THE CONSERVATION OF GREEN SEA TURTLES (Cheloniidae: *Chelonia mydas*) AT SETIU, TERENGGANU, MALAYSIA

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by

AINI HASANAH BINTI ABD MUTALIB

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In the name of Allah, the most beneficent, the most merciful.

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"Unless someone like you cares a whole lot, nothing is going to get better. It's not."

-Dr Seuss, The Lorax

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ABSTRAK

Kajian tentang ekologi sarang dan perlakuan penyu agar (*Chelonia mydas*) telah dijalankan di Setiu. Kajian ini meliputi taburan, sifat sarang, saiz sarang, morfologi penyu bertelur, percubaan membuat sarang palsu, aktiviti bertelur yang berjaya dan waktu kemunculan. Kedua, pengurusan tapak penetasan di Setiu dinilai melalui nilai penetasan berjaya, tempoh pengeraman dan keadaan telur. Seterusnya, kajian ini menilai tumbesaran dan variasi skut karapas anak penyu berdasarkan tempoh pemindahan dari pantai ke tapak penetasan. Kajian terakhir menentukan tahap kesedaran orang awam di Setiu tentang pemuliharaan penyu berdasarkan kumpulan umur dan jantina orang awam yang meliputi tahap pemakanan telur penyu, dan trend pemakanan telur penyu dan pembahagiannya serta justifikasi yang mendorong ke arah trend pemakanan telur penyu tersebut. Data ekologi dan perlakuan dikutip sejak 2007 hingga 2012. Salah satu pantai (Telaga Papan) telah diberi fokus berdasarkan data yang dikutip pada 2012. Telaga Papan secara signifikannya mencatatkan taburan yang paling tinggi berbanding lima pantai yang lain (ANOVA, $F_{5, 42} = 8.87$, $p < 0.0001$, mean = 36.75 ± 3.73). Tahun 2012 mencatatkan rekod sarang yang paling tinggi (min = 28.71 ± 6.58). Tiada korelasi antara saiz penyu bertelur dengan saiz sarang ($r_s = 0.23$, $p = 0.14$, $p > 0.05$). Majoriti individu mendarat pada pukul 12.00 hingga 12.59 pagi (23%). Terdapat korelasi yang kuat antara aktiviti bertelur yang berjaya dengan percubaan membuat sarang palsu ($r_s = 0.8827$, $p = 0.0198$). Kajian menunjukkan terdapat perbezaan signifikan terhadap jumlah penetasan yang berjaya antara tahun 2009 hingga 2012 ($F_{3, 618} = 5.05$, $P = 0.002$). Tiada perbezaan signifikan untuk jumlah penetasan yang berjaya antara lokasi pantai daripada tahun 2009 hingga 2012 ($F_{4, 618}$= 1.06, P = 0.39). Majoriti daripada telur yang dieram berjaya ditetaskan (73.9%) dan secara keseluruhan, paling sedikit peratusan telur yang dimusnahkan oleh pemangsa semulajadi (0.5%). Jumlah penetasan berjaya paling tinggi dan signifikan dalam hatcheri tertutup (mean = 86. 84 ± 2.74, $F_{2, 202}$ = 7.75, p = 0.0006). Tempoh pengeraman paling rendah secara signifikan dalam hatcheri terbuka (min = 47.24 ± 0.62, $F_{2, 202}$ = 27.81, p < 0.0001). Dalam kajian tentang tumbesaran anak penyu, anak penyu dari Kuala Baharu Utara (KBU) dan Mengabang Sekepeng (MSK) lebih besar secara signifikan dalam ukuran panjang lengkung lurus, lebar lengkung lurus, dan berat (F= 40.07, p<0.05). Saiz anak penyu yang normal lebih besar daripada anak penyu yang mempunyai kepelbagaian skut atas karapas (χ^2 = 37.75, p < 0.05). Kajian terakhir menilai tahap kesedaran tentang penyu agar berdasarkan kumpulan umur dan jantina antara penduduk di Setiu, Terengganu (yang juga merupakan lokasi eko-perlancongan popular di Malaysia). Responden lelaki mempunyai tahap kesedaran lebih tinggi secara signifikan berbanding wanita (min = 28.86 ± 0.49, ($F_{1,770}$= 16.69, p < 0.001)). Penilaian berdasarkan kumpulan umur menunjukkan responden lebih tua mempunyai tahap kesedaran lebih rendah berbanding kumpulan umur yang lain (min = 21.19 ±1.06, ($F_{1, 770}$= 8.97, p <0.001)). Hasil kajian tentang pemakanan telur penyu menunjukkan kebanyakan rakyat tempatan sudah pun berhenti makan telur penyu. Pengurusan dan perancangan yang berintegrasi tentang pemuliharaan penyu agar perlu diadakan di Setiu. Hal ini termasuklah kajian biologi dan pemantauan, kelas kemahiran dan latihan intensif, program pendidikan dan kesedaran, perlaksanaan polisi dan undang undang, kerjasama antara agensi kerajaan dengan badan bukan kerajaan dan lain lain lagi.

THE CONSERVATION OF GREEN SEA TURTLES, (Cheloniidae: *Chelonia mydas*) AT SETIU, TERENGGANU, MALAYSIA

