SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Estimating the Population Growth Curve of Sea Turtle Eggs Production in Terengganu, Malaysia: Mathematical Modelling Approach

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ARTICLE INFO

Article history:
Received 28 April 2023
Received in revised form 12 August 2023
Accepted 20 August 2023
Available online 4 September 2023

Keywords:
Growth Curve; Exponential Model; Logistic Model; Conservation Management; Mathematical Modelling

ABSTRACT

A growth curve is a growth pattern that is unique to each organism, species, or population. In general, the growth pattern is regulated by genetic and environmental factors, resulting in unique growth curves for each subpopulation of the same species. This research was written to identify the growth curve of the Terengganu's sea turtle eggs population. This work was aided by a mathematical modelling technique, specifically the exponential and logistic growth models. The aim of this research is to select the most realistic model to describe sea turtle eggs production in Terengganu. Furthermore, this work is also intended to forecast the future population growth of sea turtles in Terengganu. Error analysis is used to compare the error produced by both models in comparison with the real data of sea turtle eggs. As a result, the logistic model is better suited to describing the growth of sea turtle eggs production in Terengganu. The logistic model indicated that the sea turtle population would steadily increase until it reached it carrying capacity. Thus, this research is critical for ensuring the sustainability of sea turtles by understanding the mechanism of logistic growth.

1. Introduction

Organisms pick an *r*- or *K*- strategy (growing exponentially or logistically) by balancing quantity (reproduction rate, number of offspring) and quality (competence for survival). To maximise fitness, species must carefully allocate the amount they invest in either the quality or quantity of offspring. The choice between quantity and quality is required since the energy or effort invested can only be directed to one of them. Yet, because survival is essential for production, the best approach is always a combination of both *r*- and *K*- methods, namely $r-K$ strategy. E.O. Wilson created the $r-K$ life history hypothesis in 1975, where r stands for the rate of reproduction. r -selection is the process through which organisms that thrive in a short-term resourceful but dangerous environment and reproduce quickly evolve. Mice, fish, and insects are r species examples. K-selection, which refers to

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https://doi.org/10.37934/araset.32.1.332342

the nurturing ability within the reproductive strategy found in evolutionarily unfavourable settings, is the reverse of r-selection. The evolution of species at the bottom of the food chain is known as K -selection. These species reproduce slowly and devote a large percentage of their resources to caring for their few young [1].

Sea turtles are unique organisms with biological characteristics of both *r*- and *K*- strategies. High reproductive output is a prominent *r*-strategy (exponential) trait of sea turtles. Sea turtles lay a high number of eggs, receive no parental care [2], and lay many clutches in a season and throughout their lives [3]. A nesting mother can deposit up to nine or ten clutches in a nesting season with an interval of thirteen days between clutches [4].

Each clutch only contains between 65 to 180 eggs. Sea turtles exhibit *K*- strategy characteristics as well, such as slow and limited growth. Sea turtles, for example, have a relatively lengthy life span ranging from 75 to 100 years [5], resulting in delayed sexual maturity. It takes an average of 20-30 years for hatchlings to mature into adults [6]. Furthermore, because sea turtles exhibit natal homing behaviour, they are impacted by carrying capacity in the same way that other *K*- selected animals are. Natal homing restricted sea turtle population growth as it is 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 [7].

Earlier, conservation efforts in Terengganu centred on coastal monitoring and hatcheries of protected nesting places [8]. Siow and Moll [9], pioneers in sea turtle monitoring, stated that sea turtle egg production in Terengganu was around 1,664,400 in 1951. Yet, this high total annual egg production is most likely understated [9]. Subsequently, in 1956, it was discovered that two million eggs were produced on Peninsular Malaysia's East Coast. Afterwards, in 2010 over 400,000 eggs were incubated, and 270,000 hatchlings were released back into their natural environment [10].

In the past, a lot of studies concentrated on determining sea turtle population increase using statistical methods; examples may be found in [11–14]. There are, however, still few studies that have predicted sea turtle growth using a mathematical modelling technique. Mathematical modelling is the depiction of physical tools and objects in terms of mathematics. Predictions, analyses, and observations are typically involved in the process of developing mathematical models. Modelling approach have been used by many fields to analyse or solving real world problems, see for examples in [15-18].

In the management of turtle conservation in the state of Terengganu, the government through the Department of Fisheries will repurchase eggs from egg collectors. Consequently, a substantial amount of funds is required for this effort. Therefore, it is necessary for the government to allocate a sufficient budget at the beginning of the year, and this matter requires projections of sea turtle egg production.

