MARINE TURTLE LANDING, HATCHING, AND PREDATION IN TURTLE ISLANDS PARK (TIP), SABAH

Coastal and Marine Resources Management in the Coral Triangle-Southeast Asia (TA 7813-REG)

Technical Report

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MARINE TURTLE LANDING, HATCHING, AND PREDATION IN TURTLE ISLANDS PARK (TIP), SABAH, MALAYSIA

Final Report[1]

Photo courtesy of Sea Turtle Research Unit (SEATRU), Universiti Malaysia Terengganu: A green turtle returns to the sea after nesting.

[1] Prepared by Juanita Joseph, PhD, Marine Turtle Scientist. Drafted on 30 September 2017.

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LIST OF ACRONYMS AND ABBREVIATIONS

CCL	Curved carapace length
CCW	Curved carapace width
cm	centimeter
CITES	Convention on the International Trade in Endangered Species of Wild Fauna and Flora
GAMM	generalized additive mixed model
GOF	General Operations Force
ha	hectares
IUCN	International Union for the Conservation of Nature
Km	kilometer
PBK	Bakkungan Island
PGL	Gulisaan Island
PSL	Selingaan Island
SEATRU	Sea Turtle Research Unit
TIHPA	Turtle Islands Heritage Protected Area
TIP	Turtle Islands Park
TIWS	Turtle Islands Wildlife Sanctuary

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EXECUTIVE SUMMARY

Malaysia has a long history of conserving marine turtles compared with other Southeast Asian countries, dating to the 1950s. Most conservation efforts have focused mainly on protecting turtles and eggs on nesting beaches. In recent years, conservation efforts have also focused on protecting turtles at their foraging grounds.

Three species of marine turtles have been recorded to nest on the Turtle Islands, with majority of nestings by green turtles (94%), followed by hawksbill turtles (6%). The nesting of olive ridley turtles has been recorded rarely, with only five nests recorded in the last four decades. Sabah TIP provides the highest nesting for green and hawksbill turtles in Malaysia. In fact, the nesting of hawksbill turtles on Gulisaan Island was once considered the highest in Southeast Asia.

For this report, the long-term marine turtle landing and hatching data from TIP were analyzed. Field sampling was also conducted to determine the predation of turtle eggs incubated at the hatcheries in the park.

The nesting of green turtles in TIP shows increasing trends, with an increment of nests in the late 1980s. In one breeding season, female green turtles in the park can lay one to nine clutches, with interesting intervals of 11 days. Green turtles are the most abundant turtle species in TIP (94%), with Selingaan providing the highest nesting (49%), followed by Bakkungan Kecil (30%) and Gulisaan (21%). The mean size (curved carapace length or CCL) of nesting green turtles in TIP is 98.57 ± 5.949 centimetres (cm), ranging from 76.0 cm to 118.5 cm. The nesting of green turtles occurs throughout the year, with peak months from May to August. The mean remigration interval is 34 months (2.83 years). Residual analysis result shows the age-to-maturity for female green turtles in TIP is 19 years. The number of green turtle remigrants is higher compared with recruits. The number of green turtle recruits is constant. The overall mean hatching success for green turtles in the park is 76%, ranging from 53% to 85%, with about 16 million hatchlings released into the ocean.

The nesting of hawksbill turtles in TIP shows gradual decreasing trends. In one breeding season, female hawksbill turtles in the park can lay one to five clutches, with a mean clutch size of 119.49 ± 32.71 (range of 39–200 eggs) and a mean interesting interval of 16 days. The nesting of hawksbill turtles consists 6% of the overall marine turtle landing in TIP. The highest nestings are on Gulisaan (78%), followed by Selingaan (14%) and Bakkungan Kecil (8%). The nesting of hawksbill turtles occurs throughout the year, with peak months from February to April. The mean nesting size (CCL) for hawksbill turtles in the park is 79.78 ± 8.87 cm, ranging from 58.0 cm to 110.0 cm. The mean remigration interval is 22 months (1.83 years). The number of hawksbill turtle remigrants and recruits shows decreasing trends on the three islands. The overall mean hatching success for hawksbill turtles in TIP is 67%, ranging from 50% to 85%, with about 1 million hatchlings released into the ocean.

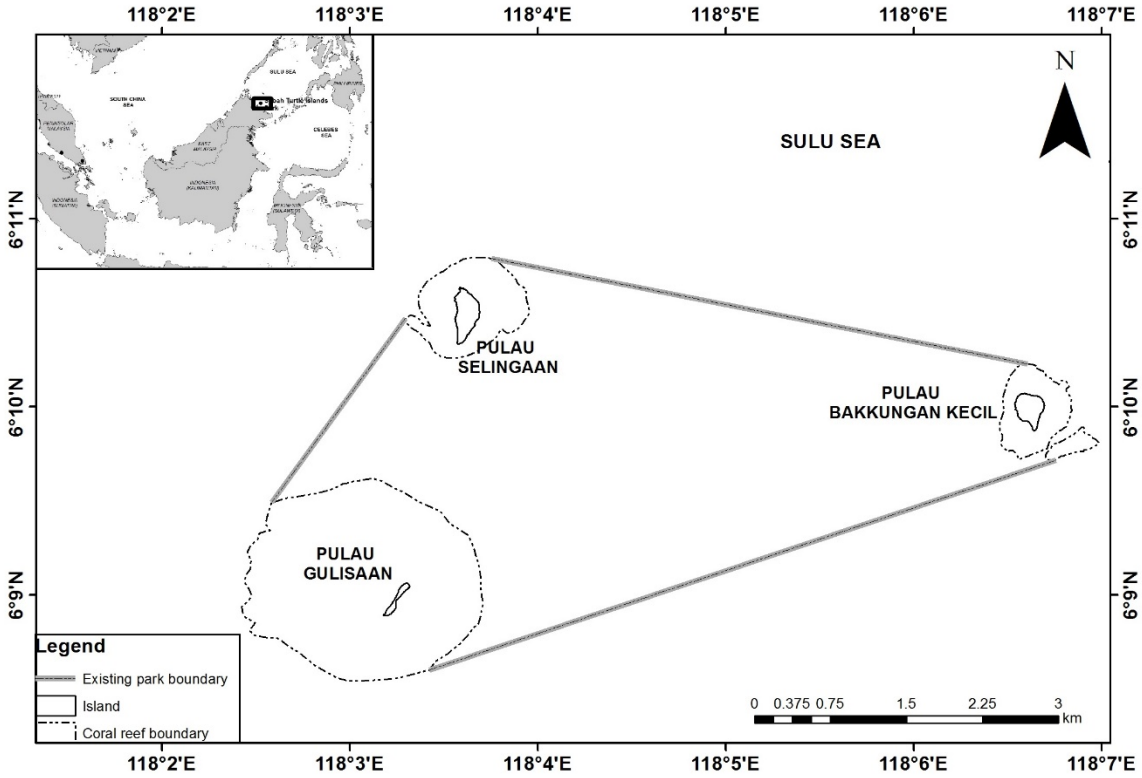
Majority of unhatched eggs in all hatcheries in the park are complete eggs. This may be caused by infertile eggs or improper handling, but further investigation is needed before conclusion can be made.

The establishment of TIP under the management of Sabah Parks for four decades now has given full protection for nesting turtles and their nesting grounds, as well as the surrounding waters within the park boundaries. The conservation of marine turtles in TIP is one of the longest in Malaysia, and Sabah Parks is recognized as one of the best agencies in Malaysia in conducting marine turtle conservation. The long-term protection of marine turtles and their eggs at nesting beaches is an effective and essential conservation strategy as it results in high hatchling output.

I. INTRODUCTION

Turtle Islands Park (TIP) was established by the Government of Sabah, Malaysia, in 1977. The park is located about 40 kilometers (km) from Sandakan, on the edge of the Malaysia-Philippines border. It consists of three islands (**Fig. 1.1**): Selingaan, 8.1 hectares (ha); Bakkungan Kecil, 8.5 ha; and Gulisaan, 1.6 ha. It covers approximately 1, 740 ha of mostly sea and coral reefs with some patches of seagrasses (Isnain et al., 2016). In 1996, TIP joined forces with the Philippine Turtle Conservation Project to form the world's first transboundary marine park, known as the Turtle Islands Heritage Protected Area (TIHPA). Encompassing TIP (three islands) and the Philippine Turtle Islands Wildlife Sanctuary (TIWS) (six islands) covering an area of 318,000 ha, TIHPA was gazetted to promote the conservation of marine turtles, coral reefs, and fishing grounds and the ecologically sustainable employment of people living in the area (Pilcher and Ali, 1999).

Figure 1.1: Map of TIP showing the three islands (Selingaan, Bakkungan Kecil, and Gulisaan) and the park boundaries



Marine turtle conservation in Sabah started in 1927, when the North Borneo British Company administration gazetted Notifications 227 and 228, which prohibited the capture of turtles and the collection of turtle shells in Kudat (Chan and Liew, 1997). Later, in 1933, exclusive licenses were issued for Sandakan residents to collect turtle eggs from the nearby Turtle Islands, consisting of the islands of Selingaan, Bakkungan Kecil, and Gulisaan. In 1966, the first turtle hatchery was built on Selingaan Island. It was operated by the management of the Game Warden, which later extended operations to the other two islands. The three islands,

categorized at that time under the Games and Birds Sanctuary, were declared a national park in 1977 and later established as TIP (Chan and Liew, 1997).

For four decades now, the establishment of TIP under the management of Sabah Parks has given full protection for nesting turtles and their nesting grounds, as well as the surrounding waters within the park boundaries. Since the park's establishment, all marine turtle nests have been protected. Sabah Parks' nesting data collections are among the longest or biggest in Malaysia, with its tagging program initiated in 1970 (Isnain et al., 2016). Moreover, the green turtles in TIP are the only nesting rookery that has shown a population recovery in Malaysia (Chan, 2006). However, the hawksbill population in the park has steadily decreased despite conservation measures (Chan, 2006).

The three islands of TIP are close to each other and considered part of a larger marine turtle population, with nesting grounds extending to the Philippine Turtle Islands (Basintal and Lakim, 1994). Tagging and genetic studies have confirmed that TIP, the six Turtle Islands of the Philippines, and a few other rookeries in Sulu Sea are from the same population (De Silva, 1986; Moritz et al., 2002; Dethmers et al., 2006). Exploitation of these marine turtles, whether at their nesting rookeries (in TIP or the Philippine Turtle Islands) or at their foraging grounds, have impacts on their overall population size.

The turtle management and conservation activities in TIP include enforcement, nightly beach patrols, hatchery and hatchlings management, turtle tagging, visitor management, and data collection (Isnain et al., 2016). The following is a summary of the activities (based on Isnain et al., 2016):

a. Beach Patrols

Beach patrols are divided into two shifts. The first shift is from 8:00 pm to 1:00 am, while the second shift is from 1:00 am to 6:00 am. Sabah Parks rangers and other staff work in shifts to monitor, tag, and measure nesting turtles; record data; transfer all turtle eggs to the hatchery; and collect and release hatchlings.

b. Hatchery and Hatchling Management

The hatchery program was established in 1966, while open beach hatchery was practiced until the late 1980s. Research showed that open beach hatcheries only produce female hatchlings in TIP (Tiwol and Cabanban, 2000). To overcome this problem, the hatcheries in the park are partly shaded to produce hatchlings with balanced sex ratios (**Fig. 1.2**). Plastic netlon mesh has replaced metal wire mesh for fences to improve the hatchlings' *in-printing* process. Turtle eggs in TIP are transplanted to the hatcheries immediately to increase the hatching success of nests, and buried at a depth of 45 cm for hawksbill turtles and 75 cm for green turtles. To protect turtle nests from predators as well as to contain hatchlings upon emergences, a plastic netlon mesh is firmly placed around the nests (**Fig. 1.3**). Each nest is properly labelled with nest number, date of nesting, turtle species, and number of eggs. Sabah Parks rangers and other staff regularly check the emergence of hatchlings. All hatchlings collected are recorded and released (**Fig. 1.4**) as soon as possible in various locations on the islands to avoid fish "feeding stations."

Figure 1.2: Hatcheries in TIP are partly shaded to produce turtle hatchlings with balanced sex ratios

Photo credit: J. Joseph

Figure 1.3: All nests transferred to the hatcheries are labelled and plastic netlon mesh is firmly placed around each nest to protect it from predators and contain hatchlings upon emergences

Photo credit: J. Joseph

Figure 1.4: Hatchlings at the hatcheries are collected and released as soon as possible in various locations on the islands to avoid fish "feeding stations"

Photo credit: J. Joseph

c. Tagging Program

The tagging program in TIP was started in 1970 (De Silva, 1986). At first, turtles were tagged on their left front flipper using Monel tags. In 1999, Sabah Parks implemented double tagging (applied on both front flippers) using Inconel tags to overcome the problem of tag loss (Isnain et al., 2016).

Aside from conducting the marine turtle conservation project, Sabah Parks also opens the islands for day visits, and Selingaan Island for the Turtle Watching Program. The program is open throughout the year, but the number of visitors is limited to 50 per night. It follows strict guidelines to minimize disturbance to nesting turtles. Visitors are charged conservation fees (**Table 1.1**).

Table 1.1: Conservation Fees to Enter Sabah TIP in 2017

Criteria	Malaysian (Amount)	Non-Malaysian (Amount)
18 years old and above	RM 20.00	RM 60.00
Below 18 years old	RM 10.00	RM 30.00
Diving fee	RM 20.00	RM 50.00
Camera fee	RM 10.00	RM 10.00

Source: Sabah Parks. RM = Malaysian ringgit; 4.24 RM = 1.00 US dollar

In recent years, the three islands of TIP, especially Gulisaan, have experienced severe erosion problems (**Fig 1.5**). Aside from this, being on the edge of the border between Malaysia and the Philippines, safety is also a main concern in the park. The Malaysian General Operations Force (GOF) and Marine Police are placed on the three islands. However, in July 2015, the

Government of Malaysia decided to withdraw the GOF from Gulisaan Island (Sabah Parks, *pers.comm.*). Since then, no one is allowed to stay in Gulisaan, and Sabah Parks staff members only collect and transfer all turtle eggs to Selingaan the next morning. Transferring the eggs the next morning from Gulisaan to Selingaan (a boat ride of about 5–10 minutes) lowers the hatching success of the eggs. But this is the best solution at the moment to avoid the poaching of turtle eggs.

Figure 1.5: The remaining nesting beach on Gulisaan Island after a series of severe erosions caused by natural factors. No one is allowed to stay in Gulisaan since July 2015. All turtle nests are now transferred to Selingaan Island the next morning

Photo was taken in May 2017. Photo Credit: J. Joseph.

A. Species Overview

Marine turtles are symbolic animals because of their migratory nature and endangerment (IUCN 2016). They conduct long-distance migrations (e.g. Bowen et al., 1995), have unique life cycles, and, once mature, return to their natal beach to reproduce. The natal philopatry shapes the genetic population differentiation of marine turtles. These marine reptiles are unique components of complex ecological systems. Because they migrate thousands of kilometers (km) and take decades to mature, turtles serve as important indicators of the health of coastal and marine environments on both local and global scales (Frazier, 1999). In other words, conserving sea turtles means protecting not only turtle populations but also the seas and coastal areas they live in.

All species of marine turtles, except the Kemp's ridley (*Lepidochelys kempi*), are found in Southeast Asian waters. They nest in the region, except the flatback (*Natator depressus*) (Limpus et al., 2001). The tropical waters of Southeast Asia support many nesting populations and feeding assemblages, and are of global significance for sea turtle populations (Moritz et al., 2002; Jensen et al., 2016). All species of marine turtles are considered important protected

marine animals under the Convention on International Trade in Endangered Species of Wild Fauna and Flora or CITES (Groombridge and Luxmoore, 1989).

Various factors are implicated in the decline of sea turtles globally. Marine turtles are long-lived, have a low rate of reproductive success and a high rate of juvenile mortality, and, particularly important, have a human-influenced mortality of adults. The major threats to marine turtles in Southeast Asia include a continuous overexploitation of eggs and adults, getting caught as bycatch in trawl and long-line fishing, habitat loss, environmental degradation, direct human disturbances, and pollution. In Malaysia, only Sabah and Sarawak give full protection to marine turtles, while the State Government in Peninsular Malaysia still permits the commercial sale of marine turtle eggs (Sankar, 2016).

Four species of marine turtles have been recorded to nest in Malaysia: the green turtle (*Chelonia mydas*), leatherback turtle (*Dermochelys coriacea*), hawksbill turtle (*Eretmochelys imbricata*), and olive ridley turtle (*Lepidochelys olivacea*). Due to a long history of egg exploitation, incidental capture in fishing gear, and harvesting of marine turtles in their foraging grounds, these animals have experienced significant declines in population. The last recorded nests of leatherback turtles in Rantau Abang, Terengganu, Malaysia, was in 2010, and no nesting had been recorded ever since (Abdul Karim, 2016). The leatherback turtle is now considered locally extinct, the olive ridley turtle is on the verge of extinction, while the green and hawksbill turtles struggle to survive due to continued exploitation and anthropogenic threats in Malaysia. Only the green turtles of the Sabah Turtle Islands show signs of population recovery, after the Sabah State Government instituted strict conservation measures starting in the 1970s (Chan, 2006). In 2016, the green turtles in Terengganu showed an early sign of population recovery after the overall nesting doubled from the 1990s (Joseph, 2016).

Three species of marine turtles have been recorded to nest in TIP. About 94% of the nestings in the park are by green turtles (*Chelonia mydas*), 6% by hawksbill turtles (*Eretmochelys imbricata*), and very rarely (0.002%) by olive ridley turtles (*Lepidochelys olivacea*).

