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FULL PAPER

# An analysis of the growth based on the size and age distributions of the hawksbill sea turtle inhabiting Cuban waters

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## Abstract

The first costal scute (C 1) collected from 2,749 hawksbill turtle (*Eretmochelys imbricata*) captured in Cuban waters in 1993 and 1994 were analyzed to determine their body size and age distributions. The C 1 width (C 1 W) was converted to the straight carapace length (SCL) using a formula, $SCL=4.3527\ (C\ 1\ W)^{0.8484}$, to examine its body size distribution. The SCL ranged from 51.3 to 96.1 cm with 68.8 cm of mean and 68.6 cm of median. Ages of captured turtles estimated from the C 1 surface patterns were ranged from 3.3 to 61.5 years old with 15.8 years of mean and 14.5 years of median. A growth function of van Bertalanffy, $M(t)=A\ (1-Be^{-kt})$, was applied to determine the relationship between the age and body size (SCL). A formula, $SCL=80.4\ (1-0.663e^{-0.118(Age)})$, was derived and indicated a slowdown in the growth after about 14 years old. The maturation age and the rate of sexually matured Cuban hawksbill turtles were also discussed based on these results.

Keywords: age distribution, Cuba, growth, hawksbill turtle, size distribution

## Introduction

The hawksbill turtle (*Eretmochelys imbricata*), one of the existing sea turtles, is included on the Red List as a critically endangered species by IUCN (International Union for the Conservation of Nature and Natural Resources)[2], as well as listed in the Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The threats sea turtles face today include overexploitation in pursuit of its carapace, flesh, or eggs, loss of nesting habitat, and marine pollution[23]. To eliminate these threats, conservative protective measures including habitat protection[7,18], along with such aggressive measures as "head starting" in which hatchlings are raised in captivity and then released in the wild[6,12,20], have been adopted through trial and error. Evaluation of these measures will require the monitoring of wild turtles, understanding changes in the hawksbill populations as well as changes in age distribution, and estimating the numbers of individual turtles, their sizes, and age distributions based on those changes.

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However, few studies have been conducted on marine turtles due to the difficulty in following and monitor them at close range in their habitats with the naked eye. Moreover, there is the lack of data on their migration routes and a stage-by-stage developmental distribution of the hawksbill that would justify our sampling methods. Thus, it is not easy to predict changes in the size and age distribution of populations. Meanwhile, researchers have been gathering basic ecological data necessary to analyze the population dynamics of the marine turtle, such as their age or size at the beginning of breeding, the length of the breeding season, and a mortality table. More specifically, the relationship between body size and sexual maturity has been studied[11,22]. After being recaptured by tagging, growth speed was determined based on weight and carapace size, and then growth characteristics of the turtle were analyzed[1,4,16]. When age estimation was possible or the turtle's age was already known, the age of sexual maturity could be estimated from the relationship between age and carapace size or weight[24]. However, since the age assessment method of the hawksbill had not been established, their basic biological information, in most cases, was based on body size.

This study was conducted to clarify the growth characteristics of hawksbill turtles in Cuban waters. A newly developed age-assessment method that utilized the periodicity of the hawksbill carapace patterns[13], was used to estimate the age distribution. The distribution of their body size was estimated from the first costal scute width (C 1 W)[14]. The maturation age and the rate of sexually matured Cuban hawksbill turtles were also examined based on these results.

## Materials and Methods

The first costal scutes (C 1) from 2,749 wild hawksbill turtles that were captured in Cuban waters in 1993 and 1994, using top fishnets with 46～53 cm mesh, 91.4～109.7 m in length, and 60～75 m in depth. The sex in each turtle was unknown. The C 1 widths (C 1 W) were measured using a tape measure (±0.1 cm). Based on C 1 W values, SCL was estimated using a formula, $SCL=4.3527\ (C1W)^{0.8484}$[14], to analyze body size distribution. C 1 s were individually photographed under identical conditions and these photographs were scanned and converted into image data by computer. I examined the age based on the periodicity of the carapace surface pattern as described previously[13]. Briefly, the pattern of black speckles on the carapace are divided into two periods, one being the formation period and the other being the lesser formation period, which occurs once a year and whose cycles have nothing to do with genetics or the growth of the shell.

Degree of deviation in the SCL and age distributions from the normal distribution was tested by determining the skewness (indicating asymmetry) and kurtosis (indicating the peaks of a distribution) from the distribution of those histograms,

To examine the relationship between the age and SCL, growth rate was determine using the formula of van Bertalanffy, $M(t)=A\ (1-Be^{-k\ (Age)})$, where (A), (k), and (B) were the estimated asymptote, intrinsic growth rate, and growth constant, respectively[27]. The SCL was divided into 5 cm-size classes, and the numbers of females, males and matured turtles in each class were estimated using the previous data reported by Carrillo et. al.[3] and Moncada et al.[17].

