BOAT STRIKE ASSESSMENT ON RESIDENT SEA TURTLES IN MABUL ISLAND, SABAH, MALAYSIA

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The materials in this thesis are original except for quotations, summaries and references which have duly acknowledged.

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ABSTRACT

Boat strike is one of the major threats to sea turtles especially at shallow reef areas where boat traffic is heavy. In the Southeast Asian region, there is no published study on boat strike on sea turtles. The current study aims to determine the effects of boat strikes on the resident sea turtles in Mabul Island (4.246°N 118.630°E), which is one of the tourist hotspots and is also key foraging ground of green (*Chelonia* mydas) and hawksbill (*Eretmochelys imbricata*) turtles, located in southeast Sabah, Malaysia. Wild green and hawksbill turtles in Mabul were hand-captured in the reefs and were brought onto the boat for data collection. A detailed physical examination was done on all captured turtles before they were released back to the water. The data consisted of 432 individual sea turtles caught from March 2013 to November 2017 (43 days of field work), with 405 (93.7%) greens and 27 (6.3%) hawksbills. There were 38 (9.4%) green turtles and no hawksbill turtle found to have boat strike injuries. A total of 58 boat strike injuries were documented, which consisted of cut wounds (58.6%), parallel cuts (19.0%), deep incised wounds (13.8%), and blunt force wounds (8.6%), with cut wound being the dominant type ($\chi^2 = 36.207$, $df = 3$, $p < 0.01$). This study developed a novel approach to categorise the severity of these injuries using the ranking system, with increasing order of severity from Ranks 1 to 6. The number of different boat strike injury severity rankings were evenly distributed ($\chi^2 = 3.508$, $df = 4$, $p = 0.48$). The severity of the boat strike injuries on sea turtles is dependent on the boat speed and the ability of the turtles to avoid the approaching boats. The current study showed that the posterior part of the carapace of a sea turtle is most susceptible to boat strikes compared to other parts of the body. The established dive sites located in close proximity to the island (between 200 and 350 m from Mabul) were found with highest percentages of turtles with boat strike injuries: Paradise 1 (15.4%), Paradise 2 (11.1), Panglima Reef (10.9), and Lobster Wall (9.5%), as opposed to those further away (between 1,000 and 1,500 m from Mabul): Ray Point (4.7%) and Eel Garden (4.3%). Higher percentage of sea turtles with boat strike injuries found at Paradise 1, Paradise 2, and Panglima Reef may be caused by the higher localised boat traffic (between 5 and 20 passing boats every minute at daytime) surrounding the island as motorised boats are the main mode of transportation in Mabul. It is suggested that boat speed regulations should be implemented at these areas and reef areas with depth < 20 m as foraging turtles will swim to the surface to breathe. This study has provided important baseline information on the effects of boat strike incidents on green turtles and this issue needs to be addressed as Mabul is one of the key foraging grounds for green and hawksbill turtles coming from various natal origins.

