ANIS SYAFINAS BINTI MUHAMMAD DAHRI MASTER OF SCIENCE 2024

ASSESSMENT OF SEA TURTLE CONSERVATION IN TERENGGANU BASED ON ECOLOGICAL MODELS

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Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Institute of Oceanography and Environment Universiti Malaysia Terengganu

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DEDICATION

Dedicated this thesis to:

Mr Muhammad Dahri Bin Che Saad @ Yahaya (Abah) & Mrs Zubaidah Binti Ariffin (Mama)

My selfless angles that were sent by Allah SWT from heaven. Angels that remind me of the goodness in the world and inspired me to be the greatest version of myself although everybody else thinks it's impossible. I would never be able to pay your kindness and love.

My siblings that are miles away but always in my heart and complete me: Anis Nabilla, Muhammad Farid, Norhidayah, Muhammad Aiman and Muhammad Ammar Rayyan

My only Tok Mummy, Mrs Fatimah that always love and support me. The only beautiful remains of Tok Miah and Tengku Wan Su Binti Tengku Mahmud Bin Tengku Long Senik that I have. My only Mak Tok, Mrs Habsah that always love, take care and pray for me.

My friends who know all my imperfection but still stay and love me. Because of you guys, I laugh a little harder, cry a little less, and smile a lot more: Maryam Hakimah, Zunnurain Zamzam and others.

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Thanks a lot. May Allah SWT bless all of you.

Abstract of thesis presented to the Senate of Universiti Malaysia Terengganu in fulfilment of the requirements for the degree of Master of Science

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ANIS SYAFINAS BINTI MUHAMMAD DAHRI

JULY 2020

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The sea turtle conservation in Terengganu involving the mixed conservation strategy where some nesting beaches were protected while others were tendered. Subsequently, the Department of Fisheries (DoF), listed a total of 38 nesting beaches with 12 were protected under sanctuary and sea turtle conservation reserve. Besides, 26 other nesting beaches were tendered by the tender holder under the Turtle Enactment 1951. This implemented by the Terengganu state government to solve the sea turtle eggs ownership crisis between locals. Surprisingly, although the sea turtle population depletion in Terengganu was extremely obvious now, the effectiveness and sustainability of this mixed conservation strategy had never been closely examined. Thus, this research aimed to assess the sustainability of the sea turtle conservation strategy in Terengganu. This assessment was accomplished under five objective which was (1) To analyze the sustainability of this mixed conservation strategy based on the current population abundance of sea turtles in Terengganu, (2) To identify the growth curve possessed by the sea turtle population in Terengganu under the mixed

conservation strategy, (3) To investigate the sustainability of current harvest limit and set a new sustainable maximum harvest limit of sea turtle eggs in Terengganu, (4) To define the sustainability of prey-predator interaction between human and sea turtles in Terengganu, and (5) To identify possible sustainable economic activity between eggs harvesting and non-consumptive tourism-related activity. Thus, Chapter 1 and Chapter 2 were set as an introduction and literature reviews. These aims were completed in Chapter 3 to Chapter 8 and generally concluded in Chapter 9.

Firstly, to analyse the sustainability based on the current population abundance of sea turtle in Terengganu, Chapter 3 focused on the current nesting density. Each protected and tendered beach were evaluated by incorporating a physical parameter which is the length of the coastline. This enables the identification of actual productivity for each nesting beaches. The result in this study indicates that the average yearly nesting density for each beach are much lower in tendered beaches (26km^{-1}) compared to the protected beach (195 km^{-1}). This presented the adverse effect of sea turtle exploitation under the tender system. This also an early indication that this mixed conservation strategy was unsustainable. The yearly nesting density from 2011-2015 also demonstrated the biennial nesting pattern which indicated that the current major nesting mothers were the Green turtle (*Chelonia mydas*). This possibly suggested that other sea turtle species such as Hawksbill turtle (*Eretmochelys imbricate*) and Olive Ridley turtle (*Lepidochelys olivacea*) was functionally extinct. Besides, this objective also predicted the numbers of current nesting mothers and future new nesting mother (recruitments). This prediction was facilitated by current nesting mothers and future nesting mother formula. The average number of annual current nesting mothers was 500 individuals. In the future, under a survival rate of one in a thousand, the female hatchlings hatched in 2011-2015 only add to an average of 181 new nesting mothers annually between 2036-2040. Assuming the worse where only one in ten thousand female hatchlings survive, on average only 18 new nesting mothers will be added into the population annual. With such low number of nesting mother, this population were highly susceptible to extinction. This first objective was able to support the hypothesis that this interaction was not sustainable.

Secondly, this research tried to identify growth curve possessed by sea turtle population in Terengganu under sea turtle eggs exploitation in Chapter 4. Research into this subject was important as sea turtle possessed characteristics of an individual that grew both logistically ($K -$selection) and exponentially ($r -$selection). Plus, even if a few different populations came from the same species, the growth curve possessed by them can differ according to their environmental factor. For instance, the farmed turtle may grow exponentially due to its rich nutrient diet, fast maturity and low mortality compared to wild sea turtles. The analysis of growth curve possessed by the population was crucial in identifying the way the population size grows and response to the stressor such as sea turtle eggs harvesting. The wrong assumption on growth curves leads to over or underprojection of future sea turtle population size. As a result, the exponential growth model predicted that the sea turtle population in Terengganu continue to grow without limit. This situation was far from reality where the sea turtle population in Terengganu was seriously depleted. The logistic growth model predicted a possibility of the population growth limited to not more than 650, 000 eggs. This was aligned with previous records. Consequently, the sea turtle population Terengganu is assumed to grow logistically. As the sea turtle population in Terengganu grew logistically, it was vulnerable to any form of exploitation. This population takes a long time to reproduce, hence unable to cover up the eggs lost from the exploitation activity in Terengganu. This reflects the possibilities that sea turtle eggs exploitation in Terengganu was unsustainable.

Thirdly, Chapter 5 of this research attempted to investigate the sustainable maximum harvest limit of sea turtle eggs in Terengganu and setting up a new sustainable maximum harvest limit in Terengganu. Setting up a harvest limit was mandatory to ensure species continuity and sustainability. The Maximum Sustainable Yield (MSY) and Modified Maximum Sustainable Yield (MMSY) were employed to study the sustainability of the current harvest limit. MMSY model was modified from the MSY model by considering the natural death rate. Then, the MMSY model was employed to set up a new harvest limit. MSY predicted that the sea turtle population in Terengganu will be increased and continue to sustain more than 550, 000 eggs yearly. This prediction was opposite to the current sea turtle population depletion in Terengganu. This over projection happened as the MSY model ignore the significant natural death rate at about 0.999%. On the other hand, the MMSY model predicted that the number of sea turtle eggs will be decreased and lead to zero production of eggs in 35 years. This can be assumed as the extinction of the sea turtle population in Terengganu as adult sea turtles would eventually stop reproducing eggs due to old age and death. Plus, without eggs there will be zero hatchlings production and recruitments to replace the sea turtle that died off, thus extinction will happen in no time. MMSY model also stated that the maximum sustainable harvest limit of sea turtle eggs in Terengganu was only 0.0215. However, it is suggested for a total ban as this study do not include the death rate from other anthropogenic factors such as adult predation by fisherman, death in the fishing net, plastic engulfment and others. Since the death rate from other anthropogenic factors was not included, the total might exceed 0.0215. Thus, the production of new eggs and hatchlings were unable to cover up the losses leading to critical depletion and extinction.

Moreover, this research determined to define the sustainability prey-predator interaction between human and sea turtles in Terengganu in Chapter 6. The sustainability of prey-predator interaction was important for population dynamics in an ecosystem. The population dynamic was achieved if both prey and predator populations can continually co-exist in an ecosystem. A decrease or increase in either the prey or predator population size might adversely affect the other population and resulted in extinction. Lotka-Volterra Model and Tender System Model had facilitated the investigation on the sustainability of this prey-predator interaction and prediction on extinction (in years) of sea turtle population in Terengganu. Lotka-Volterra model predicted that this prey-predator interaction is unsustainable. The sea turtle eggs production would decrease exponentially and approach zero within six months. However, the number of tender holders will increase rapidly and reaches 400,000 individuals within six months. The Tender System model inspired by the Lotka-Volterra model predicted that this interaction is not sustainable and extinction occurred in only four years. As Tender System model prediction was aligned with the rapid sea turtle population decline in Terengganu, this model was used again to set a new harvest limit for population sustainability. The Tender System model also suggested that the population recovery can only be achieved after eight years of instant 100% sea turtle eggs harvest ban was implemented. By implementing the instant 100% sea turtle eggs harvest ban, hopefully, half of the population could be saved. This has a dissimilarity to the MMSY model's prediction as it also taking into account the predator population size (number of tender holders). Again, there is an urge for a total ban on sea turtle eggs harvesting as this model also exposed that this interaction was not sustainable.

This study also looking into the possible sustainable economic activity between eggs harvesting activity (consumptive) and sea turtle tourism product (non-consumptive). Identifying sustainable economic activity was crucial in ensuring the wild species continuity in the ecosystem. Engaging in destructive economic activity such as consumptive or direct use can result in species extinction. Thus, Chapter 7 was composed to identify the qualitative aspect of the sea turtle eggs current market in Terengganu. The first section of Chapter 7 was used to determine the price trend between the peak, low and non-nesting season in Terengganu. Then the section was dedicated to determining a few important characteristics of the sea turtle eggs market in Terengganu. Surveys for both sections was carried out at Pasar Payang, Terengganu since previous research and the preliminary surveys revealed that almost 91% of the consumers get sea turtle eggs from Pasar Payang. The enumerators in this survey focused on the sea turtle eggs sellers. The secondary sources are then used as references and comparisons in this analysis. Results prove that the price of sea turtle eggs depends on the eggs supply that relies on the seasons. According to the survey, the sea turtle eggs were cheaper during the on-season (RM 3-RM 7 per eggs) due to loads of sea turtle eggs supply. In contrast, the sea turtle egg price rose in the off-season (RM 6-RM 12 per egg) due to supply shortage. Plus, the sea turtle egg price also heavily depends on their origin. It can be deduced that sea turtle eggs from Terengganu have a higher price compared to Sabah since customers considered them to be new and fresher. Customers believed that new eggs are better as they taste better, have higher traditional medical values and are healthier.

This survey also reveals that the majority of sea turtle eggs sold in Pasar Payang were originated from Terengganu itself in both seasons. The second section of Chapter 7 focused on analyzing (i) Number of vendors, (ii) Quantity in a packet, (iii) Quantity of eggs per seller, (iv) Restock time, (v) Shelf life, (vi) Consumer (vii) Reason to consume (viii) Cooking method (ix) Product derived from unfinished eggs. Results show that the number of vendors selling sea turtle eggs in Pasar Payang is also influenced by the total eggs supply. About 12 vendors sold eggs during the on-season compared to only 7 in the off-season. All vendors sold sea turtles eggs as a side item during both seasons, indicating that the total ban on the selling of the eggs would result in minimum adverse impact toward them. Customer preferences were 5 eggs and 10 eggs per packet. Each vendor prepared more packets with 5 eggs since more customers buy fewer eggs per purchase due to its high price. However, vendors offered a discount of about RM 0.10 per egg for consumers that buy more eggs per purchase to increase their sales. This showed that the sea turtle eggs price depends on the number of eggs in each purchase. Adding to that, the eggs supply determined the number of eggs per seller where each eggs seller was in possessed 370 to 500 eggs during the on-season and only less than 75 to 100 eggs during the off-season. All sellers obtain the same number of eggs because eggs from Terengganu are supplied by the same supplier (egg collector). Since all eggs from Terengganu were supplied directly by the egg collector, no middle man existed, thus less price markup was observed. Yet, all eggs from Sabah were supplied by a middle man. Eggs from Terengganu were restocked more often during on-season compared to off-season due to higher eggs supply during on-season. However, the restock time for eggs from Sabah were undetermined since it will only ships to Terengganu as one batch after reaching 3,000 eggs. Since the shelf life of sea turtle eggs was between 2 to 5 months, this is possibly happening. This survey also showed that a total ban on sea turtle eggs selling would not adversely affect the tourism sectors in Terengganu since the major sea turtle eggs consumer were the local people, not the tourist.

Lastly, Chapter 8 was composed to evaluate the qualitative aspect of the market activity related to sea turtle tourism products in Terengganu. Terengganu is a tourism-based state thus, ensuring sea turtle survival is important to ensure the continuity of the tourism sector. The sea turtle tourism products in Terengganu were divided into five categories which are: (i) Hatchling released, (ii) Accommodation, (iii) Day trip, (iv) Nest adoption and (v) Turtle adoption in this study. Information for this study was obtained by interviews and secondary sources such as webpage, social media and reports. The results indicated that the fee for the hatchlings releases program ranges from RM 20 to RM 50/hatchlings. The fee was charged based on the targeted customers that have different economic statuses. Besides, the average price offered for day trip package in Terengganu range from RM 93 to RM 319 according to (i) the frequency and type of activities offered, (ii) the distances from the mainland, (iii) the number of tour operators competing for customers, (iv) popularity of the islands, and (v) facilities provided on the islands. Moreover, accommodation related to sea turtle programs is also offered in Terengganu based on sole or mixed experience tourism. The sole experience tourism-based accommodation charges a lower fee at about RM 114/person/day to RM 191/person/day compared to mixed experience-based accommodation that charged at about RM 227/person/day to RM 239/person/day. Results have shown that the type of accommodation offered depends on the sea turtle density. Project on beaches with higher sea turtle density tend to offer sole experiences accommodation whereas projects on beaches with lower sea turtle density tend to offer mixed experience accommodation. Thus, this proves that the nesting density of sea turtles have a great influence on the possible economical activities in Terengganu. Furthermore, the nest and sea turtle adoption programs were carried out in Terengganu with fees ranging from RM 100 to RM 600. The fee is charged according to the source of the eggs. The projects on protected beaches tend to offer lower fees since the eggs were free, their only cost involved the management of the sanctuary or hatchery. However, projects that obtained eggs from tendered beaches charged higher adoption fees to cover the management cost, pay for the tender price, tender holders and the eggs collectors. Since every adoption program focused on saving sea turtles on certain life stages (nesting mothers, hatchlings and nest) each project only offered the adoption programs for the life stages they were interested in. This proved that the tendered beaches can generate bigger income if utilized for conservation purposes. Looking at the market survey in Terengganu, it can be concluded that the sea turtle tourism product possibly generates sustainable and greater income than the sea turtle eggs harvesting. This is supported by the previous analysis involving the ecological models that also revealed that sea turtle eggs harvesting, which is a form of direct use resulted in species extinction. In conclusion, the current mixed conservation strategy was not sustainable based on ecological modelling and economic survey. Therefore, to ensure both economic and species sustainability in Terengganu, a conservation strategy that protected sea turtles 100% was strongly recommended. This thesis suggested a conservation strategy involving a total ban on sea turtle eggs harvesting and selling.

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PENILAIAN KESAN KONSERVASI PENYU DI TERENGGANU

ANIS SYAFINAS BINTI MUHAMMAD DAHRI

JULAI 2020

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Pemuliharaan penyu di Terengganu melibatkan strategi pemuliharaan campuran di mana sesetengah pantai penetasan dilindungi sementara yang lain dipajak. Kemudian, Jabatan Perikanan (DoF), menyenaraikan sebanyak 38 pantai penetasan di mana 12 dilindungi sebagai santuari dan rizab pemuliharaan penyu. Selain itu, 26 lagi pantai penetasan dipajak kepada pemegang tender dibawah Enakmen Penyu 1951. Ini dilaksanakan oleh kerajaan negeri Terengganu untuk menyelesaikan krisis pemilikan telur penyu antara penduduk tempatan. Anehnya, walaupun penyusutan populasi penyu di Terengganu sangat jelas sekarang, keberkesanan dan kelestarian strategi pemuliharaan campuran ini tidak pernah dikaji dengan teliti. Oleh itu kajian ini bertujuan untuk menilai kelestarian strategi pemuliharaan penyu laut di Terengganu. Penilaian ini dicapai di bawah lima objektif iaitu (1) Untuk menganalisis kelestarian strategi pemuliharaan campuran ini berdasarkan jumlah populasi penyu laut di Terengganu saat ini, (2) Untuk mengenal pasti keluk pertumbuhan yang dimiliki oleh populasi penyu laut di Terengganu di bawah strategi konservasi campuran , (3 Untuk menyiasat kelestarian had penuaian semasa dan menetapkan had penuaian maksimum baru yang lestari bagi telur penyu di Terengganu, (4) Untuk menentukan kelestarian interaksi pemangsa-penyu antara-manusia dan penyu di Terengganu, (5) Untuk mengenal pasti kemungkinan aktiviti

ekonomi lestari di antara penuaian telur dan aktiviti berkaitan pelancongan yang tidak konsumtif. Oleh itu, Bab 1 dan Bab 2 ditetapkan sebagai pengantar dan tinjauan literatur. Objektif ini diselesaikan dalam Bab 3 hingga Bab 8 dan disimpulkan secara umum dalam Bab 9.

Pertama, untuk menganalisis jumlah populasi penyu laut semasa di Terengganu, Bab 3 memfokuskan pada kepadatan sarang semasa. Setiap pantai yang dilindungi dan ditender dinilai dengan mengambil kira parameter fizikal iaitu panjang garis pantai. Ini membolehkan pengecaman produktiviti sebenar untuk setiap pantai penetasan. Hasil dalam kajian ini menunjukkan bahawa purata tahunan kepadatan sarang untuk setiap pantai jauh lebih rendah di pantai yang ditender (26km^{-1}) berbanding dengan pantai yang dilindungi (195 km^{-1}). Ini menunjukkan kesan buruk dari eksploitasi penyu di bawah sistem tender. Ini juga merupakan petunjuk awal bahawa strategi pemuliharaan campuran ini tidak lestari. Kepadatan sarang tahunan dari tahun 2011-2015 juga menunjukkan corak sarang dwitahunan yang menggambarkan bahawa ibu bersarang utama ketika ini adalah penyu hijau (*Chelonia mydas*). Ini mungkin menunjukkan bahawa spesies penyu yang lain seperti penyu karah (*Eretmochelys imbricate*) dan penyu lipas (*Lepidochelys olivacea*) telah pupus secara fungsi. Selain itu, objektif ini juga meramalkan jumlah ibu bersarang semasa dan ibu bersarang baru (pengambilan). Ramalan ini difasilitasi oleh formula ibu bersarang semasa dan formula ibu bersarang masa depan. Jumlah tahunan ibu bersarang secara purata adalah 500 individu. Di masa depan, di bawah kadar kelangsungan hidup satu dari seribu, anak penyu betina yang menetas pada tahun 2011-2015 hanya menambah rata-rata 181 ibu bersarang baru setiap tahun antara tahun 2036-2040. Dengan andaian lebih buruk di mana hanya satu dari sepuluh ribu anak betina yang bertahan hidup, puratanya hanya 18 ibu bersarang baru yang akan ditambahkan ke dalam populasi tahunan. Dengan bilangan ibu bersarang yang rendah, populasi ini sangat mudah pupus. Objektif pertama ini dapat membuktikan bahawa interaksi ini tidak lestari.

Kedua, penyelidikan ini cuba mengenal pasti keluk pertumbuhan yang dimiliki oleh populasi penyu di Terengganu dibawah eksploitasi telur penyu dalam Bab 4. Penyelidikan mengenai subjek ini penting kerana penyu laut mempunyai ciri-ciri individu yang tumbuh secara logistik (pemilihan$-K$) dan eksponensial (pemilihan$-r$). Selain itu, walaupun beberapa populasi yang berbeza berasal dari spesies yang sama, keluk pertumbuhan yang dimiliki oleh mereka boleh berbeza mengikut faktor persekitaran mereka. Sebagai contoh, penyu yang diternak dapat tumbuh secara eksponensial kerana diet yang kaya nutrien, kematangan yang cepat dan kematian yang rendah dibandingkan dengan penyu liar. Analisis keluk pertumbuhan yang dimiliki oleh populasi tersebut sangat penting dalam mengenal pasti bagaimana ukuran populasi tumbuh dan bertindak balas terhadap tekanan seperti penuaian telur penyu. Anggapan yang salah pada keluk pertumbuhan membawa kepada lebihan atau pengurangan unjuran jumlah populasi penyu di masa depan. Hasilnya, model pertumbuhan eksponensial meramalkan bahawa populasi penyu di Terengganu terus bertambah tanpa had. Keadaan ini jauh dari kenyataan di mana populasi penyu laut di Terengganu mengalami penurunan yang serius. Model pertumbuhan logistik meramalkan kemungkinan pertumbuhan populasi tidak melebihi 650, 000 telur. Ini sejajar dengan rekod sebelumnya. Akibatnya, populasi penyu laut Terengganu di andaikan berkembang secara logistik. Oleh kerana populasi penyu laut di Terengganu meningkat secara logistik, ia rapuh terhadap segala bentuk eksploitasi. Populasi ini memerlukan masa yang lama untuk membiak, sehingga tidak dapat menggantikan telur yang hilang dari aktiviti eksploitasi di Terengganu. Ini mencerminkan kemungkinan eksploitasi telur penyu di Terengganu tidak dapat lestari.

Ketiga, Bab 5 dari penyelidikan ini berusaha untuk menyelidiki had penuaian maksimum penuaian telur penyu laut di Terengganu dan menetapkan had penuaian maksimum lestari baru di Terengganu. Menetapkan had penuaian adalah wajib untukmemastikan kesinambungan dan kelestarian spesies. Hasil Lestari Maksimum (HLM) dan Hasil Lestari Maksimum yang dimodifikasi (HLMM) digunakan untuk mengkaji kelestarian had penuaian semasa. Model HLMM diubahsuai dari model HLM dengan mengambil kira kadar kematian semula jadi. Kemudian, model HLMM digunakan untuk menetapkan had penuaian baru. Hasilnya, odel HLM meramalkan bahawa populasi penyu di Terengganu akan meningkat dan terus mengekalkan lebih dari 550, 000 telur setiap tahun. Ramalan ini bertentangan dengan penurunan populasi penyu di Terengganu sekarang. Lebihan unjuran ini berlaku kerana model HLM mengabaikan kadar kematian semula jadi yang besar pada sekitar 0,999%. Sebaliknya, model HLMM meramalkan bahawa jumlah telur penyu akan berkurang dan menyebabkan pengeluaran telur menjadi sifar dalam 35 tahun. Ini dapat dianggap sebagai kepupusan populasi penyu di Terengganu kerana penyu dewasa akhirnya akan berhenti menghasilkan telur. Selain itu, tanpa produksi anak dan pengambilan baru untuk menggantikan penyu yang mati, kepupusan akan berlaku dalam masa yang singkat. Model HLMM juga menyatakan bahawa had penuaian maksimum telur penyu laut di Terengganu hanya 0.02152. Walau bagaimanapun, adalah disarankan untuk larangan total kerana kajian ini tidak mengambil kira kadar kematian dari faktor antropogenik lain seperti pemburuan penyu dewasa oleh nelayan, kematian di jaring ikan, menelan plastik dan lain-lain.

Tambahan lagi, penyelidikan ini bertujuan untuk menentukan kelestarian interaksi mangsa-pemangsa di antara penyu dan manusia di Terengganu dalam Bab 6. Kelestarian interaksi mangsa-pemangsa adalah penting untuk dinamika populasi dalam ekosistem. Dinamika populasi dapat dicapai sekiranya populasi mangsa dan pemangsa dapat terus wujud bersama dalam ekosistem. Penurunan atau peningkatan saiz populasi mangsa atau pemangsa boleh memberi kesan buruk kepada populasi lain dan mengakibatkan kepupusan. Model Lotka-Volterra dan Model Sistem Tender telah membantu penyelidikan mengenai kelestarian interaksi mangsa-pemangsa ini dan ramalan mengenai kepupusan (dalam tahun) populasi penyu laut di Terengganu. Model Lotka-Volterra meramalkan bahawa interaksi mangsa-pemangsa ini tidak dapat dilaksanakan. Pengeluaran telur penyu akan menurun secara mendadak dan mendekati sifar dalam masa enam bulan. Walau bagaimanapun, jumlah pemegang tender akan meningkat dengan cepat dan mencapai 400,000 individu dalam tempoh enam bulan. Model Sistem Tender yang diilhamkan oleh model Lotka-Volterra meramalkan bahawa interaksi ini tidak lestari dan kepupusan berlaku hanya dalam empat tahun. Oleh kerana ramalan model Sistem Tender selaras dengan penurunan populasi penyu laut yang cepat di Terengganu, model ini digunakan lagi untuk menetapkan had panen baru untuk kelestarian penduduk. Model Sistem Tender juga menunjukkan bahawa pemulihan populasi hanya dapat dicapai setelah lapan tahun larangan menuai telur penyu 100% segera dilaksanakan. Dengan melaksanakan larangan penuaian telur penyu 100% segera, semoga separuh dari populasi dapat diselamatkan. Ini mempunyai ketidaksamaan dengan ramalan model HLMM kerana ia juga mengambil kira ukuran populasi pemangsa (jumlah pemegang tender). Sekali lagi, ada keperluan mendesak untuk larangan penuaian telur penyu kerana model ini juga mendedahkan bahawa interaksi ini tidak lestari.

Kajian ini juga mengkaji kemungkinan aktiviti ekonomi yang lestari antara aktiviti penuaian telur (konsumtif) dan produk pelancongan penyu laut (tidak konsumtif). Mengenal pasti aktiviti ekonomi lestari sangat penting dalam memastikan kesinambungan spesies liar dalam ekosistem. Melibatkan diri dalam aktiviti ekonomi yang merosakkan seperti penggunaan konsumtif atau penggunaan langsung boleh mengakibatkan kepupusan spesies. Oleh itu, Bab 7 disusun untuk mengenal pasti aspek kualitatif pasaran telur penyu laut yang ada di Terengganu. Bahagian pertama Bab 7 digunakan untuk menentukan trend harga antara musim puncak, rendah dan tidak bersarang di Terengganu. Kemudian bahagian ini dikhaskan untuk menentukan beberapa ciri penting pasar telur penyu di Terengganu. Tinjauan untuk kedua-dua bahagian tersebut dilakukan di Pasar Payang, Terengganu kerana kajian sebelumnya dan tinjauan awal menunjukkan bahawa hampir 91% pengguna mendapat telur penyu dari Pasar Payang. Penemuramah dalam tinjauan ini memberi tumpuan kepada penjual telur penyu laut. Sumber sekunder kemudian dijadikan rujukan dan perbandingan dalam analisis ini. Hasil membuktikan bahawa harga telur penyu bergantung kepada bekalan telur yang bergantung pada musim. Menurut tinjauan, telur penyu laut lebih murah pada musimnya (RM 3-RM 7 per telur) kerana banyaknya bekalan telur penyu laut. Sebaliknya, harga telur penyu meningkat di luar musim (RM 6-RM 12 per telur) kerana kekurangan bekalan. Tambahan, harga telur penyu juga sangat bergantung pada asal usulnya. Dapat disimpulkan bahawa telur penyu dari Terengganu mempunyai harga yang lebih tinggi berbanding dengan Sabah kerana pelanggan menganggapnya baru dan segar. Tinjauan ini juga menunjukkan bahawa sebahagian besar telur penyu laut yang dijual di Pasar Payang berasal dari Terengganu sendiri pada kedua musim tersebut. Bahagian kedua Bab 7 tertumpu pada analisis (i) Bilangan penjual, (ii) Kuantiti dalam satu paket, (iii) Kuantiti telur bagi setiap penjual, (iv) Waktu pengisian semula, (v) Jangka hayat, (vi) Pengguna (vii) Sebab pengambilan (viii) Kaedah memasak (ix) Produk yang berasal dari telur yangtidak habis. Hasil kajian menunjukkan bahawa jumlah penjaja yang menjual telur penyu di Pasar Payang juga dipengaruhi oleh jumlah bekalan telur. Kira-kira 12 penjaja menjual telur semasa musim berbanding hanya 7 di luar musim. Semua penjaja menjual telur penyu sebagai barang sampingan pada kedua musim tersebut, yang menunjukkan bahawa larangan penjualan telur secara keseluruhan akan mengakibatkan kesan buruk minimum terhadapn mereka. Pilihan pelanggan adalah 5 telur dan 10 biji telur setiap paket. Setiap penjaja menyediakan lebih banyak paket dengan 5 telur kerana lebih banyak pelanggan membeli sedikit telur setiap pembelian kerana harganya yang tinggi. Walau bagaimanapun, penjaja menawarkan harga yang lebih rendah untuk pengguna yang membeli lebih banyak telur setiap pembelian untuk meningkatkan penjualan mereka. Ini menunjukkan bahawa harga telur penyu bergantung pada jumlah telur dalam setiap pembelian. Selain itu, bekalan telur menentukan jumlah telur yang dimiliki setiap penjual di mana setiap penjual telur memiliki 370 hingga 500 telur pada musimnya dan hanya kurang dari 75 hingga 100 telur diluar musim. Semua penjual memperoleh jumlah telur yang sama kerana telur dari Terengganu dibekalkan oleh pembekal (pengumpul telur) yang sama. Oleh kerana semua telur dari Terengganu dibekalkan secara langsung oleh pemungut telur, tidak ada orang tengah yang wujud, oleh itu kurang kenaikan harga yang dapat dilihat. Namun, semua telur dari Sabah dibekalkan oleh orang tengah. Telur dari Terengganu lebih kerap diisi semula pada musimnya berbanding dengan di luar musim kerana bekalan telur yang lebih tinggi pada musimnya. Walau bagaimanapun, waktu pengisian semula telur dari Sabah tidak menentu kerana ia hanya akan dihantar ke Terengganu sebagai satu kumpulan setelah mencapai 3,000 telur. Oleh kerana jangka hayat telur penyu laut antara 2 hingga 5 bulan, ini mungkin terjadi. Tinjauan ini juga menunjukkan bahawa larangan penjualan telur penyu tidak akan memberi kesan buruk kepada sektor pelancongan di Terengganu kerana pengguna telur penyu utama adalah penduduk tempatan, bukan pelancong. Masyarakat tempatan memakan telur penyu kerana dipercayai berkhasiat, mempunyai nilai perubatan tradisional dan memuaskan mengidam sewaktu kehamilan. Bercanggah dengan ini, pelancong memakan telur penyu kerana ingin tahu. Biasanya, telur penyu dimakan mentah atau direbus dan dibumbui dengan garam, madu, atau lada. Penjual menukarkan telur yang tidak habis menjadi jeruk untuk mengelakkannya daripada rosak dan menyebabkan kerugian.

Terakhir, Bab 8 disusun untuk menilai aspek kualitatif aktiviti pasar yang berkaitan dengan produk pelancongan penyu laut di Terengganu. Terengganu adalah sebuah negeri yang berasaskan pelancongan dengan itu, memastikan kelangsungan penyu laut adalah penting untuk memastikan kesinambungan sektor pelancongan. Produk pelancongan penyu laut di Terengganu dibahagikan kepada beberapa kategori iaitu pelepasan anak penyu, penginapan, lawatan sehari, program sarang dan penyu angkat dalam kajian ini. Maklumat untuk kajian ini diperoleh melalui temu ramah dan sumber sekunder seperti laman web, media sosial dan laporan. Hasil kajian menunjukkan bahawa julat bayaran untuk program pelepasan anak penyu antara RM 20 hingga RM 50/anak penyu. Bayaran tersebut dikenakan berdasarkan pelanggan yang disasarkan yang mempunyai status ekonomi yang berbeza. Selain itu, harga purata yang ditawarkan untuk pakej lawatan sehari di Terengganu antara RM 93 hingga RM 319 mengikut (i) kekerapan dan jenis aktiviti yang ditawarkan, (ii) jarak dari daratan, (iii) jumlah pengusaha pelancongan yang bersaing untuk pelanggan, (iv) populariti pulau, dan (v) kemudahan yang disediakan di pulau. Selain itu, penginapan yang berkaitan dengan program penyu laut juga ditawarkan di Terengganu berdasarkan pelancongan pengalaman tunggal atau campuran. Penginapan berasaskan pelancongan pengalaman tunggal mengenakan yuran yang lebih rendah sekitar RM 114/orang/hari hingga RM 191/orang/hari berbanding dengan penginapan berdasarkan pengalaman bercampur yang mengenakan sekitar RM 227/orang/hari hingga RM 239/orang/hari. Hasil kajian menunjukkan bahawa jenis penginapan yang ditawarkan bergantung pada jumlah populasi penyu laut. Projek di pantai dengan kepadatan penyu laut yang lebih tinggi cenderung menawarkan penginapan pengalaman tunggal sedangkan projek di pantai dengan kepadatan penyu laut yang lebih rendah cenderung menawarkan penginapan pengalaman campuran. Oleh itu, ini membuktikan bahawa kepadatan penyu penyu laut mempunyai pengaruh besar terhadap kegiatan ekonomi yang boleh dilaksanakan di Terengganu. Tambahan pula, program sarang dan penyu laut angkat dilakukan di Terengganu dengan bayaran antara RM 100 hingga RM 600. Bayaran dikenakan mengikut sumber telur. Projek di pantai yang dilindungi cenderung memberikan harga yang lebih rendah kerana telurnya percuma, satu-satunya kosnya merangkumi pengurusan tempat perlindungan atau penetasan. Walau bagaimanapun, projek yang memperoleh telur dari pantai yang ditender dikenakan bayaran adopsi yang lebih tinggi untuk menampung kos pengurusan, membayar harga tender, pemegang tender dan pemungut telur. Oleh kerana setiap program angkat difokuskan pada menyelamatkan penyu laut pada tahap kehidupan tertentu (ibu bersarang, anak kecil dan sarang) setiap projek hanya menawarkan program angkat untuk tahap kehidupan yang mereka minati. Ini membuktikan bahawa pantai yang ditenderkan dapat menghasilkan pendapatan yang lebih besar jika digunakan untuk tujuan pemuliharaan. Melihat tinjauan pasaran di Terengganu, dapat disimpulkan bahawa produk pelancongan penyu laut mungkin menghasilkan pendapatan yang lebih lestari dan besar daripada penuaian telur penyu laut. Ini disokong oleh analisis sebelumnya yang melibatkan model ekologi yang juga menunjukkan bahawa penuaian telur penyu laut, yang merupakan bentuk penggunaan langsung mengakibatkan kepupusan spesies. Kesimpulannya, strategi pemuliharaan campuran semasa tidak lestari berdasarkan pemodelan ekologi dan tinjauan ekonomi. Oleh itu, untuk memastikan kelestarian ekonomi dan spesies di Terengganu, strategi pemuliharaan yang melindungi penyu laut 100% sangat disarankan. Tesis ini mencadangkan strategi pemuliharaan yang melibatkan larangan penuh penuaian dan penjualan telur penyu.

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APPROVALS

I certify that an Examination Committee has met on 20th July 2020 to conduct the final examination of Anis Syafinas Binti Muhammad Dahri, on her Master of Science thesis entitled **"Assessment of Sea Turtle Conservation in Terengganu Based on Ecological Model"** in accordance with the regulations approved by the Senate of Universiti Malaysia Terengganu. The Committee recommends that the candidate be awarded the relevant degree. The members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UMT or other institutions.

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ANIS SYAFINAS BINTI MUHAMMAD DAHRI

Date:

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CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DoF	Department of Fisheries
IUCN	International Union for the Conservation of Nature
LTTW	Lang Tengah Turtle Watch
MMSY	Modified Maximum Sustainable Yield
MSY	Maximum Sustainable Yield
PEWANIS	Persatuan Wanita Kg. Mangkok Setiu
SEATRU	Sea Turtle Research Unit
TAARAS	The TAARAS Beach & Spa Resort
TEV	Total Economic Value
TRAFFIC	Wildlife Trade Monitoring Network
WWF	World Wide Fund for Nature
UN	United Nation

1 **LIST OF FORMULAS**

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$$Nesting\ Density = \frac{Number\ of nest\ in\ a\ year}{Length\ of\ coastline}$$

$$Current\ Nesting\ Mother = \frac{Total\ Number\ of\ Nest}{Average\ Number\ of\ Clutches\ Laid\ by\ One\ Turtle}$$

$$Number\ of\ \ hatchlings\ produced = (Hatching\ success\ rate\ \times Total\ eggs\ laid\ in\ protected\ beach)$$

1 **LIST OF EQUATIONS**

2

1 **LIST OF APPENDICES**

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction

Each state in Peninsular Malaysia has the right to set up rules regarding the sea turtles and their eggs since Malaysia's independence. This right was bestowed to them by the amendment of the Fisheries Act 1963 in 1985. As sea turtle is constitutionally considered as a natural resource (Jani, *et al.*, 2019), the federated state can choose the best way to manage their sea turtle within the state-federal division of law in Malaysia.. Therefore, some state was fully protecting their sea turtle such as Sabah and Sarawak by completely ban the hunting and trade in marine turtles and products (Gomez & Krishnasamy, 2019). While others applied a mixed-conservation system such as Terengganu where some nesting beaches was protected (for conservation purposes) and some were tendered (for the egg harvesting).

Initially, Terengganu does not have a specific conservation strategy implemented on sea turtle eggs harvesting. At that point, the turtle eggs only act as a protein supplement to coastal villages. Only the local fisherman had been collecting the turtle eggs such as Latherback turtles. Therefore, since the harvesting of the eggs were insignificant and the sea turtles were abundant at that moment, the local government does not implement any law or specific conservation strategy. Only after world war II, sea turtle eggs became a commercialized commodity. Then, the eggs exploitation escalated, creating the conflict of ownership between locals. To solve these issues, the Terengganu state government implemented the Turtle Enactment of 1951. Under this enactment, the nesting beaches were offered to the highest bidder for an exchange on exclusive rights to collect eggs from each lot on the nesting beaches

(Liew, 2011). The nesting beaches listed under this system was known as tendered beach. There were 26 tendered beaches from 38 nesting beaches listed by the Department of Fisheries (DoF). Only 12 beaches were protected for conservation purposes.

As a consequence, the sea turtle population was seriously depleted. The leatherback turtle was considered locally extinct in Terengganu (Liew, 2011). Besides, other species such as Hawksbills and Olive Ridleys turtle were considered as virtually extinct based on their current nesting density (Chan, 2006). Green Turtle was also struggling for their survival (Gomez & Krishnasamy, 2019). This indicates that this mixed conservation strategy was not sustainable and efficient in protecting the sea turtle population in Terengganu. Yet, this mixed conservation system was continued up to today. Research on evaluating the sustainability of this mixed conservation system was lack. Thus, this research was aimed to assess the sustainability of this mixed conservation system.

To assess the sustainability of this mixed conservation system, five objectives were completed. The five objectives were composed as stated: (1) To analyze the sustainability of this mixed conservation strategy based on the current population abundance of sea turtles in Terengganu, (2) To identify growth curve possessed by sea turtle population in Terengganu under the mixed conservation strategy, (3) To investigate the sustainability of current harvest limit and set a new sustainable maximum harvest limit of sea turtle eggs in Terengganu, (4) To define the sustainability of prey-predator interaction between human and sea turtles in Terengganu, and (5) To identify possible sustainable economic activity between eggs harvesting and non-consumptive tourism-related activity.

This research initiates the usage of ecological modelling as a tool to evaluate the interaction sustainability and predicting future population size for the whole Terengganu. Previous research as mentioned in chapter two was mostly focused on evaluating only the current situation in a specific area, not all nesting beaches in Terengganu. By predicting future interaction's sustainability and future population size, this research was able to suggest the new sustainable conservation strategy for the Terengganu state government.

1.2 Significant of Study

This research was a pioneer in evaluating the sustainability of the mixed conservation system in Terengganu using ecological modelling and preliminary research on economic activity. The modified ecological modelling can also be implemented in other states and countries in the world that practices sea turtle eggs harvesting. Facilitated by the modified ecological modelling and preliminary economic activity assessment, this research was capable of evaluating the sustainability of both tendered and protected beaches listed by DoF, Terengganu.

There were a few previous studies carried out on the population abundance of sea turtles in Terengganu. Yet, the previous study as mentioned in subchapter 2.6 was focused on only a limited number of beaches and usually put aside the geographical factor of each nesting beach. This previous study is not capable of representing the implication of a tender system to the population of sea turtles. This thesis compares the nesting density that involved the geographical factor which is the length of the coastline instead of using the number of nests or eggs solely. This research use nesting density (nest km^{-1}) as it represents the true productivity of a beach and provided a fair comparison. This was a basis in understanding the implication of tender systems under the mixed conservation strategy in Terengganu as it takes all the nesting beaches into account.

Secondly, this research was the first to provide an insight into the mixed conservation strategy impact on the life-history strategy of the sea turtle population in Terengganu. Specifically, this is the first attempt to identify and evaluate whether the natural selection characteristics possessed by sea turtle was able to withstand the egg exploitation under the mixed conservation system practices in Terengganu. This is important as understanding and predicting how the population grow (either exponentially or logistically) was crucial in predicting possible population response (in term of population size) to anthropogenic stress such as egg exploitation. The natural selection characteristic was the one responsible for determining whether the species will continue to exist by having the ability to compensate for the death from exploitation and natural cause.

Further do, this research attempt to evaluate the sustainability of the current harvest rate of sea turtle eggs in Terengganu and sea turtle-human prey-predator interaction level in Terengganu using ecological modelling was considered as a novel, both in Malaysia and internationally. This is because other countries that also harvested sea turtle eggs (as mentioned in subsection 2.3) manage their sea turtle eggs only by looking at the current impact of the harvest on turtle eggs (traditional method). For instance, Thailand stops the sea turtle eggs harvest under concession due to serious depletion that is already visible to the naked eyes. Contradicted to Thailand, this research utilized ecological modelling to predict the impact of sea turtle eggs harvesting under the current mixed conservation system in Terengganu in a long run.

As prevention was better than cure, this research also set a new harvest limit and new sea turtle-human interaction level to ensure the sustainability of sea turtles in the future. This is important because when the Turtle Enactment 1950 was first implemented, it only focussed on resolving community issues as mentioned in subsection 2.4. There is no sustainable harvest limit or sustainable level of prey-predator interaction research and implementation were done.

Specifically, this research was the first attempt for evaluating the sustainability of the current harvest rate. Before this, no study based on ecological modelling had been conducted to simulate the impact of the current harvest rate implemented on the sea turtle population size in Terengganu. Feudal studies on the impact of harvest rate were carried out by gathering the nesting data for years and comparing them. Those were time and money consuming. Moreover, this feudal method was unable to identify the potential extinction threat from the beginning of harvest. Usually, if the population depletion was visible in the nesting trend, the species extinction was unavoidable just like the leatherback extinction in Terengganu. Moreover, this research is also the first research that takes into account the significant natural death rate in sea turtle population growth prediction in Terengganu. This research modified the ecological modelling by including the natural death rate of sea turtles. The general model used for species harvesting which is the MSY abandon the natural death rate and may result in overestimation of the population growth. Overestimation in population growth may lead to overharvesting and species extinction. In this research, including the natural death rate is also important in identifying the new sustainable maximum annual harvest rate of sea turtle eggs in Terengganu to ensure population recovery.

Adding to that, this research is also the first attempt in incorporating the characteristics of the sea turtle harvesting business (such as tender system) into the prey-predator interaction. Previous approaches such as those highlighted by the Lotka-Volterra model assume that the predator population size increase and decrease like living things such as animal and plant. This generalization may result in under or overestimation of the predation impact. Businesses such as the tender system that devours on the sea turtle eggs do not possess living things characteristics as the number of tender holders was fixed and not influenced by the production of sea turtle eggs in Terengganu. In this research, the ecological modelling was personalized by assuming the predator (tender system) do not possess any growth or death rate. This research is also the first attempt in pointing out the banning percentage of sea turtle egg harvesting for encouraging sustainable interaction and sea turtle population recovery in Terengganu.

Not only that, but this research also includes preliminary research on sustainable economic activities that generate income by utilizing the existence of sea turtles in Terengganu. This research also introduced and classify the experience tourism concept in Terengganu. Experience tourism was not a new sensation in Terengganu. However, this concept was quite estranged in Terengganu where it lacks a deeper classification based on the package offered by the tourism operator. This research also renews the price data that shows an inconsistency between seasons. Besides, this research also helps to illustrate the relationship between egg production and the price of eggs which is inversely proportional. It also illustrated that the sea turtle eggs market was not stable and possibly collapse together with sea turtle extinction in Terengganu.

As the endnote, all the information generated by this research from an ecological or market perspective was crucial for the Terengganu state government as guidance in making sustainable management decisions for sea turtles in Terengganu.

1.3 Problem Statement

The primary theme of this study was to further understand and evaluate the sustainability of the current mixed conservation strategy in Terengganu. Thus, five research questions (RQs) to achieve the aim:

I. Are the mixed conservation strategy was sustainable based on the current population abundance of sea turtles in Terengganu?

II. What is the growth curve possessed by the sea turtle population in Terengganu under the mixed conservation system that permitted the eggs exploitation?

III. Are the current harvest limit was sustainable? If not, what is the new sustainable maximum harvest limit of sea turtle eggs in Terengganu?

IV. Was the prey-predator interaction between humans and sea turtles in Terengganu sustainable? If not, what are the new sustainable level of interaction suggested for Terengganu?

V. What is the possible sustainable economic activity between eggs harvesting and non-consumptive tourism-related activities?

Chapters 3, 4, 5, 6, 7 and 8 was constructed to answer these questions.

1.4 Aim and Objective

This thesis is aimed to evaluate the sustainability of tender systems in Terengganu from an ecological and economical perspective. To do so, five objectives were composed, which are

(I) To analyze the sustainability of this mixed conservation strategy based on the current population abundance of sea turtles in Terengganu

(II) To identify growth curve possessed by sea turtle population in Terengganu under the current mixed conservation strategy in Terengganu

(III) To investigate the sustainability of the current harvest limit and set a new sustainable maximum harvest limit of sea turtle eggs in Terengganu

(IV) To define the sustainability of prey-predator interaction between humans and sea turtles in Terengganu and set a new sustainable level of prey-predator interaction in Terengganu.

(V) To identify possible sustainable economic activity between eggs harvesting and non-consumptive tourism-related activities.

The first objective was composed to evaluate the impact of the mixed conservation impact based on current population abundance and trends in Terengganu. In this recent study, the population abundance such as nesting density, number of mothers, major nesting mother species and number of future nesting mothers were considered from both protected and tendered nesting beaches. In this objective, a few simple mathematical formulae such as nesting density, current nesting mother, number of hatchlings produced and future nesting mother was used. Some formula was based on previous formula while some were composed using the scientific fact from the previous study.

The second objective of this research was to determine the growth curve possessed by the sea turtle population in Terengganu under the mixed-conservation strategy. This mixed conservation strategy involves the eggs exploitation that possibly altered the life-history characteristic of sea turtle populations in Terengganu. Egg exploitation increases the mortality rate of sea turtle. Sea turtles are organisms that fall in between the characteristics of organisms that are having pure exponential or logistic growth curves. Since they do produce huge numbers of eggs just like organisms that possessed an exponential growth curve. However, they also have higher age at maturity and a long life span just like organisms that possessed a logistic growth curve. Thus, the ecological modelling namely the exponential and logistic model was used to facilitate the analysis for this objective.

The third objective was to investigate the sustainability of the current harvest limit and set a new sustainable maximum harvest limit of sea turtle eggs in Terengganu. Historically, an area with low human density is likely to have low rates of exploitation which resulted in higher sea turtle density (Becker *et al.*,2019). However, this section focussed on the impact of the exploitation or harvest rate of sea turtle in Terengganu. The new harvest limit suggested in this analysis by subjecting a few new harvest intensity and observation on its impact on the population size for 100 years. The ecological model used in this section was Maximum Sustainable Yield (MSY) and Modified Maximum Sustainable Yield (MMSY).

Then, this study moves to another objective, which is to define the sustainability of prey-predator interaction between human and sea turtles in Terengganu. Predators and prey can directly affect the relative abundance of each other or they can affect the abundance of other species indirectly on a shorter time scale than an evolutionary time scale (Trites, 2018). This section analysis was facilitated by the Lotka-Volterra prey-predator model and Tender System model. In this research, it is assumed that the tender holder has no limits for capture and processing the sea turtle's eggs. This chapter also tried to find out the sustainable prey-predator interaction between the tender system and sea turtle eggs. It is assumed that the number of the tender holder is inversely proportional to the rate of sea turtle egg exploitation, Last but not least, after all the evaluation on ecological modelling was done, this study into possible sustainable economic activity between eggs harvesting and non-consumptive tourism-related activity in Chapter 7 and 8. Economic activity in Terengganu involves both consumptive economic activities and non-consumptive economic activity. This is because sea turtle eggs are eaten for pleasure, as the source of protein, traditional reasons, and medicinal benefits by most people in Malaysia (Kamaludin *et al*., 2018). On the other hand, sea turtle also an asset that generates income by non-consumptive activity which is tourism. Sea turtles have become among the most significant assets in eco-tourism as it was considered as an endangered species due to human activities (Ghazali & Jamil, 2019). Tourism activity that was investigated in this section was the hatchling release, accommodation, day-trip and nest or turtle adoption program. Determination of sustainable economic activity in Terengganu was facilitated by the primary data (enumerator survey and interview) and secondary data (written document and media survey). Economic activities involving sea turtle is considerably huge in Terengganu and have a visible impact on the community, thus at the end of this thesis, the most sustainable economic activities were suggested and concluded in Chapter 9.

1.5 Hypothesis

The focus of this study was to further understanding and evaluating the sustainability of the current mixed conservation strategy in Terengganu. Due to this main focus and method used, the hypothesis of this research was not divided into the null and alternate hypothesis as it does not involve any statistical hypothesis testing. Nevertheless, the hypothesis was varied according to the research objective in each chapter.

Firstly, for population abundance, it is hypothesized that the nesting density (nest/km) of the protected beach was higher than in the tendered beach as an implication of sea turtle eggs harvest. This is based on the statement from the Department of Fisheries (DoF) (2008), where the dramatic depletion in the nesting population of all species was contributed by the excessive eggs exploitation. Secondly, according to the nesting trend in 2011-2015, the major nesting mother in Terengganu was from the green turtle species as the nesting trend display a biennial nesting pattern. This is due to previous research on Pulau Redang Marine Park Centre (PRMPC) where green turtle contributed for 96.18% (1,233 nests laid) of the total nesting recorded while hawksbills accounted for the remaining 3.82% (49 nests laid) (Ghazali & Jamil, 2019). Redang and Perhentian Island was among the major nesting beaches in Terengganu thus the species density throughout Terengganu may be aligned to the PRMPC. The biennial nesting pattern was generally displayed by the green turtle. This indicates that other species such as hawksbill and olive ridley was so low in number until they cannot influence the nesting pattern in Terengganu. In addition to that, this study hypothesized that the current number of nesting mother was lower compare to the previous nesting mother. This hypothesis was made as Chan (2006) mentioned that anecdotal evidence suggests over 80% declines in green turtle population where current annual nesting density average only 2,000. Adding to that, it is hypothesized that the number of future nesting mother would be much lower than the current nesting mother and considered as locally extinct if the current sea turtle eggs exploitation continues. Pilcher (2001) express the possibility of no breeding females available in a population after 25 years if 100% of the population was harvested annually before reaching sexual maturity.

Secondly, this research looks into the growth curve of the sea turtle population in Terengganu. It is hypothesized that the sea turtle population in Terengganu was vulnerable to extinction due to eggs exploitation under the current mixed conservation system as it exhibits the logistic growth curve. This hypothesis was made as sea turtle display some crucial characteristic of species possessing the logistic growth curve. The sea turtle population recover slowly from losses because it takes many years for sea turtles to mature and reproduce (Ocean Studies Board & National Research Council, 2010). Besides, each nesting beaches has its carrying capacity. For example, according to a previous study on the East Island, French Frigate Shoals, under the current condition the carrying capacity 1.9 and 2.1 million hatchlings. Thus, when 20 000 to 30 000 females nesting the carrying capacity was approached as there were 80 000 to 120 000 nests (Tiwari *et al.*, 2010). Compared to the Terengganu case, there is a lack of study on the carrying capacity of each beach. However, this hypothesis was drawn as each nesting beach possibly possessed its nesting limit.

Thirdly, this research looks into the harvest rate of sea turtle eggs in Terengganu. For the first section, it was hypothesized that the current harvest rate is unsustainable and possibly lead to the extinction of sea turtle in three decades if continued. This hypothesis was made as only one in a thousand or ten thousand sea turtles will survive to reach sexual maturity (McGuire *et al.*, 2017). The hypothesis was drawn according to research in this section where the natural death rate of sea turtle in Terengganu was as high as 0.999. Besides, the primary threat to marine turtle survival in Malaysia is commercial egg exploitation (Tan, 2004). Although 12 from 38 nesting beaches were protected, due to the high natural death rate, the protected beach was unable to supply enough hatchlings to compensate for death from natural and exploitation factor (total mortality). This study also hypothesised the implementation of a maximum annual harvest rate of 25% from the current harvest rate was sustainable and will help in population recovery. However, the total banning of the sea turtle eggs harvests in Terengganu was needed as this study does not consider the death rate from other anthropogenic factors such as trap in a gill net, boat strike, plastic pollution and adult hunting.

Moving to the other section, this section focussed on the prey-predator interaction between human-sea turtle in Terengganu. It was hypothesized this interaction was not unsustainable and lead to extinction in a few years if the current level of interaction was continued. The research in this section come into this hypothesis as the consumption of eggs was considered as a human activity that threatens to further decrease sea turtle populations (Zuardo, 2009). This statement reflects the possibilities that this type of interaction (egg harvesting) was unsustainable. Besides, it was also hypothesized that if the immediate 100% or total ban on sea turtle eggs harvesting was implemented then population recovery was possible. Limpus (1993) generally mentioned that the incubation goal should be greater than 70%, possibly as high as 100% of clutches successfully producing hatchlings to increase the size of the depleted sea turtle population.

Finally, yet an important section of this research was on determining the sustainable economic activities between the consumptive activity which is the sea turtle eggs harvesting and non-consumptive egg harvesting which is related to tourism activity. This study hypothesized that the non-consumptive economic activity (tourism) of sea turtle generated more income and more sustainable in the long run. This hypothesis was drawn as the previous studies in India stated that sea turtles have become important for their non-consumptive uses in tourism, educational and scientific research within the last three decades. This generates employment opportunity and information services as well as other economic and cultural benefits (Tripathy & Choudhury, 2007). Sea turtle has become one of tourist attraction in Terengganu thus it is possible that it also has a significant economic impact as mentioned in the previous research.

1.6 Justification on Using the Sea Turtle Eggs as References

Terengganu's sea turtle population health and survival were reflected by the numbers of eggs in this research. The number of eggs was used throughout this thesis as references even to calculate the numbers of current nesting mothers and prediction on numbers of future nesting mothers. The numbers of eggs were chosen as a reference or benchmark for predicting the sea turtle population survival due to numerous reasons.

Firstly, the number of eggs was selected as the sea turtle eggs was fixed on the place that the mothers laid or at the relocated area. In this life stage, the sea turtle eggs are immobile thus helps in identified the accurate sea turtle population size at each nesting beaches and in Terengganu due to the "natal homing" behaviours as mentioned in section 2.2. If this thesis employed the adult or juvenile turtles in the water, overestimation possibly occurred as the sea turtles might be from the neighbouring state such as Kelantan or Pahang. As mentioned in section 2.2, sea turtles are a migratory species where the sea turtles in Terengganu waters might be on their migration to or from their nesting beaches or foraging ground.

Since the budget for this research was limited, there is no way to conduct the genetic testing for ensuring each counted individuals were born in Terengganu. The cost of genetic testing was as was enormous. Besides, the sea turtles in a foraging ground might be born and come from a few different beaches. For instances, the green turtles born in the rookeries along the South China Sea and the Sulu Sea utilized the South China Sea (Joseph *et al.*, 2019). Thus, the sea turtle that the researchers came across in the South China Sea might come from neighbouring state such as Kelantan, Pahang and Johor or neighbouring countries such as Brunei, Philippines, China, Vietnam or Indonesia. This is because sea turtles were a long distances traveller that also travels across the different sea for examples the sea turtle that utilized the Celebes Sea was born in the Sulu Sea, Micronesia and New Guinea (Joseph *et al.*, 2019).

Secondly, the eggs life stage was preferred in this study as it escapes the overestimation from tag loss. This tag loss contributed to bias prediction due to the population size overestimation such as overestimating the numbers of nesting females in a season, underestimation of the number of clutches deposited by individual turtles and incorrect inter-nesting data (Chew *et al.*, 2015). Usually, the extinction of the sea turtle population was predicted using sexually matured females as a reference because they were more often obtain a tag of all types during the nesting process because of the ease of attachment (Long & Azmi, 2017). Yet, since sea turtles have a long duration of the life cycle, the tag lost rate was skyrocket (Reisser *et al.*, 2008).

Thirdly, the numbers of sea turtle eggs produced were the first indicator of population depletion. The number of eggs incubated was employed as the baseline for monitoring nesting trends and hatching success (Long & Azmi, 2017). This happened as the population depletion will firstly become apparent on the eggs stage. When others life stages exhibit a reduction sign it is already late to save them as the population was already seriously depleted. This is because other life stages take time to display the effect of harvesting (Long & Azmi, 2017).

Lastly, the numbers of eggs were the most suitable reference in this research because this research focussed on evaluating the impact of sea turtle eggs harvesting due to the tender system under the mixed conservation system practices by the

Terengganu government. This is supported by Long & Azmi, (2017) where the only consumed part of sea turtles in Malaysia has always been the sea turtle eggs. In Terengganu, this sea turtle eggs harvesting was an important aspect in looking at the sustainability and survival of sea turtles because the conservation work focused mainly on nesting sites (Long & Azmi, 2017). This research does not focus on the impact of eggs harvesting on the numbers of sea turtles in water because only a little data is known about in water turtle population (Long & Azmi, 2017), the over or underestimation of population size can occur.

1.7 Research Framework

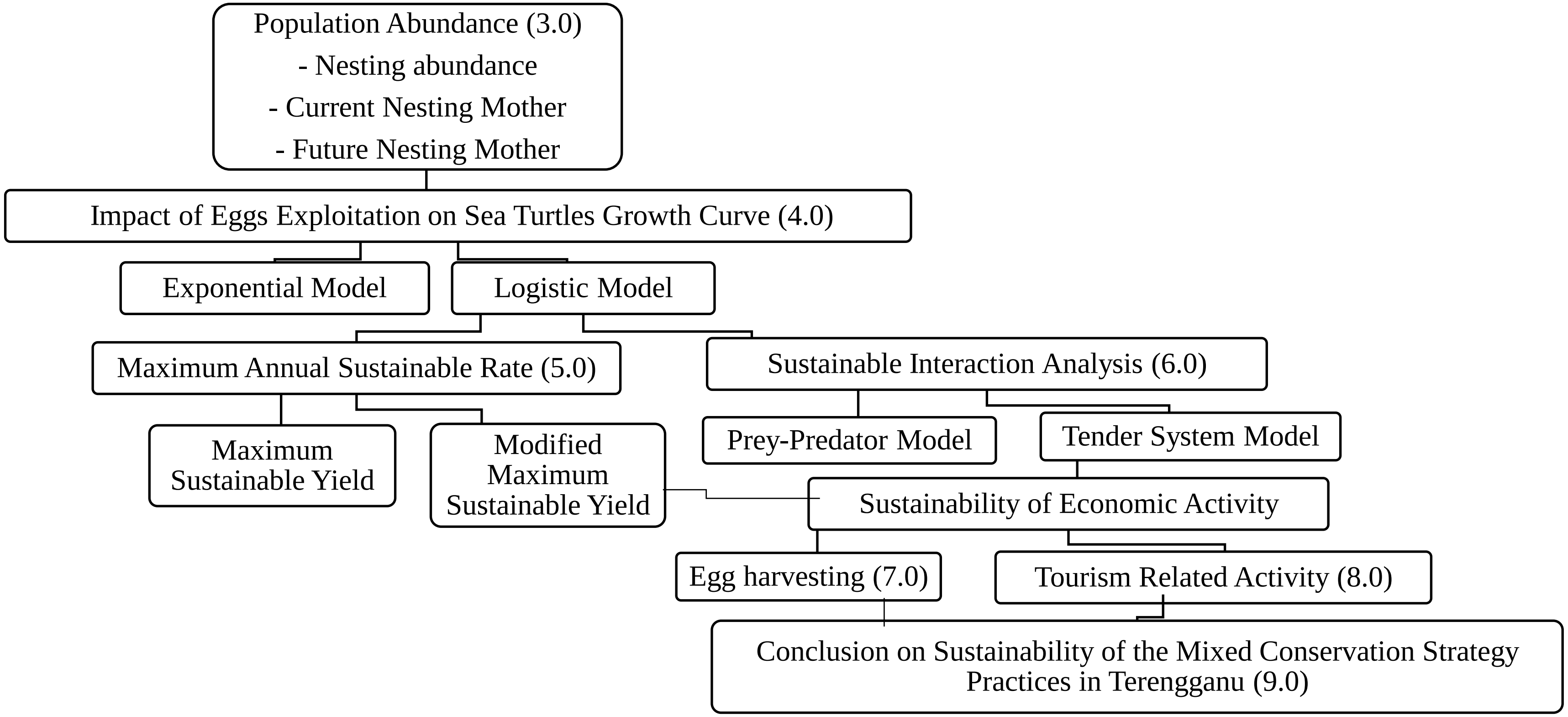

Figure 1.1 The evaluation of sea turtle conservation in Terengganu under current mixed conservation strategy practice according to chapter in this thesis: chapter 3 (3.0), chapter 4 (4.0), chapter 5 (5.0), chapter 6 (6.0), chapter 7 (7.0), chapter 8 (8.0) and chapter 9 (9.0).

The sea turtle conservation in Terengganu was facilitated by the mixed-conservation strategy in Terengganu. The evaluation of sea turtle in Terengganu involves both ecological analysis and preliminary study on economic activity that was fuelled by the existence of sea turtle in Terengganu. This research was carried out according to Figure 1.1. Some formula and model used in this research was either the original, modified or newly proposed. Some model was modified from the original model to fit the characteristics of sea turtle and tender system under the mixed conservation system implemented in Terengganu. Plus, other formulas that were newly proposed was constructed from finding and the statement from previous research.

1.7.1 The Abundance of Sea Turtle

This evaluation was initiated by investigating the sustainability of the mixed conservation strategy in Terengganu based on the current population abundance of sea turtles in chapter 3. The population abundance in the nesting beaches usually counted from the number of activities (track, crawl, body pit), eggs, clutches and nesting female (SWOT Scientific Advisory Board, 2011). This study estimated the population abundance of sea turtle based on the nesting density, current nesting mother and future nesting mother. The population abundance in this thesis was evaluated based on those three criteria as the most accessible life stage of a sea turtle was the nesting females and their hatchlings (Kaska *et al.*, 2017). For the first section, the nesting density was evaluated by dividing the number of total clutches in each nesting beach by its length of coastline.

This equation used in this section was mentioned by Shanker *et al.*, 2003 for evaluating the true productivity of each nesting beaches. The number of the nest (clutches) was used in this thesis as using the number of the nest (clutches) was more accurate to describe the reproductive output than all other activities. This was a reliable parameter as it only takes into account the successful nesting attempts (SWOT Scientific Advisory Board, 2011). The length of the coastline which is the physical parameter of the nesting beaches was included in this analysis to find out the true nesting density of each beach.. The length of the coastline was considered the most accurate physical parameter to be used in this research since no research has been carried out to determine the total surface area suitable for nesting on each beach in Terengganu. Not all areas on the beaches are suitable for nesting since sea turtle chooses their nesting spot based on a few factors such as the grain size, beach vegetation cover, mineral composition of the sand, nest inundation, height above sea level and distance from the sea (Fadini *et al.*, 2011). In addition to that, many beaches in Terengganu were badly affected by erosion that possibly reduces the nesting beaches carrying capacity. This occurred as the beach erosion influences the morphological changes that beach scarps undergo leading to reduced beach height, width, and quality (Rivas *et al.*, 2016). Thus, without the confirmation on the width and physical assessment of the beach, using total surface area possibly leads to overestimation. The length of the coastline was a better measurement because it was less affected by the high or low tide, erosion and others.

Then, the nesting density (nest/km) was plotted to display the true beach productivity. This was done to illustrate the effect of sea turtle eggs harvesting on the nesting density that has not been done in Terengganu. The protected beach act as a control in this section. Supposedly, an area that historically gave a low human density is likely to have low rates of exploitation which resulted in higher sea turtle density (Becker *et al.*, 2019). Therefore, the protected beach should have a higher nesting density compared to the tendered beach that had to undergo exploitation. The comparison of nesting density level help in recognizing the turtle nesting hotspot. Identifying the turtle nesting hotspot was important to ensure that the nesting density was maintained. Besides, comparing the nesting density was also important to detect the beaches with low nesting density for immediate action such as a total ban to prevent extinction.

Apart from assessing the true productivity of each nesting beach in Terengganu, the nesting density trend between years also illustrated to find out the species of major nesting mother. This was done by looking at the nesting pattern display on the nesting trend between 2011-2015. Knowing the major nesting mother species was crucial as it reflected the species of hatchling produced in Terengganu.

Usually, this was only done by monitoring process by the ranger or tender holder. The problem was monitoring process was high in cost and not standardize in Terengganu, making most of the tendered beach having no record of the number of nesting mother. The research in this thesis, taking into account the nesting pattern making it possible to identify the most abundant nesting mother species in Terengganu. This was influential in making management decision to rescue the species that were critically depopulated and at the same time maintain the major species level. This step was mandatory as every sea turtle species was vital for healthy marine ecosystems (Hamann *et al.*, 2010). The differences in sea turtle species diet were important in shaping the marine environment and put them to balance. For instance, the hawksbill existence was crucial in maintaining the reef diversity as it reduced the sponge population to prevent coral overgrowth event. On the other hand, the green turtle function in eliminating the less productive seagrass biomass reduced that material to fertilizer (through digestion) and redistribute that fertilizer within its habitat (Teelucksingh *et al.*, 2010). Terengganu have four sea turtle species before namely the leatherback, Olive Ridley, hawksbill and green turtle. However, the leatherback was already locally extinct. Therefore, it is important to check out how the other species was doing and concentrate the conservation effort in increasing the fewer abundance species.

Moreover, chapter 3 also look into the number of current nesting mother in Terengganu. This was also usually done by monitoring. This research looks into a new way of estimating the number of nesting mother as it is important in determining the population continuity. The number of females was the best measurement for population abundance and trends, patterns in reproductive output and other biological factors (SWOT Scientific Advisory Board, 2011). The number of sea turtle nesting mother was assumed using the formula stated by Shanker *et al.*, 2003 and SWOT Scientific Advisory Board, 2011. For determining the number of nesting mother, the number of the nest was divided by the average number of clutches that possibly laid by one nesting mother. The total number of eggs was the number of total eggs in Terengganu obtained from DoF data (2011-2015). This study assumed that the number of clutches able to be produced by a nesting mother was 9. This is support by the data from Chagar Hutang which has a nesting mother that produces as many as nine clutches. This support by the United States Wildlife Service (2015) where it mentioned that the highest number of clutches that a female can produce as many as nine clutches.

Furthermore, the analysis in chapter 3 was carried out to predict the number of the future nesting mother in Terengganu using a new proposed formula. The formula was initiated by finding out the number of hatchlings produced from the protected beach facilitated by multiplying the number of total eggs laid in the protected beach with the hatching success rate. Only eggs laid in the protected beach was considered able to produce hatchling. This is because the sea turtle eggs laid in the tendered beach was considered dead and unable to contribute to the population size growth. This assumption was made as sources the buy-back system stop in 2018 due to lack of fund. The number of hatchlings produce refers to the number of hatchlings produce in the whole Terengganu.

A value of 0.6682 was set as the hatching success rate. This was set according to the success rate of sea turtle in Chagar Hutan. This is because Chagar Hutang was a closes representative of sea turtle hatching rate in nature where most of the nest was left for incubation in its original place. Relatively, over 80% of the sea turtle clutches deposited in Chagar Hutang has undergone *in-situ* incubation (Chan, 2013). Likewise, the hatching rate of sea turtle in the wild was assumed as in Chagar Hutang as it is the major nesting beach in Redang Island. Redang Island has a reputation of having the highest concentration of green turtle (*Chelonia mydas*) nesting in Peninsular Malaysia. Again, Chagar Hutang hatching success was considered in this research since it had undergone long-term monitoring on nesting activities (Morita *et al.*, 2006).

What’s more, this study assumed that all of the hatchlings were successfully emerge and release to the sea due to ranger assistant in the protected beach. The future nesting mother was predicted by multiplying the number of hatchlings produced with the regional sex ratio’s rate which is 0.7 to identified how many female sea turtles produced by the protected beach in Terengganu from 2011- 2015. Limpus (1993) stated that 70% of the hatchling released would be female according to the regional sex ratio for hatchling produced from in situ nests. Then, to find out the number of female hatchlings that able to survive until sexual maturity, the number of female hatchlings was multiple with $\frac{1}{1\,000}$ and $\frac{1}{10\,000}$. Bean (1980) suggested that only one in a thousand or ten thousand hatchlings will survive to adulthood. The female hatchlings produce in 2011-2015 were assumed to reach maturity and return to Terengganu within 25years. This is because it is assumed that only after 25 years, the green turtle was able to return to laying eggs (McGuire *et al.*, 2017.). The number of future nesting mother was compared to the number of the current nesting mother as it is crucial to identify the possibility of sea turtle extinction due to this mixed conservation system that permitted the sea turtle egg harvest. This is the first attempt as previous research usually only concentrated on certain beaches in Terengganu which do not reflect the situation in all other beaches.

1.7.2 Growth Curve of Sea Turtle

The growth curve possessed by sea turtle in Terengganu under the current mixed conservation system that involves the harvesting of the eggs was identified in chapter 4. This chapter was composed to pinpoint how the sea turtle growth response to the sea turtle eggs exploitation which had never been acknowledged in Terengganu or other regions. The sea turtle growth response was evaluated according to the exponential and logistic model in chapter 4. These two models were selected as it frequently used to provide the future projection of the population size over time (Karmeshu & Lara-Rosano, 1987). Wei *et al.* (2015) also mentioned that those two models were popular in research specifically for population growth. These two models were also selected in this research mainly because they fulfilled the crucial characteristic of sea turtle as discussed in the upcoming paragraph.

The exponential model was the simplest realistic model for population dynamic (Tsoularis, 2001). The exponential growth model assumed that the population size expands exponentially with time (Karmeshu & Lara-Rosano, 1987). Generally, “exponential” refers to the rapid and steady expansion. Interpreting it from the growth concept, it probably refers to the rapid and steady increase of individual number in a population. This exponential model was tested for the sea turtle population in Terengganu as it possibly possessed an exponential growth since each sea turtle was capable of producing a large number of eggs within the reproductive age as mentioned in subsection 2.2. There was a possibility that this large number of eggs produced by sea turtle yearly can cover up the loss from the tender system under the mixed conservation system. This possibly leads to an increase in the population size every year. This indicated that egg harvesting was not adversely affecting the population as the population grows exponentially.

Secondly, this chapter investigated the possibility of the sea turtle population in Terengganu growth logistically. The logistic growth model assumed that the population size grew logistically where it acknowledged the possibility of "scarce resources" (Karmeshu & Lara-Rosano, 1987). This model highlighted the concept of restricted population growth. The restriction was known as a saturation level (carrying capacity) characteristic of the environment experienced by a stable population (Tsoularis, 2001). This was aligned with some sea turtle characteristics where it displays the "natal homing" behaviour as mention in subsection 2.2. This behaviour makes them restricted to only lay eggs on the nesting beach where they were born. Besides, each nesting beach has its own carrying capacity where it can only house a certain number of eggs or nests at a time. The second restriction was because the sea turtle was incapable of producing eggs every year throughout their life as mention in subsection 2.2. This point out that number of eggs produced by sea turtle was also limited in a way. Due to those limitations, sea turtle in Terengganu possibly unable to produce enough eggs to cover up the eggs harvested by the tender system under this mixed conservation strategy. This possibly leads to depopulation and extinction. This show that the sea turtle possibly grows logistically thus unable to withstand the egg harvesting stress.

1.7.3 Maximum Harvest of Sea Turtle Eggs

Previously, no research on sea turtle harvest limit was carried out in Terengganu. Although sea turtle egg harvesting was legal from the 1950s, there is no law and implementation of the sustainable harvest limit leading to population depletion. For this particular reason, chapter 5 was dedicated to investigates the sustainability of the current harvest limit in Terengganu. Besides, this chapter also composed to investigate the new sustainable maximum harvest limit of sea turtle eggs in Terengganu. This research was the first because the Turtle Enactment 1950 only focussed on solving ownership conflict that arose between the local community. Besides, based on the literature review, there is no other similar research was conducted using similar approaches on sea turtle egg harvesting limit in others country. This objective was achieved by using the Maximum Sustainable Yield (MSY) model and the Modified Maximum Sustainable Yield Model (MMSY). The investigation was initiated by investigating the sustainability of the current harvest rate on sea turtle egg exploitation in Terengganu based on the MSY model. The MSY model was selected as a tool in this study because the vast majority of regional management bodies has been adopted. By far, the assessment of exploited populations (stocks) around the world was widely facilitated by the MSY model (Tsikliras & Froese, 2019). MSY was identified as the maximum yield that possible to be taken indefinitely from a stock (the maximum harvest) that is sustainable in the long run (Thorpe, 2019).

Undoubtedly, the MSY model was able to evaluate the sustainability of some other species accurately. Yet, the MSY model was unable to predict the actual impact of sea turtle egg harvesting in Terengganu. This happens as the MSY model neglected the natural death rate of sea turtle. As mention in subsection 2.2, the sea turtle generally has a high natural death rate where only one in a thousand or ten thousand hatchlings was capable to survive until reached their sexually matured age. Due to the high death rate of the sea turtle, neglecting this parameter would produce a resulted that conflicted with the actual impact of egg harvesting in the real world. Thus, the MMSY model was proposed and inspired by the MSY model. The MMSY model was modified to consider the natural death rate. The MMSY model assumed that the total death of sea turtle was the sum-up of the natural death rate and the egg exploitation rate. The MMSY model was then used to evaluate the sustainability of the current harvest rate.

The current harvest rate sustainability evaluation from MMSY was compared to the MSY to select the best model representing the reality of the egg harvesting impact on sea turtle population size in Terengganu.

Subsequently, the MMSY model was also used to determine the new sustainable annual harvest rate of sea turtle eggs exploitation. The new sustainable annual harvest rate was tested at the scale of 0% (0.0000), 25% (0.0215), 50% (0.0430), and 75% (0.0644) from the current harvest rate. For instance, if the suggested new sustainable annual harvest limit was 25% from the current harvest limit, it means that only 0.0215 of the total sea turtle eggs production on the tendered beaches should be allowed for harvesting. The new sustainable harvest limit was selected as the one that able to prevent extinction in Terengganu and able to ensure the sea turtle existed continuously for as long as possible.

The usage of MMSY in setting up a new sustainable annual harvest limit was crucial to avoid overestimation as there was an immediate consequence on population size, age composition and sex structure due to the harvesting. Moreover, the overestimation should be avoided as the harvesting has an indirect consequence due to the impact of changing population size and structure on the demographic processes (Langvatn & Loison, 1999). When the government overestimate the sea turtle population size or underestimate the impact of sea turtle eggs harvesting, the consequent was devastating, leading to depopulation and eventually extinction.