The scientific classifications of these marine turtle species are:

Kingdom: Animalia
Phylum: Chordata
Class: Reptilia
Order: Testudines
Family: Cheloniidae

Genus: *Chelonia*
Species: *Mydas*
Species Authority: (Linnaeus, 1758)
Common Name: Green turtle
Local Name: *Penyu agar*, *Penyu hijau*
Conservation Status by IUCN: Endangered
CITES: Appendix 1

Genus: *Eretmochelys*
Species: *Imbricata*
Species Authority: (Linnaeus, 1766)
Common Name: Hawksbill turtle
Local Name: *Penyu karah*, *Penyu sisik*
Conservation Status by IUCN: Critically Endangered
CITES: Appendix 1

Genus: *Lepidochelys*
Species: *Olivacea*
Species Authority: (Eschscholtz, 1829)
Common Name: Olive ridley turtle
Local Name: *Penyu lipas*
Conservation Status by IUCN: Vulnerable
CITES: Appendix 1

1. Green Turtle

The green turtle (**Fig. 1.6**) has a circumglobal distribution, occurring throughout tropical and subtropical waters. Analysis of historic and recent published accounts indicate extensive subpopulation declines in all major ocean basins over the last three generations as a result of overexploitation of eggs and adult females at nesting beaches and of juveniles and adults in foraging areas, incidental mortality relating to marine fisheries, and degradation of marine and nesting habitats (Seminoff, 2004).

Figure 1.6: The green turtle (Chelonia mydas) is the most abundant marine turtle species nesting in TIP

Photo credit: J. Joseph.

In Malaysia, green turtles can be found nesting in Sabah, Sarawak, Terengganu, Pahang, Johor, Penang, and Perak. Like other green turtle populations elsewhere, the green turtles in Malaysia conduct long-distance migrations from their nesting grounds to foraging grounds and vice versa (e.g. Liew et al., 1995; Papi et al., 1995; Liew et al., 2000). Genetic studies have proven that, once mature, the green turtles in Malaysia return to their natal beaches to reproduce (Dethmers et al., 2006; Joseph, 2006; Jensen et al., 2016; Joseph & Nishizawa, 2016).

Green turtles spend most of their lives in foraging grounds but, once mature, return to their natal beaches to breed. The primary diet of green turtles in foraging grounds consists of seagrass and marine algae. In Malaysia, a few important foraging grounds have been identified (Chong, 2012). Genetic mixed stock analyses have shown that Brunei Bay is an important foraging ground, especially for green turtles from TIP and other areas in Sulu Sea (Joseph et al., 2016).

2. Hawksbill Turtle

The hawksbill turtle (**Fig. 1.7**) has a circumglobal distribution throughout tropical and subtropical waters of the Atlantic, Indian, and Pacific oceans. Analysis of historic and recent published and unpublished accounts indicate extensive subpopulation declines in all major ocean basins over the last three generations (>80%) as a result of overexploitation of adult females and eggs at nesting beaches, degradation of nesting habitats, catching of juveniles and adults in foraging areas, incidental mortality relating to marine fisheries, and degradation of marine habitats (Mortimer and Donnelly, 2008).

Figure 1.7: A hawksbill turtle (*Eretmochelys imbricata*) in TIP

Photo credit: J. Joseph.

The only important remaining populations of hawksbill turtles in Southeast Asia are found in Malaysia and Indonesia. In Malaysia, the major nesting beaches of hawksbill turtles are in Sabah Turtle Islands (400 to 600 nests per year) and Melaka (200 to 300 nests per year). Hawksbill turtles are also found nesting in Terengganu and Johor (10 to 50 nests per year). Nesting in Indonesia is higher, with overall density of 1,000 to 2,000 nests per year (Chan, 2001). In general, nesting populations of hawksbills have declined in nearly every rookery in the region.

Clear genetic differences have been observed between hawksbill turtles in TIP and in other rookeries in Malaysia (Nishizawa et al., 2016). This is indicative of natal philopatry of hawksbill turtles in the region. Mixed-stock analysis of hawksbill samples collected from foraging grounds in Malaysia shows the presence of multiple haplotypes, suggesting that hawksbill turtles from various rookeries contribute to foraging grounds in Malaysia (Nishizawa et al., 2016). Some of the hawksbill turtle haplotypes detected in the foraging grounds in Tun Sakaran Marine Park and Pulau Sipadan have been observed in the relatively proximate rookeries of Sulu Sea (Nishizawa et al., 2016).

3. Olive Ridley Turtle

The olive ridley turtle has a circumtropical distribution, with nestings occurring throughout tropical waters, except the Gulf of Mexico (IUCN, 2016). In Malaysia, olive ridley nestings are

fragmentary, with nestings in Penang (< 10 nests per year) and Sarawak (< 5 nests per year). This species is less studied in Malaysia compared with green and hawksbill turtles.

II. METHODOLOGY

A. Data Collection

Sabah Parks collected the long-term data on marine turtle landings and hatchings in TIP. The data it collected before 1979 were not included in the analysis because these were scattered and incomplete. Field sampling to observe the conservation project and to determine predation of turtle eggs in the park was conducted from 11 to 13 May 2017 (**Fig. 2.1** and **Fig. 2.2).**

Figure 2.1: The nesting beach on Selingaan Island

Photo credit: J. Joseph.

Figure 2.2: Excavation of hatched nests on Selingaan and Bakkungan Kecil to determine why eggs failed to hatch

Photo credit: Sabah Parks.

B. Statistical Analysis

The long-term data on marine turtle nestings, eggs, and hatchings were presented in graphs. Estimation of nesting trends in TIP and number of recruits (new mothers) were analyzed in a generalized additive mixed model (GAMM), using the GAMM function of the mgcv R package (Wood, 2006). Due to limited data available, certain data analysis could not be conducted.

III. ANALYSIS OF MARINE TURTLE LANDINGS, HATCHINGS, AND PREDATION IN SABAH TURTLE ISLANDS PARK

A total of three species of marine turtles were recorded nesting in TIP (**Table 3.1**). Majority of the nestings (94%) were by green turtles, followed by hawksbill turtles (6%). Only five cases of olive ridley nestings were recorded since 1979—two nests in 1986 and one nest in 1987 on Selingaan, and one nest in 1994 and another nest in 2001 on Gulisaan.

Sabah Parks recorded more than 260,000 green turtle nestings from 1979 to 2016. From these nestings, about 21 million eggs were incubated and about 16 million hatchlings were released into the ocean (**Table 3.2A**). The range for the yearly mean hatching success was from 53 % to 85%. The highest nesting of green turtles was recorded on Selingaan (49%), followed by Bakkungan Kecil (30%) and Gulisaan (21%).

For hawksbill turtles, more than 16,000 nestings were recorded from 1979 to 2016. From these nestings, more than 1.5 million eggs were incubated (data from 1983 to 2016 only) and about 1 million hatchlings were released into the ocean (**Table 3.2B**). The range for the yearly mean hatching success was 50% to 85%. The highest nesting of hawksbill turtles was recorded at Gulisaan (78%), followed by Selingaan (14%) and Bakkungan Kecil (8%).

Table 3.1: Summary of Marine Turtle Nestings, Number of Eggs Incubated, Number of Hatchlings Released, and Mean Hatching Success (%) in TIP

Marine Turtle Species	Number of Nestings Recorded (1979–2016)	Number of Eggs Incubated (1983–2016)	Number of Hatchlings Released (1983–2016)	Overall Mean Hatching Success (1983–2016)
Green Turtle (*Chelonia Mydas*)	262,573	20,811,800	15,829,811	76%
Hawksbill Turtle (*Eretmochelys Imbricata*)	16,805	1,575,547	1,057,760	67%
Olive Ridley Turtle (*Lepidochelys Olivacea*)	5	No data	No data	No data
Total	**279,383**	**22,387,347**	**16,887,571**	

Table 3.2: Summary of Marine Turtle Nestings, Number of Eggs Incubated, Number of Hatchlings Released, and Mean Hatching Success (%) in TIP, by island, from 1979 to 2016. PGL = Selingaan Island, PBK = Bakkungan Island, PGL = Gulisaan Island

Table 3.2A: Green Turtle

Nesting Site	Number of Nestings Recorded	Number of Eggs Incubated	Number of Hatchlings Released	Mean Hatching Success (%)
PSL	128,500 (49%)	10,183,364	8,046,576	79
PBK	78,934 (30%)	6,271,192	4,780,908	76
PGL	55,139 (21%)	4,357,244	3,002,357	69
Combined (PSL, PBK, and PGL)	**262,573**	**20,811,800**	**15,829,841**	**76**

Table 3.2B: Hawksbill Turtle

Nesting Site	Number of Nestings Recorded	Number of Eggs Incubated	Number of Hatchlings Released	Mean Hatching Success (%)
PSL	2,356 (14%)	224,752	171,363	76
PBK	1,271 (8%)	110,490	79,023	72
PGL	13,178 (78%)	1,240,305	807,374	65
Combined (PSL, PBK, and PGL)	16,805	1,575,547	1,057,760	67

A. Green Turtle

1. Nesting Trends

Nestings of green turtles in TIP from 1979 to 2016 ranged from 2,243 to 14,716 nests per year (with mean ± SD = 6909.82 ± 3537.13). **Figure 3.1** summarizes the green turtle nesting trends in the three islands of TIP. Data from 1979 to 2016 show that the three islands exhibit increasing nesting trends. The nesting trends are similar, although the level is different among the islands. The graph for combined data clearly shows rising peaks.

Figure 3.1: Number of green turtle nests recorded in TIP from 1979 to 2016. PSL = Selingaan, PBK = Bakkungan Kecil, and PGL = Gulisaan (Data in Appendix 1)

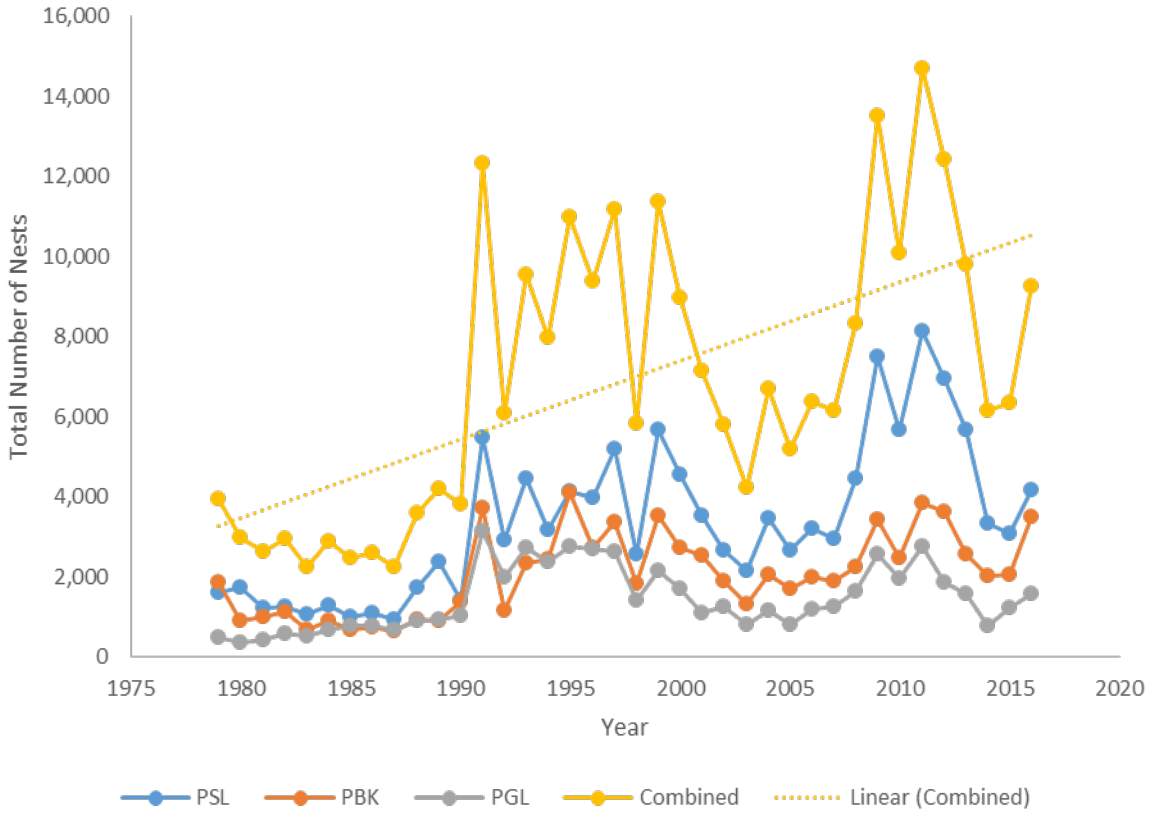
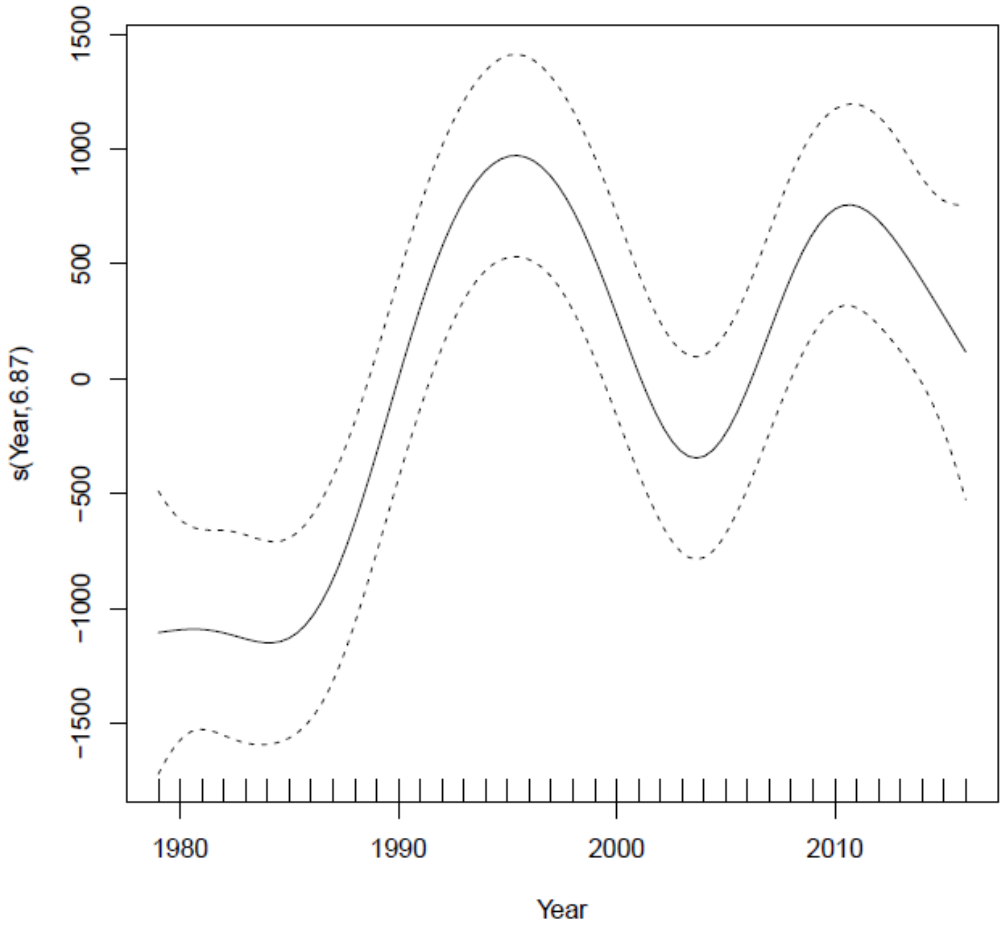


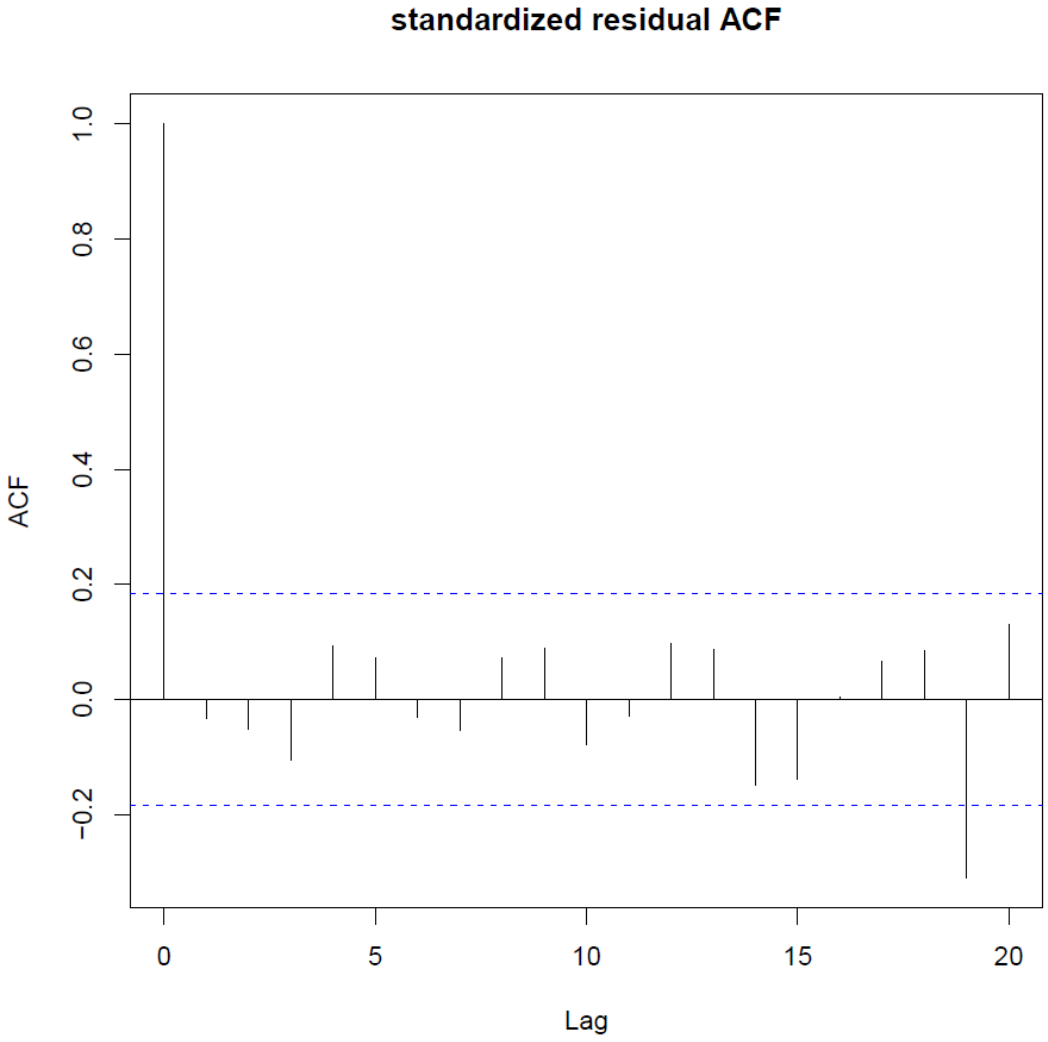
Figure 3.2 shows the average temporal dynamics (excluding the effect of the islands) using GAMM. The nesting trend shows two peaks (1994-1996 and 2010-2012) and troughs (1984-1986 and 2003-2004). Increment of nests in the late 1980s was observed. Cyclic peaks and troughs may be related to maturity years of the green turtles in TIP. Individuals born in 1984–1986 may have come back to lay their first eggs in TIP in 2010–2012.