ABSTRAK

PENILAIAN PELANGGARAN BOT TERHADAP PENYU RESIDEN DI PULAU MABUL, SABAH, MALAYSIA

Pelanggaran bot adalah salah satu ancaman utama kepada penyu terutamanya di kawasan terumbu karang yang cetek, di mana trafik bot di kawasan tersebut adalah sibuk. Tidak ada kajian yang didapati di mengenai pelanggaran bot pada penyu di Asia Tenggara. Kajian ini bertujuan untuk menentukan kesan pelanggaran bot pada penyu yang ditangkap di Pulau Mabul (4.246°N 118.630°E). Ia adalah antara tempat tumpuan pelancong dan juga antara kawasan ternakan penting kepada penyu hijau (Chelonia mydas) dan sisik (Eretmochelys imbricata), yang terletak di tenggara Sabah, Malaysia. Penyu hijau dan sisik liar di kawasan terumbu karang di Mabul ditangkap dan dibawa ke dalam bot untuk pengumpulan data. Peperiksaan fizikal terperinci dilakukan kepada semua penyu yang ditangkap, sebelum dibebaskan kembali ke dalam air. Kajian ini mempunyai data sebanyak 432 ekor penyu yang ditangkap dari Mac 2013 hingga November 2017 (43 hari kerja lapangan). Sebanyak 405 (93.7%) ekor penyu adalah penyu hijau dan 27 (6.3%) ekor penyu adalah penyu sisik. Terdapat 38 (9.4%) ekor penyu hijau dan tidak ada penyu sisik didapati mempunyai kecederaan pelanggaran bot. Sejumlah 58 kecederaan pelanggaran bot telah didokumentasikan, terdiri daripada kategori-kategori seperti luka potong (58.6%), luka potong selari (19.0%), insisi dalam (13.8%), dan luka bertakik (8.6%). Luka potong mempunyai kategori kecederaan pelanggaran bot yang paling banyak ($\chi^2 = 36.207$, dk = 3, $p < 0.01$). Kajian ini telah menghasilkan satu pendekatan baru untuk membezakan tahap keparahan kecederaan tersebut melalui sistem taraf, dari Taraf 1 hingga ke 6 mengikuti keparahan kecederaan. Bilangan keparahan kecederaan pelanggaran bot dari pelbagai taraf diagihkan sama rata ($\chi^2 = 3.508$, dk = 4, $p = 0.48$). Keparahan kecederaan pelanggaran bot bergantung kepada kelajuan bot dan keupayaan penyu untuk mengelakkan bot-bot yang mendekati. Kajian ini menunjukkan bahawa bahagian belakang karapas penyu adalah tempat yang paling mudah terdedah kepada serangan bot berbanding dengan bahagian badan yang lain. Lokasi tapak-tapak selam yang berdekatan dengan pulau (di antara 200 dan 350 m dari Mabul) mempunyai peratusan penyu hijau dengan kecederaan pelanggaran bot yang tertinggi: Paradise 1 (15.4%), Paradise 2 (11.1), Panglima Reef (10.9), dan Lobster Wall (9.5%), berbanding dengan yang jauh (di antara 1,000 dan 1,500 m dari Mabul): Ray Point (4.7%) dan Eel Garden (4.3%). Lebih banyak penyu yang dijumpai di Paradise 1, Paradise 2, dan Panglima Reef terdapat kecederaan pelanggaran bot mungkin disebabkan oleh kesibukan lalu lintas bot (di antara 5 dan 20 bot berlepas setiap minit pada waktu siang) di sekeliling, kerana bot bermotor adalah pengangkutan utama di Mabul. Kajian ini mencadangkan bahawa peraturan mengenai kelajuan bot harus dilaksanakan di kawasan tersebut dan di kawasan terumbu karang dengan kedalaman < 20 m kerana penyu akan berenang ke permukaan air untuk bernafas. Kajian ini telah memberikan maklumat asas yang penting mengenai kesan pelanggaran bot pada penyu hijau dan isu ini perlu ditangani kerana Mabul adalah antara kawasan ternakan yang penting kepada penyu hijau dan sisik yang berasal daripada tempat yang berbeza.

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LIST OF SYMBOLS

%	-	percent
=	-	equals to
<	-	less than
>	-	more than
α	-	alpha value
χ^2	-	Chi-square value

LIST OF ABBREVIATIONS

cm	-	centimetres
df	-	degree of freedom
ESA	-	Endangered Species Act
g	-	grams
hp	-	horsepower
hr	-	hour
kg	-	kilograms
km	-	kilometres
m	-	metres
max	-	maximum
min	-	minimum
N	-	sample size
NMFS	-	National Marine Fisheries Service
SCL	-	Straight Carapace Length
SD	-	standard deviation
STIP	-	Sabah Turtle Islands Park
USFWS/FWS	-	U.S. Fish and Wildlife Service

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CHAPTER 1

INTRODUCTION

1.1 Sea Turtles

The seven extant species of sea turtles include the green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), Kemp's ridley (*Lepidochelys kempii*), loggerhead (*Caretta caretta*), flatback (*Natator depressus*) and leatherback (*Dermochelys coriacea*) (Meylan & Meylan, 1999). Leatherback sea turtles are classified under the family Dermochelyidae while the rest of the six species belong to the family Cheloniidae. The existence of these species of sea turtles date back to a hundred million years ago (Spotila, 2004).

The dorsal shell of the sea turtle is called carapace which is made up of the axial skeleton covered by keratinised scutes, while the ventral shell is called plastron which is composed of derivatives of the axial and appendicular skeleton (Wyneken, 2001). The carapace is tough and is made up of different composition arranged in layers with varying mechanical properties to sustain incoming impact (Achrai & Wagner, 2013). It serves to protect them against injuries caused by predatory attacks and other forms of physical impacts (Achrai & Wagner, 2013).