1.7.4 Prey-predator Interaction of Sea Turtle Eggs Harvest

Moving to the next research, chapter 6 in this thesis was invented to analyse the sustainability of the prey-predator interaction between human and sea turtles in Terengganu. More or less, this is the first effort on defining the sustainable level of sea turtle and human interaction that tied by the prey-predator relationship due to the egg harvesting under the mixed conservation system. The prey-predator interaction that was focussed on in this chapter was predation. Fundamentally, predation was defined as an interaction involving individuals of one species killed and consuming a notable fraction of the biomass of individuals of another species (Abrams, 2000). Sea turtle was predated by many species in nature along with its life phase. However, the biggest threats to the survival of the sea turtles proved to be the implication of human activities. Sea turtle was commercialized for their eggs and shell, captured for their meat and became a falling victim to both commercial and artisanal fisheries (Inter-American Convention Secretariat, 2004).

Malaysia was the highest consumer of sea turtle eggs among Asian country. In Kelantan and Terengganu, the sea turtle eggs are usually sold openly at public markets as the harvesting and selling of sea turtle eggs are legal (Rusli *et al.*,2020). Thus, it is important to identify either the current level of prey-predator interaction between sea turtle and human under the tender system was sustainable or vice versa. In chapter 6, this identification was carried out using the Lotka-Volterra model and tender system model. The Lotka-Volterra equations were formed to elucidate the ecological system dynamic (Blaszak & Hu, 2019). The Lotka-Volterra model was selected to facilitated analysis in chapter 6 because it was a non-linear differential equation that focused only on the predator-prey interactions. Moreover, this equation was selected for the analysis because it ignores the competition, disease, and mutualism interaction that occurred to sea turtles (Blaszak & Hu, 2019).

Eventually, it appeared that the usage of the Lotka-Volterra model possibly leads to overestimation. This happens as the Lotka-Volterra model assumed that the growth of prey in the absence of predation was unrestrained. Contradicted to the prey population, the predator depleted exponentially in the absence of the prey population. The prey growth rate was reduced by the predator. On the other hand, the predator growth rate will increase by the prey. Both prey and predator growth rate were proportional to the prey and predator populations (Rahmani Doust & Holizade, 2014). According to this assumption, the Lotka-Volterra model assumed that the amount of prey consumed by the predator equal the total amount of growth in the predator. Rahmani Doust & Holizade (2014) clearly state that the population growth proportional to the food (prey) available. Besides, the Lotka-Volterra model assumed that the predator has a natural death.

It appears that the Lotka-Volterra model assumption was contradicted the reality of the tender system under the mixed conservation system practised by the Terengganu government since the 1950s. For instance, the prey (sea turtle) has restricted growth even in the absence of a predator (tender system) as it possessed a logistic growth curve which eventually makes them stop growing when the carrying capacity is achieved. At the same time, the predator (tender holder number under tender system) does not grow in size (increase in number) approximately to the number of prey (sea turtle eggs) predated (harvested) by the predator. Regardless of any number of eggs harvested, the number of tender holders remain unchanged. Moving to the next point, the predator (tender holder) do not experience natural death (termination) as long sea turtle eggs were laid in Terengganu. This seen in the data from DoF that was utilized in this research where none tender holder was closed from 2011-2015.

Thus, due to all differences between tender system characteristics and the Lotka-Volterra model assumption, the Tender System model was was proposed. This model was inspired by the Lotka-Volterra model, yet modified to accommodate the tender system characteristics as mentioned in the previous paragraph. Both the Lotka-Volterra model and the Tender System model was used to evaluate the sustainability of the current level of the prey-predator interaction between human and sea turtles in Terengganu. The sustainability of the current level of prey-predator interaction was defined by the prediction of the extinction year and population size trend. A model that closely represented the current sea turtle population depletion in Terengganu was selected as it considered to be more accurate.

After that, the investigation on a new sustainable level of prey-predator interaction between human and sea turtle in Terengganu was carried out using the Tender System model. Only the Tender System model was selected for this analysis as it perfectly fits the characteristics of the tender system under the mixed conservation system in Terengganu. Facilitated by the Tender System model, the level of new sustainable interaction was tested based on the level of prey-predator interaction that possibly able to encourage the sustainable interaction and sea turtle population recovery in Terengganu. The level of interaction was tested were 0% (0.0000), 25%

(0.0215), 50% (0.0430), and 75% (0.0644). If only 50% of the tender system suggested operating annually, the exploitation rate that allowed was only 0.0430. The most reasonable level of interaction was selected as the new suggested level of prey-predator interaction between human and sea turtles in Terengganu. “Reasonable” in this section was considered as the banning percentage of the tender system that most possible prevent the sea turtle extinction in Terengganu.

1.7.5 Market Survey of Sea Turtle

The possible sustainable economic activity involving sea turtle was determined in Chapter 7 and Chapter 8. This research focussed on identifying the possible sustainable economic activity between eggs harvesting (consumptive) activity and non-consumptive tourism-related activity. Although both tourism activity and egg harvesting that involved sea turtle had been carried out for decades, there is no evaluation on the most sustainable economic activity in Terengganu that integrated both ecological and economic aspect. This research thesis was the first research that tries to incorporate both ecological and economical aspect to reverse the serious depletion of sea turtle in Terengganu. The first few beginning chapters in the thesis which is chapter 3 to 6 was dedicated to evaluating the sea turtle sustainability based on the ecological spectrum using some mathematical model. The sustainability evaluation based on the economic spectrum was then carried out in the last chapter which is chapter 7. This approach was chosen in this thesis because other economists and ecologists to a large extend agreed that combining biological and economic information assists in identifying strategies to reverse biodiversity and ecosystem loss (Troëng & Drews, 2004).

Besides, although some previous research had discussed some tourism activity, lack of the “experience tourism” evaluation because it only springs up like mushrooms starting from the last few years up to now. Based on preliminary research and visitation, new conservation projects emerge rapidly a few years back, for instance, Perhentian Turtle Project, Perhentian Island Terengganu was established in 2015 while Island Watch Conservation Initiative (IWCI), Rawa Island, Terengganu was established in 2018. The market survey will be divided into two chapters which are Chapter 7 entitled “Market Survey on Sea Turtle Eggs Consumption in Terengganu” and Chapter 8 “Market Survey on Sea Turtle Tourism Products in Terengganu”. Chapter 7 focussed on the market survey of consumptive use (sea turtle egg selling). While, Chapter 8 focussed on the market survey of the non-consumptive sea turtle tourism products (such as hatchling release, accommodation, day trip, nest/turtle adoption program).

The classification of both consumptive and non-consumptive use was based on the Total Economic Value (TEV). TEV can be identified as an all-encompassing framework that economists utilized to determined and categorize environmental benefits (Emerton, 2016). Eggs selling was considered as the direct use value of sea turtle that classified as consumptive. The sea turtle eggs harvesting was considered as direct use as it was used directly as a commodity in Terengganu. Thus, the direct value can be defined as the raw materials and physical products which directly used for production, consumption, and sale (Emerton, 2016). This aligned with MacMillan & Phillip (2008) that interpreted the direct use value as the ecosystem goods and services that are advantaged human being directly. The sea turtle egg selling was classified as consumptive use as it involved the harvesting or removal of the sea turtle eggs from its population and ecosystem. Besides consumptive use, the direct use values also made up by the non-consumptive use. The non-consumptive use can be expounded as activities that do not need product harvesting for example the enjoyment of recreational and cultural activities (Pagiola *et al.*, 2004). In Chapter 8, the hatchling release, accommodation and day trip were considered as the non-consumptive use under the “experience tourism” group.

Experience tourism concept was becoming more popular in Terengganu in recent year. Experience tourism generally refers to a tourism activity that promotes a new experience to the tourist. The 21st century is the new economic era that involved the experience economy. The tourism businesses and destination are bound to recognize that experience, not goods or services within the current era to thrive and compete globally. Visitors are motivated to travel and repeat visits to the destinations and recommend it to friends and relatives due to the experience (Mendes *et al.*, 2016).

In addition to that, nest and turtle adoption in Chapter 8 was considered as the willingness to pay under existence value. The existence value was considered as a non-use value (Bamwesigye *et al.*, 2020) under the TEV. The non-used value was defined as the pleasure people may experience just by realizing that a resource exists although they never expect to use that resource directly themselves (Pagiola *et al.*, 2004). Bamwesigye *et al.* (2020) mentioned that the existence value rose as some individuals demonstrate a willingness to pay for conserving a biological diversity element although they or others have no intention to benefit from it (Bamwesigye *et al.*, 2020). This was generally recognized as the existence value or passive use value (Pagiola *et al.*, 2004).

All those values mentioned above was evaluated by the market price of one unit of economic activity. This is based on the earliest and simplest way to evaluate the good or service by looking at its market price. For instance, what it costs to buy or is worth selling it (Emerton, 2016). The sea turtle egg selling evaluation was based on the price of one sea turtle egg sold in Pasar Payang, Kuala Terengganu, Terengganu. The sea turtle egg price was plotted and compared based on month and season. The characteristic of the sea turtle eggs market in Terengganu was also noted as side information. The hatchling release, accommodation and day trip were evaluated based on the fee charges for one individual (pax) per day. Then, the price per pax was compared between tourism operator within the same activity for discussion of the price differences. Lastly, Chapter 8 also measures the amount of money that the tourist willing to pay for adopting a sea turtle or nest as an effort to conserve the sea turtle population in Terengganu. This then compared between the tour operator and the price differences was discussed.

This market price approached was also chosen as it able to link the quality or quantity changes of ecosystem goods and services to output changes of a marketed good or service ("production function" techniques). Besides, the price market technique was chosen as it can be used to directly ask the consumer how they value the ecosystems ("stated preference" techniques) (Emerton, 2016). This is important as the turtle has become among the most crucial assets in eco-tourism as it is classified as an endangered species. Human activities induce turtle extinction (Ghazali & Jamil, 2019).

1.8 Thesis Structure

This thesis is structured as a series of data chapters. Chapters 3 to 8 are designed to be published as a stand-alone research paper, bookended by a general introduction chapter (Chapter 1), literature chapter (Chapter 2) and a general conclusion chapter (Chapter 9). Chapter 1 is the general introduction for this research to address the problem and research background of this research. This gave a clearer picture of how this research will be navigated. Chapter 2 which is the literature review was composed to give some background information on previous research conducted on this topic. While chapter 8 was intended to conclude all research carried out in Chapter 3 to 8. Some repetition in general themes in the introduction and discussion sections of some chapters, and also the methods sections existed in this thesis.

Chapter 3 is evaluating the population abundance of sea turtle in Terengganu. The first section in this chapter was composed to evaluate the current population size of sea turtles in Terengganu using nesting density. The nesting density help to determine the actual productivity of each tendered and protected nesting beach. Plus, nesting trend is described in detail based on annual increase and decrease of nesting density Besides the dominant species was determined by looking at the yearly nesting density trend for the nesting pattern such as biennial nesting pattern. In the second section of this chapter, the number of current nesting mothers and prediction of future nesting mothers provides a stable foundation for this research. This chapter gave us rough ideas on which nesting beaches and species are badly affected and need immediate action.

Chapter 4, answered the implication of egg collection to the life history of the sea turtle population in Terengganu. To understand the life history characteristics of a population, we need to understand the growth curve it possessed. Every species and population possessed unique growth curves, either exponential or logistic to ensure species survival. However, a sea turtle was not a species that perfectly belong to any of the two groups. Thus, this chapter was composed to investigate either the sea turtle possessed the exponential or logistic growth curve under the mixed conservation strategy practised in Terengganu that permitted sea turtle eggs harvesting. The growth curve confirmation of sea turtle in chapter 4 will be used as guidance for assuming the growth rate of sea turtle in Terengganu under ecological model analysis in Chapter 5 and 6.

Chapter 5 was composed to investigate the sustainability of the current annual harvest rate of sea turtle in Terengganu. This analysis was facilitated by the MSY model and MMSY model. Between MSY and MMSY, the more accurate model was determined by the predicted population size and its alignment with the population decline that took place in Terengganu currently. The unsustainable harvest limit was marked by sea turtle extinction. If the harvest is not sustainable, then the section afterwards focussed on the analysis of the new sustainable maximum annual harvest limit by using the MMSY model. The sustainable harvest limit was suggested if it ensures population growth and recovery before undergoing population extinction as mention in section one of this chapter.

Chapter 6 answer the sustainability of this interaction facilitated by the Lotka-Volterra prey-predator model and Tender System model. Both models were used to investigate the sustainability of this interaction. Besides, both two models also used to predict the extinction of the sea turtle population in Terengganu under current exploitation. The model that closely represents population depletion in reality was selected and referred for prediction on future population growth. Besides, if the current interaction rate is not sustainable, the selected model will be used for finding new interaction limit in this chapter. This part will simulate the different degrees of the egg-collection ban for achieving a sustainable interaction level as a suggestion to the Terengganu government's new conservation strategy.

Chapter 7 and 8 can shed some light on the sustainability of economic activities carried out in Terengganu by utilizing the sea turtle population. This study was conducted as chapter 3 to 6 suggested that this mixed-conservation strategy was unsustainable and need for an urgent banning. Thus it is important to see if sea turtle egg harvesting has a significant economic impact on local and Terengganu government. The findings were compared with the tourism-related economic activity to identify the possible sustainable, long-lasting and most important sector. The preliminary research on both consumptive uses which is egg harvesting and non-consumptive used which is economic activity generated by the tourism sector were investigated in this chapter 7 and 8. This was conducted by the enumerator survey, interview and secondary resources such as previous research.,

Chapter 9 is a general conclusion and chapter. The major research findings, limitations, and challenges encountered while conducting this research were stated in this chapter. This chapter also provided some suggestion and directions for future research.

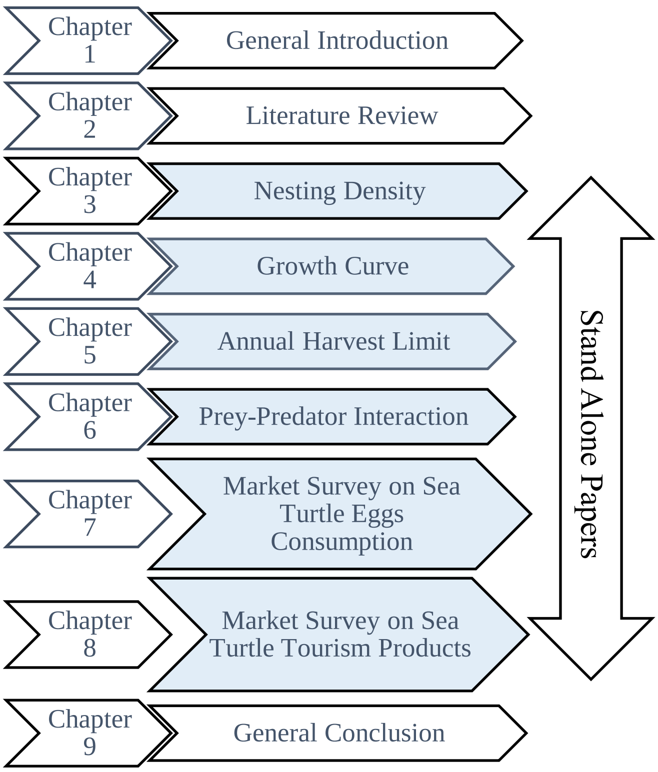

Figure 1.2 Schematic diagram of the study concept in this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Status of Sea Turtle

Sea turtle population have been drastically declined by anthropogenic activities until they may no longer fulfil their historical and ecological roles (Ceriani *et al*., 2019). This worldwide phenomenon causes population depletion that pushes the sea turtle to extinction. Population depletion possibly occurred when the sea turtles faced mortality more than they could produce new individual. For instance, in Atlantic Ocean (Bioko Island., Equatorial Guinea), western Atlantic Ocean (Aves Island, Venezuela), Southeast Asia (Sukamade, Indonesia; Terengganu, Malaysia), northern Indian Ocean (Gujarat, India; Hawke's Bay and Sandspit, Pakistan; Sharma, Peoples Democratic Republic of Yemen), and western Indian Ocean (Seychelles Republic), the subpopulation declines over 50%. While greater decline which is more than 80% can be seen in the eastern Pacific Ocean (Colola, México), western Pacific Ocean (Ogasawara Island, Japan), Southeast Asia (Berau Islands and Pangumbahan, Indonesia; Sarawak, Malaysia), north-eastern Indian Ocean (Thamihla Kyun, Myanmar), and Mediterranean Sea (Turkey)'s subpopulation. The absolute reduction is suggested in those case as all population depletion has taken place in less than three-generation (Seminoff, 2002).As mention before, this absolute reduction also occurred in Southeast Asia. Malaysia, Indonesia and Vietnam were an example of countries that were included in the Southeast Asia region. Six turtles that existed in this region were the Green turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricate*), Leatherback turtle (*Dermochelys coriacea*), Olive Ridley turtle (*Lepidochelys olivacea*), Loggerhead turtle (*Caretta caretta*), and Flatback turtle (*Natator* *depressus*). The previous study compiling the population size of those three countries demonstrate that sea turtles were under a great threat as illustrated in Table 2.1 below.

Table 2.1 Range and IUCN Red list status of sea turtle species occurring in Southeast Asia (Gomez & Krishnasamy, 2019).

Species	IUCN Status	Range States
Green Turtle	Endangered	Indonesia, Malaysia, Viet Nam
Hawksbill Turtle	Critically Endangered	Indonesia, Malaysia, Viet Nam
Leatherback Turtle	Vulnerable	Indonesia, Malaysia, Viet Nam
Olive Ridley Turtle	Vulnerable	Indonesia, Malaysia, Viet Nam
Loggerhead Turtle	Critically Endangered	Indonesia, Malaysia, Viet Nam
Flatback Turtle	Data Deficient	Indonesia

According to Table 2.1, the Critically Endangered (CR) refers to a species that was viewed as facing an extremely high risk of extinction in the wild. This status is given to a species that has undergone more or equal to 50% reduction in ten years or three-generation according to whichever is longer with a maximum of 100 years. Meanwhile, Endangered (EN) species was considered as facing a very high risk of extinction in the wild. Endangered species were characterised by equal or more than 20% of the individuals in twenty years or five generations whichever longer with a maximum of 100 years. In addition to that, the species that had a Vulnerable (VU) status display less than or equal to 10% of individual reduction in 100 years.

On top of that, there is another status called Data Deficient (DD) which are not categorised as a threat. Inadequate information for forming a direct or indirect assessment on the extinction risk of a species causes it to be marked as Data Deficient. A species was considered as Data Deficient based on its incomplete distribution and/or population status. Albeit the data on abundance and/or distribution are lacking, the species may be well studied and biologically well known. As a consequence, species that fall under this category are not targeted for conservation action. This might harm the species as if a species seriously threatened, while no conservation efforts are carried out due to unknown distribution and densities data. Thus, there is a great need in assessing and completing the data and analysis for the status of all species (IUCN Standards and Petitions Committee, 2019).

All species have their designated status as mentioned in Table 2.1. However, the status of sea turtles in the Southeast Asia region and Malaysia have some differences. All four sea turtle species end up considered as threatened species in Malaysia. Generally, most of the sea turtle population in Malaysia are declining except for the Green turtle population in Turtle Island Park, Sabah (Joseph, 2017). Leatherback turtles are considered locally extinct, Olive Ridley is on the verge of extinction, Hawksbill and Green Turtle are struggling for their survival (Gomez & Krishnasamy, 2019).

The extinction scenario of sea turtles in Malaysia is best defined according to a document produced by the IUCN Standards and Petitions Committee in 2019. Generally, a species is considered extinct (EX) when the last individual has died. The species was inferred as extinct when extensive surveys in the expected habitat, at appropriate times (seasonal, annual, diurnal), throughout its historic range unable to record any living individual. The surveys were carried out according to the species life cycles and life forms over a time frame. According to the survey, extinction can be divided into a few categories such as virtual, functional, ecological and local extinction. For instance, the virtual or functional or ecological extinction was a depletion that resulted in the low abundance of a species. Due to its small abundance, it no longer interacts significantly with other species although it still existed in the community (Rao & Larsen, 2009). In addition to that, local extinction or extirpation are defined as a condition where the last individual of a species in a specific area had died (Buckley *et al.*, 2019).

Narrowing this information down, the sea turtle in Terengganu which is one of the states in Peninsular Malaysia also at high risk. Between the 1970s and 1980s, the East Coast of Peninsular Malaysia, especially in Terengganu had been famously known for its unique and abundant nesting of sea turtles (Yeo *et al.*, 2007). Yet, this situation took the turn for the worse when a drastic decline in the sea turtle population occurred. Three species that declined dramatically in Terengganu were the Leatherbacks, Hawksbills and Olive Ridleys. According to current nesting numbers, the Leatherbacks, Hawksbills and Olive Ridleys of Terengganu were considered virtually extinct (Chan, 2006). Then, Leatherback Turtle became seriously depleted and eventually considered locally extinct where zero nestings were recorded after 2010 (Gomez & Krishnasamy, 2019). Although there is no historical data available, the Hawksbill and Olive Ridley depletion rates are equally severe to the Leatherback Turtle depletion rate (Chan, 2006). Green turtles in Terengganu is also classified as endangered by the IUCN Red List of Threatened Species (Tan, 2004).As mentioned before, one of the factors for severe depletion in Terengganu was the exploitation of sea turtle eggs. This eggs collection culture plays a part in sea turtle extinction by removing tens of thousands of eggs. This practice was pointed out as one of the factors for the Leatherback Turtle extinction in Malaysia (McLellan *et al.*, 2009). This practice, known as the tender system is continued as Terengganu adopted a mixed-conservation strategy. Under this conservation strategy, some sea turtle eggs are legally exploited under Turtle Enactment 1951, while other eggs were incubated for conservation purposes. To understand more about the impact of this conservation strategy, it is essential to look at the biological aspect of sea turtles, the legislation in sea turtle management and its sustainability in the upcoming subsection.

2.2 Biology of Sea Turtle

Sea turtles are susceptible to extinction under exploitation due to a few factors. Firstly, the sea turtle faces various threats when it migrates. The vast ontogenetic migrations of sea turtles take place between hatchling, juvenile and adult habitats. This migration continues during a cycle of reproductive migrations between foraging areas and suitable nesting beaches was ongoing throughout adulthood (Stokes *et al.*, 2015).

Migration leads to higher extinction risk of sea turtle as females return to nest in the vicinity of their natal beach. This process is known as natal homing (Naro-

Maciel *et al.*, 2012). Natal homing defined as a behaviour pattern where animals leave their geographic area of origin when young, migrate considerable distances and return to the area of origin to reproduce (Lohmann & Lohmann, 2019). The genetic evidence of natal homing had been seen in loggerheads hawksbills, leatherbacks and olive ridleys. Besides, a limited area of coastline in the western Gulf of Mexico also displayed natal homing of Kemp's ridley turtles (Lohmann *et al.*, 2013). Thus, if nesting beaches have no longer producing hatchlings, in the future there will be no nesting mothers, adult male sea turtle, hatchlings and eggs to continue the life cycle. This situation eventually leads to extinction. Moreover, migration often exposed species that have an aggregative behaviour and occurrence in geographically diverse habitats to heightened threats in comparison to non-migratory species (Stokes *et al.*, 2015). Absent of maternal care (Rusli, 2016) was one of few factors that increased threats for migratory species. Due to the threat, it was estimated that the survival rate of sea turtles was lower where only one in 1,000 to 10,000 hatchlings will survive to adulthood (Bean, 1980.).

Furthermore, the sea turtle was unable to combat the impact of exploitation because of its reproductive characteristic that leads to slower growth and reproduction. Although sea turtles have a long lifespan, about 75 years old (Florida Marine Research Institute, 2001) to 100 years for some species (Bean, 1980), it takes a longer time to develop sexual maturity. Hatchlings need an average of 20-30 years to grow into adults (Kemf *et al.*, 2005). Besides, sexually mature female sea turtles only produce limited numbers and sizes of clutches which varies between populations. United State Wildlife Service (2015) stated that a nesting mother can only lay nine clutches at most in a season. Adding to that, each clutch was laid with an interval of thirteen days (Mclellan *et al.*, 2009), this exposure increased the hunter’s threat to nesting mothers. Besides, the sea turtle was badly affected by eggs exploitation because they produce a limited number of eggs. A clutch usually only contains 65 to 180 eggs (United State Wildlife Service, 2015). Plus, it is estimated that at maximum, males only visit the breeding site 2.6 times more often than females (Hays *et al.*, 2010). Furthermore, even if males breed more frequently, females only nest in multi-year cycles of 1-9 years depending on the species (Mclellan *et al.*, 2009). This also resulted in a limited number of eggs that drive sea turtle to extinction under egg exploitation.

The extinction of the sea turtle population not only impacting the tourism industry but also impacting nature. Sea turtle was pointed as "ecosystem engineers" as they physically modify coastal landscapes (Allen, 2007). Firstly, the Green turtles cut off the less productive seagrass biomass, convert that material to fertilizer and redistribute it throughout the habitat. Apart from that, this shortening reduced seagrass meadow's capacity to entrap particles and lowering substrate recruitment, causing "substantial" changes in the physical structure of nearshore habitats. This shortening of the grass blades lessens the self-shading, temperature, sulphide levels, hypoxia and slime moulds infection which can damage the health of the seagrass meadow. The cropping and fertilization serve to elevate the seagrass meadow's health that brings an overall health benefit to the habitat (Teelucksingh *et al.*, 2010).

Secondly, the Hawksbills turtles also beneficial for the marine habitat. As coral reef resident in their large juvenile or adult lives, sponges are its primary food. Compare to coral, sponges can have higher biomass thus competing with corals for space in reef habitats. The existence of the Hawksbills turtle was beneficial in maintaining species diversity in reef habitats. The Hawksbills turtle helps reducing sponge populations to maintained species diversity. On the other hand, leatherbacks turtle are obligate jellyfish consumers. The leatherback is capable to consume large numbers of jellyfish daily, up to its weight. This help in controlling the jellyfish population from dominating an ecosystem. Jellyfish was capable to dominate the ecosystem and resist a return to the vertebrate dominated environment due to large ecosystem perturbations and overfishing. A shift to invertebrate dominated ecosystem threatens commercial fishery resources (Teelucksingh *et al.*, 2010). This shown that the existence of the Leatherback turtle help in maintaining the species composition in a marine ecosystem.

Sea turtle helps to provide marine nutrients back into the terrestrial ecosystem. Usually, the nutrient flow between terrestrial and marine ecosystems was unidirectional. The rain and rivers wash nutrients and minerals from land to the marine environment. Those minerals and nutrients were sequestered into marine food webs by several mechanisms such as phytoplankton production. The opportunities to move nutrients in the reverse direction from the marine environment to land ecosystems were rare. Nevertheless, according to a previous study, more than 70% of energy and nitrogen contained in sea turtle eggs returns to the sea in the form of living turtles. Despite that, that energy mostly remained on the land as unhatched eggs, shells or incorporated into the terrestrial and avian egg and hatchling predators (Teelucksingh *et al*., 2010). All this process proved that sea turtles are important prey and predator that was essential to the marine ecosystem.

The sea turtle importance had been increasingly recognized in marine and coastal ecosystems, thus their survivability was a vital aspect to look at. Hence, managing and conserve sea turtle is important. However, according to the previous reading, every country adopted various management strategies according to their priority between sea turtle conservation and its economic importance. Those practice around the world was described as in subsection 2.3.

2.3 Sea Turtle Eggs Management in the World

Some countries in the world conserve the sea turtle population 100% where they ban all sorts of exploitation of sea turtles such as developed country. On the other hand, some countries allowed a controlled amount of exploitation to improve their livelihood. This scenario can be seen in developing countries where their priority is torn between conservation and economic growth. Apart from that, there is a country that is lacking laws, protection, and management of sea turtles. This country typically the least developed or poor country, where they do not even have enough capacity to manage their natural resources, the capacity is concentrated to ensure the country's survival. This section will be focused on the example of countries that utilize sea turtle as a commodity.

Thailand is an example of a developing county that allowed a certain degree of exploitation to control the sea turtle population in nature. In the regulation, the nesting beach of sea turtles is declared as a concession area. For commercial purposes, the eggs were harvested at 70-80 % while only 20-30% were incubated under human care. The young sea turtles were released to the sea to keep natural populations according to the agreement between the government and the concessionaires (Chantrapornsyl, 1996). There is no evidence that this release was witnessed by the government officials, so no evidence that this release running as it should. This concession system is ineffective as the sea turtle population decrease. Nowadays, the sea turtle eggs concession has no longer existed as they were fully protected, however, due to economic struggle, local peoples still collecting the turtle eggs (Chantrapornsyl, 1996).

Besides that, in Ostional, Costa Rica a legal commercialized egg collection is carried out as it recognized as having a significant economic value by the community. Earns for one nest of eggs is equivalent to one-fourth of a month's salary of an agricultural or farm labourer. Moreover, egg collection has been the primary income source of 70% of households (Campbell, 2003). This culture claimed to be the best-known example of egg used, but nobody knows for sure how it impacts the natural balance of the terrestrial and oceanic habitat.

Moreover, the poor countries face a different situation where they have inadequate legislation specifically to protect sea turtle populations such as The United Republic of Tanzania. Although the Fisheries Act, 2003 mentioning the marine turtle conservation legislation, the reference to the protection of turtle nesting or foraging grounds, or the compulsory use of Turtle Excluder Devices (TEDs) in trawl nets are absent. The limited capacity faces by the Fisheries Division also becomes an obstacle in enforcing relating to turtle conservation in Tanzania. The laws are rarely applied as they have limited personnel and equipment such as vehicles and patrol boats, particularly in rural areas. In Tanzania, turtle eggs are a crucial source of protein, thus nest raiding was widespread as it is seen as not contravening the law. The turtle eggs are collected for domestic use and sold occasionally for TSh 20 – 100 per egg (equivalent to 0.0087-0.043 dollar) or TSh 50 – 100 per slice of an omelette (equivalent to 0.022-0.043 dollar). Based on this report, the nesting numbers face a significant decline over the past 10-20 years. The eggs are collected along the coast at Saadani, Temeke, Mapanya Island (Mkuranga), Rufiji, Kilwa, and Mtwara (Muir & Sense, 2005).

Although sites with effective monitoring conservation education have a reduction of egg harvesting, this practice is still occurring at other unprotected sites. Moreover, in Southeast Asia, egg collection is one of the main threats to sea turtle survival (Tan, 2004). In comparison to the management systems of other places in the world, Malaysia, one of the Asian countries have a mix-mode management system, some states allowed some degree of exploitation as an economic source, while others totally protected their sea turtles. Basically, in Peninsular Malaysia, less than 10% of eggs were retained for incubation in the early 1970s. The percentage of eggs protected in Peninsular Malaysia has been increased to approximately 50% in 2001 where the licensees marketed the remainder eggs (Tan, 2004). In addition to this, further explanation of sea turtle management in Malaysia was provided in subsection 2.4.

2.4 Sea Turtle Eggs Management in Malaysia

All the states in Malaysia have independent laws for sea turtle management. Some such as Terengganu allowed the egg collection, whereas some ban the egg collection such as Sarawak and Sabah. Serious depletion leads Sabah and Sarawak to this bold action in totally banning the sea turtle egg market. Sarawak implemented these drastic changes since their sea turtle populations declined steadily over years with little chance of recovery. Their chances for recovery were slim since over 4,100,000 eggs were harvested between 1967 and 1978 in Sarawak. Besides, they are only had little chance to recover since only 2% of the eggs laid in Sarawak were transplanted to the hatcheries (Tan, 2004). This uncontrolled harvest not only leads to lower survival chances but also population depletion where the annual sea turtle nest production drops to between 2,000 and 3,000 nests from 1970 to 2000 (Phu *et al.*, 2021). Thus, it is assumed that the annual production of sea turtle eggs between the year 1970 to 2000 were only between 130,000 to 540,000 eggs since every clutch (nest) usually only contains 65 to 180 eggs (United State Wildlife Service, 2015).

Plus, Sabah is also another state that implemented a total ban over sea turtle eggs harvesting. However, a total of over 6,000,000 eggs were collected in Sabah between the years 1965 to 1978. At the same time lightly over 2,700,000 were transplanted to hatcheries with a 66% hatching rate (Tan, 2004). Yet, the eggs collecting activity in Sabah come to an end in the 1970s when the Sabah Government compulsorily acquired the Turtle Islands from private ownership to provide total protection for the nesting turtles and their eggs on the islands. This huge step brings remarkable recovery for the sea turtle population in Sabah (Chan, 2006). This total ban boosts the population of sea turtles in Sabah as observed today. Today, although Turtle Island Park only included three islands namely Selingaan Island, Gulisaan Island and Bakkungan Kecil Island, it has the highest sea turtle nesting population in Malaysia. The annual nesting abundance of Turtle Island Park was more than 8,000 from the year 1991 to 2000. Then, the annual nesting abundance increased between10,000 to 15,000 for the past five years of 2017 (Phu *et al.,* 2021).

On the other hand, there are states in Malaysia that set rules to protect their sea turtles but have inadequate implementation such as Pulau Pinang. Pulau Pinang has helped in decreasing egg poaching by the establishment of the Kerachut Turtle Conservation Centre in 1995 and enforcement of the strict laws of the Penang State Government (Fisheries Methods of Turtle and Eggs, 1999; Wildlife Ordinance, 1997). Based on a study conducted by Salleh and Sah (2015), no nests were poached at Pantai Kerachut, but six nests were poached at Teluk Kampi. Poachers were unable to steal the eggs because the conservation centre is located on Pantai Kerachut. Pantai Kerachut was patrolled by two to four staffs all day. Besides, the nocturnal surveys were carried out on Pantai Kerachut from 1900 to 0600 hrs every night. In addition, the nests were also checked during the morning track counts at 0800 hrs before tourists entered the beach (Salleh and Sah, 2015). Yet, the nesting habitat of sea turtles in Pulau Pinang is still not actively protected although their nesting activity is dangerously low at a total of 165 nests from 2001 to 2009. (Phu et al., 2021). A newspaper report in 2014 reveals that the conservation centre has been able to identify a minimum of 40 nests in Pantai Kerachut. Plus, the centre also collected up to 6,000 eggs and protect them until hatched between January and April ("Conservation efforts pay off", 2014). Salleh and Sah (2015) revealed that eight green turtles landed, 106 emergences, 38 nests, and 158 digging attempts were made in one breeding season. Each nesting mothers were able to produce between three to eight nests. In a season, each nesting mother can lay 170 to 979 eggs.

However, the scenario is different in Terengganu where until today the tender system is continued. From 2011 to 2015, 26 nesting beaches were tendered, while only 12 beaches are protected as sanctuary or sea turtle protection reserve. This scenario begins when turtle eggs that once a protein supplement to coastal villages became a commercialized commodity. This triggered the conflicts of ownership that arose among the egg collectors when the exploitation of turtle eggs escalated. Then, the Turtle Enactment of 1951was implemented to resolve these conflicts. In this law, the exclusive right to collect eggs from each lot was exchanged with a tender offer for the highest bidder of divided nesting beaches lots. Back then, for the poorer state of Terengganu, sea turtle eggs are an important source of revenue (Liew, 2011). Then, the tender prices increased as the business of egg collection became lucrative. To be profitable, all the eggs are harvested and then not a single leatherback nest was spared from these licensed egg collectors (Liew, 2011).

As a result, the only eggs available for recruitment were those in state-run hatcheries. Although the tendering system was able to reduce illegal poaching and helped to provide statistics to the authorities, it failed to prevent the leatherback population from gradually decreasing. Terengganu state government finally enforced a complete ban on the sale of leatherback eggs in 1988 as the annual nesting numbers were less than 400 (Liew, 2011). Nowadays, the leatherback already locally extinct, but the tender systems continue until today for green sea turtle eggs and hawksbill sea turtles. Although the DoF requires the egg collector to sells back the eggs to the state-run hatchery, this buy-back system only lasts until 2018 due to a lack of funds. The buyback scheme can be defined as the government act to save the sea turtles by buying eggs from the collectors and manages them in a hatchery. Besides saving the sea turtles, this scheme also provides an income to the collectors (Gomez & Krishnasamy, 2019).

.

Thus, the current flow of sea turtle eggs in Terengganu was illustrated in Figure 2.1

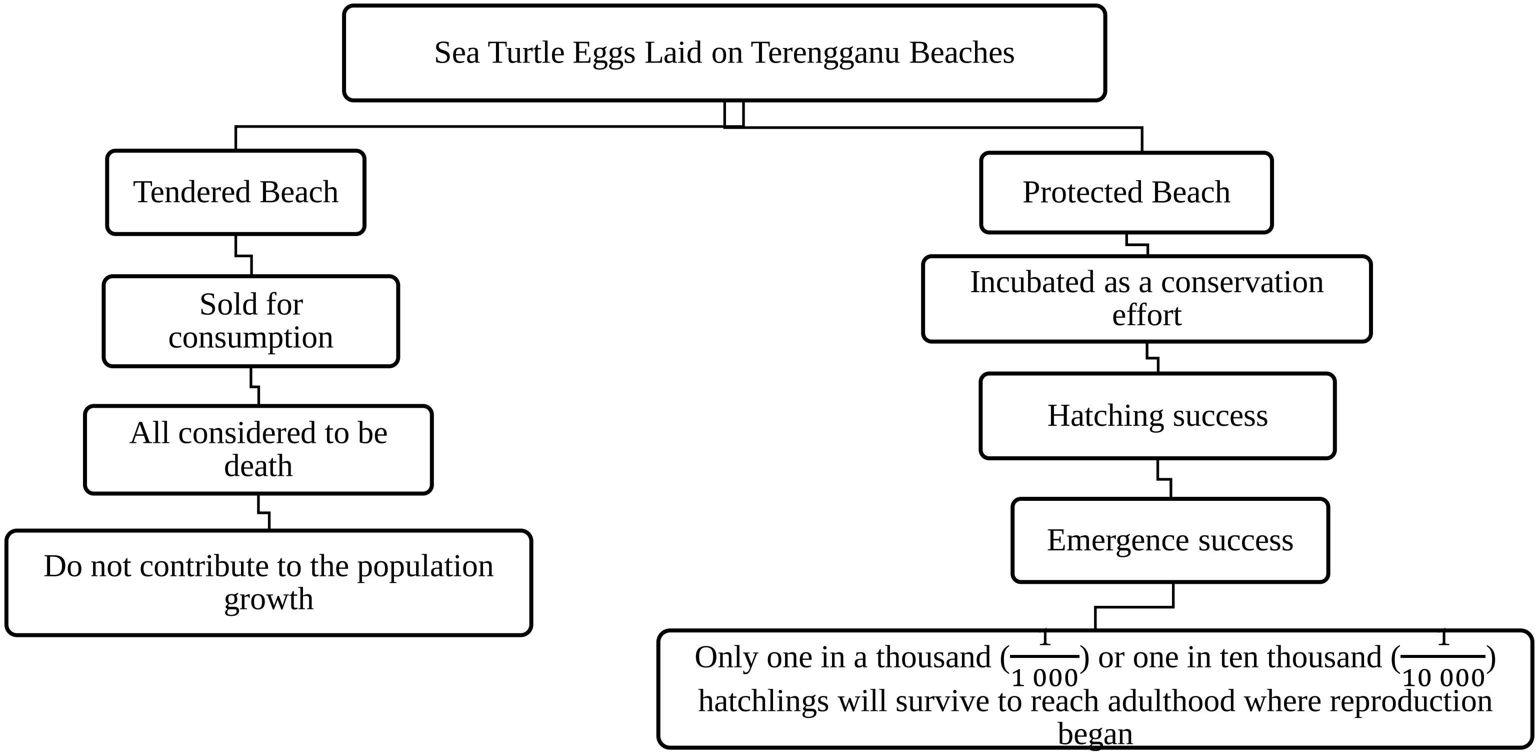

Figure 2.1 Journey of sea turtle eggs that had been laid in Terengganu.

The current situation indicated that the exploitation threat for sea turtles is greater than before. Due to lack of funds, instead of ending up in hatchery for incubation, all sea turtle eggs from 26 tendered beaches in Terengganu end up for human consumption. The tender system does help in solving the local conflict on sea turtle eggs ownership, but no research on the sustainability of this system was carried out. The population size of the sea turtle was getting lower, hence this research aimed to investigate if this mixed conservation strategy was sustainable and help conserving the sea turtle population in Terengganu.

2.5 Sustainability of Sea Turtle

Sustainability was crucial for the coexistence of human and sea turtles. Sustainability may be interpreted as keeping species or ecosystem well-being over a long and perhaps indefinite period. The sustainability concept originally invented in forestry where the harvesting should never exceed the new growth of the forest (Kuhlman & Farrington, 2010). If this concept applied to sea turtle eggs mix conservation strategy (where more than half of beaches were tendered and fewer beaches were protected) in Terengganu, some amendments need to be considered. The sustainability of sea turtle in Terengganu might be defined as the condition where the death rate from all factors such as natural death, accidental death and harvest (such as the eggs exploitation) does not exceed its growth rate.

Generally, research on the sustainability of sea turtle under the mixed conservation strategy in Terengganu was still lacking. One of the factors leading to this scenario was because predicting the sustainability of sea turtle was difficult. As a long-lived and migratory species, parameters such as lifespan, sex ratio, distribution, habitat preferences, growth rates, age at maturity, fecundity and survival rate for sea turtles were difficult to obtain (Kaska *et al.*, 2017). Those parameters that crucial for sustainability analysis was differed according to the environment and anthropogenic factors it faces. For example, the growth rate of sea turtle in Terengganu is assume to be lower than in Sabah. This assumption was made since Terengganu continue the sea turtle eggs exploitation compared to the Sabah government that took bold action for completely protecting the sea turtles and their eggs since 1970 (Chan, 2006). Nevertheless, sustainability cannot be determined just by looking at the surface level of interaction. Thus, an in-depth study was crucial to determine the sustainability of human-sea turtle interaction in Terengganu.

An in-depth study on the sustainability of interaction can be carried out by a few approaches. Those approaches must include social, economic and environmental as sustainability is almost always viewed in these three dimensions (Kuhlman & Farrington, 2010). For an environmental approach, the population abundance and the sustainability assessment of human-sea turtle interaction conducted. The population abundance was determined by using the formulae for nesting density, the number of current nesting mothers and prediction on future nesting mothers. The population abundance was further explained in the literature review, specifically in section 2.6. Subsequently, the sustainability assessment of human-sea turtle interaction was conducted using ecological modelling. Some ecological models were used in this research including:

(a) Exponential and Logistic model that facilitated the identification of growth curve possessed by sea turtle population in Terengganu

(b) Maximum Sustainable Yield (MSY) model and Modified Maximum Sustainable Yield Model (MMSY) that utilized to identify the maximum limit of sea turtle eggs harvest per season

(c) Lotka-Volterra Prey predator model and Tender system model to discern the population sustainability in this interaction

Those approaches were further discussed in section 2.7 to 2.9. Those approaches were adopted as various modelling had been used in intensive research to clarify complex ecological problems over the last several decades. Furthermore, this validates our research as the requirements for knowledge of the interactions between ecosystems and ecological properties have strongly increased in the modern ecological study. Moreover, due to the fast development of computer and information sciences, a lot of modelling techniques and algorithms have been developed and used for ecosystem management and ecological studies (Guo *et al.*, 2015).

This study not only covers the environmental approaches in determining sustainability, but it also touches on the economic approach that was linked with the social aspect as reviewed in section 2.92.9. This market analysis conducted according to the classification of Total Economic Value (TEV). TEV defined as a consistent approach in the economic evaluation of natural resources by considering natural resources within the ecosystems (Dushin & Yurak, 2019). The market analysis conducted according to the TEV because it can be used for natural resources in economic evaluation for the ecological crisis and overexploitation of natural resources (Dushin & Yurak, 2019). The market analysis involved:

(a) Used value, specifically the direct use (sea turtle eggs selling) and indirect use (activity generating income indirectly from sea turtle).

i. Direct used of sea turtle involve identifying the sea turtle egg market in Pasar Payang

ii. Indirect use of sea turtle mostly including the experience tourism such as hatchling release, accommodation related to sea turtle activities, and day trip activities

(b) Non-used values of sea turtles in Terengganu under the classification of existence value was also included in this research. The existence value of sea turtle includes the nest and turtle adoption fee. Those findings will be discussed and related to the social aspect of the local community in Terengganu.

2.6 The Abundance of Sea Turtle

A group of living organism composed of similar individuals who are capable of exchanging genes and interbreeding in a given environment known as a species. Yet, abundance was defined as the total number of individuals of a given species in an ecological community (Ochiaga, 2014). According to this concept, the population abundance of sea turtle in Terengganu can be considered as the total number of sea turtles in the ecological community such as the nesting beaches in Terengganu state. Knowledge of the abundance of sea turtles on nesting beaches in Terengganu was crucial for sea turtle conservation management. Accurate knowledge of population distribution and abundance were crucial to greatly improve the effective management of animal species (Cassey, 1999). For the sake of ensuring the effective management of sea turtle species, its population abundance had been monitored for decades. The previous study considered the nesting mother, total number of eggs, nest, hatchlings or its combinations as the point of references for nesting abundance. This section reviewed, some journal and written sources of sea turtle abundance in Terengganu according to years of its publication.

Hendrikson and Alfred (1961) among the pioneer that measured the population abundance for example by the numbers of eggs produced by each state in the East Coast of Malaysia. Turtle eggs production on East Coast was estimated by Hendrikson and Alfred (1961) at about 2 million in 1956. However, this probably underestimates (Siow, & Moll, 1982). The freshwater turtle namely the painted terrapins *(Callagur borneoensis*) were considered in this previous research as it laid its eggs on the ocean coastal beach (Effendy & Azizan, 2007). Although this research supply information such as the estimated annual yield of turtle eggs in Terengganu, it neglected the data on the actual number of the nests, eggs, nesting mother and distribution (such as nesting density per coastline length or area).

Table 2.2 The estimated annual yield of turtle eggs in Terengganu according to Hendrikson and Alfred (1961) for the year 1951 and 1956 (Siow, & Moll, 1982).

Species	1951	1956
Leatherback Turtle (*Dermochelys coriacea*)	853,700	294,000
Green Turtle (*Chelonia mydas*)	770,200	298,000
Olive Ridley Turtle (*Lepidochelys olivacea*)	40,500	240,000
Hawksbill Turtle (*Eretmochelys imbricate*)	Not Applicable	10,700
Painted Terrapins (*Callagur borneoensis*)	Not Applicable	13,500
Total	1,664,400	856,200

Apart from that, research by Siow (1982) also mentioned that a hatchery was set up by the Department of Fisheries in Terengganu (DoF) in 1961. This hatchery system has released more than 500,000 hatchlings into the sea (Chan *et al*., 1985). This illustrates that the number of hatchlings also used as a reference for population size. Although the number of hatchlings release was enormous, using hatchling as a reference for population size was less viable. This situation results from high predation face by the hatchlings where only one in thousand or one ten thousand hatchlings will survive predation and able to reaches adulthood.

Additionally, according to Chua (1988), between 1967- 1976, a total of 37,654 leatherback turtle visits the East Coast of Peninsular Malaysia, specifically the sampling site located in Rantau Abang, Terengganu. The population abundance of the breeding population in Rantau Abang was estimated at 15,525 females. Moreover, this previous research also mentioned that in 1972, the maximum nesting density recorded was recorded in the middle part of the nesting beach up to 886 nests per km (Chua, 1988). Even though this research is an early effort to evaluate the truth nesting density by taking into account the length of nesting beaches, this research only limited to Rantau Abang, not others part of Terengganu.

Subsequently, Limpus (1993) research also emphasizes the critical population depletion of sea turtle in Terengganu. This research asserted that since the 1950s, the leatherback population was depleted at a rate of more than 99%. Although there were about 2000 females turtles in the 1950s, not more than approximately 10-15 females will breed in Terengganu during 1993. Limpus (1993) also reveals that almost 100% of leatherback turtle’s eggs were harvested where effectively no hatchlings were produced by Terengganu. Also, the hatchery was established in 1961 but only incubate a small fraction of total eggs production in Terengganu. Only about 8366 eggs were incubated in Terengganu in 1961. The proportion of eggs laid that was removed to the hatchery increased over the following years. At maximum, 91,147 eggs were relocated to the hatchery in 1974. Limpus (1993) also stated that nesting numbers have greatly decreased in recent year. So, even with 100% of the eggs that were laid in Terengganu going to the hatchery, the number of eggs being incubated still suffer reduction.

Besides, 1,005,415 leatherback turtle eggs had been moved into the protected incubation of beach hatcheries in Terengganu since 1961. Over that 32 years, Limpus (1993) mentioned that 484,898 leatherback hatchlings released into the sea. The maximum number of hatchlings released was in 1976 with a total of 44,480 hatchlings. The average success in hatchlings production had been 47.4% yearly. This indicated that incubation success had been consistently very poor since 1988. However, this crisis may begin as early as the mid-1970s. Although approximately 500,000 hatchlings had been released from Terengganu hatcheries in the past 32 years, Limpus (1993) indicate that yearly it can only supply 16 new adults into the nesting population. This prediction was made by assuming that only one in a thousand hatchling will survive and reach maturity. Besides, this prediction on future nesting mother was made by assuming that most hatchlings produced will be females. Limpus (1993) conclude that leatherback is critically reduced and in imminent danger of extinction unless urgent conservation action is carried out.

Next, Limpus (1993) also revealed that there was a 60% depletion of the Terengganu-Pahang green turtle population since the 1950s. However, only long-term population data can be trusted for evaluating the stability of the population. The best forecast for the annual green turtle nesting population in Peninsular Malaysia varies approximately between 300-1,500 females. Most of these breeding occurred in Terengganu and Pahang. Besides, the highest proportion of green sea turtle eggs being placed into the hatchery and incubated in Terengganu was only about 45% in 1990.

This is more than the number of eggs incubated in 1991 and 1992 at about 24% and 44%. The recent level of hatchling production was about 50,000 to 80,000 green turtle eggs. This was insufficient to provide recruitment that able to maintain the current population levels. It is presumed that the current hatchling release rates possibly contributed to less than 100 adult female recruitment annually under one in a thousand survivorship. This is because effectively no green turtle hatchlings had been produced in many years from these rookeries and current small numbers of hatchlings released. Limpus (1993) conclude that the Green turtle nesting population in Peninsular Malaysia is severely depleted. The hatchlings production was insufficient to guarantee the long-term survival of the green turtle population. To assured this population survival, Limpus (1993) suggested strong conservation management.

Not only green and leatherback turtle but Olive Ridley turtles also severely decline more than 95% since the late 1950s. Although Northern Terengganu had the best nesting concentration within Malaysia, its nesting number had depleted as severe as the leatherback turtle. Limpus (1993) also stated that in 1992, it is estimated that there was less than 20 nesting female of Olive Ridley turtles. Plus, there are zero reasons to consider that the reduction of breeding turtle in this species will not continue. The situation worsened as most Olive Ridley turtle's eggs were collected by licensed eggs collector and sold for human consumption. Besides, in Peninsular Malaysia, there is no concerted effort to ensure the large-scale production of Olive Ridley turtle. Limpus (1993) pointed out that in Terengganu, there has been a small but increasing proportion of Olive Ridley turtle eggs purchased by the Department of Fisheries (DoF) in recent years. The highest proportion of eggs being incubated was 38% in 1991. However, only 28% of Olive Ridley turtle was incubated in 1992. As a result, very few hatchlings have been produced in Terengganu for the past 30 years. Possibly, only approximately 20,000 hatchlings were produced within that period. This was an implication of the low effort in eggs incubation and lowered incubation success. In Limpus (1993) research, it is identified that the annual production level of hatchling was less than 2,000. According to one in a thousand survival rate, this will only contribute to less than 2 adult female recruitment annually. Limpus (1993) deduced that the Olive Ridley turtle population in East Coast Peninsular Malaysia is critically declining and in imminent danger of extinction except if urgent conservation action is carried out.

Limpus (1993) also touch on the hawksbill turtle status that was significantly depleted in Peninsular Malaysia. Anyhow, the dilemma for assessing the status of this species was limited information. Based on annual egg production data supply by Rahman as in Table 2.3, less than 10 female hawksbill turtles nesting in Terengganu.

Table 2.3 Olive Ridley Turtle's eggs production in Terengganu from 1984-1992 according to Rahman (Limpus, 1993).

Year	Egg Laid	Eggs to Hatchery	Hatchlings
1984	955	-	-
1985	1,465	-	-
1986	13,285	318	130
1987	1,395	852	352
1988	7,086	475	393
1989	2,095	920	463
1990	8,541	6,801	3,904
1991	3,351	2,643	1,387
1992	3,322	2,377	1,365

Based on Table 2.3, Limpus (1993) presume that the hatchling production was insufficient to ensure the long-term survival of this population. He suggested a good prospect of strong conservation management to ensure its survival. Although Limpus (1993) provide an insight of all four species, the data was less standardized where some data was provided with the population graph only without the table of exact values. In addition, he suggests strong conservation management, but the accurate and precise harvest limit was not mentioned (exact number or mass of eggs can be harvest). Last but not least, this study focused on population prediction just for 1993 where it was a lack of long–term prediction and plan of population size as ecological modelling and software were not applied in this research.

Furthermore, Chan (2000) also mentioned that all the last attempt to save the Leatherback turtle over the final years of the millennium cannot stave off its depletion. This journal also mentioned the prediction of this species extirpation by 2003. The day of complete annihilation appears to draw even nearer as in 1998 only 19 nests were laid. The condition became critical as in 1999, only nine nests were laid in Terengganu. Likewise, Chan (2006) also issued that the most dramatic declines in Terengganu were exhibit by the leatherbacks, hawksbills and Olive Ridleys turtles. Those three species were considered virtually extinct. The leatherback population show that its yearly nesting has plummeted from 10,000 in 1950 to less than a dozen in recent years based on the available record. This statement was supported by Hamann *et al.* (2006) that pointed out the population has declined from approximately 5,000 nests per year in the 1960s worsen to less than 10 nests per year in the 2000s.

Moreover, no historical data available for the hawksbill turtle and Olive Ridley turtle in Terengganu, however, the declines are no less dramatic than the leatherbacks. On the other hand, the green turtle population of Terengganu have not been monitored sufficiently. Thus, no clear picture can be provided, yet, anecdotal evidence suggests declines of over 80% where the current annual nesting density average only 2,000. Chan (2006) also illustrated the nesting trend of Leatherback (Figure 2.2), Hawksbill (Figure 2.3), Olive Ridley (Figure 2.4) and Green turtle (Figure 2.5).

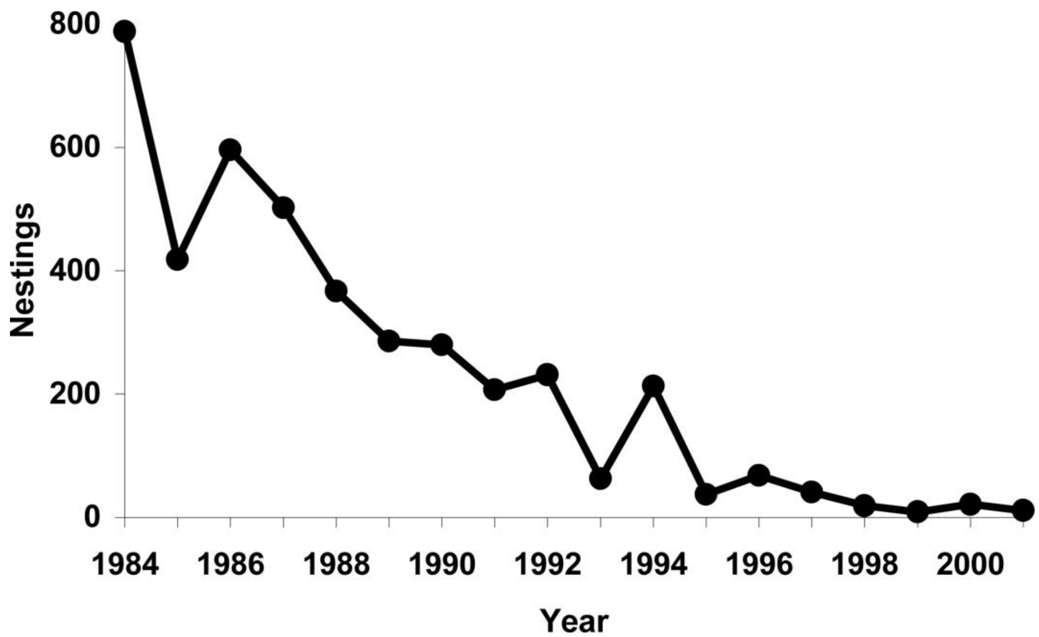

Figure 2.2 Nesting trends of the Leatherback turtles in Terengganu according to Chan (2006).

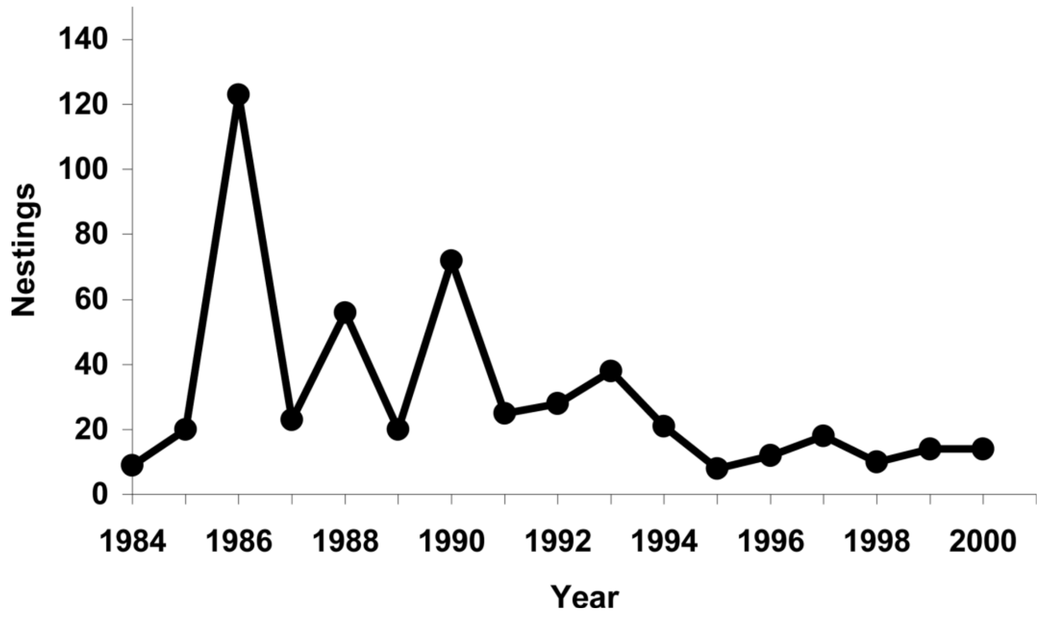

Figure 2.3 Nesting trends of Hawksbill turtles in Terengganu according to Chan (2006).

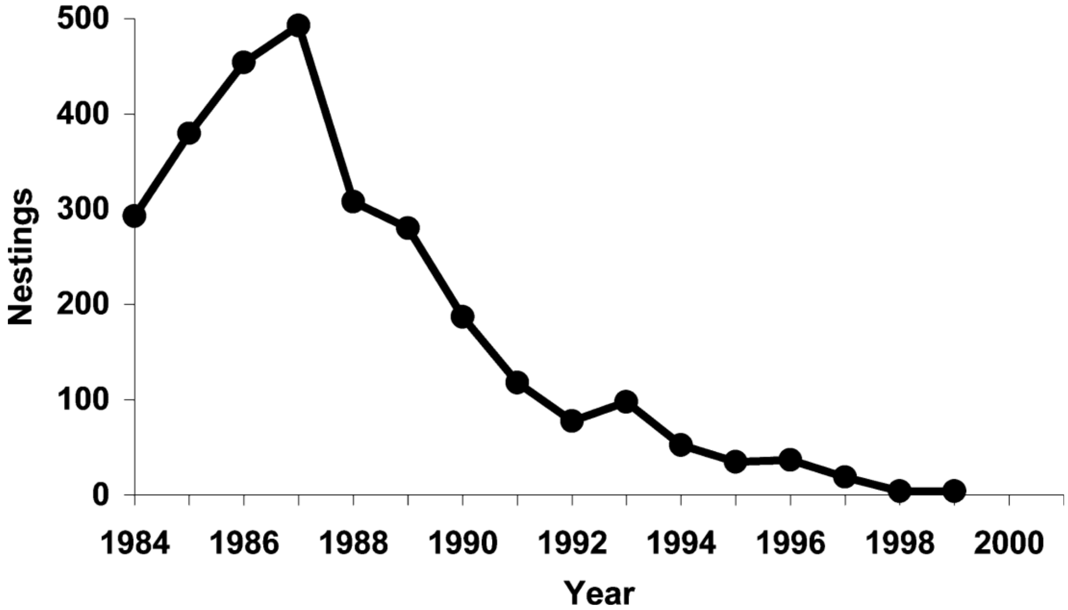

Figure 2.4 Nesting trends of Olive Ridley turtles in Terengganu according to Chan (2006).

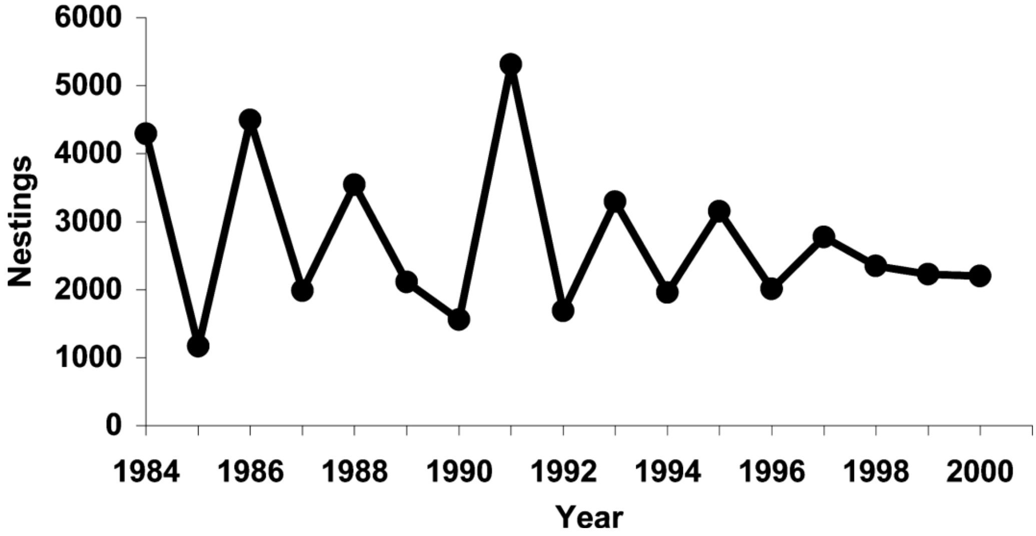

Figure 2.5 Nesting trends of Green turtles in Terengganu according to Chan (2006).

Next in the list was research focussed on a specific nesting beach namely Chagar Hutang, Redang Island in Terengganu was also carried out by Chan (2013). This study indicates that the major nesting species in Chagar Hutang was the Green turtle. The Green turtle was accountable for 98.2% of the clutches deposited on Chagar Hutang from 1993-2008. Only 1.8% of the nesting observed over the 16 years belong to Hawksbill turtle as it was comparatively rare. The total clutches number recorded for Green turtle species fluctuated from as low as 221 in 2005 to as high as 687 in 1999. Within 16 years period, a total of 6,947 clutches were deposited on Chagar Hutang. As a contradiction, the Hawksbill nesting population was a remnant where the clutches deposited as low as 0 in 2003 and as high as 21 in 1996. According to trend analysis, within 1993–2001, there was a sharp decline in sea turtle nesting. Regardless of that decline, a steady increase was noted from 2004 onwards. Within these 16 years, a total of 126 clutches were deposited.

Apart from that, Chan (2013) also mentioned that the conservation project in Chagar Hutang had been able to commit at 80% of the clutches incubation for both green and hawksbill turtles. This overall percentage of the clutches incubation was considered high. Nevertheless, during 1993-1996 (four initial conservation years), the project was given a quota by its sponsor for egg purchase leading to a relatively lower level of protection. Besides, the level of protection was lower as to procure 100% egg purchase from the licensed egg collectors was not possible. From 2005 onwards, the level of green turtle's egg protection rose to 100% when the beach was declared a turtle sanctuary. This ends decades of egg exploitation in Chagar Hutang. Despite that, the conservation project had incubated 100% of hawksbill turtle's eggs from 1998.

Aside from that, Chan (2013) also indicated that the total number of clutches that have been protected was 5561 for green turtle and 106 for hawksbill turtle within 16 years. Within 1993-2008, a total of 493,290 green turtle eggs had been incubated and 387,322 hatchlings were released to the ocean. Besides, the total average emergence success was 78.5% and the total average hatching success was 81%. Chan (1993) also brings upon the total number of eggs incubated within 1993-2008 at about 13,586. This resulted in 8094 hatchlings that released back to the ocean. The overall emergence success for hawksbill turtle was 59.6%. Furthermore, the hatching success rate of hawksbill turtle in Chagar Hutang was 63.6%. Yet, in 2003, no hawksbills nested leading to zero hatchling production.

Furthermore, Chan (2013) also touched on the number of the adult population represented by tagging individuals over the 16 years. A total of 928 tagged individuals for sea turtle species. Yet, only 17 individuals of Hawksbill turtles were tagged. In proportion, newly tagged turtles higher than the remigrants in most years. Only three turtles bore old tags first applied in 1993 out of 113 nesting mothers. Chan (2013) also mentioned that an average of 32% of total nesting turtles accounted over the 16 years was remigrants. Each year, the total number of green turtles landed for nesting ranged from 44 in 2005 to 140 in 1993. Annually, an average of 85 turtle nests over the 16 years. Chan (2013) provided crucial information on sea turtle abundance in Chagar Hutang, which was a protected beach. However, it failed to represent an actual situation and possibly population oppression at the tendered beach.

Again, Abd Mutalib *et al.* (2015) also conducted a study focusing on nesting ecology and behaviour of turtles in Setiu, Terengganu. This study also included the number of eggs clutches laid in selected beaches namely Telaga Papan (TP), Mengabang Sekepeng (MSK), Kuala Baharu Selatan (KBS), Kuala Baharu Utara (KBU), Kuala Tok Cha (KTC), and not available (N/A). From 2007 to 2012, 719 nesting attempts were recorded in total with an average of 17.786 nestings. Telaga

Papan had a significantly higher number of successful nesting attempts compared to other beaches. According to years, the highest number of successful nesting attempts in Setiu was in 2012. Plus, 2008 recorded the lowest numbers of successful nesting attempts. Nonetheless, no significant difference in successful nesting attempts can be observed between years.

Finally, Abd Mutalib *et al.* (2015) also specify that 51.3% of successful nesting attempts in 2012 in Setiu occurred at Telaga Papan beach. Moreover, Kuala Kuala Tok Cha with 21.9% of successful nesting attempts was in second place. This followed by Mengabang Sekepeng (18.4%) and Kuala Baharu Selatan (4.5%). The least successful nesting attempts at about 4.0% were recorded in Kuala Baharu Utara. Further detail on the number of successful nesting was included in

This study was successful in determining the hotspot for sea turtle nesting by incorporating the ecological and behavioural data besides relating it to the physical parameter of each plot of the beach. Yet, this research lacks information on successful hatching rate, emergence rate, and hatchling and adult population size.

Table 2.4 Number of Green turtle nests at Setiu according to beaches and year (Abd Mutalib *et al.*, 2015).

Year	**Yearly sum of nesting**	**Beach**	**Number of nesting**
2007	75	TP	50
		MSK	0
		KBS	25
		KBU	0
		KTC	0
		N/A	0
2008	28	TP	27
		MSK	0
		KBS	0
		KBU	0
		KTC	0
		N/A	1
2009	99	TP	71
		MSK	4
		KBS	17
		KBU	4
		KTC	3
		N/A	0

Year	Yearly sum of nesting	Beach	Number of nesting
2010	141	TP	85
		MSK	34
		KBS	11
		KBU	11
		KTC	0
		N/A	0
2011	175	TP	78
		MSK	19
		KBS	43
		KBU	3
		KTC	32
		N/A	0
2012	201	TP	103
		MSK	37
		KBS	9
		KBU	8
		KTC	44
		N/A	0
Total	719		

Notes: TP: Telaga Papan, MSK: Mengabang Sekepeng, KBS: Kuala Baharu Selatan, KBU: Kuala Baharu Utara, KTC: Kuala Tok Cha, N/A: not available.

In term of population abundance, the current study carried out for this Master thesis took into account the nesting density for both tendered and protected beaches. To obtain the nesting density, the number of sea turtle eggs laid were related to the length of coastline for each beach. This ensures that the beaches were evaluated according to their true productivity. This method is known as the absolute density which refers to a quantitative measure of numbers per unit area (Cassey, 1999). Besides, this section also pointed out the current number of nesting mother in Terengganu. In addition, this study also predicted the number of future nesting mother in Terengganu. Both numbers of current and future nesting mother were important to evaluate the continuity and sustainability of sea turtle in Terengganu.

2.7 Growth Curve of Sea Turtle

For individuals and species, growth is one of the most essential measurable life-history parameters. Understanding growth is fundamental to understanding life histories, demography, ecosystem dynamics, and fisheries sustainability according to recent comparative and analytical work. Regardless of species, growth correlates with many life-history traits including natural mortality rate, lifespan and reproductive allocation. Plus, growth also correlates with traits that also influence the response of species to exploitation (Pardo *et al.*, 2013). This indicated that growth curves can be used to evaluate the impact of species exploitation.

The growth curve is a powerful graphic tool to display growth rate or growth velocity over time (Cole, 2012). The wide array of models useful for describing changes in population, body mass and other parameters that experience growth over time used growth curve. The growth curve was among the most widely studied and well-developed mathematical and statistical techniques in all scientific research (Höök *et al.*, 2011). Thus, analysing and incorporate the growth curve into the ecological model is important to evaluate the sustainability of sea turtle in Terengganu that was exploited under its mixed-conservation strategy.

This thesis presented an ecological growth model that was considered as the mechanistic models and theories. Mechanistic model and theories were different approaches that fit the data and develop a description of processes underlying growth that takes place in an organismal system. This model was usually derived from a differential equation relating to the growth rate (dy/dt) to size (y). This mathematical relationship illustrated the mechanism that was governing the growth process (Karkach, 2006). This is possible as mathematical modelling was interpreted as a collection of equations based on quantitative description of a real-world phenomenon, it is created in the hope that the predicted behaviour will resemble the actual one (Zabadi *et al.*, 2017). Not only used extensively for somatic growth, but a large number of growth functions such as the monomolecular, logistic, and Gompertz ones have also been derived by this approach (Karkach, 2006).

Two general mathematical models used to evaluate the population growth in the ecology field were the exponential and logistic growth model. The exponential model proposed in 1798 by Malthus. This simple model was capable of providing an adequate representation of population growth in an ideal environment with unlimited resources. He assumes that the population grows at a rate proportional to the size of the population. However, in 1845, Verhulst proposed the logistic growth model. He observed a different situation occurred in nature where when a population size increase, the population growth rate gradually decreases due to limiting factors. Eventually, the population became slower and stop where no more future population growth can be observed (Zabadi *et al.*, 2017).

Although both models originated from observations of the biological reproduction process (Zabadi *et al.*, 2017), each theory differs according to the characteristic of species used as references in composing the model. Generally, each species possessed either $r-$ or $K-$ selection characteristic that impacts its growth rate and pattern. MacArthur and his colleagues proposed and popularized the theory of $r-$ and $K-$ selection in the 1960s and early 1970s. This selection theory arose when MacArthur and Wilson (1967) envisioned an island. Firstly, due to the island abundant resources, it was colonized. Resources then became limited as the environment became fully occupied. They then concluded that the kind of selection that organisms experienced would change over time and would be associated with the amount of density-dependent regulation or resource limitation experienced by a population (Reznick *et al.*, 2002).

Furthermore, MacArthur and Wilson also consider $r-$selection as the selection that would favour individuals with a high capacity for an increase in population size in an expanding population. On the other hands, the organisms that would experience density-dependent mortality and would be consistently exposed to the intense intraspecific competition is defined as and $K-$ selection. This selection characteristic was termed after the parameter for carrying capacity, K. The $K-$ selection had traits that favour individual persistence in the face of scarce resources and high intraspecific competition. This condition prevails when populations remain close to their carrying capacity (Reznick *et al.*, 2002). Other typical traits of organisms with $r-$ and $K-$ selection was also described in Table 2.5

Table 2.5 Comparison of the typical traits between organisms possessed $r-$ strategies (such as rabbits and sparrows) and $K-$ strategies (for example the elephants and parrots) according to Heylighen & Bernheim (2004).

Trait	$\boldsymbol{r-}$ **organisms**	$\boldsymbol{K-}$ **organisms**
Life expectancy	Short-lived	Long-lived
Size	Small	Big
Endurance	Vulnerable, weak	Well-protected, robust
Maturation rate	Fast	Slow
Ability to take risk	Prone	Risk-averse
Type of Exploiter	Opportunistic	Consistent
Intelligence	Less intelligent, experienced	More intelligent, experienced
Sex drive	Strong	weak
Age at sexual maturity	Early	Late
Number of offspring	Large	Small
Offspring size at birth	Small	Large
Maternal/paternal care	Little care	Much care
Population size	Variable	Stable

Yet, some organisms such as sea turtles possessed mixed traits from both $r-$ and $K-$ selection. As listed previously in subsection 2.2, the sea turtle was considered a long-lived animal. Although sea turtle returned to the same nesting beach they were born to lay eggs, they may be considered opportunistic exploiter as they migrate and have different diet according to their life stages and species. Sea turtle can be considered intelligent organism due to their ability to detect and interpret cues for moving and identifying dangerous situation. For instance, the multisensory cues (visual, olfactory and magnetic field) were used by turtle hatchlings while crawling towards the sea (Fuentes-Farias *et al.*, 2011).

Adding to that, according to subsection 2.2, the sea turtle might be considered to have a weak sex drive as a female can only nest in multi-year cycles of 1-9 years depending on the species. The literature review did mention that the male sea turtles only breed twice frequent than female at most, however, numbers of offspring still depend on the numbers of eggs produced by the female. In addition, sea turtle has a slow maturity where the age of sexual maturity in sea turtle was late. Besides, although the numbers of eggs (offspring) were large, it produced hatchling that considered to be small in size. Moving to the next point, sea turtle only has little maternal care where the nesting mother chooses a good nesting site for laying eggs to increased hatchling success. However, the nesting mother didn't monitor or protect the eggs and hatchlings. Thus, the population size was highly variable according to the environmental factor (such as weather, sea-level rise and others) and anthropogenic threat (eggs exploitation, adult exploitation, death by fishing gear, death by pollution such as plastic, oil and others). Law enforcement and conservation also shape the sea turtle population size.

Previously, there were many studies conducted on the growth curve of animal and plant using the exponential and logistic model. However, there was a lack of study on the impact of sea turtle exploitation on the growth curve of sea turtle based on numbers of individuals facilitated by exclusively exponential and logistic growth model. A previous study on sea turtle growth focussed on their physical growth such as weight, size, carapace length, life stages and others such as Crouse *et al.* (1987), Warden *et al.* (2017), Becker *et al.* (2019), Hatch *et al.* (2019). Those study mostly assume population growth is equal to the sea turtle physical growth, Yet, the study on long-term population size prediction that used the number of individuals as the parameter has lacked. This research utilized growth in the number of individuals to display the impact of eggs exploitation on their growth curve before discussion on this interaction sustainability. In chapter 4, numbers of eggs were used to reflect the numbers of the future individual (future eggs laid in Terengganu) using both logistic and exponential model. The growth curve that reflected the number of eggs close to the historical record as mentioned in section 2.6 was concluded as the growth curve possessed by the sea turtle population of Terengganu under eggs exploitation.