## Results

The histogram of SCL is shown in Figure 1. The SCL were ranged from 51.3 to 96.1 cm with 68.8 cm of mean and 68.6 cm of median.

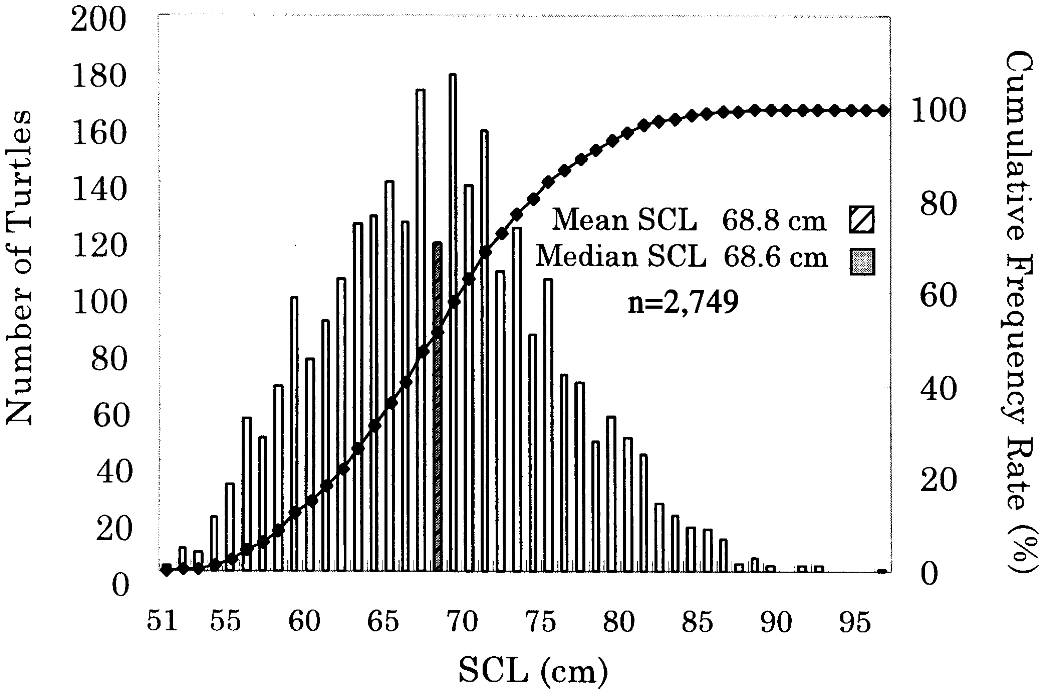


Fig. 1. The straight carapace length (SCL) histogram of hawksbill turtles netted in Cuban waters in1993and1994. Bars indicate the numbers of turtles, and the sequential line shows the cumulative frequency rate (%). The gray solid bar indicates the median SCL (50%of the cumulative frequency rate), and the bar with diagonal lines indicates the class with the mean SCL.