The goal of the current study is to use mathematical modelling to detect the growth curve that the production of sea turtle eggs in Terengganu possesses. The exponential and logistic models, which are classified as single-species models [19], are taken into consideration in this study. These models have really been widely applied for a variety of other real-world applications [20–23]. The error analysis is then performed on both models. The model with the minimum error will then be selected as the ideal model to depict the growth of the Terengganu sea turtle population. These two models were chosen because they are commonly used to predict population growth over time [24]. Furthermore, these two models have been widely employed in population growth studies [25]. Nonetheless, these models were chosen primarily because they included the most important reproductive characteristic of sea turtles.

2. Methodology

This section covers the data collection procedure, the exponential and logistic models, and finally the error analysis. These steps have been taken to determine the best growth model for sea turtle egg production in Terengganu.

2.1 Data Collection for Terengganu Sea Turtle Eggs

The Terengganu State Department of Fisheries Malaysia (DoF) [26] provided secondary data for this study. DoF supplied nesting data includes nesting density, location, and beach type. All beaches with no nesting data records were labelled as having no nesting data (ND) and were believed to have 0% nesting density. Figure 1 depicts the trend for the sea turtle eggs for 12 years data.

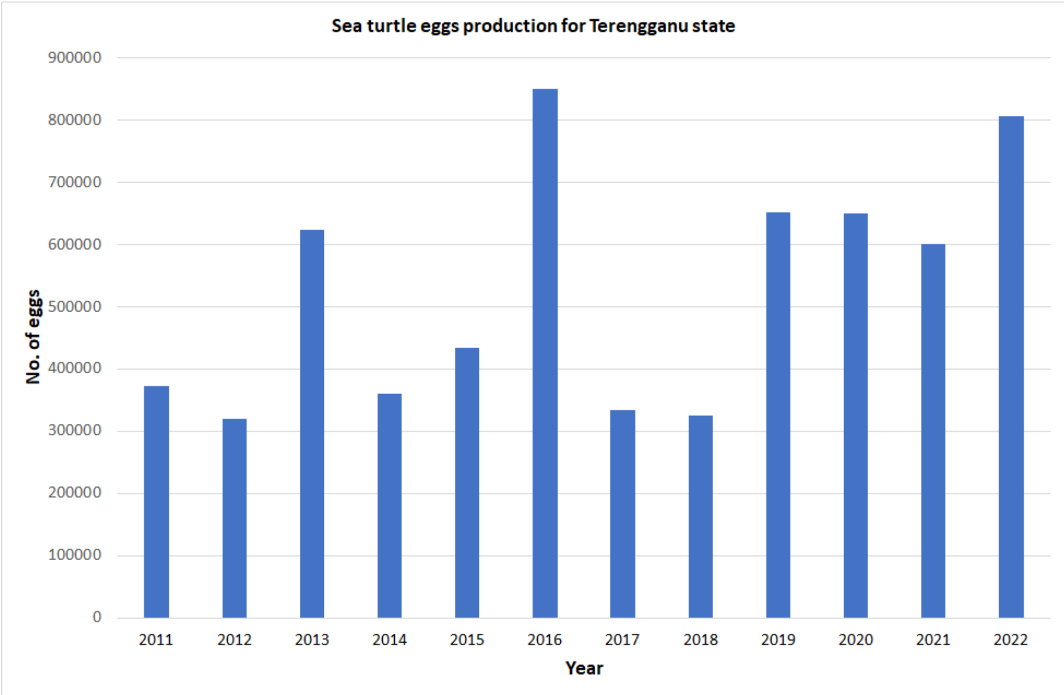

Fig. 1. The annual sea turtle eggs production in Terengganu from year 2011-2022 [26]

2.2 Determination of Growth Rate of Sea Turtle Eggs Production

The growth rate, r for sea turtle eggs production can be calculated based on the annual growth rate. The formula can be given as:

$$\text{Annual growth rate} = \frac{\text{Sea Turtle Eggs Production in Recent Year}}{\text{Sea Turtle Eggs Production in Previous Year}} - 1. \tag{1}$$