2.8 Maximum Harvest of Sea Turtle Eggs

Harvest can be expressed as the animal or plant removal from a population, normally by humans (Sinclair *et al.*, 2006). Among the general harvest model used in population management was the Maximum Sustained Yield (MSY). MSY was defined as the harvest that intersects the peak of the hump-shaped net recruitment curve (Sinclair *et al.*, 2006). MSY was useful for regulating the harvest limit because it was capable of demonstrating the highest theoretical equilibrium yield that can be continuously taken from a stock under existing (average) environmental conditions. Specifically, MSY was able to point out the highest catch while allowing the population to sustain itself indefinitely through somatic growth, spawning, and recruitment. (Tsikliras & Froese. 2018). However, based on the literature review, no research on sea turtle eggs harvest based on tender or concession system had been done before.

However, there are researches on the maximum sustainable yield of Hawksbill turtle harvest. The first one was a fisheries model for calculating the sustainable harvest level of sea turtle in the Cuban Archipelago was presented by Dr Takeyuki Doi in the year of 1992. This research was used as a petition for the reclassification of Cuban Hawksbill by CITES (Heppell *et al.*, 1995). In the defence, based on this research, members of the Japanese Bekko Association and proponents of renewed trade in Cuba argued that the Hawksbill turtle population in the Cuban Archipelago capable of sustaining few thousand individuals harvesting each year as it is large enough. Besides, they argued that the Cuban sea turtle population "closed" to immigration from other Caribbean islands. Few assumptions were made as a basis in this model including only Cuban rookeries turtle feed on adjacent reef habitat because the Cuban Hawksbill turtle population is stable and nonmigratory. By this assumption, they further assume that the sea turtle harvest in Cuban feeding areas won't affect other Caribbean nesting colonies or nations. The DOIRAP estimate that the sustainable yield of Cuban Hawksbills is at about 5,500 turtles annually based on the growth rate estimated by Doi *et al.* (1992) and fishery data from Cuba (Heppell & Crowder, 1996). This research was doubted as Heppell *et al.* (1995) mention that Doi and his colleagues do not specify the data source used by them. Doi and his colleagues failed to provide the sample sizes and sources used for fecundity, sex ratio and yield estimation. Hepell *et al.* (1995) had repeated the analysis, the conclusion made was that for sustainable harvest level analysis, the current model was insufficient. Heppell & Crowder (1996) that also repeated the experiment had stated that the Cuban sea turtle population was overfished as the harvest level was 33% more than the maximum harvest rate. Reading both sources, it can be concluded that using the Von-Bertalanffy growth curve was unsustainable for predicting the sustainable yield of the sea turtle. Besides, there are many critical assumptions made and integrated into the model. Moreover, some parameter was only assumed and calculated based on the preliminary survey on a limited area. Some over-estimation arose as those studies neglected the probability that the turtle in the feeding ground does not belong to the other rookeries /nation as stated by Heppell & Crowder (1996).

The model stated in the previous paragraph was far from adequate to test the annual maximum harvest rate of sea turtle eggs in Terengganu. As far as the literature review, there had no other model have been tested or modified for sea turtle eggs. As mentioned in the previous literature review which is subsections 2.3 and 2.4, other countries or states just stop sea turtle eggs harvesting when the sea turtle population decline already became apparent. Thus, in this thesis, the MSY model was modified to become the Modified Maximum Sustainable Yield (MMSY) based on sea turtle biology literature in subsection 2.2. This is because when stock size is low, it is vitally important to set a management framework according to harvest control rules that ensure fishing mortality rates below those associated with maximum sustainable yield. This can revamp the fish stocks to the level that is capable of producing maximum sustainable yield (Shelton & Morgan, 2014).

2.9 Prey-predator Interaction of Sea Turtle Eggs Harvest

Although the reproductive output of sea turtles is high, their offspring have a low survival rate. It is estimated that only one in a thousand hatchlings will survive to reach sexual maturity (Bean, 1980). Mammals such as raccoons, skunks, opossums, mongooses, coatis, domestic pigs, dogs, jaguars, and other animals like the monitor lizards (*Varanus*), ghost crabs, ants, fly maggots consume the green turtle throughout their life-cycle. Immediately after they pip the egg-shells, some hatchlings are invaded by ants, maggots, and mites. When they reach the nest surface, they were chased by the crab, mammals, and birds. The main predators in the water are sea birds and carnivorous fishes. This can be proved with the discovery of hatchlings in the stomach of a dolphin (*Coryphaena hippurus*), and giant grouper (*Epinephelus, lanceolatus*) that can devour entire juvenile green turtles. Until the turtle reaches a size big enough to avoid being swallowed, the predation will continue. The most formidable enemy of green sea turtles throughout life cycles are sharks (Fischer *et al*., 1990). Yet, nothing can be parallel to the rate of sea turtle population decline due to human exploitation. An obvious depletion in the turtle population was resulting from intensive turtle harvesting since the first human settlement and that became routine (Allen, 2007).

For this reason, sea turtle eggs exploitation also happened in Terengganu way before up to today. Nevertheless, no evaluation on the sustainable level of human-sea turtle prey-predation in Terengganu had been carried out. As far as the investigation on literature source had been conducted, no other country or state had attempted to evaluate the prey-predator interaction of human and sea turtles under egg harvesting. Hence, this section will discuss the prey-predator interaction in the exploited marine fish population. For instance, Spencer & Collie (1996) study the predation of spiny dogfish on groundfish species, the Georges Bank haddock (*Melanogrammus aeglefinus*). A realistic model was developed in their study to facilitate the evaluation of the prey-predator system by considering the alternate prey. This is due to the extensive seasonal migrations on a spatial scale undertaken by the dogfish in the Northwest Atlantic. The spatial scale migration was on a much larger scale than some of their prey's habitat, making them include the possibilities of alternate prey. The study was set for three different conditions, (i) The prey is harvested, the predator is not harvested, (ii) The predator is harvested, the prey is not harvested, and (iii) The predator and the prey are harvested. As the result, it is identified that when the predator is low, the abundance of the predator can increase by consuming the alternate prey. This pattern was consistent with dogfish–haddock abundances based on observation. Plus, it is known from the findings that the prey species can be at a high equilibrium in a longer time (Spencer & Collie, 1996).

The research conducted by Spencer & Collie (1996) might be working great for marine fish. Yet, the tender system and sea turtle eggs harvesting in Terengganu behave differently than prey-predator interaction between marine fishes. Thus, the Lotka-Volterra prey-predator model was modified into the Tender System model to evaluate the impact of sea turtle egg harvesting under a mixed-conservation system in Terengganu. Besides, it is used to set a new annual limit for prey-predator interaction level in this mixed conservation research strategy.

2.10 Market Survey of Sea Turtle

The market survey of economic activity associated with the sea turtle in Terengganu in this thesis was facilitated by Total Economic Value (TEV). The sea turtle in Terengganu helps to generate income by the consumptive way (sea turtle eggs harvesting) and non-consumptive ways such as tourism-related activities. However, based on the literature review, it is clear that the evaluation of total economic value for sea turtles has not been carried out thoroughly in Terengganu. Only the investigation on the Total Economic Value (TEV) of Redang Island Marine Park, Terengganu in 2012 reveals that it is worth RM 354 million whereas it is worth RM 1.049 billion Perhentian Island Marine Park (Kamarruddin Ibrahim *et al.*, 2013). The TEV of Perhentian Island Marine Park and Redang Island Marine Park in 2015 was determined as RM1.049 billion and RM354 million. (Malaysia Marine Park Department, n.d.).

Previous literature referred to Hendrickson & Alfred (1961) research that highlighted the drastic drop of the sea turtle eggs production in the East Coast region that was originally two million in 1956 to only a million. Yet, the sea turtle eggs market value at that time was US$ 240,000. Besides that, the east coast state government also collected another US$ 98,404 as revenue from leasing the egg collecting beaches to the highest bidder (tender system) in 1978. This total tender fee collected by the state government can be further brake down into Kelantan (US$ 985), Terengganu (US$ 96,322) and Pahang (US$ 1,097) (Siow & Moll, 1982). Besides, based on Troëng & Drews (2004) research in Rantau Abang, the gross revenue to egg collectors from the sale of leatherback eggs to the Fisheries Department in 1984 at US$54,867 dropped to only US$158 in 2002. This was caused by the 99% decline in nesting activity. 99% of the Leatherback turtle population between 1956-2002 (Troëng & Drews, 2004). Furthermore, Chan (2006) estimated that the yearly income generated by the state government from the tender fee was no more than RM100,000 or US$27, 000.

Adding to the previous research, the tourism activity was also generating income from the existence of sea turtle in Terengganu. For instance, SEATRU UMT, WWF-Malaysia, the Lang Tengah Turtle Watch (LTTW) at Lang Tengah Island and Bubbles Dive Resort at Tanjung Tukah Beach, Perhentian Island was among the organisation that involved in tourism and conservation program in Terengganu (Jani *et al.*, 2019). Yet, no research compiles the indirect/non-consumptive value of sea turtle in Terengganu such as under the experience tourism which included the hatchling release, accommodation and day-trip.

On the other hand, there is an existence value study that focussed on the willingness to pay had been done in Terengganu. Kamaludin *et al.* (2018) mentioned that in the form of a surcharge to the monthly water bill, the public was willing to pay 2.29% from their bill as the sea turtle conservation fund. Another research was conducted specifically at Rantau Abang Turtle Sanctuary between a targeted group namely group A (residents), group B (visitors to Rantau Abang Turtle Sanctuary) and group C (tourists). The willingness to pay for Turtle Conservation and the Financial Viability of Rantau Abang Turtle Sanctuary, Terengganu have differed between the group about RM 1 0.02 (residents), RM1 07. 1 1 (the visitors) and RM6 1 .93 (the tourist) (Samdin, 2002). Those two research do mention the willingness to pay however, it does not include the willingness for the public or tourist to pay for sea turtle continue existence on the term of nest, eggs and turtle adoption.

Terengganu, due to lack of TEV evaluation in for Terengganu sea turtle population, this literature also review the TEV research on sea turtle has been carried put in Sabah. Based on field surveys conducted in May 2014 with marine stakeholders, including 60 fishing households, 9 resorts, and 7 government and academic institutions, it clear that TEV of marine turtles contributes to the Semporna Priority Conservation Area in Sabah, Malaysia. It is estimated that the TEV of marine turtles was USD 23 million, ranging from USD 21–25 million. The non-consumptive value of marine turtles is estimated to far exceeded the consumptive use-value. There are potential for generating 1146 tourism jobs, equivalent to USD 469,000 in employment income per year as a result of protecting marine turtles (Teh *et al.*, 2017).

Due to the willingness of tourist to contribute USD 1.5 million for marine turtle protection and conservation annually, conservation could be partially funded from tourism. The discounted TEV of marine turtles could reach up to USD 716 million over 30 years if full protection of turtles was implemented now is a piece of evidence shown by the scenario analysis. The discounted TEV of marine turtles under status quo conditions (USD 262 million) is less more than double compared to the situation if the total protection implemented now (Teh *et al.*, 2017). Most analyses on the economic value of sea turtle in Sabah had been carried out. Terengganu needs to follow Sabah footstep to ensure correct valuation for selecting the correct sea turtle management strategy (total protection conservation strategy or mixed conservation strategy).

Therefore, the study in Chapter 7 and 8 attempted to preliminarily evaluate the current market of the sea turtle eggs selling and sea turtle tourism product based on TEV as mentioned in Figure 2.6 below.

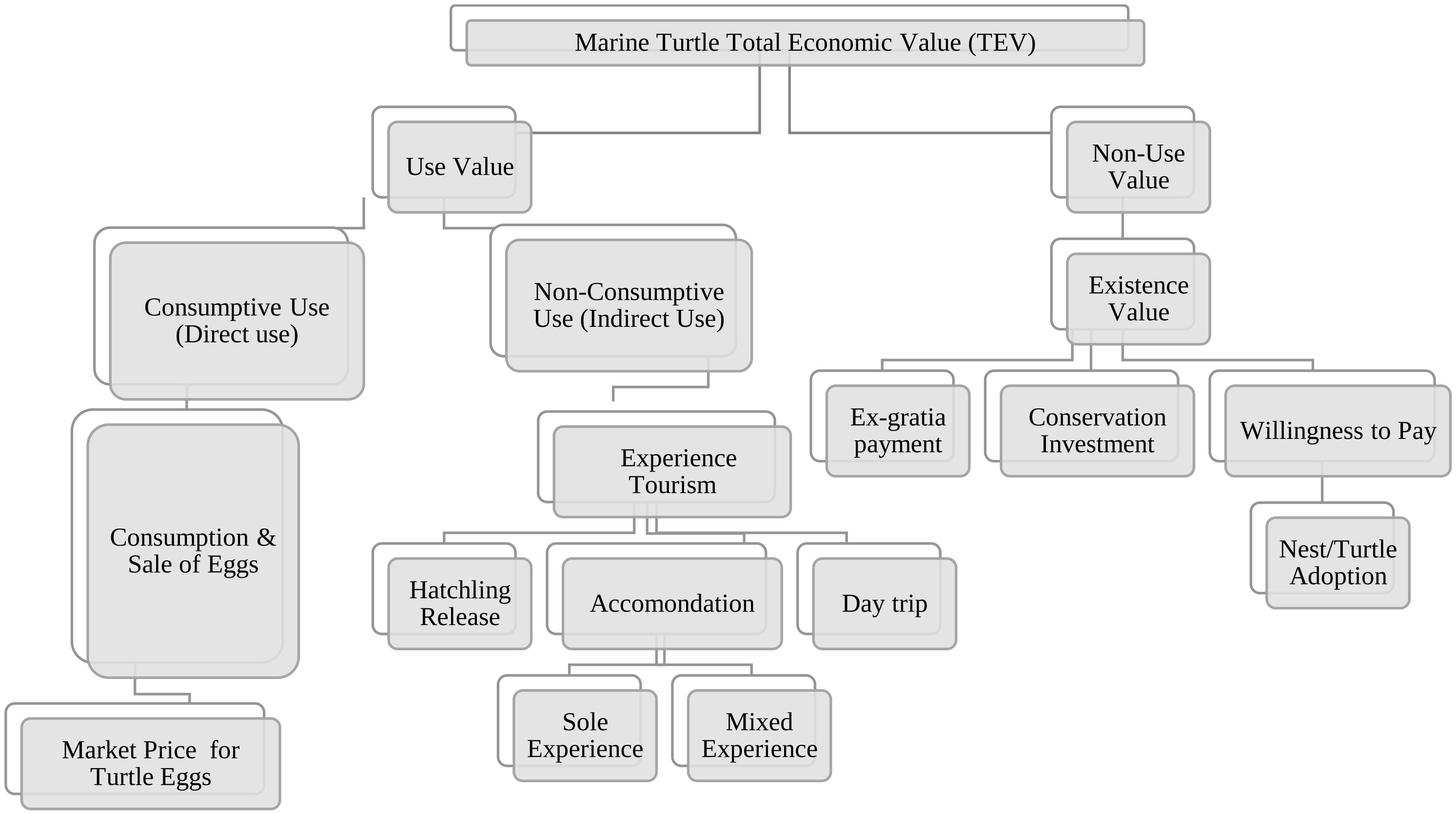

Figure 2.6 Illustration on components of Total Economic Value (TEV) of sea turtles, which divided into Use Value (UV) and Non-Use Value (NUV).

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Figure 2.6 describes the economic activities involving sea turtles in Terengganu based on Total Economic Value (TEV). TEV is a generally used framework applied to ecosystem valuation and endangered species. The sum of its use and non-use values is used to defined TEV. Tangible and intangible ecosystem goods and services that are used for consumption or production in the use-value category can be split into three categories which is 1) direct use values, including consumptive and non-consumptive use; 2) indirect use value refers to value from ecological services arising from properly functioning ecological systems, e.g., coastal protection, water purification, climate regulation functions; and 3) option value refers to a value derived from potential future use of ecosystem services and covers existence and bequest values (Pascual *et al.*, 2010).

Consumption and sales of eggs, meat and shell can be considered as the consumptive use under the use value category. Marine experience tourism including turtle watching activity, research and education camps like the volunteer program organized by Sea Turtle Research Unit (SEATRU) and Lang Tengah Turtle Watch (LTTW) falls under the non-consumptive use category and can be considered as a functional benefit that does not harm the resources and can be continuously utilized from time to time. Existence value falls under the non-use value category. Non-use value is the value usually described as independent of the individual's present use of the resource. This value is described as the value from knowing that a particular environmental asset exists such as an endangered species. While, "bequest value", is the value arising from the desire to bequeath certain resources to one's heirs or future generations, for example, habitat preservation (Sharp & Kerr, 2005).

The values that citizens perceive to be embodied in the environment is affected by the changes in natural character. Commonly, these changes generally termed "existence values", "passive use values", or "non-use values" and it is independent of use of that environment. The nature of the proposed changes and the views of the people doing the valuing determined the existing value (Sharp & Kerr, 2005). The ex-gratia payment is a payment given to compensate the people to stop them from taking the sea turtles eggs. This one-time payment value usually above the market price thus the people will agree to stop The conservation investment by the organisation and public is also a type of existence value, for example, the money invested in rescue the sick sea turtles. Willingness to pay for the sea turtle conservation such as the nest adoption organized by the LTTW or SEATRU is one of the existence value. Those give satisfaction from the knowledge of evidence and conservation of habitat and species of sea turtles in Terengganu.

Although turtles are tapped as a major tourism draw and the species is categorised into its 8 clusters of tourism products and tourist destinations by the Terengganu state government, the study on sea turtle TEV are lack in Terengganu. In 2012, RM3.34 billion of the state's revenue is contributed by the tourism industry where 3.38 million visitors with 2.77 million locals and 607,000 foreigners arrived in Terengganu (Rosli & Yeoh, 2013). As the community and government are unaware of the full potential of sea turtle economic value, eggs harvesting are still legal. Besides that, activity that can generate huge income such as ecotourism are less develop in Terengganu compare to Sabah. Ecotourism has the potential to facilitate the community protection of sea turtle resources for use in a non-consumptive manner for the community's socioeconomic benefit just like in Baja California (Finkbeiner, 2009).

CHAPTER 3

ASSESSMENT OF NESTING DENSITY IN TERENGGANU

3.1 Introduction

Conservation in Terengganu involved both protected and tendered beaches. Sea turtle eggs laid on the protected beach are considered 100% protected whereas, in the tendered beach, the situations are vice versa. This strategy was known as the mixed-conservation strategy. This strategy implemented to control the exploitation and provide statistical data of sea turtle besides improving community income (Liew, 2011). Based on statistical data, Terengganu has a lower nesting density compared to Sabah Turtle Island Park (STIP). The annual nesting density of Terengganu is just 2 300, while for STIP was 6 500 (Chan, 2010). The Sabah excellency factor may lay on their conservation strategy as they 100% ban sea turtle slaughter and egg market. Thus, this chapter is intentionally composed to evaluate the impact of beach management (tendered and protected beaches) on its nesting density. This not only helps to uncover the adverse effect of sea turtle egg exploitation but also help to evaluate the effectiveness of the mixed conservation strategy which has been implemented in Terengganu.

Previously, the research on nesting density was conducted but only focussed on one or a few beaches as mention in section 2.6. Most of the research however does not include the tendered beaches. For instance, Chan (2010) reported and highlighted the impacts on the total protected conservation strategy of the nesting activity by green and hawksbill turtles in Chagar Hutang Sanctuary, Terengganu. Over 16 years of conservation effort in Chagar Hutang resulted in the incubation of 6947 (98.2%) green turtle clutches and 126 hawksbill turtle clutches. Chagar Hutang had produced 387,322 live green turtle hatchlings and 8094 live hawksbill turtle hatchlings. After a 16-years conservation effort, 928 green turtles and 17 hawksbills were tagged. Although the population size of sea turtles in protected beaches is well represented by the previous study, it is incapable of representing the population size for tendered beaches. This previous work was a good initiation however, it lacks comparison with other beaches in Terengganu as it only assessing a single beach. Therefore, this study intended to seek a clearer picture of how the Terengganu conservation strategy affect the sea turtle population by analysing and fairly compare nesting density and nesting trend for each protected and tendered beaches in Terengganu.

The analysis involved two sections which are the nesting density and the nesting trend. Nesting density is the number of the nest in an area whereas nesting trends are nests characteristics possessed by each beach. Firstly, nesting density is obtained by considering the length of the coastline as stated in Shanker *et al*, 2003. Coastline length is an important geographical factor in determining the true productivity of each beach. The impact of egg exploitation on the nesting beaches was known by comparing the calculated nesting density (nest/km) between the protected and tendered beaches. Then, in the second part, the nesting trend is divided into three areas which are the nesting pattern, current and future population size of nesting mother. The nesting pattern enables the determination of the most abundant species in Terengganu. The population size of the current nesting mother, based on Shanker *et al.*, 2003 help in identifying the current numbers of nesting mother. Meanwhile, the population size of future nesting mothers predicted the changes in population sizes of the nesting mother.

This research was not intended to perfect the conservation strategy. A perfect conservation strategy that satisfied human and environmental needs never existed. However, this study is important because only by knowing the current state of the sea turtle population in Terengganu, the local government able to set the priority in species conservation. The right conservation strategy is capable of boosting the sea turtle population size. Conserving the sea turtles not only do wonder to the environment but also improving society income and living standards.

3.2 Methodology

Terengganu located in the east part of Peninsular Malaysia. Terengganu has 38 nesting beaches. The total numbers of protected beaches in Terengganu are 12 which divided into 2 sanctuary and 10 turtle conservation reserve beaches. However, certain beaches are divided into few plots like in Rantau Abang Beaches, only one lot under protection while the other two were under the management of the tender system. The total number of beaches lots under the tender system is 26. The monitoring activity for protected beaches is carried out by ranger, whereas for tendered beaches is carried out by the tender holder and eggs collectors hired by the tender holders. All the data from January till December are reported to the Department of Fisheries. In this paper, the analysis used the nesting data from 2011-2015 (DoF) from illustrated beaches in Terengganu as in Figure 3.1.

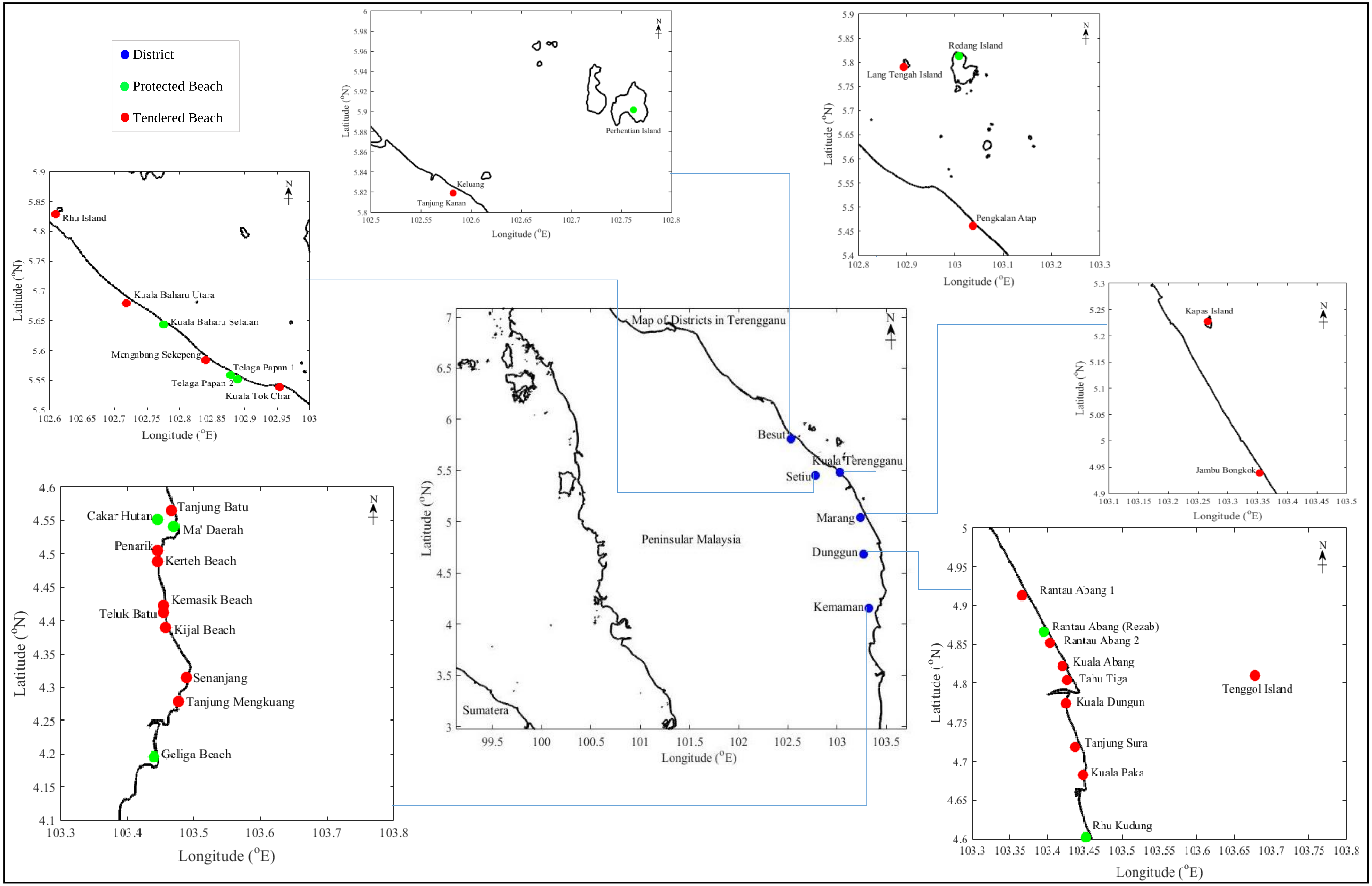


Figure 3.1 Map of nesting beaches in Terengganu according to the districts.

3.2.1 Calculation of Nesting Density

The nesting density of each beach was determined. Firstly, the midpoint of each nesting beach is entered and then marked. Then, the coastline is marked and the length is retrieved in kilometre (km). The nesting density is calculated as below according to Shanker *et al.*, 2003. Then, the graph of the nesting density versus time is plotted to illustrate the productivity of each beach. The nesting pattern can be observed and compared between protected and tender beaches.

$$Nesting\ Density = \frac{Number\ of nest\ in\ a\ year}{Length\ of\ coastline}$$

3.2.2 Calculation of Nesting Mother

The current numbers of nesting mother are calculated as follows using a formula inspired by Shanker *et al.*, 2003,

$$Current\ Nesting\ Mother = \frac{Total\ Number\ of\ Nest}{Average\ Number\ of\ Clutches\ Laid\ by\ One\ Turtle}$$

The female green sea turtle lay one to ten clutches in a season at the Kosgoda rookery (Ekanayake *et al.*, 2016). However, based on the interview with staff and ranger in Chagar Hutang, 9 had been chosen as the number of clutches laid by sea turtle in Terengganu since nesting mother nest for up to 9 clutches in a season. This is supported by the United States Wildlife Service (2015) that stated that in a season, the highest number of clutches that a female can lay is as many as nine clutches at about thirteen days of interval between clutches.

While the prediction on numbers of future nesting mothers is carried out by calculated the number of hatchlings produced and the number of hatchlings survived to adulthood. In order to calculate the hatching success rate, Chagar Hutang is used as references for the hatching success rate in the wild as most of the nest are in-situ. The hatching success rate of Chagar Hutang which is 0.6682 is applied to the numbers of eggs laid on the protected beaches to obtain the total number of female hatchlings produced during 2011-2015. The formula is as stated below,

$$Number\ of\ \ hatchlings\ produced\ annually$$
$$= (Hatching\ success\ rate\ \ \times Total\ eggs\ laid\ in\ protected\ beach)$$

The hatchling assumed 100% emerge and released to the sea as there are rangers that checking and assisting them. Besides that, it is assumed to come back to their natal beach after 25 years as greens turtles, *Chelonia mydas* ready to start nesting and laying eggs (McGuire *et al.*, 2017.). However, if there is 1, 000 hatchlings, only one will survive to adulthood. In other cases, in 10.000 sea turtle eggs, only one might survive to adulthood (Bean, 1980). Thus, this formula was adopted to calculate the number of future nesting mother,

$$Future\ Nesting\ Mother$$
$$= (Number\ of\ hatchlings\ produced \times 0.7) \times \frac{1}{1000}\ or\ \ \frac{1}{10000}$$

The hatchlings released assumed to be 70% female as according to regional sex ratio for hatchling produced from in situ nest are 70% female (Limpus, 1993). After obtaining the number of current nesting mothers, it will be compared with the number of future nesting mothers and the trend is observed.

3.3 Results and Discussion

This section will illustrate the nesting density analysis of sea turtle nesting beaches in Terengganu. Besides, the number of current sea turtle nesting mother and prediction on future nesting mother. The results for each section will be discussed in each section.

3.3.1 Nesting Density

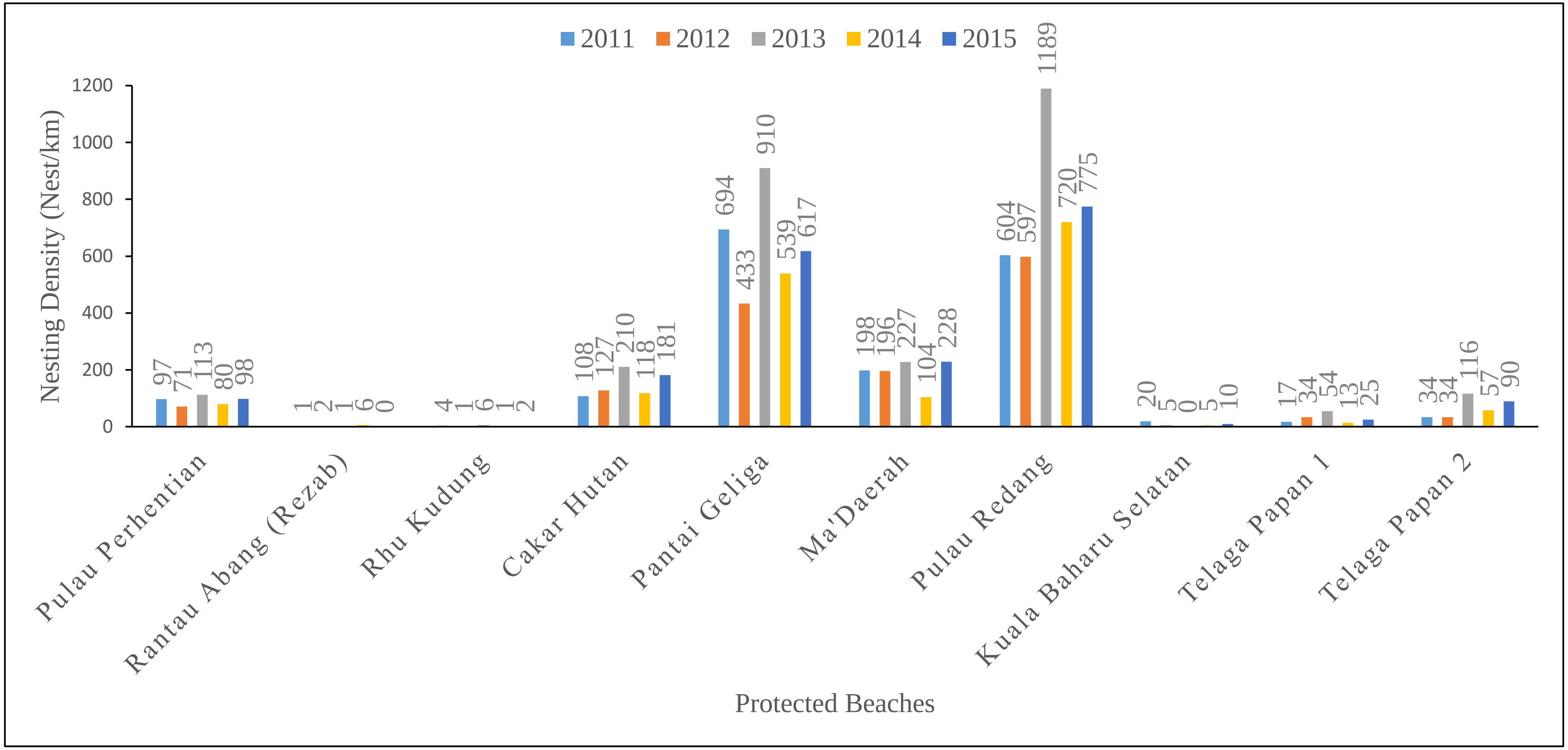


Figure 3.2 Nesting density of protected beach in Terengganu within 2011-2015.

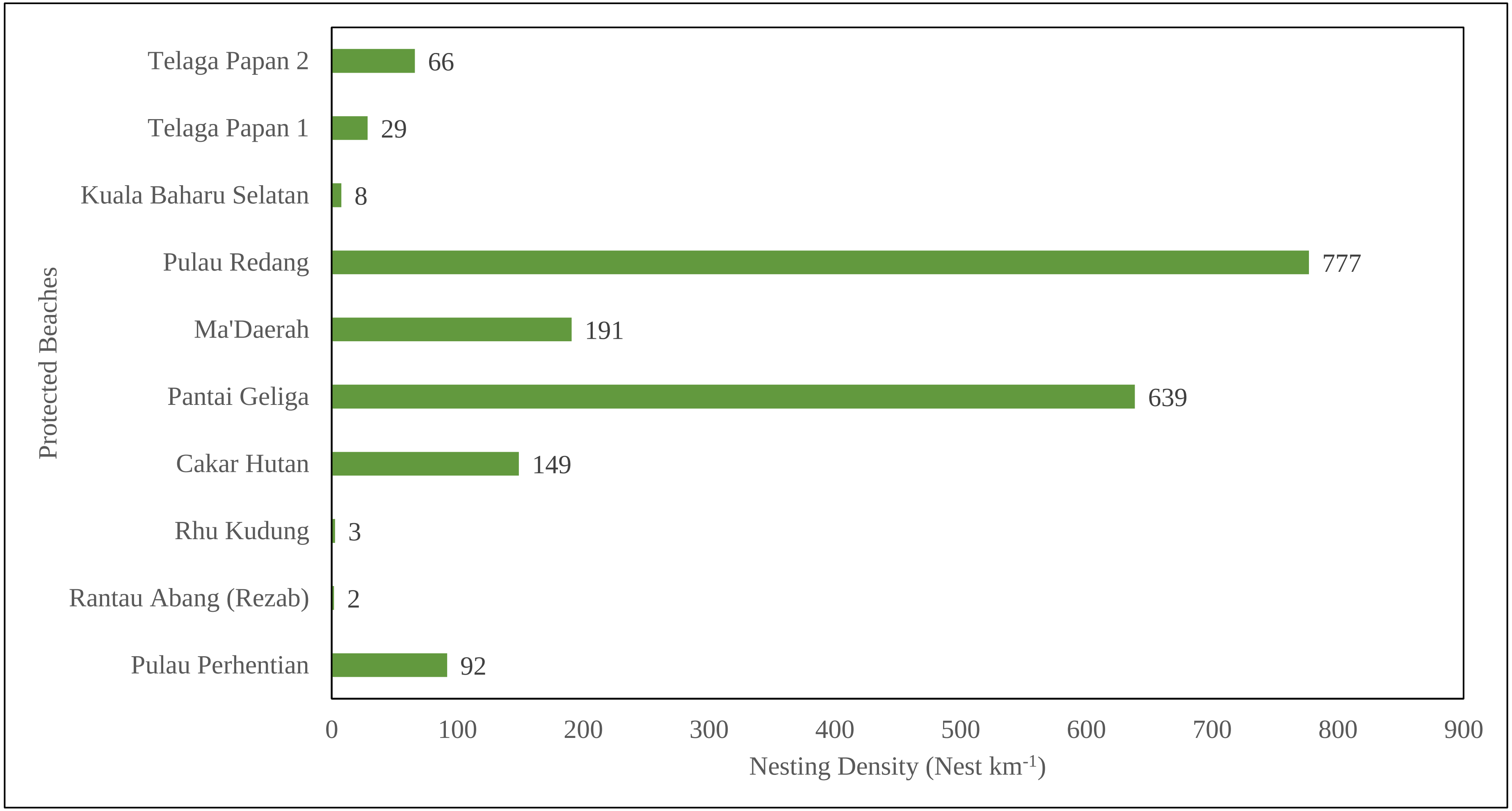


Figure 3.3 Annual average nesting density of protected beaches in Terengganu within 2011-2015.

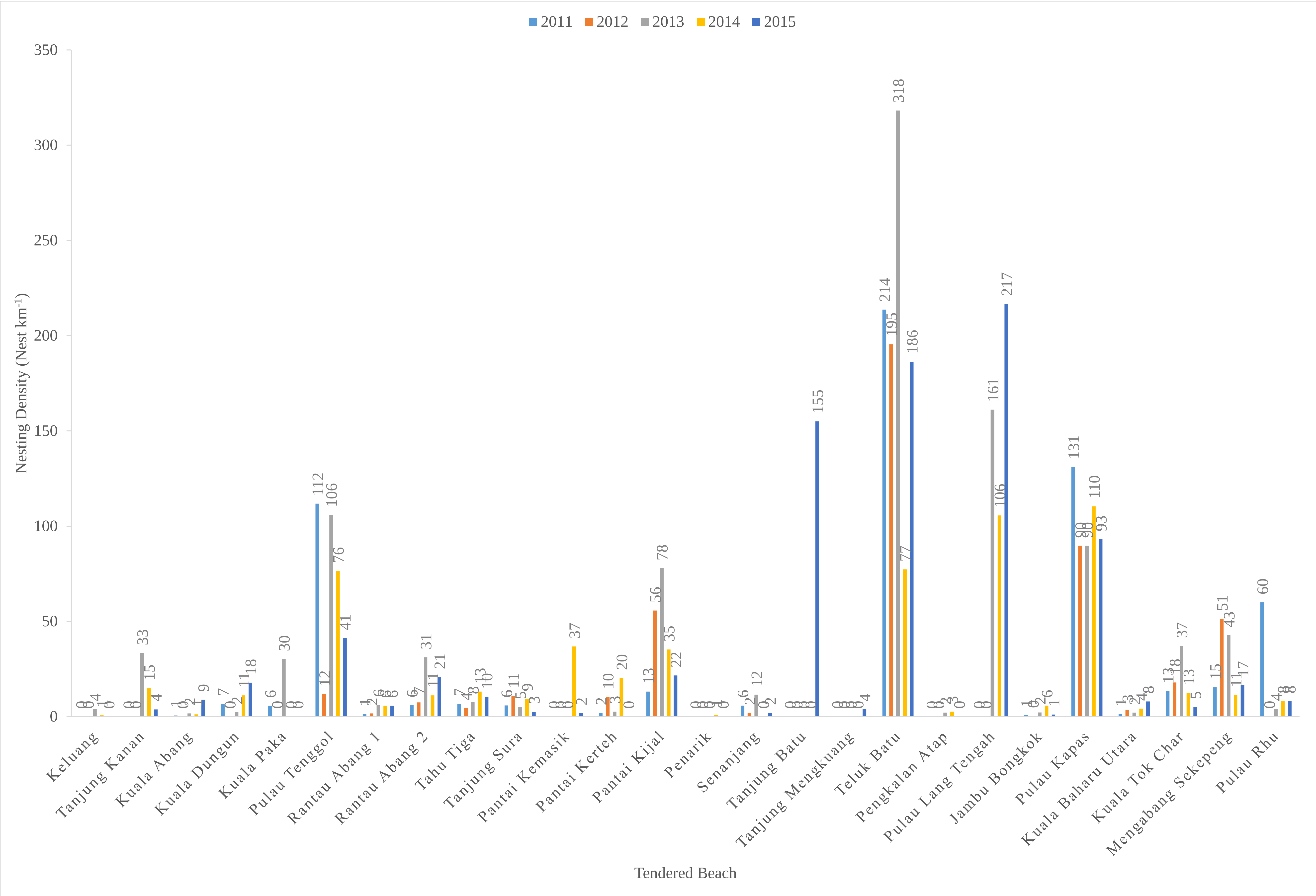


Figure 3.4 Nesting density of tendered beach in Terengganu within 2011-2015.

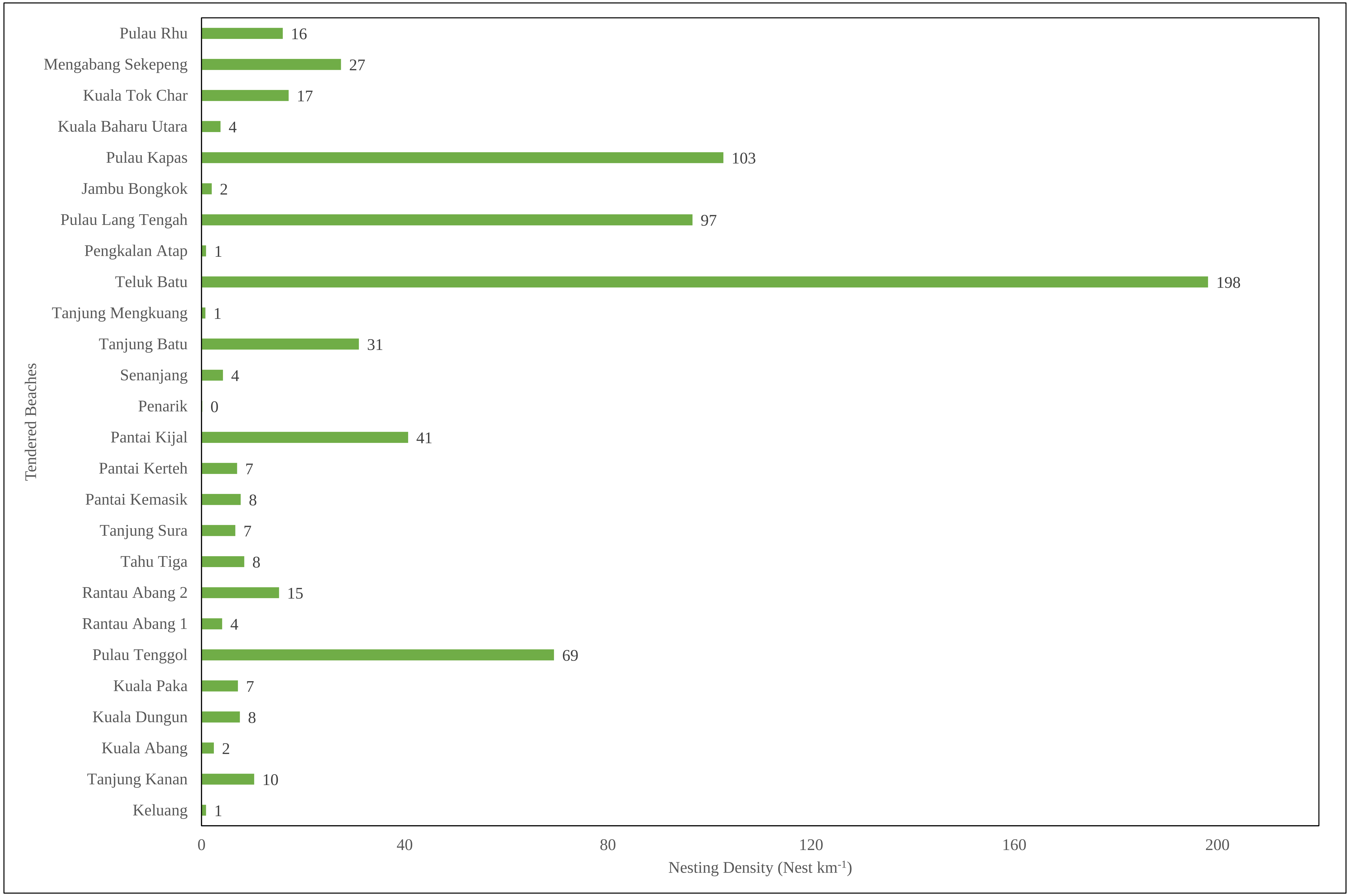


Figure 3.5 Average annual nesting density of tendered beaches in Terengganu within 2011-2015.

Based on Figure 3.2 and Figure 3.3, each protected beach in Terengganu has a yearly average nesting density is 195 nest km^{-1}. However, the average yearly nesting density of each tendered beaches as shown in Figure 3.4 and Figure 3.5 is only 26 nest km^{-1}. This show that the nesting density on protected beaches was higher in the protected beaches than in the tendered beaches.

From 2011-2015, Pulau Redang has the highest nesting density in Terengganu of 1189 nest km^{-1} (Figure 3.2). Other nesting hotspots in the protected beaches category are Pantai Geliga, Ma' Daerah and Pulau Perhentian. Pulau Redang and Pulau Perhentian are in the marine protected area as it is gazetted as marine parks with the length of the coastline of 3.13 and 3.12 km but, the nesting density has a major difference. CNN survey in 2013 has chosen Pulau Perhentian as the 13th Best Beach in the world (Tourism Terengganu State Secretariat., 2014). Thus, Pulau Perhentian must be a diving spot and attracted tourists from around the world. An assumption that could be made was the excessive tourist and human activity might change the geographical and demographical characteristics, sea turtle might find that the condition is unfavourable. With an exception of the places with established turtle sanctuary (for example, Sabah and Sarawak Turtle Islands; Rantau Abang, Ma' Daerah and major nesting beaches in Perhentian and Redang Islands in Terengganu), other prime beaches and near coastal are developed for tourism that resulted in the disappearance of turtle nesting habitats (Ghazali & Jamil, 2019). Other research stated that the hotels, guest houses and restaurant in many countries such as Malaysia, Indonesia, and the United State of America, Greece and Sri Lanka have been established alongside beaches which are the nesting beaches for sea turtles. This precludes sea turtle nesting from happening due to the pollution, noise and light. In addition to that, it is known that light makes baby turtle disoriented. Moreover, turtles also can be injured from speedboats used by tourist (Tisdell & Wilson, 2003).

Furthermore, Pulau Redang was suitable for turtles as the nesting bay. This is because it is equipped with a high variability of beaches as it has a large islands periphery. Thus, in term of turtle nesting, Pulau Redang, Terengganu is the most vital islands on the East coast of Peninsular Malaysia (Ghazali & Jamil, 2019). Besides that, Pulau Redang has two important beaches that were protected by the Terengganu government for conservation purposes which is Mat Kepit and Mat Simpan (Joseph & Liew, 2014). In addition to that, Pulau Redang nesting also includes the nesting density from Chagar Hutang. Chagar Hutang currently has high nesting density as it is plausibly arguably the single most important nesting site for green turtle in peninsular Malaysia (Chan & Liew, 1999). The high nesting density at Chagar Hutang was achievable as from 1993 until now, Sea Turtle Research Unit (SEATRU) from Universiti Malaysia Terengganu has been conducting research and conservation activities there (Rusli *et al.*, 2020).

Although Chagar Hutang in Pulau Redang has a high nesting density, some protected beaches have a low nesting density. The beaches with low nesting density might be affected by leatherback and olive ridley turtle extinction and serious depletion of hawksbill turtles. Contradicted to Pulau Redang that probably has green turtle as major nesting species, those protected beaches that has low nesting density might have leatherback or olive ridley major nesting species. When the major nesting species were eventually disappeared, the nesting density became low as only the minor species which nest on those beaches remain. For instance, protected beaches such as Rantau Abang, Rhu Kudung, Telaga Papan and Kuala Baharu has high leatherback nesting density. This was proven by the Department of Fisheries (2008) report where back then, between Jambu Bongkok to Kuala Abang, about 15 kilometres stretch of coastline, a high abundance of leatherback turtle can be found with the centre at Rantau Abang. Protected beaches with low nesting density such as Kuala Baharu and Telaga Papan might be also affected by the olive ridley disappearances. Although the population of olive ridley turtle in Peninsular Malaysia are relatively small in number, most of it can be found in Terengganu. Kuala Baru, Telaga Papan, Pulau Kapas, Dungun, Paka and Geliga was the major nesting or landing place for olive ridley turtle (Ramli & Hiew, 1999). The low nesting density was resulted from leatherback or olive ridley turtle extinction in Terengganu due to eggs exploitation before the government decided to gazette those beaches as protected beaches.

Moving to the tendered beaches, according to Figure 3.4, the highest nesting density for the tendered beach is only just 318.18 nest km^{-1} on Teluk Batu. The tendered beach has a longer coastline which is 32.4 km compare to the protected beach that only has 21.65 km. Some tender beaches have a nesting density lower than 10 nests annually.

This can be considered as the effect of sea turtle egg's exploitation impact that took place from before the 1950s up to recent years. As a comparison to protected beaches, it is not sensible to blame the species extinction for low nesting density in tendered beaches. This is because some of the tendered beaches was having the green turtle as the major nesting species. Tendered beach such as Penarik, Chukai, Kerteh, Paka and Geliga was among the beaches that have the most extensive green turtle nesting in Malaysia (Ramli & Hiew, 1999) as well as protected beaches such as Pulau Redang and Pulau Perhentian Besar (Ramli & Hiew, 1999). Based on the literature review, the nesting beaches for sea turtle species in Terengganu can be simplified as:

Table 3.1 Location of sea turtle nesting beaches in Terengganu according to previous research.

Species	**Nesting Beach**
Leatherback Turtle	Rantau Abang, Telaga Papan, Megabang Sekeping, Kuala Bharu, Tanjung Kanan, Pulau Kerengga, Rantau Merchang, Jambu Bongkok, Kuala Abang, Rhu Tiga, Kuala Dungun, Tanjung Sura, Kuala Paka, Kebun Pakar, Rhu Kudung, Tanjung Batu, Chakar Hutan, Ma Daerah, Penarik, Pantai Kerteh, Pantai Kemasik, Kijal, Senanjang, Tanjung Mengkuang, Geliga (Hamann *et al.*, 2006)
Green Turtle	Pulau Redang, Pulau Perhentian Besar, Penarik, Chukai, Kerteh, Paka and Geliga (Ramli & Hiew, 1999), Kemaman (Chan, 2010), Teluk Mak Nik (Kamal, 2018)
Olive Ridley Turtle	Kuala Baru, Telaga Papan, Pulau Kapas, Dungun, Paka and Geliga (Ramli & Hiew, 1999)
Hawksbill Turtle	Perhentian islands (e.g. Pasir Tiga Ruang) (Tan, 2004), Redang Island (e.g.Chagar Hutang) (Chan 2010)

The Department of Fisheries should collaborate with local villagers and Non-Government Organisation to conserve all sea turtle nesting beaches. This result exposes some tendered beach that might have replicated or false data. For instance, the Tanjung Batu nesting density, for 2011-2014, no nesting was recorded, suddenly, in 2015, it has a nesting density of 155 nest km^{-1}. This hypothesis was made based on 2011-2015 data analysis, it is obvious that the peak year for sea turtle nesting between the years 2011-2015 was in 2013, not 2015. Secondly, the tendered data was suspicious because, after four years of zero or unknown nesting, all of sudden, it jumps to 155 in the year 2015. The sudden leap and not tally data was a strong argument that the Terengganu government need to make a new intervention to make sure that they receive the actual data. Employing more staff to evaluate spy on the tendered beach regularly might help to turn this situation. Take note and learn from the concession system that happens in Thailand as mentioned in the literature review section 2.3. The Thailand government trusted the tender concession to incubate and release 20-30% of total sea turtle eggs laid on nesting beaches under concession management without any government official supervision. Thailand government solely trust the concession although no evidence of the incubation or release was submitted. The sea turtle population in Thailand then suffer a devastating decline, forcing the Thailand government to fully protect the sea turtle nesting beaches although it too late for some of the beaches.

Yet, some tendered beaches have a quite high nesting density. Those high nesting densities was possible to be obtained as those beaches were under some conservation program. For example, Teluk Batu includes the nesting density from Pantai Teluk Mak Nik that has been a turtle conservation centre (Tourism Terengganu, 2020). This hatchery was managed by the late Mr Ariffin Hassan (or known as Pak Su Cherating) and Rimbun Dahan Turtle Hatchery (Kamal, 2018). Teluk Mak Nik was a tendered beach that supposedly experienced drastic sea turtle decline. However, the green turtle population survived thanks to the late Pak Su and his team effort. This depicted that the sea turtle population can also be able to rescue by the local community in Terengganu if they were exposed and educated with the conservation and the importance of sea turtle. Back to the late Pak Su and his team effort, the sea turtle eggs were brought from the local villagers who sell them as a source of income by the late

Pak Su and Dahan Turtle Hatchery. Then, the eggs were buried in the sanctuary within the fenced protected nesting area by the late Pak Su and his volunteers. The late Pak Su and his team also closely monitored the incubated eggs and releasing hatchlings to the sea (Kamal, 2018). This conservation effort was then further helped by DoF Terengganu when a turtle sanctuary was renowned on Pantai Teluk Mak Nik in Kemaman in 2018 (David, 2018).

Another example of a tendered beach that was tendered for conservation purposes by the Non-Government Organisation (NGO) is Pulau Lang Tengah. Pulau Lang Tengah was tendered by the Lang Tengah Turtle Watch (LTTW). Based on the interview and field visitation with LTTW, LTTW pays the tender holder fee then they incubated the eggs at the turtle bay which is a piece of land owned by the family of the founder of LTTW, Miss Hayati Mokhtar. Besides that, they also pay the people to collect the eggs from other beaches like Lang Sari that might be missed by the volunteers or intern during the beach patrol. Since 2013, this project was already underway.

This is direct proof that human exploitation of sea turtle eggs gave an adverse impact on the sea turtle population in Terengganu. This was also supported by Becker *et al.* (2019), whose previous research stated that an area that had a low human density is likely to have low rates of exploitation which resulted in higher sea turtle density. Tan, 2004 also mentioned that the primary threat to marine turtles in Malaysia is the commercial sea turtle egg (Lang Tengah Turtle Watch, 2020). Few years of conservation effort from the LTTW team has helped to save the sea turtle population in Pulau Lang Tengah, Terengganu.

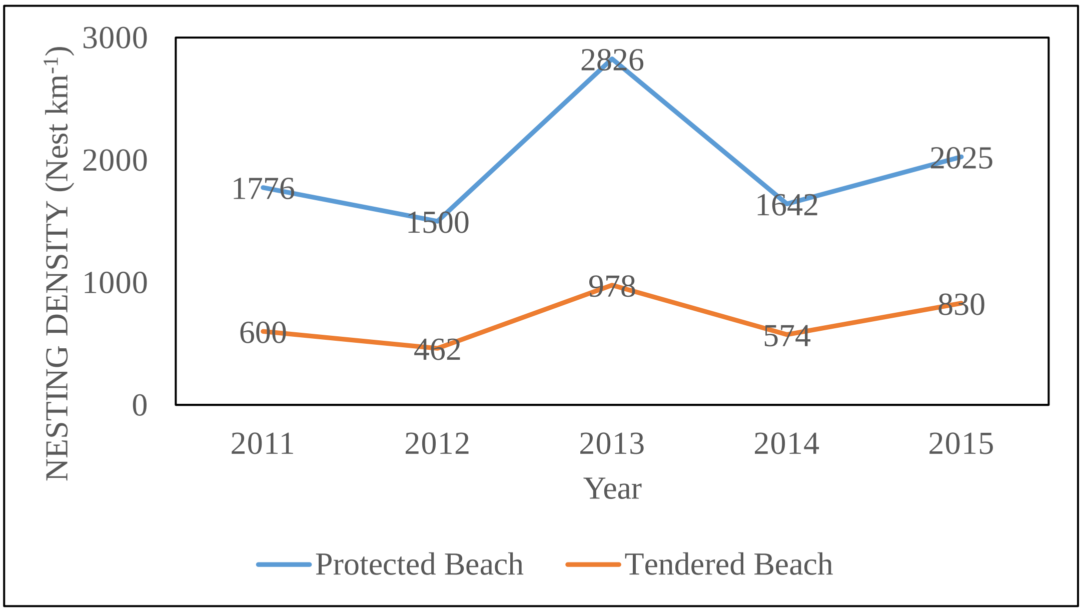


Figure 3.6 Yearly average for nesting density of a protected beach and tendered beach from 2011-2015.

Figure 3.6 shows a biennial nesting pattern as one year will have a high nesting density while the next year will have a low nesting density. As the data given by the department of fisheries is incomplete as it did not state the species, either the green turtles or hawksbill turtle, we can conclude that the majority of sea turtle nest in Terengganu is green turtle due to few reasons. Firstly, the green turtle is recognized as the major species that nest in one of the major nesting beaches, Pulau Redang from the nesting data collected from 1993 to 2008. Chan (2010) mentioned that only a remnant population of hawksbill turtles nesting occurred in Terengganu. The yearly nesting density of hawksbill in Terengganu from 1987-1996 was only ranged from 12-72 nest. The majority of nesting happens in Pulau Redang that has 0-49 nest annually (Chan, 2010). This indicated how low the nesting density of sea turtle in Terengganu. With the extinction of leatherback and olive ridley turtle, the green turtle was the major nesting species in Terengganu.

Secondly, due to the biennial nesting pattern obtained in our result that support by Chan (2010) that one of the characteristics of green turtles is said to be the biennial nesting pattern. Other may be questioning why the existences of green sea turtle are related to hawksbill. The relationship between green turtle and hawksbill can be observed due to two reasons, firstly they probably share the same habitat and nesting beach preferences. The green sea turtle is the most tropical of the marine turtles together with the hawksbill (Fischer *et al.*, 1990). Plus, the survey in Pulau Redang recorded that during the monitoring period from 1993 to 2008, from the total of 7072 nests, green turtle nest is 6947 (98.2%) while the hawksbill nest is only 1.8% or 125 nests. Secondly, the hawksbill has a relationship with the green turtle as they have an overlapping nesting timing. Green turtle nesting occurred all year round but more prominent in April to September with these two months accounting for 40% of the nests deposited in the entire year, for hawksbill, except for 2007 where the nesting occurred between August to October, nesting typically take place between April to June (Chan 2010). The shorter nesting season might also be an indication and reason for the low nesting density of hawksbill turtles.

This result indicates a serious issue faced by the hawksbill as it can be concluded that their number was too low until they have no influences on the total nesting pattern. Based on

Figure 3.6, it is suspected that Hawksbill is already locally extinct in Terengganu, just like the leatherback. Despite Redang Island is one of the major nesting beaches in Terengganu and the result of Chan (2010) entitle to reflect whole nesting scenario in Terengganu, research needs to be carried out to determine the current population size of hawksbill either healthy, extremely decreasing or locally extinct. As they were in extremely low numbers or extinct, the nesting pattern was overshadowed or masked by the nesting pattern from the green turtle species that relatively have a higher number of individuals.

Yet, this analysis was based on data provided by DoF Terengganu. This data does not include all beaches or islands. For example, in an interview with a staff that used to be stationed at Bidong Island, Mr Azlan gave a piece of important additional information on hawksbill turtles, there were many hawksbills turtle nest on the Karah Island that was closed by the Bidong Island. This island gets the name from the high density of hawksbill turtle nest on the island or generally known as “penyu karah” or “penyu sisik” by the local. Sadly, this island was not inside the DoF list, but also the eggs was predated by the fisherman. During the market survey, some egg seller, tender holder and local customers for sea turtle eggs also confess that olive ridley still existed on the beaches that were not listed by the Terengganu government as nesting beaches and monitored. The tender holder also confesses that some nesting beaches can be accessed by the fisherman, egg collectors and tender holder by boat were silenced by them as they want to collect the sea turtle eggs. DoF need to do new research to identify all nesting beaches on the mainland and island to know the exact nesting density and prevented further species extinction.

3.3.2 Nesting Mother Prediction

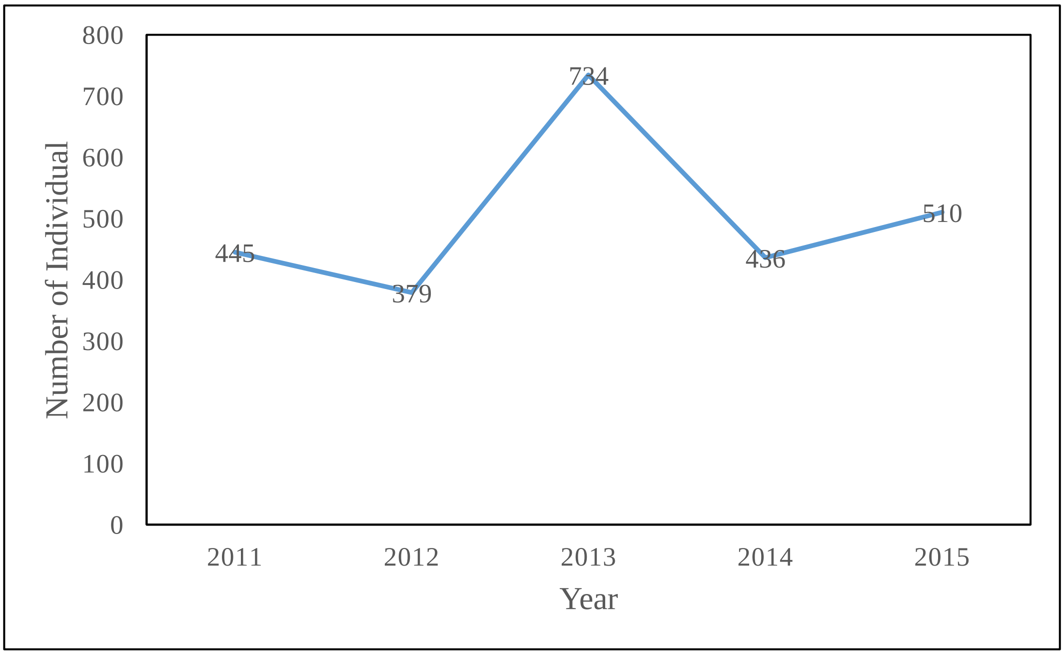


Figure 3.7 Current numbers of nesting mother in Terengganu from 2011-2015.

According to Figure 3.7, there are between 379 to 734 individual sea turtles that nest in Terengganu annually. The average number of sea turtles that nest in Terengganu between 2011-2015 was 501 individuals each year. This figure also illustrated the lowest number of nesting mothers which is 379 can be observed in 2012. The highest number of mothers recorded in Terengganu from 2011 to 2015 is in 2013, which is 734. The number of nesting mother in Terengganu was really low compared to the Baguan Island in Sabah. The total numbers of green sea turtles nesting in 2011 at Baguan Islands are 14 220. This boosted the population of Baguan’s green turtles as the green turtles have been listed as Endangered on the IUCN Red List of

Threatened Species (International Union for Conservation of Nature, 2018). This is the direct impact of the conservation strategy chosen by the different state where Sabah has totally protected their sea turtles as mentioned in section 2.4 compared to Terengganu that continues to harvest sea turtle eggs on most nesting beaches and left only 12 beaches for conservation purposes.

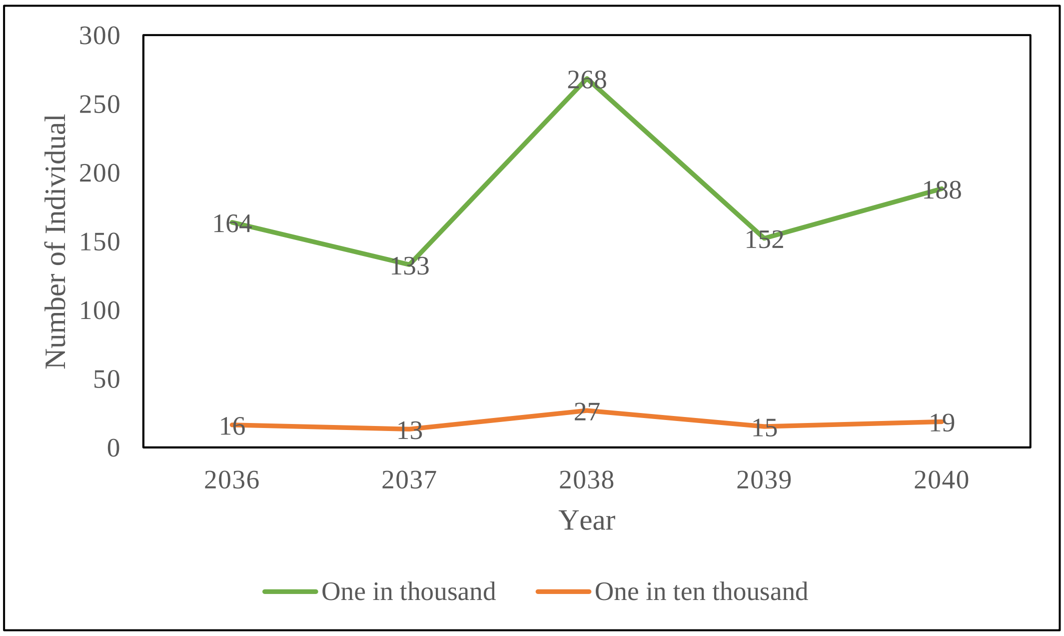


Figure 3.8 Future nesting mother in Terengganu prediction under the survival rate of one in thousand and one in ten thousand.

Worse, Figure 3.8 predicted that the number of future nesting mother will be reduced compared to the numbers of current nesting mothers. Under the survival rate of one in a thousand, it is predicted that the lowest number of future nesting mothers that come back for nesting were 133 individuals in 2037. While the highest numbers of nesting mothers that can be observed were 268 individuals in the year 2038. The numbers of nesting mothers predicted to be lower under the survival rate of one in ten thousand. The minimum number of predicted nesting mother under a survival rate of one in ten thousand were 13 individuals in 2037. On the other end, the highest number of nesting mother were predicted to be 27 individuals in 2038.

Again, the number of predicted nesting mother were far behind the sea turtle populations in Baguan Island, Sabah. If taken into account that the survival rate of hatchling to reach maturity is 1%, the numbers of eggs in 2011 alone will contribute to 13,000 to the Baguan's adult turtle population (IUCN, 2018) compared to only 164 adult sea turtles that will come back to nests in 2036 on Terengganu. If the survival rate is considered as one in ten thousand, Terengganu maybe only have 16 adult sea turtles in 2036. This one from ten thousand cases is possible due to increasing anthropogenic threats. This can be supported by the data produced by SEATRU where only 226 recruitment or new mother is recorded from 1993 to 2017 in Chagar Hutang which is considered as a protected beach. This proves that large amounts of hatchlings were needed to sustain the sea turtle populations in Terengganu. Besides that, this also shows that even protected beaches can only produce a small number of new mother due to the high death rate of sea turtles in the wild. Thus, it is completely sensible to expect zero new mothers produced from the tendered beaches. This eventually leads to the sea turtle serious depletion and extinction on the tendered beaches as mentioned in section 3.3.1. A higher number of hatchlings also need to be produced by the protected beaches since a higher number of sea turtles were needed to overrule their high natural death rate. However, populations of sea turtles in protected beaches do not face drastic declines due to all the conservation effort such as eggs incubation and hatchlings release that continues up to today.

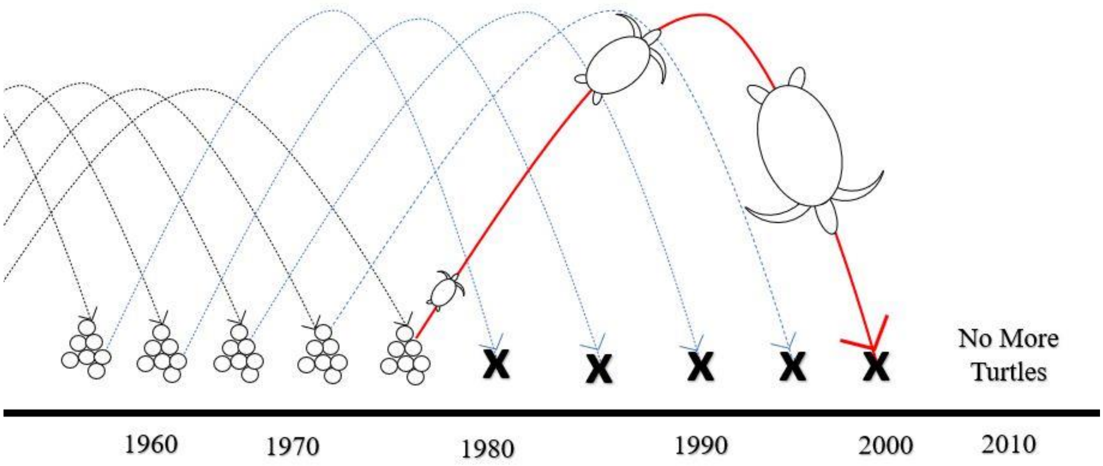


Figure 3.9 Redraw of simple hypothetical case, if 100% of turtles were harvested each year before laying eggs (Pilcher, 2001).

High annual eggs production should not excite the government agency, local and scientific since the nesting mother that returned to Terengganu beaches nowadays might be the only sources for sea turtle eggs production. Therefore, there is a huge possibility where there are zero recruitment and sea turtle eggs 50 years in the future as stated in Figure 3.9. This figure described a theory by Mortimer 1995 where there would reach a point at which no further breeding females would be available. However, only after 25 years of 100% harvest, this situation would become apparent (Pilcher, 2001). This was also supported by Liew (2006) that mentioned the sea turtle overharvesting impact was unable to be detected until it is too late. This is because this species takes a long time to reach sexual maturation at about 30 years. This signifies that the hatchlings that were release today will only come back for nesting 30 years later. Thus, the overharvesting was not visible to the naked eyes until after 30 years.

Thus, to prevent this catastrophe, Terengganu should consider the Baguan Island total conservation model as an inspiration. Terengganu should implement new law enforcement that totally prevents poaching, egg collection and habitat destruction was strengthened by training park wardens, law enforcers, and community volunteers such as in Baguan Island. In Baguan Island, an increase of patrolling efforts and enforcements team included officers from the Philippine Coast Guard and Philippine Navy Marines. In the Baguan scenario, to link government agencies and NGOs, that worked closely and have developed a joint network of protected areas to safeguard turtles (IUCN, 2018) can be observed. Terengganu can join forces with NGOs and others state such as Pahang and Kelantan to patrol and protect sea turtles. Moreover, Terengganu also can join hands with others country such as Indonesia to patrol and conserve the sea turtle population including around the Natuna Island that closely related to the Terengganu state.

3.4 Conclusion

Terengganu practised a mixed-conservation system which included protected and tendered beaches. Eggs laid on the protected beaches were totally incubated. Meanwhile, the eggs laid on the tendered beaches were assumed to die totally since all of the eggs end up at the market due to a lack of government fund. Although this strategy helps in controlling the sea turtle eggs exploitation and providing income for the local communities, zero studies were conducted to test the sustainability of this mixed-conservation system. Therefore, this chapter was aimed to evaluate the sustainability of this mixed-conservation system based on the beaches management (tendered or protected beaches) on its nesting density. Based on the nesting density, this chapter also uncovers the species structures, total numbers of current nesting mothers that nest in Terengganu and predict the annual female hatchlings productions and total numbers of future nesting mothers in Terengganu. Other than annual eggs productions, the number of currents nesting mothers and future prediction were studied in this chapter since it was able to reflect the sustainability and continuity of sea turtles in Terengganu.

As results, the first section of this chapters has proven that the tender system adversely affects sea turtle populations in Terengganu. The protected beaches have a higher annual average nesting density is 195 nest km^{-1} compared to the tendered beach which is only 26 nest km^{-1}. This situation arose since the human exploitation of sea turtle eggs under a tender system further decrease the population survival. Besides that, although the sea turtle species structure in Terengganu previously also contains four species including the Green, Hawksbill, Leatherback and Olive Ridley turtles. Only two species remain in the populations which are the Green and Hawksbill turtles. The biennial nesting pattern observed from the yearly nesting density trend confirmed that the major nesting species in Terengganu were the green turtles. This conclusion was achieved since the biennial nesting pattern indicated that only a few hawksbill turtles remain in the population, thus they are not capable of influencing the nesting pattern of sea turtles in Terengganu. Due to their fewer numbers, Hawksbill turtles can be considered functionally extinct in Terengganu.

Moreover, the second part of this chapter also predicted the number of the current nesting mothers based on the annual sea turtle eggs production in Terengganu. The number of current nesting mothers in this section was originated from both protected and tendered beaches. Based on the nesting data in Terengganu from 2011-2015, the lowest annual number of nesting mothers were recorded in 2012 where 397 individuals turtle nest annually. Meanwhile, the highest annual numbers of nesting mothers were recorded in 2013 where 734 individuals turtle nest annually. On average, approximately 501 individuals turtle nest in Terengganu each year. Then, the second section of this chapter also revealed the prediction on the number of future nesting mother in Terengganu between the year 2036 to 2040. This prediction was made based on the annual sea turtle eggs production and the regional sex ratio of sea turtles. All the predicted future nesting mother were assumed to originate from protected beaches since all eggs laid in tendered beaches were assume to be dead. The lowest number of future nesting mothers can be observed in 2037 where only 133 individuals will come back to nest under the survival rate of one in a thousand. On the other hands, the highest numbers of nesting mothers can be observed in 2038 where 268 individuals were predicted to nest under the survival rate of one in a thousand. The number of predicted future nesting mothers was severely low under the survival rate of one in ten thousand. The lowest number of nesting mothers can be observed in 2013 where only 13 individuals turtle predicted to nest in Terengganu. While the highest number of nesting mother can be observed in 2038 where 27 individuals were predicted to nest in Terengganu. Therefore, the second section had proven that the number of future nesting mother will be reduced compared to the numbers of current nesting mothers due to the impact of eggs exploitation in Terengganu.

Last but not least, this chapter was important because it helps to uncover the hidden impact of sea turtle egg exploitation toward the survival of the sea turtle population in Terengganu by incorporating their biological characteristics. These biological characteristics such as survival rate, sex ratio, age at maturity and others were important in determining the population growth. In addition to that, this chapter also assists in evaluating the effectiveness of the mixed-conservation strategy which has been implemented in Terengganu. Since this chapter has proven that the mixed-conservation system in Terengganu was unsustainable, it is recommended for the

Terengganu government to completely ban the sea turtle eggs exploitation and put end to the mixed conservation system in Terengganu. Thus, since the population size of sea turtles were already severe the government, locals and others should act now or never.

CHAPTER 4

THE POPULATION GROWTH CURVE OF WILD EXPLOITED GREEN TURTLE IN TERENGGANU

4.1 Introduction

Life history is a specific pattern of development, maturation, reproduction, survival, and lifespan that define an organism's life cycle (Fabian and Flatt, 2012). Individual species and populations have unique life history characteristics and strategies to optimize their survival and density. An area that had a historically low human density is likely to have low rates of historical exploitation and higher sea turtle density (Becker *et al.*, 2019). However, throughout the world, sea turtle populations that face exploitation and pressure from anthropomorphic threats possess different life history characteristics than that of protected sea turtle populations.

Current literature lacks on the research of the changes in life-history characteristics, specifically the increasing death rate of these exploited sea turtle populations. Therefore, this study determined to investigate the life history characteristics of sea turtle populations in Terengganu, Malaysia. Within Terengganu, nesting beaches were divided into two categories which are tendered beaches and protected beaches.

Tendered beaches are characterized as beaches or lots under tender holder control. Under the Turtle Enactment of 1951, each lot on the nesting beaches was offered to the highest bidder (tender holder) in exchange for exclusive rights to collect eggs (Liew, 2011). On the other hand, protected beaches are all beaches where egg collection is completely prohibited and all turtle eggs are incubated for conservation purposes (Liew, 2011). Nowadays, the conservation effort focussed on the green turtles by beach monitoring and hatcheries on protected nesting areas in Terengganu (Jani *et al.*, 2019).