ABSTRACT

This study conservation of green sea turtles (*Chelonia mydas*) at Setiu was studied by determining their distribution, nest characteristics, clutch size, nesting morphology of the nesting green turtles, false crawl attempts, successful nesting attempts and emergence hour. Hatchery management was also facilitated by measuring the successive hatching rate, duration of incubation, egg condition, hatchlings' growth and hatchlings' carapacial scutes variation. This study also assessed socio-demographic aspect on the trends of consuming turtle eggs. Secondary data on nesting ecology and behaviour were collected from 2007 to 2012. Data on successful hatching rate and days of incubation were collected from 2009 to 2012. Hatchlings' growth and carapacial scute variation were determined in the year 2012. Survey forms were collected from the communities in Setiu to assess their level of awareness regarding green sea turtle conservation. Telaga Papan has significantly the highest distribution of green marine turtle nesting than the other five beaches (ANOVA, $F_{5, 42} = 8.87$, $p < 0.0001$). The highest number of successful nesting attempts was in 2012 (mean = 28.71 ± 6.58). There was no correlation between size of the female turtles and the number of eggs ($r_s = 0.23$, $p = 0.14$). The majority of the turtles landed between 1200h and 0159h (23%). There was a strong correlation between successful nesting attempts with false crawls ($r_s = 0.88$, $p = 0.02$). Results show that there was a significant difference in successive hatching rate between the years ($F_{3, 618} = 5.05$, $P = 0.002$). There was no significant difference for successive hatching rates among the beaches over the four years ($F_{4, 618} = 1.06$, $P = 0.39$). The majority of the eggs were successively hatched in 2012 (73.9%), with the least number of eggs consumed by natural predators (0.5%). Successive hatching rate was significantly higher in shaded hatchery (mean = 86. 84 ± 2.741, $F_{2,202}$ = 7.75, p = 0.0006). Duration of the incubation is significantly was shorter in open hatcheries ($F_{2, 202}$ = 27.81, p < 0.0001). In the study of hatchling's growth, hatchlings from Kuala Baharu Utara (KBU) and Mengabang Sekepeng (MSK) were significantly larger in straight curve length (SCL), straight curve width (SCW) and body weight (F= 40.07, p<0.05). Normal hatchlings were significantly larger than those with carapacial scute variation (χ^2 = 37.75, p < 0.05). The awareness level among male respondents was significantly higher level of awareness compared to female ($F_{1, 770}$= 16.69, p < 0.001). On the age factor, older respondents scored significantly lowest than other age groups ($F_{1, 770}$= 8.97, p < 0.001). Results on turtle eggs consumption showed that most of the locals had stopped consuming. In conclusion, it is suggested that an integrated planning and management on conservation of green sea turtles to be done in Setiu. More progressive biological research and monitoring, with intensive trainings and classes, community development programs, stricter law implementation, with strong collaboration of government and non-government organization must be continuously done in order to conserve green turtles.

CHAPTER 1

INTRODUCTION

1.1 Introduction to Chelonian: General Insight on Taxonomy, Distribution, Dietary and Threats

The order Testudines comprises terrapins, tortoises, sea turtles and soft-shell turtles (System, 2013). Turtles are ancient reptile that survived the evolutionary years, and almost considered as living dinosaurs (Frazier et al., 2003). Members of the order Testudines have bony plates of the outer surface of the body, except for soft-shell turtles that have rubbery or leathery skin covering their small bones (Scheyer et al., 2007). Turtles have shell (also known as carapace) that may or may not be covered with horny shields. The ventral part of the turtle's body is called plastron (Eckert et al., 1999c).

The turtles' common names are usually associated with their habitat. Terrapins and soft-shell turtles are turtles that inhabit brackish and freshwater, while tortoises live on land. Sea turtles on the other hand, are described as turtles that inhabit the marine ecosystem. These members of Testudines require a longer maturity period, do not provide parental care and produce large amounts of eggs to compensate the high mortality rate during the egg and juvenile phase (Cox, 1998; Rebel, 1974; Hendrickson, 1980).

Sea turtles are Cryptodirans (a suborder of Testudines, although they have lost the ability to conceal their head) and are found in tropical and subtropical oceans of the world. Overall, there are seven species of sea turtles, which are the leatherback turtle (*Dermochelys coriacea*), hawksbill turtle (*Eretmochelys imbricata*), green turtle (*Chelonia mydas*), Olive Ridley turtle (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*), Kemp's ridley turtle (*Lepidochelys kempii*), and flatback turtle (*Natator depressus*). Only the first four of the aforementioned species are found in the coastal areas of Malaysia.

It appears that sea turtles face more challenges than the other two chelonians. The ocean environment requires its inhabitant to have a more efficient system of mobility. Adaptations such as elongated front flippers ensure a more efficient swimming speed, helping the sea turtles to survive in the raging ocean environment. However, this limb modification seems to cause awkwardness for the sea turtles whenever they are on the land (especially female sea turtles that land for nesting purposes).

Green turtle is widely distributed within 35° north latitude and 35° south latitude (Spotila et al., 2000; Spotila, 2004; Rebel, 1974). Despite its expanded distribution, this species is globally classified as 'endangered' (IUCN, 2012). Green turtle is aptly named due to the fat under its carapace is green in colour. Green turtles' have various coloration (such as greenish black or brown to grey), while the plastron's colour is always white (Eckert et al., 1999c; Hendrickson, 1980). It is highly migratory and has an approximately 3-year interval of nesting activity. Green turtles return to their natal sea/ beach after reaching maturity (45-50 years old) (Allen & Edwards, 1995). The body parts such as meat are usually exploited for food (Cox, 1998).

1.2 Conservation Efforts for the Survival of Green Sea Turtles

Conservation, as defined by Adams (2004), is defined as ‘preservations and protection of living nature; species, habitats and ecosystem’. According to IUCN (2009) conservation is ‘the management of human use of organisms or ecosystems to ensure such use is sustainable. Besides sustainable use, conservation includes protection, maintenance, rehabilitation, restoration and enhancement of populations and ecosystems. In a work related to sustainable fisheries in Canada, conservation is listed as one of the aspects besides social and economic values that determine the fate of the natural resource (Olver et al., 1995).

This study was part of a conservation effort of green sea turtles at Setiu, Terengganu. Prior to realizing this effort, the role of green sea turtles need to be understood in the functions and structure of ecosystems (Center et al., 1984). The importance of sustaining this species can be seen from its ecological roles. Firstly, feeding activities of green sea turtles can ensure stability in the marine and coral reef ecosystem. Green sea turtles are commonly found in shallow waters, feeding exclusively on sea grass (Wilson et al., 2010). Adult green sea turtles are more selective than the juveniles, in which that the latter are more omnivorous than the former (Arthur et al., 2008). Sea turtles constantly feed on the middle sections of the seagrass, causing the oldest and upper part of the vegetation to drift away. This action will improve the productivity and nutrient cycling in the coral reef ecosystem. As the blades of the seagrass are removed, the shading effect at the bottom of ocean bed is reduced, which in turn hinders the growth of microbes (fungi and algae). In addition, the constant grazing guarantees that the ocean currents will not be clogged (Spotila, 2004; Bjorndal, 1980).