The annual growth rate was calculated according to the number of eggs laid in Terengganu between 2011-2022 as listed in **Error! Reference source not found.**Figure 1 previously. C onsequently, there are 11 consecutive annual population growth. Then, the average of these growths can be determined based on the following formula:

$$r = \frac{\text{Sum of growth rates r from 2011-2022}}{2022-2011}. \tag{2}$$

2.3 First Approach: Exponential Model

This section investigated whether the Terengganu sea turtle population is growing at an exponential rate. The exponential model was used in this study because it works well with simple homogeneous populations [19]. The exponential model is the most basic realistic model for population dynamics [23], assuming that population size increases exponentially over time [20]. According to the growth notion, the population witnessed a rapid increase in the number of individuals. The exponential model was employed in this study because each sea turtle can produce a significant number of eggs throughout its reproductive age. Hence, the exponential model for sea turtles in Terengganu was built based on Kot [19]. The flow diagram for exponential model is shown in Figure 2 where x denoted as the number of green turtle eggs in Terengganu while r represents the growth rate of the eggs.

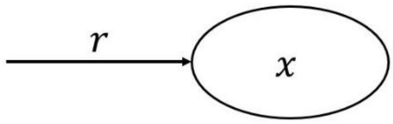

Fig. 2. Flow diagram of the exponential growth model

Thus, the exponential growth model for sea turtles in Terengganu is constructed based on Kot [19] as mentioned below:

$$\frac{dx}{dt} = rx. \quad (3)$$

The above Eq. (1) is written in the ordinary differential equation form [19]. All symbols in Eq. (3) are described in Table 1.

Table 1
Description of notations for model (3)

Notation	Description
dx/dt	Rate of changes for sea turtle eggs over time
t	Time (in years)
x	The population size of sea turtle eggs at time t
r	The average annual growth rate of the sea turtle eggs in Terengganu

The Eq. (3) can be solved by integrating this equation to get the following solution:

$$x(t) = x_0 e^{rt}, \quad (4)$$

where $x(t)$ is the number of eggs at time t, x_0 is the number of eggs at the beginning and r is the growth rate.

2.4 Second Approach: Logistic Model

This study also looked into whether the Terengganu sea turtle population is growing logistically. This logistic model is used in this study because it recognises the potential of "scarce resources" [24]. The scarcity of resources hampered population growth. This limitation is a saturation level known as carrying capacity, which is defined by the environment encountered by a stable population [27].

Because this model includes carrying capacity, it is classified as a density-dependence model [19]. This basically means that population growth is governed by population size and the carrying capacity of the environment at the moment. This model was used in this study because sea turtles have biological traits that are limited by carrying capacity. For instance, sea turtles exhibited natal homing behaviour, which limited them to laying eggs on or near the nesting beach where they were born. However, each nesting beach has a carrying capacity and can only contain a particular number of eggs or nests at one time. This can eventually limit and delay the increase in sea turtle population size. Hence, in this situation, the sea turtle population model was built in accordance with Kot [19] as illustrated in Figure 3.

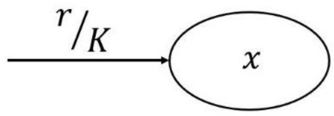

Fig. 3. Flow diagram of the logistic growth model

From the flow diagram, the logistic model equation is given below:

$$\frac{dx}{dt} = rx\left(1 - \frac{x}{K}\right), \tag{5}$$

where K denoted the nesting carrying capacity, and the rest of the symbols are as defined in **Error! Reference source not found.**. The Eq. (5) can be solved by integrating this equation to get the following solution:

$$x(t) = \frac{Kx_0}{(K - x_0)e^{-rt} + x_0}, \tag{6}$$

where $x(t)$ is the number of eggs at time t, x_0 is the number of eggs at the beginning, r is the growth rate and K is the carrying capacity.

2.5 Error Analysis

In this research, an error analysis is performed to compare the actual data with the predicted data. There are many types of error, however in this paper, we use the absolute percentage error. This type of error has been widely used by many researchers including the one by Khair *et al.,* [28]. The error analysis is performed by comparing Terengganu's actual egg production to the predicted egg production based on the exponential and logistic models. In this investigation, the absolute percentage error's formula is given as follows:

$$\text{Absolute \% Error} = \left|\frac{\text{Actual Eggs Production-Predicted Eggs Production}}{\text{Actual Eggs Production}} \times 100\right|. \tag{7}$$

3. Results and Discussion

In this section, the growth rate computed from the yearly data in Figure 1 is presented. This growth rate r is then embedded in the exponential and logistic models to predict the future number of eggs laid in Terengganu. Note that for the logistic model, we assume that the nesting carrying capacity is $K = 1$ million. Moreover, the error analysis of both models will then be illustrated in this section. Finally, the number of eggs is estimated based on the least error model.