Terengganu green turtle populations have a higher death rate compared to the protected population in nature or farmed populations, primary due to the poaching and consumption of turtle eggs by humans. This happened due to the sea turtle eggs trade originated from the legal tendered nesting beaches. This trade poses a potential threat to the sea turtle population as in 2007, the total amount of 422,000 sea turtle eggs were sold in local markets alone (Jani *et al.*, 2019). Besides that, the population of sea turtle in Terengganu was unable to withstand the eggs trade as it takes a long time to reach maturity and ability to produce young. This hypothesis was made since the previous chapter 3 identify that the major nesting mother in Terengganu was the green turtle. Thus, the biological characteristics of sea turtles in this chapter will be assumed to follow the green turtle species. The green turtles in the wild such as the Terengganu population may take as long as 25 years to reach sexual maturity (McGuire *et al.*, 2017). This differs from farmed turtles that can reach maturity 2-5 times faster than those in the wild due to proper nutrition (Owens & Blanvilla, 2013). Since the prolonged period of exploitation changes the life history traits (Hutchings, 2005), these alterations in the life-cycle and death rate can lead to changes in life-history characteristics of green turtle populations in Terengganu.

In order to evaluate the current life history characteristics of green turtles in Terengganu, this study will determine the type of growth curve seen in their populations and observed the impacts of egg exploitation threat in Terengganu. Knowing the current growth curve possessed by the sea turtle population in Terengganu was important to understand their biological needs for survival and sustainable harvest limit. The Leatherback turtle population in Terengganu extinct as Malaysian conservation and fisheries managers failed to identify the fine balance between the leatherback biological needs and harvest limit due to limited knowledge at the time (Limpus, 1993). This paper will investigate either exponential or logistic growth curves possessed by the exploited sea turtle populations in Terengganu by comparing these two models. The growth model that produces a prediction that closely resembles the sea turtle population of Terengganu growth in reality was considered as the growth curve of this population. These two models were selected as they were capable to describe the dynamics of a single population and the growth and/or decay of single homogeneous populations (Salisbury, 2011).

Investigating the life-history characteristics of green turtles help to better understand how egg exploitation shapes the sea turtle population growth curve. Determining either the sea turtle population possessed exponential or logistic growth curve help in understanding how the sea turtle grows in density. This help in evaluating the sea turtle possible response to the egg harvest stress either the sea turtle population able to survive or extinct.

4.2 Methodology

The data used in this study was the secondary data supplied by the Terengganu State Department of Fisheries (DoF). Nesting data such as nesting density, location, and type of beaches are provided by DoF. Nesting beaches with no nesting Data (ND) were assumed as having zero nesting density. Eggs that are laid on protected beaches are considered to be incubated and have a survivorship ratio of 100% for hatching, emerging and crawling to the sea, while eggs laid on tendered beaches are considered to be poached and have a survivorship ratio of 0% as none was incubated.

This chapter discusses the compatibility of exponential and logistic models for an exploited sea turtle population in Terengganu. The population growth curve was illustrated by the time plot series. The time plot series will be observed, discussed and concluded. After that, the most suitable growth curve was selected by comparing the predicted population growth with the previous population growth between 2011 and 2015 and previous literature record on the sea turtle population in Terengganu. This selected population growth curve assumed to present the current actual sea turtle population growth in Terengganu, thus it was substituted into the models in the upcoming chapter which is chapter 5 and 6 to obtain accurate population size prediction.

4.2.1 The Actual Sea Turtle Population Growth

Fecundity can be defined as the yearly annual proportion of adult females giving birth or reported as the mean observed interval (Arso Civil *et al.*, 2017). However, the fecundity or the total reproductive output from beaches in Terengganu was calculated based on the difference in the total number of eggs produced by sea turtle in Terengganu between two conservative years. The total number of eggs produced was calculated as

$$Differences\ in\ total\ number\ of\ eggs = Total\ eggs\ produced\ (\ recent\ year) - Total\ eggs\ produced\ (previous\ year)$$

The differences in the total number of eggs then converted into a percentage using a formula as follows

$$Annual\ eggs\ production\ increase\ or\ decrease\ (\%) = \frac{Differences\ in\ total\ number\ of\ eggs}{Total\ eggs\ produced\ (previous\ years)} \times 100$$

The result was illustrated using graphs and used in the comparison between the exponential and logistic results.

4.2.2 The Exponential Model

The exponential model is suitable for simple homogenous populations (Kot, 2001). By using this model, the species population size is assumed to follow the exponential growth curve. Organisms that possess the exponential growth curve show unlimited population growth regardless of any environmental conditions. Suppose that we denote x as the population of green turtles in Terengganu, then the exponential growth for this population can be illustrated as below in Figure 4.1. This flow diagram was constructed according to an exponential growth model based on Kot (2001).

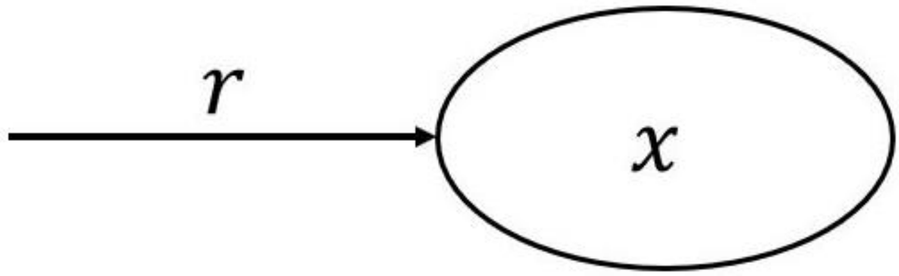


Figure 4.1 Flow diagram of the Exponential growth model.

Based on Kot (2001) and Figure 4.1, the exponential growth model for green turtles is given as follow:

$$\frac{dx}{dt} = rx$$

Equation 4.1 Exponential model

This model is written in the ordinary differential equation (ODE) form. The symbols in Figure 4.1 are described in Table 4.1

Table 4.1 Description of the parameter in the Exponential growth model.

Notation	Name of Parameter	Value	Reference
$\frac{dx}{dt}$	Rate of changes for green sea turtle population size over time	–	–
t	Time	10 and 50 years	Estimated
x	The population size of a green sea turtle	Unknown	Estimated from data
r	Green sea turtle's population growth rate	1.0464	Estimated from data

The growth rate, r can be calculated using the following

$$r = \frac{Number\ of\ Eggs\ laid\ on\ Protected\ Beach\ in\ recent\ year}{Number\ of\ Eggs\ laid\ on\ Protected\ Beach\ in\ previous\ year}$$

4.2.3 The Logistic Model

The logistic growth curve is another single population model known as the *Pearl-Verhulst equation*. The logistic model is a density-dependence model (Kot, 2001), populations that possessed the logistic growth model usually have a population growth that is limited by carrying capacity or environmental pressures. Based on Kot (2001), the logistic growth rate is illustrated as in Figure 4.2.

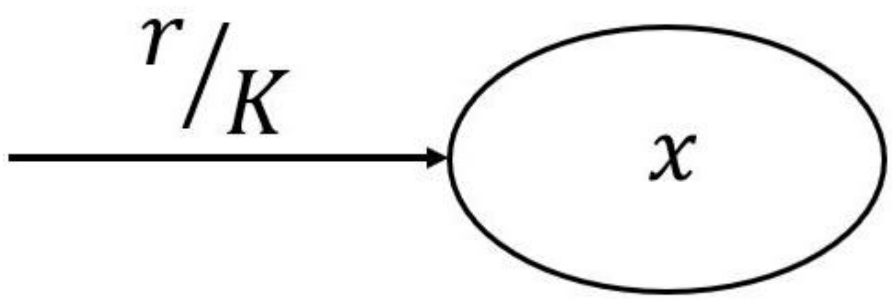


Figure 4.2 Flow diagram of the Logistic growth model.

Therefore, the logistic model is given below:

$$\frac{dx}{dt} = rx(1 - \frac{x}{K})$$

Equation 4.2 Logistic model.

where, $\frac{dx}{dt}$, r and x are defined as in Table 4.1 Description of the parameter in the Exponential growth model. Also, the growth rate, r can be calculated and valued as in previous section 4.2.2. Moreover, K or the carrying capacity in the Terengganu case is considered as the highest number of eggs annually from 2011 to 2015. From the data, we obtained that the highest carrying capacity is 622, 548 eggs. Therefore, it is assumed that $K = 622548$.

4.2.4 Models Summary

The study in this chapter adopted two unstructured population models that are considered as a single-species model (Kot, 2001) namely:

Table 4.2 Overview of the single models used in Chapter 4. The Exponential and Logistic models were tested to identify the growth curve possessed by the sea turtle population in Terengganu.

Model	Governing Equation	Assumptions
Exponential	$\frac{dx}{dt} = rx$	The population size changes only depend on intrinsic growth.
Logistic	$\frac{dx}{dt} = rx(1 - \frac{x}{K})$	The population size depends on intrinsic growth but at the same time, it is also regulated by the carrying capacity of the habitat.

4.3 Results and Discussion

This section will illustrate the prediction of the sea turtle population growth under tender system exploitation in Terengganu based on the exponential and logistic growth curve. The predicted population growth was illustrated using the time series plot. Time series plot of green turtle populations in Terengganu predicted by both the exponential and logistic model in the 10 and 50 years time frame. The results from both models were analysed. The exponential and logistic model assumed that the growth was positive. Thus, this prediction does not capture the reality of the alternate increase and decrease of the total sea turtle eggs laid in Terengganu.

4.3.1 The Actual Sea Turtle Population Growth

The total reproduction output of sea turtle experienced an increase and decrease between years. The reproduction output that was highlighted generally according to the increase and decrease of the sea turtle eggs laid in Terengganu as in . The depletion in the number of eggs laid annually is between 52,623 to 263,021 eggs. On the other hand, the increase in the annual number of eggs lain in Terengganu is between 73,515 to 302,385. Figure 4.4 illustrated that the depletion of annual eggs production in Terengganu occurred between 14% to 42%. In comparison, Figure 4.4 also stated that the annual eggs production possibly increased between 20% to 94%. The sea turtle eggs laid in 2012 decrease by 52,623 in comparison to 2011. Then, in comparison to 2012, the sea turtle eggs laid in Terengganu increased by 302,385 in 2013. Yet, a further drop in sea turtle egg laid can be observed in 2014 at about 263, 021. Although there is an increase of sea turtle eggs laid in 2015 at about 73,515, this could not cover up the population depletion that happens in 2014.

This depletion in the numbers of eggs seems insignificant. However, since the total number of eggs that were laid in the current years (between 320,163 to 622,548 eggs annually) are very small compared to the previous record in the 1950s (about 2 million eggs annually), this depletion was considered significantly high. Furthermore, although the number of eggs laid experience minimum depletion, the impact was relatively high and impossible to be covered up by other years since the eggs will grow up into a nesting mother and start laying eggs in different years than the eggs that were produced in other years. From Figure 4.3 and Figure 4.4, we can observe a huge inconsistency of annual eggs production in Terengganu between years that arose under this mixed conservation strategy. In making the management decisions, the government and others agency can do wrong management decisions leading to overharvesting and species extinction if they sample or only look at an increase and decrease in annual eggs production during a short time scale. Before making any decision, it is suggested for the government and others managing organisation to look at the population data from the 1950s until the recent years.

This increased and decreased pattern of annual eggs production observed were aligned with results in Chapter 3. These results shortly discussed here since it is already discussed in the previous chapter 3 in term of nesting density and nesting pattern. Moreover, these results were composed to be references in verifying the population increase and decrease discussed in the upcoming exponential and logistic model section.

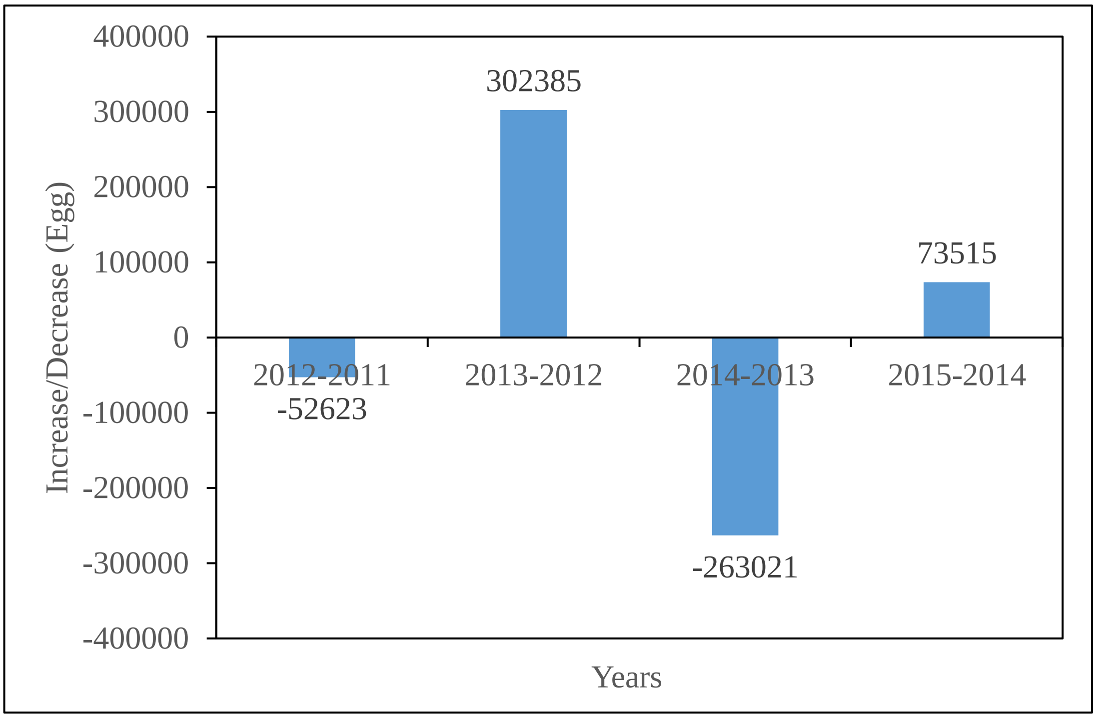


Figure 4.3 The decrease and increase pattern of the sea turtle reproductive output between 2011-2015 in term of laid eggs in Terengganu.

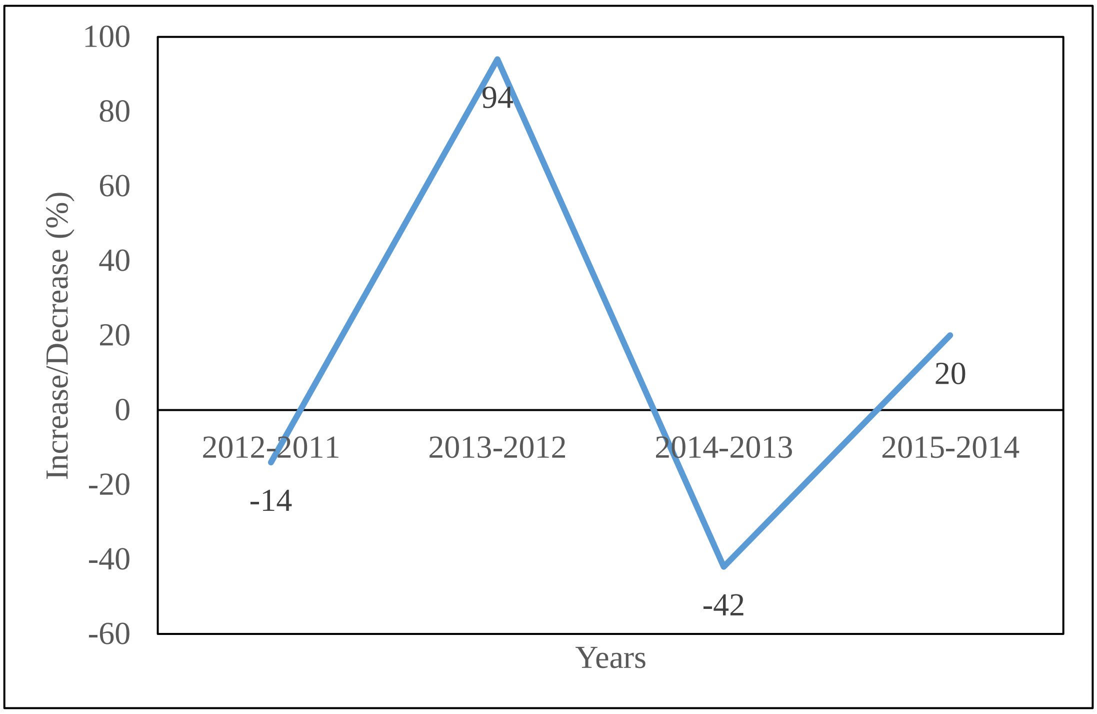


Figure 4.4 The decrease and increase percentages of the sea turtle reproductive output between 2011-2015 in term of laid eggs in Terengganu.

4.3.2 The Exponential Model

The exponential model was put onto test in this study since the sea turtle including the green turtle display some biological characteristics that resemble characteristics display by $r-$ selection species as mentioned in section 2.7 and 2.2. Generally, sea turtle has a high reproductive output as it produces a large number of eggs, absence of parental care, produces multiples clutches in a season and more frequently throughout their life. Having a high reproductive output was one of the characteristics possessed by the $r-$ selection species. Thus, based on the exponential model the sea turtle populations in Terengganu were predicted to has a drastic and unlimited growth as the time series plot illustrated in Table 4.3.

However, based on the number of sea turtles eggs according to the historical record and result of DoF data analysis in subsection 4.3.1, the exponential model prediction on sea turtle population growth in Terengganu was unrealistic. The exponential model predicted a sudden increase to 1.4×10^{10} annual eggs production in just five years. However, based on results from analysis of DoF data within 2011-2015 as mentioned in , the maximum increase of sea turtle eggs was only 302, 385 a year. Besides, the previous study in chapter 3 also revealed that the annual maximum number of current nesting mother from 2011-2015 was only 734 individual and a lower number of nesting mother was expected during 2036-2040. This low number of current and future nesting mother makes it impossible for the number of eggs to increase drastically to 1.4×10^{10}. This is due to sea turtle biological characteristics that limit the eggs production in each season as mentioned in section 2.2 because in a season (year) they only laid 9 clutches at most, yet it varies according to population (United State Wildlife Service, 2015) with the number of eggs usually limited to not more than 180 in each clutch (Hays et al., 2010).

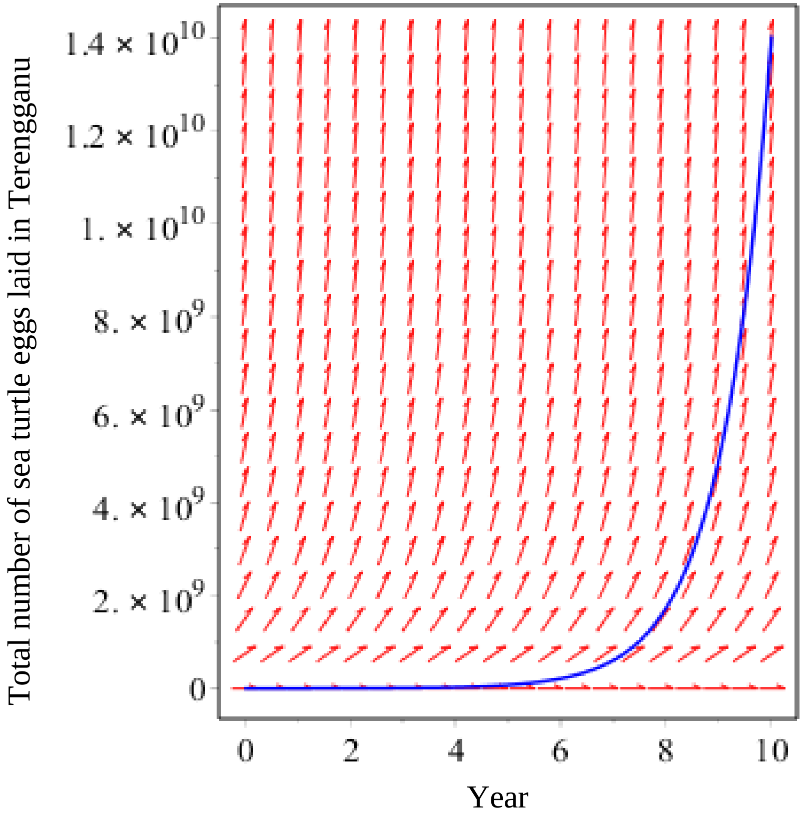
As a consequence, the exponential model overestimation happened as the sea turtles have some complex biological characteristics that work opposite to the $r-$ selection species that making it impossible for them to grow exponentially. The sea turtle population in the wild was unable to grow exponentially or in a vast amount over a short time frame because they are not homogenous. The exponential model assumed that the population is assumed is homogeneous where all of the individuals are considered to inhabit a uniform and unvarying environment with infinite available nutrients, and with no spatial limitations. This model for population growth is considered density-independent (Salisbury, 2011). In a natural population, individual turtles are not identical, as their nutrients and habitat use vary. This model is not suitable as a predictor of green turtle population size as the fact that sea turtle from different niches possessed different growth rates are not accounted for within the exponential model principal. For instance, the growth rate of the Green turtles in San Diego Bay was one of the fastest in temperate areas compares to the other Green turtles in the tropical regions (Eguchi *et al.*, 2012).

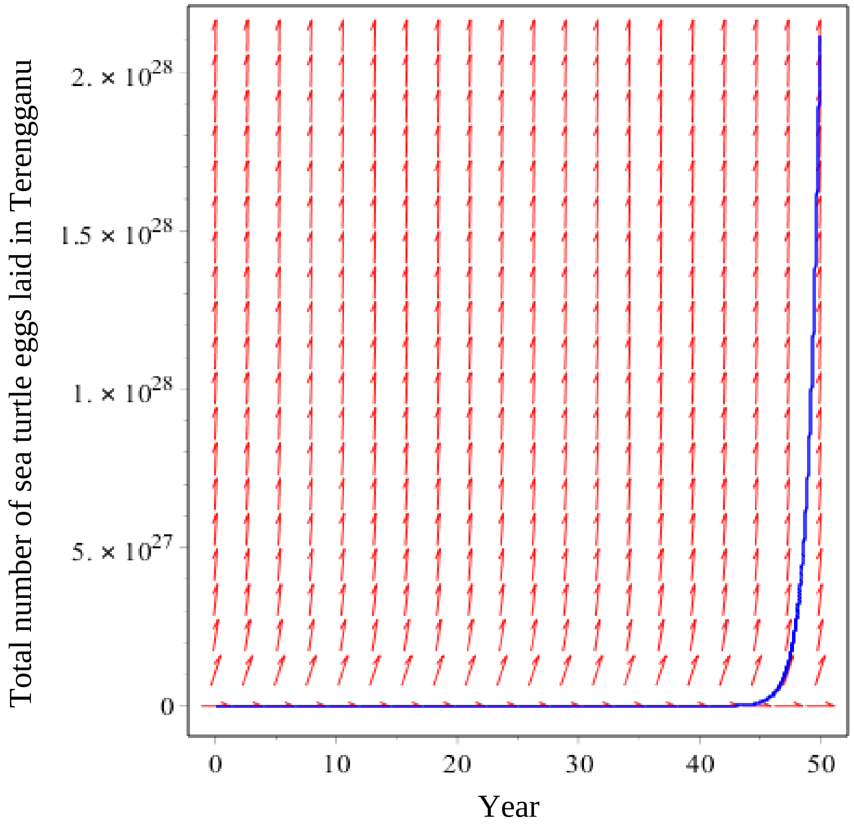
Besides that, the exponential model assumes that the population will undergo an unhindered increase (Kot, 2001) that contradicted with the sea turtle case. Each sea turtle population's size, feeding ground quality and remoteness may influence the intervals between successive seasonal nesting migrations. A two years period is a usual breeding interval however, green turtles may breed every year or wait for periods of 3 to 4 years before returning to their nesting grounds. Moreover, turtles may switch from one cycle to another due to ageing or external influences such as food quality and abundance (Fischer *et al.*, 1990). Those factors hindered sea turtle from having unlimited growth. Similarly, sea turtle growth also hindered by the carrying capacity K of each nesting beach. Furthermore, the exponential model is unreliable as it considered no predation or intraspecific competition took place in that population (Tsoularis and Wallace, 2002). Intraspecific competition between green turtles may occur due to competition for food, habitat, mate and even nesting space on the beach. For green turtles, a limited habitat type, for example, deep, or structurally complex channels availability facilitates interference competition among turtles for access to these spaces. Higher turtle densities and more complex behavioural interactions can be reflecting by more frequent and longer encounters in these areas (Carr *et al.*, 2016).

Thus, based on the biology of green turtles, this graph shows an unrealistic prediction for population growth. The exponential model was tested for the green turtle population Although the exponential model is one of the basic models for population growth for any reproducing population, Salisbury (2011) states that this model is too simple to be useful in most circumstances. This model is also too simple for sea turtle as it is a species with a complex biology and life cycle.

Table 4.3. Time series plot of the Green turtle populations in Terengganu estimated by the Exponential model within 10 and 50 years.

10 Years	**50 Years**





4.3.3 The Logistic Model

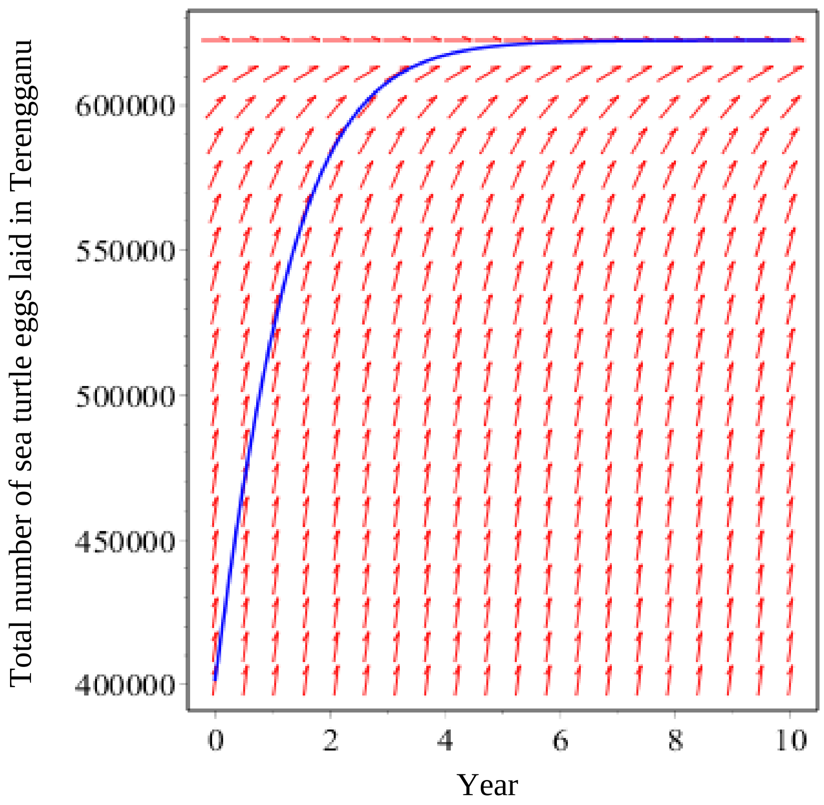
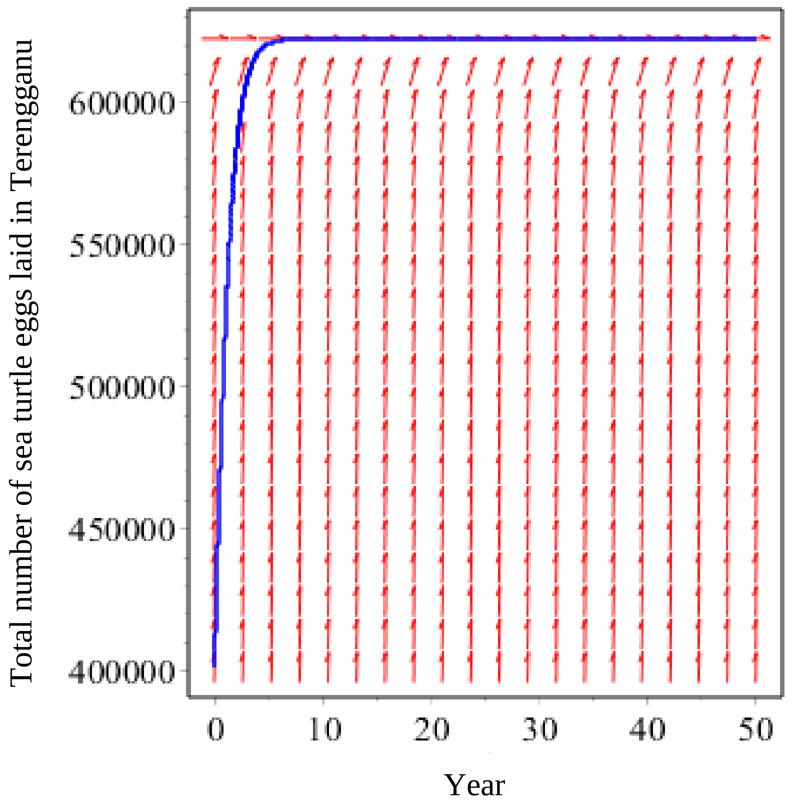
The logistic model result in Table 4.4 predicted that the sea turtle population in Terengganu will increase gradually until it reaches the habitats carrying capacity. After reaching carrying capacity, no further population growth can be observed. The logistic model predicted that there is an increase of eggs laid in Terengganu at about 650,000 in four years. This prediction was possible as between 2011-2015, the highest number of sea turtle eggs laid increase recorded in a year was about 302,385. The logistic model prediction on restricted and steady increase in total numbers of sea turtle eggs laid in Terengganu was aligned with the fact that sea turtle undergoes slower growth and reproduction as mentioned in section 2.2 and 2.7.

Contradicted to the exponential model, the logistic model seems to be more relevant to the sea turtle population in Terengganu. This is because this model includes the carrying capacity of nesting beaches as a limiting dimension. Carrying capacity, K form a numerical upper bound on the growth size noted the saturation level of population growth (Tsoularis and Wallace, 2002). In this study, the saturation level is considered as the yearly highest number of green sea turtle eggs that have been laid in Terengganu between 2011 and 2015. The number of eggs that can be incubated in each nesting beaches is fairly important as green sea turtle has relatively high fecundity where there are 38 to 195 eggs per clutch (South Yemen and Ascension Island) while the clutch size mean ranges from 84.6 eggs (in the Solomon Islands) to 144.4 eggs (in southeast Africa) (Fischer *et al.*, 1990).

Another limiting factor or carrying capacity that can be defined in future research is the species' physical characteristic limitation. The physical characteristics of interest will reach a limiting dimension when approaching maturity even in plant cases (Tsoularis and Wallace, 2002). In the case of sea turtles, especially sea turtle, the knowledge of length-at-age relationships, growth rates, and the factors influencing their variability are lacking (Goshe *et al.*, 2016). Sea turtle has a limiting dimension in their growth, or instance, 1.03 cm/year (21.6 to 11.4 cm/year) is the median growth rate for all turtles and was 4.9 cm/year for turtles ≤ 90 cm (Eguchi *et al.*, 2012). There is a need for considering the growth dimension of sea turtles from the Terengganu in the future study as it affects the survival rate. Moreover, there is a need to further study the sea turtle Terengganu population's correlation between the growth rate, breeding cycle and abundance of nutrients available in feeding grounds and distance between the nesting beaches with the feeding ground with the quantity and quality of eggs produced to enable a more accurate projection of the total reproductive output of sea turtle in Terengganu.

It is obvious that the sea turtle has prominent $K -$ selection characteristics such as slow growth and limited by the carrying capacity of nesting beaches as mentioned in section 2.2 and 2.7. Therefore, this study demonstrates that the logistic growth model was more compatible in estimating the future reproductive output of sea turtle in Terengganu because it produces prediction that was aligned with the current situation happened in Terengganu. As mentioned in the literature review in section 2.7 in the literature review, species or population that exhibit logistic growth curve have $K -$ selection characteristic that unable to produce a high number of offspring in a short time to combat egg exploitation under the mixed conservation system in Terengganu. The animal that possessed $K -$ selection invested more in quality of offspring compared to quantity (Cassill, 2019). Thus, as sea turtle was a $K -$ selection animal, they are not build for living in high predation situation. Only breeders that invest more in the quantity of offspring compared to the quality of offspring was favoured by the high rate of predation (Cassill, 2019). Thus, banning the sea turtle eggs exploitation was need to be implemented immediately.

Table 4.4 Time series plot of the Green turtle populations in Terengganu estimated by the Logistic model within 10 and 50 years.

10 Years	**50 Years**
	

4.4 Conclusion

The life history characteristic of the natural sea turtle population is widely documented. However, the changes in life-history characteristics of the exploited sea turtle population are poorly described. Egg exploitation increased the death rate of sea turtles that induced changes in key components of life-history strategy which are the growth curve. Determination of the growth curve possessed by sea turtles was important since sea turtles possessed characteristics that belong to animals that grow logistically and exponentially. Thus, this chapter tested the exploited population of sea turtles in Terengganu possessed the exponential and logistic growth curve. By understanding how they grow, it is possible to understand why they were vulnerable to the mixed conservation system, specifically the tender system. To do that, this chapter was divided into three sections which is (i) The actual sea turtle population growth, (ii) The Exponential model, and (iii) The Logistic model.

The first section which is the actual population growth were composed to identify the actual differences of annual eggs production between years. This involved subtraction of the previous annual eggs production from the recent years. Annually, a depletion of 52,623 to 263,021 eggs can be observed. Moreover, the number of eggs lain in Terengganu also increase between 73,515 to 302,385 annually. Since the total number of eggs laid in Terengganu were only between 320,163 to 622,548 eggs annually, the depletion was considered as high and threaten the species survival. Moving to the second section, the exponential model predicted that the sea turtle population in Terengganu has a drastic and unlimited growth. A sudden increase of 1.4×10^{10} in just five years were impossible based on the historical record and result of DoF data analysis on the actual population growth that was mentioned early in this paragraph. This proves that the exploited sea turtle population in Terengganu does not grow exponentially. Contradicted to the exponential model, the logistic model predicted that the sea turtle population in Terengganu will experience gradual growth until it reaches the habitats carrying capacity. The logistic model also predicted that the sea turtle population in Terengganu will not experience further growth after reaching the carrying capacity, thus their numbers will remain constant. A population increase of about 650,000 in four years was possible since the historical record and the actual population growth stated that annual eggs exploitation can experience an increase at about 302, 385 eggs. This proves that the logistic model capable of catching the restricted and steady growth of the sea turtle population in Terengganu. Therefore, the sea turtle populations in Terengganu were assumed to grow logistically.

Last but not least, since the sea turtles grow logistically, they should not be subjected to any type of exploitations. Their life history characteristic does give them the advantage to survive the tragedy that wipes out dinosaurs from the earth, not human exploitation. The sea turtles are not capable to evolve and developed a coping mechanism to cover up or avoid eggs exploitation. With that being said, the state government needs to stop eggs exploitation under the mixed conservation system in Terengganu. This fragile creature had tried to survive, yet human exploitation had push until their last defence. If extinction does happen soon, only human greediness should be blame. This chapter is relatively important since it provided a basic guide for the exploited population's life history characteristic evaluation using growth curve modelling and can be implemented to other exploited populations around the world.

CHAPTER 5

MAXIMUM HARVEST OF SEA TURTLE EGGS

5.1 Introduction

The natural and human sources threats were experienced by sea turtles (Halls & Randall, 2018). Yet, the harvest was considered as the common human activity that capable of eradicating animal or plant from a population (Sinclair *et al.*, 2006). The harvesting of sea turtle in Terengganu begun from the traditional practice in the local coastal community. Decades prior to the discovery of leatherback rookery in Malaysia by international scientists, the local fisherman had been collecting the leatherback eggs for consumption purposes. Within this time frame, the sea turtle eggs can only be seen as a protein supplement to coastal villages. Consequently, the exploitation of sea turtle eggs skyrockets after World War II, making it a commercialized commodity. The escalated sea turtle eggs exploitation was contributed by the improvement in roads, ferry services, and bridges that were built to linked villages to coastal towns (Liew, 2011).

Subsequently, the ownership conflicts became apparent between the locals as the egg exploitation expand quickly. Then, the Turtle Enactment of 1951 was implemented by the Terengganu state government to solve this issue. Under this enactment, the highest bidder was offered lots of divided nesting beaches for an exchange on exclusive rights to collect eggs in a season (Liew, 2011). Although this enactment has been around for decades, there is no research about its sustainability was conducted. This explains the absence of the law and the implementation of a fixed maximum annual harvest limit in Terengganu. This leads to the serious depletion of the sea turtle population in Terengganu. By looking at their nesting density, Chan

(2006) concluded that the Leatherbacks, Hawksbills and Olive Ridleys turtle was virtually extinct. Thing turn for the worst in 2010 when the leatherback turtle became locally extinct (Gomez & Krishnasamy, 2019). Although the green turtle doing quiet well compared to other species in Terengganu, this species also listed as endangered in the IUCN Red List of Threatened Species (Tan, 2004). The annihilation of sea turtle in Terengganu became more apparent day by day due to serious depletion and extinction. Thus, the evaluation of sea turtle eggs harvesting needs to be done urgently. With that being said, the study in this chapter was composed to evaluate the current harvest limit of sea turtle eggs on its sustainability. Moreover, the study in this chapter also intentionally composed to pin down the new sustainable maximum annual harvest limit for sea turtle eggs harvesting under the tender system.

Literature survey exposed that no research on sustainable annual harvest limit for sea turtle eggs harvesting had been carried out regarding egg exploitation in Terengganu under the mixed conservation systems. The historical record stated that the hatchery begins to incubate leatherback eggs in 1961. The incubated eggs were originated from a protected section on Rantau Abang nesting beach. Because of declined nest number, the leatherback eggs had to be purchased from commercial eggs collectors. From the total egg production, only 2% was incubated. During that time, the 2% incubation was considered to be sufficient for supplying recruitments for sustaining the sea turtle population. This incubation then altered to 15% after that. This incubation rate thought to be sufficient for population survival by scientists due to the lacks of scientific information. Yet, the actual conservation rate hinge on the funding availability. Ranging from 9.5% to 53.5%, the true actual percentage most of the time was 15% higher than the management target. The leatherback eggs were attempted to be saved about 100% by the government with the establishment of the Terengganu Turtle Sanctuary Advisory Council (Liew, 2011). However, Liew (2011) also mentioned that the Malaysian leatherback population was already critically diminishing. Despite the government effort to incubated 100% of leatherback eggs, it still ends up extinct. Detailed conservation rate was stated in Liew (2011) nevertheless, only a section of Rantau Abang nesting beach and leatherback turtles became a focal point in this record. Adding to that, this record proves that no sustainable maximum annual harvest limit study, law and implementation in Terengganu due to the inconsistent incubation rate recorded in this previous literature.

Since this study intended to evaluate the sustainability of the current harvest rate and classify the new sustainable maximum annual harvest limit, the Maximum Sustainable Yield (MSY) and Modified Maximum Sustainable Yield (MMSY) model was employed to assist this study. MSY is defined as the highest possible annual catch that can be sustained over time, by maintaining the stock at the level producing maximum growth for a given fish stock (Tudela & McLachlan, 2011). In another word, under existing or average environmental conditions, MSY was the highest theoretical equilibrium yield that can be continuously harvested from a stock. Owning to this model advantages, this model was practical for setting the harvest limit (Tsikliras & Froese, 2019). Despite this advantage, the MSY model only considered the death rate resulted from the exploitation of the species. The MSY model completely abandons the natural mortality rate. Ignoring the natural death rate can result in overestimation as the sea turtle population have a high death rate resulting from natural causes. Generally, only one in 1,000 to 10,000 hatchlings able to reach adulthood (McGuire *et al.*, 2017) making the natural death rate of sea turtle as great as 0.999. Due to the shortcoming of the MSY model, the MMSY model was proposed to assist this study. The MMSY model was inspired by the MSY model. Regardless of this, the MMSY include the natural death rate in the total death rate. The total death rate in the MMSY model was assumed as the addition of the natural death rate and death rate resulted from sea turtle eggs exploitation in Terengganu. For this very reason, both MSY and MMSY model was tested for the first past of study in this chapter which is evaluating the sustainability of sea turtle eggs current harvest rate in Terengganu. Yet, because the MMSY model was closely represented the sea turtle population in real life, this model was selected for analysis to determine the new sustainable annual harvest limit of sea turtle in Terengganu.

In short, this study was crucial as this is the first trial to appraise the sustainability of the sea turtle eggs harvesting that took places in Terengganu from decades ago. This study was also the first attempt to predict the extinction point of sea turtles in Terengganu that experience egg harvesting by the tender system under the mixed conservation system practices by the Terengganu government. This study was extremely important because it is the first attempt to set a sustainable maximum annual harvest limit of eggs harvesting in Terengganu. There is a rise in research based on possible management strategies because of the natural threats coupled with additional stress placed on turtles by human activities (Halls & Randall, 2018). This study was the first one to focus on the importance of taking into account the natural death rate for setting up the harvest limit for the sea turtle species that have high natural mortality. The Terengganu government can also be beneficial from this study as it can assist the government to set up the new sustainable maximum annual harvest limit. Furthermore, this MMSY model also can be used by other parties to evaluate the sustainable annual harvest limit of species in other places, state and countries that also have enormous natural death rate.

5.2 Methodology

The secondary data from the Terengganu State Department of Fisheries (DoF) was used in the study of this chapter. This secondary data includes the nesting density, location, and type of beaches. Generally, secondary data was known as the data gathered in the past and manipulated to answer new questions (Martins *et al.*, 2018). The nesting data for some beaches supplied by DoF were labelled as "ND" which explained as no nesting data. Thus, these beaches were considered as having no nesting or zero nesting for the particular years where it was labelled as ND. Another assumption that was made was all eggs incubated on the protected beaches have 100% survivorship for hatching, emerging and crawling to the sea stage. Contradicted to the assumption on the protected beaches, the eggs laid on the tendered beaches are assumed to be poached completely leading to 0% incubation and survival. The eggs in tendered beaches are assumed to have a 100% mortality rate.

The first section of this chapter will investigate the sustainability of the current harvest rate of sea turtle eggs in Terengganu based on the MSY and MMSY model. Between MSY and MMSY model, the model that produced the 50 years prediction that closely represents the decrease of sea turtles in Terengganu will be chosen as the most suitable model to represented and evaluate the sea turtle eggs harvesting in Terengganu or elsewhere. Then, the second section was composed for investigating the new sustainable maximum annual harvest limit of sea turtle egg harvesting in Terengganu. The second section evaluation will be facilitated by the MMSY model. The maximum annual harvest limit that able to help the sea turtle survived up to 100 years were choose as the suggested new sustainable maximum annual harvest limit. In both sections, the sea turtle population size response to the current harvest limit and tested new sustainable maximum annual harvest limit was illustrated using the time-series plot. The results of this chapter were compared to the result in chapter 6 and discussed and concluded in the last Chapter 9.

5.2.1 Sustainability of Current Sea Turtle Eggs Harvest Limit

The exploitation and diverse human activities have resulted in sea turtle depletion worldwide for a few centuries (Girard *et al.*, 2016). As mentioned in previous chapters, the sea turtle depletion in Terengganu rooted in their eggs exploitation by the tender system under the mixed conservation system practices by the Terengganu government. This mixed-conservation system resulted in severe population depletion as mention in previous chapters, making it essential to undergo the sustainability analysis. The MSY and MMSY models were chosen for this analysis. MSY model was selected as it capable of pointing out the highest catch while allowing the population to sustain itself indefinitely through somatic growth, spawning, and recruitment (Tsikliras & Froese, 2019). The MSY model also selected as it assumed that the population grow logistically, aligned with the result produced in Chapter 4 where the sea turtles proved to grow logistically. Kinfe & Zenebe (2016) mentioned that the MSY model begins with the logistic equation and assumption where the level of fishing rate is proportional to the fish stocks. Based on the basic principle of the MSY model as mentioned in Kinfe & Zenebe (2016), the anthropogenic death rate which eliminates an individual from a population was assumed as the exploitation rate of sea turtle eggs in Terengganu. Thus, the MSY model in this study can be illustrated as below,

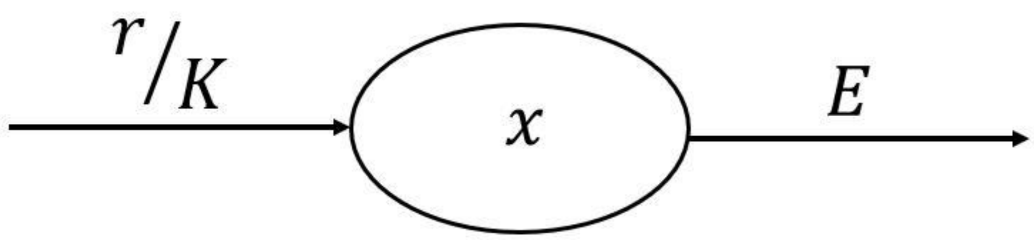


Figure 5.1 Flow diagram of the MSY model.

$$\frac{dx}{dt} = rx(1 - \frac{x}{K}) - Ex$$

Equation 5.1 MSY model.

The parameter $\frac{dx}{dt}$, r and x are as previously defined in Table 4.1. Besides that, the carrying capacity, $K = 622548$ as defined in section 4.2.3. The average annual exploitation rate of sea turtle eggs was set as $E = 0.0858$ according to calculation of the DoF nesting data from 2011 to 2015. In order to get the annual average exploitation rate, the total rate of eggs laid in the tendered beach was divided by 5 because 5 in this formula represented the number of years from 2011-2015. The formula was stated as below,

$$E = (\frac{Total\ eggs\ laid\ in\ tender\ holder\ beach\ from\ 2011 - 2015}{Total\ eggs\ laid\ in\ Terengganu\ beach\ from\ 2011 - 2015})/5$$

The MSY model is often used to describe the exploitation of species that have less significant natural death rates such as organisms with $r-$ selection characteristics (as mentioned in section 2.7 and Chapter 4). The organisms with $r-$ selection characteristics generally have a short to medium life span enabling them to reach maturity and produce hatchlings at an early age and in large numbers. These fast life-history characteristics also resulted in a shorter life span. Therefore, the MSY model abandoned the natural death rate. Natural death or mortality generally defined as the death of the individuals in the population to natural sources such as predation, disease and old age (Simpfendorfer *et al.*, 2005).

Including the natural mortality in the sustainability analysis of sea turtle eggs harvesting in Terengganu was important since it has a high natural mortality rate. Halls & Randall (2018) mentioned that from every 1, 000 eggs, only one can make it into adulthood. This makes the natural mortality rate as high as 0.999. Thus, the MMSY model that takes into account both natural death and death rate from fishing mortality (exploitation) was proposed. The MMSY include both natural and fishing mortality since the total death rate of a population was the sum of the fishing and natural mortality (Simpfendorfer *et al.*, 2005). The MMSY mortality expressed the total mortality rate, the natural mortality rate and the fishing mortality (sea turtle eggs exploitation rate in the form of finite rate. The finite rate was a rate that applied to another fixed period (Simpfendorfer *et al.*, 2005). The finite rate in the MMSY model was based every year. Thus, the MMSY model was composed as below in

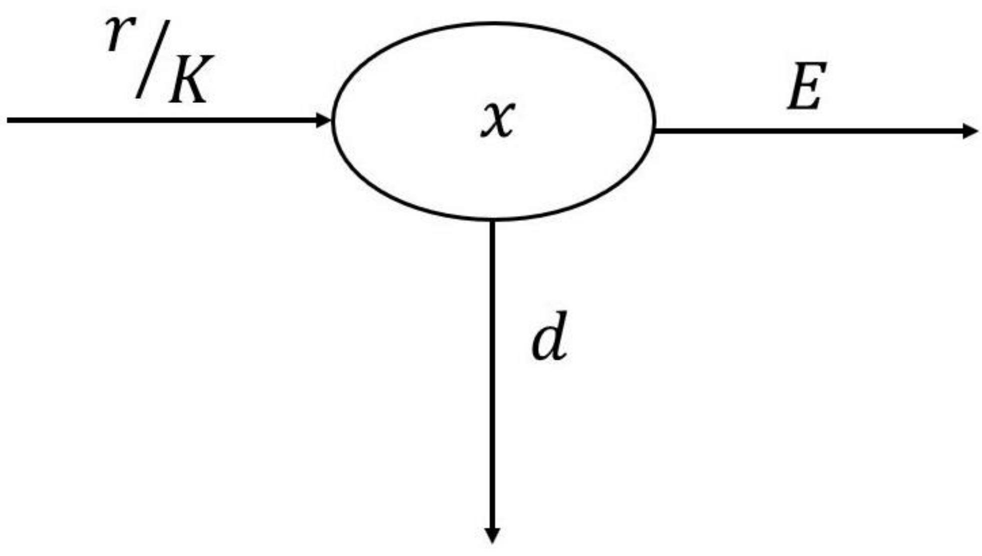


Figure 5.2 Flow diagram of the MMSY model.

$$\frac{dx}{dt} = rx(1 - \frac{x}{K}) - (E + d)x$$

Equation 5.2 MMSY model.

The parameter $\frac{dx}{dt}$, r and x are defined in Table 4.1. Besides that, the carrying capacity, $K = 622548$ whereas the sea turtle eggs exploitation rate is set as $E = 0.0858$ as mentioned in the MSY model previously. The added element in the MMSY model which is the natural death rate, d is set $d = 0.9999$. This assumption was made since the survival rate of sea turtle that was only $\frac{1}{1\,000}$ or stated as $\frac{1}{10\,000}$ in other cases (McGuire *et al.*, 2017), making the death rate became was 0.9999.

The total death rate was considered as the sum of E and d. The time phase plot was produced by both MSY and MMSY model within 10 and 50 years thus, $t = 10$ and $t = 50$. This phase plot gave prediction the sea turtle in Terengganu growth and was compared and discussed. The best model that aligned with the real situation of sea turtle population depletion that occurred in Terengganu was chosen to represent the case.

5.2.2 New Sustainable Annual Harvest Limit

This section was tailored for determining the sustainable maximum annual harvest limit of sea turtle eggs harvesting in Terengganu. Since only the MMSY model concept closely represented the sea turtle eggs harvesting situation in Terengganu, this model was employed in the study of this section. An assumption that the fishing or harvest rate (exploitation rate) was inversely proportional to the sea turtle density. This assumption was made based on a statement in Becker *et al.* (2019) where historically, an area that had a low human density is likely to have low rates of exploitation. The low rates of exploitation make the area has higher sea turtle density. According to this assumption, a few new harvest rates were obtained using the formula as follow,

$$New\ harvest\ rate\ (E') = E \times Suggested\ annual\ harvest\ limit\ (\%)$$

It is assumed that the harvest rate, $E = 0.0858$ and fixed for all suggested annual harvest limit throughout the study in this section. The suggested annual harvest limit referred to as the degree of the tender system openness. Generally, this tender system openness was a suggestion on the percentage of the tender system that should be allowed to run annually or in each nesting season. For instance, if only 50% of the tender system suggested for operation each year, the calculation for the $New\ harvest\ rate = 0.0858\ \times \frac{50}{100}$ which is equal to 0.0430. This means that the harvest rate that allowed was only 0.0430. A further list of the tender system openness and the new harvest rate can be seen in Table 5.1.

Table 5.1 List of suggested annual harvest limits and new harvest rates under the MMSY model.

Suggested Annual Harvest Limit (%)	New Harvest Rate
0	0.0000
25	0.0215
50	0.0430
75	0.0644

The sustainability of the suggested new annual harvest limit was tested by substituting the value of the new harvest rate as E' into the MMSY model. This simply means that each of the new suggested harvest limit replaced the value of harvest rate of sea turtle egg, E used in the sustainability of the current annual harvest limit analysis in section 5.2.1 of the MMSY model. These new harvest limits were suggested because the preliminary trial on the model revealed that if the differences between the two consecutive annual limits differences were below 25%, a closely similar prediction was produced. This leads to producing results with is no significant prediction. Thus, this research was set for having 25% differences (gaps) between the two proposed harvest limits.

Moreover, these MMSY model prediction on the sea turtle population growth in Terengganu based on harvest limit was illustrated with the help of the time series plots in the 100 years time-lapse. Thus, the measurement of time in this analysis was based on the year where $t = 100$. The growth prediction of each time phase plot was discussed and concluded. This help in suggesting the new sustainable annual harvest limit of sea turtle eggs in Terengganu.

5.2.3 Models Summary

According to the characteristics used by Kot (2001) to classify a model, it can be deduced that both models used in the study of this chapter were the unstructured population models that are considered as a single- species model. The MSY model was based on Kot (2001). However, the MMSY model was first proposed in the study. The summary of the models was stated as in Table 5.2 below,

Table 5.2 Overview of the single models used in Chapter 5. The MSY and MMSY models were used for evaluating the maximum sustainable annual harvest rate in Terengganu.

Model	Governing Equation	Assumptions
Maximum Sustainable Yield (MSY)	$\frac{dx}{dt} = rx(1 - \frac{x}{K}) - Ex$	The population size depends on the growth rate and limits by the carrying capacity of the habitat Individuals in the population is eliminatedby human exploitation.
Modified Maximum Sustainable Yield (MMSY)	$\frac{dx}{dt} = rx\left(1 - \frac{x}{K}\right) - (E + d)x$	The population size is dependent on the growth rate and is limited by carrying capacity. Individuals in the population are eliminated by human exploitation and natural death.

5.3 Result and Discussion

The result section was divided into two parts which is the "Sustainability of Current Sea Turtle Eggs Harvest Limit" and the "New Sustainable Annual Harvest Limit". The first part which is the "Sustainability of Current Sea Turtle Eggs Harvest Limit" illustrated the sustainability evaluation on the current harvest rate of the sea turtle eggs harvesting in Terengganu based on the MSY and MMSY models. The sustainability prediction on the current harvest limit (0.0858) was illustrated within 10 and 50 years. The sea turtle growth prediction by the MSY model was compared to the MMSY model and discussed. The model that closely represented the real-life situation of sea turtle in Terengganu was selected as the true prediction. The point where the sea turtle eggs hit zero in this selected model was accepted as the references for the extinction point in Terengganu.

The second part of this result section was the "New Sustainable Annual Harvest Limit". This section illustrated the sustainability of each proposed new annual harvest limit such as $0.0000, 0.0215, 0.0430$, and 0.0644. This part was facilitated by the MMSY model. The result illustrated the prediction of sea turtle population growth within 100 years based on the proposed new annual harvest limit. The sea turtle growth prediction based on each proposed harvest limit then compared and discussed. The proposed harvest limit that helps the sea turtle population to sustain throughout the 100 years would be selected as the new harvest limit.

5.3.1 Sustainability of Current Sea Turtle Eggs Harvest Limit

The MSY model in Figure 5.3 and Figure 5.4 predicted that the sea turtle eggs laid will continue to increased and eventually stop increase when carrying capacity at about more than 5,50 000 was achieved. In simple words, the MSY model predicted that the current harvest rate of sea turtle eggs in Terengganu is sustainable. On contrary, the MMSY model predicted that the number of eggs laid in Terengganu will continue to drop and eventually reach extinction point in 35 years due to insufficient hatchlings production. This extinction point was marked by zero sea turtle eggs production in Terengganu. This predicted extinction event was also an indicator that the current eggs harvesting under the tender system in Terengganu was unsustainable.

The MSY model was also tested in this study as it usually used as a management strategy for other species as mentioned in section 2.8. Besides, the MSY model was included in this study to tested if ignoring the natural death rate of sea turtles have no significant impact on the population size growth prediction. Yet, the MMSY model prediction was selected as it is the closes one to represent the sea turtle population reduction that occurred in Terengganu. Thus, the MMSY model prediction was considered the most accurate model to represent the sea turtle eggs harvesting in Terengganu for a few reasons.

Firstly, the MMSY model considered the sum-up of the sea turtle death resulted from natural and exploitation causes as the total death rate. The exploited sea turtle eggs do not contribute to the population growth as almost all of them end up in the market or restaurant for human consumption. The licenses egg collectors harvested almost all sea turtle clutches as it is a profitable venture. The markets and restaurants buy these sea turtle eggs at a very high price (Tan, 2004). Liew (2011) also mentioned the same situation whereby to become profitable, the eggs collector had to harvest all eggs due to the rise in tender price as this business became lucrative. Adding to that, the eggs, hatchlings and juvenile turtles that died before they reach sexual maturity also maturity do not contribute to the population growth. Only $\frac{1}{1\ 000}$ or stated as $\frac{1}{10\ 000}$ sea turtle hatchling can survive up to their sexual maturity McGuire *et al.*, 2017), making the natural death rate of sea turtle as high as 0.9999. Since the MMSY model considered mortality from natural and exploitation causes, the overestimation of sea turtle population size was avoided. This contradicted the MSY model that only considered the death from exploitation as the total death rate, leading to the overestimation of the sea turtle population

Secondly, the MMSY model was chosen as it highlighted the fact that the total mortality of sea turtles in Terengganu is 100%. This was different from previous researches or models such as MSY that considered only 100% harvesting will result in the extinction of a species. Pilcher (2001) point out that the population was harvested 100% annually will end up with no breeding females available within 25 years. Lovich *et al.* (2018) also stated that killing 100% of the female alligator snapping turtle before they can nest result in no more adult turtles. If the female alligator snapping turtles takes 15 years to mature, zero nest will be produced after 1987 due to 100% harvesting of the female alligator snapping turtle before they can nest. Plus, between the years 1987 to 2002, the observation conducted by Lovich *et al.* (2018) revealed the appearance of returning adult turtles every year. However, things take turn for the worse in 2002 when the numbers of females that able to nest in the population became zero (Lovich *et al.*, 2018). These two previous pieces of research deducted that 100% harvesting that resulted in mortality was the factor for population extinction. It can be considered that 100% harvesting equal to 100% mortality. The study in this chapter agreed that 100% mortality leads to sea turtle extinction. Yet, this study cannot agree that the 100% mortality that causes extinction was only from harvesting activity. This research established that the 100% mortality of sea turtle build-up by both natural mortality and harvesting or exploitation mortality.

Thirdly, the MMSY model was chosen as it emphasizes the fact that a large number of hatchlings needs to be produced to replace “menopause” or dead sea turtles. Biologically, one day no more eggs will be produced as the lacks of insufficient hatchlings production resulted in insufficient or no recruitments. Recruitments were crucial in replacing the old sea turtles as the sea turtles only remain reproductively active at about 20 years after reaching sexual maturity (Tan, 2004). Thus, this study proved that having a 100% mortality rate (sum of natural and harvesting death rate) would destroy the population from “the bottom up. The root of these green turtles bottom-up destruction was the eggs overharvesting which had similarly observed in plentiful parts of south-east Asia and elsewhere. This situation arose as no new hatchlings would enter the population (Tan, 2004). A detailed description of how 100% harvesting leads to the bottom-up destruction of the species was mentioned by Tan (2004) as follow:

- After 10 years of 100% egg harvest

  - The numbers of breeding adult and sub-adults will remain the same as in the unexploited population

  - The juvenile turtles will be reduced in numbers

  - After a year of 100% egg harvest, the hatchlings were annihilated from the population thus the number of hatchlings remain in the population will be zero

- After 20 years of 100% egg harvest

  - The numbers of breeding adults will remain the same such as in the unexploited population

  - Numbers of juveniles and sub-adult in the population will be lower than the population after 10 years of 100% harvest

  - Zero hatchlings will be produced in the population

- After 50 years of 100% egg harvest

  - Breeding adults that spotted on the nesting beach begin to decrease in numbers

  - The minimum age of remaining females in the populations was 50 years old

  - No hatchlings, juveniles and sub-adults remain in the population

  - At this stage, the population depletion was recognizable to the general public

  - The population was on the verge of extinction

- After 70 years of 100% egg harvest

  - The turtle population was expected to be extinct in the 71st year

The MMSY model predicted the sea turtle extinction within 35 years. This was different from the time scale stated by Tan (2004) where the sea turtle will extinct in the 71st year. The legal sea turtle eggs harvesting start with the implementation of Turtle Enactment 1951. It has been 69 years of legal sea turtle eggs exploitation in Terengganu if counted from the years of 1951- 2020. Years of sea turtle eggs harvesting in Terengganu resulted in this population depletion that visible to the public eyes. The depletion was marked by the sea turtles nesting density decline. This depletion was displayed by sea turtle species in Terengganu such as by the leatherback turtle species. In the year of 1951, this population ranked as a landmark population (Liew, 2011) since there were about 853,700 eggs laid by the leatherback turtles (Siow, & Moll, 1982), yet in 2010, this species was considered locally extinct due to zero nesting was observed in Terengganu (Gomez & Krishnasamy, 2019). Another species of sea turtle that occurred in Terengganu which is the green turtles also experiences depopulation as the current annual yearly average nesting density only 2,000 (Chan, 2006) although, in the year 1951, it is estimated there were 770,200 eggs yield yearly (Siow, & Moll 1982). Other species that occurred in Terengganu which is the Olive Ridley turtle and hawksbill turtle seriously depleted and eventually considered virtually extinct (Chan, 2006) although previously they were estimated to be producing 240,000 and 10,700 eggs yearly (Hendrikson & Alfred, 1961).

Lastly, the MMSY model prediction on the sea turtle extinction in Terengganu will occur within 35 years was possible if we assumed that most of the nesting mothers in Terengganu was at least 50 years old as mentioned by Tan (2004). This assumption was made as in chapter 4, it is predicted that the number of sea turtles produced in Terengganu would not exceed the number of sea turtle eggs produced in the past such as in the year 1950. Then this chapter also predicted that there will be zero sea turtle eggs produced 35 years in the future. Logically, it can be deduced that these two situations arose because the (1) number of current nesting mother was lesser compared to the past. This is due to the sea turtle biology as mentioned in section 2.2 where the numbers of sea turtle eggs produced by each turtle were limited as they are unable to produced eggs every season, produced only a few nests in a season and have a limited number of eggs in each clutch. (2) Most of the current nesting mother was old and possibly undergo “menopause” thus extinction possibly occurred as no or an inadequate number of recruitments was produced. Possibly, no or inadequate recruitments were produced as previously the licensed eggs collectors sold most of the sea turtle eggs to the market to be profitable and only sold a small fraction of egg to the hatcheries for incubation (Tan, 2004).

As mentioned in the previous paragraph, this is because the sea turtles only remain reproductively active for 20 years (Tan, 2004). After 20 years, the sea turtle undergoes “menopause” which makes them unable to produce hatchlings. This research can only assume the age of the majority mother as at least 50 years old due to this fact because no complete research on the nesting mother age was conducted in every nesting beach in Terengganu previously or currently. In the future, it is suggested that research was conducted on the Terengganu nesting mother age and included in the mathematical or ecological model to increase the model sensitivity and accuracy.

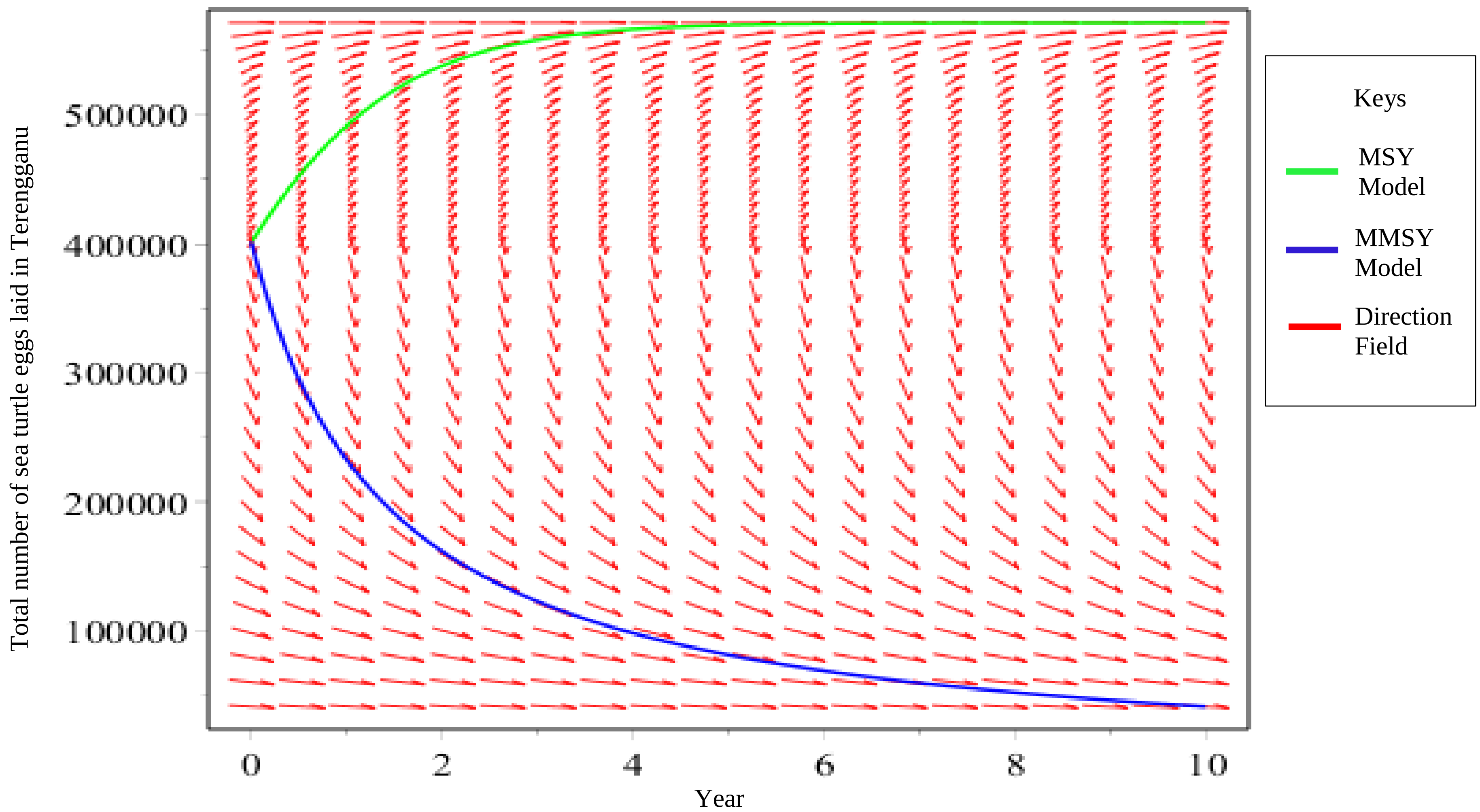


Figure 5.3 The sea turtle population growth prediction based on MSY and MMSY models within 10 years.

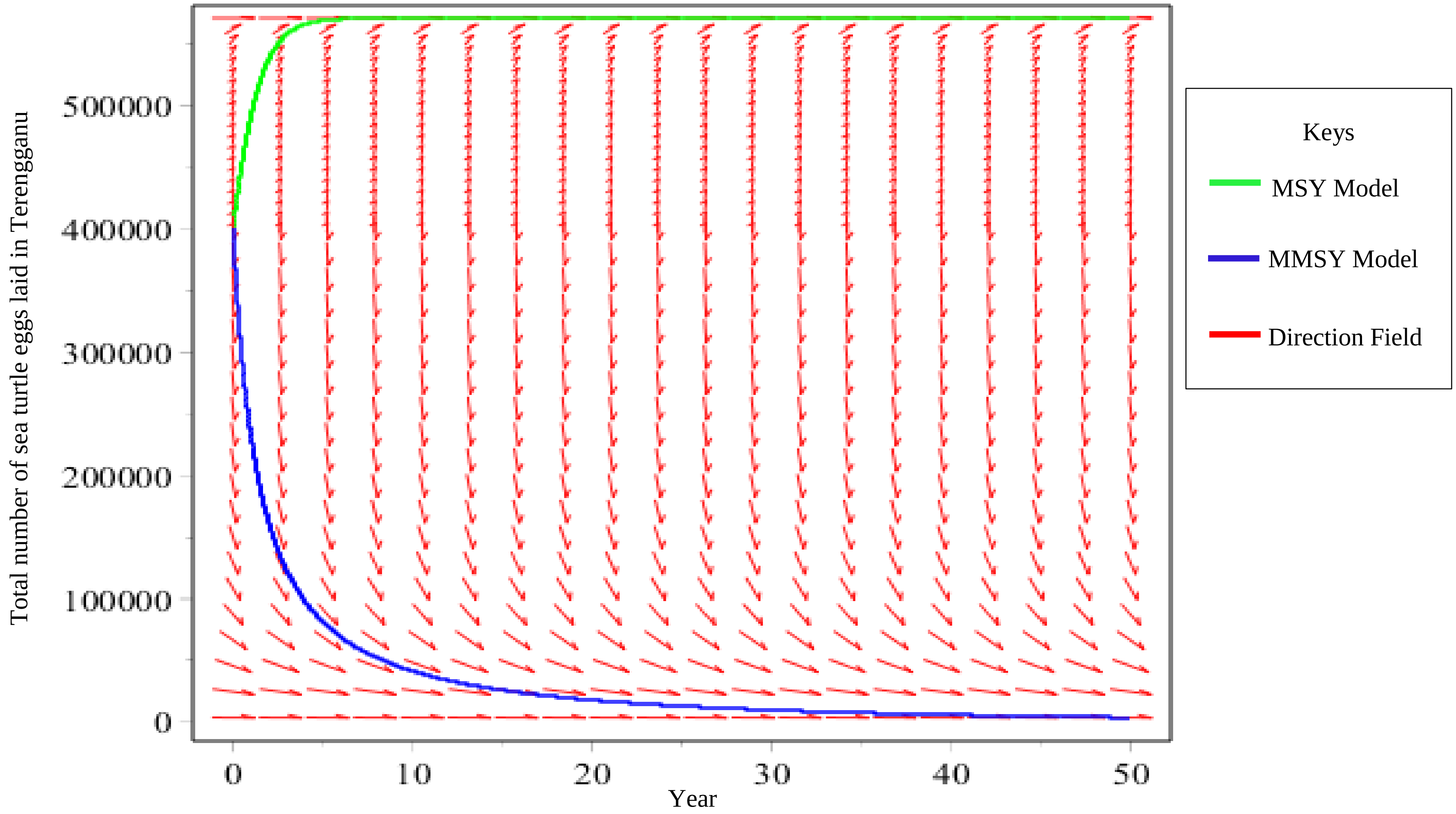


Figure 5.4 The sea turtle population growth prediction based on MSY and MMSY models within 50 years.

5.3.2 New Sustainable Annual Harvest Limit

The prediction on the total numbers of sea turtle eggs laid in Terengganu was illustrated in Figure 5.5 were based on the proposed annual harvest limit between 0.0000 to 0.0644. Only the annual harvest limit within 0.0000 to 0.0215 will result in population continuity within 100 years. However, the sea turtles in Terengganu will extinct within 85 years due to zero eggs production if the proposed annual harvest limit of 0.0430 was implemented. The condition worsened where there will be no sea turtle eggs production after just 70 years if the proposed annual harvest limits of 0.0644 were implemented.

Based on this result, only the proposed annual harvest limits of 0.0000 (total ban) and 0.0215 were sustainable since they were capable to ensure the continuity of the sea turtle eggs in Terengganu for up to 100 years. The proposed annual harvest limits of 0.0430 and 0.0644 were not sustainable since both resulted in zero sea turtle eggs laid in Terengganu within 100 years. This supported by Cheilari & Rätz (2009) where the alteration in the ecosystem resulted from the human-induced mortality depending on its magnitude. The sea turtle eggs harvesting capable of egregiously impacting the ecosystem and sea turtle population in Terengganu. Since the harvested sea turtle eggs ended up for human consumption in the market such as Pasar Payang, Terengganu, it does not contribute to the population size growth. Due to their high natural death rate that was as high as 0.9999, even the slightest sea turtle eggs harvest can lead to extinction. Although Terengganu has 12 protected sea turtle nesting beaches, due to the high natural death rate these beaches were unable to produce enough sea turtle eggs and hatchlings for recruitments leading to the inevitable sea turtle extinction.

Besides that, the prediction of only the proposed annual harvest limit 0.0000 and 0.0215 was sustainable since sea turtles in the wild such as Terengganu was biologically unequipped to battle the mortality from higher sea turtle eggs harvesting. Biologically, sea turtles have a slow life history as mentioned in section 2.2 and Chapter 4 where they take an average of 20-30 years to achieve sexual maturity (Kemf *et al.*, 2005). This slow life history strategy allowed for high mortality in hatchling that was offset by high reproductive potential and longevity in sea turtles (Robinson & Paladino, 2013). Robinson & Paladino (2013) asserted that this strategy had worked for millions of years, yet many populations were depleted due to the elevated mortality from anthropogenic sources. Robinson & Paladino (2013) statement aligned with this finding as the sea turtle eggs harvesting was one of the mortality types in sea turtles that resulted from the anthropogenic activity. Due to their slow life history, sea turtles were unable to evolve (such as having earlier sexual maturity) to cope with the harvesting pressure. Contradicted to sea turtles, harvesting stimulates other species that possessed a faster life history such as fishes to experience the rapid life-history evolution that include an early maturation at a small size (De Ross *et al.*, 2006). Arula *et al.* (2017) strongly agreed with this theory by stating that some other highly exploited fish produced individuals that are having a smaller size and younger age when they experience the first maturation. For instance, due to overfishing, the European smelt (*Osmerus eperlanus*) have an early maturation that significantly affects its recruitment abundance (Arula *et al.*, 2017). The European smelt was considered a species with faster life history. This proves that the sea turtles have an opposite coping mechanism that contrasts with the species with faster life history. The species possessed the faster life history are capable of taking harvesting as an advantage. Contradicting to those species, sea turtles were unable to benefit from the harvesting activity, they gradually depleted and eventually extinct.

Thus, to prevent extirpation, this study suggested that the annual harvesting rate was reduced to 25% from the current harvest rate before the total ban of the sea turtle eggs harvest. This step-by-step ban might help the local people to switch to alternative livelihoods such as the traditional handicraft that includes the songket weaving, batik industry, mengkuang and pandanus weaving, rattan weaving, wood carving, wau makings, brassware, keris making and traditional boat or ship construction. This is since the radical action of a sudden total ban on the sea turtle eggs could lead to a negative effect on the culture and the local people livelihood (Jani *et al.*, 2020).

Yet total ban is a must to recover the population size of sea turtle in Terengganu since the key driver of the population growth was the interplay between reproductive success and mortality (Tsikliras & Froese, 2019). The harvesting rate should be reduced since the sea turtles possessed a slow life history that results in a slower growth rate. This enables the sea turtle population size to recover at least as much as in the 1951's where the eggs production was about 1,664,400 eggs (Siow, & Moll, 1982). The total ban was also crucial since this study only considered the mortality rate from a natural source and eggs harvesting, not from other anthropogenic factors such as the death in a gill net, boat strike, plastic pollution and adult hunting. In future research, it is suggested that to include the anthropogenic death rate from other factors as it might reveal a higher mortality rate that helps to uncover more serious depletion.