Sea turtles spend most of their time inhabiting the marine environment. The habitats at different life stages (Bresette et al., 2010) of sea turtles are classified into four sections: 1) early juvenile nursery habitat (usually pelagic and oceanic), 2) later

juvenile developmental habitat (usually demersal and neritic), 3) adult foraging habitat, and 4) adult inter-nesting and/or breeding habitat (Musick & Limpus, 1997). Sea turtles occupy different marine habitat at specific life stages. The nesting and foraging grounds of sea turtles are different, therefore the sea turtles sighted underwater at a given location may be of different populations: foraging turtles that resides around the area most of the time across long period of time, and nesting turtles that visit the area during nesting season (Senko et al., 2010; Teh et al., 2018).

Sea turtles are unique in various traits that are different from other marine animals. They are oviparous animals which possess a pair of lungs and breathe in air for respiration. Adult females lay eggs on sandy beaches and return to the sea. Once the eggs hatch, the hatchlings enter into a state called 'swim frenzy' where they actively swim away from land until they reach the epipelagic habitat (Burgess et al., 2006). It was believed that these hatchlings swim off to the sea and are subjected to the ocean current until they grow into much larger size (Bolten, 2003; Luschi et al., 2003). However, recent studies had shown that they do not drift along with ocean currents but may be actively swimming in the sea (Putman & Mansfield, 2015). The hatchlings spend about three to five years in the sea as carnivores before moving on into their next life cycle (Reich et al., 2007). Post-hatchlings can complete their development at the neritic zone or in the oceanic zone (Bolten, 2003). Studies had shown that juvenile green and hawksbill turtles show high fidelity towards their residential areas (Palaniappan & Haziq Harith, 2017) and hawksbills exhibit short range migration to foraging sites (Horrocks et al., 2001). When reaching adulthood, sea turtles conduct seasonal migration over long distance between established feeding and breeding sites (Plotkin, 2003).

In the waters of Malaysia, four species of nesting sea turtles can be found which include green, hawksbill, olive ridleys and leatherback sea turtles (Chan, 2006). The Sabah Turtle Islands Park (STIP) in Sabah is among the largest nesting grounds for green turtles in Southeast Asia (Jensen et al., 2016). In 2016, the number of green turtle nests amounted to more than 10,000 at STIP (Joseph, 2017). Redang Island, Geliga, Paka, and Ma Daerah of Terengganu, are also important nesting grounds of green turtles in Malaysia (SEAFDEC Meeting on Regional Sea Turtle Data Management, 2000; Chan, 2013; Joseph, 2017). Other green turtle landing sites are

in the coasts of Penang, Malacca, Perak, Pahang, and Johor (Liew, 2002; Salleh et al., 2012). Whereas for the hawksbills, a total of 243 to 713 nests were laid from 1979 to 2016 at STIP annually (Joseph, 2017). In Melaka, hawksbill turtles had between 200 and 300 nests annually (Chan, 2006). Other hawksbill landing sites include Johor and Terengganu (Liew, 2002). In Peninsular Malaysia, annual nesting of leatherback turtles in Rantau Abang and Dungun of Terengganu had declined rapidly from 800 nests in 1984 to less than 50 nests in 2001 (SEAFDEC Meeting on Regional Sea Turtle Data Management, 2000; Chan, 2006). There were only five to 8 nests annually from 2004 to 2010, and no nesting from leatherbacks since 2011 (Kadir, 2016). Landings of olive ridleys were extremely rare and is on present at the coasts of Penang (Salleh et al., 2012). A total of 11 olive ridleys, 1,723 green and 10 hawksbill turtle nests were recorded in 2000 (Tisen & Bali, 2001), whereas in 2001, there were more than 2,000 annual green turtle nests (Chan, 2006) in the Talang-Satang National Park (TSNP) of Sarawak. The total annual turtle nesting in TSNP maintained at about 3,000 nests from 2005 to 2013 (Bali et al., 2016).

Green and hawksbill turtle populations are distributed worldwide in tropical and subtropical regions (Seminoff, 2004). Green turtles feed on sea grasses and algae, and inhabit the neritic zone including the nearshore and inshore areas where food resources are abundant (Arthur et al., 2008). Hawksbills forage mainly on sponges and inhabit coral reef, hardbottom, seagrass, with cliff wall areas (Musick & Limpus, 1997; Bjorndal & Bolten, 2010). Both foraging green and hawksbill turtles show high fidelity towards their residential areas (Blumenthal et al., 2009; Palaniappan & Haziq Harith, 2017). The nesting green turtles from Talang Satang National Park and Redang Island of Terengganu tend to migrate to the waters of Sabah (Luschi et al., 1996; Liew et al., 2000). Through published studies, several foraging grounds of sea turtles in Southeast Asia had been identified (Kadir, 2016). The sea turtle foraging grounds in Malaysian waters are located in Lawas (Joseph et al., 2016), Mantanani (Pilcher 2010), Mabul Island (Palaniappan & Haziq Harith, 2017), and Sipadan Island (Tinsung et al., 2011). Studies had shown that the foraging grounds of sea turtles consist of mixed stock aggregations from various nesting rockeries (Joseph et al., 2014; Joseph et al., 2016; Nishizawa et al., 2016; Nishizawa et al., 2018). Protecting foraging grounds of sea turtles thus helps ensure healthy populations of sea turtles of various origins.