Figure 3.2: Nesting trends in the three islands of TIP based on the average temporal dynamics analyzed using GAMM



Residual analysis with autocorrelation was conducted. The second order is preferred (**Fig. 3.3**), possibly indicating that one-year remigration is not common in the green turtle population in TIP. The 19-year autocorrelation is slightly significant, a possible indication that the green turtles in the park mature in approximately 19 years and return to TIP to lay their first eggs.

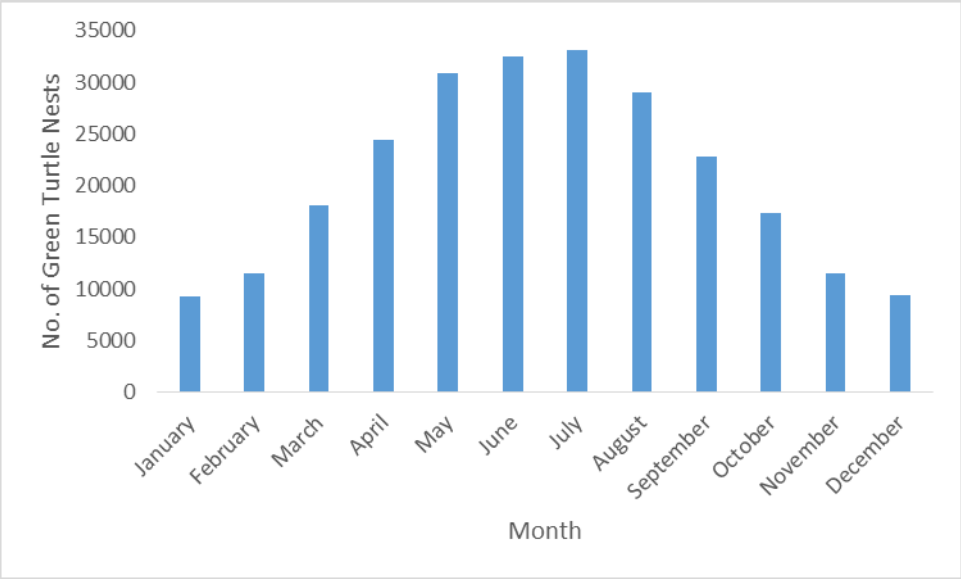
Figure 3.3: Time plot of the standardized residual analysis with autocorrelation of green turtles nesting in TIP



2. Peak Nesting Season

Figure 3.4 presents the monthly nesting of green turtles in TIP from 1979 to 2016. Nestings occur throughout the year. The peak months for green turtle nesting in the park are May to August.

Figure 3.4: Monthly nesting of green turtles in TIP from 1983 to 2016 (Data in Appendix 2)



3. Number of Nesting Females

Tagging was started in TIP in the 1970s. However, in the early years, only single tagging was implemented using Monel tags. In 1999, double tagging was started using Inconel tags (Isnain et al., 2016).

For determination of individual nesting females, only tagging data from 2000 to 2016 could be—and were—analyzed. A total of 119,299 individuals were double tagged from 2000 to 2016, ranging from 3,576 to 13,725 individual green turtles per year (mean ± SD = 7017.59 ± 3055.36) within the 17-year period.

Figure 3.5 shows the number of remigrants (nesting females tagged in previous years) and recruits (nesting females first tagged in the current year; neophytes) in TIP. From 2000 to 2016, a total of 80,949 remigrants (ranging from 1,989 to 10,262 individuals per year; mean ± SD = 4661.71 ± 2598.7) and a total of 38,350 recruits (ranging from 1,582 to 3,463 individuals per year; mean ± SD = 2555.88 ± 519.27) were recorded. All islands showed the same trend in number of nesting turtles, with more turtle remigrants than recruits.

Figure 3.5: Number of green turtle remigrants and recruits in TIP from 2000 to 2016 (Data in Appendix 3)

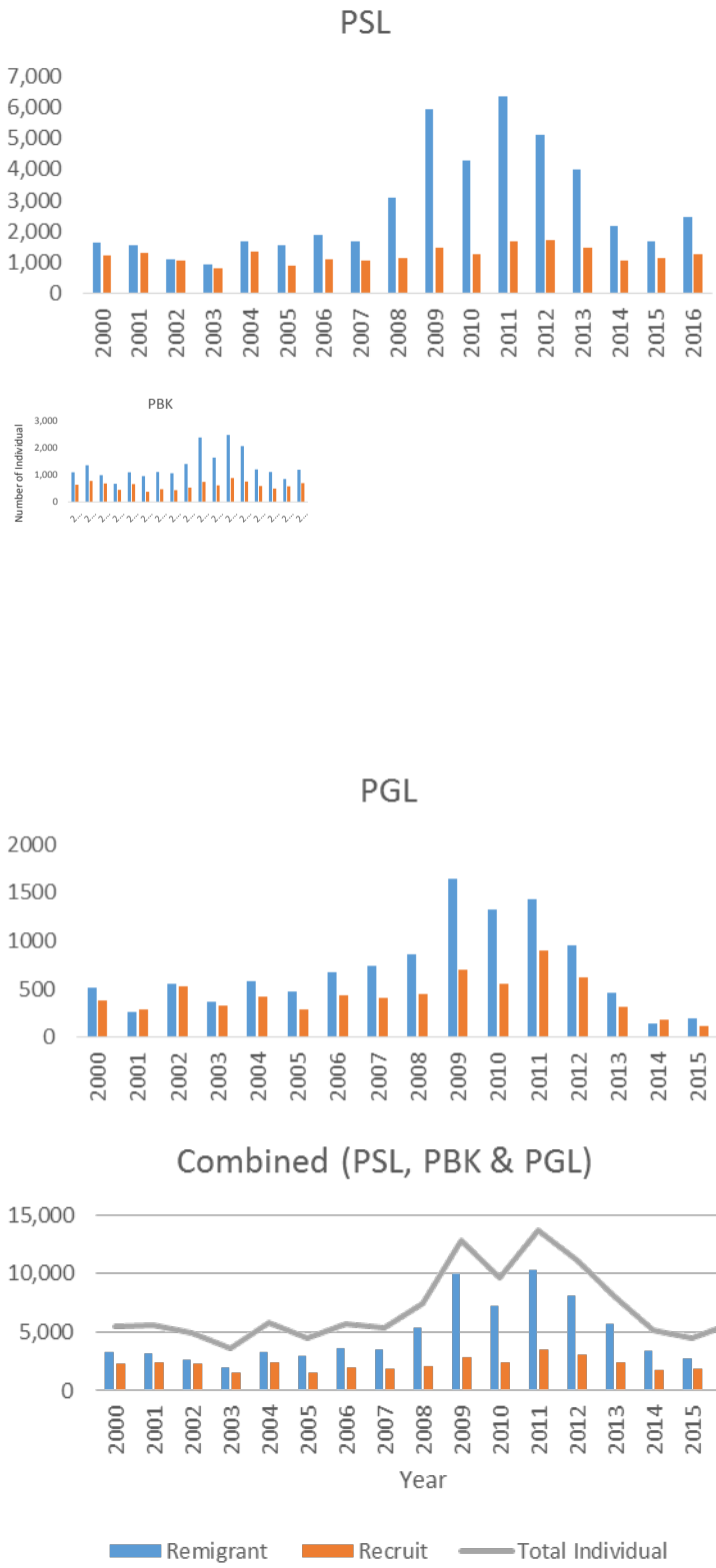


Figure 3.6 presents the number of green turtle recruits in TIP. The number of green turtle recruits seems to be stable. GAMM further analyzed the ratio of recruits (recruits / recruits + remigrants) with the assumption of binomial distributions (**Fig. 3.7**).

Figure 3.8 shows different trends among the three islands, with all islands showing peaks and troughs of the ratio. Peaks of the ratio correspond to troughs of the number of nests and vice versa. This indicates that the number of green turtle recruits is relatively constant, and fluctuation is due to the fluctuation of turtle remigrants.

Figure 3.6: Number of green turtle recruits in TIP (Data in Appendix 3)

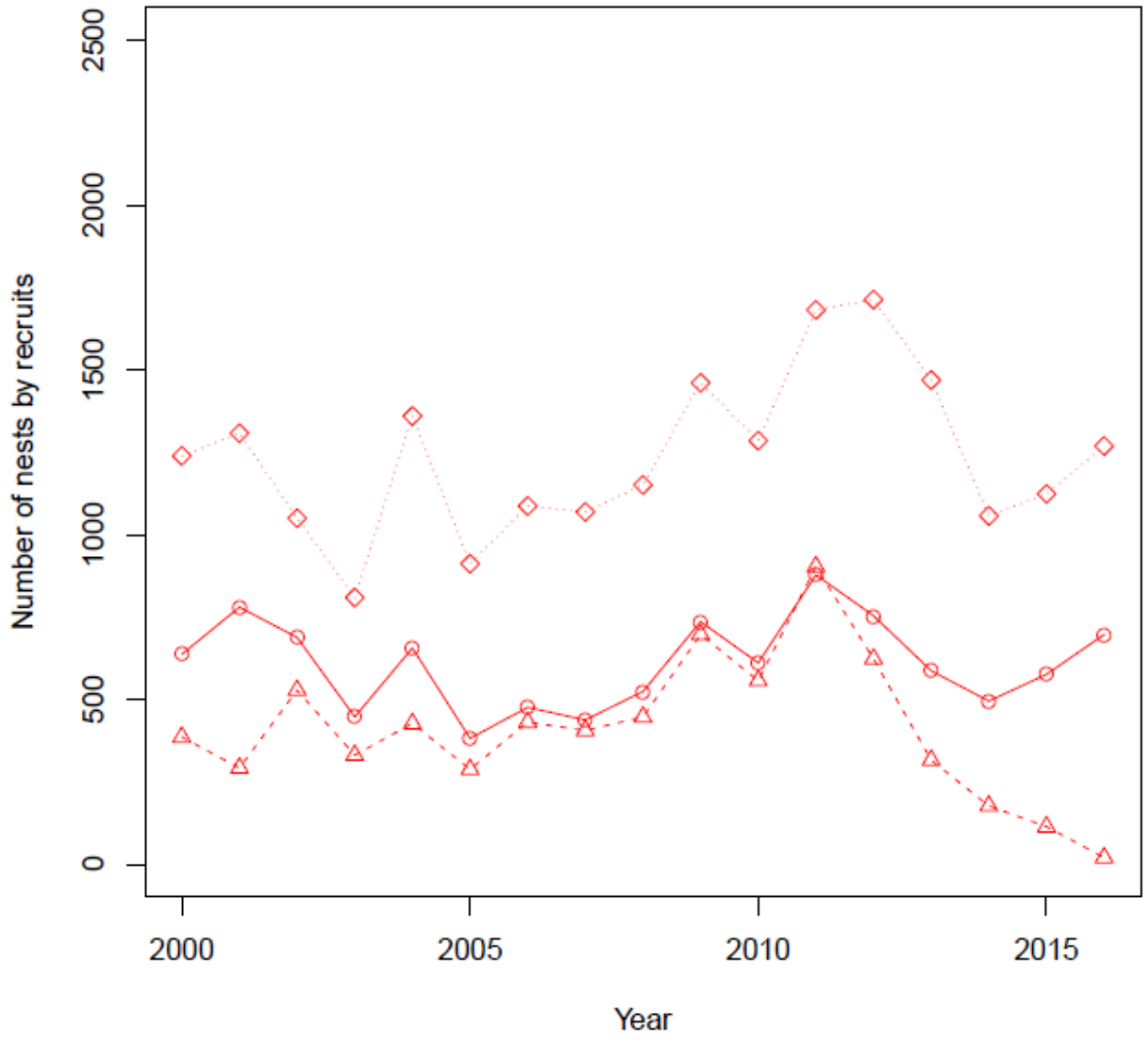


Figure 3.7: Ratio of recruits on the three islands of TIP (Data in Appendix 3)

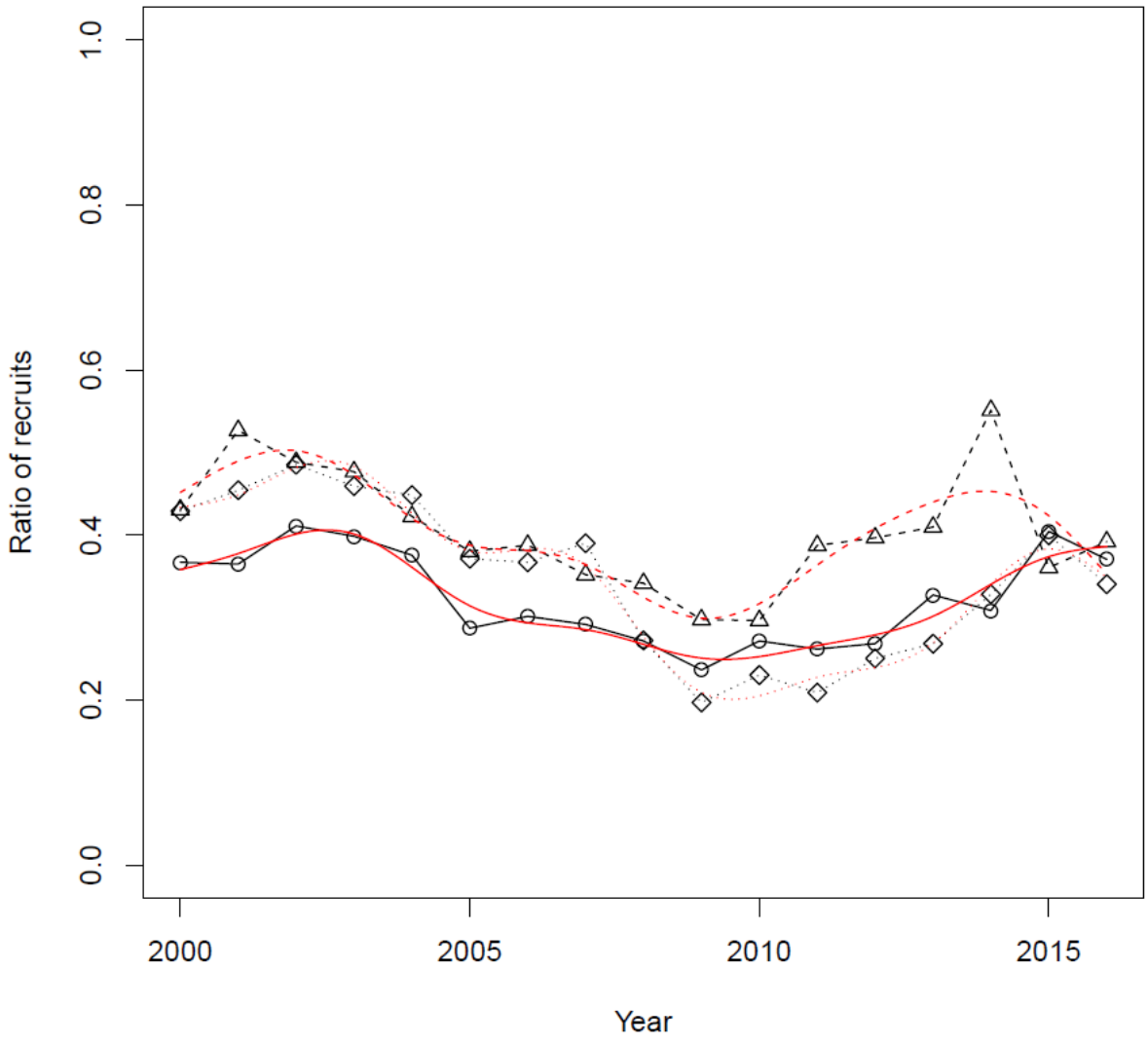
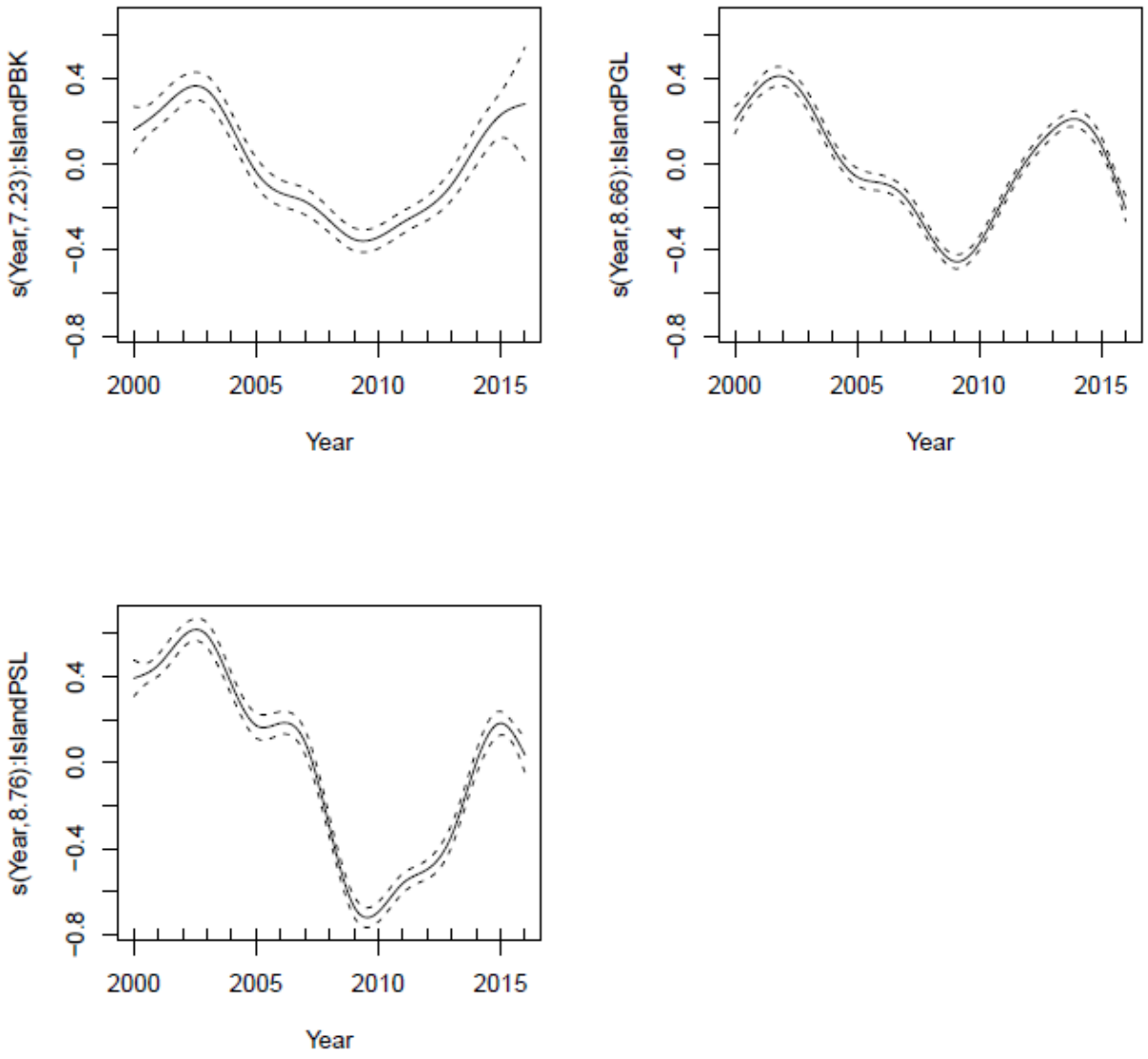