3.1 Growth Rate for Sea Turtle Eggs

Based on the formulas given in Eq. (1) and Eq. (2), the annual growth rate and the average annual growth rate of sea turtles in the Terengganu are obtained as in Table 2. There are 11 values of the annual growth rates, in which they are mixed of positive and negative values. Positive values indicate that there are increasing number of eggs for current year in comparison with the previous year, while the decreasing number for the previous year will give negative values. Thus, by summing all the annual growth rate, the average growth rate obtained is $r = 0.199$.

Table 2
The annual growth rates and average growth rate r

Year	Eggs Production in Recent Year	Growth rate
2011	372786	0
2012	320163	-0.141
2013	622548	0.944
2014	359527	-0.422
2015	433042	0.204
2016	850347	0.964
2017	332666	-0.609
2018	324515	-0.025
2019	650438	1.004
2020	650096	-0.001
2021	599893	-0.077
2022	806110	0.344
Average growth rate		0.199

3.2 Model Comparison Based on Error Analysis

As a matter of fact, the absolute error was considered in this study to select the best model for sea turtles in Terengganu. Since errors are unavoidable, the model with the minimum error is regarded as the ideal growth model. According to Table 3, the exponential model has an absolute error between 0 and 317%, with an average error of 166.5%. The logistic model, on the other hand, has an error range of 0-117.8% with an average error of 37.9%.

Table 3
The comparison of absolute error (%) for exponential and logistic models

Year	Actual Sea Turtle Eggs Production	N	Exponential Model	Absolute % Error	Logistic Model	Absolute % Error
2011	372786	0	372786	0.0	372786	0.0
2012	320163	1	455322	42.2	420607	31.4
2013	622548	2	556131	10.7	469965	24.5
2014	359527	3	679260	88.9	519919	44.6
2015	433042	4	829651	91.6	569477	31.5
2016	850347	5	1013337	19.2	617681	27.4
2017	332666	6	1237693	272.1	663675	99.5
2018	324515	7	1511722	365.8	706764	117.8
2019	650438	8	1846421	183.9	764440	17.5
2020	650096	9	2255223	246.9	782402	20.4
2021	599893	10	2754537	359.2	814530	35.8
2022	806110	11	3364399	317.4	842867	4.6

Average Error (%)	166.5	37.9

Since the logistic model has smaller errors as compared to the exponential model, therefore logistic model is more reliable for the actual data provided in Figure 1. Biologically, we can say that the production of sea turtle eggs in Terengganu would grow logistically.

Meanwhile, Figure 4 graphically shows the comparison between actual data with the two models. It can be seen clearly that the actual data is more fitted with the logistic model (grey curve) compared to the exponential model (orange curve).