Sea turtles are important marine organisms as they play a part in the marine food chain, such as consumers, prey, and competitors; hosts for parasites and pathogens; nutrient transporters; substrates for epibionts such as barnacles; and as landscape modifiers (Bjorndal & Jackson, 2003). Eggs laid by sea turtles on nesting beaches are a source of nutrients for natural predators such as dogs and raccoons, whereas unhatched eggs will become decomposing materials in the food chain and absorbed by plants (Bouchard & Bjorndal, 2000). Hatchlings that emerge from hatched eggs will enter into the ocean and may be consumed by natural predators in the marine environment (Bouchard & Bjorndal, 2000). The eggshells and chorio-allantoic fluid will remain on the beach to fertilise the soils (Bouchard & Bjorndal, 2000).

Sea turtles are also traditionally being utilised by humans. Sea turtles are traditionally exploited as a source of nutrients from their meat as well as eggs, and the skin of sea turtles are processed into leather accessories (Campbell 2003). Various parts of the sea turtles are also utilised as medicine (Hoinsoude et al., 2002; Alves 2006). Sea turtles are known as key organisms for marine conservation in various regions (Chatwin 2007). The presence of sea turtles in the marine ecosystem is an indicator for 'Good Environmental Status' (GES) in the conservation strategies in all European Seas: Baltic Sea, Black Sea, Mediterranean and North East Atlantic set by the European Union's Marine Strategy Framework Directive (Cardoso et al., 2010). The sea turtles were listed under the 'Abundance/distribution maintained within an acceptable range' criteria as they represent animals at the top of the food web and are charismatic species (Cardoso et al., 2010).

1.2 Threats to Sea Turtles

Under the International Union for Conservation of Nature (IUCN) Red List (2019), the hawksbill and Kemp's ridley turtles are listed as 'critically endangered'; green turtles are 'endangered'; leatherback, olive ridley and loggerhead turtles are 'vulnerable'. Overall, sea turtle populations around the globe are threatened by various human activities.

Threats to sea turtles that result in mortality should be addressed as these animals are long-lived, and have slow maturity rates. One major threat to sea turtles is the world-wide unintentional catch by the artisanal (Barrios-Garrido & Montiel-Villalobos, 2016) and commercial fisheries industries (Eckert & Sarti, 1997; Donoso & Dutton, 2010; Lewison et al., 2014). These studies had documented high numbers of sea turtles being captured and drowning.

Unsustainable development on coastal areas at tropical regions are reducing the available space for the sea turtles to nest (Lopez et al., 2015). The lack of planning and proper management on coastal development, in addition to the lack of legislation on environmental planning can damage the environment (El Mrini et al., 2012). Coastal development also promotes artificial lighting during the night and causes disturbance to nesting sea turtles and the disorientation of turtle hatchlings when they crawl towards the sea after they hatch (Witherington & Martin, 2000).

Marine debris such as plastics can be mistaken by the sea turtles as food which lead to death (Derraik, 2002; Barnes et al., 2009; Ryan et al., 2009). Oil spills and other pollutants may greatly increase the mortality of sea turtles and also other marine animals (Stewart et al., 2011; Noone et al., 2013). The presence of xenobiotic compounds that are toxic inorganic elements and includes PCBs, OCPs, and PAHs render sea turtles to be more susceptible to diseases (Aguirre et al., 1994; Keller et al., 2006; Camacho et al., 2013). Heavy metals in sea turtles accumulate in the liver, kidneys, pancreas, and spleen (Caurant et al., 1999; Sakai et al., 2000).

In Malaysia, sea turtles are subjected to bycatch from pelagic trawlers and artisanal fisheries (Lewison et al., 2011), and intentional catch by illegal foreign vessels (Pilcher et al., 2008; Kaur et al., 2010). In Semporna, Sabah, sea turtle eggs are also being poached for consumption (Teh et al., 2018). These poached eggs were sold between RM 1 and 2 per egg in Semporna, and an estimate of 7,500 to 15,000 sea turtle eggs were consumed every year, which is equivalent to an economic value of 3,500 to 7,050 USD (Teh et al., 2018).