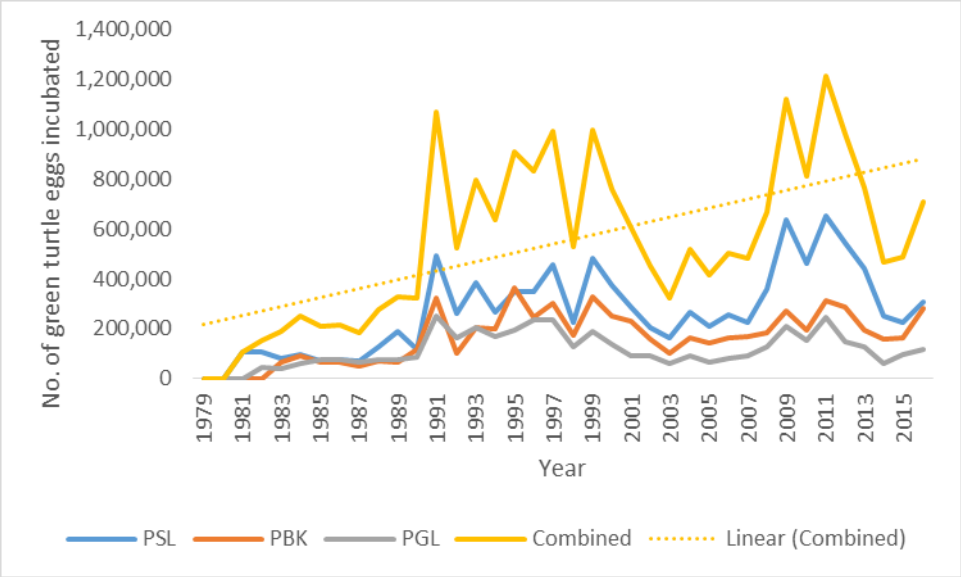
Figure 3.8: Nesting trends by green turtle recruits on the three islands of TIP analyzed using GAMM



4. Number of Eggs Incubated

Figure 3.9 shows the number of eggs incubated in TIP. The number of eggs incubated correlates with the number of nests produced by green turtles in the park, meaning that if turtle nests increased, the number of eggs incubated increased as well.

Figure 3.9: Number of green turtle eggs incubated in TIP from 1979 to 2016 (Data in Appendix 1)



B. Hawksbill Turtle

1. Nesting Trends

Nestings of hawksbill turtles in TIP from 1979 to 2016 ranged from 243 to 713 nests per year (with mean ± SD = 442.24 ± 114.14). **Figure 3.10** summarizes the hawksbill turtle nesting trends in the three islands of TIP. Data from 1979 to 2016 show that the three islands exhibit gradual decreasing trends. When this was further analyzed using GAMM (**Fig. 3.11**), a clear gradual decreasing trend was shown for hawksbill turtle nestings in the park.

Figure 3.10: Number of hawksbill turtle nests recorded in TIP from 1979 to 2016. PSL = Selingaan, PBK = Bakkungan Kecil, and PGL = Gulisaan (Data in Appendix 4)

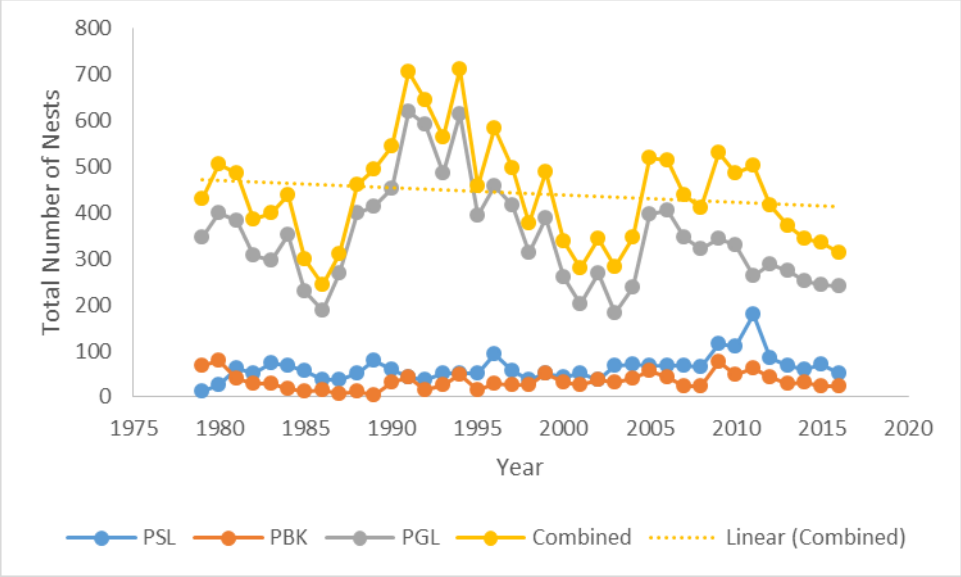
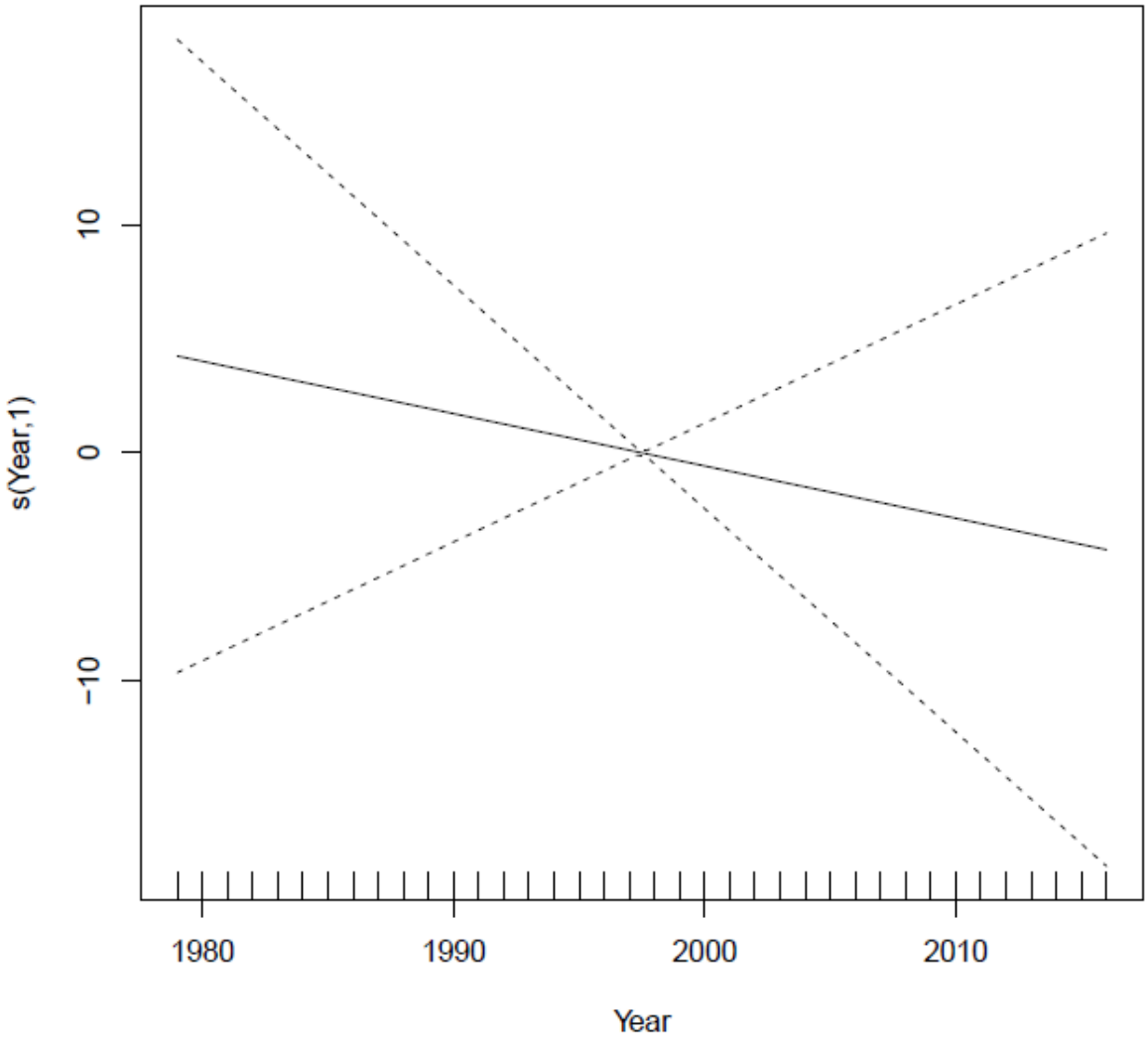


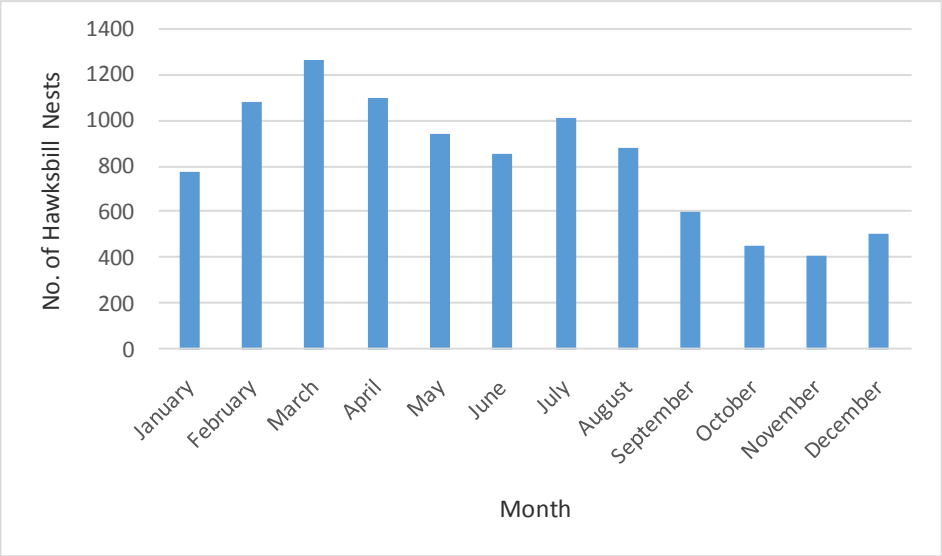
Figure 3.11: Nesting trends in the three islands of TIP based on the average temporal dynamics analyzed using GAMM



2. Peak Nesting Season

Figure 3.12 presents the monthly nesting of hawksbill turtles from 1979 to 2016. Nestings occur throughout the year, with peak months from February to April.

Figure 3.12: Monthly nesting of hawksbill turtles in TIP from 1982 to 2016 (Data in Appendix 5)

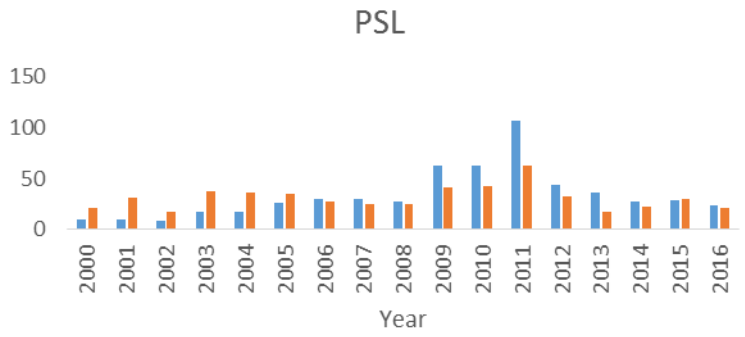


3. Number of Nesting Females

Tagging data from 2000 to 2016 were analyzed. A total of 3,889 individuals were double tagged, ranging from 71 to 400 individual hawksbill turtles per year (mean ± SD = 228.76 ± 100.42), during the 17-year period.

Figure 3.13 shows the number of remigrants and recruits in TIP. From 2000 to 2016, a total of 2,058 remigrants (ranging from 40 to 237 individuals per year; mean ± SD = 121.06 ± 64.51) and a total of 1,831 recruits (ranging from 31 to 152 individuals per year; mean ± SD = 107.71 ± 41.12) were recorded. There was no significant difference in the number of remigrants and recruits recorded in the three islands.

Figure 3.13: Number of hawksbill turtle remigrants and recruits from 2010 to 2016 (Data in Appendix 6)



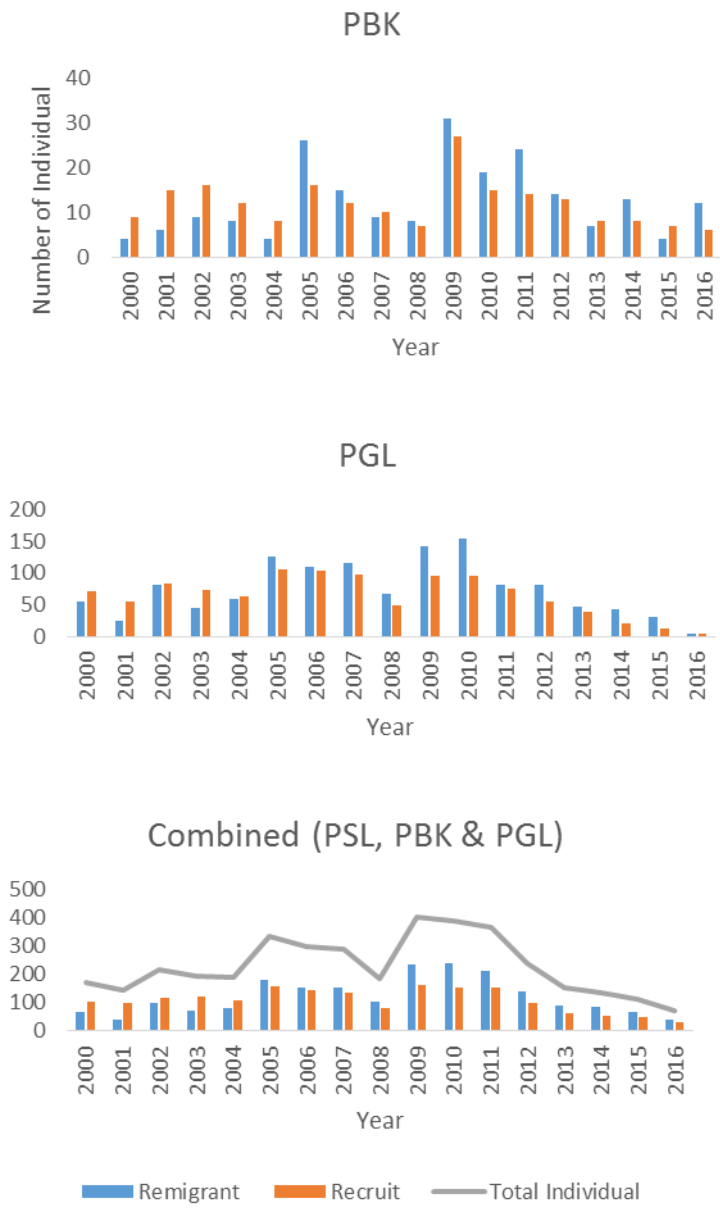


Figure 3.14 presents the number of hawksbill turtle recruits in TIP. The number of recruits shows decreasing trends. The ratio of recruits (recruits / recruits + remigrants) was further analyzed using GAMM (**Fig. 3.15**).

Figure 3.16 shows the same trends in the three islands. The ratio decreased through the years.