Nesting activities of sea turtles can also improve the nutrient contents of dunes on of the beach, especially by the unhatched sea turtle eggs and natural predation (Wilson et al., 2010). This supply of nutrients (such as phosphorus and nitrogen) will enhance the beach vegetation, therefore, reducing beach erosion, and improve their own nesting habitats (Wilson et al., 2010). For example, flow of nutrients, such as organic matter, energy, lipids, nitrogen, phosphorus along a 21-km nesting area in Melbourne Beach were due to nesting activities (Bouchard & Bjorndal, 2000). Nutrients are recycled through four phases: (1) through hatched eggs (remaining of embryonic fluid and eggshell), (2) unhatched eggs (entering the detrital food chain), (3) natural predation, and (4) root penetration (absorbance of nutrients by the plant through the unhatched eggs) (Bouchard & Bjorndal, 2000; Wilson et al., 2010). Increase of community dynamics can be accomplished by having sea turtles to nest at the beach, which expands the egg matter and nest organism to the dunes (Wilson et al., 2010).

Conserving green sea turtles could help maintain a healthy food web interaction in the coral ecosystem. In general, barnacles or epibionts will latch onto sea turtles while drifting in the sea. This will attract bigger organisms (e.g. fish and shrimp) to feed on these barnacles and epibionts. Sea turtles are also described as 'feeding station' for them (Wilson et al., 2010; Sazima et al., 2004). Not only does it provide food for the fish, this activity would clean the body parts of sea turtles and reduce the load that is carried by the sea turtles. Another example of sea turtles' contribution towards maintaining the food web interaction is natural predation. Natural predation of sea turtles usually occurs during the egg and hatchling phases, returning the nutrient flow back to the beach. Eggs usually predated by land predators, such as monitor lizards, ants, and ghost crabs, while hatchlings are predated by bigger fish (Wetterer & Lombard, 2010; Bouchard & Bjorndal, 2000).

Male and female green sea turtles have been reported to bask on the beach, but this activity was observed at certain coastal regions especially in Hawaiian Island (Whittow & Balazs, 1982; Balazs, 1976). Sea turtles allow seabirds to perch on their carapace while basking. These seabirds seek protection from the attack of the sharks, and gain food from the school of fish that are formed underneath the turtle's carapace (Spotila et al., 2000).

Sea turtles are a significant might be an immense cultural asset to society in certain regions. In China, sea turtles are an epitome of longevity due to its migratory nature and long lifespan. Hunting and exploitation of turtles are required to improve one's social status in some countries, such as Mexico, Kenya, Nicaragua and Tahiti (Frazier, 1999). The turtle hunting is also being culturally practiced by locals in Indonesia, as part of their traditional belief. Body parts of turtles such as meat and eggs are consumed by the locals in Malaysia, Indonesia, China and Mexico among others as part of their diet routine (Senko et al., 2009; Chan & Shepherd, 2002).

Globally, sea turtles contribute huge economic impact in terms of tourism industry (Tisdell & Wilson, 2002; Wilson & Tisdell, 2001; Tisdell & Wilson, 2001). Ecotourism that involves sea turtles has been practised in several parts of the globe, such as at Mon Repos (Australia) (Tisdell & Wilson, 2001), Setiu, Terengganu (Malaysia) (Abd Mutalib et al., 2013; WWF, 2007, 2009), Tortugeuro (Costa Rica) and others. However, this industry could negatively affect the population of sea turtles without control, proper planning and sound management. Strong light and noise pollution at the beach front hotels and resorts could deter nesting female marine turtles from landing and affect the emergence of hatchlings to the sea. Thus, the term ecotourism is introduced as part of non-consumptive tourism activity based on wildlife (Wilson & Tisdell, 2001; Tisdell & Wilson, 2001).

1.3 Aims of Study

Conservation of sea turtles is crucial in sustaining the population and maintaining their role in the marine ecosystem. At this moment, leatherback turtles are perilously making their way towards extinction since it is classified as globally critically endangered by the Red List of International Union for Conservation of Nature (IUCN). Conservation efforts need to be improved, especially on our dearth of information regarding its current status. Consequently, a proper set of effective and efficient strategies needs to be implemented to ensure the sustainability of this species.

This study provides initial information and evaluation of green sea turtles conservation at Setiu, Terengganu. Apart from being an important nesting site in the East Coast of Peninsular Malaysia, conservation of green sea turtles in this area is hatchery-related and focuses on protection of its beaches. We described these two aspects in this study. Community-based conservation and ecotourism are emphasized, and their importance in striking a balance and socioeconomic growths between sustaining natural resources (specifically green sea turtles). The objectives of the study are as follow:

(i) To determine the nesting ecology and behaviour of green sea turtles at Setiu by determining their distribution, nest characteristics, clutch size, morphology of the nesting green turtles, false crawl attempts, successful nesting attempts and emergence hour.

(ii) To facilitate the management of the hatchery by measuring the successive hatching rate, duration of incubation, egg condition, hatchlings' growth and hatchlings' carapacial scutes variation.

(iii) To determine whether if there was any significant effect of age groups and gender on the consumption of turtle eggs.

(iv) To determine the consumption trends of the respondents and the proportion as well as their justifications for consuming turtle eggs.

1.4 Organization of Thesis

Chapter 1 provides the introduction and the objectives of the study. A general look on *Chelonia mydas* is also presented in this chapter to give some insights, basically on its taxonomy, distribution, dietary, threats and others.

Chapter 2 consists of several sections. The first section discusses the study site, divided into sub-sections, such as nesting beaches, demographic structures and rainfall and daily temperature. The second section reviews the species, including from the aspects of taxonomy and physical description, growth and lifespan, reproduction and breeding, distribution and habitat, food and dietary, products and threats.

Chapter 3 focuses on the nesting ecology and behaviour of green sea turtles at Setiu. Sections of this chapter are: the distribution of successful nesting activities, measurements of curved carapace length, curve carapace width and clutch size, correlation between clutch size and mean of curved carapace length, emergence hour of nesting activities, and correlation between false crawls and successful nesting activities.