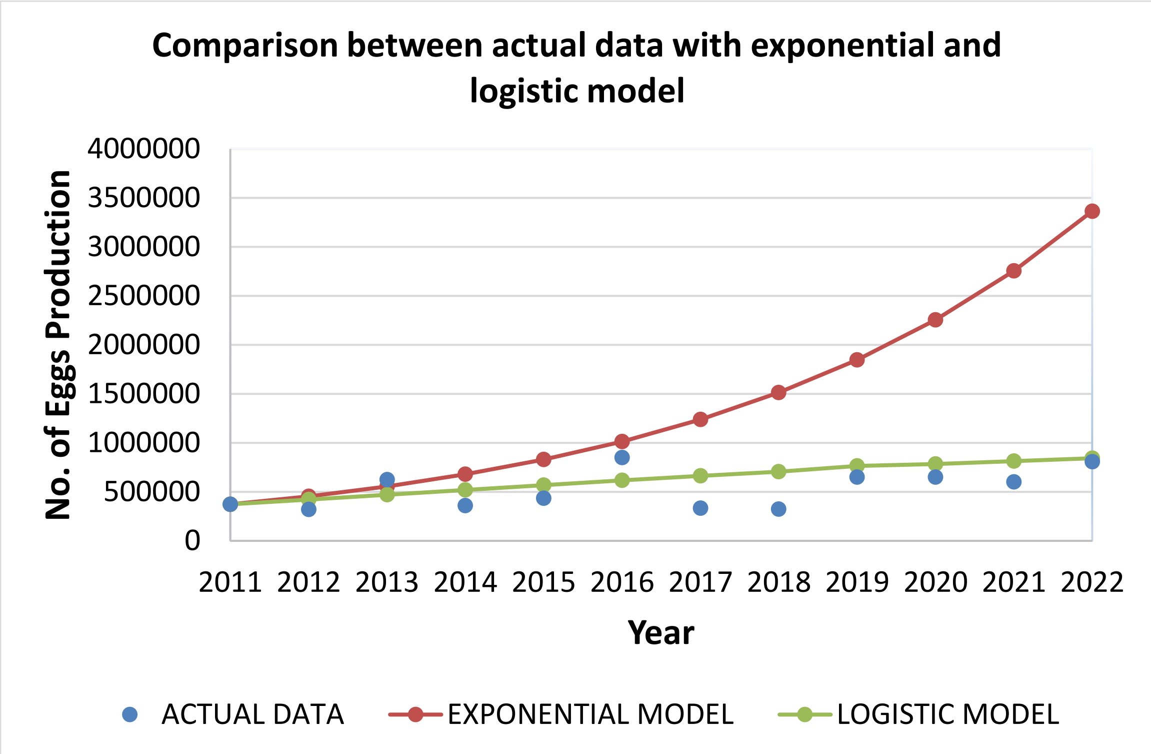

Fig. 4. Comparison between actual data with exponential and logistic models

Therefore, following from the above results, it can be said that sea turtle eggs in Terengganu grow logistically, demonstrating that their survival strategy is to prioritise quality over quantity [29]. For example, sea turtle hatchlings have increased intellect and viability in recognising many physical cues to live and care for themselves. This was seen as hatchlings crawled towards the sea using multisensory signals (visual, olfactory, and magnetic fields) [30]. Sea turtles evolve this *K*-selection defence strategy because they are constantly confronted with restricted resources and intense intraspecific competition. This, however, makes them incapable of producing a large number of offspring in a short period of time, limiting their population growth. Population growth was limited by carrying capacity. Carrying capacity is a numerical upper limit on population growth observed at saturation [27]. The carrying capacity of sea turtles limits their growth for a variety of biological reasons, including:

i. intraspecific density-dependent factors
ii. weak sex drive
iii. uncertain nutrition
iv. high mortality rate

3.3 Prediction of Sea Turtle Eggs based on Logistic Model

From the previous section, we have obtained that the logistic model gives fewer errors compared to the exponential model. Thus, in this section, we use the logistic model to predict for future number of sea turtle eggs for eight incoming years (i.e., from years 2023-2030). The results are shown in Table 4 and the plot is as in Figure 5.

Table 4
The actual and forecasted data using the logistic model (4)

Year	Actual Sea Turtle Eggs Production	Logistic Model
2011	372786	372786
2012	320163	420607
2013	622548	469965
2014	359527	519919
2015	433042	569477
2016	850347	617681
2017	332666	663675
2018	324515	706764
2019	650438	764440
2020	650096	782402
2021	599893	814530
2022	806110	842867
2023	-	867579
2024	-	888916
2025	-	907183
2026	-	922708
2027	-	935819
2028	-	946835
2029	-	956048
2030	-	963726

In Figure 5, we divide the time series into two regions, in particular Region I and Region II. Region I is the region in which the actual data is plotted with the predicted data using the logistic model. In this region, the predicted curve is increasing steadily from the year 2011 to 2022. On the other hand, Region II shows the future number of sea turtle eggs that are expected to be produced by the state of Terengganu from years 2023 to 2030. In this region, the number of eggs is increasing but with a slower pattern as compared to Region I and, finally maintain between 800,000 to 1 million eggs. In fact, 1 million is the value that has been assigned to be the nesting carrying capacity for the logistic model in Eq. (4).