Figure 3.14: Number of hawksbill turtle recruits in TIP (Data in Appendix 6)

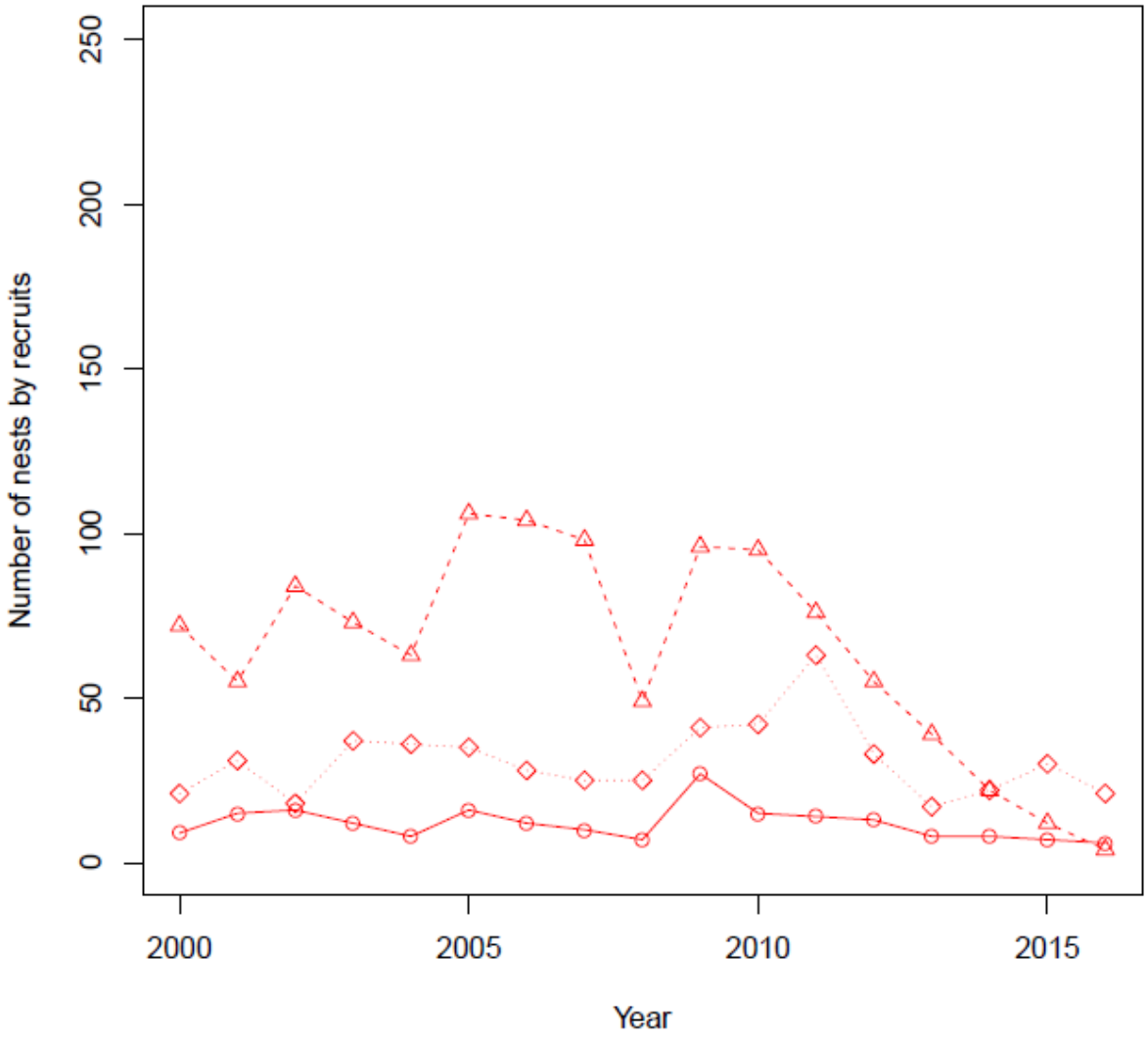


Figure 3.15: Ratio of hawksbill turtle recruits on the three islands of TIP (Data in Appendix 6)

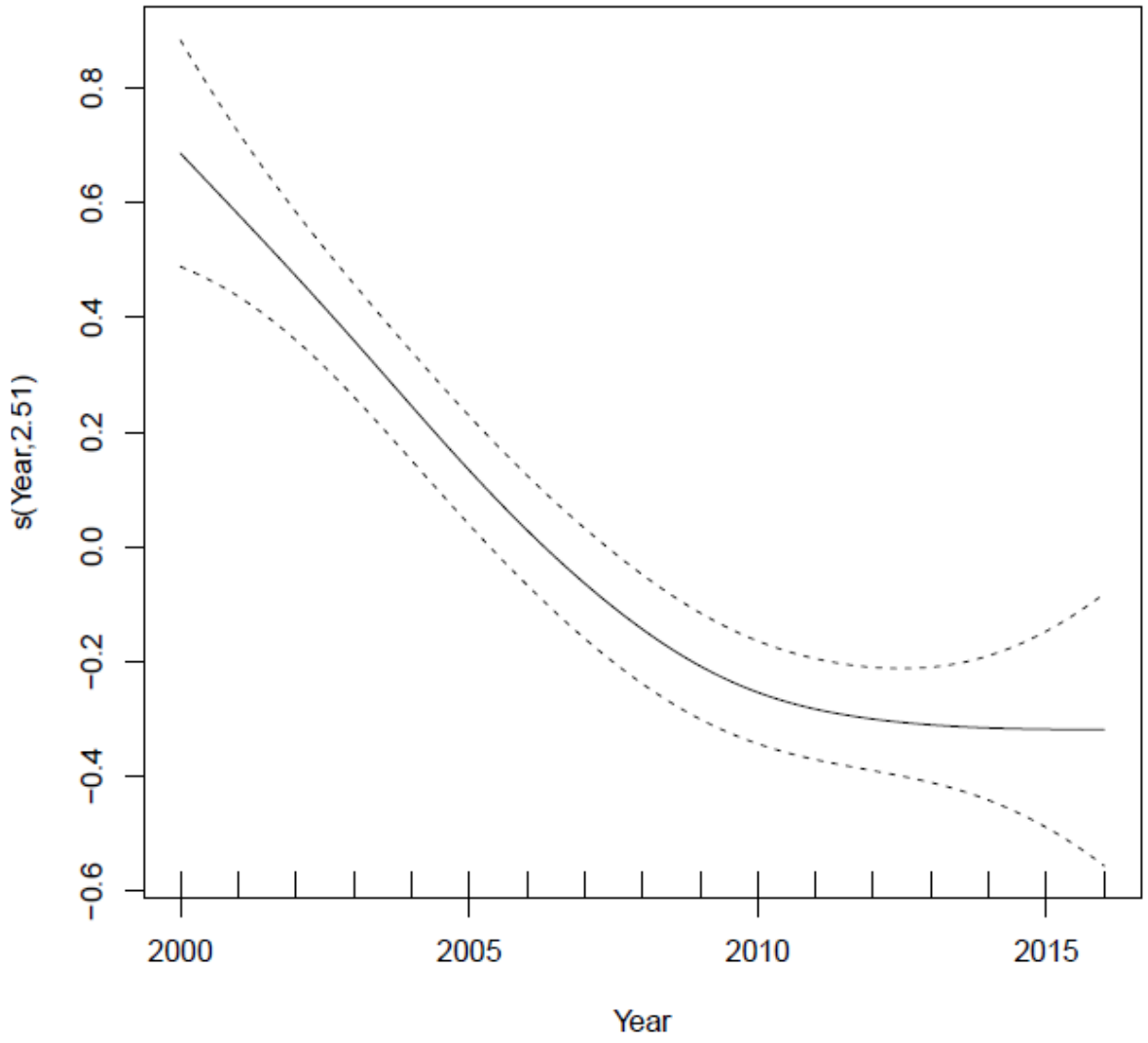
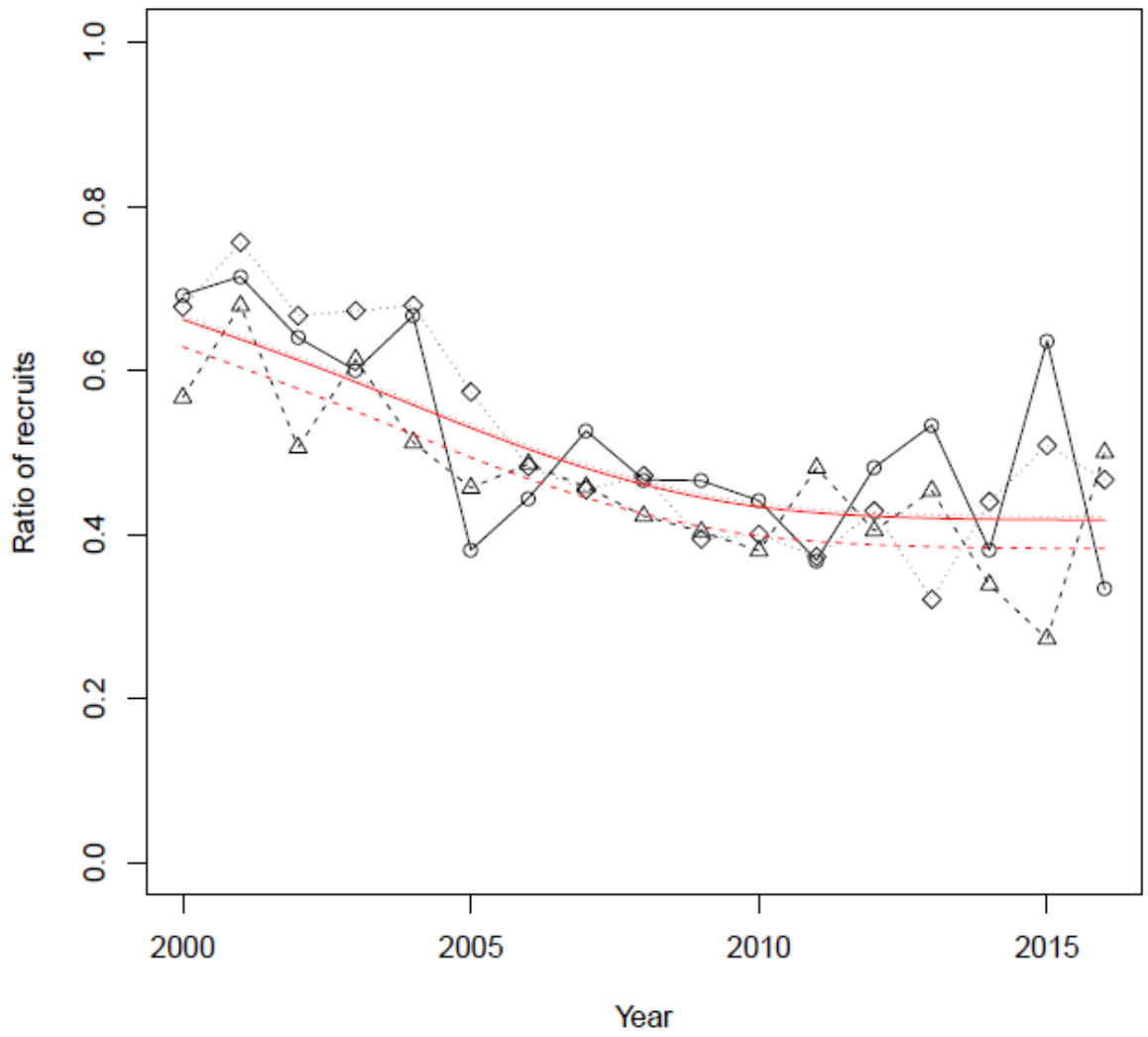


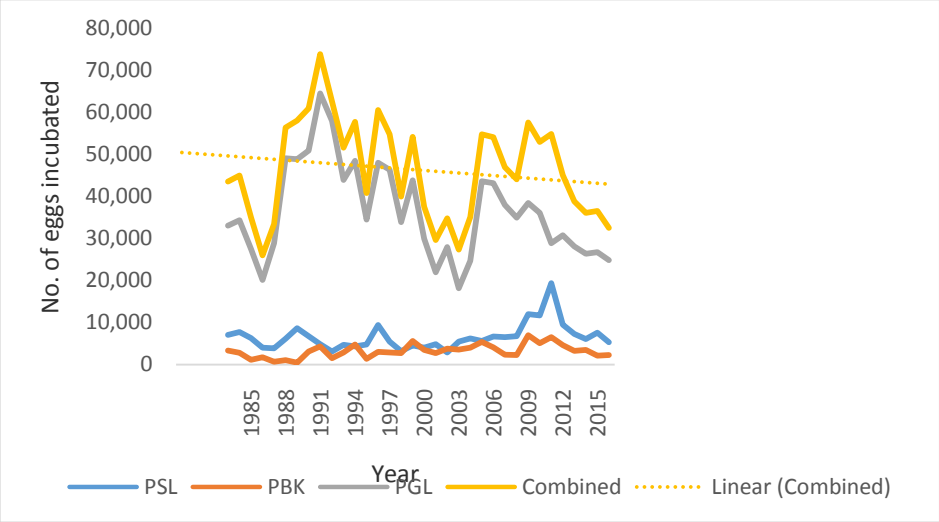
Figure 3.16: Decreasing trends of hawksbill turtle recruits on the three islands of TIP analyzed using GAMM



4. Number of Eggs Incubated

Figure 3.17 shows the number of eggs incubated in TIP. The number of eggs incubated correlates with the number of nests produced by hawksbill turtles in the park, meaning that if turtle nests increased, the number of eggs incubated increased as well, and vice versa.

Figure 3.17: Number of hawksbill turtle eggs incubated in TIP from 1983 to 2016 (Data in Appendix 4)



C. Biological Data of Marine Turtles Nesting in TIP

The summary of biological data (turtle body size, remigration interval, nesting interval, nesting frequency, and clutch size) for the marine turtles nesting in TIP (data from 2000 to 2016) is presented in **Table 3.3.** Detail data for remigration and nesting intervals are shown in **Figure 3.18** and **Figure 3.19**, respectively.

The female green turtles in TIP have a mean curved carapace length (CCL) of 98.57 cm ± 5.94 cm (range: 76.0-118.5 cm) and a mean curved carapace width (CCW) of 87.23 cm ± 5.68 cm (range: 70.0-109.5 cm). The female green turtles lay their nests in intervals of 11 days, with a mean clutch size of 84.28 eggs (range: 15–178 eggs) and nesting frequency of 3.41 nests (range: 1–9 nests) per year. For the female hawksbill turtles in the park, the mean CCL is 79.78 cm ± 8.87 cm (range: 58.0-110.0 cm), while the mean CCW is 69.18 cm ± 10.33 cm (range: 47.0-100.7 cm). The female hawksbill turtles lay their nests in intervals of 16 days, with a mean clutch size of 119.49 eggs (range: 39–200 eggs) and nesting frequency of 1.91 nests (range: 1–5 nests) per year. The green and hawksbill turtles in TIP do not nest every year. The mean remigration interval is 34 months (2.83 years) for the green turtle, and 22 months (1.83 years) for the hawksbill turtle.

Table 3.3: Summary of Biological Data for Marine Turtles Nesting in TIP (Values in brackets are the data range)

Species	Mean Nesting Size (CCL, cm)	Mean Nesting Size (CCW, cm)	Remigration Interval (Months)	Nesting Interval (Days)	Nesting Frequency (Nests/Year)	Mean Clutch Size (Eggs/Clutch)
Green Turtle	98.57 ± 5.94 (76.0-118.5)	87.23 ± 5.68 (70.0-109.5)	34 (7-83)	11 (1-146)	3.41 (1-9)	84.28 ± 21.77 (15-178)
Hawksbill Turtle	79.78 ± 8.87 (58.0-110.0)	69.18 ± 10.33 (47.0-100.7)	22 (10-60)	16 (7-146)	1.91 (1-5)	119.49 ± 32.71 (39–200)
Olive Ridley Turtle	No data	No data	No data	No data	No data	No data

CCL = curved carapace length, CCW = curved carapace width, cm = centimetre

Figure 3.18: Remigration interval (months) for green and hawksbill turtles nesting in TIP from 2000 to 2016 (Data in Appendix 7A and Appendix 7B)