Chapter 4 evaluates the hatchery management in the Setiu. The chapter will determine the significant difference of successive hatching rates (i) among years (from 2009 until 2012), (ii) among beaches in Setiu, and (iii) among beaches at Setiu for the year 2012. The percentage of eggs' condition after they were hatched and excavated was also evaluated as well as successive hatching rates, and duration of incubation, both based on type of hatcheries (shaded, open, Styrofoam) were determined.

Chapter 5 consists of the morphological study of the hatchlings. The distributions of basic measurements of the hatchlings, which are straight carapace length (SCL), straight carapace width (SCW), and weight based on the location and type of hatchlings (normal hatchlings or hatchlings with carapacial scute variation) are determined. The effect of degree of carapacial scute variation towards the measurement of the hatchlings (SCL, SCW and body weight) was also determined. Finally, the carapacial scute variation based on the relocation time (minute) is evaluated.

Chapter 6 presented the level of awareness of the locals at Setiu regarding the conservation efforts that have been done in there. This chapter assesses the level of awareness based on age and gender of the respondents. The aspect of consumption trends was also taken into account in this chapter.

Chapter 7 concludes the thesis by summarizing the whole findings of the study and emphasizing on several recommendations for a better conservation and management effort of marine turtles.

Chapter 3 to **Chapter 6** are written as stand-alone. There are repetitions in the information that might appear in some chapters.

CHAPTER 2

GENERAL LITERATURE REVIEW

2.1 Study Areas

This study was carried out at Setiu, (5°35'-5°41' N, 102°43'-102°50' E) Terengganu, Malaysia. This district is the latest inaugurated district in Terengganu, established by Modernisation Administrative and Management Planning Unit (MAMPU) on the 1st January 1985. Setiu comprises 10.5% of Terengganu state, and is adjacent to Kuala Terengganu district, Hulu Terengganu district, and Besut district (Setiu, 2013).

Setiu is the largest district in Terengganu covering approximately 1,304 km^2. The district consists of 7 sub-districts, which are Mukim Hulu Nerus, Mukim Calok, Mukim Hulu Setiu, Mukim Guntung, Mukim Tashik, Mukim Pantai, and Mukim Merang. The coastal part of Setiu faces the South China Sea. This means that the coastal areas of this district are heavily affected by Northeast Monsoon from November until March every year (Setiu, 2013; WWF, 2007).

Three of the working chapters in the study are generally carried out in five beaches of Setiu which are Telaga Papan, Kuala Tok Cha, Mengabang Sekepeng, Kuala Baharu Selatan and Kuala Baharu Utara. Two of these beaches are reserved areas, which are Telaga Papan and Kuala Baharu Selatan. The rest is privately owned and tendered by licensed egg collectors. The last working chapter, which determines the level of awareness of the locals at Setiu regarding the conservation of green sea turtles, was done in the villages along these beaches in this district.

The following sub- topics provide an important overview of the study. These sub topics provide information regarding the nesting beaches and demographic structures.

2.1.1 Nesting Beaches

Setiu comprises lagoons, mangrove forests, peat swamps, freshwater marshes, *Melaleuca* swamp forest, lowland dry forest, estuaries, and sandy beaches. These areas are the habitat for approximately 29 species of wildlife, 112 species of birds and 28 species of reptiles. Some of the species that frequent the habitats are; painted terrapin (*Callagur borneoensis*), river terrapin (*Batagur baska*), plain pouched hornbill (*Aceros subruficollis),* macaques (*Macaca fascicularis),* wild pigs (*Sus scrofa),* and monitor lizards (*Varanus salvator)*. The beach comprises dunes and slope, colonized by littoral spinegrass (*Spinifex littoreus),* Beach morning glory *(Ipomea pes-caprae),* and Screw pine (*Pandanus odoratissimus)*. There are scattered populations of blanket grass (*Axonopus compressus*) and stands of she-oak trees (*Casuarina equisetifolia*) at some parts of the beach (WWF, 2007).

Setiu is a prominent nesting ground for green sea turtles (*Chelonia mydas*), and this species is the most abundant sea turtle species found here. Based on the personal communications with the locals (especially rangers and licensed collectors), common sightings or other species were found previously (approximately around 1970s). These species were hawksbill turtle (*Eretmochelys imbricata*) and Olive ridley turtles (*Lepidochelys olivacea*).

The beaches are sandy and wide (approximately from 10m until 60 meter). The width and vegetation of the nesting beaches are varied along the beaches. The length of the beaches is shown in the table below.

Table 2.1: Length of nesting beaches in Setiu

Beaches	Length (KM)
Kuala Baharu Utara	8.94
Kuala Baharu Selatan	7.04
Mengabang Sekepeng	7.18
Telaga Papan	10.20
Kuala Tok Cha	3.20

Generally, data were collected from all of these beaches, given emphasis to Telaga Papan Beach in 2012. This beach was chosen since it is one of the reserved areas and there is more manpower (rangers and volunteers) that could assist during the collection of data. Telaga Papan has wide, long and connected geographical conditions. The beach is accessible by land since it is connected to the main road. Also, the location provides less time constraint for beach patrollers to send the eggs to the hatchery.

2.1.2 Demographic Structures

Setiu is populated by Malay, Chinese, Indian, aboriginals, immigrants and others. Malay locals (97.8%) are predominant at Setiu, followed by immigrants (2.0%), Chinese (0.02%), and Indians (0.01%) (Setiu, 2013). Based on a report in 2007, more than half of the 600 respondents in Setiu earned less than RM500 per month (WWF, 2007). The highest number of respondents are working in fisheries or aquaculture sector (27.0%), followed closely by services sector (25.0%). A large proportion of the respondents received only up to primary education level (47.3%), secondary education level (38.8%), no formal education (11.2%), higher education (0.1%) and others (0.01%) (WWF, 2007).

