Morphometric diversity of Hawksbill Turtle (*Eretmochelys imbricata*) at the Kelapa Island and Harapan Island Turtle Conservation Centers

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Abstract. Kepulauan Seribu National Park (TNKpS) is one of the marine nature conservation areas located in Pulau Seribu, DKI Jakarta Province. Kelapa Island and Harapan Island are centers for hawksbill turtle conservation, as several islands in the TNKpS are their landing and nesting areas. The study aimed to analyze the morphometric characteristics of hawksbill turtles based on their life stages. Morphometric measurements were carried out on 54 samples of hawksbill turtles of different ages with 13 parameters to differentiate cohorts, then a correlation analysis was conducted between carapace length and hawksbill turtle weight and nMDS analysis. Hawksbill turtles (*Eretmochelys imbricata*) in SPTN Region I Kelapa Island, and Region II Harapan Island showed a negative allometric growth pattern, with a correlation level of 0.001 for hatchlings (very low) to 0.938 for juveniles (very strong). The nMDS analysis showed similarities in characteristics from the early hatchling to early juvenile phases and there were 3 cohorts of hawksbill turtles conserved in SPTN Regions I and II TNKpS, based on carapace length.

1 Introduction

1.1 Background

Kepulauan Seribu National Park (TNKpS) is a marine nature conservation area located on the Thousand Islands, DKI Jakarta Province, which is geographically located between 5°23'-5°40'S and 106°37'E north of Jakarta [1]. The management of the Thousand Islands Marine National Park is carried out by the Thousand Islands National Park Office (BTNKpS). The management of the TNKpS area is divided into three National Park Management Section (SPTN) areas, namely SPTN Region I Kelapa Island, SPTN Region II Harapan Island and SPTN Region III Pramuka Island (BTNKpS). There are 2 types of turtles in the Thousand Islands National Park, namely the hawksbill turtle (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*) [1].

Sea turtles are marine biota that utilize land areas for egg-laying every season. Six of the seven sea turtles are found in Indonesian waters: the olive ridley turtle (*Lepidochelys olivacea*), the green turtle (*C. mydas*), the flatback turtle (*Natator depresus*), the hawksbill turtle (*E. imbricata*), the leatherback turtle (*Dermochelys coriacea*), and the loggerhead turtle (*Caretta caretta*) [2].

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SPTN Region I Kelapa Island and SPTN Region II Harapan Island are conservation centers for hawksbill turtles that successfully lay eggs in the TNKpS area with a higher number of hawksbill turtles than other TNKpS areas. TNKpS is a landing area and habitat for hawksbill turtles because of the relatively few predators, good beach morphology, and tidal patterns that approach vegetation areas, making it easier for hawksbill turtles to reach the nesting area.

The hawksbill turtle (*E. imbricata*) is a sea turtle characterized by its beak-shaped snout, a downward-curving upper jaw, and a relatively sharp, eagle-like shape, often referred to as the "Hawksbill turtle". Hawksbill turtles are listed in the IUCN Red Data Book as critically endangered [3]. One of the most visible characteristics of the hawksbill turtle is the arrangement of the segments that adorn its carapace. The average adult hawksbill turtle can grow to one meter and weigh around 80 kg. The largest hawksbill turtle ever caught weighed 127 kg [1]. To understand and support the conservation of hawksbill turtles (*E. imbricata*), research on the morphometric diversity of hawksbill turtles in the Seribu Islands National Park in SPTN Region I, Kelapa Island, and SPTN Region II, Harapan Island, is crucial. By understanding and knowing the variations in the morphometric characteristics of the hawksbill turtle, we can take more appropriate actions to protect this endangered species.

1.2 Purpose

This study aims to analyze the morphometric characteristics and correlation between carapace length and weight of hawksbill turtles in SPTN Region I Kelapa Island and SPTN Region II Harapan Island, Kepulauan Seribu National Park.

2 Methods

2.1 Time and place

In-situ data collection was conducted from March 17 to 24, 2025, at SPTN Region I Kelapa Island and SPTN Region II Harapan Island, Kepulauan Seribu National Park. There were 54 hawksbill turtle samples, including 15 samples of 2-day-old hatchlings, 10 samples of 10-day-old juveniles, 10 samples of 15-day-old juveniles, 10 samples of 90-day-old juveniles, and 9 samples of young turtles. The data collection locations can be seen in Figure 1. Data processing was carried out at the Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, IPB University.