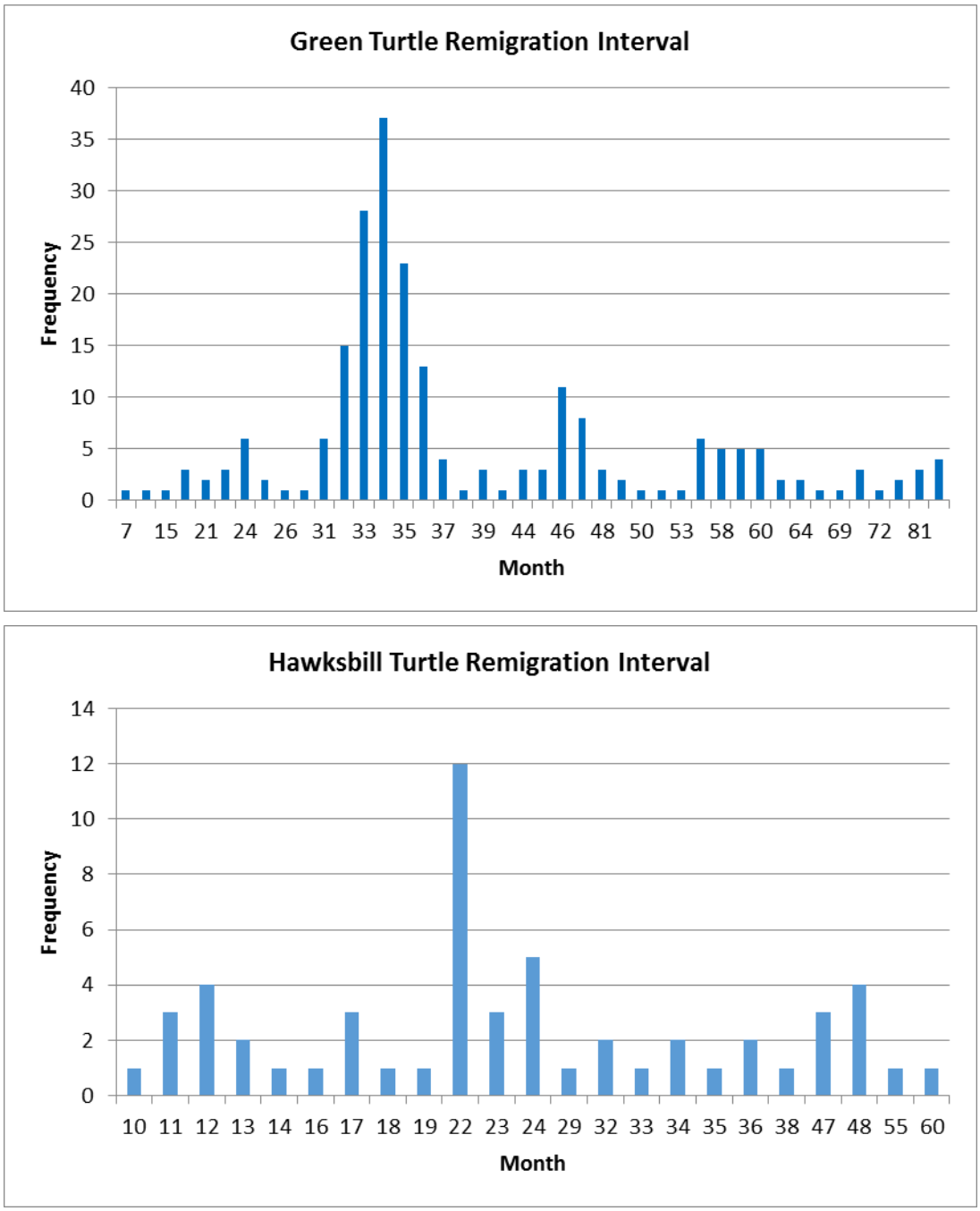
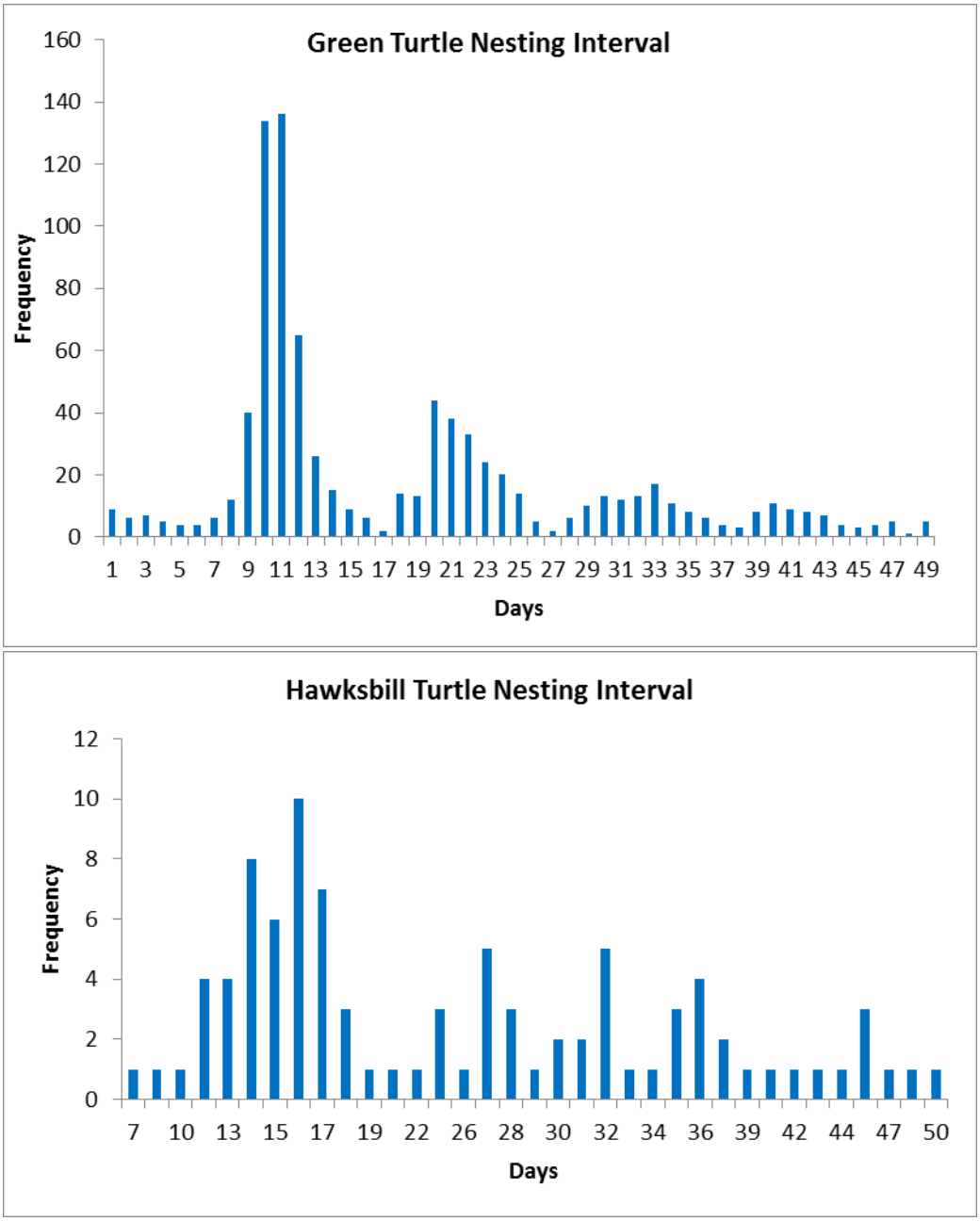


Figure 3.19: Nesting interval (days) for green and hawksbill turtles nesting in TIP from 2000 to 2016 (Data in Appendix 8A and Appendix 8B)



D. Hatching Success

Hatching success is the proportion of eggs from which hatchlings emerge in the nest chamber. In this report, hatching success refers to the number of hatchlings collected from each nest at the hatcheries by Sabah Parks staff. No further analysis was made on the survival rate of these hatchlings after being released into the sea. Overall, the hatching success for green turtles nests in TIP shows no clear trend (**Fig. 3.20),** with some years showing an increase in hatching success and other years showing a decrease. The overall mean hatching success for green turtles in TIP is 76% (combined for all islands) and ranges from 53% to 85%. Hatching success

was very low in 1992 (Bakkungan Kecil), 1998 (all islands), 2001 (Gulisaan), 2010 (Gulisaan), and 2015 (all islands).

Figure 3.20: Mean hatching success of green turtle nests incubated at hatcheries in TIP (Data in Appendix 1)

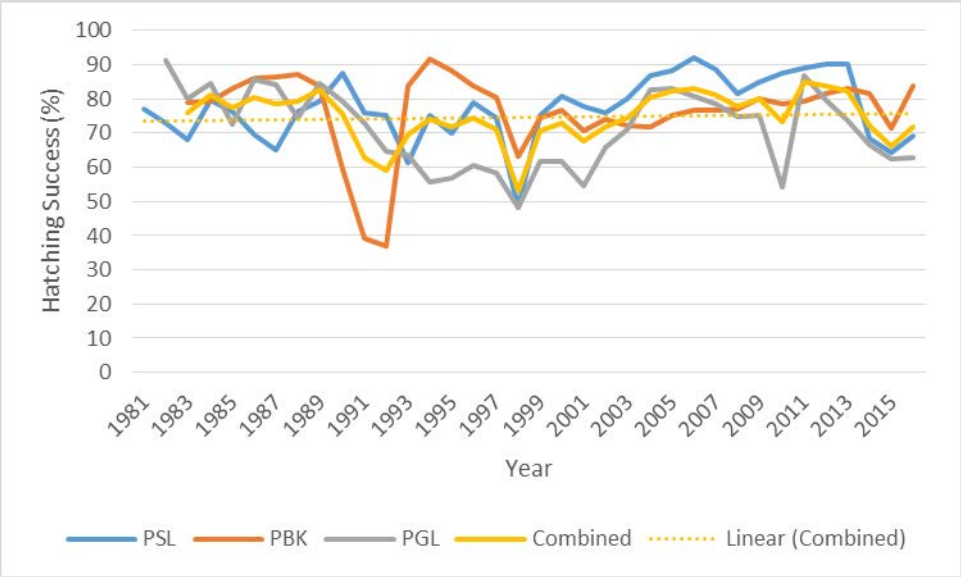
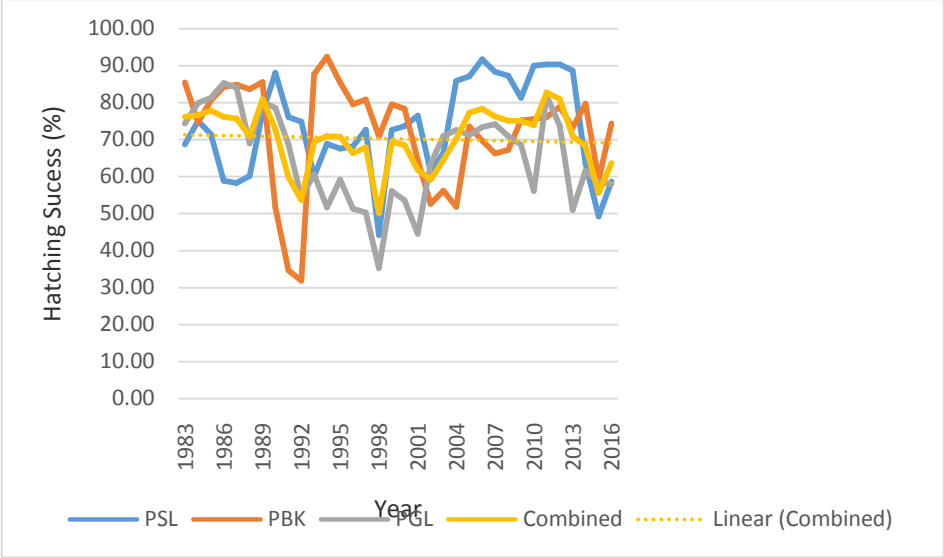


Figure 3.21 shows the hatching success of hawksbill turtle nests incubated at the hatcheries in TIP. The same patterns were observed in the three islands. No clear trends were observed; hatching success increased in some years, while it decreased in other years. The overall mean hatching success for hawksbill turtles in the park is 67% (combined for all islands), ranging from 50% to 83%. Hatching success was low in 1992 (Bakkungan Kecil), 1998 (all islands), 2001 (Gulisaan), 2002 and 2004 (Bakkungan Kecil), 2010 and 2013 (Gulisaan), and 2015 (all islands).

Figure 3.21: Mean hatching success of hawksbill turtle nests incubated at hatcheries in TIP (Data in Appendix 4)



E. Predation of Marine Turtle Eggs

All turtle nests laid on the three islands of TIP are transferred to a protected beach hatchery (**Fig. 3.22**). In about 2% to 3% of cases, marine turtle nestings are not detected and the nests are left to incubate naturally. Since all eggs are now transferred to the hatchery, natural predation of turtle eggs in the park has become very low. However, for any hatchery program, the handling of turtle eggs is very important because it determines the hatching success of each nest.

Figure 3.22: A hatchery on Selingaan Island

Photo credit: J. Joseph.

During the field visit to TIP (11–13 May 2017), predators of turtle eggs were identified. The predators were:

a. **Monitor Lizards (Varanus Salvator):** A few monitor lizards were observed on Selingaan and Bakkungaan Kecil (**Fig. 3.23**). Monitor lizards are known to prey on turtle eggs and hatchlings. Since most eggs in TIP are now transferred to protected hatcheries, the problem of nests being eaten by monitor lizards has become minimal. However, according to Sabah Parks staff, monitor lizards sometimes go to the hatchery and dig some nests under incubation. Monitor lizards eat about 15-20 nests per year at Selingaan and Bakkungan Kecil hatcheries (Sabah Parks staff, *pers. comm*).

Figure 3.23: An adult monitor lizard in TIP

Photo credit: J. Joseph.

b. **Ghost Crabs:** Ghost crabs are known to eat turtle eggs and hatchlings. Ghost crabs were observed at nesting beaches and hatcheries in TIP.

c. **Rats:** Rats can sometimes be found at hatcheries. But in recent years, the rat population in TIP has been put **under** control.

d. **Ants:** Ants are found at the hatcheries and can be predators of turtle eggs and hatchlings.

e. **Cats:** During the field visit, cats were observed in Selingaan and Bakkungan Kecil. They were introduced to the islands as pets or abandoned in the islands by fishermen. According to Sabah Parks staff, cats sometimes go to the hatcheries and eat or kill turtle hatchlings.

1. Analysis of Unhatched Eggs Incubated at the Hatcheries

During the field visit, 52 nests that have hatched were excavated from the hatcheries on Selingaan and Bakkungan Kecil. A total of 3,933 eggs were analyzed (**Table 3.4**).

Figure 3.24 summarizes the analysis of unhatched eggs from hatcheries on Selingaan and Bakkungan Kecil. Nests from Gulisaan are transferred and incubated at a hatchery on Selingaan.

Majority of unhatched eggs in all hatcheries in TIP are complete eggs (**Fig. 3.25**). This may be due to improper handling or infertile eggs, but needs further investigation. Ants predated most of the unhatched eggs, especially the nests incubated on Selingaan (Fig. 3.26). Fungi (Fig. 3.27), maggots, crabs, and plant roots also caused unhatched eggs. Some dead hatchlings were also found in the excavated nests with no sign of predation.

Table 3.4: Analysis of Unhatched Eggs at Hatcheries in TIP

Hatchery	Number of Nests Analyzed	Number of Eggs Analyzed	Hatching Success (%)	Analysis of Unhatched Eggs (%)	Mean Incubation Period (Days)
Selingaan	20	1568	81%	Complete eggs (62), ants (19), maggots (9), fungi (8), crabs (2), dead hatchling (1)	67
Bakkungan	20	1,418	84%	Complete eggs (47), rotten eggs (4), ants (34), maggot (1), fungi (10), plant roots (2), dead hatchlings (2)	64
Selingaan (Nests from Gulisaan)	12	947	79%	Complete eggs (74), ants (16), maggot (0.5), fungi (2), plant root (0.5), crabs (7)	64
Total	**52**	**3933**	**81%**		

Figure 3.24: Analysis of rotten eggs at hatcheries in TIP. PSL = Selingaan, PBK = Bakkungan Kecil, and PGL* = Gulisaan. Nests from Gulisaan are transferred and incubated at a hatchery on Selingaan

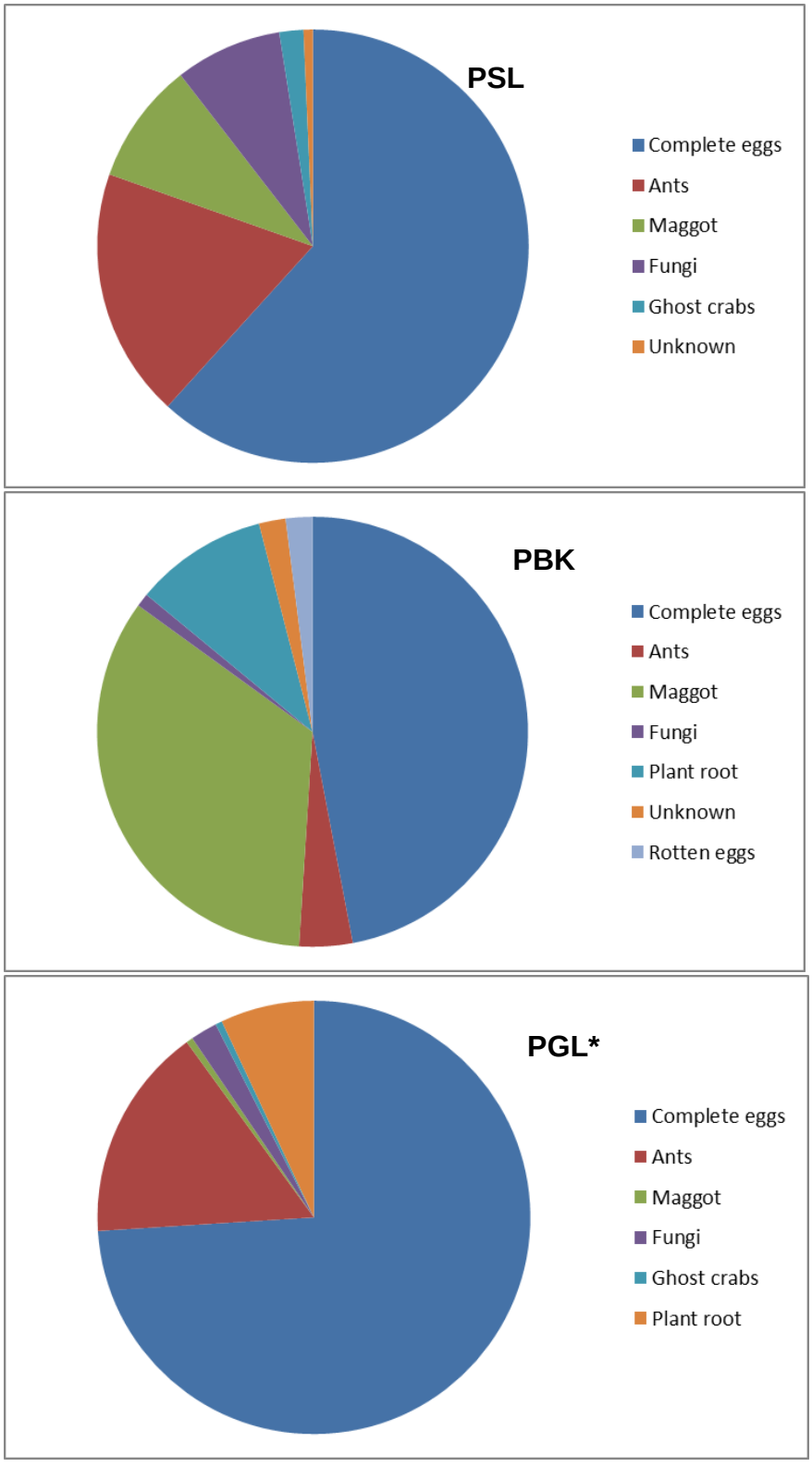


Figure 3.25: Complete unhatched eggs at a hatchery in TIP

Photo credit: Sabah Parks.

