater, E.R., 2005. Cetaceans of the Bohol Marine Triangle Area, Bohol, Philippines: Assessment and Monitoring. Poster presented at the 16th Biennial Conference on the Biology of Marine Mammals. San Diego, California. December 12 – 16, 2005.

Scarpaci, C., Dayanthi, N., Corkeron P.J., 2003. Compliance with regulations by "swim-with-dolphins" operations in Port Phillip Bay, Victoria, Australia. *Environmental Management* 31(3), 432-347.

Scarpaci, C., Dayanthi, N., Corkeron, P.J., 2004. No detectable improvement in compliance to regulations by "swim-with-dolphin" operations in Port Philip Bay, Victoria, Australia. *Tourism in Marine Environments* 1(1), 41-48.

Schaffar, A., Garrigue, C., 2008. Exposure of humpback whales to unregulated tourism activities in their main reproductive area in New Caledonia. IWC SC60/WW8. http://www.iwcoffice.org/_documents/sci_com/SC60docs/SC-60-WW8.pdf. [Accessed 16/03/09].

Schneider, K.B., 1973. Age determination in sea otter. Projects W-17-4 and W-17-5. Marine Mammal Investigations. Alaska Department of Fish and Game.

Shane, S.H., Wells, R.S., Wursig, B., 1986. Ecology, behavior and social organization of the bottlenose dolphin: a review. *Marine Mammal Science* 2, 34-63.

Souza, S.P., Begossi, A., 2007. Whales, dolphins or fishes? The ethnotaxonomy of cetaceans in Sao Sebastiao, Brazil. *J. of Ethnobiology and Ethnomedicine* 3(9), 1-15.

Tan, J.M.L., 1995. *A Field Guide to the Whales and Dolphins in the Philippines*. Makati City: Bookmark. 125 p.

Weinrich, M., 2005. A review of collisions between whales and whale watch boats. *J. of Cetacean Research and Management* IWC SC/57/WW8. http://www.whalecenter.org/pdfs/WorldwideCollisionsBoatsSC57WW8.pdf. [Accessed 16/03/2009].

Wells, R.S., Scott, M.D., 1997. Seasonal incidences of boat strikes on bottlenose dolphins near Sarasota, Florida. *Marine Mammal Science* 13, 475-480.

Wells, R.S., Scott, M.D., 2009. Common bottlenose dolphins *Tursiops truncatus*. In: Perrin, W.F., Wursig ,B., Thewissen, J.G.M. (eds.), *Encyclopedia of Marine Mammals*, 251-253 pp. 2nd edition. Elsevier, USA.

Williams, R., Bain, D.E., Smith, J.C., Lusseau, D., 2009. Effects of vessels on behaviour patterns of individual southern resident killer whales *Orcinus orca*. *Endangered Species Research* 6, 199-209.

Williams, R., Lusseau, D., Hammond, D. 2006. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation* 133(3), 301-311.

Williams, R., Trites, A.W., Bain, D.E., 2002. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *J. of Zoology London* 256, 255-270.

World Wildlife Fund (WWF), 2008. Humpback whale research & conservation project in the Babuyan Islands. http://www.wwf.org.ph/about.php?pg=wwd&sub1=00003 [Accessed 15/02/09].

Wursig, B., Jefferson, T.A., Schmidly, D.J., 2000. *The Marine Mammals of the Gulf of Mexico*. Texas A & M University Press, College Station, TX.