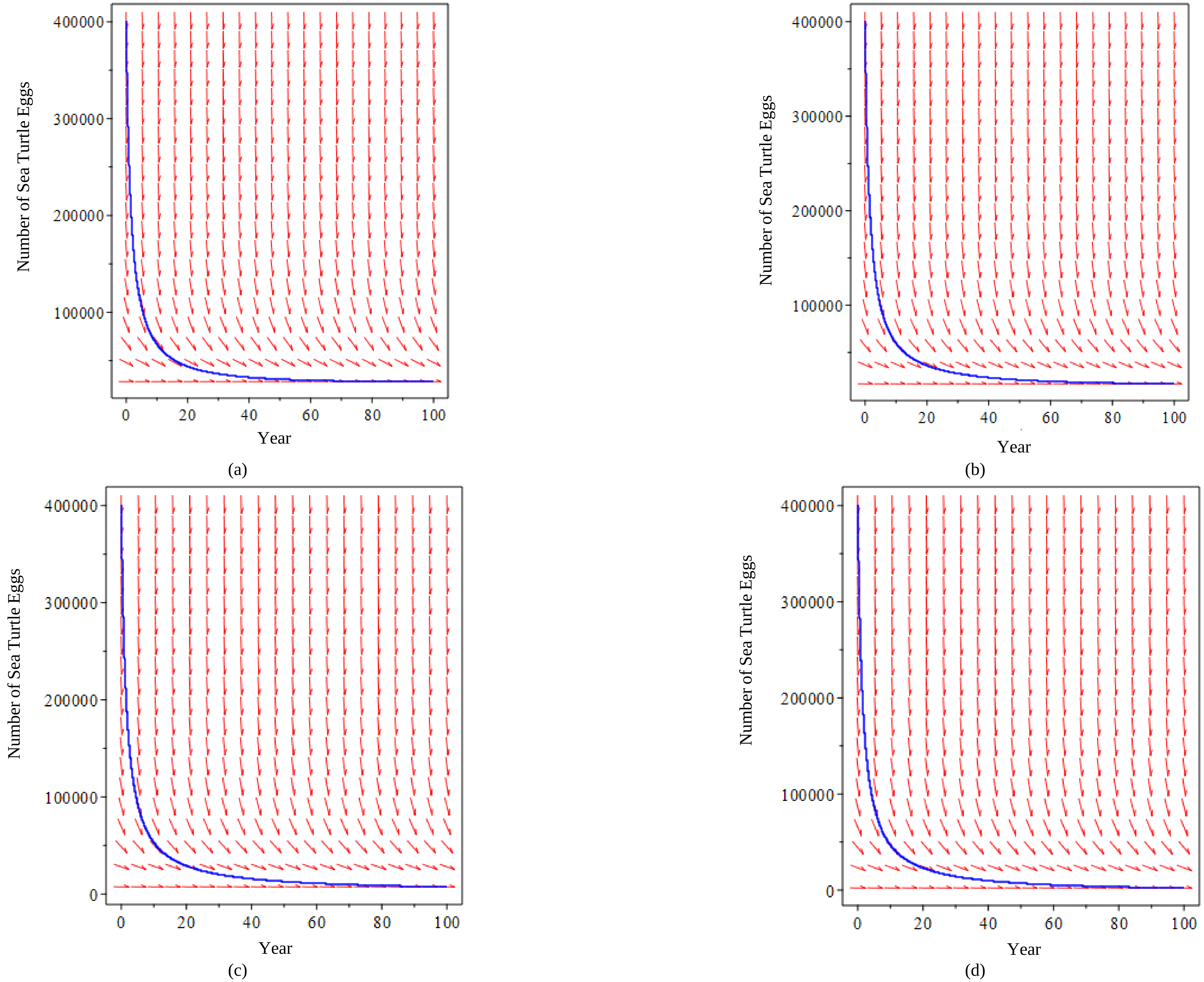


Figure 5.5 The MMSY model prediction on the sea turtle population size according to the proposed annual harvest limit of (a) 0%, (b) 25%, (c) 50% and (d) 75%.

5.4 Conclusion

Finally, the sea turtle eggs harvesting in Terengganu were unregulated since its implementation in 1951 under the Turtle Enactment 1951 up until now. Due to this unregulated harvest, the sea turtle population size depletion became more serious as time passes. Since sea turtle possessed a high natural death rate, even small-scale eggs harvesting able to drag this population into extinction. Thus, both the Maximum Sustainable Yield (MSY) and Modified Maximum Sustainable Yield (MMSY) model was applied to evaluate the sustainability of the current harvest rate at about 0.0858. The MSY model predicted that the current harvest rate is sustainable and the population will continue to thrive within 50 years.

Contradicted to the MSY prediction, the MMSY predicted that the current harvest rate of sea turtle eggs harvesting was unsustainable as the population will continue to depleted and local extinction (extirpation) within 35 years. This study chooses the MMSY model over the MSY model since the MMSY model capable of representing the population depletion aligned with sea turtle population of Terengganu depletion that happen in reality.

Additionally, the MMSY model was chosen because it is more sensitive since it considered the impact of the high natural death rate on the sea turtles population growth, making it capable to escape overestimation. Besides evaluating the current harvest rate of the sea turtle population, this study also intended to determine the sustainable new harvest rate for sea turtle eggs harvesting in Terengganu.

This study also suggested that the maximum sustainable annual harvest rate not more than 0.0215. Thus, it is suggested for step-by-step ban starting which is only operating 0.0215 of the tender holder before moving to a total ban on the eggs harvesting industry to ensure sea turtles continuity in Terengganu. Due to the current state of the art in this field, there are a few limitations to these models.

Firstly, these models were not comparable since no other study has been done on determining the sustainable annual harvest rate of sea turtle eggs harvesting. As mentioned before in section 2.3, others country such as Thailand stops their sea turtle eggs harvesting when the depletion was visible without carried out the sustainability analysis.

Secondly, this model may be the least accurate since it does not incorporate the productivity of the nesting mother. At this moment, there is a lack of information on the definite productivity of each nesting mothers. The productivity of each nesting mother differs by age. Since the productivity of each mother influences the annual eggs production, it is suggested that future research incorporated the productivity of each nesting mothers. Besides that, it is suggested that future research incorporated the death rate from other anthropogenic activity to increase the sensitivity and accuracy of the Tender System model.

CHAPTER 6

SUSTAINABILITY OF HUMAN–SEA TURTLE INTERACTION IN TERENGGANU

6.1 Introduction

Sea turtle had been closely related and shaping Malaysian culture and tradition. For instance, the sea turtle eggs consumption by the local since the sea turtle eggs are considered a delicacy. This practice turns humans into apex predator while turning the sea turtles turn into prey. Due to predation, the population size of sea turtles (prey) decreased and reached an alarming state. The nesting trends of the green turtles is unclear since their population in Terengganu were not been monitored sufficiently. However, the anecdotal evidence suggested that there is an 80% population decline. An average of 2,000 nests each year is the current nesting density of Terengganu's green turtles (Chan, 2006).

The nesting density setback urge government and non-government organization (NGO) to save sea turtles in Terengganu. Built-up sanctuaries, bought eggs from collectors, incubated the eggs, release the hatchlings into the sea, conducted campaigns on awareness and conducted research is among the effort done to rescue this species. People's perception is that the turtles are in good stead, eventually, despite all the attention and funds they gained, they are far from that and are edging close to extinction (Tusin, 2010). Since government and NGO effort seem hopeless, the exploited sea turtle population is subjected to unsustainable interaction and extinction. Thus, this chapter adopted the Lotka-Volterra prey-predator model and Tender System model to investigate the sustainability of the current level of the prey-predator interaction between sea turtles and the tender system in Terengganu. In both models, only two parties involved, the tender system which is considered as a predator while sea turtle eggs are considered as prey.

Since the current level of prey-predator interaction between sea turtles and the tender system was probably not sustainable, the second section of this chapter revolved around testing and determining new sustainable prey-predator interaction level between sea turtles and the tender system in Terengganu. However, this second section only utilized the Tender System model because this model was closely represented the real situation in Terengganu. The Tender System model assumed that the predator growth rate β was not equal to the exploitation rate of sea turtle eggs, α. The parameter β was assumed to be independent of α since the number of tender holders under the tender system in Terengganu (predator) was consistent regardless of an increase or decrease of annual sea turtle eggs production. Despite being a predator, the tender system possessed no living things characteristics such as experiencing growth and death since the number of tender holders was static at 26 individuals between 2011-2015. On the other hand, the Tender System model assumed that the prey population grow logistically since the previous study in Chapter 4 indicated the wild exploited sea turtle population in Terengganu grow logistically.

Lastly, this approach and results were useful in assisting the local government in making management decision for managing the natural resources sustainably. This approach can also be used for other states, country or regions that still utilized sea turtles as economic resources. The mathematical modelling is chosen as it is a new cost-efficient approach to assesses exploitation compare to the other previous research. Previously, Loggerhead sea turtle, *Caretta caretta* population evaluation was carried out by nest counts and from in-water aerial surveys are mimicked to generate stochastic ‘known’ populations (Warden *et al.*, 2017). This previous research simulated every life stage of the loggerhead sea turtles using a high human resource, work hours, capital and advances in technology, thus this research is hard to be carried out without expertise and huge capitals.

6.2 Methodology

As mentioned in other previous chapters, this chapter also utilized the secondary data provided by the Terengganu State Department of Fisheries (DoF). Data provided by the DoF includes the nesting density, location, and type of beaches (protected or tendered beaches). Some of the nesting beaches in the data were labelled as “ND” which indicates that there is no nesting data for the respective beaches. Therefore, the beaches labelled as ND for particular years were assumed as having no nesting or zero nestings. Moreover, the eggs that were incubated on the protected beaches was assumed to have 100% survivorship within the hatching, emerging and crawling to the sea stage. Yet, all eggs that were laid on the tendered beaches were considered to poach completely. Thus, the incubation and survival of eggs laid on tendered beaches were considered as 0%, making it possessed a 100% mortality rate.

The first section of this chapter will which is the “Sustainability of the Current Level of the Prey-predator Interaction” investigate the sustainability of the current level of prey-predator interaction between sea turtles and the tender system in Terengganu facilitated by the Lotka-Volterra model and the Tender System model. Both models illustrate the prediction of population growth within 10 and 50 years time-lapse. A model between those two that illustrate the population growth that most aligned with the current sea turtle population declined was chosen as the most compatible models to portray and assess the prey-predator interaction of sea turtles and the tender system in Terengganu.

The chosen model which is the Tender System model then utilised in the second section which is the “New Sustainable Level of the Prey-predator Interaction” to investigate the new sustainable level of the prey-predator between the sea turtles and tender system in Terengganu. The second section will be predicted over 10 and 50 years. Therefore, the prey-predator interaction level that capable to ensure the sea turtles population achieve the fastest population recovery and survive up to 50 years were considered as the sustainable prey-predator interaction level. The population size response to the level of prey-predator interaction between the sea turtles and the tender system in Terengganu was evaluated based on the annual sea turtle eggs production and the number of total tender holders in both sections. In both sections, the phase portrait plot and time-series plot were utilized to demonstrated the population size response to the level of prey-predator interaction between the sea turtles and the tender system in Terengganu. The results of this chapter were compared to the result in chapter 5, discussed and concluded within Chapter 9.

6.2.1 Sustainability of the Current Level of the Prey-predator Interaction

This section will describe both models which are the Lotka-Volterra model and the Tender System model in term of the parameters, equations and flow diagrams. However, the results and discussion of both models in this section were combined.

The Lotka-Volterra model is a simple classic model used to describe the dynamics of the prey-predator relationship. The Lotka-Volterra model capable of predicting the co-existence or extinction of the prey and predator populations. By adopting this model, the author can shed some light on the sustainability of the sea turtle-tender system interaction as well as the prediction of doomed days for sea turtles in Terengganu. This model is a pioneer mathematical model that describes prey-predator interaction was proposed by Alfred Lotka in 1925 and Vito Volterra in 1926. This mathematical model that refers to as Lotka-Volterra (1926) is formulated as

$$\frac{dx}{dt} = rx - \alpha xy,$$

$$\frac{dy}{dt} = \beta xy - dy,$$

Equation 6.1 Lotka-Volterra Model.

where t refers to time and the $\frac{dx}{dt}$ denotes the rate of change of prey population over time. Meanwhile, $\frac{dy}{dt}$ denotes the rate of change of the predator population over time (Mohd Roslan *et al.*, 2019). The prey-predator model assumes that the prey population has an unlimited food supply at all times. Plus, r denote the growth rate of prey and the term rx refers to the exponential growth of the prey. It is assumed that the prey population x will grow proportionally to its size, $\frac{dx}{dt} = rx, r > 0$ in the absence of the predator. Whereas, the predator population y would decrease proportionally to its size in the absence of prey. This can be defined as $\frac{dy}{dt} = dy, d > 0$.

Besides that, the prey population will experience decline while the predator population will experience growth each at a rate proportional to the frequency of encounters between individuals of the two species ($-\alpha xy$ for prey, βxy for predators, $\alpha, \beta, > 0$) when both predator and prey are present. The changes of the prey's numbers given by its growth minus the rate at which it is preyed upon. The growth of the predator population represented by βxy. The predator's growth determined by the food supply, minus natural death. Equations allow for the equilibrium point with non-zero components $P(d/\beta, r/\alpha)$ with $\alpha, \beta, r, d > 0$ (Anisiu, 2014). This model usually applied for the evaluation of prey-predator interaction between animals such as fox and rabbits. This model can be pictured in the flow chart as follows,

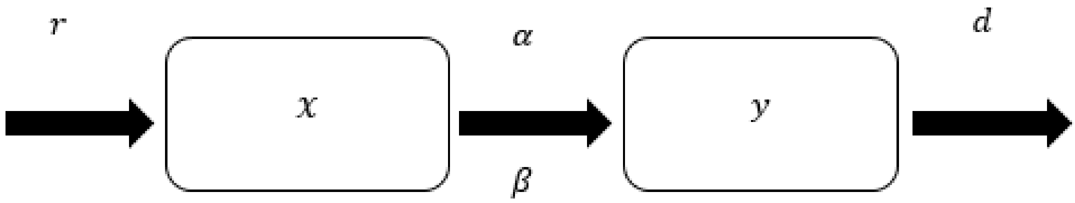


Figure 6.1 Flow diagram of the Lotka-Volterra model.

However, the Lotka-Volterra model does not represent the actual situation of the sea turtle eggs exploitation under the tender system in Terengganu. The tender systems consisted of tender holders that given an exclusive right to collect eggs for one nesting season (Liew, 2011). The beaches listed under tender systems are considered as the tendered beaches. This is rather a unique case as this paper is attempted to investigate the prey-predator relationship between an animal species and a tender system which is the anthropogenic based eggs predation system that possessed non-living things characteristics. So, the tender system model is a model that incorporates two types of parameters which is life-history and management criteria are proposed. In this chapter, the life history includes the prey growth rate r, predator growth rate β and the carrying capacity K. On the other hand, the management was the exploitation rate of sea turtle eggs α and natural termination rate of tender holder d.

Moreover, despite the ability of this system to "predate" sea turtle eggs, it does not growth in number or size. Thus, to make this model compatible with the evaluation of sea turtle- tender system interaction in Terengganu, a few improvements were made. Firstly, this model assumed that the number of sea turtle eggs laid on beaches in Terengganu reflects the sea turtle population size in Terengganu. Secondly, it is assumed that the exploitation rate α was not proportional to the growth rate of tender holder numbers β. In this case, the exploitation rate symbolizes the predation rate of tender holders on the sea turtle eggs. Furthermore, the growth rate of the tender system was represented by the tender holder numbers. The number of tender holders symbolizes the growth of the predator population. In this case, the number of tender holders β is assumed to be fixed at 26 as there are 26 tender beaches.

Plus, the natural termination rate of the tender system d in Terengganu that symbolizes the death rate of predator is assumed to be zero. This is because as long as sea turtle eggs existed, none of the tender systems will be closed. According to the DoF data, the number of tender holders remain consistent between 2011-2015. Last but not least, the tender system model assumed that the sea turtle population growth logistically by implementation the $rx(1-\frac{x}{K})$ into the equations. This assumption was made since the sea turtle egg growth rate in Terengganu possessed a logistic growth curve based on the research findings in Chapter 4. The carrying capacity of sea turtle eggs K represented by the annual highest number of eggs between 2011-2015. Thus, the proposed tender system model's flow diagram can be depicted as in

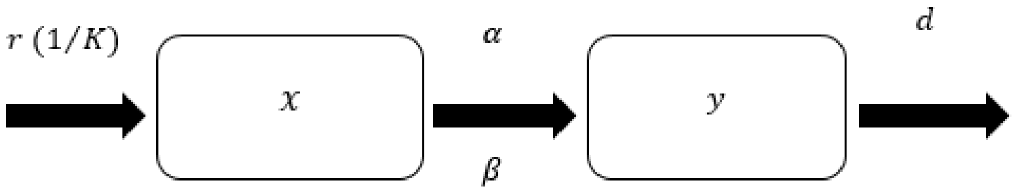


Figure 6.2 Flow diagram of the Tender System model.

From Figure 6.2, a differential equation of the Tender System model was constructed as follow:

$$\frac{dx}{dt} = rx\left(1 - \frac{x}{K}\right) - \alpha xy,$$

$$\frac{dy}{dt} = \beta xy - dy.$$

Equation 6.2 Tender System Model.

Therefore, the values and descriptions of each variable and parameters used in the Lotka-Volterra and Tender System model were described in Table 6.2 below:

Table 6.1 Description and values for variables and parameters of the Lotka-Volterra and Tender System models.

Variables/ Parameter	Description	Values for Lotka-Volterra Model	Values for Tender System Model
$\boldsymbol{x}$	Number of sea turtle eggs	unknown	unknown
$\boldsymbol{y}$	Number of the tender holder	unknown	unknown
$\boldsymbol{t}$	Time (Years)	$[10, 50]$	$[10, 50]$
$\boldsymbol{r}$	The growth rate of sea turtle eggs	1.0464	1.0464
$\boldsymbol{\beta}$	The growth rate of tender holder	0.0858	0.0000
$\boldsymbol{K}$	Carrying capacity of sea turtle eggs	622548	622548
$\boldsymbol{\alpha}$	Exploitation rate of sea turtle eggs	0.0858	0.0858
$\boldsymbol{d}$	Natural termination rate of tender holder	0.0000	0.0000

In Table 6.1, the values of parameters β and d are assumed while $r, K,$ and α are estimated from real data obtained from the DoF. The parameters that appeared in both models are assumed to be positive. The tender holder is a building block of tender systems. Thus, the numbers of tender holders y depend on the number of beaches listed by the Terengganu state government for the tender system. Both models were illustrated in the 10 and 50 years time-lapse, making the $t = 10$ and $t = 50$. Both models then compared, discussed and concluded.

6.2.2 New Sustainable Level of Prey-predator Interaction

This section was composed to establish the sustainable prey-predator interaction level between sea turtles and the tender system in Terengganu. Since the Tender System model was the model that closely represented the reality of sea turtle eggs exploitation under a tender system in Terengganu, this model was chosen to facilitate the study in this section. This section assumed that the exploitation rate and sea turtle density were inversely proportional because Becker *et al.* (2019) stated that an area with a low human density possibly has low rates of exploitation. These low exploitation rates resulted in higher sea turtle density (Becker *et al.*, 2019). Therefore, a few new exploitation rates were obtained using the formula as follow,

$$New\ exploitation\ rate\ (\alpha') = \alpha \times Suggested\ annual\ exploitation\ limit\ (\%)$$

It is assumed that the exploitation rate, $\alpha = 0.0858$ and fixed for all suggested annual exploitation limit throughout the study in this section. The suggested annual exploitation limit referred to as the degree of the tender system openness. Generally, this tender system openness was a suggestion on the percentage of the tender system that should be allowed to run annually or in each nesting season. For instance, if only 50% of the tender system suggested for operation each year, the calculation for the $New\ exploitation\ rate = 0.0858 \times \frac{50}{100}$ which is equal to 0.0430. This means that the exploitation rate that allowed was only 0.0430. A further list of the tender system openness and the new exploitation rate can be seen in Table 6.2.

Table 6.2 List of the suggested annual harvest limits and new exploitation rates under the Tender System model.

Suggested Annual Exploitation Level (%)	New Exploitation Rate(α')
0	0.0000
25	0.0215
50	0.0430
75	0.0644

The sustainability of the suggested new exploitation rate was tested by substituting the value of the new exploitation rate as a replacement of α into the Tender System model. These exploitation limits were suggested because the preliminary trial on the model revealed that if the differences between the two consecutive annual exploitation limit differences were below 25%, closely similar predictions were produced. This can lead to producing results with is no significant predictions. Thus, this research was set for having 25% differences (gaps) between the two proposed annual exploitation limits. The suggested annual exploitation limits of 0% were the instant complete ban of sea turtle eggs exploitation. However, the suggested annual exploitation limits of 25%, 50% and 75% were the step-by-step ban. This means that the number of tender holders will be lowered from year to year until it reaches the complete ban. For examples, the suggested annual exploitation limit was 25%, thus the number of tender holders will be reduced by 75% in the upcoming years. Under the suggested annual exploitation limits of 25%, the initial number of tender holders which is 26 individuals will be reduced to 7 and eventually became 0 (complete ban) in the upcoming years.

Moreover, these Tender System model prediction on the sea turtle and tender holder population growth in Terengganu based on the new exploitation rate were illustrated with the help of the phase portrait and time series plots in 10 and 50 years time-lapse. Thus, the measurement of time in this analysis was based on the year where $t = 10$ and $t = 50$. All the phase portrait were used to determine the stability of this interaction by looking at the orientation of the arrow either having a stable point or saddle point. The growth prediction of each time phase plot was discussed and concluded. This help in suggesting the new sustainable annual exploitation rate of sea turtle eggs under the sea turtles-tender system prey-predator interaction in Terengganu.

6.2.3 Models Summary

This section summarized the information regarding the Lotka-Volterra and Tender System models as mentioned in Table 6.3. It can be deduced that both models used in the study of this chapter were the two species population models. Each model consisted of two non-linear differential equations. Each non-linear differential equation describing either the prey or predator population. The Lotka-Volterra model was based on Mohd Roslan *et al.* (2019) and Kot (2001). However, the Tender System model was first proposed in this study to closely represent the actual situation of the sea turtle and tender system within Terengganu.

Table 6.3 The overview of the Lotka-Volterra and Tender Systems models used for assessing the sustainability of sea turtles-tender system prey-predator interaction in Terengganu.

Model	Governing Equation	Assumption
Lotka-Volterra	$\frac{dx}{dt} = rx - \alpha xy$ $\frac{dy}{dt} = \beta xy - dy$ $(\alpha = \beta)$	This original Lotka-Volterra model proposes that sea turtle eggs grow exponentially. The exploitation rate is assumed to be equal to the tender holder's growth. Plus, the tender holder growth is determined by subtracting the tender holder's growth rate from its termination rate.
Tender System	$\frac{dx}{dt} = rx(1 - \frac{x}{K}) - \alpha xy$ $\frac{dy}{dt} = \beta xy - dy$ $(\alpha \neq \beta)$	This modified model proposed that the sea turtle eggs possessed a logistic growth curve. The sea turtle egg exploitation rate is proposed to be unequal to the tender holder growth. The number of tender holders assumed to be fixed since it has zero growth rate despite high or low annual sea turtle eggs production. Besides, the tender holders have a zero natural termination rate as long as the eggs are available. Plus, the population growth of the tender holder is determined by subtracting the growth of the tender holder from its termination rate.

6.3 Result and Discussion

This section was divided into two parts. The first part which is the "Sustainability of the Current Level of the Prey-predator Interaction" illustrated and discussed the results for the sustainability analysis of the current prey-predator interaction level of the sea turtle-tender system in Terengganu. The second part which is the "New Sustainable Level of the Prey-predator Interaction" pictured and discussed the impact prediction of a few suggested new annual exploitation rate to the sea turtle and tender holder population growth. The second part also helps in determining the new sustainable annual exploitation rate.

6.3.1 Sustainability of the Current Level of the Prey-predator Interaction

Based on Table 6.4 the Lotka-Volterra model predicted that the current prey-predator interactions between the sea turtle and tender system in Terengganu are not stable since the phase portrait plot consisted of a saddle point. Besides, the time-series plot of the Lotka-Volterra model predicted that this interaction is unsustainable since the number of tender holders will increase rapidly and reaches 400 000 individuals within six months. The Lotka-Volterra model also predicted that the sea turtle eggs production will drop drastically and approaching zero within six months. The sea turtle can be considered functionally extinct when they experience drastic depletion and approach zero. Furthermore, the Tender System model also predicted that the current prey-predator interactions between the sea turtle and tender system in Terengganu are not stable since the phase portrait plot consisted of saddle points. However, the time-series plot of the Tender System model predicted that the number of tender holders was constant at 26 individuals. Meanwhile, the sea turtle eggs production predicted to be seriously depleted and almost none within four years. This indicated the functional extinction of sea turtle in Terengganu. The Lotka-Volterra and Tender System model predicted that the sea turtles and tender system could not be co-existed in Terengganu as both models are having saddle points. Saddle points can be identified as the arrows point outward and diverge from the singular point (Canale, 1970). A saddles point indicated an unstable singular point or critical points (Nixon, 2015). This unstable singular point existed since under this interaction, one of the species were predicted to undergo serious depletion that leads to its extinction.

Although both the original Lotka-Volterra and Tender System model both produce saddle points for phase portrait plot, they predicted different consequences of the current exploitation rate. The original Lotka-Volterra model indicated that the current rate of exploitation was unsustainable where the sea turtle eggs production will continue to deplete without a limit and became functionally extinct within six months. The Lotka-Volterra model assumed this sudden depletion since it assumed that the prey and population experience exponential growth based on Mohd Roslan *et al.* (2019) and Kot (2001). This means that this model not only assumes that the population increase exponentially in numbers, but can also decrease or decay exponentially. On the other hand, the Tender System model predicted that this interaction is unsustainable as the population has a limited growth as they grow logistically as mentioned in Chapter 4. Due to this limited growth, the sea turtle eggs production decreasing in number year by year to the point that this population extinct within four years. Since the Tender System model assumed that the sea turtle population grow logistically, this population will increase and decrease logistically. Thus, the Tender System model capable of closely representing the sea turtles-tender system prey-predator interaction in Terengganu. There are a few reasons that unable the Lotka-Volterra model represented the exploitation of sea turtle eggs case in Terengganu.

Firstly, the Lotka-Volterra model composed from the Selachians (old term for shark and shark-like fish) case study. This predatory fish increased in frequency during wartime and due to increase fishing, their number decreased. The prey species, however, have an opposite pattern (Kot, 2001). Both the fishing industry and the selachians are different from the sea turtle eggs exploitation under the tender system in Terengganu. This is because the Lotka-Volterra model assumed that the population possessed an exponential growth rate, thus assuming that the existence of sea turtle eggs exploitation under the tender system possesses no extinction threat. Lotka-Volterra prey-predator models stated that the loss of prey due to predation is assumed to be proportional to both the number of prey and predator resulting in a mass-action term. Besides that, the production of new predator is assumed to be led by the loss of prey (Kot, 2001). However, in the Terengganu case, regardless of any amount of sea turtle eggs production, the number of the tender holder in the tender system is fixed since they possess no growth. In addition to that, the Lotka-Volterra model also abandons the carrying capacity (K) of each nesting beaches. Each beach has a maximum limit on the number of the nest it can hold at one time to prevent environmental degradation. Moreover, if the nesting beaches are already packed, there is a probability that other nesting mothers will come and destroyed the existing nests leading to hatching failure and lower their survival rate. Since sea turtles only nest on their natal beaches, the carrying capacity is crucial in determining the population growth of sea turtle.

Besides that, the exponential population growth prediction by the Lotka-Volterra model also unable to reflect the current situation occurring in Terengganu where the sea turtles are decreasing at a terrifying rate but still surviving for years. Thus, this model is not compatible to be used for sea turtle populations as the sea turtle population takes time to increase or decrease in number. The Lotka-Volterra model leads to over projection of the growth and depopulation of prey and predator that lead to over or underestimation of both populations. As mentioned before in Chapter 3, the sea turtle nesting data of Terengganu from 2011-2015 display exclusive characteristics of green turtle which is a biennial nesting pattern. Thus, we considered that the major nesting species in Terengganu is the green turtles. Then, in Chapter 4, it is proven that these green turtles in Terengganu grow logistically.

Since the Lotka-Volterra model is not suitable to represent the Terengganu case, the model was modified into the Tender system model. The modification is made is by defining that the exploitation rate and the growth rate of the predator are not equal. The number of tender systems in Terengganu is assumed to have consistency from year to year at 26. The number of eggs laid every year does not influence the number of tender systems. Thus, it is assumed that the loss of eggs due to egg exploitation will give zero growth to the tender system. As a result, the Tender System model predicted that the sea turtle population in Terengganu will undergo extinction between four years, contradicted to the results of the MMSY model in Chapter 5. The

MMSY model predicted that the sea turtle population in Terengganu will extinct within 35 years under the current exploitation rate. Both the Tender System model and MMSY model predicted an extinction but at two different times. This difference occurs because the Tender System model was more sensitive to the population changes. The MMSY model predicted the sea turtle population can last longer because it does not take into account the population sizes of the tender system(predator) which is the total number of tender holders. Besides, the MMSY model also ignores the interaction that existed between the prey (sea turtle eggs) and predator (tender systems). Contradicted to the Tender System model, the MMSY model only takes into account the current number of annual sea turtle eggs production and the total death rate (from natural and exploitation factors) in making sustainability analysis and future predictions.

The prediction of the Tender System model on sea turtle population extinction within four years might puzzle the readers since the turtles and turtle eggs are still around in 2019. The nesting mother that currently producing the eggs from Terengganu were originated from eggs produced more than 20 years ago since the exploitation rate is lower in the past. This assumption was made since any hatchling released came back to their natal beach after 20-50 years as sexually matured greens turtles to start nesting and laying eggs (United State Wildlife Service, 2015). At that time, almost all eggs are harvested and sell back to the government hatchery under the buy-back scheme, thus the survival rate is higher. However, the buy-back scheme that helps in conservation and control sea turtle eggs smugglings have stopped in 2018 due to a lack of funds. This is rather a threatening situation as they will end up in the market and contribute nothing to the population growth. The government has to takes a fast action in preventing the extinction as the available nesting mother will eventually stop producing eggs at some point as mentioned in previous chapters, leading to sea turtle extinction in Terengganu.

Table 6.4 Comparison between the Lotka-Volterra model and Tender System model under the 10 years and 50 years prediction.

<table>
<tr><th>Years</th><th colspan="2">Lotka-Volterra model</th><th colspan="2">Tender System Model</th></tr>
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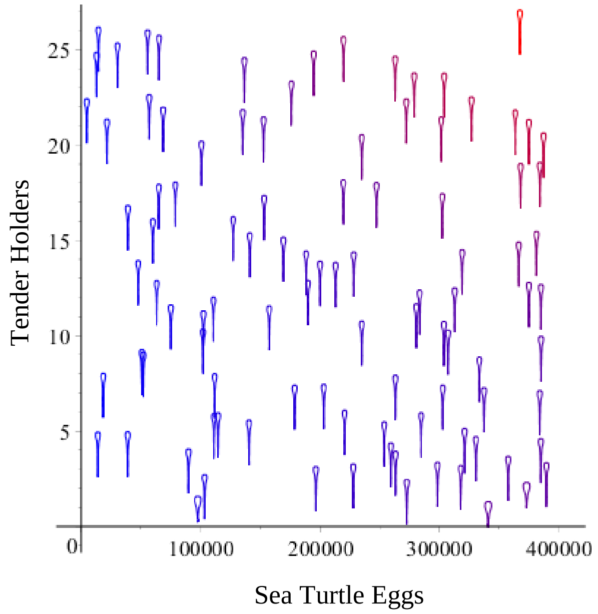
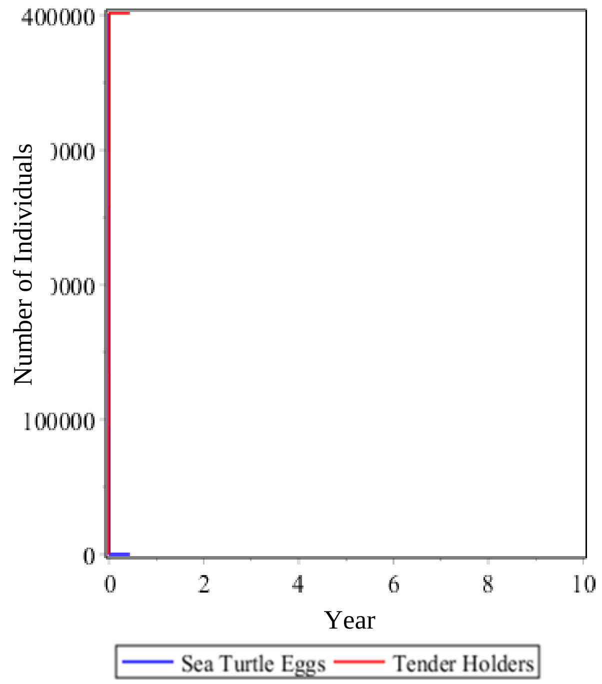
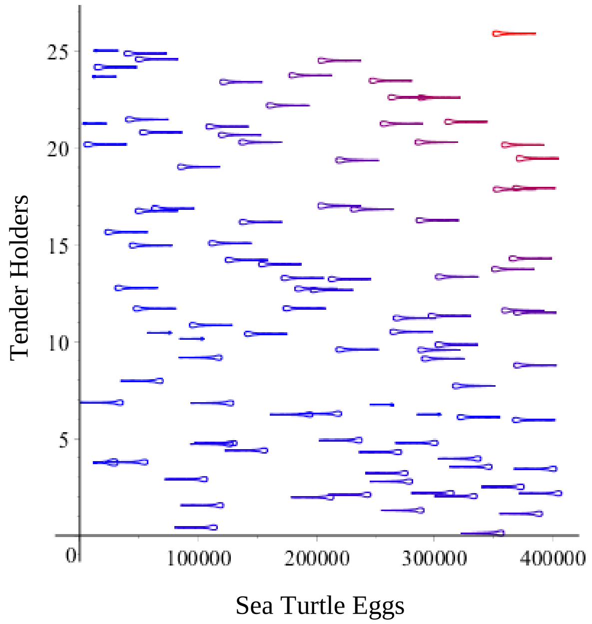
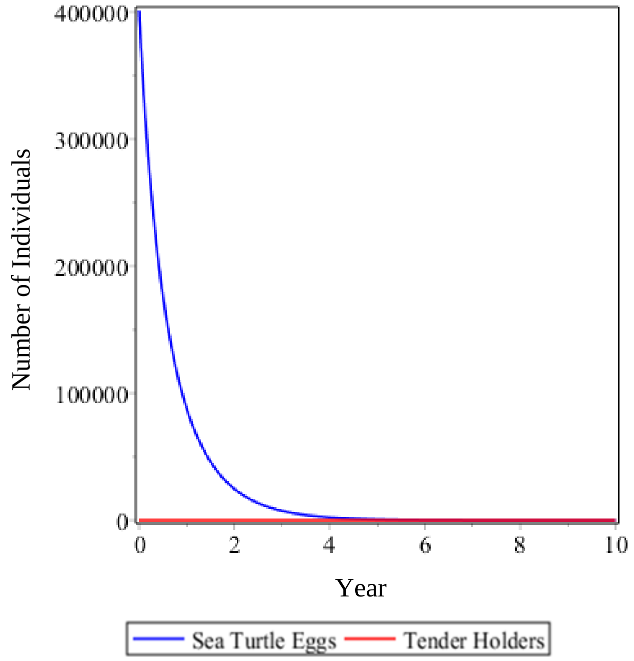
<td></td>
<td></td>
<td></td>
<td></td></tr>
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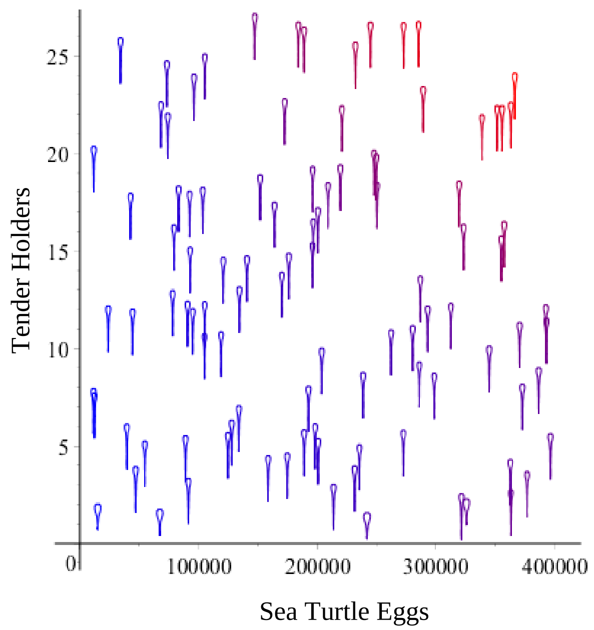
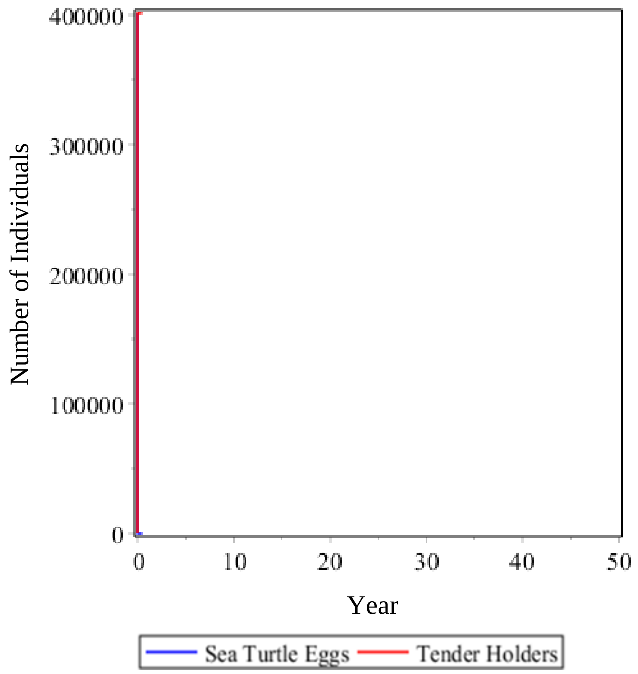
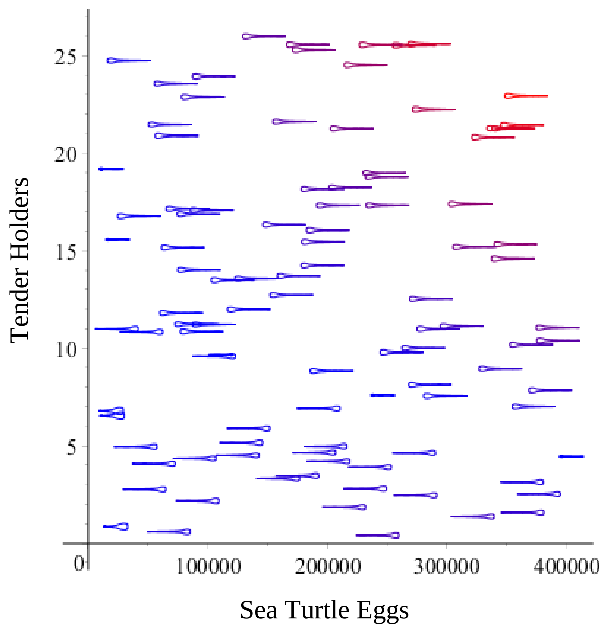
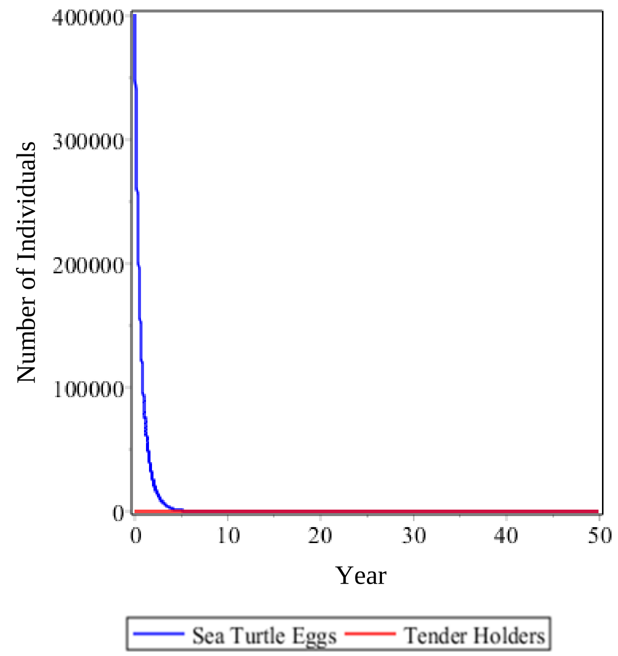
<td></td>
<td></td>
<td></td>
<td></td></tr>
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6.3.2 New Sustainable Level of Prey-predator Interaction

The time series plots in Table 6.5 and Table 6.6 shows that the Tender System model predicted that the most sustainable level of prey-predator interaction was the exploitation rate of 0.0000 (total ban of eggs exploitation). The total ban was suggested since it results in the shortest recovery periods of the sea turtle population in Terengganu at about eight years (Table 6.5). Although the phase portrait plot (Table 6.5 and Table 6.6) of the total ban consisted of the saddle points that reflect an unstable relationship between the tender holders and sea turtle eggs production, this interaction was able to sustain sea turtle populations in Terengganu. This interaction consisted of saddle points since the sea turtles and tender system won't be able to coexist. Under the total ban, the tender system was instantly closed by terminating all tender holders, this marks the extinction of the tender system in Terengganu.

The recovery of the sea turtle population takes a long time at about fifteen years when the exploitation rate was increased to 0.0215 (Table 6.6). The phase portrait plots of exploitation rate of 0.0215 also consisted of the saddle points that starting to oscillate around a point. These saddle points also pictured an unstable prey-predator relationship between sea turtles and the tender system. Even though the tender system was totally banned in the end, the tender holders were terminated step-by-step at a 75% limit at a time, therefore, allowing them to coexisted in a short period. Then, the sea turtle population in Terengganu takes about twenty years to recover if the exploitation rate was elevated to 0.0430. The phase portrait plot also contained the saddle points under an exploitation rate of 0.0430. Thus, the sea turtles-tender system interactions under an exploitation rate of 0.0430 also deemed as unstable. Nonetheless, the saddle points oscillated more around a particular point since the step-by-step ban of 50% allowed the tender system to last longer before totally banned.

Last but not least, it can be observed that the time taken for sea turtles to recover also increase to thirty-five years when the exploitation rate was increased to 0.0644. However, the phase portrait plots of the sea turtles and tender system under the exploitation rate of 0.0644 build-ups from the points that mostly oscillated towards a singular point. In phase portrait, the stationary values of x and y are denoted by a singular point or the critical point of a system. If the singular point is stable, the resulting motion converges towards it (Canale, 1970). The prey-predator interaction between sea turtles-tender system under the exploitation rate of 0.0644 is the most stable compared to other new exploitation rates. The phase portrait assumed that the interaction was stable since both population (sea turtles and tender system) still presented approaching to end of the time frame. This happened since the step-by-step ban of 25% enables the longest survival of the tender system before totally banned compared to other exploitation rates. Yet, the exploitation rate of 0.0644 was considered unsustainable since it causes the longest lag to achieve population recovery. Since the sea turtle population under the current exploitation rate was predicted to extinct within four years, the population would not achieve recovery if the exploitation rate of 0.0644 was implemented.

Based on results from Table 6.5 and Table 6.6, it is deduced that the sea turtle population growth and recovery increase if their exploitation rate were decreased. This is supported by the fact that predators and prey can directly affect the relative abundance of each other in the time scale shorter than the evolutionary time scale (Trites, 2018). Besides that, it is observed that a faster population recovery happened when the tender holder termination rate is higher. However, due to the carrying capacity of each nesting beach, at the maximum point, each beach can support, no future increase can be observed. Since the National Research Council in 1990 has stated that the green turtles are globally threatened but only a few reliable assessments of abundance status and trend of any green turtle stock existed (Balazs & Chaloupka, 2004), the tender system should be completely banned. Complete ban also important because there is human-induced mortality such as bot strike, ghost net, gill nets, and others that threaten the existence of sea turtle besides the natural and human-induced mortality.

Table 6.5 The impact of new annual exploitation rates on sea turtle population under 10 years prediction.

<table>
<tr><th>Graph</th><th>Annual Exploitation 0%</th><th>Annual Exploitation 25%</th><th>Annual Exploitation Rate 50%</th><th>Annual Exploitation Rate 75%</th></tr>
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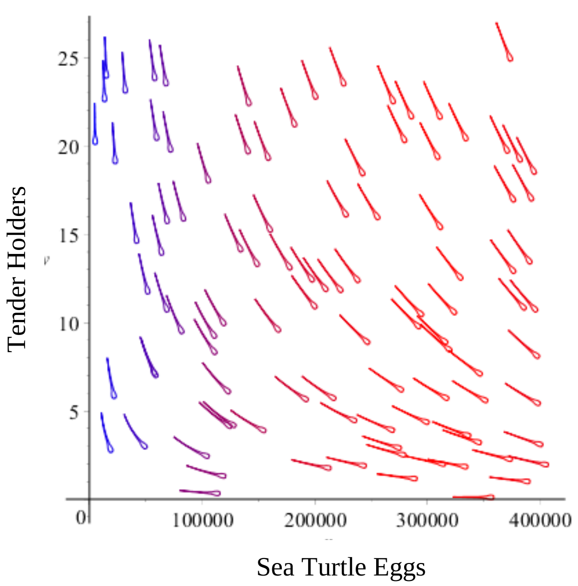
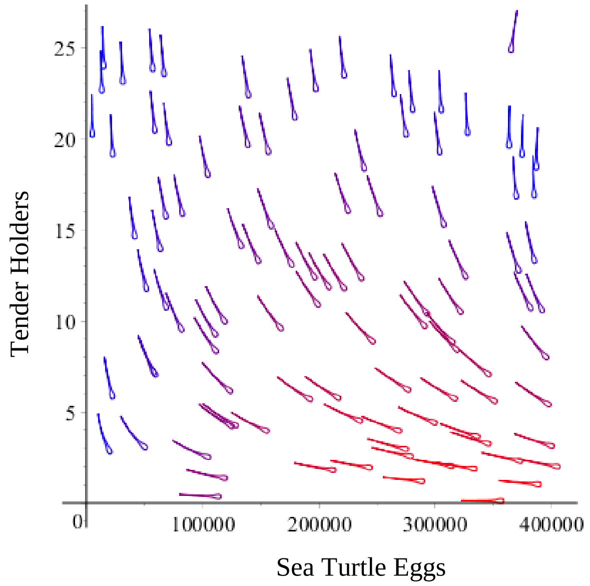
</td>
<td>$\alpha' = 0.0215$
</td>
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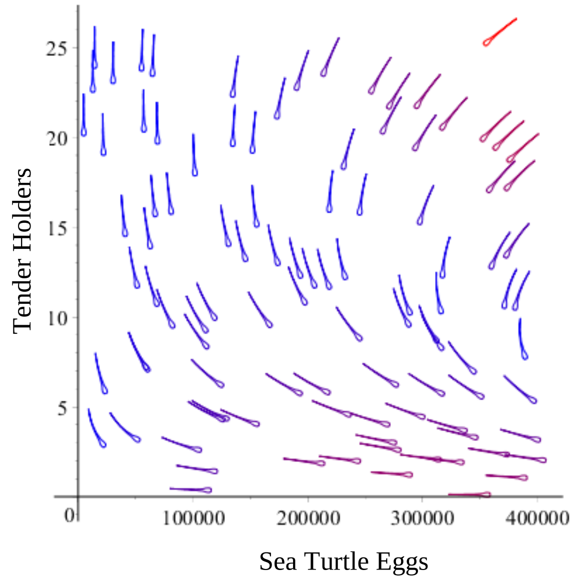</td>
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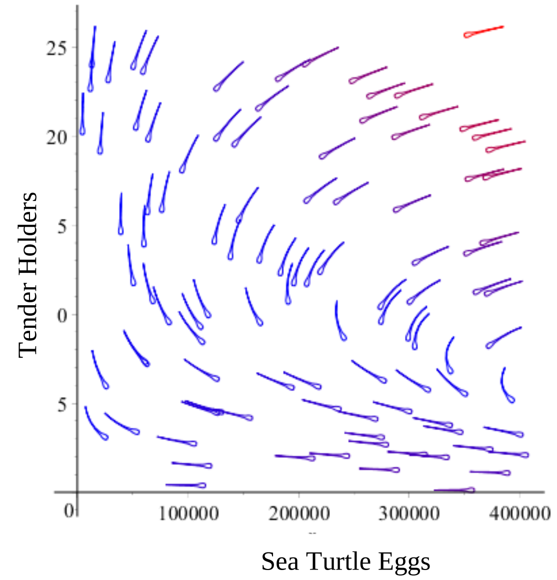
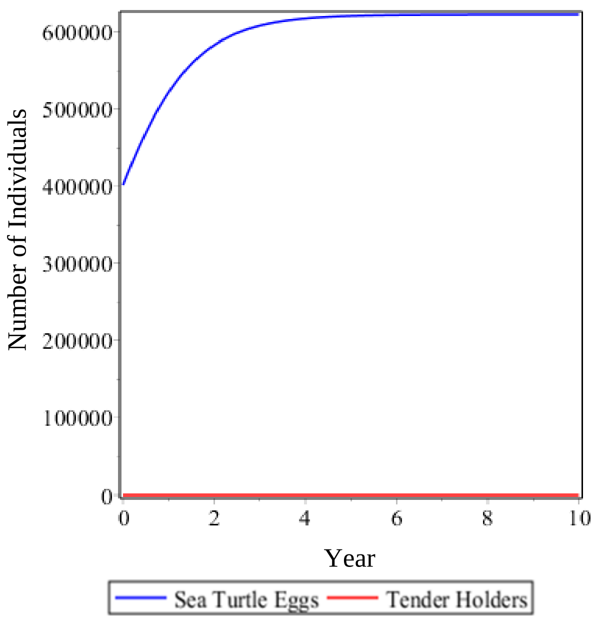
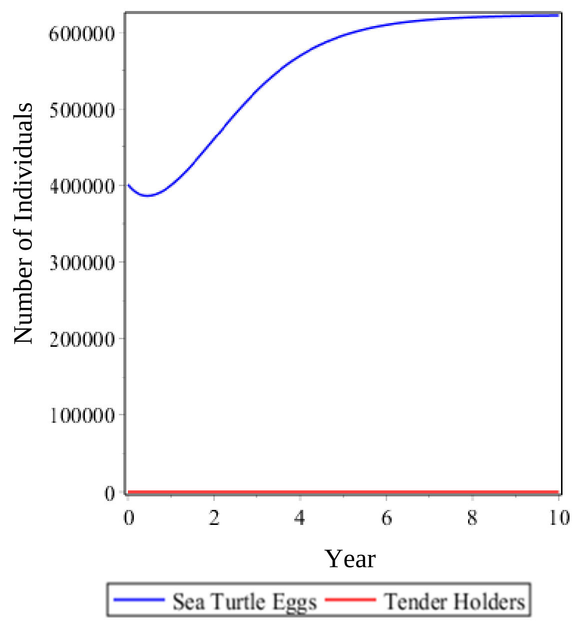
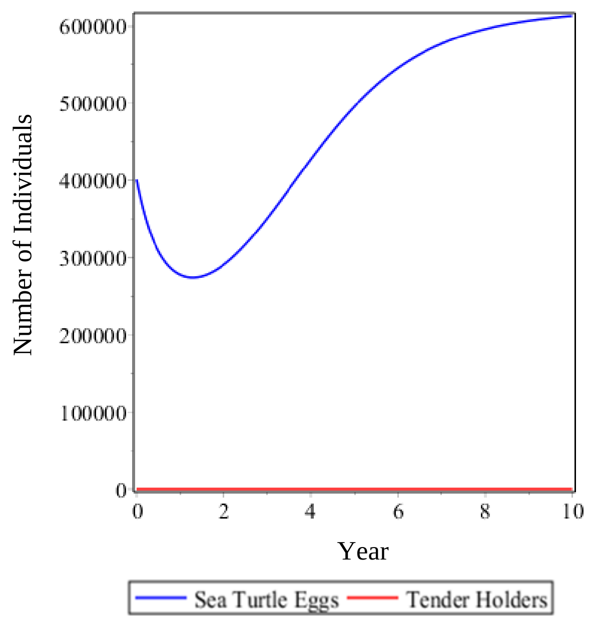
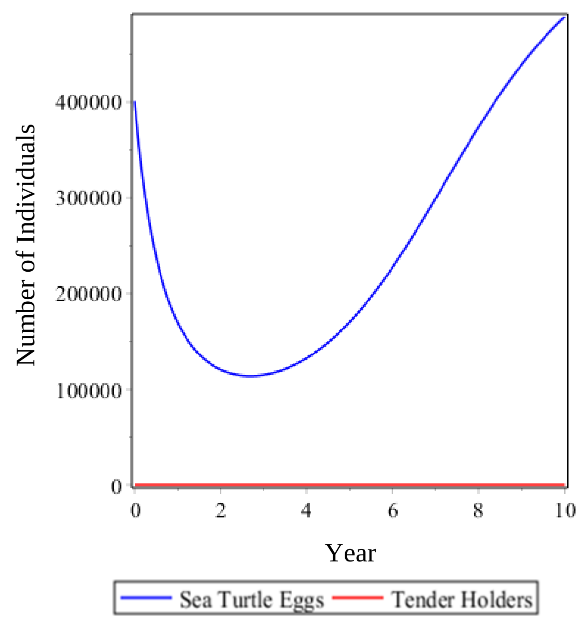
</td></tr>
<tr><td>Time Series Plot</td>
<td></td>
<td></td>
<td></td>
<td></td></tr>
</table>

Table 6.6 The impact of new annual exploitation rates on sea turtle population under 50 years prediction.

<table>
<tr><th>Graph</th><th>Annual Exploitation Rate 0%</th><th>Annual Exploitation Rate 25%</th><th>Annual Exploitation Rate 50%</th><th>Annual Exploitation Rate 75%</th></tr>
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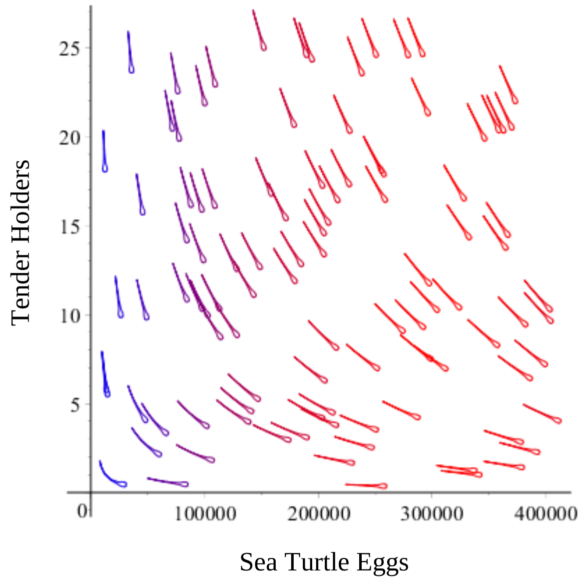
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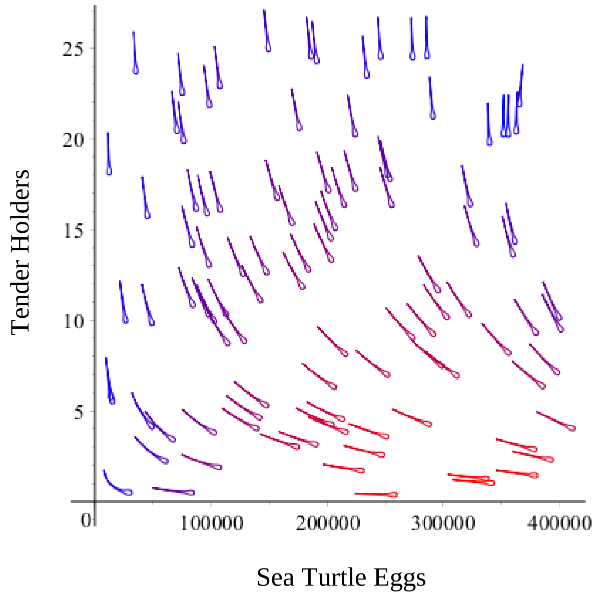
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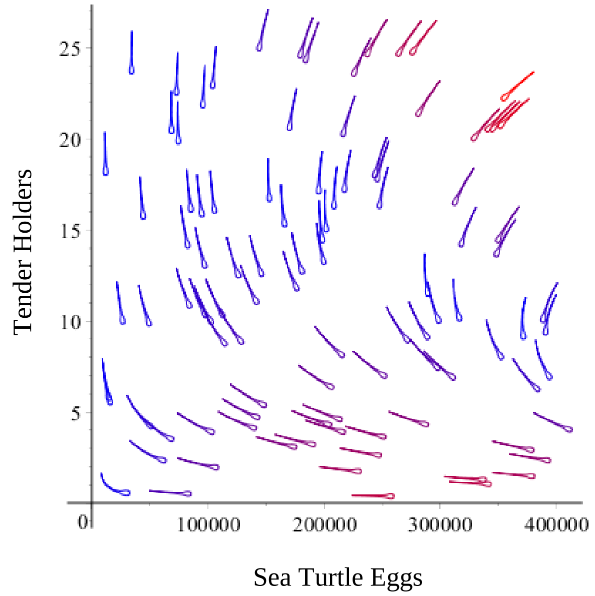
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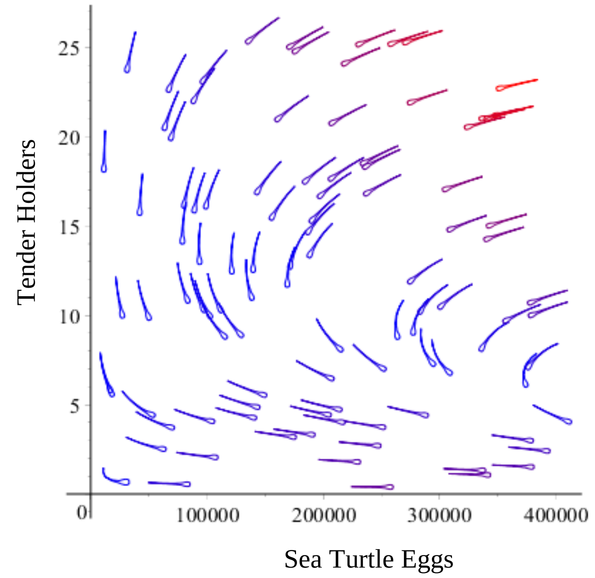
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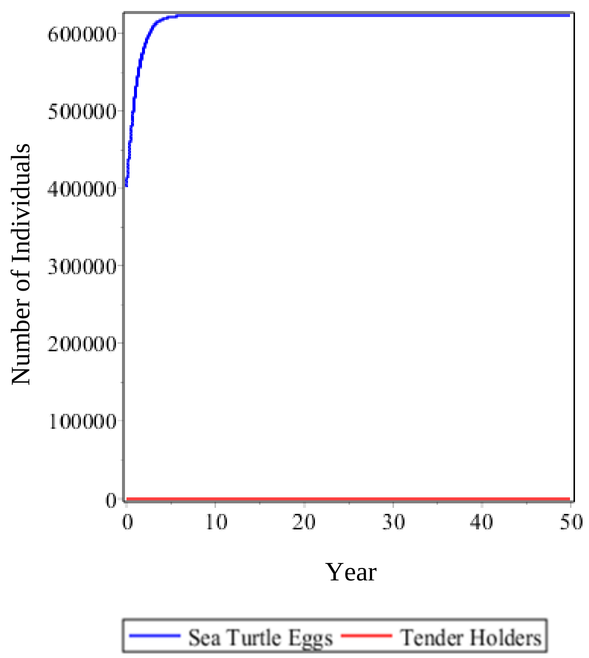
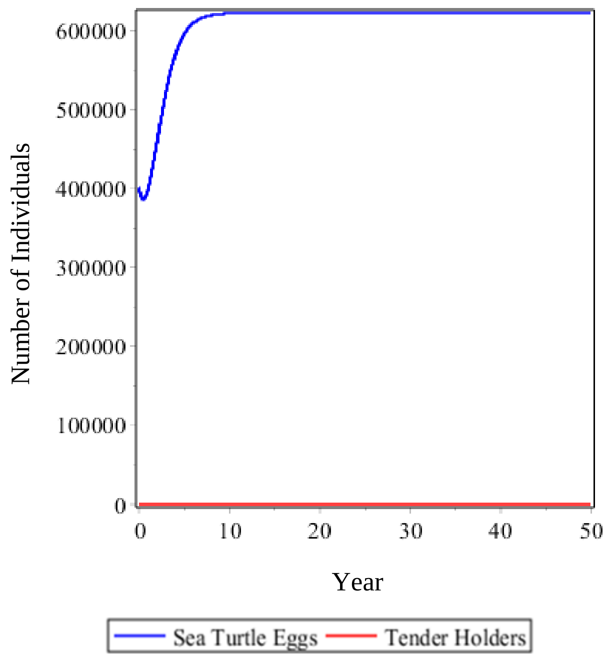
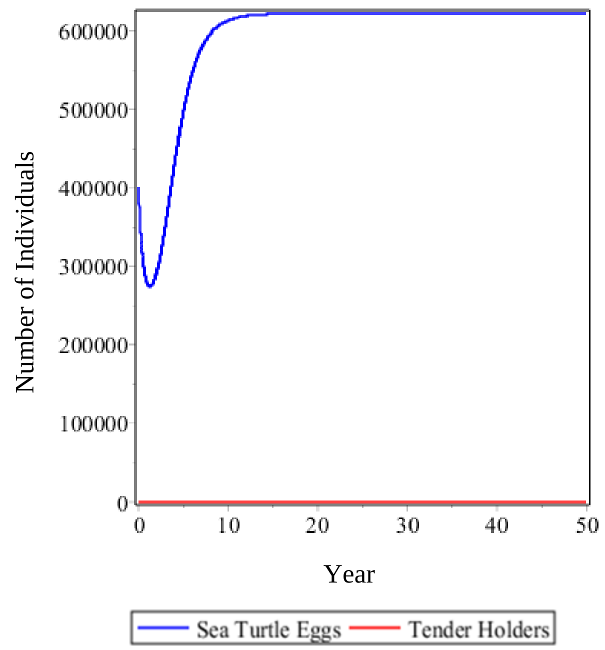
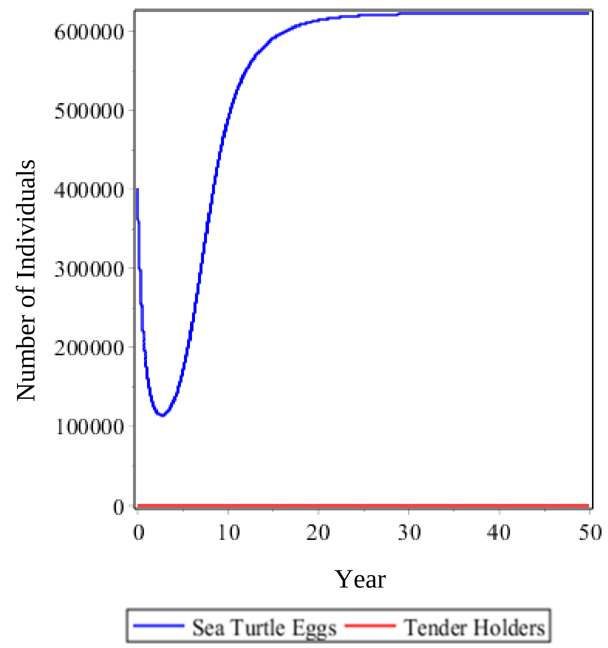
<tr><td>Time Series Plot</td><td>
</td><td>
</td><td>
</td><td>
</td></tr>
</table>

6.4 Conclusion

The conservation of sea turtles in Terengganu involves both the protected beach and tender systems. The tender system is introduced to reduce government management costs while increasing the community income under the buy-back system. However, the majority of the sea turtle eggs end up in a market due to limited government funds. An unregulated harvest possesses an extinction threat as the tender holder harvests all eggs, leaving none for conservation purposes. Facilitated by the Lotka-Volterra model and the Tender System model, the level of the prey-predator interaction between sea turtle and tender holders under the tender system is evaluated. Lotka-Volterra model predicted that the sea turtle population sizes will be decreased exponentially and eventually become functionally extinct in six months. Besides that, the Lotka-Volterra model also predicted that the number of tender holders will decrease exponentially and expanded as high as 400 000 individuals in six months. The Lotka-Volterra model prediction was contradicted to the population seatback occurring in Terengganu. In reality, although the sea turtle undergoes a rapid depletion under the current exploitation rate of the tender system, the sea turtles continue to survive since the 1950s. Besides, the number of tender holders were fixed at 26 individuals from 2011-2015 based on data supplied by DoF. Since the Lotka-Volterra model is not a perfect fit to evaluate the sustainability of the tender system in Terengganu, the Tender System model is proposed. The Tender System model includes both life-history characteristics and management criteria as parameters. This is rather an important change as previously, other types of business are not evaluated according to their nature, but “forcibly” evaluated as an animal. This Tender System model predicted that the sea turtle population in Terengganu will seriously be depleted and eventually functional extinct within 4 years although the number of tender holders fixed at 26 individuals throughout the time scale. This indicates that the sea-turtle-tender system interaction is unsustainable.

The Tender System model then used to identify the new sustainable level of the prey-predator interaction based on the exploitation rate of the sea turtle population in Terengganu. A few new exploitation rates were suggested for experimentation between 0.0000 to 0.0644. Only the exploitation rate of 0.0000 (instant total ban) helps the population to recover in the shortest time which is eight years. Therefore, applying the instant total ban is a must to at least save half of the sea turtle population in Terengganu. The total ban on the tender systems also able to eliminate the community dependency on the sea turtle eggs market as an income that was investigated and discussed in the next chapter, Chapter 7.

This proposed Tender System model and results can be applied to biological and conservation fields. Result produces by this research can be used by the government and decision-makers to update the new economic policies accordingly to sustain the population of sea turtles in Terengganu. As Terengganu is a tourism state, it can imitate an economic plan in Sabah that generates huge continuous income for the state by indirect used as studied and discussed in Chapter 8. However, this research has its limitations. This research provides a rough idea of how big is the population size, but it cannot give a hundred per cent accuracy as many uncontrolled events occurred in nature. Plus, inadequate data also have an impact on the result. As an improvement, a more detailed model that includes the age of nesting mother and renews survival rate of sea turtles in Terengganu is suggested for future research as it has a significant influence on the estimation of the population survivals.

CHAPTER 7

MARKET SURVEY ON SEA TURTLE EGGS CONSUMPTION IN TERENGGANU, MALAYSIA

7.1 Introduction

Approximately 110 million years ago, the first sea turtles evolved. When the extinction of the dinosaurs occurred, this highly successful group of animals survived and currently inhabit all oceans of the planet (Solano *et al.,* 2004). Surprisingly, in today worlds, many sea turtle populations face extinction although there is no similar natural disaster that able to wipe out dinosaurs. Among the extinct sea turtle population were the leatherback population in Terengganu. One of the factors that cause the leatherback turtle to extinct in Terengganu was the long history of eggs exploitation (WWF, 2009). Nowadays, this eggs exploitation continued for other species in Terengganu such as the green turtles and hawksbill turtles. However, the qualitative study of the current market was not updated in recent years. Therefore, this study was composed to identify the qualitative aspect of the sea turtle eggs current market in Terengganu.

The sea turtle eggs were sold in the local market such as Pasar Payang, Pasar Chukai, Pasar Paka, Pasar Dungun, Pasar Marang, Pasar Chabang Tiga, Pasar Batu Enam, Pasar Jertih, and Gelliga. However, Pasar Payang was selected as a study site. Pasar Payang started to operate in 1967 in the city of Kuala Terengganu, Malaysia. Pasar Payang is an urban public market that is promoted as a tourist attraction because of its local products such as batik, local food and local crafts (Zakariya *et al.*, 2016). Pasar Payang were selected since 91% of sea turtle eggs consumers brought it from Pasar Payang (WWF, 2009). Besides, based on the preliminary survey, Pasar Payang open all year long, thus enable better tracking of sea turtle eggs price and market characteristics. This is supported by the fact that at least 1,000 eggs were being sold daily at Pasar Payang, Kuala Terengganu. Since Pasar Payang opened daily, it is estimated that the annual sale of sea turtle eggs is 365,000 eggs. In addition to that, the state-base trading in Terengganu remains constant based on the current market survey in 2018 (Gomez & Krishnasamy, 2019).

Previously, the study conducted by World Wide Fund for Nature (WWF) in 2009 revealed that the price range for eggs sold to the market range around RM 1.30 to RM 2.20 with a mean of RM 1.70 each. Besides, this previous study also stated that the sea turtle eggs price does not vary between peak, low and non-nesting season. However, this study also stated that other studies conducted by WWF-Malaysia revealed price fluctuation where a sea turtle egg can cost RM 2.50 during nesting season and up to RM 4.00 during the non-nesting season or known as the off-season (WWF, 2009). Although these two studies were conducted by WWF-Malaysia, the result contradicted each other, indicating that a new study should be done to justify the current price trend of the sea turtle eggs in Terengganu, specifically Pasar Payang.

Thus, the recent study in this chapter aims to determine the price trend between the peak, low and non-nesting season in Terengganu. Moreover, this study also composed to identify some important characteristic of the sea turtle eggs market in Terengganu. Therefore, this study was arranged accordingly where the first section involved finding out the price range of sea turtle eggs according to season and origin. The origin of eggs was an important factor influencing the price since some eggs that were sold openly and legally in the state of Terengganu were acquired illegally from other states (such as Sabah) and neighbouring countries (such as Indonesia and the Philippines), similar to a “money laundering scheme” (Gomez & Krishnasamy, 2019).

Then, the second part of this study was designed to clarify the characteristics of the sea turtle eggs market in Terengganu. Among the characteristics that were taken into accounts were the number of vendors, quantity in a packet, quantity of eggs per seller, restock time, shelf life, consumer, the reason to consume, cooking methods, and products derived from unfinished eggs. This second part was important as it gave more clearer picture of the way the sea turtle eggs market operate. Last but not least, this study will help the state government and community to identify the price trend of the sea turtle eggs in Terengganu based on the season. The monthly price trends able to demonstrate the crucial link between sea turtle egg supply and the market price. Besides, this study also helps to clarify the current sea turtle eggs market characteristic in Terengganu. This study is important to demonstrate the impact of the sea turtle eggs selling and consumption on the sea turtle population size.

7.2 Methodology

In order to conduct the study, The Focus Group Discussions (FGD) were carried out with professionals and expert based on previous findings such as the previous WWF report on sea turtle consumptions. Then, the pre-surveys were conducted to identify more question related to this topic and to test the reliability of this questionnaire. Afterwards, the questionnaire design was finalized by including the suitable questions. The unsuitable and unrelated questions were removed from the questionnaires. Then, the final surveys were carried out from the August of 2018 to January of 2019.

The data obtained in the final survey were classified as the primary data. The field survey was conducted with the assistance of five enumerators in four continuous months. There is a repetitive survey for each month to prevent bias. The targeted respondents were turtle egg sellers in Pasar Payang, Terengganu which is 12 at most (WWF, 2009). Pasar Payang is chosen as a sampling venue because the previous study conducted by WWF (2009) revealed that 90.8% of sea turtle egg's consumer obtain their supply from Pasar Payang. Thus, Pasar Payang considers an adequate sampling site for representing the sea turtle eggs market in other places in Terengganu.

Generally, this questionnaire was designed to identify the sellers' trading activities in the market. The questionnaire was also designed to observe sea turtle eggs price and market. The questionnaire was divided into two sections. The first section is about the qualitative pricing of sea turtle eggs and their origin. The second section involved other qualitative aspects of current market characteristic based on the current practice. To avoid getting inaccurate information or being reluctant, the respondents were asked by enumerator that undercover as local, tourists from other states and countries. The question is asked indirectly.

The enumerators involved in these field surveys were the Sea Turtle Research Unit (SEATRU) teams. The enumerator asked the respondence (egg sellers) these basic questions including:

a) Price: This data will be used to evaluate the trend in sea turtle egg prices between seasons.

b) Number of vendors: This data can reflex the relationship between the on and off-season, specific on availability of eggs with the number of vendors selling sea turtle eggs

c) Quantity in a packet: The quantity in a packet would suggest the number of eggs usually brought by customers.

d) Quantity of eggs per seller: This data would give a picture of how the sea turtle eggs are distributed to the sellers from the supplier.

e) Restock time: This data will show the relationship between the on and off-season in Terengganu with the sea turtle eggs availability.

f) Shelf life: This data would give a clearer picture of how long a turtle egg can be put on sales by the seller. The comparison of the price trend between the new and old egg prices also drawn from this information.

g) Consumer: This will indicate either the demand for sea turtle eggs come from the locals or the tourists.

h) Reason to consume: This information helps in understanding what attract the consumer to eat the sea turtle eggs. This might help in suggesting ways to stop the public from consuming sea turtle eggs.

i) Cooking method: The cooking method will give data on how the tourist or locals preference in enjoying the sea turtle eggs. This also helps in understanding the reason for that particular cooking method.

j) Product derived from unfinished eggs: This data will assist in identifying other products derived from the sea turtle eggs.

The information obtains from the price and origin of the sea turtle eggs were illustrated using a graph. While other information obtained on sea turtle eggs market characteristics was compiled in a table. All the results will be observed, discussed and concluded.

7.3 Results and Discussion

The first part of this section describes the quantitative analysis of the sea turtle eggs price trend according to the respective season. This first part aimed to observe the market trend of direct use of sea turtle which is egg harvesting. Then, the second part illustrated the quantitative analysis of the sea turtle eggs market characteristics. This second part helps in demonstrating the sea turtle market features in detail.

7.3.1 Sea Turtle Eggs Pricing

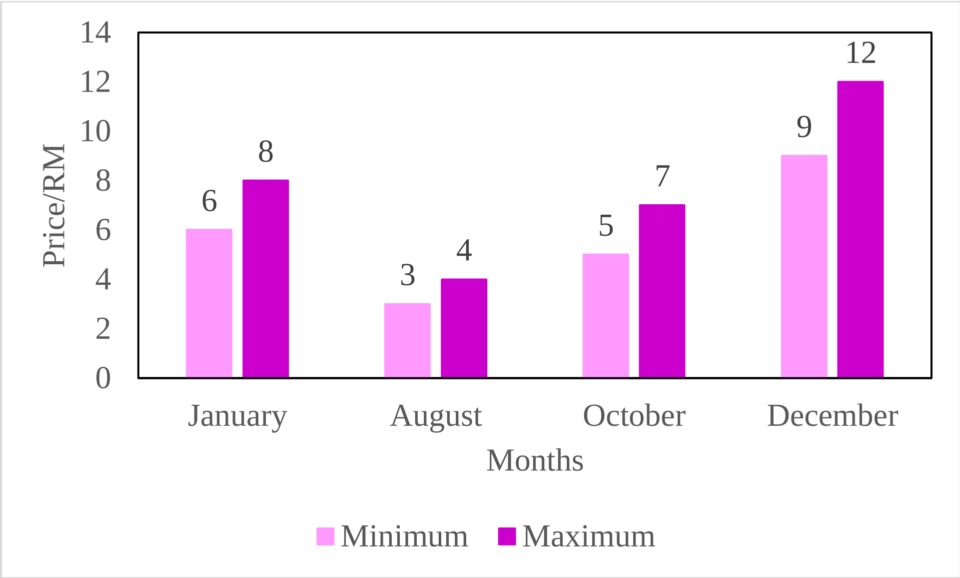


Figure 7.1 Monthly price trend of sea turtle eggs in Pasar Payang.