Figure 3.26: Unhatched eggs predated by ants at a hatchery in TIP

Photo credit: Sabah Parks.

Figure 3.27: Unhatched eggs affected by fungi at a hatchery in TIP

Photo credit: Sabah Parks.

IV. DISCUSSION

A. Marine Turtle Landing

1. Nesting Trends

The nesting of green turtles in TIP shows increasing trends. About 2,500–4,000 nests were deposited per year from 1979 to 1990. This increased to 7,000–14,716 nests per year from 2000 to 2016. Like other marine turtles, the green turtles in the park do not nest every year. The mean remigration interval is 34 months (2.83 years). Because of this, there is inter-annual variation in nesting data. In one breeding season, female green turtles in TIP can lay one to nine clutches, with interesting interval of 11 days. Green turtles are the most abundant turtle species in the park (94%), with Selingaan providing the highest nesting (49%), followed by Bakkungan Kecil (30%) and Gulisaan (21%).

Analysis of the long-term nesting data for green turtles shows that the three islands exhibit increasing trends. Based on the average temporal dynamics graph, the nesting trends of green turtles in TIP exhibit two peaks and troughs. Increment of nests in the late 1980s was observed, possibly because of intensive conservation efforts. The large inter-annual variation in green turtle nestings observed in the park demonstrates the importance of long-term data sets to determine sea turtle nesting trends. The increasing nesting trend suggests that conservation efforts are successful. Although positive, the nesting trends of green turtles in TIP should be interpreted cautiously within a historical context. A longer monitoring may be necessary for an accurate conclusion. It will also be beneficial if there was landing data in the 1960s and 1970s so that accurate comparison can be made.

The nesting of hawksbill turtles consists 6% of the overall marine turtle landing in TIP. Like the green turtles, the hawksbill turtles in the park do not nest every year. The mean remigration interval is 22 months (1.83 years). The shorter remigration interval of hawksbill turtles in TIP compared with those on Redang Island (Chan and Liew 1999) suggests that female turtles use nearby foraging grounds. Remigration interval has a big effect on population dynamics, population viability, and recovery potential (Seminoff et al., 2015).

In one breeding season, female hawksbill turtles in TIP can lay one to five clutches, with mean clutch size of 119.49 ± 32.71 (range of 39–200 eggs) and mean interesting interval of 16 days. The highest nesting of hawksbill turtles was recorded in Gulisaan (78%), followed by Selingaan (14%) and Bakkungan Kecil (8%). The analysis of long-term nesting data for hawksbill turtles in the park shows gradual decreasing trends for the three islands. Based on the nesting data, the nesting trends were stable from 1986 to 1996, and then gradually decreased in 2000 onwards.

There are many factors contributing to the decline of hawksbill turtles in TIP. The main reason could be the loss of the nesting beach on Gulisaan, which has suffered severe beach erosions (**Fig. 4.1**). With majority of hawksbill turtle nestings occurring on Gulisaan (78%), the loss of the nesting beach on the island has affected the overall nesting of hawksbill turtles in TIP. Female hawksbill turtles exhibit strong nest site fidelity and prefer a certain beach on which to lay their eggs (Witzell, 1983). In TIP, hawksbill turtles favor Gulisaan as a nesting site, which means the island is an important nesting beach and is critical for hawksbill turtles in Sulu Sea. Female hawksbill turtles prefer a nest site usually associated with vegetation (Cuevas et al., 2010). However, other factors such as beach slope, nearshore habitat features, oceanographic conditions, and sand compaction may also influence the place where a female hawksbill turtle lays eggs (Garcon et al., 2010; Walcott et al., 2012).

Other factors contributing to the decline of hawksbill turtles in TIP are getting caught as bycatch in fisheries and harvesting of hawksbill turtles at their foraging grounds. Nesting of hawksbill turtles elsewhere has been reported to decline more than 80% in the last three generations. This is why the International Union for Conservation of Nature (IUCN) has categorized the hawksbill turtle as critically endangered (Mortimer and Donnelly, 2008).

As with any assessment based on long-term data, there is a level of uncertainty about the final results. The marine turtles in TIP do not nest every year. Because of this, the nest estimation only provides information about the proportion of adult females that nest in any given year, but not the total adult females in the population. Aside from this, the marine turtles in the park are considered part of a larger population, with their nesting grounds extending to the Philippine Turtle Islands. Thus, estimation of population trends should be considered for all the nesting rookeries in the wider area.

Figure 4.1: The remaining nesting beach on Gulisaan Island after a series of severe erosions caused by natural factors

Photo credit: J. Joseph. Photo was taken in May 2017.

Cyclic peaks and troughs may also be related to the age-to-maturity (age at first reproduction) of female green turtles in TIP. Based on residual analysis with autocorrelation, it is suggested that female green turtles in the park mature and lay their first eggs in approximately 19 years. The age-to-maturity for green turtles appears to be the longest among all species of sea turtles

(Hirth, 1997). Estimates of the age-to-maturity vary widely between populations as well as turtle species. For green turtles, the published age at sexual maturity is estimated to be as long as 50 years. The shortest duration reported is 15–19 years for green turtles in the Cayman Islands (Bell et al., 2005). In Malaysia, the age-to-maturity for green turtles in other nesting rookeries aside from TIP is relatively unknown.

The age-to-maturity for hawksbill turtles in TIP and in other nesting rookeries in Malaysia is also unknown. The long-term nesting data of hawksbill turtles in TIP exhibit decreasing trends and do not show cyclic peaks or troughs; hence, the age-to-maturity for hawksbill turtles in the park cannot be determined. In northeastern Australia, first breeding is estimated to occur at 31–36 years for females and 38 years for males (Limpus and Miller, 2008). In Hawaii, the estimated age-to-maturity is between 17 and 22 years (Snover et al., 2013). In other words, age-to-maturity estimates vary widely between populations of hawksbill turtles.

The nesting size (CCL) of green turtles in TIP ranges from 76.0 cm to 118.5 cm (analyzed from 2016 nesting data, n = 1555), with a mean of 98.57 cm ± 5.949 cm. In this study, it is estimated that the green turtles in the park reach maturity in about 19 years, possibly with a minimum size of 76.0 cm. The nesting size (CCL) of hawksbill turtles in TIP ranges from 58.0 cm to 110.0 cm (analyzed from 2016 nesting data, n = 150), with a mean of 79.78 cm ± 8.87 cm. Previously, it was reported that the mean nesting size of green turtles was 98.5 cm (Trono, 1991), while the mean nesting size of hawksbill turtles was 76.0 cm, with a range of 59.7 cm to 98.0 cm (Pilcher and Ali, 1999). The slight differences in the nesting size of marine turtles in TIP compared with previous studies may be due to the number of samples analyzed in the present study. There is variation in the mean nesting size of marine turtles among nesting sites, but most populations of green turtles are in the CCL size range of 95 cm to 110 cm (Hirth, 1997). In Redang Island, Terengganu, Malaysia, the mean nesting size of green turtles is 99.2 cm (range: 82.4–120.3 cm) (Chew, 2015), while that of hawksbill turtles is 82.3 cm (range: 76.7–87.5 cm) (Chan and Liew, 1999). There are some populations with mean nesting size ranges that are substantially larger or smaller. Substantial differences in the size of nesting turtles suggest local adaptation or conditions (Seminoff et al., 2015).

2. Peak Nesting Season

The nesting of green and hawksbill turtles occurs throughout the year (January to December) in TIP, but the two species have different peak nesting seasons. The peak months are May to August for green turtles, and February to April for hawksbill turtles. Marine turtles exhibit seasonal nesting variations that are often correlated with air and sand temperatures. This study found that hawksbill turtles in TIP prefer to lay their eggs during the early months of the year, when air temperature is slightly lower. On the other hand, the peak nesting season of green turtles in the park coincides with the months when the air temperature is slightly higher (dry season). According to Khatib et al. (2012), the maximum monthly air temperature is lowest in December and starts to rise in the following months. The peak nesting seasons of green and hawksbill turtles in TIP are similar with those reported elsewhere in Malaysia (e.g. Chan and Liew, 1999; Chew, 2015; Abdul Kadir, 2016).

3. Number of Nesting Females

Tagging data of marine turtles in TIP collected from 2000 to 2016 were analyzed. A total of 119,299 individual green turtles were tagged (range: 3,576–13,725 individuals), of which 80,949 were remigrants (mean ± SD = 4661.71 ± 2598.7) and 38,350 were recruits (mean ± SD = 2555.88 ± 519.27). The number of green turtle remigrants was higher compared with recruits,

and an increment was observed from 2008 to 2013. The number of green turtle recruits was relatively constant.

As for hawksbill turtles, a total of 3,889 individuals were tagged (range: 71–400 individuals), of which 2,058 were remigrants (mean ± SD = 107.71 ± 41.12) and 1,831 were recruits (mean ± SD = 107.71 ± 41.12). The number of hawksbill turtle remigrants was slightly higher than recruits. The number of hawksbill turtle recruits on the three islands showed decreasing trends.

The recruitment of females into the breeding population and of first-time breeders (recruits) into a nesting population is critical in assessing population trends. For example, if a nesting population is increasing, it is the result of increased recruitment of first-time breeders, increased survival of mature females (remigrants), or both. Among green turtles in TIP, turtle remigrants are numerous in the population, with constant first-time breeders. However, the recruitment of female hawksbill turtles in the park is decreasing, even though conservation efforts are in place. There are many factors contributing to the decrease of marine turtle recruitment, including low survival of hatchlings, harvesting of juvenile and adult sea turtles at their foraging grounds, and incidental capture or getting caught as bycatch in fisheries.

Marine turtles do not nest every year due likely to energy demands of migration (Miller et al., 1999). Remigration intervals vary from one nesting site to another. Among hawksbill turtles, for example, the remigration interval averages 1.84 years in TIP (Pilcher and Ali, 1999), 2-3 years in Redang Island, Terengganu (Chan and Liew, 1999), and 5 years in Milman Island, Australia (Limpus, 2009). In this study, the mean remigration in TIP is 2.83 years for green turtles and 1.83 years for hawksbill turtles. The variation in remigration is likely due to many factors, including distance between nesting beaches and foraging grounds, and food quality and availability during non-breeding years (Beggs et al., 2007).

4. Number of Eggs Incubated

Mean clutch size varies among sea turtle species as well as between populations. In TIP, the average clutch size is 84.28 ± 21.77 (range: 15–178 eggs) for green turtles and 119.49 ± 32.71 (range: 39–200) for hawksbill turtles. The nests incubate for variable periods of time, and the length of the incubation period is related to nest temperature. The average incubation period of marine turtle nests at the hatcheries in TIP is 65 days.

About 21 million eggs of green turtles and 1.5 million eggs of hawksbill turtles were incubated in the park from 1979 to 2016. Since the nesting of green turtles in TIP has shown increasing trends, the number of eggs incubated in the hatcheries has also increased. However, the number of nesting hawksbill turtles has declined in the park. This has reduced the number of eggs incubated in the hatcheries.

B. Hatchling Production

In any conservation effort, it is important to maximize hatchling production to ensure adequate hatchlings will replenish future stocks. This can be achieved by increasing the hatching success. In TIP, due to small nesting beaches, all eggs laid by green and hawksbill turtles are transferred to protected hatcheries.

The overall mean hatching success for green turtles in the park is 76%, ranging from 53% to 85%. From these, about 16 million hatchlings are released into the ocean.

The overall mean hatching success for hawksbill turtles in TIP is 67%, ranging from 50% to 85%. From these, about 1 million hatchlings are released into the ocean.

The hatching success of nests in the park is considered low to moderate. More effort must be taken to increase the hatching success, especially for hawksbill turtle nests.

Monitor lizards, ghost crabs, rats, ants, and cats are predators of turtle eggs in TIP. Since all turtle nests are now transferred to protected beach hatcheries, the predation of turtle eggs is very low and does not pose a serious threat.

Majority of unhatched eggs in all hatcheries in TIP are complete eggs. This may be due to infertile eggs or improper handling, but needs further investigation before conclusion can be made. In many turtle hatcheries, the main factors that lower the hatching success are handling of eggs and delay in transferring eggs to a hatchery. If a hatchery is run efficiently, the hatching success can be increased to 90% or more. Thus, training should be conducted regularly, especially for new staff, to ensure the handling and transferring of eggs to the hatcheries is conducted efficiently.

V. CONCLUSION AND RECOMMENDATIONS

The conservation of marine turtles in TIP is one of the longest in Malaysia, with a period exceeding forty years. However, because of incomplete and poor data management during the early years, only data from 1979 to 2016 could be traced and analyzed. The long-term data collected by Sabah Parks were very valuable, providing information on population abundance and long-term trends, age-to-maturity (age at first reproduction), and reproductive output (e.g. clutch size, clutch frequency, interesting interval, and remigration interval). Since the nestings of marine turtles, especially green turtles, in TIP are very high (large data collected every month) and tagging data are collected for a long period of time, a computer program should be designed to record and manage data more efficiently. Long-term data should be analyzed at least once every 5–10 years to evaluate the success of conservation efforts in the park. This can be done by collaborating with turtle scientists from local and international institutions.

Double tagging has been implemented in TIP since 1999 (Isnain et al., 2016). The data obtained from the tags, if analyzed properly, can provide valuable information on the biology of marine turtles in the park. However, tag loss estimation must be done so that an accurate estimation of population status and dynamics can be obtained. It is necessary to evaluate tag loss to improve the tagging methodology and the selection of appropriate tag types. Training on tagging methodology should be conducted regularly, especially for new staff, to improve the tagging programs in TIP. Regular training on egg handling for Sabah Parks staff should also be conducted.

With the help of marine turtle scientists from local and international institutions, TIP should conduct a review of green and hawksbill turtle nestings in the park at least once every 5-10 years. Such a review is important to determine the status of marine turtle nestings in TIP, as well as to review the overall success of conservation efforts.

The migratory routes of marine turtles normally cross the territorial waters of many countries or the open ocean. Thus, efforts to protect these animals can be very complex and challenging. To conserve marine turtles, international collaboration is needed.

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Appendix 1

Number of Green Turtle (*Chelonia Mydas*) Nestings, Number of Eggs Incubated, Number of Hatchlings Released, and Mean Hatching Success (%) in TIP from 1979 to 2016

PSL = Selingaan, PBK = Bakkungan Kecil, PGL = Gulisaan (Sabah Parks Data)

	Nest recorded				Eggs incubated				No of hatchlings released				Hatching Success (%)			
Year	PSL	PBK	PGL	Total	PSL	PBK	PGL	Total	PSL	PBK	PGL	Total	PSL	PBK	PGL	Mean
1977	No Data	No Data	No Data		No Data	No Data	No Data		No Data	No Data	No Data					Hatching
1978	No Data	No Data	No Data		No Data	No Data	No Data		No Data	No Data	No Data					Success (%
1979	1,597	1,866	477	3,940	No Data	No Data	No Data		No Data	No Data	No Data					
1980	1,721	902	349	2,972	No Data	No Data	No Data		No Data	No Data	No Data	0				
1981	1,214	992	426	2,632	105,429	No Data	No Data	105,429	81,190	No Data	No Data	81,190	77.01			
1982	1,265	1,114	569	2,948	106,137	No Data	46,586	152,723	77,369	No Data	42,571	119,940	72.90		91.38	
1983	1,065	667	511	2,243	82,309	65,908	41,338	189,555	56,188	52,071	33,128	141,387	68.26	79.01	80.14	75.80
1984	1,300	913	673	2,886	96,470	93,255	58,827	248,552	76,891	73,845	49,813	200,549	79.70	79.19	84.68	81.19
1985	1,004	690	763	2,457	70,100	64,120	74,743	208,963	53,511	53,302	54,346	161,159	76.34	83.13	72.71	77.39
1986	1,099	735	765	2,599	77,141	64,281	73,531	214,953	53,721	55,269	63,134	172,124	69.64	85.98	85.86	80.49
1987	951	640	667	2,258	69,311	50,983	65,305	185,599	45,014	44,122	55,088	144,224	64.94	86.54	84.35	78.61
1988	1,751	946	910	3,607	129,472	73,111	75,276	277,859	98,971	63,836	56,202	219,009	76.44	87.31	74.66	79.47
1989	2,363	907	935	4,205	188,746	64,821	73,257	326,824	149,961	54,408	62,028	266,397	79.45	83.94	84.67	82.69
1990	1,410	1,393	1,022	3,825	119,200	117,399	86,238	322,837	104,352	69,953	68,311	242,616	87.54	59.59	79.21	75.45
1991	5,474	3,730	3,134	12,338	493,990	324,633	252,168	1,070,791	375,015	127,376	184,011	686,402	75.92	39.24	72.97	62.71
1992	2,933	1,157	1,993	6,083	260,254	101,102	161,680	523,036	195,847	37,479	104,356	337,682	75.25	37.07	64.54	58.96
1993	4,468	2,358	2,731	9,557	385,835	205,693	206,625	798,153	236,538	172,392	131,761	540,691	61.31	83.81	63.77	69.63
1994	3,184	2,446	2,362	7,992	266,965	201,067	169,197	637,229	201,108	184,116	94,521	479,745	75.33	91.57	55.86	74.26
1995	4,143	4,102	2,747	10,992	350,372	364,274	195,628	910,274	245,683	321,930	111,201	678,814	70.12	88.38	56.84	71.78
1996	3,975	2,729	2,693	9,397	350,436	246,677	235,965	833,078	276,634	207,080	143,037	626,751	78.94	83.95	60.62	74.50
1997	5,189	3,385	2,618	11,192	454,447	303,919	233,125	991,491	338,343	244,531	135,900	718,774	74.45	80.46	58.29	71.07
1998	2,575	1,835	1,422	5,832	224,598	175,059	127,508	527,165	108,724	110,374	61,292	280,390	48.41	63.05	48.07	53.18
1999	5,689	3,523	2,151	11,363	481,756	326,553	188,430	996,739	363,215	243,441	116,379	723,035	75.39	74.55	61.76	70.57
2000	4,541	2,742	1,701	8,984	372,351	252,292	138,670	763,313	301,428	193,359	85,594	580,381	80.95	76.64	61.72	73.11
2001	3,522	2,540	1,094	7,156	288,554	228,099	90,143	606,796	225,146	161,482	49,164	435,792	78.03	70.79	54.54	67.79
2002	2,649	1,906	1,262	5,817	203,299	156,105	93,430	452,834	154,224	115,760	61,444	331,428	75.86	74.16	65.76	71.93
2003	2,139	1,305	801	4,245	162,626	100,375	60,164	323,165	130,542	72,355	42,763	245,660	80.27	72.08	71.08	74.48
2004	3,465	2,065	1,162	6,692	265,024	162,619	89,110	516,753	230,081	116,727	73,589	420,397	86.82	71.78	82.58	80.39
2005	2,658	1,718	816	5,192	209,208	144,317	63,034	416,559	185,204	108,816	52,352	346,372	88.53	75.40	83.05	82.33
2006	3,199	2,008	1,182	6,389	257,802	165,011	82,677	505,490	237,653	126,730	66,700	431,083	92.18	76.80	80.68	83.22
2007	2,967	1,907	1,265	6,139	226,694	165,984	90,891	483,569	200,747	127,320	71,426	399,493	88.55	76.71	78.58	81.28
2008	4,471	2,240	1,628	8,339	359,592	183,480	124,866	667,938	293,403	141,193	93,253	527,849	81.59	76.95	74.68	77.74
2009	7,510	3,421	2,579	13,510	637,816	271,894	209,249	1,118,959	542,338	218,275	157,146	917,759	85.03	80.28	75.10	80.14
2010	5,666	2,457	1,963	10,086	460,821	194,182	155,552	810,555	403,004	152,565	84,324	639,893	87.45	78.57	54.21	73.41
2011	8,128	3,835	2,753	14,716	653,480	314,378	243,792	1,211,650	582,398	249,156	211,314	1,042,868	89.12	79.25	86.68	85.02
2012	6,947	3,618	1,863	12,428	542,487	289,146	149,260	980,893	488,436	236,142	118,869	843,447	90.04	81.67	79.64	83.78
2013	5,684	2,554	1,564	9,802	443,505	194,539	126,394	764,438	400,742	161,338	93,020	655,100	90.36	82.93	73.60	82.30
2014	3,341	2,024	786	6,151	250,357	157,641	61,025	469,023	171,767	128,358	40,708	340,833	68.61	81.42	66.71	72.25
2015	3,074	2,055	1,229	6,358	226,617	163,859	96,505	486,981	146,211	116,853	60,178	323,242	64.52	71.31	62.36	66.06
2016	4,169	3,509	1,573	9,251	310,163	284,416	117,055	711,634	214,977	238,954	73,434	527,365	69.31	84.02	62.73	72.02