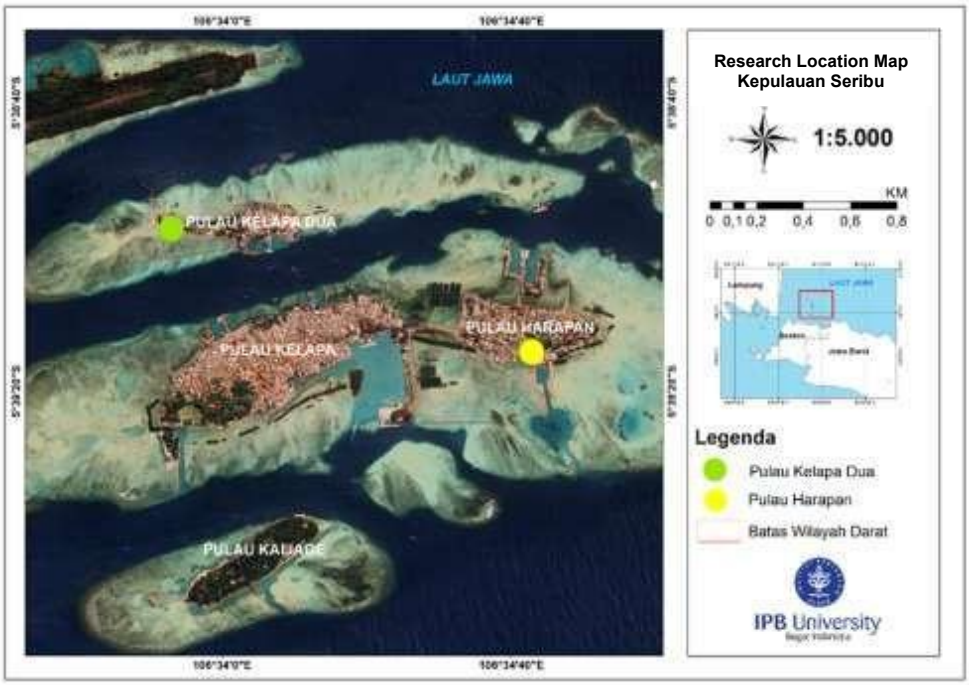

Fig. 1. Map of hawksbill turtle morphometric research sites in TNKpS.

2.2 Tools and materials

The tools and materials used in the morphometric analysis of hawksbill sea turtles are presented in Table 1.

Table 1. Tools and materials for morphometric research on hawksbill sea turtles.

No	Tools and Material	Purpose
1	Measuring tape	Measuring carapace length, carapace width, and other measurements
2	Scales	Measuring the weight of the turtle
3	Vernier	Measuring hard-to-reach parts of the body
4	Camera	Documenting the measurement process and the physical condition of the turtle
5	Data sheet	Recording the measurement data obtained
6	Stationery	Writing the data on the data sheet
7	*Microsoft Excel*	Data Processing and Analysis
8	*Microsoft Word*	Data Processing and Analysis
9	*Software PAST*	Data Processing and Analysis
10	Laptop/PC	Data Processing and Analysis

2.3 Work procedures

This research was conducted in several stages, data collection, additional data collection, and data analysis. Beginning with morphometric measurements, the obtained data were explained for their morphometric variations. The results of the morphometric analysis were then used to analyze the relationship between straight carapace length and weight and to analyze the nMDS. The results produced an analysis diagram that was then interpreted.

2.4 Data analysis

2.4.1 Morphometric variation analysis of hawksbill turtles

Morphometric variation analysis of sea turtles was conducted by measuring their bodies. Measurements were taken based on the turtle life stages. The measurement data obtained was collected based on stage and averaged to determine the morphometric mean value for each stage of the turtle life. Hawksbill sea turtles go through several stages in their lives, namely hatchling, juvenile, young turtle, and adult turtle, with the following descriptions:

1. Hatchling = The youngest stage, where the umbilical cord is still clearly visible, with a carapace size of < 10 cm.
2. Juvenile = Umbilical cord absent, carapace length 10 – 40 cm.
3. Young turtle = After juvenile but not yet mature enough to lay eggs, carapace length between 40 – 80 cm.
4. Adult turtle = Carapace length > 80 cm.

Morphometric measurements of sea turtles generally include 12 measurement parameters, namely straight carapace length (SCL), straight carapace width (SCW), curved carapace length (CCL), curved carapace width (CCW), front limb length (FLL), hind limb length (HLL), head length (HL), head width (HW), head circumference (HC), total tail length (TTL), length between cloaca and tail tip (CETL), length between plastron tip and cloaca (PCL) [4].