The monthly price trend of sea turtle eggs in Pasar Payang illustrated in **Error! Reference source not found.** above. Based on this figure, the sea turtle eggs price were the cheapest in August since the maximum price for an egg is just RM 4. The sea turtle eggs price then increased to at high as RM 7 in October because it is approaching the end of nesting seasons. The sea turtle egg price was at its peaks in December where the maximum price for an egg is RM 12. Yet, the price of eggs dropped to a maximum of RM 8 per egg in January.

The egg price was standardized between vendors because the sea turtle eggs are obtained from the same supplier based on the enumerator survey. This "standardized price" is known as the homogenous market. Results from earlier studies demonstrate that a homogenous market is not formed by a natural segment, where consumer preference in rapport with a certain product or technology is the same. Certain standard consumption classes have specialists name consumers classes. To enter this market, the trademarks need to be placed somewhere in the centre of the market with an average offer (Neamtu & Neamtu, 2007). This study has consistently shown that vendors in Pasar Payang would sell their eggs in the range of three to four ringgit each in August.

However, in most months, sea turtle eggs at the market have a higher price than the price list announced by the Terengganu state government where for buy-back system, it ranges from RM5 for a leatherback turtle egg to RM4 for other species (Murali and Tusin, 2010). As sea turtle eggs from Terengganu are only from the tender beach that has low nesting density, it creates a monopoly system. The tender holder monopoly the sea turtle eggs market as the egg seller has to agree with the price that they were offered or else, no supply for the vendors. The tender holders are free to choose whom they want to sell the eggs to since the demand for sea turtle eggs exceeding the supply of sea turtle eggs.

The price offer differences between government and market make supplying to the market appears more lucrative than selling back to the government for incubation in government hatchery. Besides that, it appears that most of the eggs in Pasar Payang come from Terengganu. Since most of the eggs sold in Pasar Payang originated from Terengganu, there is a doubt in the nesting data provided by the tender holders. Based on Chapter 3, almost all tendered beaches have a low nesting density, some have zero nesting density. There is a possibility that the data is not actual data where tender holders only told DoF about a fraction of eggs laid there, not the total annual numbers of eggs laid there. Except for the tender holders and eggs collectors, nobody knows what is the actual nesting density since DoF does not force the tender holders to sells 100% of their eggs to DoF. Moreover, due to lack of staff, DoF was unable to patrol the beaches and verified the number of eggs that were laid in tendered beaches.

From this result, it can be deduced that the price of sea turtle eggs depends heavily on its nesting density (supply). The nesting density of sea turtles depends on the seasonal factors in Terengganu. According to Chapter 3, the major nesting mother in Terengganu is the green turtle. The nesting season for green turtle in Terengganu was between March to October, this is known as the “on-season” period whereas the “off-season” (non-nesting season) is between November to February. The price of an egg in August only range between RM 3.00 to RM 4.00 This is because the peak season for sea turtle nesting is between May to August (Sharma, 1994) for green turtle in Terengganu. Thus, the eggs are cheaper in august as the sea turtle eggs supply are relatively abundant compared to October, December and January. Whereas, the sea turtle eggs in December were between RM 9.00 to RM 12.00. The sea turtle eggs sold in December are assumed to be stored from October. The enumerator survey shows that the eggs can be stored for up to two to five months before being turns into pickles. This is supported by a statement of a trader at Pasar Payang market for two decades namely Salleh Solat where green turtle eggs are sold at RM30 for a packet of 10 and the price could be double or triple during the off-season (“X-rated egg rush”, 2010).

Nevertheless, according to the survey, the price of sea turtle eggs starts to decrease again in January. The sellers claimed that there are turtles that nest in January as the raining frequency is getting lesser as the monsoon season starts from October to February (Chan *et al.*, 1988). Besides, based on the survey, the sea turtle eggs originated from Terengganu were more expensive compared to the sea turtle eggs originated from Sabah. Sea turtle eggs from Terengganu consider being fresher from Sabah. Sabah’s turtle eggs need to travel a great distance before arriving in Pasar Payang, while eggs from Terengganu travel shorter distance as it is in the same state. This is also supported by the fact that Olive Ridley turtle eggs were being sold at RM12.50 for 10 while green turtle eggs from Pulau Redang were being sold at RM25 for 10. Besides that, a bag of 10 green turtle eggs from Sabah was being sold at RM20.50 (Hoong, 2005).

The survey also reveals that the sea turtle eggs from Terengganu are more preferable by the customers as they assumed it is fresh and new. Due to the preferences, eggs that originated from nesting beaches in Terengganu fetch higher prices compared to those originated from somewhere else (WWF, 2011). This proves that sea turtle eggs are a price-sensitive product, that related to the seasons. Whenever sea turtle eggs are in short supply such as off-seasons, the price rise. Thus, the relationship between sea turtle eggs supply and price in Terengganu are inversely proportional.

Looking at the price per unit of sea turtle eggs in Pasar Payang, this economic activity does not generate a significant income because it is not profitable and it cannot replace the main income. This is visible as the turtle nesting population decline in the 1990s, the licensed egg collectors did not make as much money as before (Tan, 2004).

Moreover, egg collectors are not financially stable, thus if the sea population decreases, they lost their side income. It is suggested that turtle egg collection was a supplement to their household income as the monthly income of 50% of egg collectors are RM 1 000, while the rest is between RM1 001 to 2 000. Egg collection makes up about 28% of their household income per month (WWF, 2009). Therefore, although the "turtle industry" is made up of an estimated 110 jobs, involving people from beach patrolling that collect eggs to transporting and marketing of the eggs (Tow & Moll, 1982), it is unsustainable for sea turtles to be harvested as mention in previous Chapter 6 and 5. Thousands of sea turtles died this way every year, making extinction possible soon if the current exploitation of sea turtles eggs continues.

7.3.2 Market Characteristic

Market characteristic is at the heart of understanding the sea turtle eggs market in Pasar Payang, Kuala Terengganu, Terengganu. There are many characteristics displayed at Pasar Payang according to Table 7.1 such as (i) Number of vendors, (ii) Quantity in a packet, (iii) Quantity of eggs per seller, (iv) Restock time, (v) Shelf life, (vi) Consumer (vii) Reason to consume (viii) Cooking method (ix) Product derived from unfinished eggs.

(i) Number of vendors

There are more vendors at Pasar Payang during on-season compared to during the off-season. There are 12 vendors in total during august which is peak nesting season compare to only 7 vendors during December which is in the off-season. This is supported by a survey conducted by TRAFFIC in two dry and wet market in Kuala Terengganu, where at least there are seven vendors selling turtle eggs (Gomez and Krishnasamy, 2019). This is also relevant with a survey that was conducted by World Wide Fund (WWF) Malaysia in 2009 where they interviewed 12 sea turtle egg sellers in Kuala Terengganu. This indicates that the recent survey has represented 100% of the market in Pasar Payang. It can be deduced that the number of vendors selling the sea turtle eggs depends heavily on the sea turtle eggs supply. If the number of sea turtle eggs available increase, then the number of vendors increases such as in on-season. If the number of sea turtle eggs available decrease, the number of vendors will decrease such as in the off-season.

According to the observations, the sea turtle eggs are the side item that each egg seller sold. Therefore, if the sea turtle eggs selling was completely banned in Terengganu, the eggs sellers will possibly experience minimum impacts. During the survey, most of the egg sellers mainly sold food items such as “serunding”, traditional desserts, sweets and others. Only one seller sold other kitchen necessity which is chicken and duck eggs as the main trading item. It also has been noted by WWF survey in 2009 that most hawkers sold food items, fruit, vegetables and kitchen necessity, where sea turtle eggs are only one of the items that are sold. However, during the recent survey, it is noticed that there are no hawkers (sellers) that also sold fruit and vegetables along with sea turtle eggs.

(ii) Quantity in a packet:

Regardless of the season, the sea turtle eggs vendor always have the 5 eggs packet and 10 eggs packet ready. However, observation shows that there is more 5 eggs packet than 10 eggs packet. This show that most people only buy five or fewer eggs.57.3% of customers in Pasar Payang bought 1-5 eggs whereas only 32.6 % bought 6-10 eggs during each purchase (WWF, 2009). The vendor also allowed the customer to buy only one egg as sea turtle eggs are considered as an expensive item that is less affordable for someone with a lower income or who have a tighter budget such as students. The vendor also offers a lower price if more eggs are purchased each time for both seasons (on-season and off-season). For example, during the survey in October, if the buyers decided to buy only one egg, the price offered was RM 7 per egg, whereas if buyers decide to buy ten eggs, the price offer was RM 6 per egg. Vendors use this strategy to encourage the consumer to buy more eggs. This strategy is effective to the local consumers that were the regulars or hardcore users since the goods appeared cheaper, thus saving a lot of money. Usually, people with higher income tend to buy more eggs each time compared to the ones with lower income

(WWF, 2009). Thus, it can be deduced that the quantity of eggs on each purchase influences the price of the sea turtle eggs.

(iii) Quantity of eggs per seller

The number of eggs per sellers vary according to the eggs supply. At a time, each seller has between 370 to 500 eggs during on-seasons. However, this number drops to less than 75 eggs to 100 eggs during the off-seasons. Plus, the sea turtle eggs that originate from Terengganu are distributed equally to the seller as the seller claimed it is from the same supplier. The supplier is usually the egg collector. Align with this recent field survey result, previous research also has established that none of the egg collectors sold the eggs to the middle man (WWF, 2009). This shows that all the eggs that origin from Terengganu are supplied directly from the nesting beaches where the absence of the middle men means that there is less price markup present. Whereas, this recent study also revealed that the sea turtle eggs originated from Sabah are supplied by a middle man. This is supported by a seller named Ahmad Syukri that stated that sea turtle eggs from outside the state are supplied by the agent ("Terengganu traders selling turtle eggs", 2006).

However, this recent research finding which is most of the sea turtle eggs sold originated from Terengganu itself were contradicted The Star report stated that most of the eggs came from Sabah or Indonesia ("Terengganu traders selling turtle eggs", 2006). Vendors reveal that most eggs observed in Pasar Payang are from Terengganu itself, claimed as from Pulau Redang by all of the sellers. The customer preferences might have changed as although previously traders sold eggs supplied from Sabah and Indonesia, great demand is noticed for Terengganu eggs (Murali and Tusin, 2010). Egg from Terengganu can be distinguished by a layer of sand on the egg's shell, while the eggs from Sabah appear to have a cleaner shell, this result aligned with previous research by Nyok (2013). Besides, the vendors also revealed a piece of extra information on identifying the origin of sea turtle eggs where the sea turtle egg's shell from Sabah is thicker than the one that originated from Terengganu.

(iv) Restock time

The sea turtle eggs are restocked every two days during on-season. During December, the restock time is irregular as the supplier cannot guarantee the availability of sea turtle eggs. This is due to the short supply of sea turtle eggs during off-season and monsoon. The interval between restocks increase during a certain month in the off-season such as in January where it took four to six days for the vendor to receive the supply. However, according to the vendors, the eggs from Sabah takes a longer time to restock as they need to gather one batch of eggs which contain around 3 000 eggs before being ship to Peninsular Malaysia. One person will act as a middle man to distributed one hundred eggs from each batch to each sea turtle eggs vendors in Pasar Payang. A large number of eggs in one batch was possible since every year, about tens of thousands to as many as 400,000 sea turtle eggs are exported from Sabah to Terengganu (Gomez and Krishnasamy, 2019).

(v) Shelf life

Sea turtle eggs from Terengganu were displayed and advertised as the "fresh eggs" for up to two to five months. The method used to ensure these eggs last up to five months were by putting the eggs into the refrigerator for a day after every three days on the display at the vendor counter. Eggs from Sabah has shorter shelf life since it can only last for a few days before it became inedible. This is supported by a report by The Star where the sea turtle eggs that originated from Sabah only can be stored for few days before turn bad ("Terengganu traders selling turtle eggs", 2006). Besides that, this recent research proved that the price for older sea turtle eggs was less expensive than the new one, this is because it was more preferable and considered as fresher and more beneficial for health such as more effective in curing disease. From the survey, it is known that the unpacked eggs are more expensive than the packed ones as they are relatively new compared to the packed ones. The older eggs were packed so they would be sold first especially with to the customers in a rush. However, customers can request the unpacked eggs although the sellers will try to trick customer to believe that eggs in both groups were equally fresh and of the same age.

(vi) Consumer

According to this recent study, the demand for sea turtle eggs is higher from the local community compared to the tourists. Local people that buy eggs for their consumption are primary customers for sea turtle eggs where some of them are considered regular customer (WWF, 2009). Generally, the amount of tourist during the survey are less during the off-season as it overlaps with the monsoon season. Tourist visits Terengganu as it is one of the states in Peninsular Malaysia that has always been popularly known for beach tourism and island (Abdullah *et al.*, 2014). During monsoon season, the islands are closed and water activity is limited thus, the number of tourism decrease.

The second most important buyers for sea turtle eggs are local tourist from others state in Malaysia. This is then followed by individuals that bought sea turtle eggs in bulk for resale (WWF, 2009). The local tourist act as a middle man or agent that visit Terengganu to survey for the trusted vendor and prices before purchasing sea turtle eggs. The vendors also provide tourist from outside of the state with their handphone number if they want to order either in small or huge quantity. A small quantity of sea turtle eggs is posted for places outside Terengganu if requested by the customer. However, the sea turtle eggs can become spoilt and degraded. If the eggs are degraded, the vendor provides no replacement or money refund. The orders with a large number of eggs are usually picked up by the customer.

(vii) Reason to consume

This recent survey revealed that the local community consume sea turtle eggs as they believe that it is nutritious. Besides that, the local community also believed that sea turtle eggs are the traditional medication sources. Sea turtle eggs are believed to cure asthma, muscle and joint pain, enhance elderly health. Adding to that, some women consume it due to their pregnancy craving. Male consume eggs as they believe that this will increase their libido as it acts as an aphrodisiac. Despite all the health benefit claimed from consuming sea turtle eggs, there is no scientific evidence that supports this conception (Andar & Hitipeuw, 2012). Sea turtle eggs also considered a delicacy to local. The sea turtle eggs are considered as “fine food” as they are not consumed daily and only consume in a small amount (WWF, 2009) as they are quite expensive. Tourist, on the other hand, consume sea turtle egg purely because they want to try or experience it as mentioned by WWF (2009). They are fuel by their curiosity about the taste, smell, texture and benefit of sea turtle eggs.

In order to reduce sea turtle egg consumption, it is important to educate the community on heavy metal content in sea turtle eggs. Long-lived organisms such as sea turtles have a high concentration of heavy metal as it persists and bioaccumulate in marine ecosystems. Heavy metal toxicity can cause adverse behavioural, physiological and biochemical effects on humans. In children, the neurological impacts include hyperactivity, poor attention span and low IQ especially. The disruption of enzymes activity also inhibited the haemoglobin synthesis, insufficient transport of oxygen and anaemia. Children with anaemia are easily fatigued and have difficulty in learning. Moreover, other consequences of heavy metals are renal dysfunction, osteoporosis, type–2 diabetes, renal and prostate carcinogen (Joseph *et al.*, 2014).

(viii) Cooking method

Based on this recent study, the sea turtle eggs are either eaten raw or boiled. The sea turtle eggs are usually seasoned with salt, honey, or peppers. It is advisable for pregnant women to only consume sea turtle eggs that have been boiled for three to five minutes. To avoid pregnant women from consuming raw or undercooked eggs that cause serious complication or even death for pregnant that naturally has a weakened immune system (Medeiros *et al.*, 2006).

(ix) Product derived from unfinished eggs

The survey in Pasar Payang revealed that the Pickle or known as salted eggs are derived from unfinished sea turtle eggs. The sea turtle eggs were converted into pickles to prevent sea turtle eggs that are at the end of their shelf life from decaying. A maximum of thirty eggs per round are wash and immerse in a salty solution. According to the vendors, if the eggs that are put in one container or flask exceeds thirty egg and not enough salty solution, the pickle eggs will be degraded faster compare to other salty eggs.

Table 7.1 The sea turtle market characteristics in Pasar Payang.

Month	Number of vendors	Eggs quantity per pack	Quantity of eggs per seller	Restock time (day)	Shelf life (month)	Consumer	Consumption reasons	Cooking method	Product from unfinished eggs
August	12	5 and 10	500	2	2	Local and tourist	-Local: Asthma, Muscle and joint relief enhance elderly health, Pregnancy craving, Aphrodisiac, Delicacy -Tourist: Try	-Raw -Boil	Pickle
October	10	5 and 10	370	2	2 to 5	Local and tourist	-Local: Asthma, Muscle and joint relief enhance elderly health, Pregnancy craving, Aphrodisiac, Delicacy -Tourist: Try	-Raw -Boil	Pickle
December	7	5 and 10	75 and less	not fix	N/A as eggs finish before restock time	Mostly Local,	-Local: Asthma, Muscle and joint relief enhance elderly health, Pregnancy craving, Aphrodisiac, Delicacy -Tourist: Try	-Raw -Boil	Pickle
January	9	5 and 10	100	4 to 6	2	Mostly Local,	-Local: Asthma, Muscle and joint relief enhance elderly health, Pregnancy craving, Aphrodisiac, Delicacy -Foreigner Tourist: Try - Malaysian Tourist: Supply agent	-Raw -Boil	Pickle

7.4 Conclusion

In conclusion, the sea turtle eggs selling continued with the remaining sea turtle species such as hawksbill and green turtles up until today. Yet, there is a lack of qualitative study in describing the current sea turtle eggs market in recent years. Thus, this chapter is aimed to identify the qualitative aspect of the sea turtle eggs current market in Terengganu. The first part of this study composed to determine the price trend between the peak, low and non-nesting season in Terengganu. The second part was composed to figure out some important characteristic of the sea turtle eggs market in Terengganu. The first part of this study revolved around determining the price range of sea turtle eggs according to the season and origin. According to this study, the price of sea turtle eggs influenced by the supply of sea turtle eggs. The price per unit of sea turtle egg was cheaper during the on-season (RM 3-RM7) than in the off-season (RM 6-RM 12). The lowest price of sea turtle eggs can be observed during peak season which is RM 3 per egg in August. Besides that, this study proved that the price of sea turtle eggs also heavily influenced by the origin of the eggs. Sea turtle eggs from Terengganu were more preferable and have a higher price since it is considered fresher. Most sea turtle eggs sold in Pasar Payang originated from Terengganu itself, not from other state or countries.

Then, this study was composed to shed some light on the characteristics of the current sea turtle eggs market in Terengganu. The characteristics that were focused on in this study was the number of vendors, quantity in a packet, quantity of eggs per seller, restock time, shelf life, consumer, reason to consume, cooking methods, and products derived from unfinished eggs. This second part was composed to illustrate the sea turtle eggs market operation in Pasar Payang, Kuala Terengganu, Terengganu. The surveys revealed that the number of sea turtle eggs vendors in Pasar Payang was influenced by the total eggs supply. Since the eggs supply were greater during on-seasons, the number of vendors were also higher, as high as 12 individuals in the peak season (August). On contrary, only 7 vendors can be observed during off-seasons such as in December. However, regardless of the seasons, all vendors sell sea turtle eggs as side items. This suggested that a complete ban of sea turtle eggs selling would affect them on a minimum scale. Besides, the vendors preferred to pack the eggs in 5 and 10 eggs packet. Vendors prepared more packets with 5 eggs since the customers preferred to buys fewer eggs due to its high price. Thus, it is proven here that the customer preferences were on fewer eggs. All vendors allowed consumers to even buy a single egg. Yet, all vendors will lower the price per egg if the consumer buys in a larger quantity. This strategy was utilized by the vendors to encourage consumers in buying more eggs. This strategy works well with local consumers which were regulars, hardcore or having a higher income. Based on these facts, it is concluded that the price of the sea turtle eggs depends on the quantity of eggs purchases on every transaction. Plus, the number of eggs per seller was heavily influenced by the eggs supply. Sellers have the highest number of eggs (370 to 500 eggs at one time) during the on-season. Nonetheless, each seller only has less than 75 eggs to 100 eggs at one time during the off-seasons. The sea turtle eggs that originate from Terengganu are obtained from the same suppliers that distributed an equal number of eggs to all of the sellers. The suppliers were the eggs collectors, thus no middle man involved leading to less price markup. However, all eggs that were originated from Sabah were supplied by the middle man to eggs sellers in Pasar Payang. Besides that, this study also concludes that the restocks time of sea turtle eggs during the on-season is more frequent compared to the off-season since sea turtle eggs are abundant in the on-season. However, the restock time for sea turtle eggs from Sabah is undetermined because it would only be shipped to Terengganu if the eggs were accumulated to 3000 eggs per batch. Furthermore, based on this study, it can be inferred that the fresh sea turtle eggs have a long shelf life between 2 to 5 months. Based on the information from the vendors, the local community were the major consumers of sea turtle eggs. The local community consume the sea turtle eggs because it is believed to be nutritious, have traditional medicine value and pregnancy craving. However, the tourist which is the minority consumer of sea turtle eggs consumes it due to an urge to experience it. Usually, the sea turtle eggs were consumed directly (raw) or boiled and seasoned with salt, honey, or peppers. Lastly, to be profitable and prevent losses, the vendors converted the sea turtle eggs into pickles to prevent them from degradation.

Therefore, since the major consumer of sea turtle eggs were not the tourist, completely banning the sea turtle eggs market should have no adverse impact to the tourism sectors in Terengganu. This ban is important to protect the tourism sector which is the major economic sector in Terengganu. The state government need to ban this economic activity to ensure the continuity of sea turtles in Terengganu since it helps in maintaining the health of the marine ecosystems. The marine ecosystems are important in maintaining the tourism sector in Terengganu because the main attraction of Terengganu state tourism is the beautiful islands and beaches as discussed in the upcoming Chapter 8.

CHAPTER 8

MARKET SURVEY ON SEA TURTLE TOURISM PRODUCTS IN TERENGGANU, MALAYSIA

8.1 Introduction

Sea turtles are not only important for the environment but also responsible and contribute to the economic growth of a state or country. As one of our national heritage, the uniqueness of sea turtles is capable to attract tourist from around the world. Previously, it is estimated that 50,000 local and foreign tourists visited Rantau Abang, from June to August, although it just a small village in Terengganu. Moreover, a tourist complex project worth US$ 2.2 million was developed by the Tourist Development Corporation around Rantau Abang. (Tow & Moll, 1982). The early establishment of ecotourism not only boosted the state’s revenue but also have provided job opportunities for the local community such as by catering to tourist's needs. However, in those time, Rantau Abang was one of the most important in the world as the leatherback turtle used to lay more than 10,000 egg clutches per season in 1956 (Mortimer, 2000).

Nowadays, there are only approximately 37 nests per season in Rantau Abang (Chapter 3). The drastic depletion that eventually leads to the leatherback extinction strongly suggest that the sea turtle eggs consumption were not sustainable. Thus, this study was composed to observe the market activity related to sea turtle tourism product in Terengganu. The ecotourism activity involving the sea turtle population such as the hatchling released, accommodation, day trip, nest and turtle adoption were carried out in Terengganu to attract tourist. These tourism-based economic activities were the non-consumptive ways of generating income. These non-consumptive economic activities possibly able to helps in sustaining the sea turtle population in Terengganu. Thus, this study is carried out to observe the market activity related to sea turtle tourism products. To achieve this aim, this study is divided into a few parts according to the tourism product category which is the hatchling released, accommodation, day trip, nest and turtle adoption. On each part, the qualitative assessment was carried out based on the price per unit of sea turtle tourism products. Interviews and surveys on non-consumptive use of sea turtles based on the price per unit for hatchling release and accommodation related to sea turtle programs such as the volunteer program offered in Terengganu are included. The amount of money that is willing to be paid for the existence of the species will be included by referring to the price of nest and turtle adoption fees. Then, the finding will be compared with the consumptive use of sea turtle which is egg exploitation in upcoming Chapter 9.

The prices per unit of non-consumptive sea turtle tourism products were possibly higher than the consumptive product such as eggs harvesting that was mentioned in Chapter 7 previously. A previous case study of Rantau Abang exposed that the gross revenue for consumptive use in 2002 was only US$ 158, whereas the gross revenue for non-consumptive used was US$ 480, 149. This previous case study also indicates that the gross revenue trend will experience a tremendous downfall when the population decrease (Troëng & Drews, 2004). This previous case study indicates that the gross revenue pattern was influenced and directly proportional to the population trend. Therefore, it is possible to look at the sustainability of tourism-based economic activity. However, since there is a lack of information based on the yearly gross revenue of this economic activity, the evaluation was carried out by looking at the price per unit of the products in this study. This recent study was important for demonstrating to the government the possible potential of sea turtle tourism products in generating huge and sustainable income for Terengganu and its community. Plus, this study also capable of helping the government to identify the sea turtle tourism that needs to be nurture, focused and further developed to ensure the tourism sector and sea turtle population continue thriving.

8.2 Methodology

This observation was carried out by gathering the information from the package that was offered in Terengganu according to internet search and interviews. The internet search and interviews were used as a sampling method since the price of tourism products able to changes fast and differ year by year. Besides that, most documented and published price were outdated since tourist operators prefer social media as a medium to advertise their products since it eases the communications between the tour operators and possible customers. It has been suggested that the non-consumptive used to generate greater gross revenue than consumptive use (Troëng and Drews, 2004). Thus, based on sea turtle related product in Terengganu, it is assumed that the package price for each unit of non-consumptive use is more than the price of each unit of consumptive use by sea turtles. The maximum price for hatchling released, accommodation, day trip, nest and turtle adoption programs were considered in this study. This study utilized the price per person for a day as the measurement to compared between package or sea turtle tourism activity. As mentioned in the literature review section 2.10, the sea turtle tourism products such as hatchling release, accommodation and day trip were put under the experience tourism category in this chapter. Besides, the nest and turtle adoption were grouped under the willingness to pay category in this chapter. Then, the price variations were interpreted, discussed and concluded.

8.3 Results and Discussion

All sea turtle tourism activities in this part were divided into two categories. The first category is the “Experience Tourism” that contains results and discussions for the sea turtle tourism products such as hatchling release, accommodation and day trip. The second category is the “Willingness to Pay” that pictures the results and discussions of the sea turtles and nest adoption programme. Then, the price variations were interpreted, discussed and concluded.

8.3.1 Experience Tourism

Sea turtle related products that are offered by Terengganu are various experiences of tourism for visitors. In leisure and tourism, experiences are described as "a subjective mental state felt by participants". In another word, events that commit people in a particular manner and memorable are considered as experiences (da Costa Mendes *et al.*, 2010). Generally, experiences tourism are tourism activities that involve the participant to have a pleasant hands-on experience during their stay. These experiences might focus on entertainment, education, esthetics or escapism. Sea turtle product in Terengganu involved experience tourism such as (i) hatchling release, (ii) accommodation (iii) day trip that highlighted sea turtle as the main attraction. The tourism sector is carried out to generates a huge revenue and gave tremendous benefit to the state government, firm, business owner, and the local community. This section discussed the packages under experience tourism as offered in Terengganu.

(i) Hatchling Release

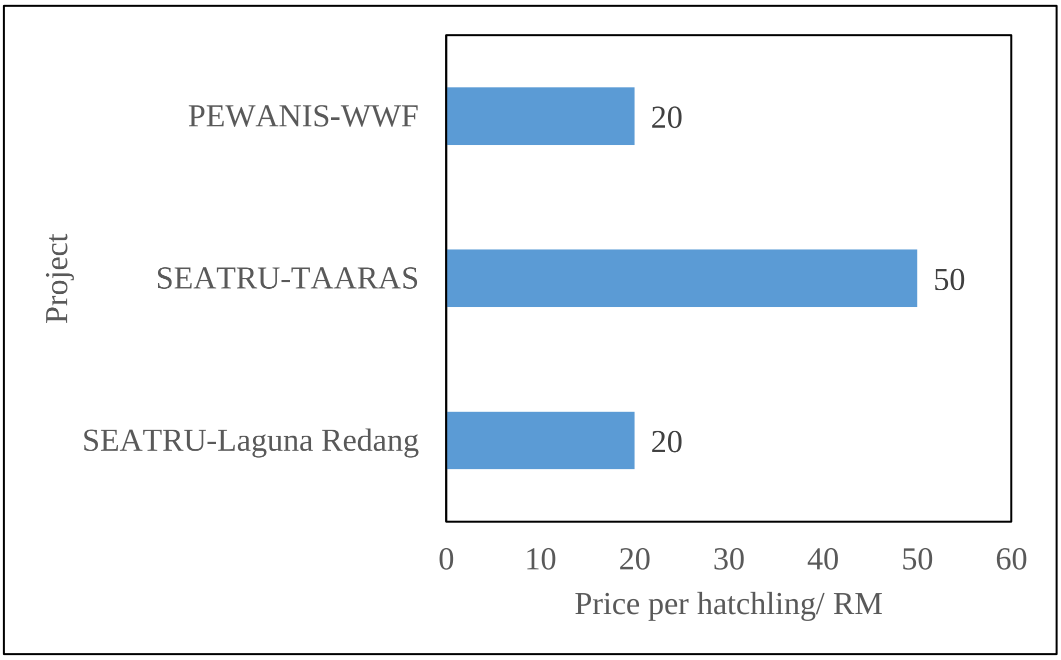


Figure 8.1 Fee for hatchling release programme in Terengganu.

Figure 8.1 above shows the fee for a person to join hatchlings release in Terengganu. Hatchling release activities involve anyone including students, children and others were an exciting activity (Shanker *et al.*, .2003). Based on the observation in Terengganu, hatchling release is carried out by allowing the participant that already paying the fee to release a hatchling from the nesting beaches and participants watch their hatchlings until it reaches the water. Some participant even immerses in an extra bond with the hatchlings by given a name to their hatchlings, record the videos and cheering for their hatchling as if their hatchlings participate in a race towards the sea. The price per pax is referring to the price per hatchling. The fee for the hatchling release is considered as a donation and will be used by the project for conservation work to save more turtle eggs.

In Terengganu, three projects carried out hatchling release which is Persatuan Wanita Kg. Mangkok Setiu (PEWANIS)-World Wide Fund for Nature (WWF), Sea Turtle Research Unit (SEATRU), The Taaras Beach and Spa resort (TAARAS) (SEATRU, 2018). Among those, the highest fee charged for each hatchling release was in the Sea Turtle Research Unit (SEATRU). The Taaras Beach and Spa resort (TAARAS) in Redang Island was RM 50.00. Although the hatchling release fee in TAARAS was the highest, the fee is equal to the Kasturi Resort-Rimbun Dahan Turtle Hatchery, Pahang. Yet, the collaborations of SEATRU and Laguna Redang were RM 20.00 each, the price was similar to the PEWANIS-WWF project.

Hatchling release in Terengganu was dominated by Non-Government (NGO) project. Since the hatchlings release programmes were managed by the NGO, the fees were higher compared to the government organisation in other states such as Cherating Turtle Sanctuary, Pahang. The minimum charge for sea turtle release was only RM 5.00 per person under the governance of the Department of Fisheries (DoF) (Badri, 2015). Variation of fee for hatchling release is noticeable between the Non-Government (NGO) and a Governmental project. These charges vary due to the target audience groups. The governmental hatchery such as Cherating Turtle Sanctuary under the maintenance of DoF only collected minimum fees since their main target was to educate the local community that mostly having financial difficulties. In addition to that, the main focus of the DoF hatchery is intended to protected and conserve sea turtles.

Contradicted to this, the NGO project such as in TAARAS Resort, PEWANIS and Laguna Redang Hotel targeting more foreigners and tourists that are financially capable. Some project such as the hatchling release under the SEATRU project needs to charge more because they provide souvenirs such as the button batch on sea turtle conservation. Besides that, some other projects such as PEWANIS (WWF, 2009) and The Kasturi Resort (Rimbun Dahan Hatchery in Pahang) that involve hatchery under community care are intended to raise some income for the community (The Kasturi Resort, 2017). Usually, these hatchling release activities are advertised on the resort and hotel web page to attract tourist such as in Pandan Laut Beach Resort (Pandan Laut Beach Resort, 2010). Some others projects advertised their hatchling release program on their web page, Facebook pages and Instagram such as by SEATRU or PEWANIS. This helps them to attract future customers since it eases communication, provide the latest information and offers and helps them to plan out their vacations smoothly.

The turtle releasing activities should be increased to prevent it from shrink and extinct just like turtle watching activities in Terengganu. Turtle watching activities involve witnessing the sea turtle mothers during their nesting process. Places that famous for this activity included Rantau Abang. However, as mentioned in Chapter 3, many of the nesting beaches have low nesting density nowadays such as in Rantau Abang. According to Mr Alex Lee (the owner of Terrapuri Heritage Village Resort), this once lively town has turned into a “ghost town”. Until 1995, Mr Alex used to handle the turtle watching activities for at least 16 people at one time. This business was profitable at that time as a tourist is willing to pay about RM 50 per person to witness this majestic leatherback turtle previously. At that time, Rantau Abang is a hotspot for turtle watching in 1985, no less than 1,000 tourists crowded around a leatherback (Chan, 2000). Since the beaches have low or no nesting density, the tour operators could not guarantee any of the nesting mothers would appear, thus they have to end this business. This marked the loss of one economic activity, as well as a medium to educate the tourist and local community on the importance of sea turtle survivals.

(ii) Day Trip

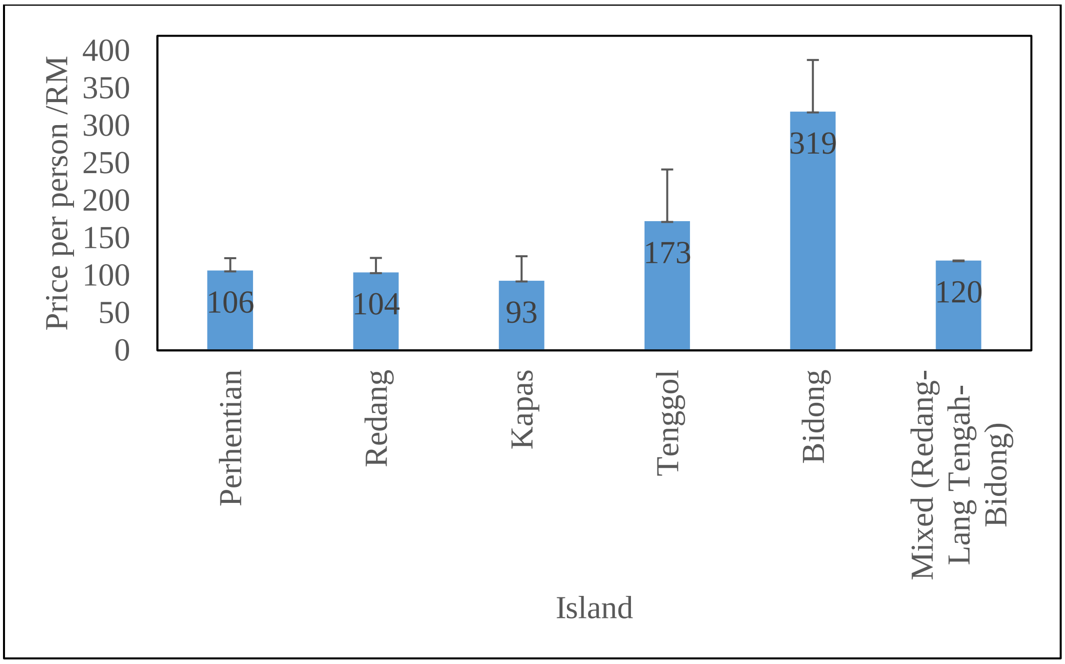


Figure 8.2 Day trip package for the island in Terengganu.

Figure 8.2 illustrated the day trip package provided in Terengganu that focussed on a few islands such as the Perhentian, Redang, Kapas, Tenggol, Bidong and Lang Tengah. Day trip to the island in Terengganu can be generally defined as one day visit to the island or few islands that occupied by several activities such as snorkelling, diving, hiking and exploration of the island history, interesting landmark and others. The existence of sea turtle populations is important since those day trip also focuses on activities involving them such as snorkelling at the Turtle Bay in Redang Island (Azahari Boat Services, 2019). Although activities offered by each package seems to look alike, the price per person for a day trip package is different between islands due to a few factors.

This result demonstrated that the cheapest average price package per person is a day trip to Kapas island (RM 93) whereas the most expensive was to Bidong island

(RM 319). The highest standard deviation possessed by Bidong island and Tenggol island as every package to each island relatively has huge different price gap. The price for a day trip to Tenggol and Bidong islands distinct from the package offered on other islands. The mixed island package has the lowest standard deviation as there is only one package that offers customers snorkelling activities at three different islands.

Perhentian and Redang island have almost equal average price per package which is RM 106 and RM 104. This situation happens as they are equally popular. Perhentian, Redang and Tioman island are listed as the most beautiful island in Malaysia and are popular tourist destinations on the east coast of the peninsular not long ago (Weng, 2009). Since more tour operators compete for customers, the tour operators tend to offer a lower price for day trip package compare to Tenggol and Bidong Island that has fewer service operator. This can be seen as the survey only reveals that there are eleven tourist operators in Perhentian Island, seven in Redang Island, five tourist operators in Kapas Island, five tourist operators in Bidong Island and only two in Tenggol Island. Based on the minimum package price offered, Perhentian and Redang Island offer the lowest price which is RM 85, followed by Tenggol Island which is RM 160 and Bidong Island which is RM 220.52.

On the other hands, Kapas island service operators can offer a lower price at a minimum of RM 55 for a day package as it is highly accessible, only located less than 5 km from the mainland (Traeholt, 2010). Thus, due to the short distances, for many years, Kapas island has been a popular destination for local day-trippers (Traeholt, 2010). Besides that, the day tip package is less expensive as the boat ticket that is included in the package are cheaper compared to other islands due to the shorter distance. This can be seen as Redang Island located 45 kilometres from the mainland of Terengganu (Liew *et al.*, 1995), Tenggol Island was 30 km away (Reef Check Malaysia, 2011), Perhentian island located 21 km away (David *et al.*, 2016), while Bidong/Yu Island located 15-25km (Reef Check Malaysia, 2011). In addition to that, since many people can reach this island, its exclusivity became less, thus the price became lower.

Moreover, the price of each package also depends on the infrastructure provided on the respective island. Although Kapas Island does have an established tourist market, due to its small size, it is not a major tourist destination. (Reef Check Malaysia, 2011). According to a field survey, infrastructure development and focus are more intense in major tourist destination such as Redang and Perhentian Island. Kapas Island only owns four resorts and one dive operator. Besides that, Kapas Island also unable to accommodate huge numbers of visitors as there is have no main electricity, no centralised sewage treatment and limited groundwater supplies (Reef Check Malaysia, 2011). Without that basic supply, surviving even a day is quite hard and lead to extra cost as basic needs such as water and food need to be brought from the mainland.

Contradicted to Kapas Island situation, Perhentian and Redang Island is a major tourist destination. As reported by Motour Terengganu, 287,149 international tourists visited Terengganu, 90% purposely visited the two islands without visiting any other attractions in the state in 2010 (Nejati, 2014). The infrastructure in Redang and Perhentian Islands are more elaborate to cater for the tourist demand. Although Perhentian Island also has no mains electricity, no centralised sewage treatment and limited groundwater supplies, it owns 35 resorts, mainly small, family-run operations, and 15 dive operators, spread around the Perhentian Kecil and Perhentian Besar Island. On the other hand, Redang Island, mainly on Long Beach (*Pasir Panjang*), there are 10 medium-large size resorts where most of the resort have in-house dive operator. Redang Island also has no mains electricity, but they receive water supply from the mainland by the pipeline and every resort has its sewage treatment facilities. In addition to that, only this island has both boat services and an airport (Reef Check Malaysia, 2011).

Aside from differences in facilities offered by the island, the activity offered during the day trip has influences the package rate. The day-trip involving scuba diving charge more than day-trip that offer snorkelling activities. As an example, a service operator web namely Viator, the price offered are only RM 220.52 because it only includes boat transfer, marine park ticket, lunch, snorkelling, besides island history tours such as hiking to the Vietnamese temple and settlement (Viator.com., 2020).

Meanwhile, Alam Travel & Tours offered a package of RM 390 that includes, boat transfer, lunch, three-time diving sessions, and snorkelling at six different points (Alam Travel & Tours, Kuala Terengganu, 2019). Besides, the package that snorkelling at a few different islands is more expensive than at one island only. Al-Masyur International Travel & Tours offer a package of RM 120 for a day trip involving snorkelling at Redang, Lang Tengah and Bidong Island while snorkelling at Redang Island only cost only RM 95 (Al Masyhur International Travel & Tours Sdn. Bhd., 2020).

(iii) Accommodation Related to Sea Turtle Programme

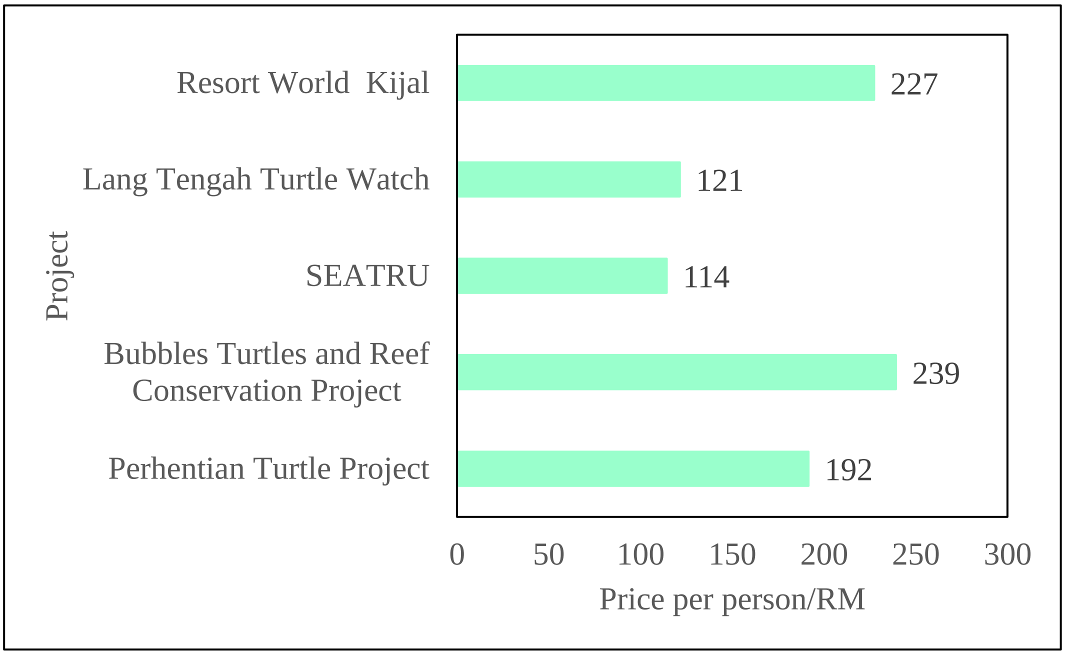


Figure 8.3 Price of accommodation related to sea turtle program per day.

Figure 8.3 illustrated the price for accommodation related to sea turtle programs for one person per day. This business is pioneering by the Non-Government Organization (NGO) in Terengganu. The sea turtle program in Terengganu that is pioneering by the hotel industry is more expensive was the Resort World Kijal, RM 227 while for Bubble Turtle and Reef Conservation Project RM 239 per day. Whereas, the cheapest charge for sea turtle related accommodation offered by SEATRU is RM114 per day while RM 191 per day for Lang Tengah Turtle Watch (LTTW). This is due to the different experience tourism model practices by the tour operators that provided accommodation as mention in Figure 8.4 below:

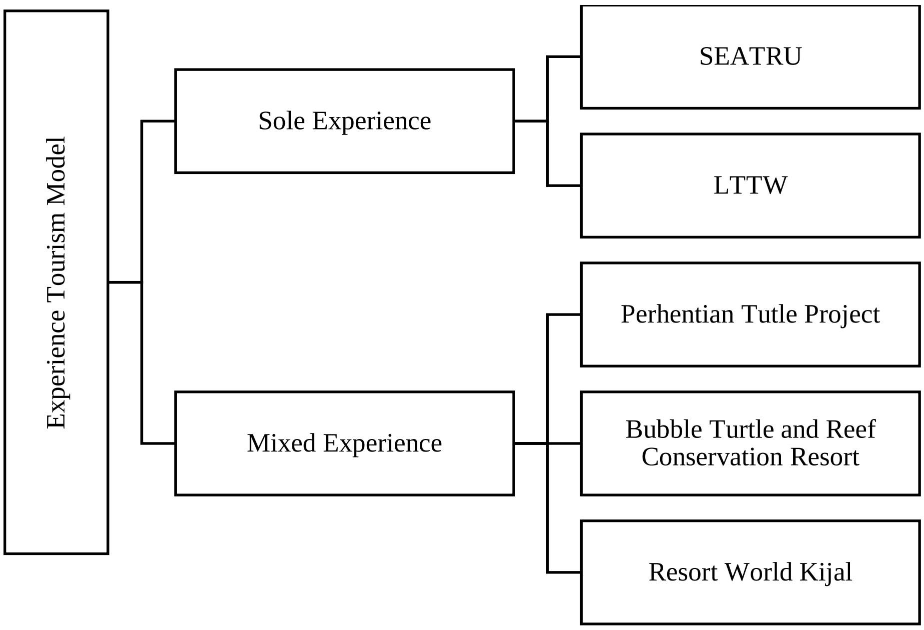


Figure 8.4 Experience Tourism Model that has been implemented for accommodations related to the sea turtle program in Terengganu.

Experience tourism model a stated in Figure 8.4 comprise both the sole and mixed experience program. Sole experience involving SEATRU (2018) and LTTW (2018) usually contains the volunteering program. In this kind of programme, the participant usually stayed at the field and carried out sea turtle conservation program by themselves such as beach patrol, nest marking, nest relocation, nest check, and hatchling release. They also involved in preparing their own need such as preparing food, tidying their bed, doing their laundry and others. This kind of camp is charging the volunteers for their stays. This strategy is profitable, as they have free human resources and at the same time obtained money to continue this project.

Besides there are camps in Terengganu that provide the visitors with mixed experience such as the Perhentian Turtle Project (2019), Bubble Turtle and Reef Conservation Project (2019) and Resort World Kijal (Genting Malaysia Berhad, 2020). All these three projects commonly accommodate their visitor at hotel, resort or dorm that are equipped with fan, air conditioning and personal bathroom. Moreover, their personal needs such as food, room service and others are catered to by the project staff. Adding to that, the mixed model also offers extra activity in addition to the sea turtle conservation programme.

Resort World Kijal and Bubble Turtle and Reef Conservation Resort have accommodation related to the sea turtle program, although the hotel industry has a higher charge, according to their tentative, their sea turtle program is less dense than the volunteering program. However, differ from Resort World Kijal, Bubble Turtle and Reef Conservation Resort also offer an extra activity such as scuba diving. In the other hand, the Perhentian Turtle Project has a different strategy as a visitor are involved in the island community activity such as the enjoying village life. This island community model also involves conservation effort for other species such as the reef ecosystem.

Comparing the location of sole experience and mixed experience projects, we can conclude that the sole experience projects are located at nesting beaches with higher nesting density as mention in Chapter 3. For example, the SEATRU research station is located on one of the nesting beaches in Pulau Redang, that have the highest nesting density of 1189 nest/km^{-1}. Whereas the mixed experience project is located at nesting beaches with lower nesting density, thus to attract visitor, they include other extra activity. It can be deduced that the mixed experience project capable of generating more income than the sole experience project. Although the mixed experience capable of generating more income, it is considered less intense and less significant in conserving the sea turtle populations. Yet, the mixed experience package also helps in educating local and foreign tourist.

8.3.2 Willingness to Pay

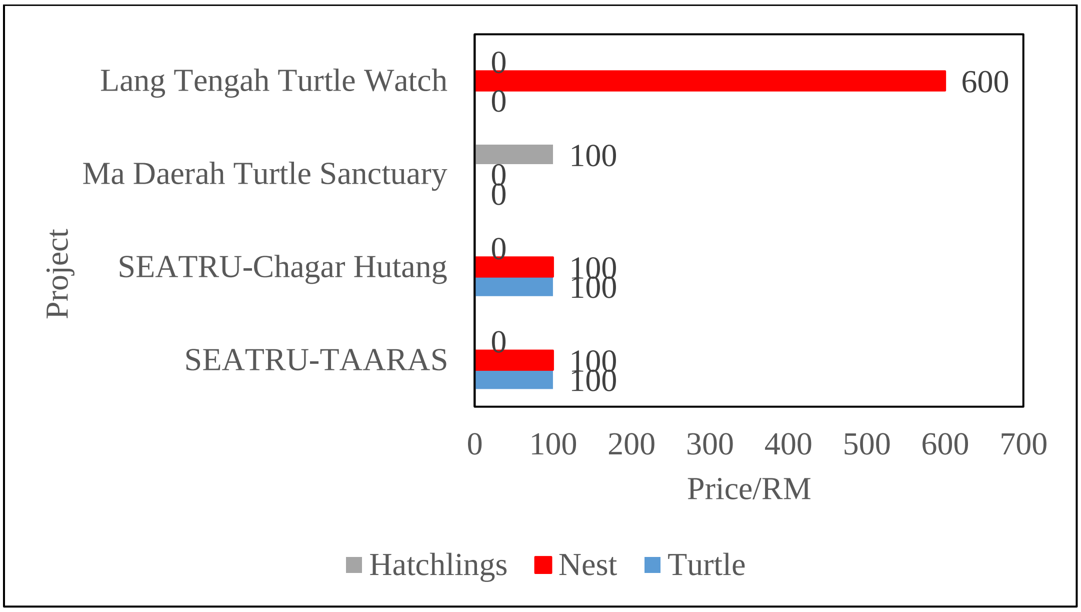


Figure 8.5 The adoption fees in Terengganu for sea turtle nest, hatchling and turtles.

The adoption fee as display in Figure 8.5 was considered as a part of the willingness to pay under the existence value in TEV. Basically, the adoption programme is a platform where the public donates money to adopt a nest, hatchling or nesting mother. The adoption program is usually advertised on the project web, social media page, and other programs such as during the hatchling release and volunteer programme. The adopter will receive an update on the nest, hatchling or nesting mother that they adopted which gave them a "sense of contribution" in saving the sea turtle life.

Figure 8.5 illustrated the fee for adoption of sea turtle in Terengganu organized by Lang Tengah Turtle Watch (LTTW, 2018), Ma' Daerah Turtle Sanctuary (Ping Anchorage, 2020), SEATRU at Chagar Hutang and SEATRU at TAARAS Resort (SEATRU, 2018). The maximum price that is willing to be contributed by the public is RM 600 per nest at Lang Tengah Turtle Watch (LTTW). While, the minimum price that is willing to be contributed by the public is RM 100 at SEATRU at Chagar Hutang and TAARAS Resort. Besides that, Ma' Daerah Turtle Sanctuary also charged RM 100 is to adopt a sea turtle hatchling. The projects offered for nesting mother adoption at the rate of RM 100 per mother are the SEATRU at Chagar Hutang and TAARAS Resort. These projects offered lower adoption fee since it is almost free for them to obtain the sea turtle eggs. Since they were gazetted as a protected beach, the management is excluded from paying the tender fees and wages for egg collectors.

The price for adoptions varies between project due to a few factors. Firstly, the adoption price varies according to the targeted adopter. This can be seen under the LTTW project at Tanjong Jara Resort, Dunggun, which is a five-star luxury hotel. Most of the tourists were from the western country that has higher currency Since their money have higher currency, RM 600 was not considered as a huge amount. This enables them to give more money for the existence of sea turtle without a second thought. This is supported by Samdin (2002) where tourism became the third biggest contributor to the foreign exchange earnings as the contribution of this industry had increased to RM 4.41 billion in 1990.

Besides that, the adoption fee charged by LTTW was the highest since they need to buy the sea turtle eggs from the tender holders and pays the eggs collector to collect eggs from the closes beach that they tendered. Eggs that were bought from tender holders and egg collectors are put in Tanjong Jara Resort’s hatchery. In addition to that, the LTTW charged a higher adoption fee since they need to agree with the price offered by the tender holder although it is higher than the price offered for the buy-back system under DOF due to the limited numbers of sea turtle eggs. An interview with Mr Firdaus, an officer at DoF Rantau Abang reveals that from 2018 until now, the price guideline in the tender advertisement released by the secretary of state government state that the price set for buy-back system is RM 5 for leatherback turtle, RM 3 for green turtle and hawksbill whereas Olive Ridley turtle and river terrapin were RM 4 each.

Moreover, the LTTW charge a higher price for the adoption fee since they need to pay the tender fees on Lang Tengah Island. Furthermore, they also pay the eggs collectors that found the eggs according to the number of eggs on each nest that they found on the tendered beaches such as at Lang Sari. Thus, LTTW charges higher than SEATRU for nest adoption as SEATRU obtained the nest from their protected beach in Chagar Hutang. This study had proved that the adoption fee for tendered beaches is higher than the protected beaches such as a sanctuary. This also shows that the tender system capable of generating more income than a sanctuary or reserve beaches for the adoption program.

8.4 Conclusion

The sea turtle populations are one of the natural attractions of Terengganu. This magnificent creature helps in improving the states and local community economy since it opens job opportunity in the tourism sector. However, the serious depletion of sea turtles occurred and possibly lead to the extinction of sea turtles in Terengganu due to egg exploitations. Therefore, this study was composed to evaluate the market activity related to sea turtle tourism product in Terengganu. Since these sea turtle tourism products were non-consumptive ways of generating income, it is possible to be sustainable. Due to the extinction of leatherback turtles in Terengganu, only a few tourism activities were still practised such as hatchling released, accommodation, day trip, nest and turtle adoption. The hatchling release, accommodation and day trip were considered as the experience tourism that highlighted sea turtle as the main attraction. On the other hand, the nest and sea turtle adoption were considered as the willingness to pay for sustaining the sea turtle population in Terengganu.

In Terengganu, the hatchlings release programme was dominated by NGOs such as Persatuan Wanita Kg. Mangkok Setiu (PEWANIS)-World Wide Fund for Nature (WWF), Sea Turtle Research Unit (SEATRU), The Taaras Beach and Spa resort (TAARAS) (SEATRU, 2018). The fee charges for hatchlings release were around RM 20 per hatchling for PEWANIS-WWF and SEATRU-Laguna Redang. The SEATRU-TAARAS project charged about RM 50 per hatchling. These differences arose since different project targeted different audiences that have different economic status. Besides that, Terengganu also offered a day trip package that focussed on a few islands such as the Perhentian, Redang, Kapas, Tenggol, Bidong and Lang Tengah. The average fee charged for day trips were RM 93 (Kapas Island), RM 104 (Redang Island), RM 106 (Perhentian Island), RM 120 (mixed: Redang-Lang Tengah-Bidong

Islands), RM 173 (Tenggol Island) and RM 319 (Bidong Island). The price differences resulted from few factors such as (i) the frequency and type of activities offered, (ii) the distances from the mainland, (iii) number of tourist operators competing for customers, (iv) popularity of the islands, and (v) facilities provided on the islands. Furthermore, Terengganu also offered accommodation related to sea turtle programs. The price for one person per day differs according to the type of experiences offered by the project or tour operator. The price offered for the sole experience tourism-based accommodation were the lowest about RM114 at SEATRU and RM 191 at LTTW. The tour operators that offered the mixed experience charge higher accommodation fee such as RM 227 at the Resort World Kijal and RM 239 while for Bubble Turtle and Reef Conservation Project. Although the accommodation related to sea turtle programs were dominated by the Non-Government Organization (NGO) in Terengganu, it can be concluded that the tour operators offered the packages based on the turtle density. The tourist operators that operated on high nesting density beaches (as mentioned in previous Chapter 3) tend to offer the sole experience accommodation. This shows that the nesting density of sea turtles influence the plausible economical activities that can be carried out on each beach.

Adding to that the sea turtles and nest adoption programs revealed that the fee charged depends on the sources of the eggs. The projects that obtained the eggs from protected beaches such as SEATRU-Chagar Hutang, SEATRU-TAARAS and Ma' Daerah Turtle Sanctuary charges a minimum fee (RM 100). These projects able to charge the minimum fee since the eggs were free, their only cost involve the management of the sanctuary or hatchery. However, the project such as LTTW charged more expensive adoption fee (RM 600) since the eggs were obtained from the tendered beach. Aside from management cost, LTTW needs to pay for the tender price, tender holders and the eggs collectors. All project does not offer all three adoption programmes. LTTW only offers nest adoption while Ma' Daerah Turtle Sanctuary only offered hatchlings adoptions. Only SEATRU-Chagar Hutan and SEATRU-TAARAS projects offered both nest and nesting mother adoptions. These differences in offered adoption programs show the life stage focussed by each project for conservation purposes. This adoption activity also shows that the tendered beach able to generate bigger income for conservation purposes compared to protected beaches.

Yet, the state government should seriously standardize the price for sea turtle eggs for conservation purposes to ensure the standardised adoptions fees for tendered beaches. The tender system can be continued with a condition where all the eggs can only be sold to the conservation project for incubation purposes.

These findings can help the government to formulate a relevant law and enforcement to ensure the continuity of sea turtle survival in Terengganu. To protect sea turtles in Terengganu, all parties need to work together and share the responsibility. The government needs to come out with an alternative to compensate the community source of income if their sea turtle business is banned as mentioned in previous Chapter 7. The state government can provide free training for the local community such as traditional crafting (boat constriction, songket weaving, batik canting, basket weaving, wood carving, brassware, kite making), ecotourism (turtle camp, hatchling release, volunteers programs, turtle watching), traditional art (ulik mayang dance, Terengganu gamelan, dikir barat and others). By doing this, it ensures the United Nation 2030 agenda in 2015, the first goal which is to end poverty in all its forms (United Nation, 2015) everywhere are tangible to fulfilled. This is important since the local community involved in sea turtle eggs exploitation are the most vulnerable to poverty if the sea turtle extinct. Since sea turtle was one of the major attractions in Terengganu, the local that has been working with the tourism sector, business owner and others are also susceptible to poverty if the tourism sector collapse due to extinction of sea turtle.

CHAPTER 9

GENERAL CONCLUSION

This Master research revolved around the mixed-conservation system that was implemented on the sea turtle population in Terengganu. Under this mixed conservation system, 12 nesting beaches are protected while the other 26 were tendered for eggs harvesting. Since 2018, all eggs laid on the tendered beaches end up in the market due to the lack of government fund. Although the sea turtle populations in Terengganu shrink rapidly, this mixed-conservation system was continued. The literature reviews also exposed that there was no research conducted to test the sustainability of this mixed conservation system towards the sea turtle populations in Terengganu before it was implemented and up to today. Thus, this research intended to evaluate the sustainability of this mixed conservation system towards the sea turtle populations in Terengganu. This research hopefully can assist the state government in implementing new laws to ensure the sustainability and survivals of sea turtle populations in Terengganu. To achieved this aim, this research was composed in an order where (i) Chapter 1 helps in giving an introduction to this current research, (ii) Chapter 2 assisted the readers to understand the current state of the art of this topic, (iii) Chapter 3 to Chapter 8 designed to analyse the sustainability of the current mixed-conservation system based on biological, ecological and economical angles, and (iv) Chapter 9 tailored to relates findings of Chapter 3 to Chapter 8 and overall concluded this Master research.

Chapter 3 were set out to analyze the sustainability of this mixed conservation strategy based on the current population abundance of sea turtles in Terengganu. This chapter tried to determine the sustainability of the mixed conservation practice according to the biological characteristics of the sea turtle population such as (i) Number of eggs in a clutch, (ii) Number of clutches laid by each nesting mother in a season, (iii) Regional sex ratio, and (iv) Survival rate of hatchlings. These biological characteristics were considered in the mathematical formulae for calculating the (i) annual nesting density, (ii) current annual number of nesting mother and (iii) number of future nesting mothers. This first section of this chapter had proven that the protected beaches have a higher average annual nesting density at about 195 nests km^{-1} than the tendered beaches that only have an average of 26 nest km^{-1}. These results were strong evidence that the tender systems were not sustainable and harming the sea turtle population in Terengganu by reducing their number that possibly leads to extinction in near future. Based on the nesting density, a biennial nesting pattern can be observed. This nesting pattern confirmed that the major nesting density in Terengganu in recent years was only the Green turtles. This nesting pattern also indicated that only a few individual Hawksbill turtles remain in Terengganu because they were not capable of influencing the nesting pattern. Thus, it is deduced that the Hawksbill turtles were functionally extinct in Terengganu just like the Leatherback and Olive Ridley turtles. Besides, this chapter also predicted the numbers of current and future nesting mothers based on the annual eggs productions since it was an important indication for sustainability and continuity of a species. The total number of nesting mothers that contributed to the annual sea turtle eggs production in Terengganu from 2011 to 2015 was only between 397 to 734 individual turtles. The annual average numbers of nesting mothers in Terengganu were 501 individual turtles. Moreover, this chapter also predicted the numbers of future nesting mothers from 2036 to 2040. These nesting mothers were assumed to be produced from eggs laid between 2011-2015. Based on calculations, the annual nesting numbers of the future nesting mothers were between 13 to 268 individuals only. These results obtained since the number of eggs produced were insufficient to cover up their high natural death rate and the death rate from the tender system in Terengganu. These results have proven that the number of nesting mother will decrease and collapse in the future under the current mixed-conservation system. These situations indicate that the extinction of sea turtle in Terengganu was possible.

Since the mixed-conservation system was proven to be unsustainable for sea turtle populations in Terengganu, Chapter 4 were dedicated to finding the causes for these phenomena. Therefore, Chapter 4 were composed to identify the growth curve possessed by the sea turtle population in Terengganu under the current mixed conservation. This chapter focussed to identify the growth curve possessed by the sea turtle populations in Terengganu because each species is equipped with certain unique biological characteristics that determined how fast the population or species can grow. Generally, all species will experience either exponential or logistic growth. Thus, looking into their growth will help in understanding why sea turtles were threatened by the mixed conservation system, specifically eggs exploitation under the tender system. To achieve this aim, this section was divided into three sections which is (i) The actual sea turtle population growth, (ii) The Exponential model, and (iii) The Logistic model. The first section was invented to identify the actual differences in annual eggs production between years. This first section acts as a reference and compared to the population size prediction of exponential and logistic models. The results from the first section were obtained by simple subtraction of the annual eggs production between two consecutive years. Results indicated that the annual depletion of eggs production was between 52,623 (14%) to 263,021 (42%) eggs. The results also indicated that the annual increase of eggs production range from 73,515 (20%) to 302,385 (94%) eggs. The inconsistency and large gap of annual eggs depletion and increases possibly indicated that the mixed-conservation system is unsustainable since it failed to help the population remain in stable population size. Besides, the exponential model in the second section indicated that the sea turtle population in Terengganu experiences a drastic and unlimited growth. The exponential model predicted that the annual eggs production will increase to 1.4×10^{10} eggs in five years. This prediction does not match the historical record and result of DoF data analysis on the actual population growth in the first chapter of this chapter. Therefore, this indicates that the exploited sea turtle population in Terengganu does not grow exponentially. On contrary, the logistic model foretold that the sea turtle population in Terengganu will grow gradually before stopping when they reach the habitat carrying capacity. When the carrying capacity is reached, the numbers of individuals in the population remain constant. The logistic model predicted that the annual eggs production reaches 650,000 in four years. According to historical evidence and the actual population growth mentioned before, this prediction was achievable since the annual maximum increase was 302,385 eggs. Therefore, sea turtles are considered to grow logistically because this model capable of catching a glimpse of the restricted and steady growth of the sea turtle population in Terengganu. Since sea turtles grow logistically, even small scales exploitation can push them to extirpation.

Owning to the fact that Chapter 4 had acknowledged that sea turtles are biologically unable to withstand even small scales exploitation, Chapter 5 were composed to identify the reason behind the unsustainability of this mixed-conservation system by focussing on the tender system. Chapter 5 were dedicated to investigating the sustainability of the current harvest limit and set a new sustainable maximum harvest limit of sea turtle eggs under the tender system in Terengganu. The Maximum Sustainable Yield (MSY) and Modified Maximum Sustainable Yield (MMSY) model were utilised to assess the sustainability of the current harvest rate at about 0.0858. The MSY model predicted that this interaction is sustainable. The MSY model predicted that the sea turtles will continue to survive within 50 years. The MSY model shown that the number of eggs laid will continue to increased and eventually stop increase when carrying capacity at about more than 5,50 000 eggs. However, the MMSY predicted that the current harvest rate of sea turtle eggs harvesting was unsustainable. The MMSY model illustrated that the population will continue to decrease and local extinction possibly took place in 35 years. The MMSY model was chosen over the MSY model as a reference for this case because the population decrease that happened in Terengganu was aligned with its prediction. Besides, the MMSY model considered a more sensitive model that incorporates the high natural death rate on the sea turtle population growth to avoid overestimation. This proves that the MMSY model was more compatible to represent the sea turtle eggs exploitation in Terengganu. Then, this chapter also dedicated to identifying the sustainable new harvest rate for sea turtle eggs harvesting in Terengganu. The proposed annual harvest limit between 0.0000 to 0.0644. Within 100 years, the sea turtle population will continue to exist under the annual harvest limit within 0.0000 and 0.0215 only. The proposed annual harvest limit of 0.0430 will pushes the sea turtles in Terengganu to extinction within 85 years due to zero eggs production. The sea turtle population are expected to extinct in 70 years under the annual harvest limits of 0.0644. This observation revealed that as the annual harvest limit escalated, the sea turtle extinction in Terengganu become nearer. Thus, the sustainable maximum annual harvest rate was

0.0215. Yet, since the age of nesting mother and their total reproductivity is unknown, it is better to put an end to this unsustainable practice.

After looking at the harvest rate of the tender system in Chapter 5, Chapter 6 was composed to look into the intensity of this prey-predator relationship by considering the number of tender holders and their existence's impact. This chapter was important since it helps in preventing over or underestimation by revealing the full intensity of the sea turtle eggs exploitation in Terengganu. For this reason, Chapter 6 were made to define the sustainability of prey-predator interaction between human (based on the tender system) and sea turtles in Terengganu and set a new sustainable level of prey-predator interaction in Terengganu. The Lotka-Volterra model and the Tender System model facilitated the first section of this chapter to identify the sustainability of current prey-predator interaction in Terengganu. The sea turtle population sizes were predicted to deplete exponentially and functionally extinct within six months by the Lotka-Volterra model. However, the number of tender holders will increase exponentially until 400 000 individuals in six months. On the other hand, the Tender System model expected the sea turtle population to critically decrease and undergo functional extinction in 4 years. Besides, the Tender System model also expected that the number of tender holders fixed at 26 individuals till the end. Both models indicated that the current level of prey-predator interaction between the tender system and sea turtles are not sustainable. Although both models showed unsustainability, only the Tender System model is capable of representing the interaction between the sea turtles and tender system in Terengganu. The Lotka-Volterra model was not suitable because its prediction was opposite to the population seatback occurring in Terengganu. Afterwards, the Tender System model was utilised to determine the new sustainable prey-predator interaction level based on the exploitation rate of the sea turtle population in Terengganu. New exploitation rates between 0.0000 to 0.0644 were put to experimentations. Results have shown that only instant total ban (0.0000) is capable of helping the population to achieve recovery in the shortest time which is eight years. It is possible to save half of the population if a total ban was applied instantly. Nevertheless, when the step-by-step ban of 0.0215 to 0.0644 was applied, the recovery time increased. The sea turtle population in Terengganu will take fifteen years to recover under the exploitation rate of 0.0215.

The recovery time increase to approximately twenty years when the exploitation rate increased to 0.0430. Adding to that, the sea turtle population needs thirty-five years to recover under the exploitation rate of 0.0644. Therefore, this chapter suggested that the instant total ban was implemented in Terengganu to avoid the sea turtle disappearance in near future.

After proving that the mixed conservation system in Terengganu was not sustainable from the biological and ecological angles, this thesis aimed to identify possible sustainable economic activity between eggs harvesting and non-consumptive tourism-related activity. To begin with this economic analysis, Chapter 7 was dedicated to determining the qualitative aspect of the sea turtle eggs current market in Terengganu. Terengganu is undoubtedly famous for sea turtle eggs harvesting and trading activity. Although the sea turtle eggs were legally harvested since the 1950s, the qualitative study in describing the current sea turtle eggs market in recent years was lacking. This study was crucial because the shareholders such as the government can only decide the sustainability of this industry by knowing it. To know this industry better, Chapter 7 was aimed to identify the price trend between the peak, low and non-nesting season in Terengganu. Moreover, this chapter also designed to pinpoint few important characteristics of the sea turtle eggs market in Terengganu. Enumerator survey conducted on the sea turtle eggs sellers in Pasar Payang, Terengganu to achieve these aims. Plus, the secondary sources were used as references and comparison in this analysis. Pasar Payang, Terengganu was chosen as a sampling site since previous research and preliminary survey prove that it supplied the sea turtle eggs to almost 91% of the consumers. The first section of this chapter contributing in identify how the price range of sea turtle eggs related to the season and its origin. Results demonstrated that the price of sea turtle eggs influenced by the supply of sea turtle eggs. The eggs supply was heavily influenced by the seasons. Due to loads of supply, the sea turtle eggs were cheaper during the on-season (RM 3-RM7 per eggs) than in the off-season (RM 6-RM 12 per eggs). The influences of supply towards the price of eggs became clearer as the price drop to RM 3 per egg in the peak season, specifically August. Thus, the first section of this chapter deduced that the price of sea turtle eggs was controlled by the supply. Furthermore, the first section also revealed that the sea turtle eggs price were determined by their origin. Basically, sea turtle eggs from

Terengganu have higher price compared to Sabah as consumers believe it to be new and fresher. Regardless of the seasons, the majority of sea turtle eggs sold in Pasar Payang were originated from Terengganu itself, not other states or countries. After that, this chapter focussed on finding out the characteristics of the current sea turtle eggs market in Terengganu. This section was important to understand the sea turtle eggs market operation in Pasar Payang, Kuala Terengganu, Terengganu. Among the characteristics that were focussed on this analysis were (i) Number of vendors, (ii) Quantity in a packet, (iii) Quantity of eggs per seller, (iv) Restock time, (v) Shelf life, (vi) Consumer (vii) Reason to consume (viii) Cooking method (ix) Product derived from unfinished eggs. The surveys have shown that the numbers of vendors selling sea turtle eggs in Pasar Payang were depending on the total eggs supply. More vendors can be observed in Pasar Payang during the on-seasons (12 individuals) than in the off-seasons (7 individuals). Yet, sea turtle eggs are the side items sold by all vendors during both seasons, thus they possible experience minimum impacts if the sea turtle eggs selling was totally banned in Terengganu. Moreover, each packet usually contained 5 or 10 eggs. More packet of 5 eggs was seen at each vendors showing that consumers tend to buy fewer eggs due to its high price. This indicated that buying fewer eggs were consumers preference. To increase their sales, vendors offered a lower price for consumers that purchase eggs in larger quantity. Usually, consumers that were regular or hardcore or having higher income tend to buy eggs in a larger quantity. Thus, it can be deduced that the price of the sea turtle eggs influenced by the quantity of eggs purchases on every transaction. At the same time, the number of eggs per seller depends on the eggs supply. The eggs supply varies according to the seasons. For instance, each eggs seller was in possessed 370 to 500 eggs at one time during the on-season. In contrast, observation revealed that only less than 75 to 100 eggs were owned by each seller during off-seasons. Since all eggs originated from Terengganu were obtained from the same egg supplier, all sellers obtained the same number of eggs. The supplier was an eggs collector. Since the middle man was absent, less price markup can be seen. Nonetheless, eggs sold in Pasar Payang that were originated from Sabah were supplied by the middle man. Furthermore, it can be determined that the sea turtle eggs that originated from Terengganu were restocked more frequent during on-season compared to off-seasons. This happens because the restock frequency depended on the eggs supply. Nonetheless, eggs originated from Sabah have an uncertain restock time since it will be gather reaching 3,000 eggs before being shipped o Terengganu as one batch. This is possible since results showed that the fresh sea turtle eggs have a long shelf life between 2 to 5 months. This study also revealed that the major consumers for sea turtle eggs in Terengganu were the local people, not tourist. Since the major consumer of sea turtle eggs were not the tourist, completely banning the sea turtle eggs market should have no adverse impact to the tourism sectors in Terengganu. The local community devour the sea turtle eggs since it is believed to be nutritious, have traditional medicine value and to satisfy the pregnancy craving. Even so, minority customers which are tourist consume the sea turtle eggs out of curiosity. Sea turtle eggs were consumed raw (directly) or boiled and seasoned with salt, honey, or peppers. The unfinished eggs were converted into pickles to avoid degradation and prevent the vendors from losses.

After conducting the market survey was done for sea turtle eggs selling, Chapter 8 was composed to look into the observe the market activity related to sea turtle tourism product in Terengganu. Tourism activities probably sustainable since it is non-consumptive ways in generating income. This study is important since Terengganu is a tourism-based state that utilised sea turtle as one of its major attractions. Besides, since the sea turtles are the ecosystem engineers, the marine ecosystem health was highly dependent on the sea turtles. Thus, the continuity of the tourism sector in Terengganu highly depends on the survival of sea turtle. Since this topic was fairly critical, this study is divided into a few parts according to the tourism product category which is the hatchling released, accommodation, day trip, nest and turtle adoption to accomplish this aim. The information was gathered by interviews or secondary sources such as webpage, social media and report. The hatchling release, accommodation and day trip falls under the experience tourism category. While, the nest and sea turtle adoption were considered to be under the willingness to pay category. Results have shown that the hatchlings release programs in Terengganu was dominated by NGOs such as Persatuan Wanita Kg. Mangkok Setiu (PEWANIS)-World Wide Fund for Nature (WWF), Sea Turtle Research Unit (SEATRU), The Taaras Beach and Spa resort (TAARAS). PEWANIS-WWF and SEATRU-Laguna Redang charges RM 20/hatchling for hatchling release programs. The price charged by the SEATRU-TAARAS project is RM 50/hatchling. The fee charged were different since they targeted different audiences with different economic status. Apart from the hatchling release, the day trip package was also offered on a few islands such as the Perhentian, Redang, Kapas, Tenggol, Bidong and Lang Tengah. The average fee charged for the day trips were varied such as Kapas Island (RM 93), Redang Island (RM 104), Perhentian Island (RM 106), mixed-Redang-Lang Tengah-Bidong Islands (RM 120), Tenggol Island (RM 173), and Bidong Island (RM 319). The price varies due to a few factors for instance, (i) the frequency and type of activities offered, (ii) the distances from the mainland, (iii) number of tourist operators competing for customers, (iv) popularity of the islands, and (v) facilities provided on the islands. In addition, accommodation related to sea turtle programs also offered in Terengganu. The type of experiences offered by the project or tour operator determined the price for one person per day. SEATRU and LTTW project both offered the sole experience tourism-based accommodation and charges a person at about RM114/day and RM 191/day. Meanwhile, other projects that offered mixed experience-based accommodation charged a higher fee such as Resort World Kijal (RM 227/day) and Bubble Turtle and Reef Conservation Project (RM 239/day). These findings revealed that the accommodation related to sea turtles in Terengganu were dominated by the Non-Government Organization (NGO). Plus, these findings proved that the experience tourism accommodation offered depends on the turtle density on the beaches where the project located. It is concluded that the sole experiences accommodation tends to be offered by the tour operators that operated on high nesting density beaches compared to the mixed experience that offered on beaches with lower nesting density (as previously mentioned in Chapter 3). This is a piece of clear evidence that the nesting density of sea turtles have a great influence on the possible economical activities that can be carried out on each beach. Moving to the adoption programs, results show that the fee charged according to the sources of the eggs. SEATRU-Chagar Hutang, SEATRU-TAARAS and Ma' Daerah Turtle Sanctuary obtained the eggs from protected beaches. Hence, this enables them to charge a minimum fee of RM 100. Since the eggs were free, their only cost involved the management of the sanctuary or hatchery allowing them to charge the minimum fee. The LTTW project charged a higher adoption fee at about RM 600 since they need to obtain the eggs from tendered beaches. A project such as LTTW needs to cover up the management cost, pay for the tender price, tender holders and the eggs collectors. Each project in Terengganu failed to offer all three adoption programmes (nesting mothers, hatchlings and nest). For instance, the LTTW project only offers nest adoption, Ma' Daerah Turtle

Sanctuary only offered hatchlings adoptions and SEATRU projects only offered nest and nesting mother adoptions. This situation occurred due to different the life stage focussed on by each project for conservation purposes. Results also illustrated the tendered beach able to generate bigger income under conservation activities compared to protected beaches. However, the state government should strictly implement a standardized price for sea turtle eggs to help standardize the adoptions fees for tendered beaches. It is suggested that all the eggs can only be sold to the conservation project for incubation purposes if the government wish to continue with the tendered system and mixed-conservation strategy.