Vessel strikes are a threat to sea turtles especially in shallow waters where commercial and recreational vessels are heavily used (Lutcavage et al., 1997; Hazel

& Gyuris, 2006; Schofield et al., 2007, 2010). In the waters of the United States of America, there was an increase of 10.5% in the number of stranded loggerhead turtles caused by vessel strikes from the 1980s to 2004, from approximately 10% to 20.5% (NMFS & USFWS, 2007). In Queensland (Australia), the number of total turtle strandings increased rapidly, while the number of sea turtle strandings caused by vessel strikes fluctuated from 12% to 16% during the period of 1990 to 2002 (Hazel & Gyuris, 2006). In the waters of Malaysia, illegal harvesting of sea turtles and their eggs had been reported (Kaur et al., 2010). However, boat strike on sea turtles is not well addressed in the Southeast Asian region.

1.3 Conservation Efforts on Sea Turtles

Conservation of sea turtles mainly aims to promote the survival of sea turtle populations in the long term by recovering depleted stocks, protection of habitats, and taking into concern the dynamics of interactions with the human communities (Eckert, 1999). Protection of sea turtles from their human-induced threats are implicated differently in different regions. All species of sea turtles are protected under the Convention on International Trade in Endangered Species (CITES) from international trading. Sea turtles in the Indo-Pacific region are also protected under the Convention on the Conservation of Migratory Species of Wild Animals (CMS).

In the United States of America, sea turtles are protected under the Endangered Species Act (ESA) which include species such as green, hawksbill, leatherback, Kemp's ridley, and loggerhead turtles (ESA, 1973). In Brazil, sea turtle conservation began in 1980 with the initiation of Projeto TAMAR (Brazilian National Sea Turtle Conservation Program) (Marcovaldi & Marcovaldi, 1999), with the aim to protect and conserve sea turtles along the Brazilian coastline. The Environment Protection and Biodiversity Conservation Act 1999 under the Australian government is enforced to conserve sea turtle populations in Australia. In the Philippines, Task Force Pawikan in 1979 was enforced to protect and conserve sea turtles, which is now under the Pawikan Conservation Project of the Department of Environment and Natural Resources (Trono, 1991; Cruz, 2004; Bagarinao, 2011).

In Malaysia, sea turtles' protection and conservation are regulated by their respective states (Fisheries Act, 1985). Sea turtles are not listed as a protected animal in the state of Perlis and Selangor of Malaysia as there were no recorded sea turtle landing (Ahmad et al., 2004). In Sabah, there are several legislations that list sea turtles as protected animals. The Wildlife Conservation Enactment 1997 had listed green and hawksbill turtles as totally protected animals; the Fauna Conservation Ordinance 1963 of Act No. 11, and the Custom Act 1967, had prohibited the trading of sea turtles in Sabah; and the Fauna Conservation (Turtle Farms) Regulations, 1964 regulates the collection of green and hawksbill turtle eggs for hatchery purposes. Sea turtles are also protected within gazetted Parks and Natural Reserves under the Parks Enactment 1984, Part VIII, No. 48 (1) d.

1.4 Significance of Study

Mabul Island, located on southeast Sabah and 15 km away from Sipadan Island is one of the tourist hotspots in Sabah and is also key foraging ground of green and hawksbill turtles in the Celebes Sea (Palaniappan & Haziq Harith, 2017). Although green turtles were reportedly nested in Mabul, the majority of the sea turtles were foraging at the reefs of Mabul and resides for years. Adult sea turtles in Mabul documented by Palaniappan (unpublished data) consisted of mostly recaptures, meaning that they reside in Mabul at a prolonged duration. Protecting the foraging population of sea turtles is important as foraging sea turtles composed of individuals from various natal origins (Joseph et al., 2014; Joseph et al., 2016; Nishizawa et al., 2016; Nishizawa et al., 2018).

Sea turtles are known as key organisms for marine conservation in various regions (Chatwin, 2007). It is therefore important to look into the susceptibility of sea turtles towards various threats to ensure the conservation of these marine reptiles and their ecosystems. Teh et al. (2018) have highlighted one important threat to the turtles in Mabul is the poaching of the eggs for consumptions. It was estimated that the non-consumptive value of the turtles could easily exceed their consumptive use value, by generating income through tourism sector (Teh et al., 2018).