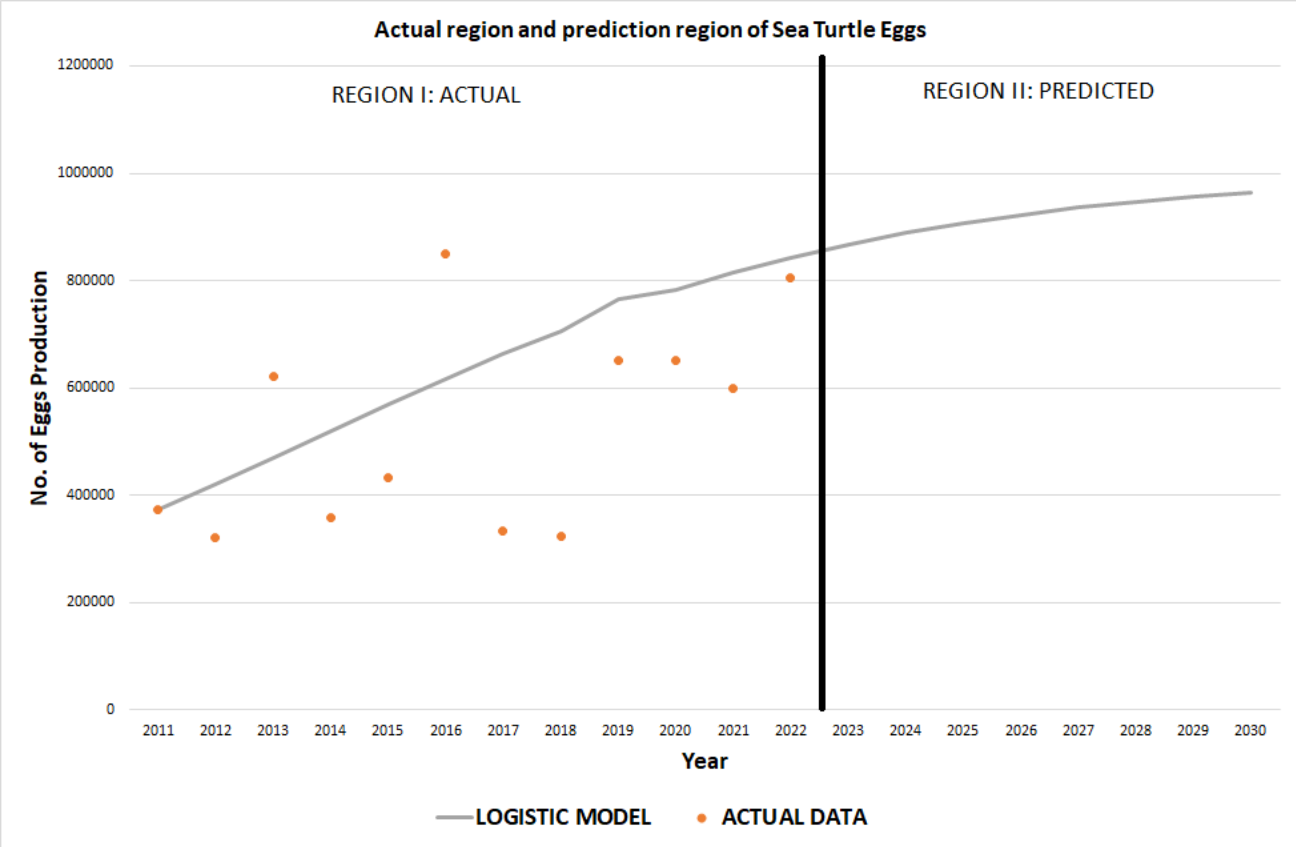

Fig. 5. The two regions of actual and predicted number of sea turtle eggs

4. Conclusions

Sea turtle eggs production varies greatly depending on the location and species of sea turtles. In this paper, we consider the production of the growth of sea turtle eggs in Terengganu state, Malaysia. The data obtained shows a pattern of fluctuations throughout the years 2011-2022. Thus, this study was aimed to identify the growth curve of the sea turtle eggs for this state. The first step was to calculate the average growth rate of the eggs. The result shows that the growth rate is 0.199 and, biologically, it means that the sea turtle eggs grow at a small percentage, that is about 20% from one year to another year. The second step was to determine the best fit for the historical data, that is, by applying a mathematical modelling technique: the exponential and logistic growth models. Both models used the same growth rate as obtained from the first step. An error analysis, namely, the absolute percentage error, was implemented on both models and the results revealed that the logistic model produced less error compared to the exponential model. Thus, the final step was to use the logistic model to make predictions for future number of eggs that will be produced by Terengganu for year 2023-2030. Since the eggs grow logistically, then the number of eggs will steadily increase until it hits carrying capacity. Thus, this research is significant in ensuring the sustainability of the sea turtle population in the future. Moreover, the results obtained from this research can be used to help the government and policy makers to increase conservation effort for such a unique population. Future research in this area should concentrate on assessing the carrying capacity, degradation point, and recovery strategy of each nesting beach in order to ensure the survival of sea turtles in Terengganu.