After observing the market survey of sea turtle eggs and tourism products in Terengganu, it can be concluded that the non-consumptive and existing values of sea turtle (tourism products) are far more valuable than the direct use of sea turtle eggs. Direct use of sea turtle eggs (eggs exploitation for consumption) might only last for a few years until the day that the whole sea turtle population are wiped out from Terengganu. Whereas, the indirect use of sea turtle can last forever if it truly follows the conservation guideline. Indirect use also generates more income as its price per unit is far more expensive than one turtle egg. There is a need to save sea turtle from exploitation since if it is continued, the sea turtle would extinct in near future and lead to the economic downfall of all other sectors including the small-scale industry, hotel industry, food and beverage industry, and others. The extinction of sea turtle not only putting pressure on the government or giant industry but also the local community. However, more research on alternative livelihood should be carried out to avoid economic burden to the local community and the state government. Nevertheless, although conservation, specifically the total ban of sea turtle egg exploitation sounds expensive, nothing can compare the cost of losing a magnificent creature such as the sea turtles and their restoration cost. Conservation of these extinct animals is in line and consistent with Goal 14 Life Under Water in Sustainable Development Goals (SDGs) in the United Nation assembly in 2015. Goal 14 promote conservations and sustainably use the oceans, seas and marine resources for sustainable development. As billions of people rely on oceans for their livelihood and food source and the transboundary nature of oceans, increased efforts and interventions are needed to conserve and sustainably use ocean resources at all levels. In the future, research on

TEV of sea turtle in Terengganu should be carried out so the local community, state government and tourist realise that this incredible species is irreplaceable. Last but not least, research on each beach and island TEV and potential should be carried out as now since it had only been conducted on Perhentian and Redang Island.

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APPENDICES

Appendix 1

Exponential model analysis

```
> restart
> with(DEtools), with(plots), with(Statistics) :
> diff(x(t), t) = r·x(t)
```

$$\frac{d}{dt}\,x(t) = r\,x(t) \qquad (1)$$

```
> r := 1.046374851;
```

$$r := 1.046374851 \qquad (2)$$

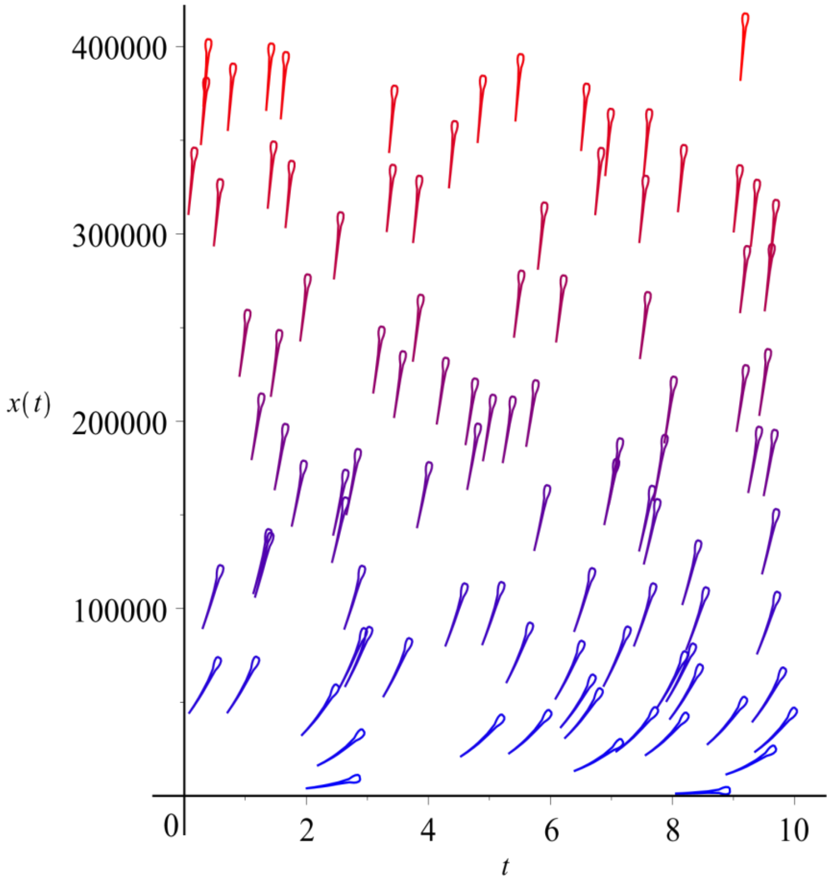
$$> \; Equilibria := solve\left(\left\{\frac{d}{dt} = 0, \right\}, \{x\}\right)$$

```
> with(DEtools, DEplot) : with(plots) :
```

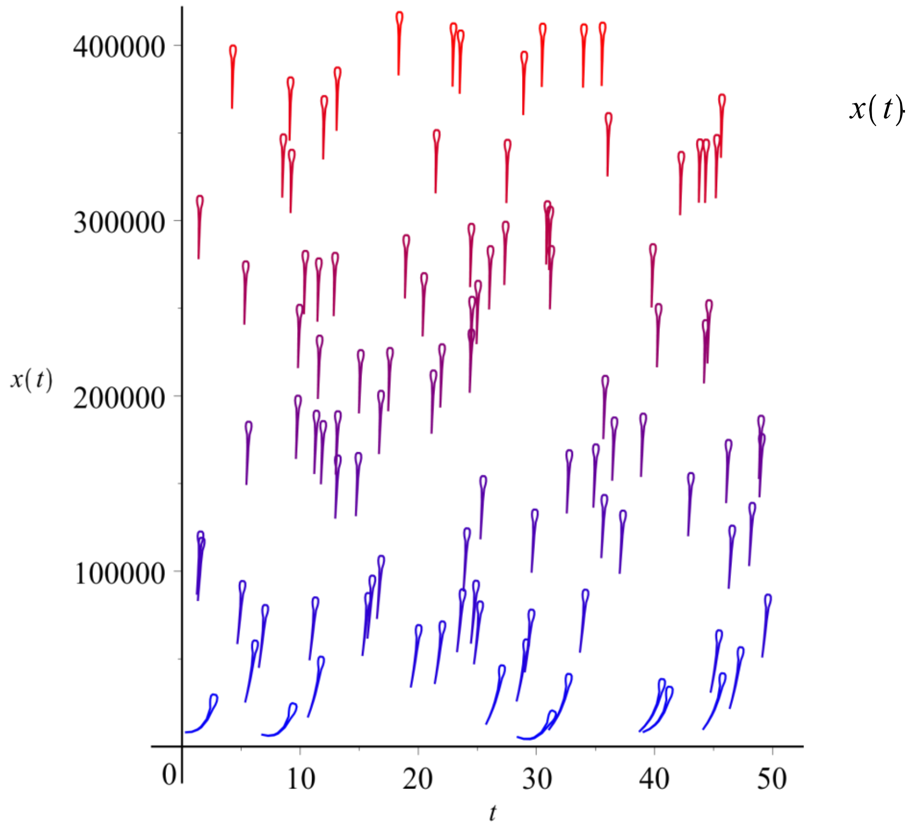
$$> \; des := \left[\frac{d}{dt}\,x(t) = r\cdot x(t)\right]$$

$$des := \left[\frac{d}{dt}\,x(t) = 1.046374851\,x(t)\right] \qquad (3)$$

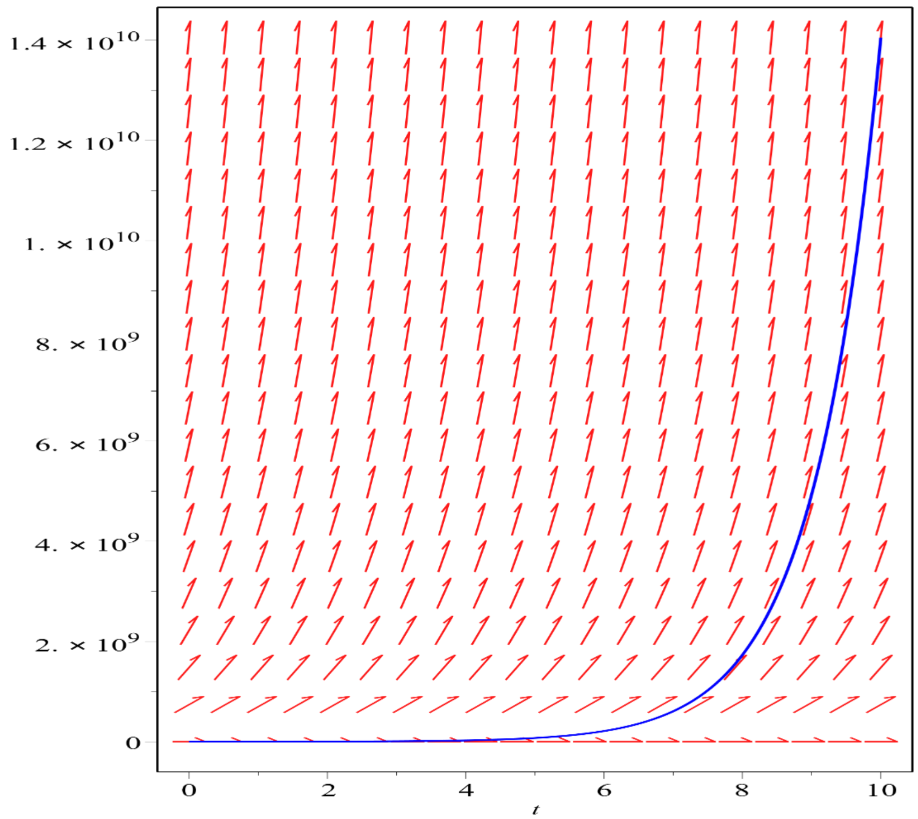
```
> DEplot(des, [x(t)], t = 0..10, x = 0..401263, dirfield = 100, arrows = fish, color = magnitude,
    linecolour = blue, numsteps = 100)
```



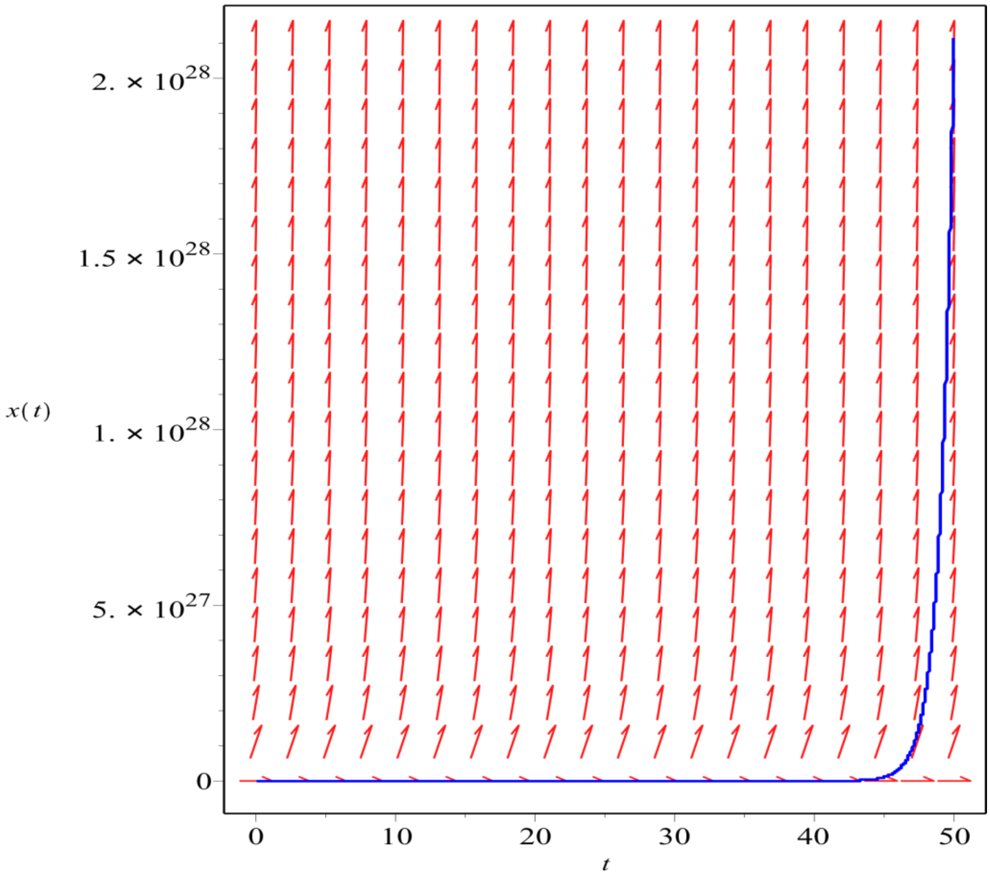

```
> DEplot(des, [x(t)], t = 0..50, x = 0..401263, dirfield = 100, arrows = fish, color = magnitude,
    linecolour = blue, numsteps = 100)
```



> $F := DEplot(des, [x(t)], t=0..10, [[x(0)=401263]], stepsize=0.01, linecolor=BLUE, linestyle=solid, thickness=1, axes=BOXED, scene=[t, x(t)])$



```
> F := DEplot(des, [x(t)], t=0..50, [[x(0) =401263]], stepsize=0.01, linecolor=BLUE,
      linestyle=solid, thickness=1, axes=BOXED, scene=[t, x(t)])
F :=
```




```
>
```

Appendix 2

Logistic model analysis

> restart

> with(DEtools), with(plots), with(Statistics) :

> $diff(x(t), t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right)$

$$\frac{d}{dt} x(t) = r\, x(t) \left(1 - \frac{x(t)}{K}\right) \quad (1)$$

> $r := 1.046374851; K := 622548;$

$$r := 1.046374851$$
$$K := 622548 \quad (2)$$

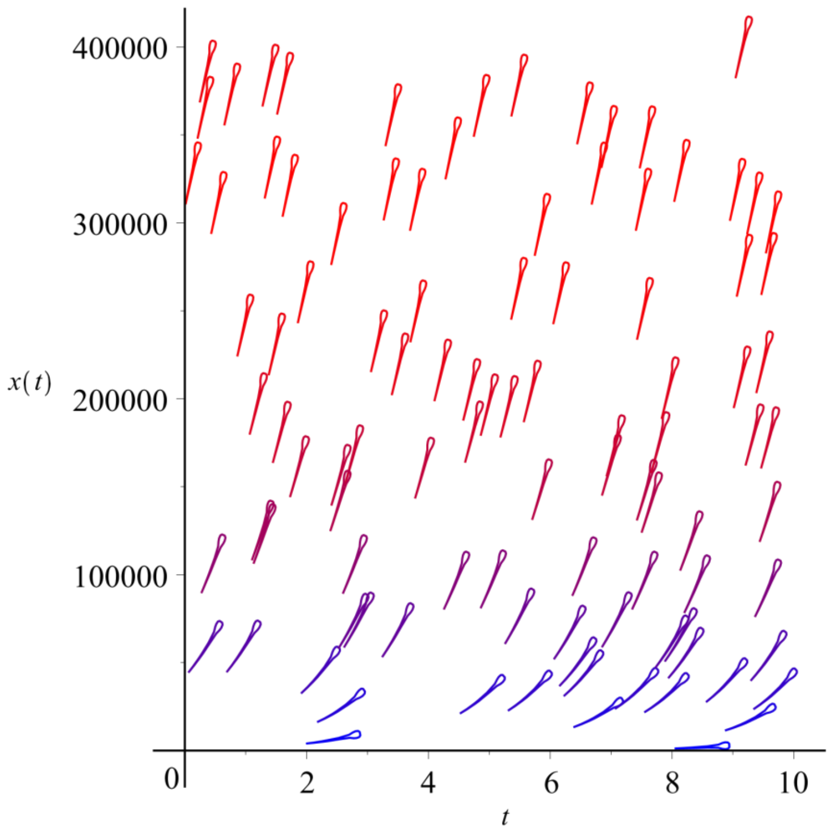
> $Equilibria := solve\left(\left\{ \frac{d}{dt} = 0, \right\}, \{x\}\right)$

> with(DEtools, DEplot) : with(plots) :

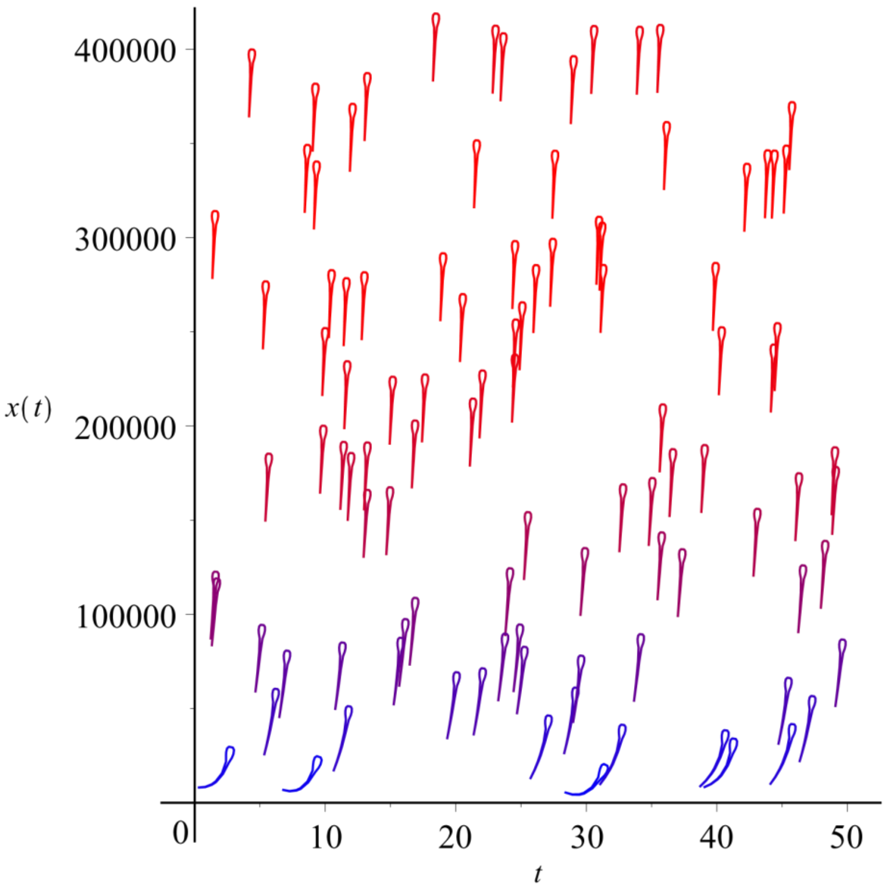
> $des := \left[\frac{d}{dt} x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right)\right]$

$$des := \left[\frac{d}{dt} x(t) = 1.046374851\, x(t) \left(1 - \frac{1}{622548}\, x(t)\right)\right] \quad (3)$$

> DEplot(des, [x(t)], t = 0 ..10, x = 0 ..401263, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)

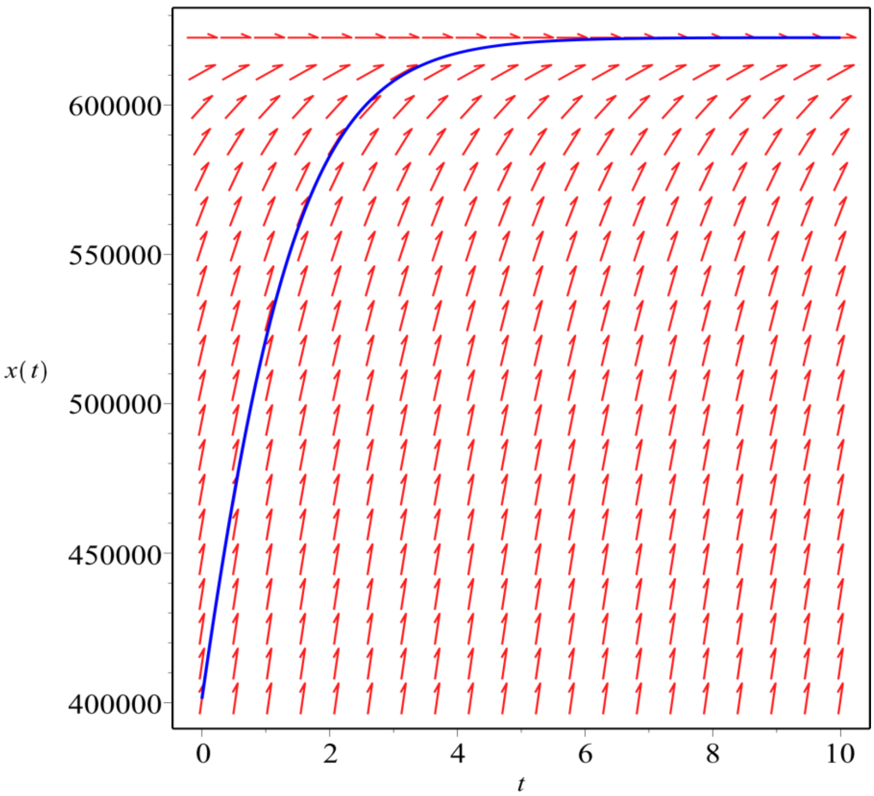


> DEplot(des, [x(t)], t = 0 ..50, x = 0 ..401263, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)



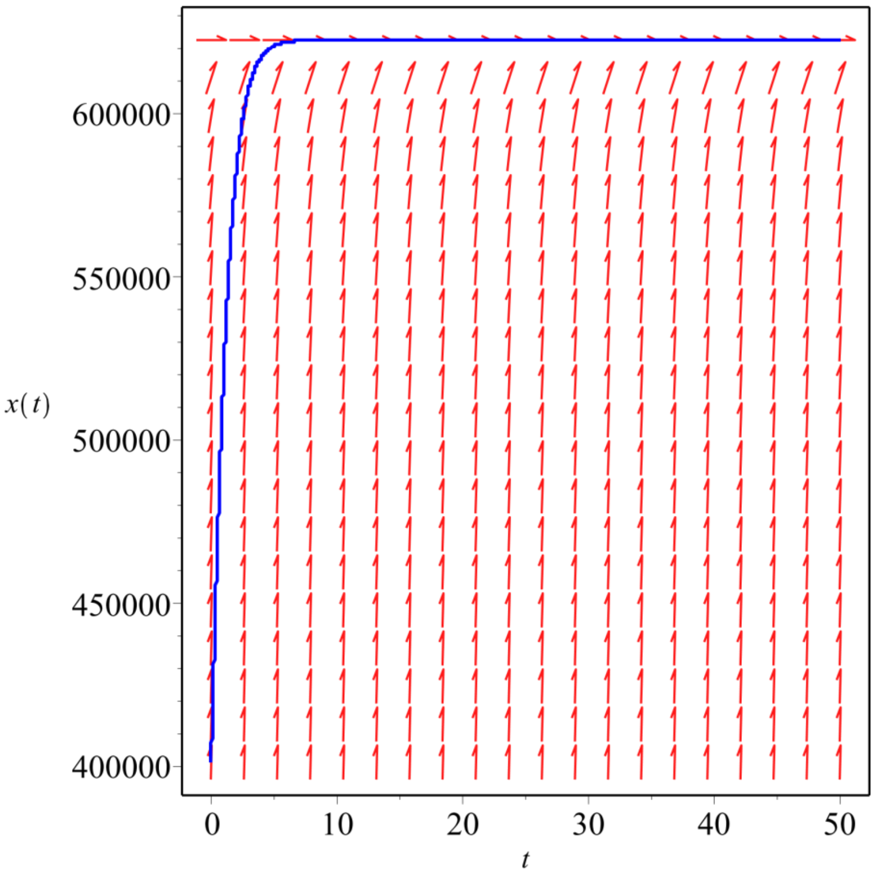
> $F := DEplot(des, [x(t)], t = 0..10, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$F :=$



> $F := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$F :=$



Appendix 3

MSY model and MMSY model analysis

> restart

> with(DEtools), with(plots), with(Statistics) :

> $diff(x(t), t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - E \cdot x(t)$

$$\frac{d}{dt} x(t) = r\, x(t) \left(1 - \frac{x(t)}{K}\right) - E\, x(t) \quad (1)$$

> $r := 1.046374851; K := 622548; E := 0.085841;$

$$r := 1.046374851$$
$$K := 622548$$
$$E := 0.085841 \quad (2)$$

> $Equilibria := solve\left(\left\{ \frac{d}{dt} = 0, \right\}, \{x\}\right)$

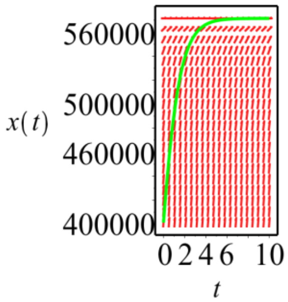
> with(DEtools, DEplot) : with(plots) :

> $des := \left[\frac{d}{dt} x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - E \cdot x(t)\right]$

$$des := \left[\frac{d}{dt} x(t) = 1.046374851\, x(t) \left(1 - \frac{1}{622548} x(t)\right) - 0.085841\, x(t)\right] \quad (3)$$

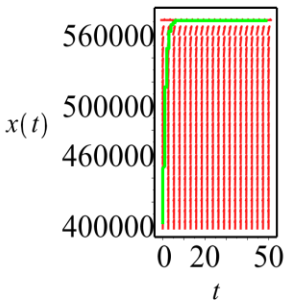
> $F := DEplot(des, [x(t)], t = 0..10, [[x(0) = 401263]], stepsize = 0.01, linecolor = GREEN,$
> $linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$F :=$



> $G := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = GREEN,$
> $linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$G :=$



> with(DEtools), with(plots), with(Statistics) :

> $diff(x(t), t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)$

$$\frac{d}{dt}\, x(t) = 1.046374851\, x(t) \left(1 - \frac{1}{622548}\, x(t)\right) - (d + 0.085841)\, x(t) \tag{4}$$

> $r := 1.046374851;\ K := 622548;\ d := 0.999;\ E := 0.085841;$

$$r := 1.046374851$$
$$K := 622548$$
$$d := 0.999$$
$$E := 0.085841 \tag{5}$$

> $Equilibria := solve\left(\left\{\frac{d}{dt} = 0,\right\}, \{x\}\right)$

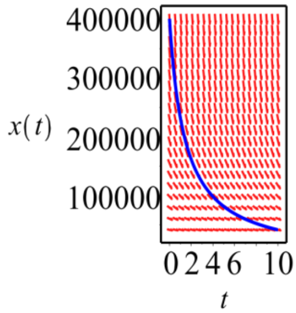
> $with(DEtools, DEplot) : with(plots) :$

> $des := \left[\frac{d}{dt}\, x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)\right]$

$$des := \left[\frac{d}{dt}\, x(t) = 1.046374851\, x(t) \left(1 - \frac{1}{622548}\, x(t)\right) - 1.084841\, x(t)\right] \tag{6}$$

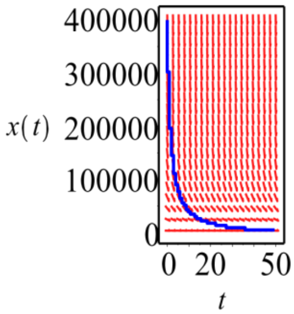
> $H := DEplot(des, [x(t)], t = 0..10, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$H :=$

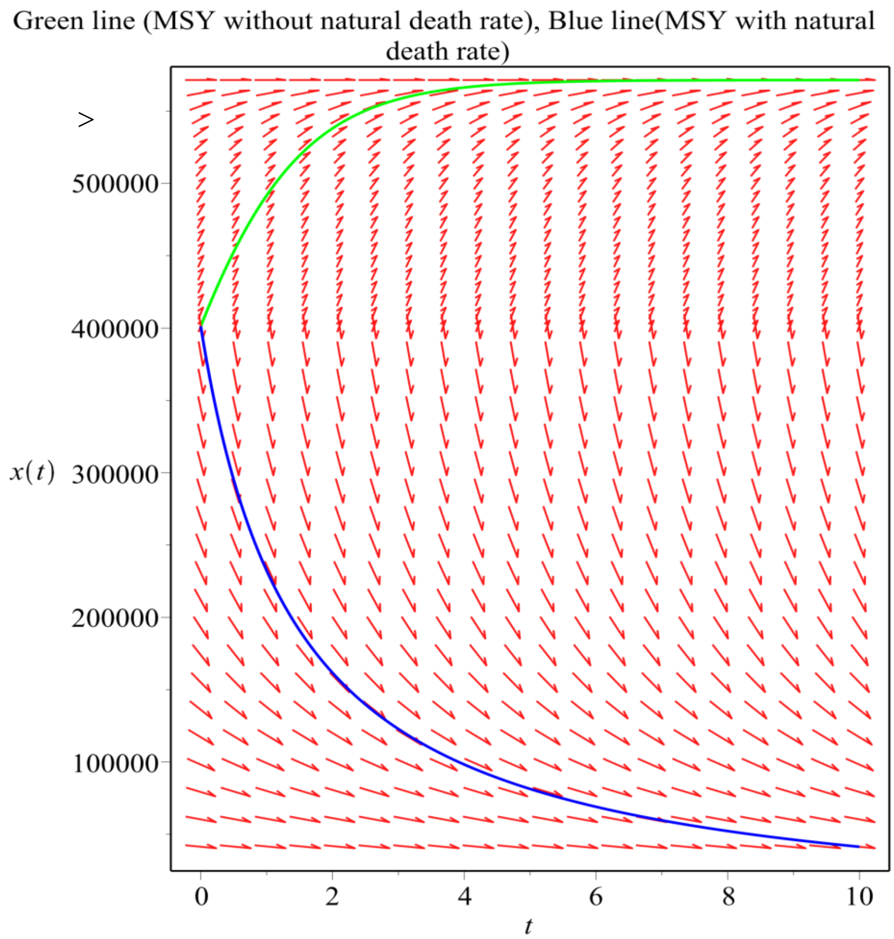


> $J := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

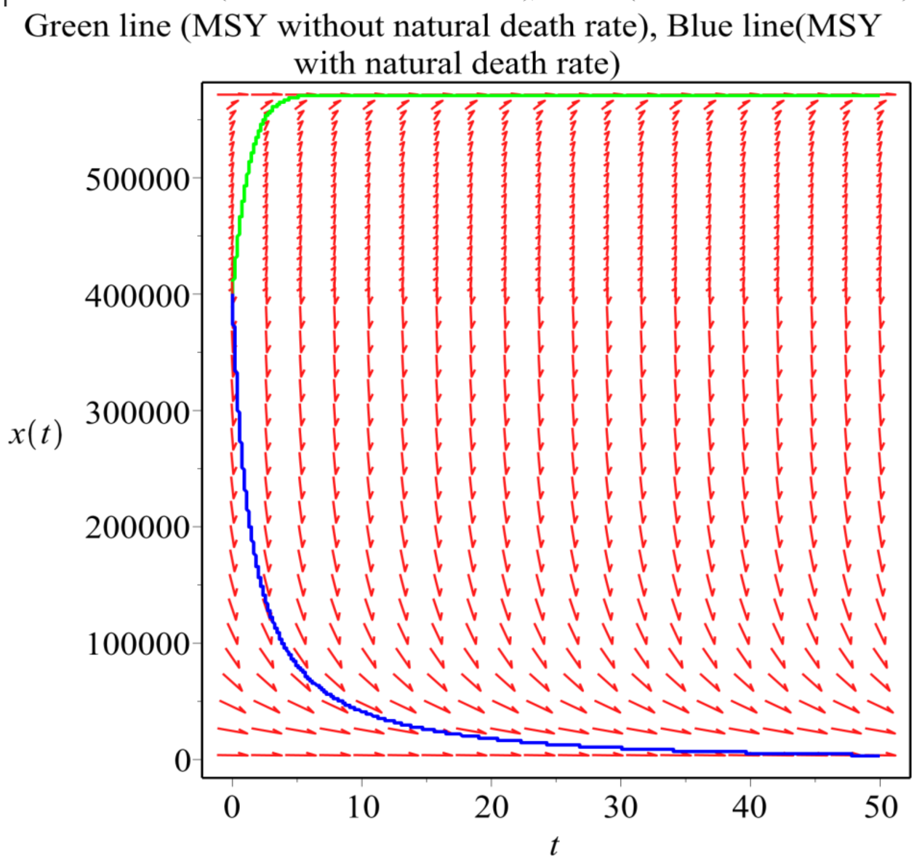
$J :=$



> $display([F, H], title$ = "Green line (MSY without natural death rate), Blue line(MSY with natural death rate)")



> *display*([*G*, *J*], *title* = "Green line (MSY without natural death rate), Blue line(MSY with natural death rate)")



Appendix 4

0% Maximum sustainable annual harvest limit

> restart

> with(DEtools), with(plots), with(Statistics) :

> $diff(x(t), t) = r\cdot x(t)\cdot\left(1 - \frac{x(t)}{K}\right) - (d + E)\cdot x(t)$

$$\frac{d}{dt}\, x(t) = r\, x(t)\, \left(1 - \frac{x(t)}{K}\right) - (d + E)\, x(t) \qquad \textbf{(1)}$$

> $r := 1.046374851; K := 622548; d := 0.999; E := 0;$

$$r := 1.046374851$$
$$K := 622548$$
$$d := 0.999$$
$$E := 0 \qquad \textbf{(2)}$$

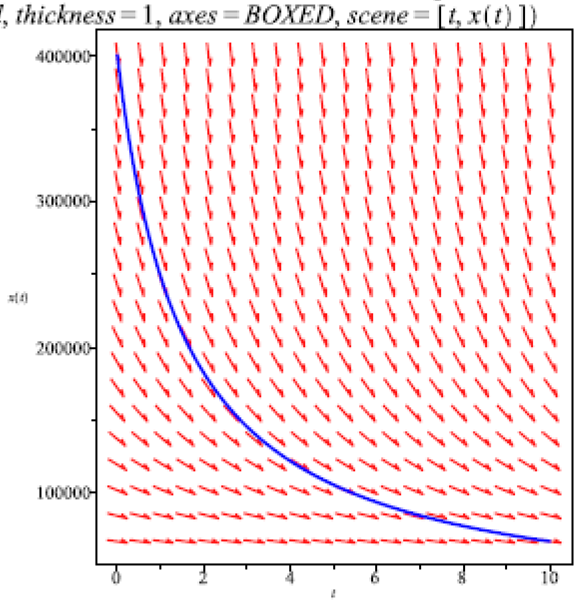
> $Equilibria := solve\left(\left\{\frac{d}{dt} = 0, \right\}, \{x\}\right)$

> with(DEtools, DEplot) : with(plots) :

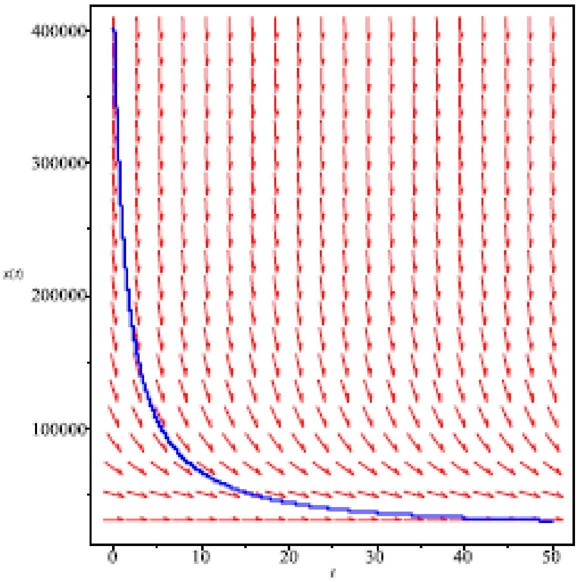
> $des := \left[\frac{d}{d\,t}\, x(t) = r\cdot x(t)\cdot\left(1 - \frac{x(t)}{K}\right) - (d + E)\cdot x(t)\right]$

$$des := \left[\frac{d}{dt}\, x(t) = 1.046374851\, x(t)\, \left(1 - \frac{x(t)}{622548}\right) - 0.999\, x(t)\right] \qquad \textbf{(3)}$$

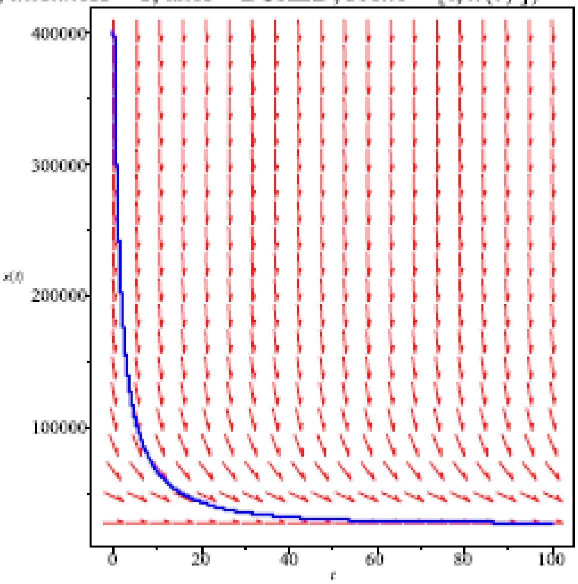
> $F := DEplot(des, [x(t)], t = 0..10, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



> $F := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



> $F := DEplot(des, [x(t)], t = 0..100, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



Appendix 5

25% Maximum sustainable annual harvest limit

> *restart*

> *with(DEtools), with(plots), with(Statistics) :*

> $diff(x(t), t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)$

$$\frac{d}{dt} x(t) = r\, x(t) \left(1 - \frac{x(t)}{K}\right) - (d + E)\, x(t) \qquad (1)$$

> $r := 1.046374851; K := 622548; d := 0.999; E := 0.02146025;$

$$r := 1.046374851$$
$$K := 622548$$
$$d := 0.999$$
$$E := 0.02146025 \qquad (2)$$

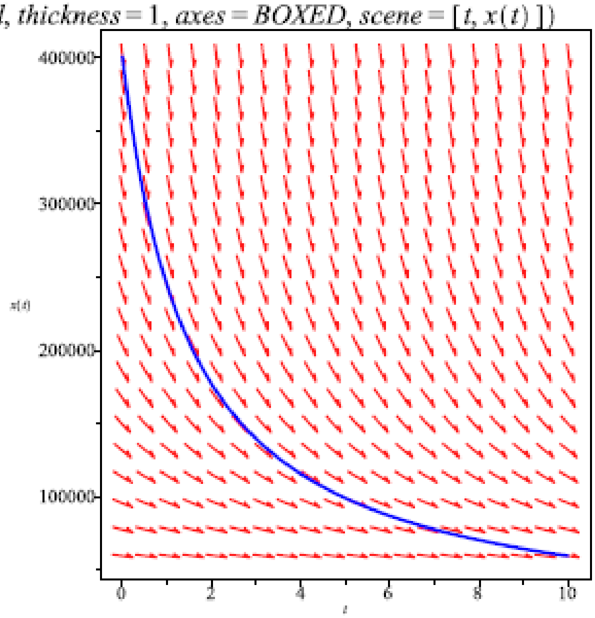
> $Equilibria := solve\left(\left\{\frac{d}{dt} = 0, \right\}, \{x\}\right)$

> *with(DEtools, DEplot) : with(plots) :*

> $des := \left[\frac{d}{dt} x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)\right]$

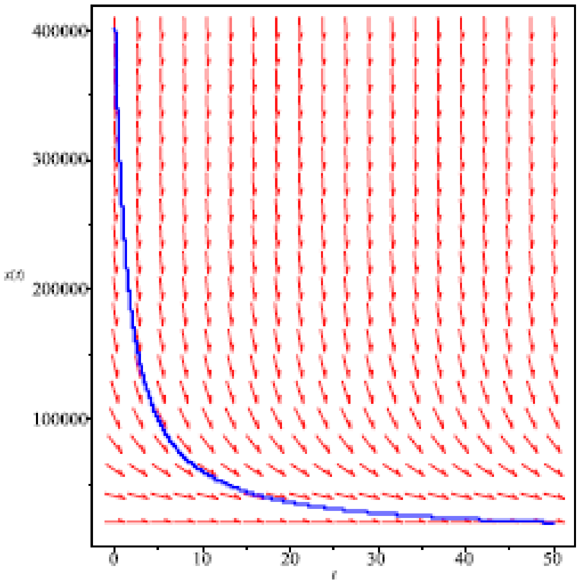
$$des := \left[\frac{d}{dt} x(t) = 1.046374851\, x(t) \left(1 - \frac{x(t)}{622548}\right) - 1.02046025\, x(t)\right] \qquad (3)$$

> *F* := *DEplot*(*des*, [*x*(*t*)], *t* = 0 ..10, [[*x*(0) = 401263]], *stepsize* = 0.01, *linecolor* = *BLUE*, *linestyle* = *solid*, *thickness* = 1, *axes* = *BOXED*, *scene* = [*t*, *x*(*t*)])

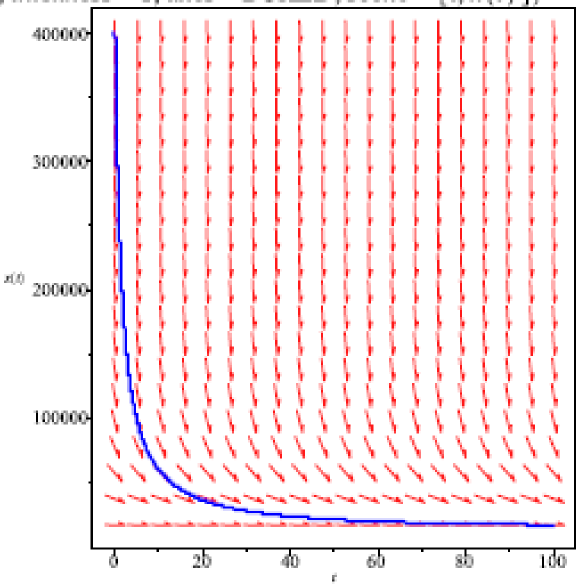


> *F* := *DEplot*(*des*, [*x*(*t*)], *t* = 0 ..50, [[*x*(0) = 401263]], *stepsize* = 0.01, *linecolor* = *BLUE*, *linestyle* = *solid*, *thickness* = 1, *axes* = *BOXED*, *scene* = [*t*, *x*(*t*)])

> $F := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



> $F := DEplot(des, [x(t)], t = 0..100, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



Appendix 6

50% Maximum sustainable annual harvest limit

> restart

> with(DEtools), with(plots), with(Statistics) :

> $diff(x(t), t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)$

$$\frac{d}{dt} x(t) = r\, x(t) \left(1 - \frac{x(t)}{K}\right) - (d + E)\, x(t) \quad (1)$$

> $r := 1.046374851;\ K := 622548;\ d := 0.999;\ E := 0.0429205;$

$$r := 1.046374851$$
$$K := 622548$$
$$d := 0.999$$
$$E := 0.0429205 \quad (2)$$

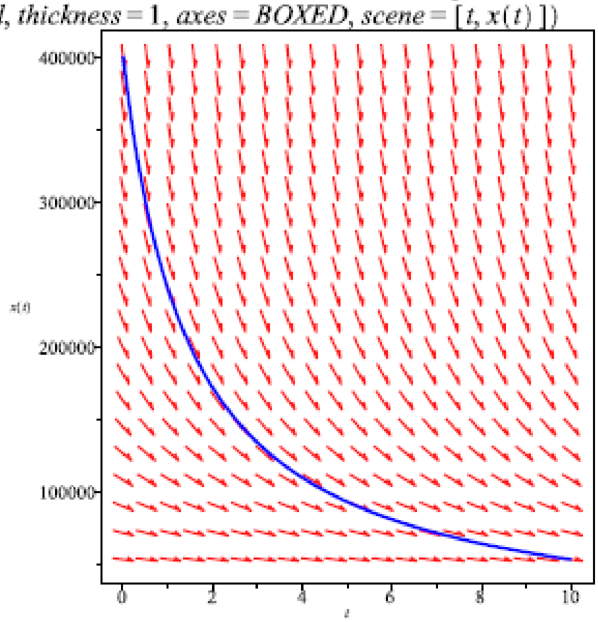
> $Equilibria := solve\left(\left\{\frac{d}{dt} = 0,\ \right\}, \{x\}\right)$

> with(DEtools, DEplot) : with(plots) :

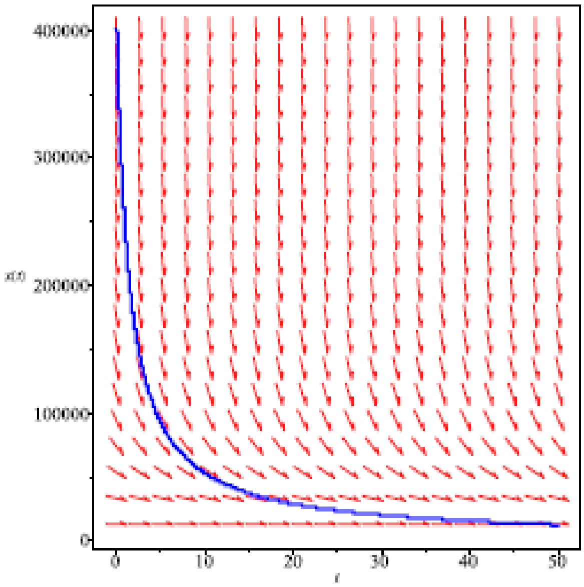
> $des := \left[\frac{d}{dt} x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)\right]$

$$des := \left[\frac{d}{dt} x(t) = 1.046374851\, x(t) \left(1 - \frac{x(t)}{622548}\right) - 1.0419205\, x(t)\right] \quad (3)$$

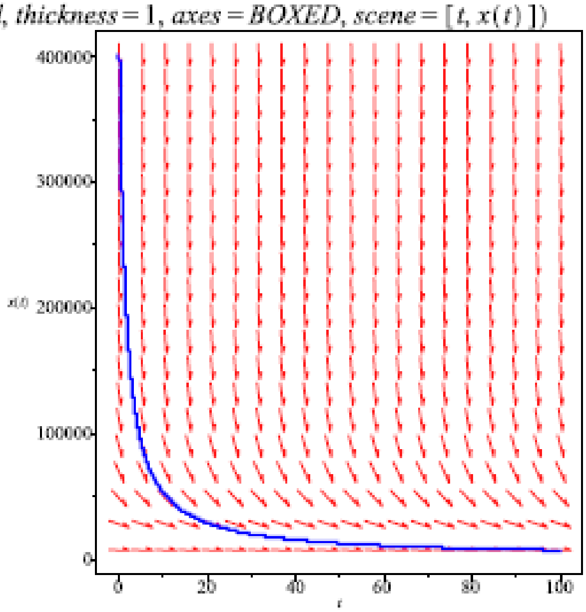
> F := DEplot(des, [x(t)], t = 0 ..10, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])



> $F := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



> $F := DEplot(des, [x(t)], t = 0..100, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



Appendix 7

75% Maximum sustainable annual harvest limit

> $restart$

> $with(DEtools), with(plots), with(Statistics):$

> $diff(x(t), t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)$

$$\frac{d}{dt} x(t) = r\, x(t) \left(1 - \frac{x(t)}{K}\right) - (d + E)\, x(t) \quad \textbf{(1)}$$

> $r := 1.046374851;\ K := 622548;\ d := 0.999;\ E := 0.06438075;$

$$r := 1.046374851$$
$$K := 622548$$
$$d := 0.999$$
$$E := 0.06438075 \quad \textbf{(2)}$$

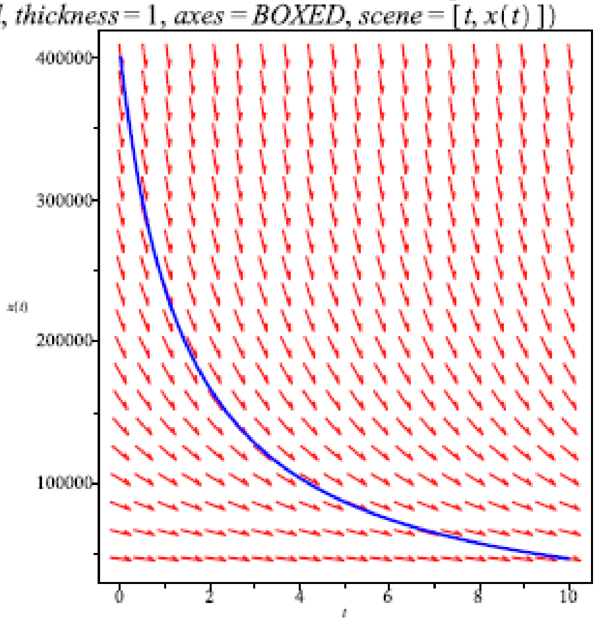
> $Equilibria := solve\left(\left\{\frac{d}{dt} = 0, \right\}, \{x\}\right)$

> $with(DEtools, DEplot) : with(plots) :$

> $des := \left[\frac{d}{dt} x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - (d + E) \cdot x(t)\right]$

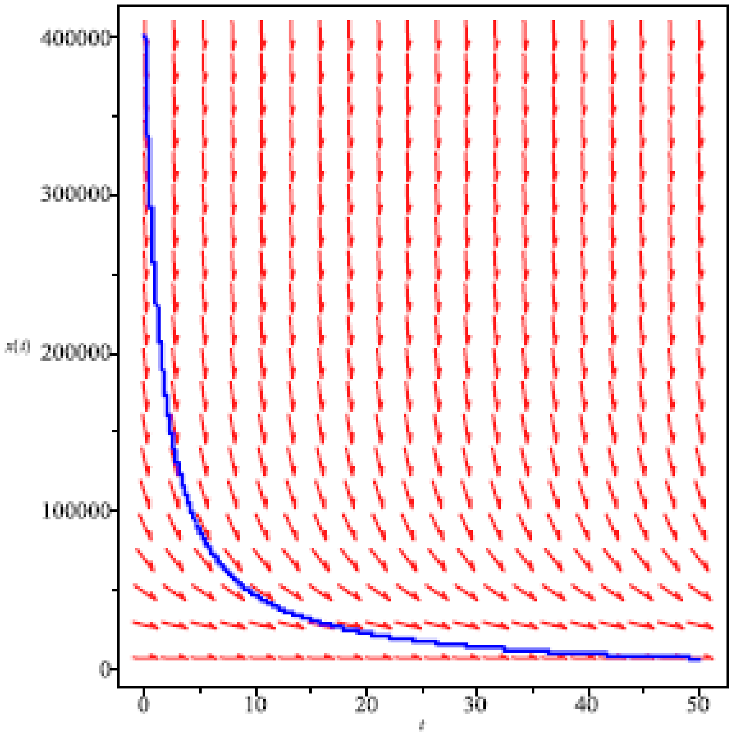
$$des := \left[\frac{d}{dt} x(t) = 1.046374851\, x(t) \left(1 - \frac{x(t)}{622548}\right) - 1.06338075\, x(t)\right] \quad \textbf{(3)}$$

> $F := DEplot(des, [x(t)], t = 0..10, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



> $F := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

> $F := DEplot(des, [x(t)], t = 0..50, [[x(0) = 401263]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$



Appendix 8

Lotka-Volterra model analysis

> restart

> $eq1 := r \cdot x \cdot \left(1 - \frac{x}{K}\right) - \beta \cdot x \cdot y$

$$eq1 := r\,x\left(1 - \frac{x}{K}\right) - \beta\,x\,y \quad (1)$$

> $eq2 := \beta \cdot x \cdot y - d \cdot y$

$$eq2 := \beta\,x\,y - d\,y \quad (2)$$

> $r := 1.046374851;\ K := 622548;\ \beta := 0.085841;\ d := 0;$

$$r := 1.046374851$$
$$K := 622548$$
$$\beta := 0.085841$$
$$d := 0 \quad (3)$$

> $Equilibria := solve(\{eq1 = 0, eq2 = 0\}, \{x, y\})$

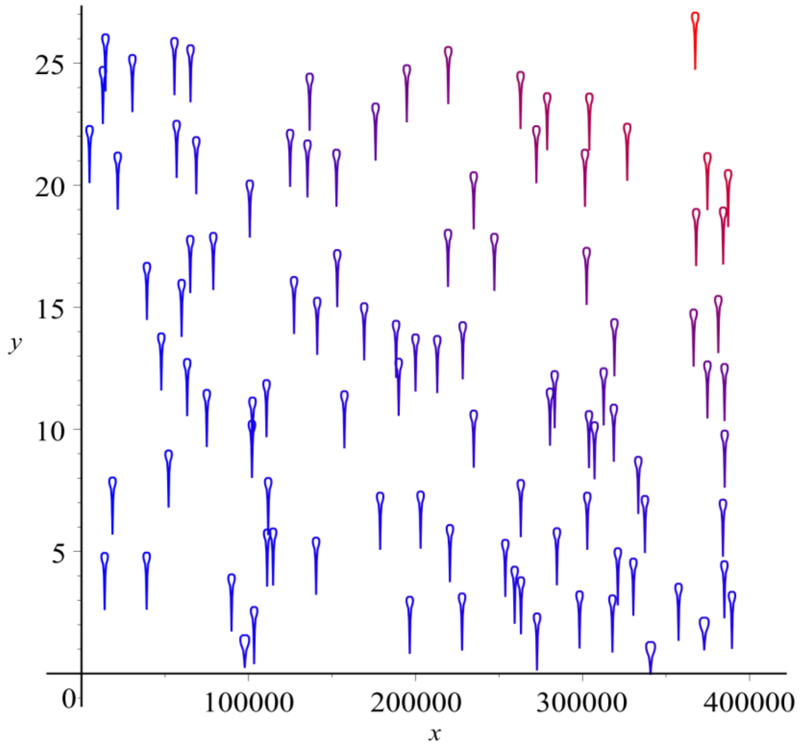
$$Equilibria := \{x = 0., y = y\},\ \{x = 6.22548\ 10^5, y = 0.\} \quad (4)$$

> $with(DEtools, DEplot) : with(plots) :$

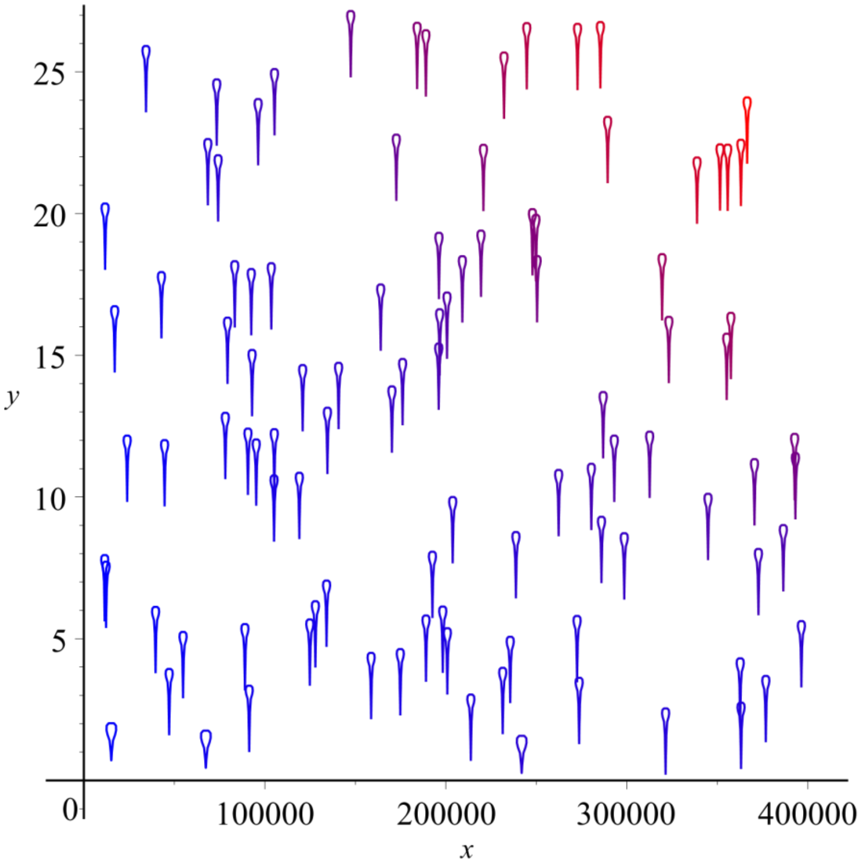
> $des := \left[\frac{d}{dt}\,x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - \beta \cdot x(t) \cdot y(t),\ \frac{d}{dt}\,y(t) = \beta \cdot x(t) \cdot y(t) - d \cdot y(t)\right]$

$$des := \left[\frac{d}{dt}\,x(t) = 1.046374851\,x(t)\left(1 - \frac{1}{622548}\,x(t)\right) - 0.085841\,x(t)\,y(t),\ \frac{d}{dt}\,y(t) = 0.085841\,x(t)\,y(t)\right] \quad (5)$$

> $DEplot(des, [x(t), y(t)], t = 0..10, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$

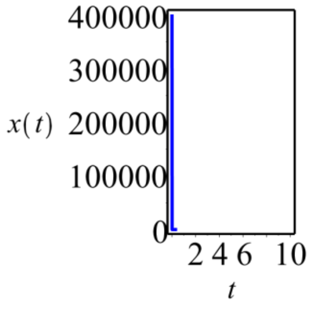


> $DEplot(des, [x(t), y(t)], t = 0..50, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$



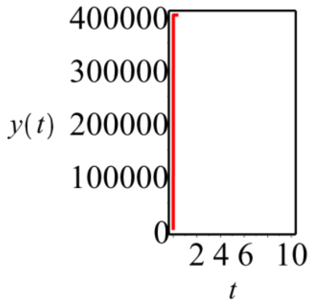
> $F := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

```
Warning, plot may be incomplete, the following errors(s) were
issued:
   cannot evaluate the solution further right of .44222331,
maxfun limit exceeded (see ?dsolve,maxfun for details)
```

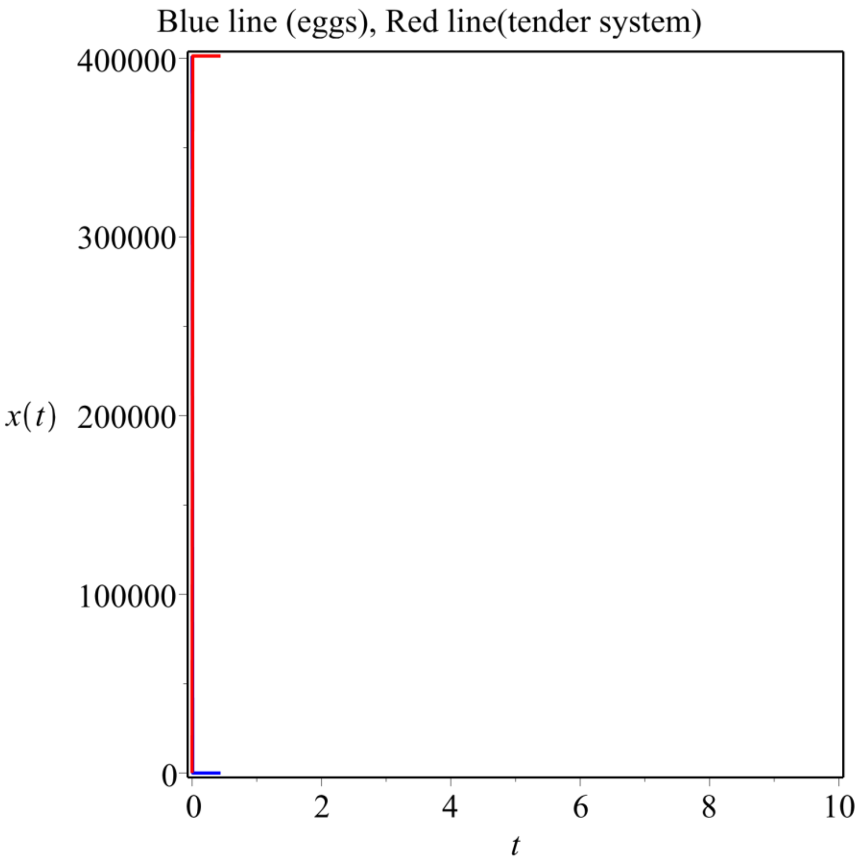
$F :=$ 

> $G := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

```
Warning, plot may be incomplete, the following errors(s) were
issued:
   cannot evaluate the solution further right of .44222331,
maxfun limit exceeded (see ?dsolve,maxfun for details)
```

$G :=$ 

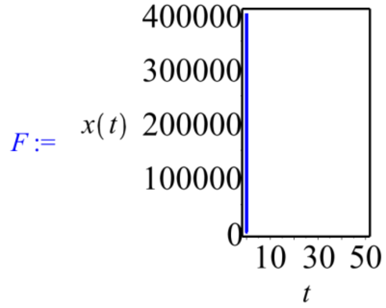
> $display([F, G], title = \text{"Blue line (eggs), Red line(tender system)"})$



> $F := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

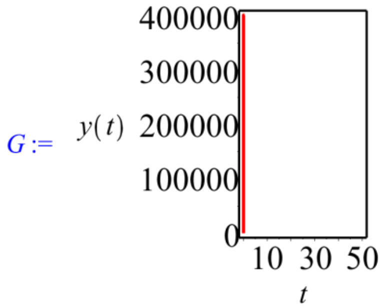
```
Warning, plot may be incomplete, the following errors(s) were
```

```
issued:
   cannot evaluate the solution further right of .44222331,
maxfun limit exceeded (see ?dsolve,maxfun for details)
```

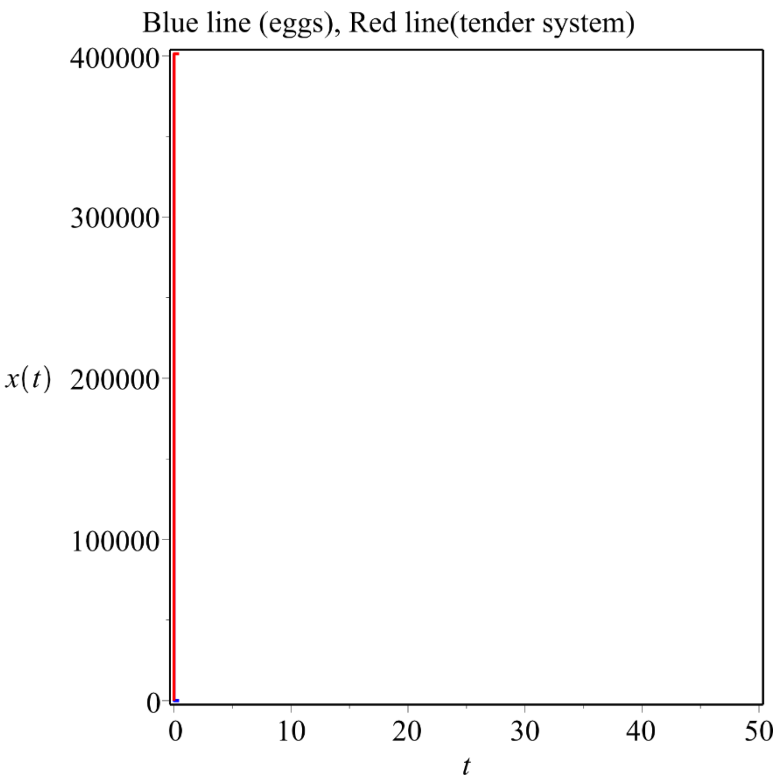


> $G := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

```
Warning, plot may be incomplete, the following errors(s) were
issued:
   cannot evaluate the solution further right of .44222331,
maxfun limit exceeded (see ?dsolve,maxfun for details)
```



> $display([F, G], title = \text{"Blue line (eggs), Red line(tender system)"})$



Appendix 9

Tender system model analysis

> restart

> $eq1 := r \cdot x \cdot \left(1 - \frac{x}{K}\right) - \alpha \cdot x \cdot y$

$$eq1 := r\,x\left(1 - \frac{x}{K}\right) - \alpha\,x\,y \qquad (1)$$

> $eq2 := \beta \cdot x \cdot y - d \cdot y$

$$eq2 := \beta\,x\,y - d\,y \qquad (2)$$

> $r := 1.046374851; K := 622548; \alpha := 0.085841; \beta := 0; d := 0;$

$$r := 1.046374851$$
$$K := 622548$$
$$\alpha := 0.085841$$
$$\beta := 0$$
$$d := 0 \qquad (3)$$

> $Equilibria := solve(\{eq1 = 0, eq2 = 0\}, \{x, y\})$

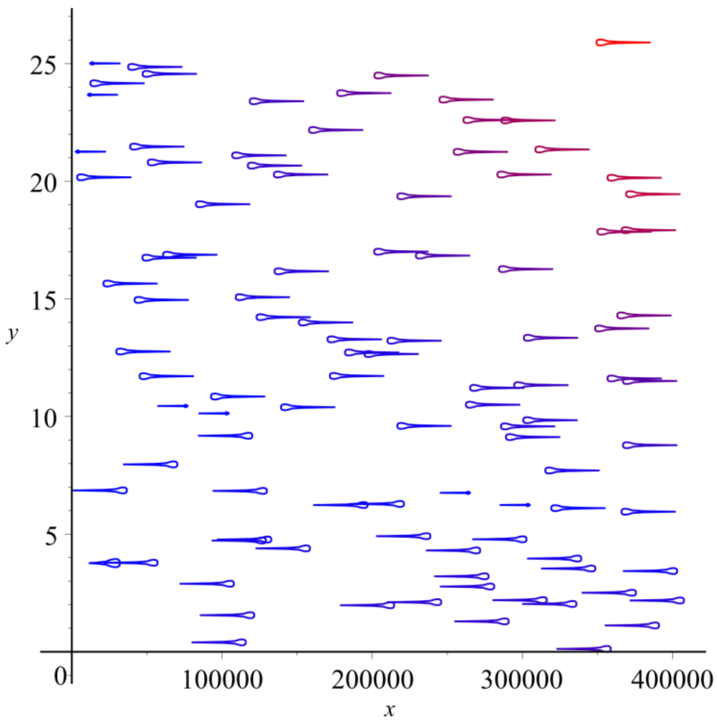
$$Equilibria := \{x = 0., y = y\}, \{x = 6.22548\ 10^5 - 51071.70037\,y, y = y\} \qquad (4)$$

> with(DEtools, DEplot) : with(plots) :

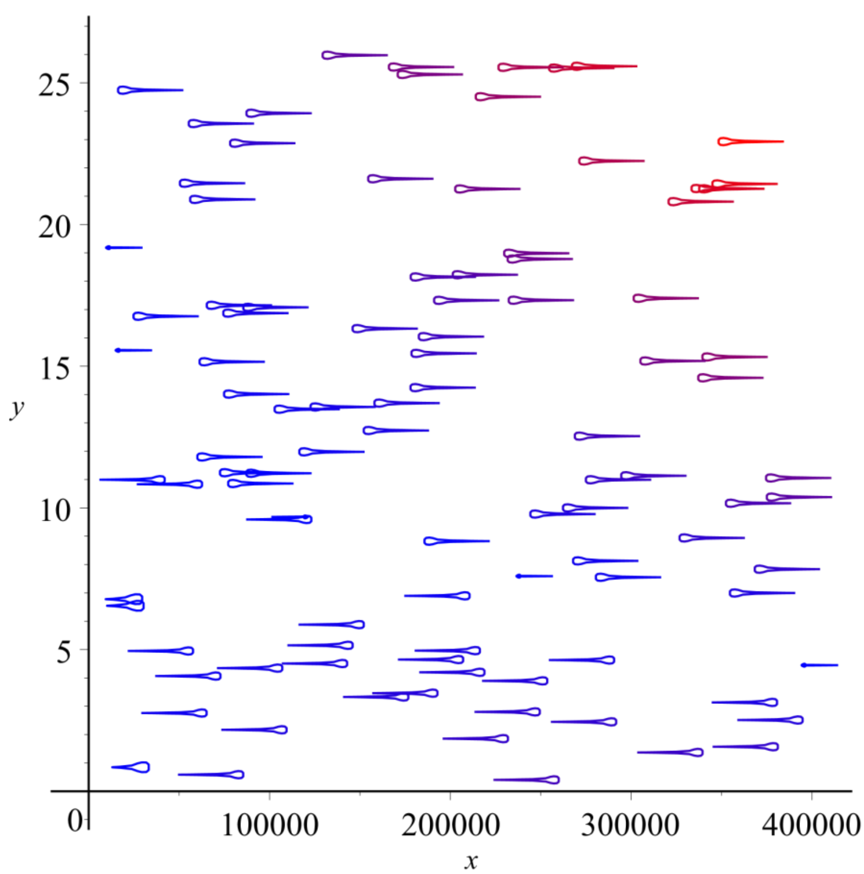
> $des := \left[\frac{d}{dt}x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - \alpha \cdot x(t) \cdot y(t), \frac{d}{dt}y(t) = \beta \cdot x(t) \cdot y(t) - d \cdot y(t)\right]$

$$des := \left[\frac{d}{dt}x(t) = 1.046374851\,x(t)\left(1 - \frac{1}{622548}x(t)\right) - 0.085841\,x(t)\,y(t), \frac{d}{dt}y(t) = 0\right] \qquad (5)$$

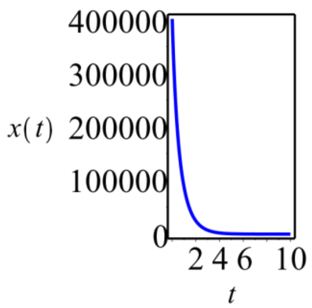
> DEplot(des, [x(t), y(t)], t = 0 ..10, x = 0 ..401263, y = 0 ..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)



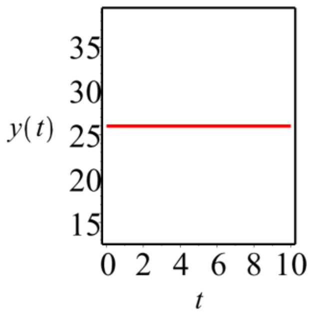
> DEplot(des, [x(t), y(t)], t = 0 ..50, x = 0 ..401263, y = 0 ..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)



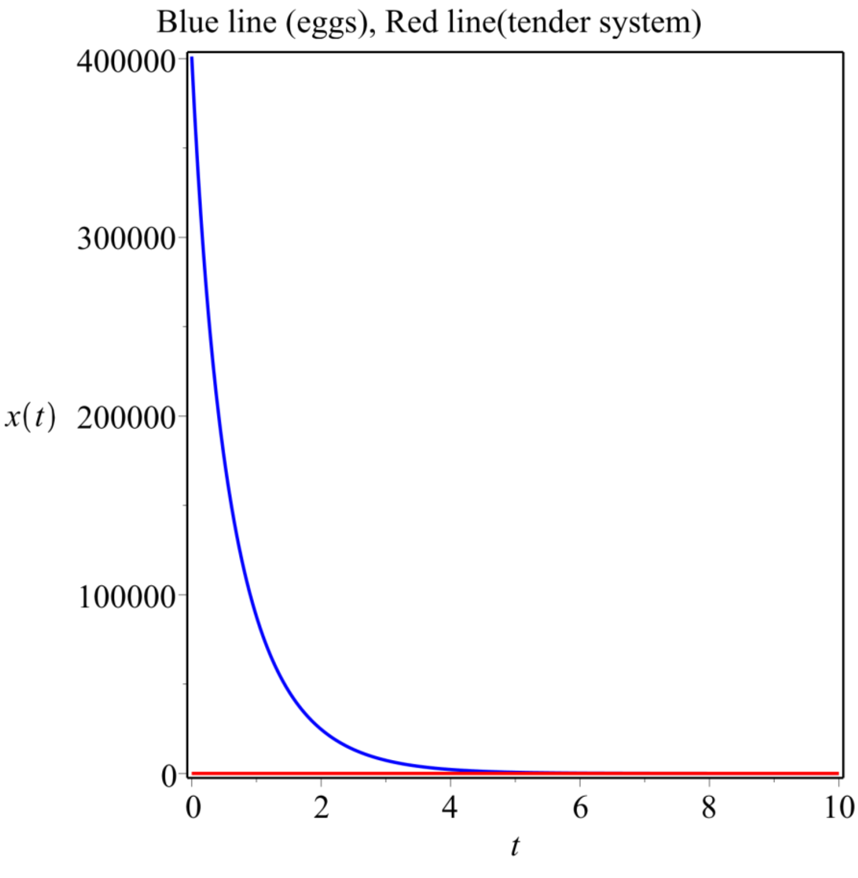
> $F := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$F :=$ 

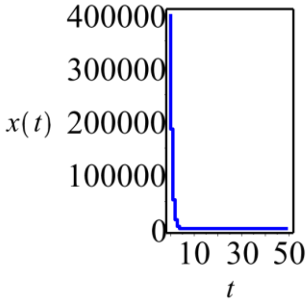
> $G := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

$G :=$ 

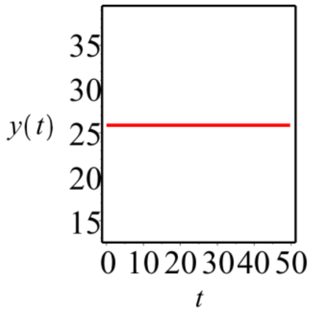
> $display([F, G], title = \text{"Blue line (eggs), Red line(tender system)"})$



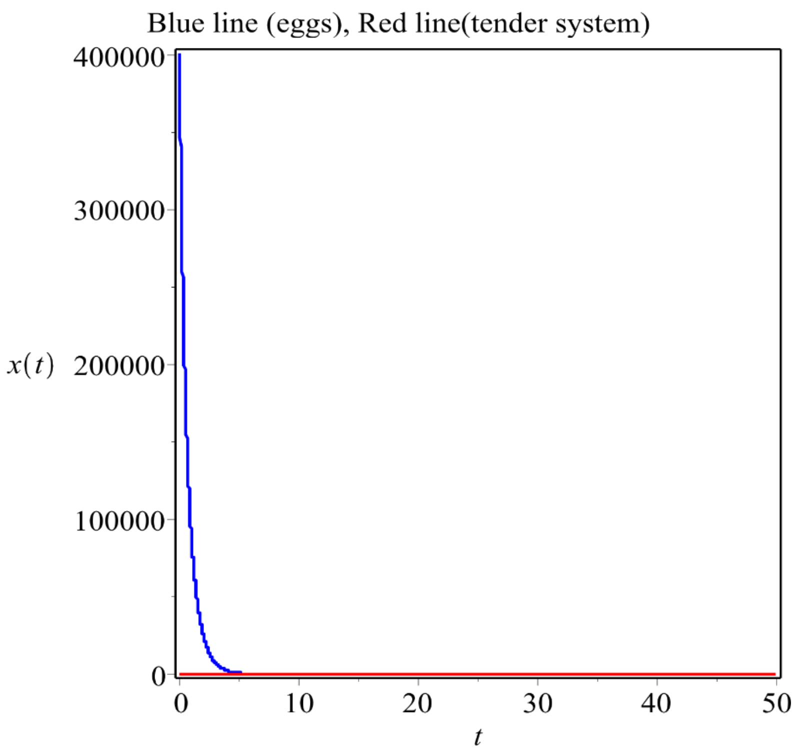
> $F := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$F :=$ 