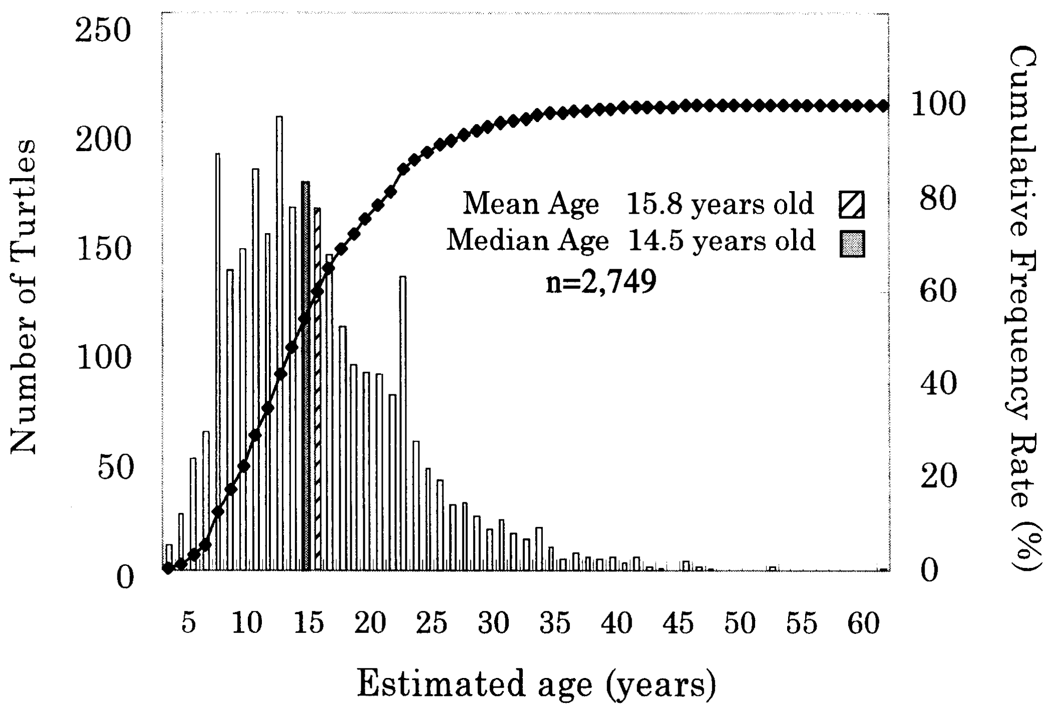


Fig. 2. The estimated age histogram of hawksbill turtles netted in Cuban waters in1993 and1994. Bars indicate the numbers of turtles, and the sequential line shows the cumulative frequency rate (%). The gray solid bar indicates the median of estimated ages (50%of the cumulative frequency rate), and the bar with diagonal lines indicates the class with the mean of estimated ages.

The skewness and kurtosis were 0.23 and 2.75, respectively. The distribution showed the curve is spread out to the right (a dome-like distribution), and was judged as having a significant bias from the normal distribution.

As shown in Figure 2, estimated ages were ranged from 3.3 to 61.5 years old with 15.8 years old of mean and 14.5 years old of median. The skewness and kurtosis were 1.18 and 5.17, respectively. The distribution showed a curve widely spread out to the right (a lognormal distribution), and was judged as having a significant bias from the normal distribution.

The scattered diagram between the estimated age and SCL, and the curved line of the growth functions, $SCL = 80.4(1 - 0.663e^{-0.118(Age)})$ ($r^2 = 0.502$), are shown in Figure 3.

Estimated numbers of females, males, and matured turtles were shown in Table. 1. The rates of sexually matured females and males out of all turtles in captivity were estimated to be 15.4% (422/2749) and≧10.6% (≧290/2749), respectively.

## Discussion

Histograms of SCL and the estimated age shown in Figures 1 and 2 had biases. This is probably due to the sizes of mesh (46-53cm) of the net used for capture. The turtles with smaller in size than the mesh size could not be captured. Those histograms indicate the distribution of the numbers of hawksbill turtles captured there, but do not represent the actual hawksbill distribution in Cuban waters.

In general, prolific animals with relatively greater longevity, such as reptiles, have a high early mortality rate (K-selection type), and their survival curves show a L-shape [21].

The dispersion of age on same SCL is uneven (Fig. 2 and Table 1), indicating that it is impossible to estimate age from size using the formula, $SCL = 80.4(1 - 0.663e^{-0.118(Age)})$ ($r^2 = 0.502$).