2.1.3 Rainfall and Temperature

The data is collected by the Meteorological Department of Malaysia (MET) in 2012. The point of data collection was at Kuala Terengganu for 8 months in 2012, which is the nearest point to Setiu. The highest rainfall was in March 2012, at 370.6 mm. Starting from April, the number of rainfall started to decline until its lowest point, which was in June (86.0 mm). The next month, the rainfall started to increase gradually until the end of nesting season, which was in October (353.6 mm) (Figure 2.1). The north-east monsoon started after the nesting season ended, which was in early October. Daily maximum temperature is the highest on average in May (32.6 °C) (Figure 2.2), and the minimum temperature was the lowest in September (24.9°C) (Figure 2.3).

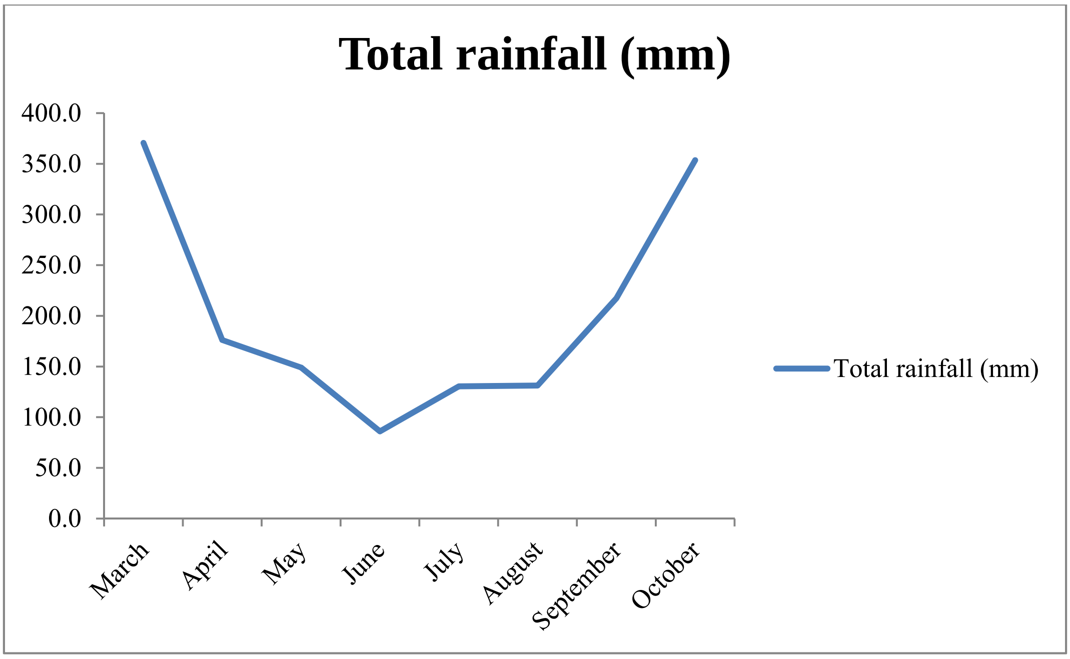

Figure 2.1: Total rainfall from March 2012- October 2012 (mm)

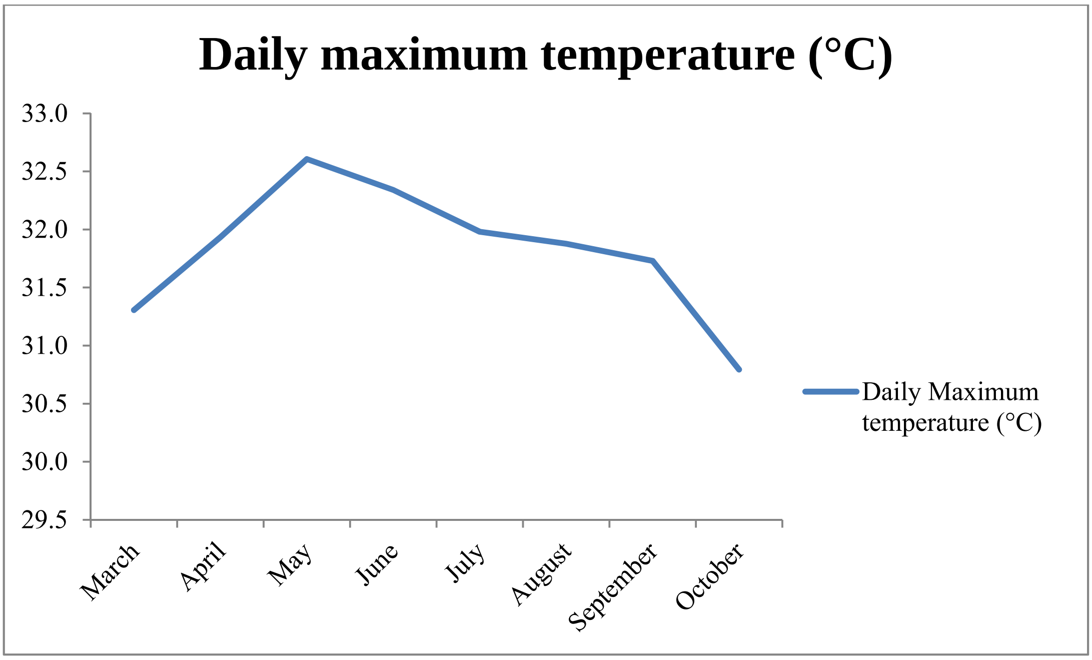

Figure 2.2: Daily maximum temperature (°C) from March 2012- October 2012.