> $G := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

$G :=$ 

> $display([F, G], title = $ "Blue line (eggs), Red line(tender system)")



Appendix 10

0% Annual prey-predator interaction level

```
> restart
```

> $eq1 := r \cdot x \cdot \left(1 - \frac{x}{K}\right) - \alpha \cdot x \cdot y$

$$eq1 := r\,x\left(1 - \frac{x}{K}\right) - \alpha\,x\,y \quad (1)$$

> $eq2 := \beta \cdot x \cdot y - d \cdot y$

$$eq2 := \beta\,x\,y - d\,y \quad (2)$$

> $r := 1.046374851;\ K := 622548;\ \alpha := 0.;\ \beta := 0;\ d := 1;$

$$r := 1.046374851$$
$$K := 622548$$
$$\alpha := 0.$$
$$\beta := 0$$
$$d := 1 \quad (3)$$

> $Equilibria := solve(\{eq1 = 0, eq2 = 0\}, \{x, y\})$

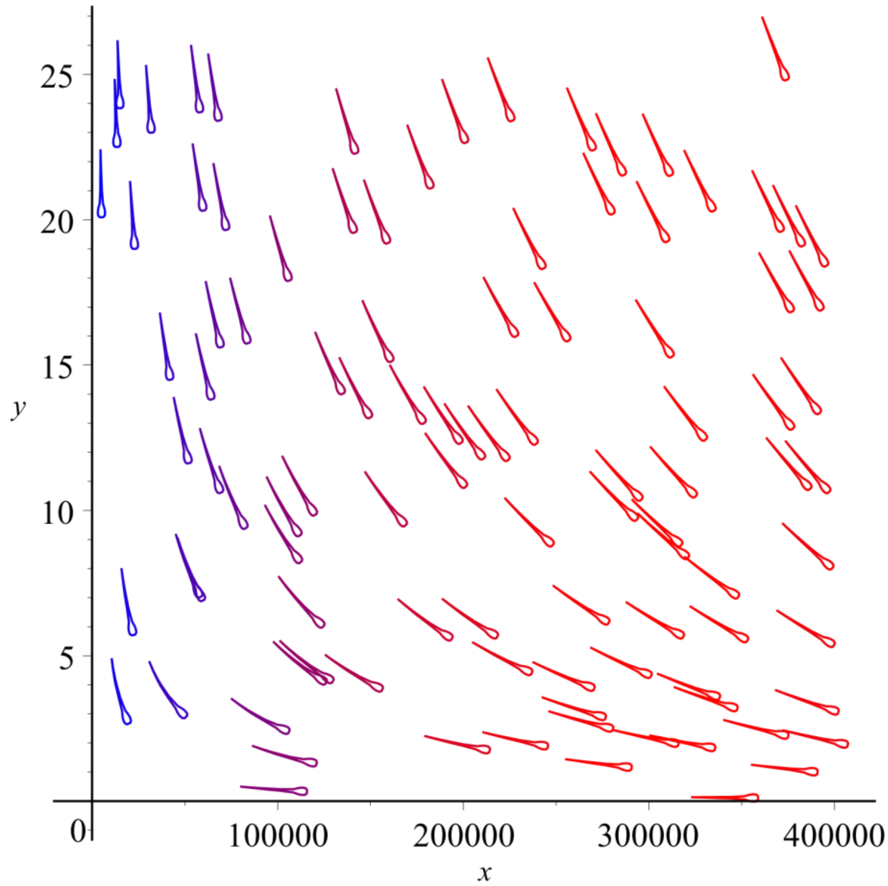
$$Equilibria := \{x = 0., y = 0.\}, \{x = 6.22548\ 10^5, y = 0.\} \quad (4)$$

> $with(DEtools, DEplot) : with(plots) :$

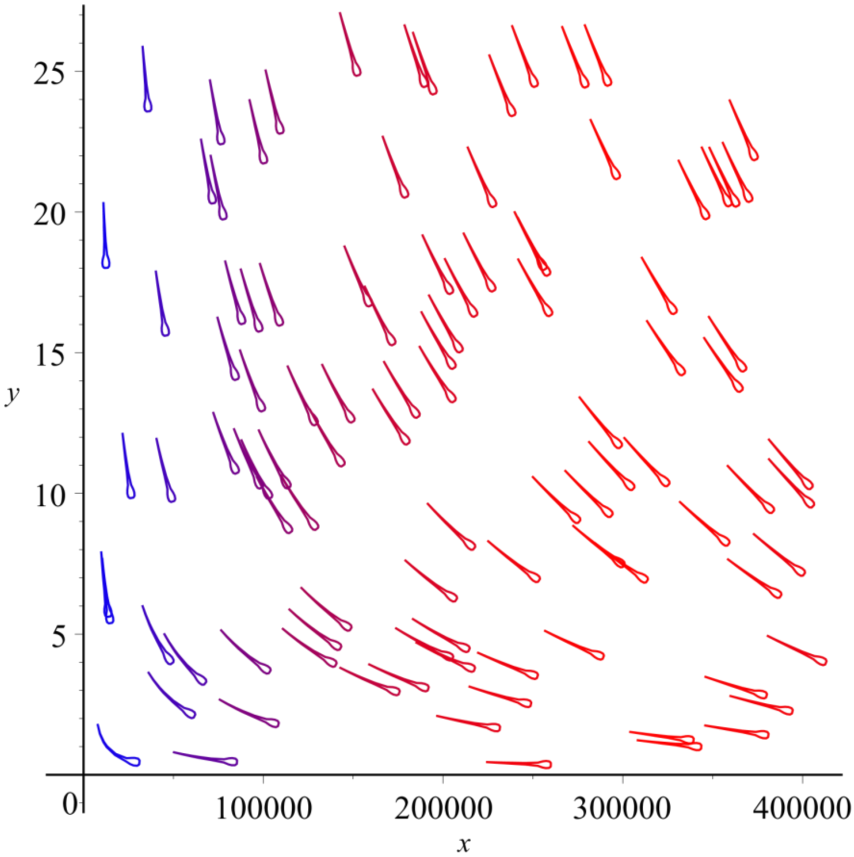
> $des := \left[\frac{d}{dt}\,x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - \alpha \cdot x(t) \cdot y(t),\ \frac{d}{dt}\,y(t) = \beta \cdot x(t) \cdot y(t) - d \cdot y(t)\right]$

$$des := \left[\frac{d}{dt}\,x(t) = 1.046374851\,x(t)\left(1 - \frac{1}{622548}\,x(t)\right),\ \frac{d}{dt}\,y(t) = -y(t)\right] \quad (5)$$

> $DEplot(des, [x(t), y(t)], t = 0..10, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$

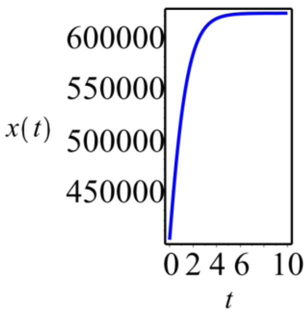


> $DEplot(des, [x(t), y(t)], t = 0..50, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$

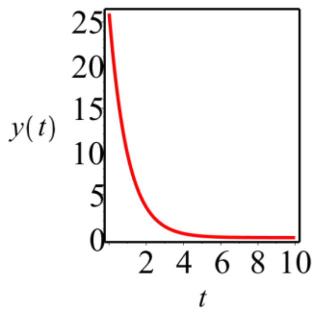


> $F := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

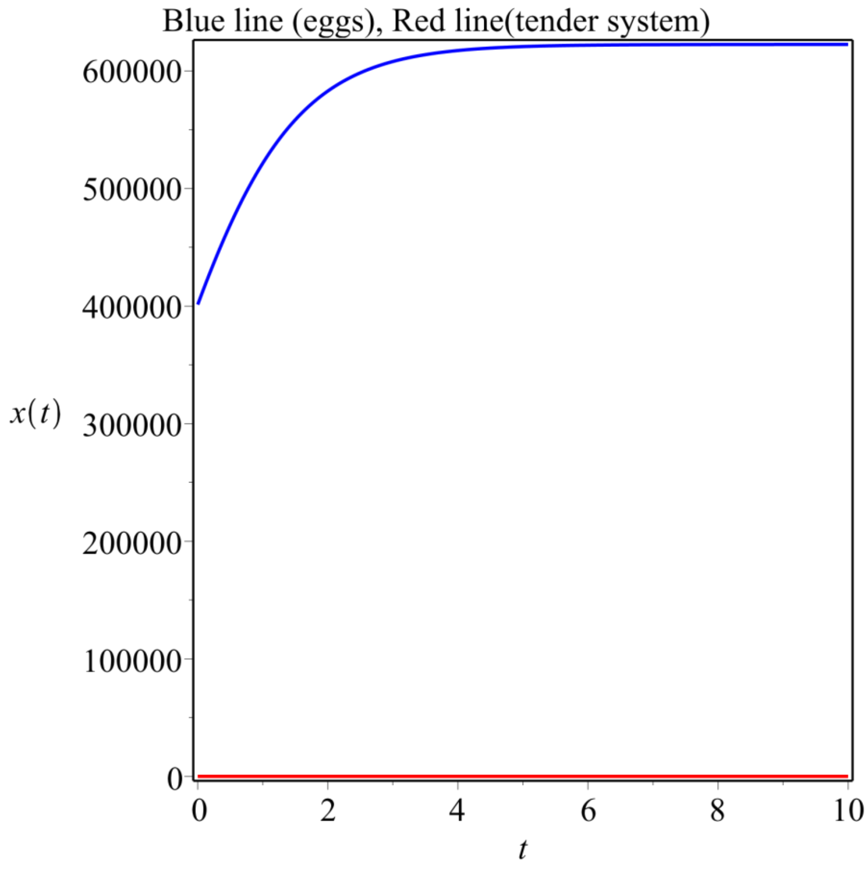
$F :=$



> $G := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

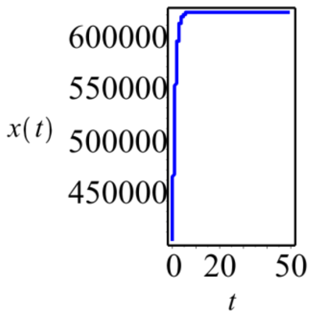
$G :=$ 

> *display*([*F*, *G*], *title* = "Blue line (eggs), Red line(tender system)")

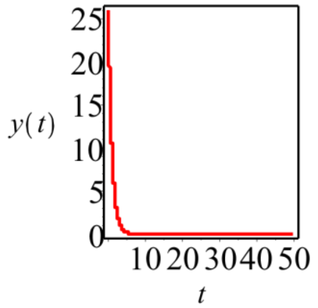


> $F := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

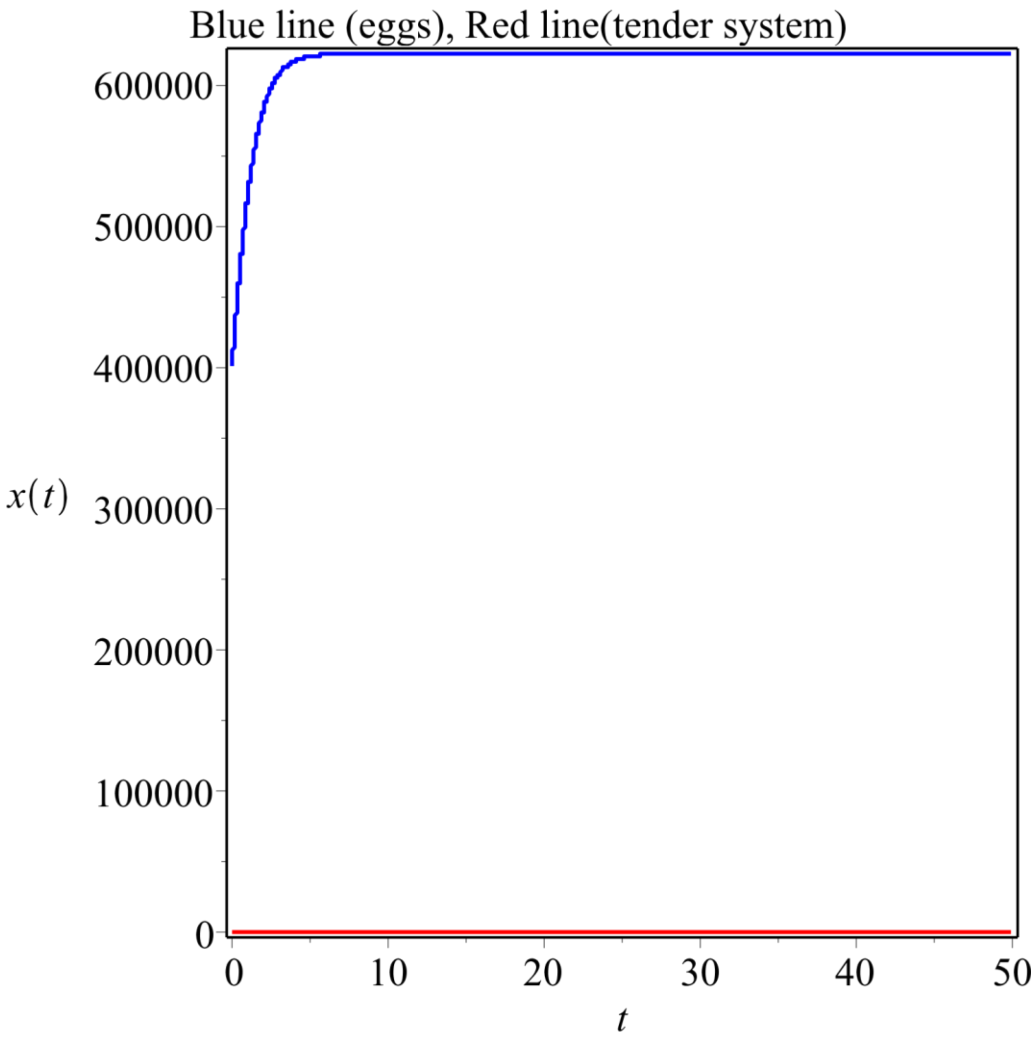
\>

$F :=$ 

\> $G := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

$G :=$ 

\> display([F, G], title = "Blue line (eggs), Red line(tender system)")



Appendix 11

25% Annual prey-predator interaction level

> restart

> $eq1 := r \cdot x \cdot \left(1 - \frac{x}{K}\right) - \alpha \cdot x \cdot y$

$$eq1 := r\,x\left(1 - \frac{x}{K}\right) - \alpha\,x\,y \quad (1)$$

> $eq2 := \beta \cdot x \cdot y - d \cdot y$

$$eq2 := \beta\,x\,y - d\,y \quad (2)$$

> $r := 1.046374851;\ K := 622548;\ \alpha := 0.02146025;\ \beta := 0;\ d := 0.75;$

$$r := 1.046374851$$
$$K := 622548$$
$$\alpha := 0.02146025$$
$$\beta := 0$$
$$d := 0.75 \quad (3)$$

> $Equilibria := solve(\{eq1 = 0, eq2 = 0\}, \{x, y\})$

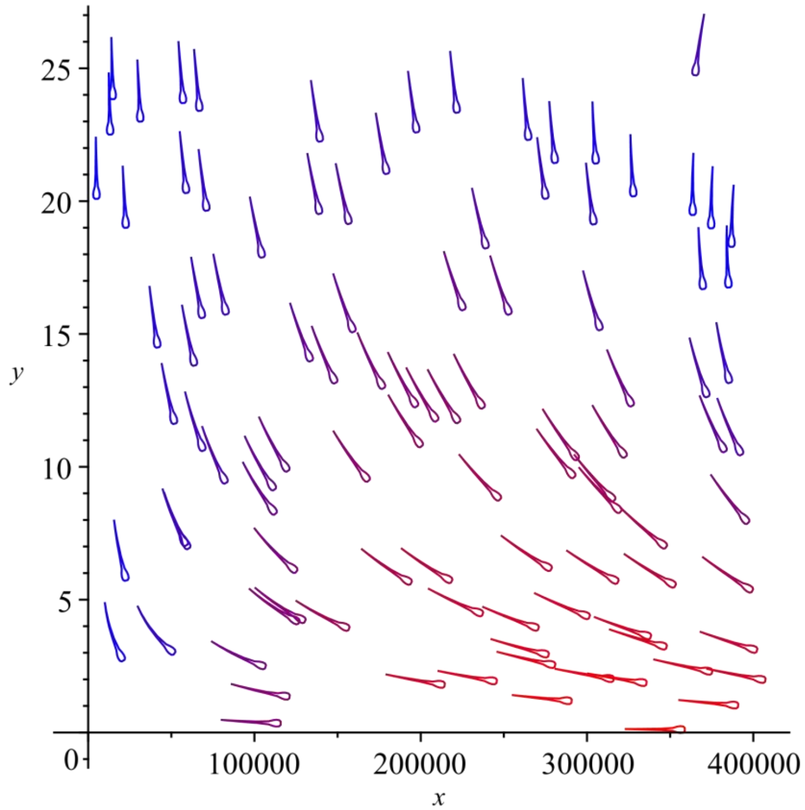
$$Equilibria := \{x = 0., y = 0.\}, \{x = 6.22548\ 10^5, y = 0.\} \quad (4)$$

> $with(DEtools, DEplot) : with(plots) :$

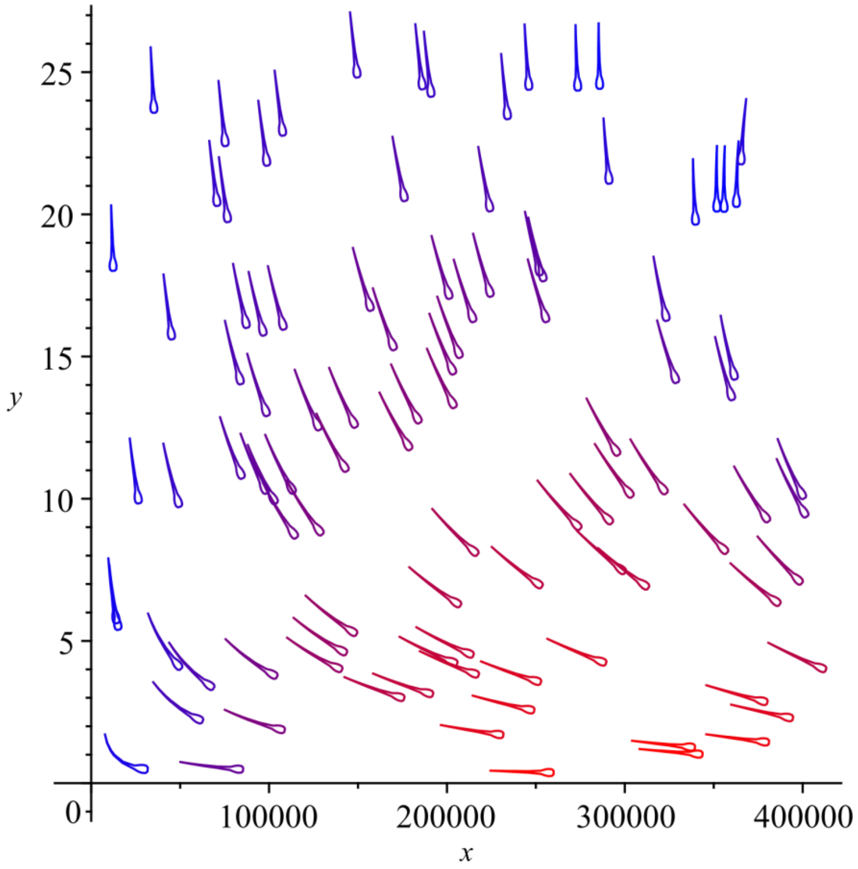
> $des := \left[\frac{d}{dt}\,x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - \alpha \cdot x(t) \cdot y(t),\ \frac{d}{dt}\,y(t) = \beta \cdot x(t) \cdot y(t) - d \cdot y(t)\right]$

$$des := \left[\frac{d}{dt}\,x(t) = 1.046374851\,x(t)\left(1 - \frac{1}{622548}\,x(t)\right) - 0.02146025\,x(t)\,y(t),\ \frac{d}{dt}\,y(t) = -0.75\,y(t)\right] \quad (5)$$

> $DEplot(des, [x(t), y(t)], t = 0..10, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$

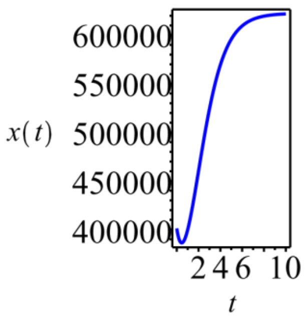


> $DEplot(des, [x(t), y(t)], t = 0..50, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$



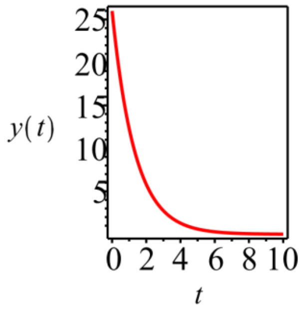
> $F := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$F :=$

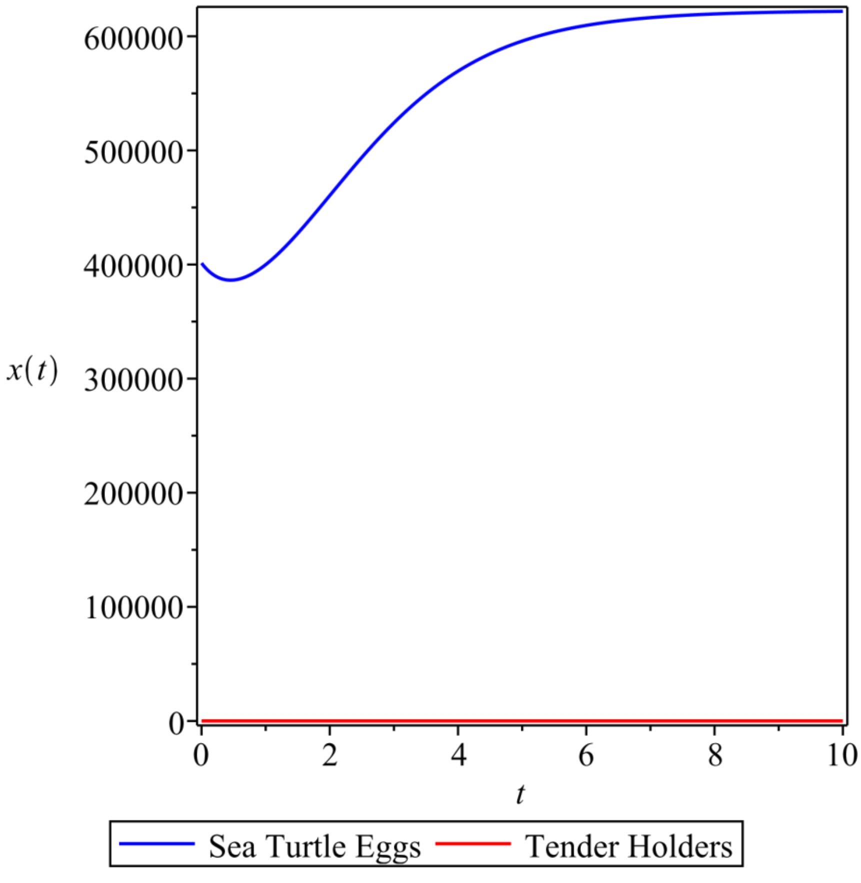


> $G := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

$G :=$



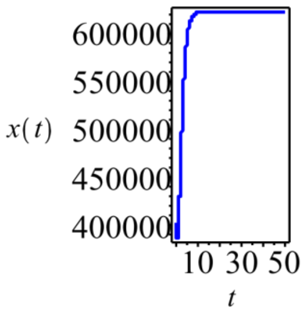
> $display([F, G])$



> $F := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

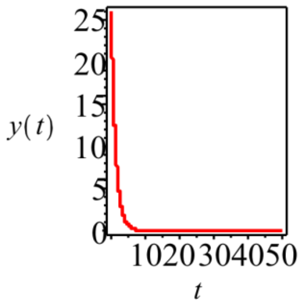
```
>
```

F :=

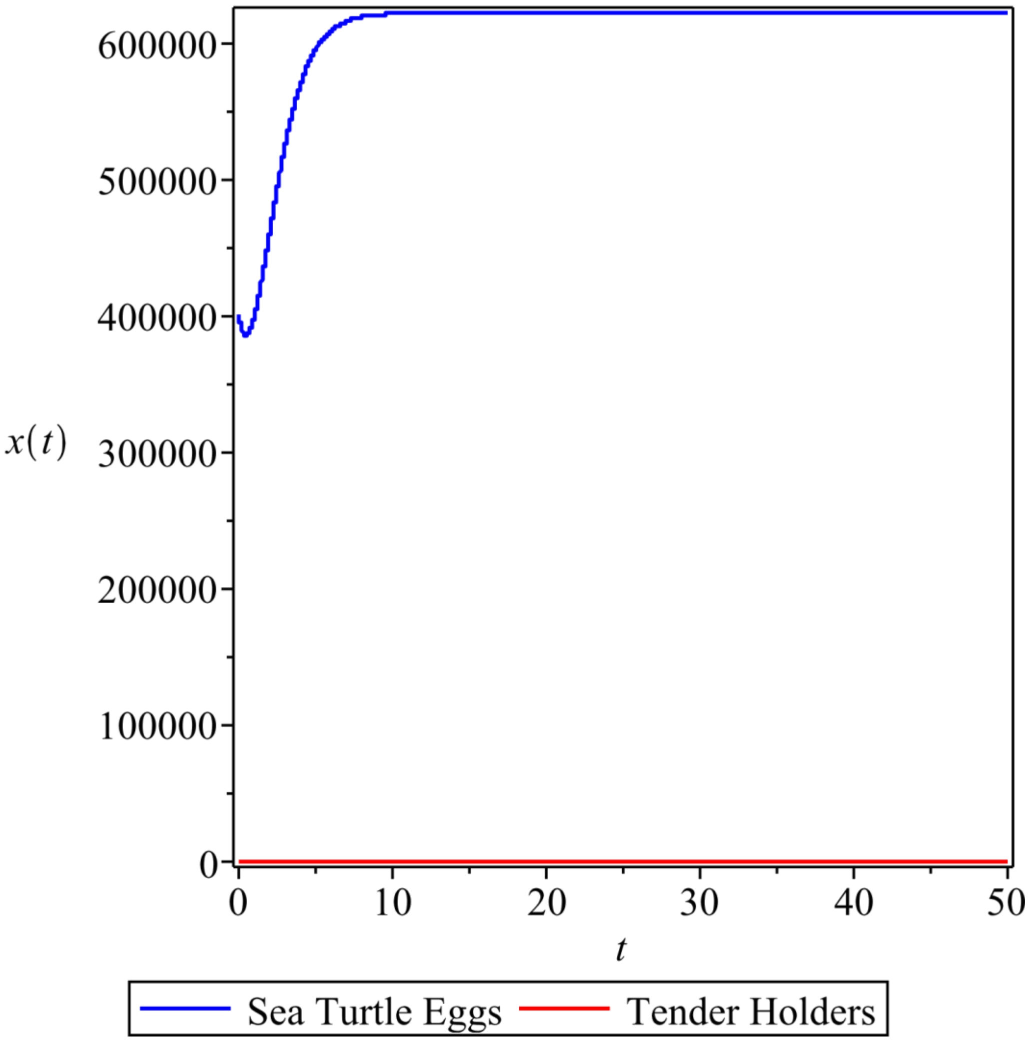



```
> G := DEplot(des, [x(t), y(t)], t = 0 ..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor
  = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])
```

G :=




```
> display([F, G])
```



Appendix 12

50% Annual prey-predator interaction level

> restart

> $eq1 := r \cdot x \cdot \left(1 - \frac{x}{K}\right) - \alpha \cdot x \cdot y$

$$eq1 := r\,x\left(1 - \frac{x}{K}\right) - \alpha\,x\,y \quad (1)$$

> $eq2 := \beta \cdot x \cdot y - d \cdot y$

$$eq2 := \beta\,x\,y - d\,y \quad (2)$$

> $r := 1.046374851;\ K := 622548;\ \alpha := 0.06438075;\ \beta := 0;\ d := 0.25;$

$$r := 1.046374851$$
$$K := 622548$$
$$\alpha := 0.06438075$$
$$\beta := 0$$
$$d := 0.25 \quad (3)$$

> $Equilibria := solve(\{eq1 = 0, eq2 = 0\}, \{x, y\})$

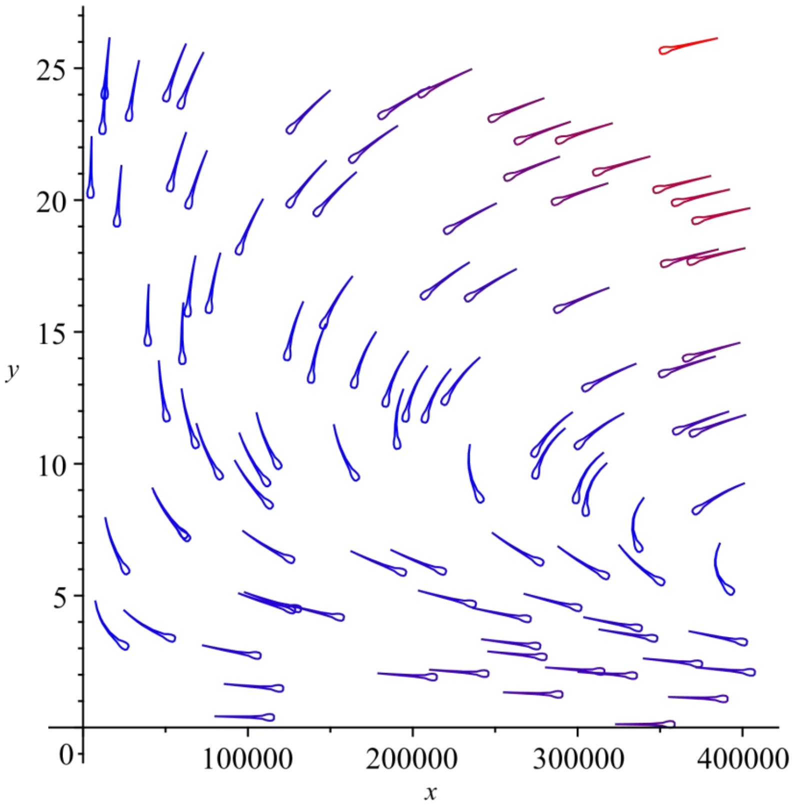
$$Equilibria := \{x = 0., y = 0.\}, \{x = 6.22548\ 10^{5}, y = 0.\} \quad (4)$$

> with(DEtools, DEplot) : with(plots) :

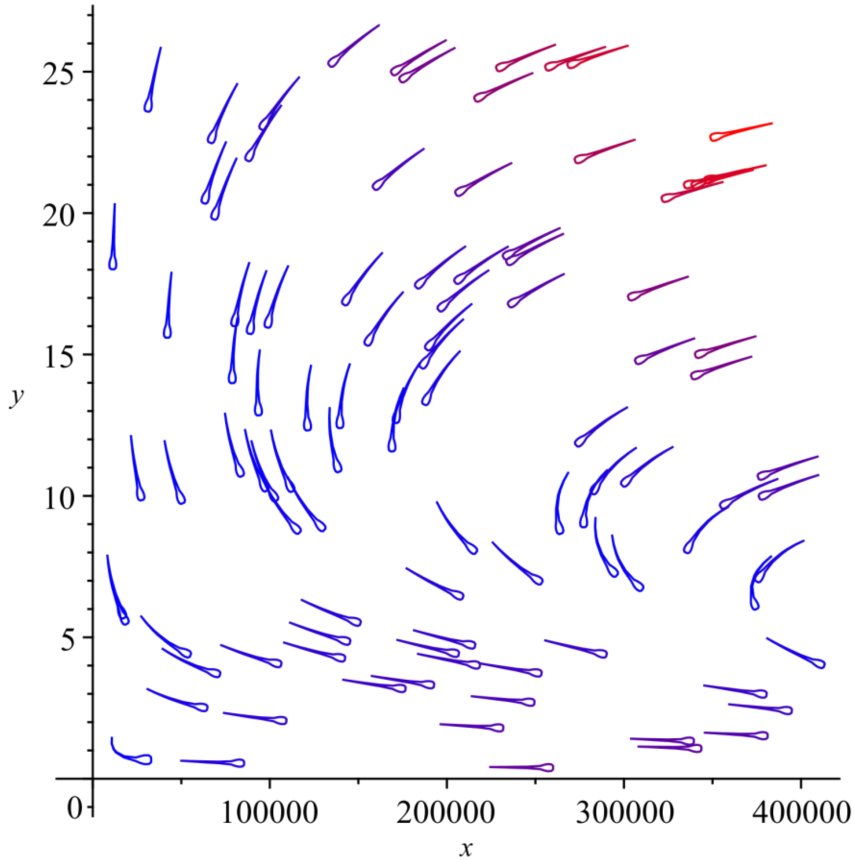
> $des := \left[\frac{d}{dt}\,x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - \alpha \cdot x(t) \cdot y(t),\ \frac{d}{dt}\,y(t) = \beta \cdot x(t) \cdot y(t) - d \cdot y(t)\right]$

$$des := \left[\frac{d}{dt}\,x(t) = 1.046374851\,x(t)\left(1 - \frac{1}{622548}\,x(t)\right) - 0.06438075\,x(t)\,y(t),\ \frac{d}{dt}\,y(t) = -0.25\,y(t)\right] \quad (5)$$

> DEplot(des, [x(t), y(t)], t = 0 ..10, x = 0 ..401263, y = 0 ..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)

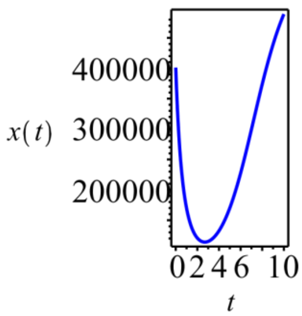


> DEplot(des, [x(t), y(t)], t = 0 ..50, x = 0 ..401263, y = 0 ..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)

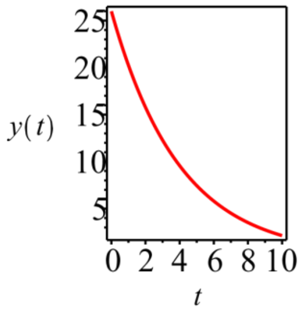


> $F := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

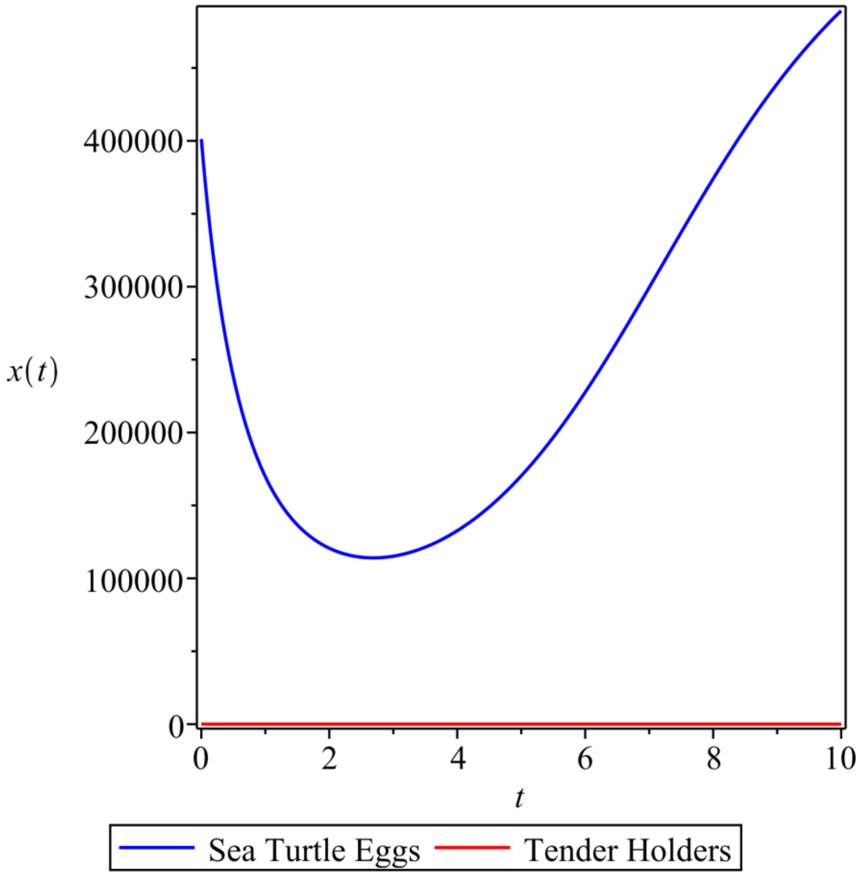
$F :=$



> $G := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

$G :=$ 

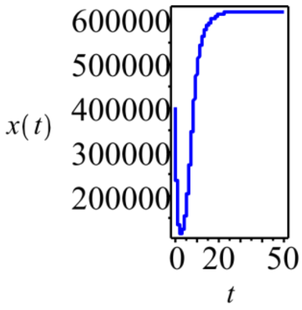
> $display([F, G])$



> $F := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

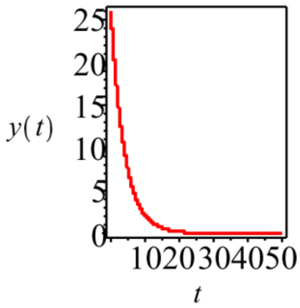
>

F :=

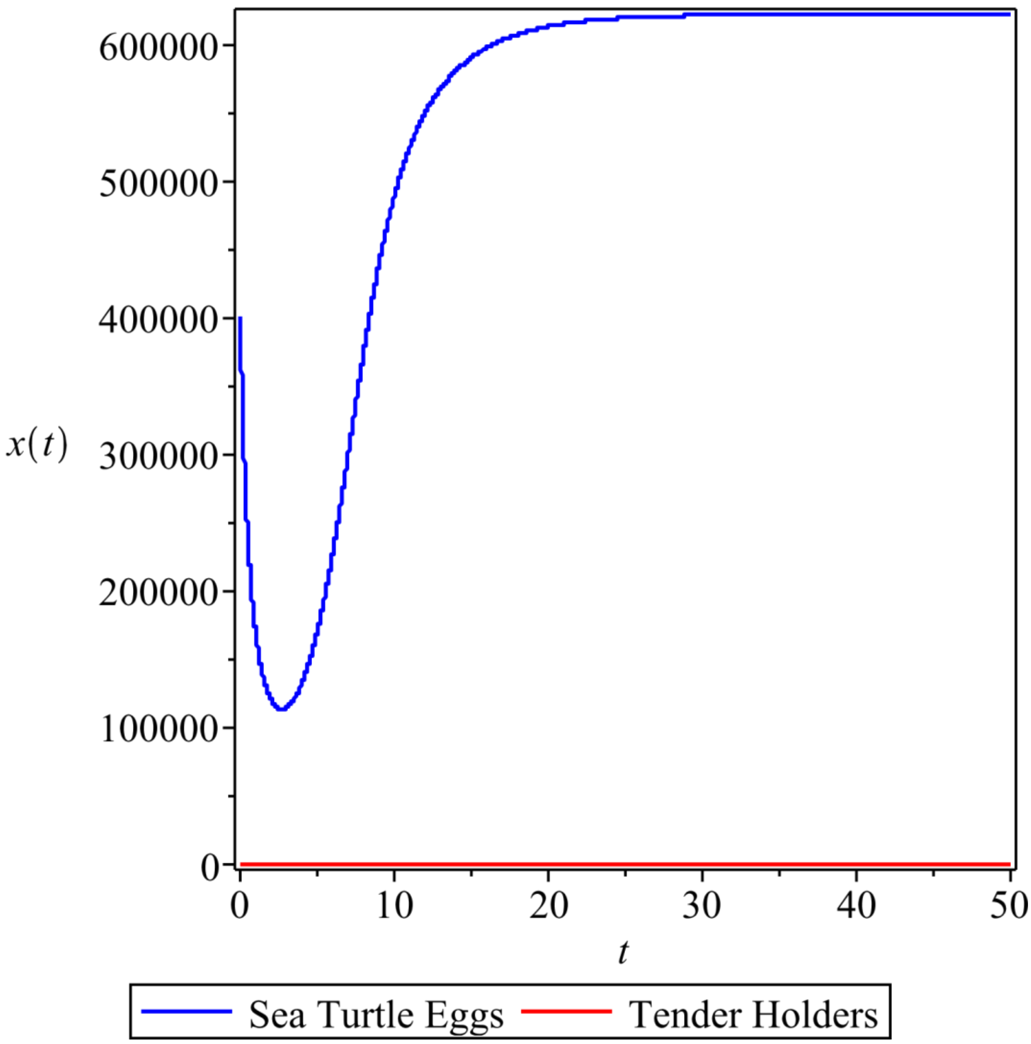


> G := DEplot(des, [x(t), y(t)], t = 0 ..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])

G :=



> display([F, G])



Appendix 13

75% Annual prey-predator interaction level

> *restart*

> $eq1 := r \cdot x \cdot \left(1 - \frac{x}{K}\right) - \alpha \cdot x \cdot y$

$$eq1 := r\,x\left(1 - \frac{x}{K}\right) - \alpha\,x\,y \quad (1)$$

> $eq2 := \beta \cdot x \cdot y - d \cdot y$

$$eq2 := \beta\,x\,y - d\,y \quad (2)$$

> $r := 1.046374851; K := 622548; \alpha := 0.06438075; \beta := 0; d := 0.25;$

$$r := 1.046374851$$
$$K := 622548$$
$$\alpha := 0.06438075$$
$$\beta := 0$$
$$d := 0.25 \quad (3)$$

> $Equilibria := solve(\{eq1 = 0, eq2 = 0\}, \{x, y\})$

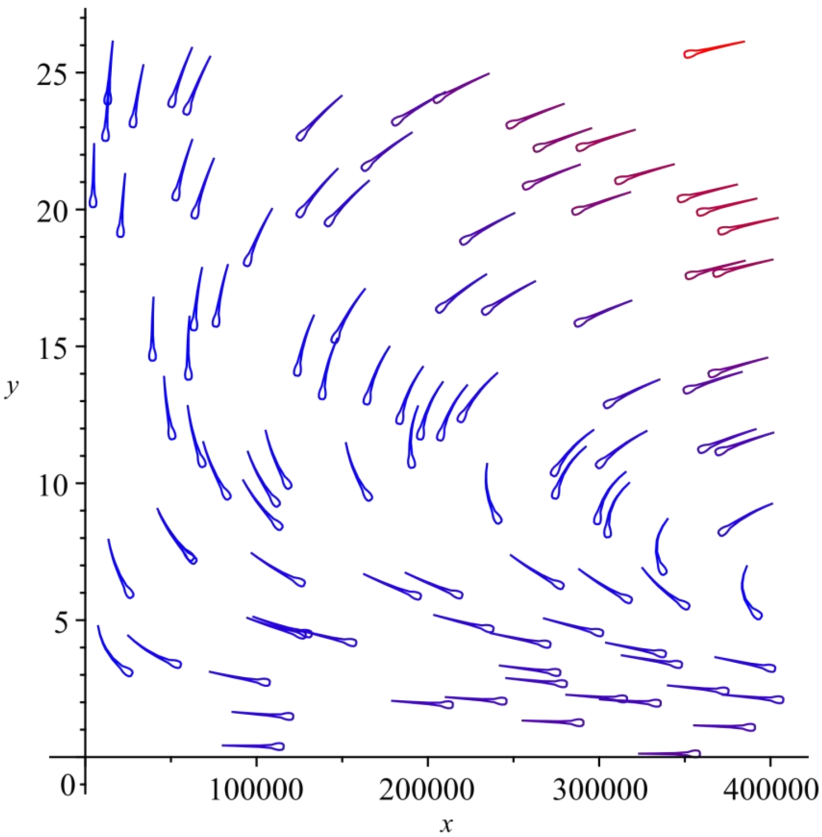
$$Equilibria := \{x = 0., y = 0.\}, \{x = 6.22548\ 10^5, y = 0.\} \quad (4)$$

> $with(DEtools, DEplot) : with(plots) :$

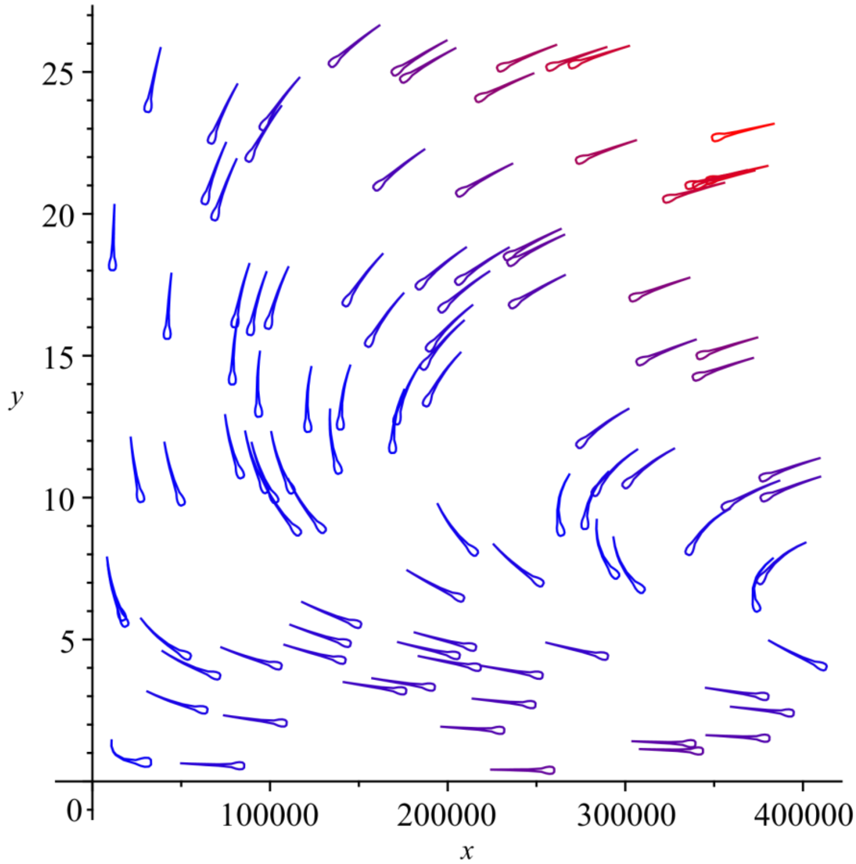
> $des := \left[\frac{d}{dt}\,x(t) = r \cdot x(t) \cdot \left(1 - \frac{x(t)}{K}\right) - \alpha \cdot x(t) \cdot y(t),\ \frac{d}{dt}\,y(t) = \beta \cdot x(t) \cdot y(t) - d \cdot y(t)\right]$

$$des := \left[\frac{d}{dt}\,x(t) = 1.046374851\,x(t)\left(1 - \frac{1}{622548}\,x(t)\right) - 0.06438075\,x(t)\,y(t),\ \frac{d}{dt}\,y(t) = -0.25\,y(t)\right] \quad (5)$$

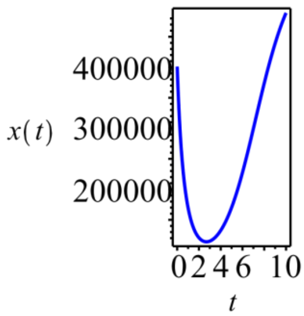
> $DEplot(des, [x(t), y(t)], t = 0..10, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$



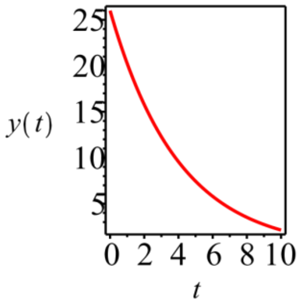
> $DEplot(des, [x(t), y(t)], t = 0..50, x = 0..401263, y = 0..26, dirfield = 100, arrows = fish, color = magnitude, linecolour = blue, numsteps = 100)$



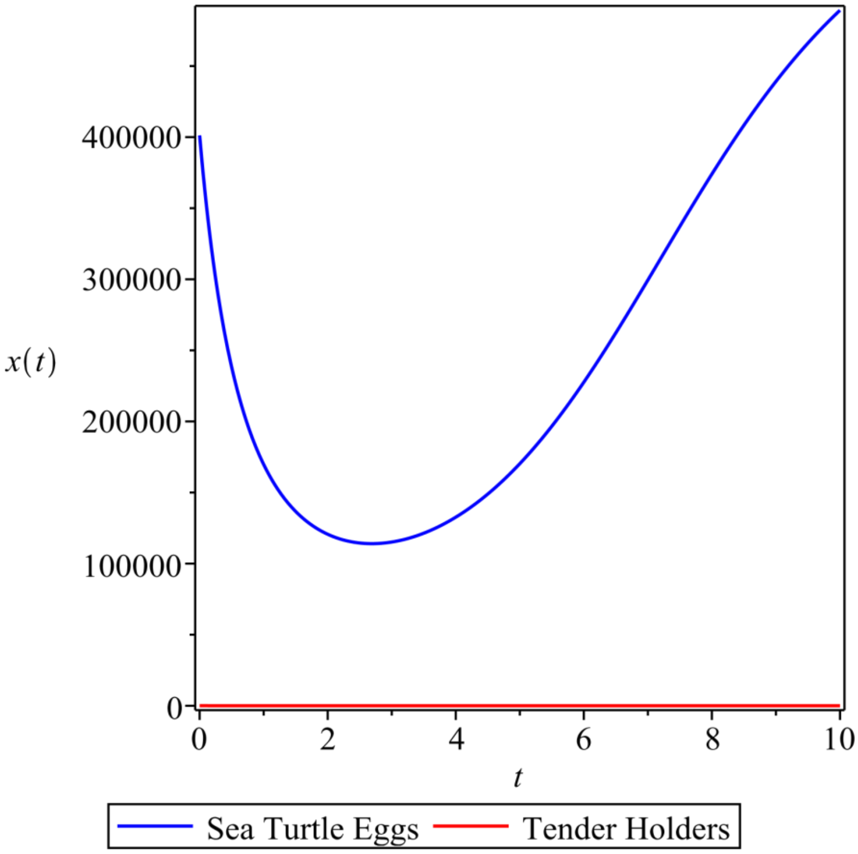
> $F := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

$F :=$ 

> $G := DEplot(des, [x(t), y(t)], t = 0..10, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

$G :=$ 

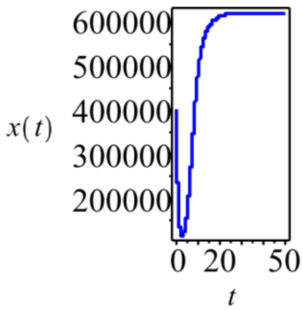
> $display([F, G])$



> $F := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = BLUE, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, x(t)])$

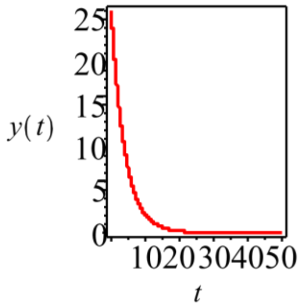
>

$F :=$

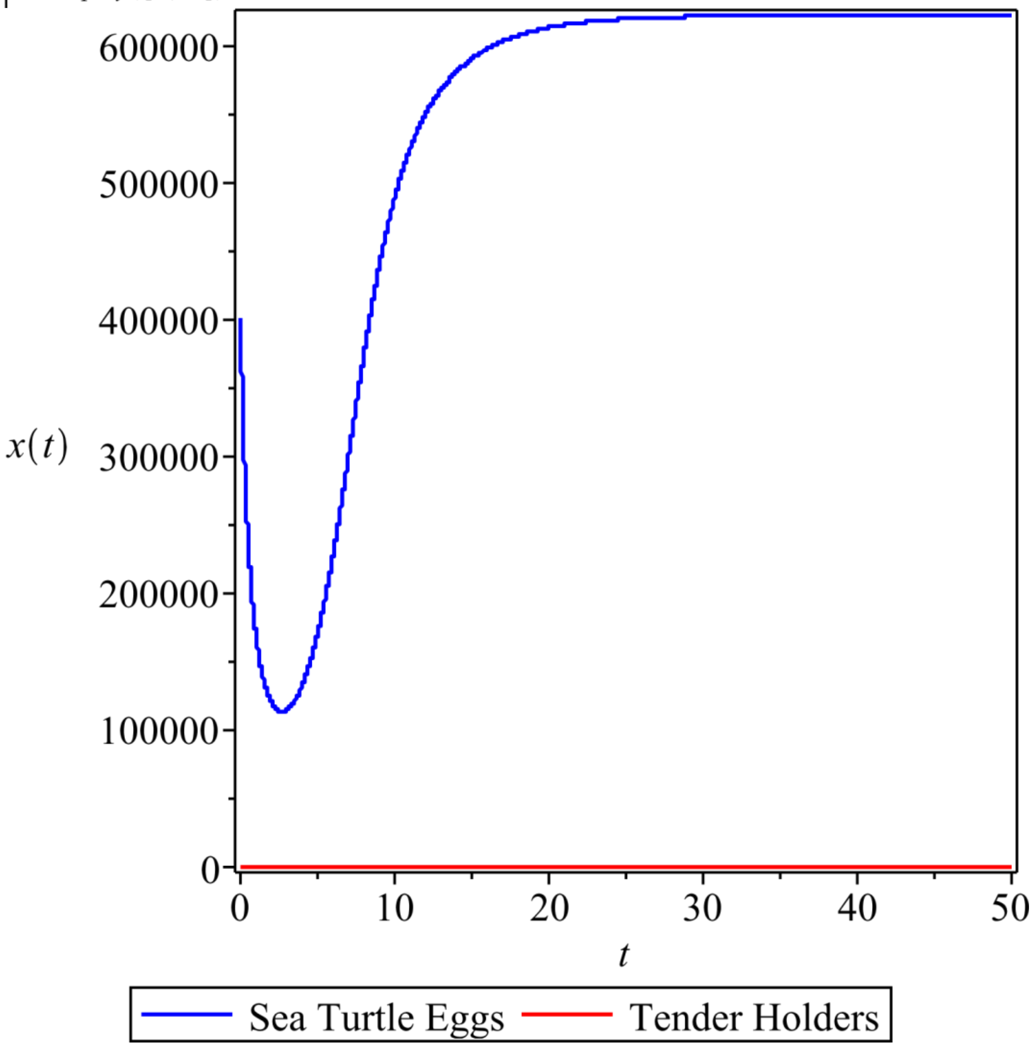


> $G := DEplot(des, [x(t), y(t)], t = 0..50, [[x(0) = 401263, y(0) = 26]], stepsize = 0.01, linecolor = RED, linestyle = solid, thickness = 1, axes = BOXED, scene = [t, y(t)])$

$G :=$



> $display([F, G])$



Appendix 14

Personal information form

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UNIVERSITI MALAYSIA TERENGGANU

ECONOMIC VALUATION OF SEA TURTLE EGG SELLERS IN TERENGGANU,2019

Dear Sir/Madam,

a) This survey is conducted by Sea Turtle Research Unit (SEATRU), Universiti Malaysia Terengganu.
b) You are selected to participate in this survey at random to provide information and opinions related to sea turtle eggs market in Terengganu.
c) Your answer to this survey will be treated confidentially and any information gathered in this survey will not be given to the third party.
d) Your cooperation in taking this study is very much appreciated.

Thank You

Respondent			
Name			
Address			
Enumerator			
Name			
Date			
Time started		Time ended	

January 2019

Appendix 15

Information sheet

SURVEY ON ECONOMIC VALUATION OF SEA TURTLE EGG SELLERS IN TERENGGANU, 2019

INFORMATION SHEET

must be given to respondent

Dear Sir/Madam,

Purpose: The purpose of this research is to investigate the economic valuation of sea turtle egg sellers in Terengganu.

Methods: We will ask you questions about your opinions on several issues related to the sea turtle eggs market in Terengganu. The interview will take approximately 15 minutes.

Confidentiality: Your answers to this survey will be stored in a computer anonymously. Any personal identification information, including your name will not be entered into the computer. Your name will only appear on the consent form and questionnaire.

Risks: There are no known risks.

Withdrawal from the survey: We would like to interview an eggs seller in Pasar Payang, Terengganu. Your participation is completely voluntary. You are free to discontinue participation at any time during the interview. You are free to refuse answering any question during the interview.

Use of your information: Your information will be analyzed qualitatively and will be used to write academic papers and reports. Only group information will be presented or published. If you withdraw during the interview, the questionnaire will be destroyed and the information you provided cannot be used in the analysis.

In the case you have any questions about the questionnaire, please contact the investigator

Prof. Dr. Mahirah Kamaludin

Email: mahirah.k@umt.edu.my

Phone: +609 668419

Appendix 16

Consent form

SURVEY ON ECONOMIC VALUATION OF SEA TURTLE EGG SELLERS IN TERENGGANU, 2019

CONSENT FORM

enumerator keep this

Do you understand that you have been asked to participate in a research survey?	☐ **Yes**	☐ **No**
Have you received and read a copy of the Information Sheet?	☐ Yes	☐ No
Do you understand the benefits and risks involved in participating in this survey?	☐ Yes	☐ No
Do you understand that you can quit taking part in this survey at any time?	☐ Yes	☐ No
Has confidentiality been explain to you?	☐ Yes	☐ No
Do you understand how your answer will be used?	☐ Yes	☐ No
Do you know what your answer will be used for?	☐ Yes	☐ No
Do you give us permission to use your data for the purposes specified?	☐ Yes	☐ No
Do you agree to participate in this survey?	☐ Yes	☐ No

| *Enumerators are not allowed to interview if there is any answer of "No" in the above questions* |

I agree to participate in this survey

____________________________ _____________________

Name and Signature Date

Appendix 17

Questionnaire

UNIVERSITI MALAYSIA TERENGGANU

PENILAIAN EKONOMI TERHADAP PENJUAL TELUR PENYU DI TERENGGANU 2019

(“ECONOMIC VALUATION OF SEA TURTLE EGG SELLERS IN TERENGGANU, 2019”)

PENDAHULUAN

a) Universiti Malaysia Terengganu dan Sarawak Forestry Corporation sedang menjalankan satu kajian bertajuk ”PENILAIAN EKONOMI TERHADAP PENJUAL TELUR PENYU DI TERENGGANU 2019”. Projek ini bertujuan menentukan nilai ekonomi telur penyu di Terengganu.

b) Maklumat yang diperlukan adalah mengenai nilai ekonomi yang diraih melalui penjualan telur penyu dan kesanggupan utuk merubah aktiviti penjanaan ekonomi supaya penyu di Terengganu dapat dipelihara secara mampan untuk generasi akan datang.

c) Tuan/ Puan telah dipilih secara rawak untuk memberikan maklumat kepada soalan-soalan yang dikemukakan untuk menjayakan kajian ini.

d) Maklumat yang diberikan akan membantu kajian ini untuk memberikan nilai ekonomi terhadap penhualan telur penyu dapat memberitahu kepada penggubal dasar tentang kerugian kos jikapenjualan telur penyu dihentikan.

e) Semua maklumat yang tuan/ puan berikan adalah RAHSIA dan hanya digunakan untuk kajian ini semata-mata.

TERIMA KASIH

BORANG SOAL SELIDIK

Responden ***Nama :*** ____________________

Alamat : ____________________

____

Interviewer ***Nama :*** ____________________

Tarikh : ____________________

Masa Mula : ____________________

Masa Tamat : ____________________.

November 2019

SEKSYEN A : SOALAN UMUM BERKAITAN CIRI-CIRI SOSIO-EKONOMI

1. Jantina responden:

	Lelaki
	Perempuan

2. Umur responden:

	Dibawah 20
	20 – 29
	30 – 39
	40 – 49
	50 – 59
	60 ke atas

3. Adakah penjual/penjaja di pasar ini pekerjaan utama anda?

	Ya
	Tidak

4. Apakah pekerjaan lain yang anda lakukan ketika musim tengkujuh (Oktober-Febuari)?

	Petani/Pekerja bidang pertanian
	Pengurus
	Pekedai dan pekerja bidang pemasaran
	Pekerja Binaan
	Kerani
	Pemilik Perniagaan Kecil/ Jualan Runcit
	Pekerja Kilang
	Tidak bekerja (pesara, pelajar, suri rumah dan sebagainya.)
	Juruteknik
	Lain-lain (sila nyatakan:___________________)

5. Apakah purata pendapatan anda dalam sebulan dalam musim tengkujuh (Oktober-Febuari)?

	RM 0 – 1,000
	RM 1,001 – 2,000
	RM 2,001 – 3,000
	RM 3,001 – 4,000
	RM 4,001 – 5,000
	RM 5,001 – 6,000
	Lebih daripada RM 6,000

6. Apakah purata pendapatan anda dalam sebulan di luar musim tengkujuh (Mac-September)?

	RM 0 – 1,000
	RM 1,001 – 2,000
	RM 2,001 – 3,000
	RM 3,001 – 4,000
	RM 4,001 – 5,000
	RM 5,001 – 6,000
	Lebih daripada RM 6,000

7. Apakah pekerjaan lain yang anda lakukan di luar musim tengkujuh (Mac-September)?

	Petani/Pekerja bidang pertanian
	Pengurus
	Pekedai dan pekerja bidang pemasaran
	Pekerja Binaan
	Kerani
	Pemilik Perniagaan Kecil/ Jualan Runcit
	Pekerja Kilang
	Tidak bekerja (pesara, pelajar, suri rumah dan sebagainya.)
	Juruteknik
	Lain-lain (sila nyatakan:___________________)

SEKSYEN B : SEKSYEN INI BERTANYAKAN SOALAN YANG BERKAITAN PELANGGAN DAN BARANGAN JUALAN

1. Kebanyakan pelanggan terdiri daripada

	Pelancong Luar Negara
	Pelancong Dalam Negara
	Penduduk Sekitar/ Terengganu

2. Barang yang menjadi tumpuan pelanggan dan jumlah unit yang dibeli setiap pelanggan

	Jenis Barangan	Jumlah Unit
	Makanan Ringgan	
	Jeruk	
	Keropok Lekor	
	Keropok Kering	
	Kuih Tradisional (Akok, Dodol, Lampuk , dan lain-lain)	
	Serunding	
	Hasil Laut Segar	
	Sayur-sayuran	
	Buah-Buahan	
	Tekstil (Songket, Batik, dan lain-lain)	
	Barangan Tembaga & Besi	
	Cenderahati	
	Telur penyu	

3. Harga setiap unit barangan dalam musim tengkujuh (Oktober-Febuari)

	Jenis Barangan	Harga Setiap Unit
	Makanan Ringgan	
	Jeruk	
	Keropok Lekor	
	Keropok Kering	
	Kuih Tradisional (Akok, Dodol, Lampuk , dan lain-lain)	
	Serunding	
	Hasil Laut Segar	
	Sayur-sayuran	
	Buah-Buahan	
	Tekstil (Songket, Batik, dan lain-lain)	
	Barangan Tembaga & Besi	
	Cenderahati	
	Telur penyu	

4. Harga setiap unit barangan di luar musim tengkujuh (Mac-September)

	Jenis Barangan	Harga Setiap Unit
	Makanan Ringgan	
	Jeruk	
	Keropok Lekor	
	Keropok Kering	
	Kuih Tradisional (Akok, Dodol, Lampuk , dan lain-lain)	
	Serunding	
	Hasil Laut Segar	
	Sayur-sayuran	
	Buah-Buahan	
	Tekstil (Songket, Batik, dan lain-lain)	
	Barangan Tembaga & Besi	
	Cenderahati	
	Telur penyu	

5. Permintaan barang dangangan ketika musim tengkujuh (Oktober-Februari)

Jenis Barangan	Meningkat	Menurun
Makanan Ringgan		
Jeruk		
Keropok Lekor		
Keropok Kering		
Kuih Tradisional (Akok, Dodol, Lampuk , dan lain-lain)		
Serunding		
Hasil Laut Segar		
Sayur-sayuran		
Buah-Buahan		
Tekstil (Songket, Batik, dan lain-lain)		
Barangan Tembaga & Besi		
Cenderahati		
Telur penyu		

6. Bekalan barang dagangan ketika musim tengkujuh (Oktober-Februari)

Jenis Barangan	Meningkat	Menurun
Makanan Ringgan		
Jeruk		
Keropok Lekor		
Keropok Kering		
Kuih Tradisional (Akok, Dodol, Lampuk , dan lain-lain)		
Serunding		
Hasil Laut Segar		
Sayur-sayuran		
Buah-Buahan		
Tekstil (Songket, Batik, dan lain-lain)		
Barangan Tembaga & Besi		
Cenderahati		
Telur penyu		

7. Adakah pengurangan bekalan telur penyu ini memberikan kerugian kepada peniaga?

	Ya
	Tidak

8. Anggaran harga telur penyu yg di tawarkan oleh pembekal kepada penjaja di luar musim tengkujuh (Mac-September)

9. Anggaran harga telur penyu yg di tawarkan oleh pembekal kepada penjaja ketika musim tengkujuh (Oktober-Februari)

10. Sumber bekalan telur penyu

	Pemegang Tender
	Peraih/ Orang tengah
	Ahli Keluarga
	Rakan
	Nelayan
	Mengumpulkan Sendiri

11. Pada pandangan anda, mengapakah pendapatan anda di musim tengkujuh berubah?

	Cuaca yang menyukarkan pelanggan berkunjung ke pasar/gerai
	Bekalan barangan bekurang
	Pembekal menaikan harga
	Pembeli kurang membeli kerana penjual menaikkan harga
	Lain-lain (sila nyatakan:___________________)

12. Pada pandangan anda, apakah inisiatif yang boleh dilakukan kerajaan bagi meningkatkan pendapatan penjual?

	Melatih rakyat ke arah sumber pendapatan alternatif
	Memperkasakan pemuliharaan sumber
	Memberi peruntukan untuk peniaga dalam musim tengkujuh
	Mengawal jenis dan jumlah barang dagangan
	Mengawal harga

TERIMA KASIH DI ATAS KERJASAMA YANG DIBERIKAN

Appendix 18

Human etiquette form

ETHICAL CONDUCT IN HUMAN RESEARCH
APPLICATION FORM

PART A: Brief Details of Project

Title of Proposal	:	**Survey on economic valuation of sea turtle egg sellers in Terengganu, 2019.**
Project Start	:	**August 2018**
Project End	:	**January 2019**
Research funding/Grant	:	**Not Applied**
Amount of Research Grant	:	**Not Applied**

PART B: Applicant Details

1. Principal Investigator

Name	:Mohd Uzair Bin Rusli
Title	: DR
Position	:Lecturer
Telephone	: +6096683163/3846
Email	: uzair@umt.edu.my
Department	:SEATRU
Academy/Faculty/Institute/Centre	: INOS

2. Co-Investigator/s (if any)

Name	:Mahirah Binti Kamaludin
Title	: DR
Position	:Lecturer
Telephone	: +609 6684191
Email	: mahirah.k@umt.edu.my
Department	:Economics
Academy/Faculty/Institute/Centre	: Faculty of Business, Economics and Social Development

(if more than one, please provide a list of co-investigators as an attachment)

3. Student Investigator/s (if any)

Name	:Anis Syafinas Binti Muhammad Dahri
Title	: Miss
Position	:Researcher
Telephone	: +601137268869
Email	: p3385@pps.umt.edu.my
Department	:SEATRU
Degree/Programme	:Biodiversity and Conservation (Msc)

Academy/Faculty/Institute/Centre : INOS

(if more than one, please provide a list of co-investigators as an attachment)

PART C: Data Collection

4. New data to be collected from human participant. Please tick any that apply.

☒ Focus group
☐ Experimental procedures/treatment/intervention
☐ Internet survey
☒ Observation
☒ Personal interviews
☐ Telephone survey
☐ Participant Journals / Diary
☒ Questionnaire
☐ Others (please state):Click here to enter text.

5. Existing records with personal data. (For example, records from organisations that contain medical status of participants)

☐ Yes
☒ No

6. Brief description of study.
   i. Background of study (less than 300 words).

   One of the factors that cause the leatherback turtle to extinct in Terengganu was the long history of eggs exploitation (WWF, 2009). Nowadays, this eggs exploitation continued for other species in Terengganu such as the green turtles and hawksbill turtles.

   ii. Rationale of study/problem statement (less than 300 words)

   The qualitative study of the current market was not updated in recent years. Thus, this study will help the state government and community to identify the price trend of the sea turtle eggs in Terengganu based on the season. The monthly price trends able to demonstrate the crucial link between sea turtle egg supply and the market price. Besides, this study also helps to clarify the current sea turtle eggs market characteristic in Terengganu. This study is important to demonstrate the impact of the sea turtle eggs selling and consumption on the sea turtle population size.

iii. Objective(s) of study.
This study was composed to identify the qualitative aspect of the sea turtle eggs current market in Terengganu.

7. Study participants (new data to be collected from human participants).
   i. Study sample. Please specify.
   Sea turtle eggs sellers

   ii. How will participants be recruited? Please specify.

   Based on observation in Pasar Payang, Terengganu, Malaysia

   iii. Who will perform the data collection?
   SEATRU Team

   iv. Participant inclusion criteria (e.g. residents aged 18 years and above).

   Not Applied.

   v. Participant exclusion criteria.

   Not Applied

   vi. Are the participants given any form of payment/incentive to participate?

   No

PART D: Risk and Benefits

8. Possible benefits to participants:
   This research possibly help the egg sellers to understand more about the sea turtles and the eggs market

9. Risk of harm (new data to be collected from human participants).

RISK	YES	NO
Will the study involve intervention, such as treatment of any type? If YES, please give details: Click here to enter text.	☐	☒
Is it possible that the duration of the procedures will cause minimal stress, in particular, for children, given their age and capacity?	☐	☒
Is it possible that the study will involve greater than minimal privacy risks, which could induce stress to research participants, such as political behaviour, illegal and sexual conduct, drug or alcohol use?	☐	☒

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Will the study cause psychological stress/pain/discomfort? If YES, please state the precautions taken to minimize such stress/pain/discomfort/risk : ____	☐	☒
Are any of these participants from a minority/culturally identifiable/disadvantaged group? (e.g. *Orang Asli*) Please specify: Click here to enter text.	☐	☒

i. If any of the responses above is yes, describe potential risk/conflict of interest of the study and **provide a plan to mitigate the risk/conflict of interest**.

Potential Risk/Conflict of Interest	Mitigation Plan

PART E: Privacy and Confidentiality

10. Describe how you will preserve participant's confidentiality as you collect and analyse the data and when you report the result. (e.g. anonymity of participants or company / organisation involved).
    Anonymity of participants
    The results will only be analysed qualitatively
    Only group information will be presented
11. Existing data (if you are using existing records containing personal data).
    i. Please state the source of the data.
       Not Applicable

    ii. Are the data sensitive? (e.g. sexual preference, health status, criminal activity)
       ☐ YES
       ☒ NO

    iii. Please provide full details of types of personal data to be used:

       Name and address

12. Data record.

i. Do you intend to use any of the following recording devices as a means of collecting data? *(tick all that apply)*

11. Audio/Sound recorder (tape/cds / telephone) ☐
- Photography (including digital cameras/phones) ☒
- Film/Video/DVD recorder ☐
- Computer ☐
- Other ☐
- *If 'Other', please give details*

____

ii. Describe what you will do with the recorded data once it has been analysed.

Maintain its confidentiality

iii. Specify who apart from yourself will have access to the research data.

Not Applicable

iv. Details who will own the data and the results of your research.

Miss Anis Syafinas

PART F: Conflict of Interest

13. Do any of the researchers have any potential conflicts of interest?

No

PART G: Ethical Approval from other Body

14. Has this proposal received Ethical Approval from another body?

(e.g. Hospital or any organisations)

☐ Yes, all sections ☐ Yes, some sections ☒ No

15. If Yes, give details below:

Name of the organisation that has approved the study: _______________

Approval No: ________________

Approval Date: _______________

If not, all sections have been approved by this body, please provide a brief account of aspects not covered:

Please provide a copy of the approval in your supporting documentation

PART H: ATTACHMENTS

16. Please tick the boxes - which of the following documents are enclosed.

☒ Questionnaire/ interview protocol
☒ Participant Information Sheet
☒ Informed Consent Form (should at least includes the followings):

- A statement that the study involves research, an explanation of the purposes of the research, the expected duration of a subject's participation, a description of the procedures to be followed, and if applicable identification of any experimental procedures.
- A description of any foreseeable risks or discomforts to the subject
- A description of any benefits to the subject, or society, that may reasonably be expected from the research.
- If appropriate, a disclosure of appropriate alternative procedures or treatments, if any, that might be advantageous to the subject.
- A statement describing the extent to which confidentiality of records identifying the subject will be maintained.
- For research involving more than minimal risk, an explanation of the compensation and medical treatments available if injury occurs, and where further information may be obtained.

- Explanation of whom to contact for answers to pertinent questions about the research and subjects' rights, and whom to contact in the event of a research-related injury.
- A statement that taking part in the study is voluntary, refusal to participate will involve no penalty or loss of benefits the subject is otherwise entitled to and the subject may discontinue participation at any time with no penalty or loss of benefits
- One of the following statements about any research that involves the collection of identifiable information.

☐ Ethical Approval from other Body

☐ Brief CV for all Investigators (not more than 2 pages of each CV)

☐ Others: Please state

____

PART I: Declaration

"In making this application, I certify that I have read and understand the Guidelines for Research Ethics University Malaysia Terengganu and I will comply with the ethical principles of the documents. I will submit, as appropriate, a report for amendment of an approved project, if there are significant changes to my research or if there is an adverse incident".

Signature of Applicant :

Name : Anis Syafinas Binti Muhmmad Dahri

Date : 25 Jun 2021

Stamp (if any) : Not Applicable

Signature of Supervisor : ____________________________

Name : DR Mahirah Binti Kamaludin

Date : ____________________________

Stamp :

I hereby endorse that this applicant is appropriately qualified in the research area involved to conduct the proposed research project and is capable of undertaking this research study in a safe and ethical manner.

Signature : ____________________________

(Dean of Faculty /Head of Department)

Name : ____________________________

Date : ____________________________

Stamp :

BIODATA OF AUTHOR

Anis Syafinas Binti Muhammad Dahri

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Anis Syafinas Binti Muhammad Dahri is a researcher in SEATRU, a research unit that focus on studying and conserving sea turtles. Previously, she enrolled in Degree of Applied Science (Fisheries) from 2013 to 2016.She recently has devoted this these years research on tender system and their impact to sea turtle population health. She has developed experience in sea turtle conservation by joining those in SEATRU research station, Chagar Hutang, Redang Island and Lang Tengah Turtle Watch (LTTW) at Lang Tengah Island and Tanjong Jara Resort, Dunggun. To spark community awareness, she has presented her result in Research and Innovation Weeks (MPI) 2019 that award her with bronze medal besides participating in 2nd Seminar on Biological Security and Sustainability (BIOSES) 2019. She determined to continue her study in phD and became a lecture that able to help educate the next generation with unique ways and her own personal manner.