Appendix 2

Number of Clutches (Monthly) Laid by Green Turtles in TIP (Sabah Parks Data)

Year	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
1979	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1980	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1981	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1982	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1983	165	98	94	106	130	147	233	299	304	261	198	208
1984	162	151	145	141	169	192	285	358	400	390	274	219
1985	196	125	133	115	109	132	190	261	304	345	293	254
1986	202	180	177	143	147	163	211	273	283	302	280	238
1987	200	159	163	143	133	127	147	183	244	260	268	231
1988	195	197	215	272	232	225	360	389	437	456	327	302
1989	268	243	447	367	310	372	388	494	404	395	276	241
1990	201	165	177	212	196	257	281	363	396	511	515	551
1991	623	570	1120	1345	1525	1286	1094	1162	1271	1032	769	541
1992	531	629	798	687	581	521	397	460	507	428	295	249
1993	269	502	703	774	970	1271	1244	901	930	825	579	589
1994	613	686	828	892	870	805	740	532	528	573	445	480
1995	618	692	837	1385	1514	1605	1326	1105	811	539	324	236
1996	292	461	807	709	978	1109	1050	896	956	879	710	550
1997	659	680	983	1161	1277	1368	1341	1056	1013	787	493	374
1998	243	251	360	545	519	713	887	849	536	381	287	261
1999	309	434	873	1247	1601	1527	1499	1215	989	788	533	348
2000	321	514	893	1475	1228	1171	1095	871	543	394	249	230
2001	258	350	554	797	1138	961	840	804	508	406	324	216
2002	207	255	460	757	941	856	653	662	435	312	176	103
2003	76	99	198	270	397	477	559	658	535	408	295	273
2004	299	451	728	751	1221	1002	732	547	360	325	160	116
2005	138	199	234	491	720	687	851	746	469	324	181	152
2006	174	250	656	772	886	1012	937	672	440	309	176	105
2007	123	211	524	749	814	1010	1039	757	435	268	123	86
2008	67	157	315	634	954	1198	1311	1377	1147	562	365	252
2009	318	472	895	1629	2084	2217	2037	1387	1071	708	433	259
2010	233	293	499	1025	1581	1237	1698	1583	886	537	279	235
2011	212	313	634	1159	1862	2024	2654	2288	1585	1076	480	429
2012	456	655	1159	1679	2164	1861	1956	1222	609	350	186	131
2013	168	284	488	792	1308	1710	1723	1312	951	598	265	203
2014	126	175	318	509	771	782	880	801	774	543	291	181
2015	152	219	280	378	640	881	803	909	792	569	443	292
2016	255	407	457	358	930	1636	1628	1596	914	560	269	241
Total	9329	11527	18152	24469	30900	32542	33069	28988	22767	17401	11561	9376

Appendix 3

Number of Green Turtle Remigrants and Recruits in Turtle TIP from 2000 to 2016

(Sabah Parks Data)

	Selingaan		Bakkungan Kecil		Gulisaan	
Year	Remigrant	Recruit	Remigrant	Recruit	Remigrant	Recruit
2000	1,649	1239	1,098	637	510	386
2001	1570	1308	1357	780	262	292
2002	1113	1050	985	688	553	528
2003	952	809	674	447	363	331
2004	1672	1360	1090	656	583	427
2005	1543	912	948	382	469	288
2006	1874	1087	1102	476	680	431
2007	1670	1069	1063	438	747	406
2008	3073	1151	1404	524	861	447
2009	5949	1461	2374	736	1645	697
2010	4290	1285	1637	611	1321	557
2011	6361	1682	2474	878	1427	903
2012	5121	1713	2053	754	947	623
2013	4003	1469	1205	587	455	316
2014	2162	1057	1108	495	144	177
2015	1687	1124	848	576	202	114
2016	2457	1269	1183	697	31	20

Appendix 4

Number of Hawksbill Turtle (*Eretmochelys Imbricata*) Nestings, Number of Eggs Incubated, Number of Hatchlings Released, and Mean Hatching Success (%) in Turtle Islands Park (TIP) from 1979 to 2016

PSL = Selingaan, PBK = Bakkungan Kecil, PGL = Gulisaan (Sabah Parks Data)

	Nest recorded					Eggs incubated					No of hatchlings released					Hatching success (%)			
Year	PSL	PBK	PGL	Total		PSL	PBK	PGL	Total		PSL	PBK	PGL	Total		PSL	PBK	PGL	Mean
1977	No Data	No Data	No Data			No Data	No Data	No Data			No Data	No Data	No Data						Hatching
1978	No Data	No Data	No Data			No Data	No Data	No Data			No Data	No Data	No Data						Success (%
1979	12	69	348	429		No Data	No Data	No Data			No Data	No Data	No Data						
1980	27	78	400	505		No Data	No Data	No Data			No Data	No Data	No Data						
1981	62	39	384	485		6,369	No Data	No Data	6,369		5,515	No Data	No Data	5,515		86.59			
1982	50	28	308	386		4,226	No Data	31,630	35,856		3,308	No Data	27,241	30,549		78.28		86.12	
1983	74	29	297	400		7,112	3,349	33,124	43,585		4,887	2,861	24,639	32,387		68.71	85.43	74.38	76.18
1984	68	19	351	438		7,818	2,795	34,463	45,076		5,868	2,089	27,543	35,500		75.06	74.74	79.92	76.57
1985	58	12	229	299		6,322	1,131	27,625	35,078		4,521	912	22,457	27,890		71.51	80.64	81.29	77.81
1986	38	16	189	243		4,098	1,755	20,185	26,038		2,414	1,479	17,225	21,118		58.91	84.27	85.34	76.17
1987	37	6	268	311		3,903	648	28,939	33,490		2,274	550	24,330	27,154		58.26	84.88	84.07	75.74
1988	50	12	399	461		6,217	1,080	49,200	56,497		3,741	903	33,926	38,570		60.17	83.61	68.96	70.91
1989	78	4	413	495		8,739	450	48,961	58,150		6,751	385	39,233	46,369		77.25	85.56	80.13	80.98
1990	60	33	453	546		6,777	3,160	51,060	60,997		5,967	1,633	40,153	47,753		88.05	51.68	78.64	72.79
1991	44	42	621	707		4,923	4,394	64,640	73,957		3,746	1,524	44,426	49,696		76.09	34.68	68.73	59.83
1992	36	15	593	644		3,121	1,512	58,068	62,701		2,336	482	31,596	34,414		74.85	31.88	54.41	53.71
1993	50	27	487	564		4,748	2,907	44,013	51,668		2,853	2,551	26,698	32,102		60.09	87.75	60.66	69.50
1994	50	48	615	713		4,409	4,821	48,595	57,825		3,039	4,454	25,119	32,612		68.93	92.39	51.69	71.00
1995	50	14	394	458		4,845	1,393	34,597	40,835		3,275	1,190	20,498	24,963		67.60	85.43	59.25	70.76
1996	94	30	459	583		9,497	3,043	48,117	60,657		6,480	2,421	24,692	33,593		68.23	79.56	51.32	66.37
1997	56	27	415	498		5,520	2,891	46,484	54,895		4,011	2,338	23,398	29,747		72.66	80.87	50.34	67.96
1998	38	26	313	377		3,249	2,791	33,995	40,035		1,437	1,978	11,983	15,398		44.23	70.87	35.25	50.12
1999	51	50	388	489		4,635	5,679	43,955	54,269		3,364	4,519	24,680	32,563		72.58	79.57	56.15	69.43
2000	44	33	260	337		4,071	3,537	30,019	37,627		3,000	2,772	16,093	21,865		73.69	78.37	53.61	68.56
2001	52	26	201	279		4,895	2,739	22,027	29,661		3,747	1,767	9,816	15,330		76.55	64.51	44.56	61.87
2002	36	38	270	344		2,928	3,826	28,088	34,842		1,799	2,013	17,806	21,618		61.44	52.61	63.39	59.15
2003	67	33	182	282		5,554	3,586	18,243	27,383		3,693	2,015	12,946	18,654		66.49	56.19	70.96	64.55
2004	70	39	237	346		6,267	4,075	24,790	35,132		5,383	2,115	18,013	25,511		85.89	51.90	72.66	70.15
2005	67	56	396	519		5,692	5,435	43,708	54,835		4,960	3,998	31,131	40,089		87.14	73.56	71.22	77.31
2006	67	42	405	514		6,756	4,117	43,301	54,174		6,199	2,873	31,799	40,871		91.76	69.78	73.44	78.33
2007	68	23	348	439		6,561	2,364	38,073	46,998		5,795	1,567	28,252	35,614		88.32	66.29	74.20	76.27
2008	66	24	322	412		6,820	2,294	35,037	44,151		5,951	1,543	24,874	32,368		87.26	67.26	70.99	75.17
2009	114	75	343	532		12,063	7,054	38,549	57,666		9,810	5,305	26,470	41,585		81.32	75.21	68.67	75.06
2010	111	47	329	487		11,726	5,124	36,167	53,017		10,555	3,872	20,284	34,711		90.01	75.57	56.08	73.89
2011	179	61	263	503		19,453	6,557	28,960	54,970		17,567	4,990	23,713	46,270		90.30	76.10	81.88	82.76
2012	85	43	287	415		9,517	4,703	30,879	45,099		8,593	3,708	22,747	35,048		90.29	78.84	73.66	80.93
2013	67	30	274	371		7,359	3,307	28,213	38,879		6,526	2,422	14,380	23,328		88.68	73.24	50.97	70.96
2014	59	32	253	344		6,140	3,545	26,476	36,161		3,904	2,826	16,300	23,030		63.58	79.72	61.57	68.29
2015	71	22	243	336		7,657	2,141	26,841	36,639		3,769	1,267	15,700	20,736		49.22	59.18	58.49	55.63
2016	50	23	241	314		5,360	2,287	24,913	32,560		3,148	1,701	14,454	19,303		58.73	74.38	58.02	63.71

Appendix 5

Number of Clutches (Monthly) Laid by Hawksbill Turtles in TIP

(Sabah Parks Data)

Year	Month											
	January	February	March	April	May	June	July	August	September	October	November	December
1979	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1980	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1981	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1982	32	48	68	50	48	37	25	30	7	18	7	16
1983	67	66	47	32	28	38	38	28	15	12	10	19
1984	58	67	84	55	54	46	29	13	11	5	3	13
1985	33	28	32	21	33	37	30	30	7	10	14	24
1986	14	21	31	38	21	30	25	12	6	11	18	16
1987	28	30	42	26	36	35	32	27	15	10	13	17
1988	45	66	67	45	32	51	43	31	18	14	21	28
1989	48	51	76	49	28	50	45	52	36	17	17	26
1990	57	47	61	46	56	59	62	47	25	32	25	29
1991	93	85	77	67	59	64	58	58	33	27	40	46
1992	73	45	84	76	56	72	82	75	24	11	17	29
1993	71	69	41	56	38	73	77	40	34	20	16	29
1994	44	72	72	55	55	68	76	71	68	69	27	36
1995	42	66	68	39	30	41	56	40	28	14	13	21
1996	38	50	75	77	60	56	83	71	27	15	12	19
1997	25	56	88	52	43	28	53	43	34	24	16	36
1998	27	27	37	42	20	39	57	45	15	19	21	28
1999	46	61	72	59	40	40	47	52	18	20	17	17
2000	42	45	44	30	34	31	34	22	16	18	8	13
2001	23	34	55	31	28	24	19	18	14	8	12	13
2002	30	64	58	37	28	31	23	24	17	7	10	15
2003	30	30	34	30	34	32	22	14	13	7	11	25
2004	30	37	25	36	35	32	41	31	26	13	20	20
2005	47	53	54	53	48	41	56	61	43	24	14	25
2006	44	57	80	54	43	52	50	42	22	20	24	26
2007	41	39	52	57	29	34	48	45	33	15	19	27
2008	44	55	46	46	46	35	45	33	16	9	23	14
2009	28	48	77	63	56	42	54	51	34	30	25	24
2010	38	56	64	67	50	28	40	59	31	23	10	21
2011	29	58	84	80	45	26	39	42	33	28	22	17
2012	25	44	50	35	56	19	36	34	37	32	30	17
2013	37	35	41	57	55	24	24	17	17	15	20	29
2014	19	29	42	41	36	52	46	24	17	11	19	8
2015	12	20	29	46	30	41	34	21	20	21	26	36
2016	34	50	20	17	40	39	31	20	22	10	13	18
Total	1394	1709	1977	1665	1430	1447	1560	1323	832	639	613	797

Appendix 6

Number of Hawksbill Turtle Remigrants and Recruits in TIP from 2000 to 2016

(Sabah Parks Data)

	Selingaan		Bakkungaan Kecil		Gulisaan	
Year	Remigrant	Recruit	Remigrant	Recruit	Remigrant	Recruit
2000	10	21	4	9	55	72
2001	10	31	6	15	26	55
2002	9	18	9	16	82	84
2003	18	37	8	12	46	73
2004	17	36	4	8	60	63
2005	26	35	26	16	126	106
2006	30	28	15	12	110	104
2007	30	25	9	10	116	98
2008	28	25	8	7	67	49
2009	63	41	31	27	142	96
2010	63	42	19	15	155	95
2011	106	63	24	14	82	76
2012	44	33	14	13	81	55
2013	36	17	7	8	47	39
2014	28	22	13	8	43	22
2015	29	30	4	7	32	12
2016	24	21	12	6	4	4

Appendix 7A

Remigration (Months) of Green Turtles in TIP

(Sabah Parks Data)

Month	Frequency
7	1
10	1
15	1
20	3
21	2
22	3
24	6
25	2
26	1
30	1
31	6
32	15
33	28
34	37
35	23
36	13
37	4
38	1
39	3
40	1
44	3
45	3
46	11
47	8
48	3
49	2
50	1
52	1
53	1
57	6
58	5
59	5
60	5
61	2
64	2
67	1
69	1
71	3
72	1
73	2
81	3
83	4

Appendix 7B

Remigration (Months) of Hawksbill Turtles in TIP

(Sabah Parks Data)

Month	Frequency
10	1
11	3
12	4
13	2
14	1
16	1
17	3
18	1
19	1
22	12
23	3
24	5
29	1
32	2
33	1
34	2
35	1
36	2
38	1
47	3
48	4
55	1
60	1

Appendix 8A

Nesting Interval (Days) of Green Turtles in TIP

(Sabah Parks Data)

Days	Frequency
1	9
2	6
3	7
4	5
5	4
6	4
7	6
8	12
9	40
10	134
11	136
12	65
13	26
14	15
15	9
16	6
17	2
18	14
19	13
20	44
21	38
22	33
23	24
24	20
25	14
26	5
27	2
28	6
29	10
30	13
31	12
32	13
33	17
34	11
35	8
36	6
37	4
38	3
39	8
40	11
41	9
42	8
43	7
44	4
45	3
46	4
48	5
49	1
50	5

Appendix 8B

Nesting Interval (Days) of Hawksbill Turtles in TIP

(Sabah Parks Data)

Days	Frequency
7	1
9	1
10	1
12	4
13	4
14	8
15	6
16	10
17	7
18	3
19	1
21	1
22	1
25	3
26	1
27	5
28	3
29	1
30	2
31	2
32	5
33	1
34	1
35	3
36	4
38	2
39	1
41	1
42	1
43	1
44	1
45	3
47	1
48	1
50	1