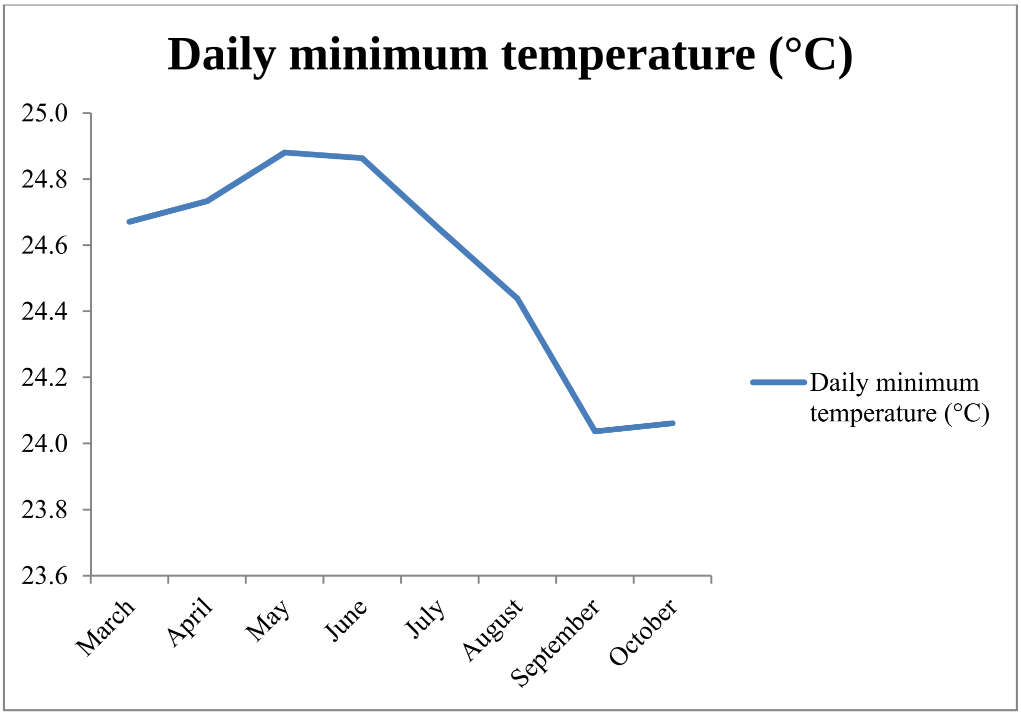

Figure 2.3: Daily minimum temperature (°C) from March 2012- October 2012.

2.2 Closer Look on Species: Green Turtles (*Chelonia mydas*)

Green sea turtle (*Chelonia mydas*) is briefly described in Chapter 1. Overall, sea turtles possess a variety of diversity and ecological characteristics, depending on its species and habitat. For instance, most of the sea turtles (including green turtles) carry out reproduction in solitary nesting, whereas two other species (Kemp's and Olive ridley) perform mass nesting (also known as arribada) (Eckert et al., 1999a). Green turtle is obliged to its herbivore diet, while leatherback turtles consume mainly jelly fish (Bjorndal, 1980; Bjorndal, 1985). In this chapter, we take a closer look on aspects such as taxonomy and physical description, growth and life stages, habitat and distribution, turtle's products and threats to green turtles.

2.2.1 Taxonomy and Physical Description of Green Turtles (*Chelonia mydas*)

In general, sea turtles are derived from a common ancestor that has not given rise to other living turtles (monophyletic group) of the suborder Crytodira. The members of this suborder close their jaw by contracting the muscle over a cartilage on the otic chamber. Contrary to other living species of crytodites, sea turtles are incapable of retracting their heads (Cox, 1998). Sea turtles show some significant features such as paddle-shaped limbs, which enable them to swim well in the sea. Their mobility in the sea is also accelerated by the enlarged shoulder girdled with a markedly elongate coracoid attached to the well-developed pectoral muscles. Although these flippers could also be propelled on land, movement of sea turtles tend to be slow, vulnerable and awkward. Removal of excess salts from the sea water is assisted by the lacrimal gland (Cox, 1998).

There are seven species of sea turtles roaming in the ocean, globally. Only four out of these seven species are found in the coastal area of Malaysia. These are green turtles (*Chelonia mydas*), leatherback turtle (*Dermochelys coriacea*), hawksbill turtle (*Eretmochelys imbricata*) and Olive Ridley turtle (*Lepidochelys coriacea*) (Ali et al., 2006; Sukarno et al., 2007). These species can be differentiated by their external morphological structures and anatomical features such as the number of prefrontal and postorbital scales and the type of scutes on the carapace. For instance, hawksbill turtles possess two pair of prefrontal scale and three pair of postorbital scales, while green turtles have one pair of prefrontal scales and four postorbital scales (Eckert et al., 1999c). Both of these species possess four pair of costal scutes, while Olive Ridley turtles have six costal pair of costal scutes. Adult leatherback turtles have no scales at all (Eckert et al., 1999c; Hendrickson, 1980), and have a skin-covered carapace with seven ridges (Cox, 1998), instead of scutes.

Green turtle (*Chelonia mydas*) originates from the family of Cheloniidae (Genus: *Chelonia*, Type: *mydas*). Classification of green sea turtles is shown in the figure below (Figure 2.4).

Kingdom	: Animalia
Phylum	: Chordata
Superclass	: Sauropsida
Class	: Reptilia
Order	: Testudines
Suborder	: Crytodira
Superfamily	: Chelonioidea
Family	: Cheloniidae
	Genus: Chelonia
	Species: *Chelonia mydas*

Figure 2.4: Classification of green sea turtles (*Chelonia mydas*) (Rebel, 1974)

An adult green turtle's head is anteriorly blunt and small, with four pairs of postorbital scales and one pair of prefrontal scales. The carapace is hard, smooth, and almost forming a heart shape. This carapace is not posteriously pointed and usually its length is less than 120 cm, usually not so wide but broadly oval (Eckert et al., 1999c). The colour of the carapace varies from greenish black or brown to grey. The plastron is always white or yellowish white (Eckert et al., 1999c; Cox, 1998). A green turtle usually has four pairs of non-overlapping costal scutes, five vertebral scutes and all of them are placed side by side (Cox, 1998) (Figure 2.5). It also has a single claw on each flipper. Certain features might differ in comparison between adult and hatchling green sea turtles. In general, the sexual dimorphism can only be seen in during adult phase of a sea turtle, of which a male turtle has a very long tail. Hatchlings of green sea turtles have carapace that are distinctively black with white and smooth margin, that serves as an adaptation feature when they return to the sea (Bustard, 1970). Although there is typically a claw on each flipper (similar to adult), two claws are found in a rare condition in some hatchlings (Eckert et al., 1999c).