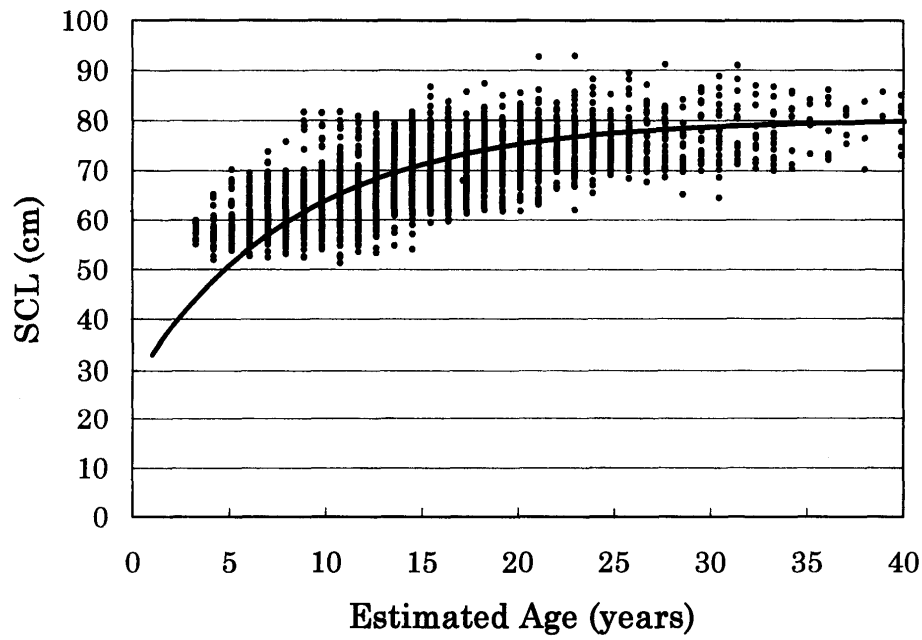


Fig. 3. The scattered diagram between the estimated age and the straight carapace length (SCL) and the curved line of the model expressions of the growth functions of van Bertalanffy, $M(t) = A(1 - Be^{-kt})$ [27]. The formula, $SCL = 80.4(1 - 0.663e^{-0.118(Age)})$ ($r^2 = 0.502$), was conducted for the size of SCL during hatching, the measured value of 5 cm was used.

Table 1. Sample size, Mean age and range of estimated age of each straight carapace length (SCL) classes.

| SCL class (cm) | No. | Range of age (years) | No. of estimated females Total[b] | Matured[c] (%)[d] | No. of estimated males Total[b] | Matured[c] (%)[d] |
|---|---|---|---|---|---|---|
| 51-55 | 67 | 3~15 | 54 | 2(4) | 13 | ? |
| 56-60 | 344 | 3~12 | 275 | 11(4) | 69 | ? |
| 61-65 | 588 | 6~21 | 470 | 33(7) | 118 | ? |
| 66-70 | 735 | 7~23 | 588 | 65(11) | 147 | 88(100)* |
| 71-75 | 581 | 10~33 | 465 | 88(19) | 116 | 116(100) |
| 76-80 | 290 | 8~33 | 232 | 107(46) | 58 | 58(100) |
| 81-95 | 117 | 14~62 | 94 | 94(100) | 23 | 23(100) |
| 86-90 | 22 | 15~47 | 18 | 18(100) | 4 | 4(100) |
| 91- [a)] | 5 | 21~43 | 4 | 4(100) | 1 | 1(100) |
| Total | 2749 | 3~62 | 2199 | 422(19.2) | 550 | ≧290(≧52.7) |

[a)] Samples of SCL ≧ 91 were dealt with one group, because of sample size.
[b)] 80 and 20% of all turtles captured in Cuban water were females and males respectively[3)].
[c)] No. of matured[c]=Total[b]×matured (%)[d]
[d)] Rate of matured based on each SCL from Moncada et. al.[17)].
* 88 indicated the number of ≧ 68 cm turtles. In the case of males, there is no information under 68 cm.

The differences in the rates of sexually matured turtles between female and male (19.2% and≧52.7%, respectively) (Table. 1) suggest that the fisheries with the top net using in this study could seriously reduce the population of matured turtles, especially matured male.

Hawksbill turtles with more than 81 cm of SCL were reported to be matured regardless of their sex[13)]. Present data (Table. 1) suggest that they will be sexually matured at 14 year old. A slowdown in the growth around 14 years old would also support a possibility that most of the elder turtles than 14 years old are sexually matured. Studies of other species of sea turtles have been performed by various researchers. Using the method of reading bone growth rings[19)], the age of sexual maturity was estimated to be 25-35 years old in wild Loggerhead females (*Caretta caretta*)[8,9,10)]. Using the method of reading bone growth rings developed by Zug et. al[27)] with slight modification, it was determined to be 15-20 years old in Kemp's Ridley (*Lepidochelys kempii*)[5)] and 13-14 years old in the Leatherback (*Dermochelys coriacea*) females[26)]. As clarified in the present study (Fig. 3 and Table. 1), even if the body size was approximately the same, the age varied widely. Also, since the growth speed of hawksbills shows a large difference depending on the region of habitat[1,15,16,25)], it is necessary to estimate the age of sexual maturity in association with the habitat.

In this study, the distributions of body size and the ages of hawksbills that were captured with nets in Cuban waters were examined. Since the samples had a bias, it probably did not represent an exact population distribution of hawksbills in Cuban waters. However, by linking the distributions to past reports on the hawksbill, the sexual matured age of hawksbill turtles in this region could be analyzed. This signifies two important facts. The present study, by comparing the values from other areas under different environmental conditions, will contribute data that can enhance our understanding of the characteristics of hawksbills in the Cuban region. It will also bear particular relevance for protection and management efforts in which it is indispensable to monitor the numbers of turtles and predict their changes in their distributions and behavior.

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