Acknowledgement
We thank Universiti Malaysia Terengganu for providing funding support for this project through Translational Research Grant (UMT/TRANS/2020/53329).

References

[1] Yinyin, Cai, Linjie Chou, and Donald Templer. "TRUST AND rK LIFE HISTORY ADAPTATION." *International Journal of Academic Research* 4, no. 4 (2012). https://doi.org/10.7813/2075-4124.2012/4-4/B.9
[2] Rusli, Mohd Uzair. "Nesting of sea turtles." In *Encyclopedia of animal cognition and behavior*, pp. 4610-4612. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-319-55065-7_628
[3] Mclellan, Elisabeth, Elies Arps, and Marydele Donnelly. "WWF Global Marine Turtle Strategy 2009-2020." *WWF, Gland, Switzerland* (2009).
[4] Ekanayake, E. M. L., T. Kapurusinghe, M. M. Saman, D. S. Rathnakumara, P. Samaraweera, and R. S. Rajakaruna. "Reproductive output and morphometrics of green turtle, Chelonia mydas nesting at the Kosgoda rookery in Sri Lanka." *Ceylon Journal of Science* 45, no. 3 (2016). https://doi.org/10.4038/cjs.v45i3.7406
[5] Bean, Michael J. "Sea Turtle Conservation." *Science* 207, no. 4437 (1980): 1297-1297. https://doi.org/10.1126/science.207.4437.1297.a
[6] Kemf, Elizabeth, Brian Groombridge, Alberto Abreu, and Alison Wilson. "MARINE TURTLES IN THE WILD. 2000–A WWF SPECIES STATUS REPORT." In *OF THE TWENTY-FIRST ANNUAL SYMPOSIUM ON SEA TURTLE BIOLOGY AND CONSERVATION*, p. 212. 2005.
[7] Lohmann, Kenneth J., and Catherine MF Lohmann. "There and back again: natal homing by magnetic navigation in sea turtles and salmon." *Journal of Experimental Biology* 222, no. Suppl_1 (2019): jeb184077. https://doi.org/10.1242/jeb.184077
[8] Mohd Jani, Jarina, Muhammad Allim Jamalludin, and Seh Ling Long. "To ban or not to ban? Reviewing an ongoing dilemma on sea turtle egg trade in Terengganu, Malaysia." *Frontiers in Marine Science* 6 (2020): 762. https://doi.org/10.3389/fmars.2019.00762
[9] Siow, K. T., and Edward O. Moll. "Status and conservation of estuarine and sea turtles in West Malaysian waters." *Biology and conservation of sea turtles. Smithsonian Institution Press, Washington, DC, USA* (1982): 339-347.
[10] Azlina, A. A., M. Hasnan, and M. Kamaludin. "Assessing public willingness to pay for sea turtle conservation in Terengganu, Malaysia." *Environmental Impacts and Conservation Evaluation (ed. Abdul Samad, AR)* (2019): 33-53.
[11] Limpus, Colin, and Milani Chaloupka. "Nonparametric regression modelling of green sea turtle growth rates (southern Great Barrier Reef)." *Marine Ecology Progress Series* 149 (1997): 23-34. https://doi.org/10.3354/meps149023
[12] Chaloupka, Milani. "Stochastic simulation modelling of southern Great Barrier Reef green turtle population dynamics." *Ecological modelling* 148, no. 1 (2002): 79-109. https://doi.org/10.1016/S0304-3800(01)00433-1
[13] Bjorndal, Karen A., Alan B. Bolten, Thomas Dellinger, Cláudia Delgado, and Helen R. Martins. "Compensatory growth in oceanic loggerhead sea turtles: response to a stochastic environment." *Ecology* 84, no. 5 (2003): 1237-1249. https://doi.org/10.1890/0012-9658(2003)084[1237:CGIOLS]2.0.CO;2
[14] Chaloupka, Milani, and George Balazs. "Using Bayesian state-space modelling to assess the recovery and harvest potential of the Hawaiian green sea turtle stock." *Ecological modelling* 205, no. 1-2 (2007): 93-109. https://doi.org/10.1016/j.ecolmodel.2007.02.010
[15] Khairi, Danial Mohd, Mohd Azman Abas, Mohd Farid Muhamad Said, and Wan Saiful-Islam Wan Salim. "Fuel consumption mathematical models for road vehicle–A review." *Progress in Energy and Environment* (2021): 59-71.
[16] Ali, Muzaffar, Zahida Yaqoob, Tanzeel-ur Rashid, Abid Hussain, and Zahid Suleman. "Model-based Performance Comparison of Different Configurations of Evaporative Cooling Systems in various Climates of Pakistan." *Progress in Energy and Environment* (2018): 1-13.
[17] Khoo, Miinyi, Vasanthi Sethu, Anurita Selvarajoo, and Senthil Kumar Arumugasamy. "Performance of fenugreek and okra for the physico-chemical treatment of palm oil mill effluent–modeling using response surface methodology." *Progress in Energy and Environment* (2021): 8-30.
[18] Marcelo, Dinno, and Bonavian Hasiholan. "Design of Dual-Porosity–Dual-Permeability Model of Ekofisk Field." *Progress in Energy and Environment* (2020): 1-10.
[19] Kot, Mark. *Elements of mathematical ecology*. Cambridge University Press, 2001. https://doi.org/10.1017/CBO9780511608520
[20] Costamagna, A. C., W. Van der Werf, F. J. J. A. Bianchi, and D. A. Landis. "An exponential growth model with decreasing r captures bottom-up effects on the population growth of Aphis glycines Matsumura (Hemiptera:

Aphididae)." *Agricultural and Forest Entomology* 9, no. 4 (2007): 297-305. https://doi.org/10.1111/j.1461-9563.2007.00348.x

[21] Clark, Aaron James, Larry Wayne Lake, and Tadeusz Wiktor Patzek. "Production forecasting with logistic growth models." In *SPE Annual Technical Conference and Exhibition?*, pp. SPE-144790. SPE, 2011. https://doi.org/10.2118/144790-MS

[22] Chowell, Gerardo, and Cécile Viboud. "Is it growing exponentially fast?–impact of assuming exponential growth for characterizing and forecasting epidemics with initial near-exponential growth dynamics." *Infectious disease modelling* 1, no. 1 (2016): 71-78. https://doi.org/10.1016/j.idm.2016.07.004

[23] Jain, Minni, Prajwal Kumar Bhati, Pranav Kataria, and Rohit Kumar. "Modelling logistic growth model for COVID-19 pandemic in India." In *2020 5th International Conference on Communication and Electronics Systems (ICCES)*, pp. 784-789. IEEE, 2020. https://doi.org/10.1109/ICCES48766.2020.9138049

[24] Lara-Rosano, F. "Modelling data uncertainty in growth forecasts." *Applied Mathematical Modelling* 11, no. 1 (1987): 62-68. https://doi.org/10.1016/0307-904X(87)90184-3

[25] Wei, Huabin, Yanqing Jiang, and Yuxing Zhang. "A review of two population growth models and an analysis of factors affecting the Chinese population growth." *Asian Journal of Economic Modelling* 3, no. 1 (2015): 8-20. https://doi.org/10.18488/journal.8/2015.3.1/8.1.8.20

[26] Department of Fisheries Malaysia. *"Annual Report 2022 Department of Fisheries Malaysia*." (2002).

[27] Tsoularis, Anastasios, and James Wallace. "Analysis of logistic growth models." *Mathematical biosciences* 179, no. 1 (2002): 21-55. https://doi.org/10.1016/S0025-5564(02)00096-2

[28] Khair, Ummul, Hasanul Fahmi, Sarudin Al Hakim, and Robbi Rahim. "Forecasting error calculation with mean absolute deviation and mean absolute percentage error." In *journal of physics: conference series*, vol. 930, no. 1, p. 012002. IOP Publishing, 2017. https://doi.org/10.1088/1742-6596/930/1/012002

[29] Cassill, Deby L. "Extending r/K selection with a maternal risk-management model that classifies animal species into divergent natural selection categories." *Scientific reports* 9, no. 1 (2019): 6111. https://doi.org/10.1038/s41598-019-42562-7

[30] Fuentes-Farias, Alma Lilia, Gabriel Gutiérrez-Ospina, Esperanza Meléndez Herrera, Verónica Camarena-Ramírez, Gerardo Ochoa-Tovar, Julieta Mendoza-Torreblanca, Raquel Martínez-Méndez, Jaime Urrutia-Fucugauchi, Armida Báez-Saldaña, and María Luisa García Zepeda. "Marine turtle hatchlings use multiple sensory cues to orient their crawling towards the sea: biological and conservation policy implications." *Advances in Bioscience and Biotechnology* 2, no. 02 (2011): 47-51. https://doi.org/10.4236/abb.2011.22008