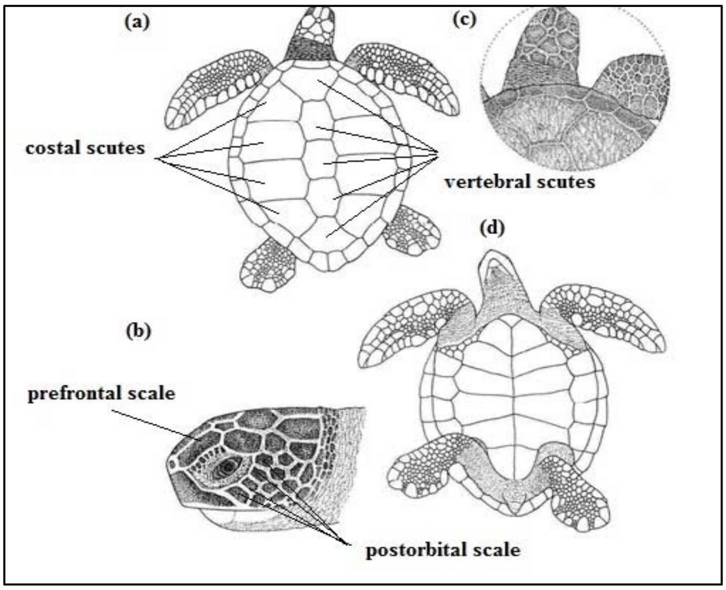

Figure 2.5: a) Structure of carapace of green turtles, showing the costal scutes and vertebral scutes. b) Head of green turtle, showing prefrontal scale and postorbital scale, c) Anteriorly rounded head, d) Plastron of green turtle, which is usually white in colour. (Eckert et al., 1999c)

2.2.2 Growth and Life Stages

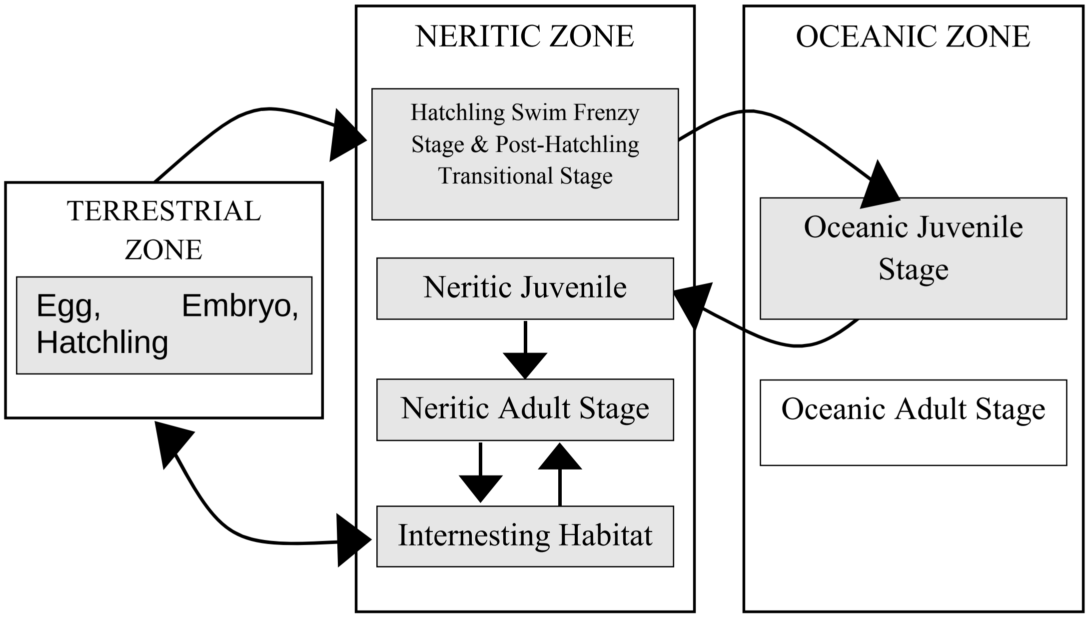

Figure 2.6: Type 2 of life history patterns of sea turtles (Bolten, 2003a)

Bolten (2003a) described patterns of life history of seven sea turtles. In this review, green turtle is classified in the Type 2 of life history patterns, in which development occurs in both neritic and oceanic zones. This life history pattern is also similar to loggerhead and hawksbill turtles (Figure 2.6).

Generally, an adult female turtle will lay eggs at the natal beach when it is sexually matured. The eggs will undergo embryonic development for 50-60 days from the date they are laid (Bolten, 2003a). Heppell et al. (2003) described that even though this phase is mostly studied, they agree that conservation on this phase alone is not adequate. This is supported by Crowder et al. (1994) who indicated that the population of loggerhead turtle was still declining, although the hatching rate had increased. Nevertheless, it is clear, however that this phase is important in recruiting hatchlings to the sub-adult and juvenile phase. Thus, although this phase is not to be neglected, optimal recovery in population of sea turtles comprises other stages too.

Hatchlings will emerge from the nest in a group and leave the terrestrial zone. Common observation indicated that these hatchlings leave in association and will start to swim separately after they enter the sea (Gyuris, 1993; Gyuris, 2000; Spotila, 2004). Hatchlings often emerge at dusk or nearing night time, to avoid hot temperature upon crawling to the sea, and to reduce the risk of predation (Spotila, 2004). Navigating at sea requires the hatchlings to use mainly their visual sense (Mrosovsky & Kingsmiix, 1985; Mrosovsky, 1978; Ehrenfeld, 1968). Since they are very sensitive to light intensities, moonlight assists their navigation to the sea. Hatchling's path may be interrupted should there be any artificial light source from the frontal beach, such as from resorts, restaurants, torch light and so on. This may lead hatchlings away from the edge of the sea, risking them to the end of their brief life (Gyuris, 1993; Wyneken & Witherington, 2001; Wyneken & Salmon, 1992; Mann, 1977; Salmon et al., 1992).

Hatchlings are also equipped with magnetic imprinting ability, in which they use to navigate their way in the open ocean. This trait is driven by an iron compound called magnetite that facilitates hatchlings in sensing the Earth's magnetic field. This compound acts as though as a compass pointing towards the North Pole. Other than helping the hatchlings find their way, this trait helps the female hatchlings to return to their natal beach to lay eggs after several decades (Lohmann & Lohmann, 1994; Lohmann et al., 2008).

Spotila (2004) describes the swimming pattern of the hatchlings such as 'a bird flight in the sky'; with its flipper frantically moving up and down. Upon returning to the sea (neritic zone), hatchlings will undergo this phase known as the 'swimming frenzy'. During this time, survival rates of the hatchlings are hard to quantify (Gyuris, 2000). Based on a study at Heron Island Reef, Australia, the majority of the hatchlings was predated by fish (93.6%) (Gyuris, 2000). This phase is also called pre-feeding phase, in which the hatchlings are exclusively depending on the yolk as their source of food (Rebel, 1974; Bolten, 2003b) . The hatchlings may also be opportunistic feeder as they feed on ctenophores, small larval crabs and shrimps (Spotila, 2004) .

Bolten (2003a) explains that hatchlings undergo a transitional period from the pre-feeding to the post-feeding phase. The hatchlings start to feed on other food from the neritic zone, and depending on the stochasticity of the currents, they will slowly move to the oceanic zone (Bolten, 2003a). This zone is poorly studied by researchers, since it is difficult to observe the sea turtles in the ocean at this stage. This stage is described as 'the lost year'; since presence and dispersal of marine turtle are limited for observation for several years (Carr & Ogren, 1960) .

Type 2 marine turtle will basically undergo their juvenile development in the oceanic stage and will fully return to the neritic phase to complete their juvenile stage (Kamezaki, 1998; Bolten, 2003a)**.** At this point, green marine turtles may have changed their feeding habit to exclusive herbivory, and feed on algae and seagrass.

The adult marine turtles will undergo the reproductive phase. Age of sexual maturity may be different for green turtles that undergo different growth condition. It may also be based on its diet, of which captive green turtle reaches sexual maturity faster than wild green turtles (Bjorndal et al., 2012) . Upon reaching this stage, both male and female turtles show differentiation and development in their physical traits.

Female marine turtles will generally grow bigger and produce more testosterone and oestrogen. Meanwhile, male marine turtles will undergo the same development, with some additions such as longer tail, soften plastron, and growth and hardened nail on the flipper. The longer tail will differentiate a male marine turtle from the female (Eckert et al., 1999c).

2.2.3 Reproduction and Breeding

The initial mating season will be indicated by the changes of hormones produced by female marine turtles. It is commonly showed that during this phase, they produce less oestrogen and more testosterone (Spotila, 2004; Jessop et al., 2000; Jessop et al., 2002) and this directs the male turtles to move towards mating ground. Hormonal changes in female turtles also cause the size of the ovary to be bigger and its structures to be transformed in such a way that the stroma is expanded and the convoluted oviduct is suspended in the body cavity (Hamann et al., 2002).

Male turtles' reproductive organs comprise functional paired testes and associated ducts. Male turtles breed seasonally, in promiscuous manner and implement scramble - mate finding tactic as their reproduction strategy. Higher rate of reproduction will depend on the density, as low density courtship will encourage scramble behaviour and vice versa. Besides, reproduction status will be elevated by male turtles if more somatic energy is kept, and level of testosterone is raised. All of these conditions will benefit in terms of searching the mate for male turtles, and expose them to more female turtles (Hamann et al., 2002; Jessop et al., 2000; Spotila, 2004).

Meanwhile, female reproductive organs are listed as ovary, oviducts, vitellogenic follicles, ovarian scars, atretic follicles, and oviducal eggs. Both of female and male turtles are described as capital breeder, which means they possess energy that can be mobilized later throughout their reproduction (Chaloupka et al., 2004). Also, viable sperms are kept in the female's oviduct for long lifespan. One female turtle mates with multiple male turtles, and usually competition begins as soon as the female turtle appears at the mating ground. The male turtle will climb on the female and hold to her carapace by using his claws. The male will insert the sperm into the female's cloaca by using his long tail, and bite her on the flippers, neck and head. Simultaneously, other potential mating mates will come to surround them and compete the spot for mating. Often, this mating ground is situated near the nesting beaches or along the migration route prior to nesting season (Hamann et al., 2002; Jessop et al., 2000; Spotila, 2004).

At the Great Barrier Reef, Australia, it has been reported that a female green turtle can be expected to live from 55 to 60 years, and reproduce approximately 2000 eggs throughout her 19 years of reproduction (Chaloupka et al., 2004). Since it takes them decades to reach reproductive maturity stage, only a small number of marine turtle could survive until they reach adulthood. Hamann et al. (2002) listed two types of factors that affect the reproductive output of female marine turtles in general, which are endogenous and exogenous. Endogenous comprises internal aspects, such as genetic, body size, health condition and others. Meanwhile, migratory distance and latitude can be among the examples of exogenous factors.

Three patterns of nesting behaviours are categorized in three ways, which are arribadas, year-round nesting, and seasonal nesting (Hamann et al., 2002). However, since arribada is exclusively for *Lepidochelys* genus, this section will discuss only on year-round nesting and seasonal nesting.

Year round nesting season occurs in a number of rookeries, such as in Philippine, Gulf of Thailand, Hon Tre Lon in Vietnam, Sabah's Turtles Island and Kerachut Rookeries in Malaysia (Ekanayake et al., 2010; Ali et al., 2004). This pattern has shown nesting all year round undisturbed, only constrained at certain months. This could be due to the success rate of mating, and beach's capability to restore nests and to accommodate the number of hatchlings returning to the sea (Ekanayake et al., 2010). Location of the nesting beach also plays an important role as certain beaches might be strategically positioned to allocate foraging sea turtles in both hemisphere, thus receiving year-round nesting (Ekanayake et al., 2010).

During seasonal observation, female marine turtle gain body weight at the beginning of the season. This might due to water intake and lipid storage. This functions as reserve throughout the entire reproductive season and migration. The clutch size might be lower for young breeder, rather than experienced breeder. This might be due to fewer follicle produce by the former group rather than the latter. Surrounding environmental condition such as thermal condition, late arrival to the foraging area and sporadic exogenous condition inhibit seasonal nesting. Seasonal nesting beaches occur in rookeries in Brunei, Cambodia, Pahang, Johor, Perak, Terengganu in Malaysia, Pengumbahan West Java in Indonesia, Andaman Sea in Thailand and so on (Ekanayake et al., 2010; Ali et al., 2004)