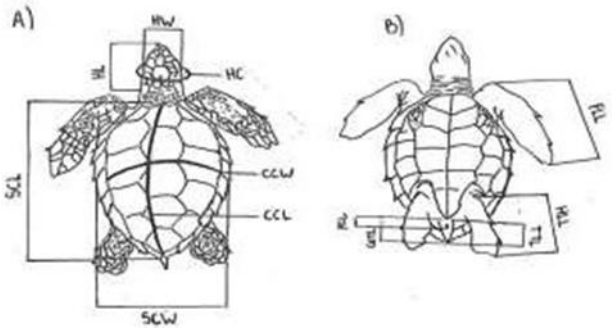

Fig. 2. Morphometric measurements of hawksbill turtles Description: A) Head and body, B) Limb, tail, weight.

The measurement data were processed using descriptive statistics. Mathematically, the average (X) is formulated as follows:

$$X = \frac{\Sigma xi}{N} \quad (1)$$

Description:
Σxi = Sum of all data values
N = Number of data points

2.4.2 Correlation analysis of straight carapace length and weight of hawksbill turtles

Carapace length and weight data can be used to observe growth patterns or relative growth. The data analysis used is regression analysis by comparing tabulations from data processing using Microsoft Excel to find the relationship between carapace length and turtle weight. The regression analysis formula:

$$W = aL^b \quad (2)$$

Description:
W = Body weight (gram)
L = Body length (cm)
a and b = Constant

This equation can be transformed into a linear form, as follows:

$$Log\ y = a\ log\ log\ x\ + log\ log\ b \quad (3)$$

$$Log\ b = \frac{\Sigma loglog\ y\ .\ \Sigma(loglog\ x\ ).\Sigma(loglog\ x\ .loglog\ y\ )}{\Sigma(loglog\ x\ )^2 - \Sigma(loglog\ x\ )^2} \quad (4)$$

Description:

$$Log\ b = \frac{\Sigma loglog\ x - N loglog\ b}{\Sigma loglog\ X} \quad (5)$$

Applicable:

$b = 3$, depicts isometric growth
$b > 3$, describes positive allometric growth or weight increases faster than length.
$b < 3$, describes negative allometric growth or weight increases more slowly than length.

Correlation analysis is used to determine the relationship between two or more variables. Guidelines for interpreting the correlation coefficient (r) are presented in Table 2.

Table 2. Interpretation of correlation coefficient results.

Coefficient Interval	Relationship Level
0,00 – 0,199	Very Low
0,20 – 0,399	Low
0,40 – 0,599	Average

Coefficient Interval	Relationship Level
0,60 – 0,799	Strong
0,80 – 1,000	Very Strong

2.4.3 nMDS analysis

nMDS analysis (non-metric Multidimensional Scaling) is one of the multivariate statistical analyses used to determine the position of data based on similarity assessment, and is used to understand interdependence or mutual dependence among data. nMDS analysis is conducted using the Bray-Curtis distance matrix to reduce multivariate data into a two-dimensional space. Points that are close indicate similar composition or characteristics, while points that are far apart indicate differences in straight carapace length (SCL) and weight of the scaly turtle at each life stage. The analysis is conducted using PAST software.

3 Result and discussion

3.1 Result of morphometric variation analysis of hawksbill turtles

The results obtained from the research at the Turtle Conservation Center SPTN Region I Pulau Kelapa and SPTN Region II Pulau Harapan consist of combined data from morphometric measurements of hawksbill turtles in the hatchling, juvenile, and young turtle phases from both locations, which can be seen in Appendix 1 to Appendix 3. The measurement data is combined because the number of hawksbill turtles in SPTN Region I Pulau Kelapa at each phase is limited compared to SPTN Region II Pulau Harapan.

The measurement parameters conducted include straight carapace length (SCL), straight carapace width (SCW), curved carapace length (CCL), curved carapace width (CCW), front flipper length (FLL), hind flipper length (HLL), head length (HL), head width (HW), head circumference (HC), total tail length (TTL), length between the cloaca and the tail tip (CETL), length between the plastron tip and the cloaca (PCL), and weight measurements were also taken. The results of the morphometric measurements are presented in the following table.

3.1.1 Morphometric variation analysis of hawksbill turtles part A (head and body)

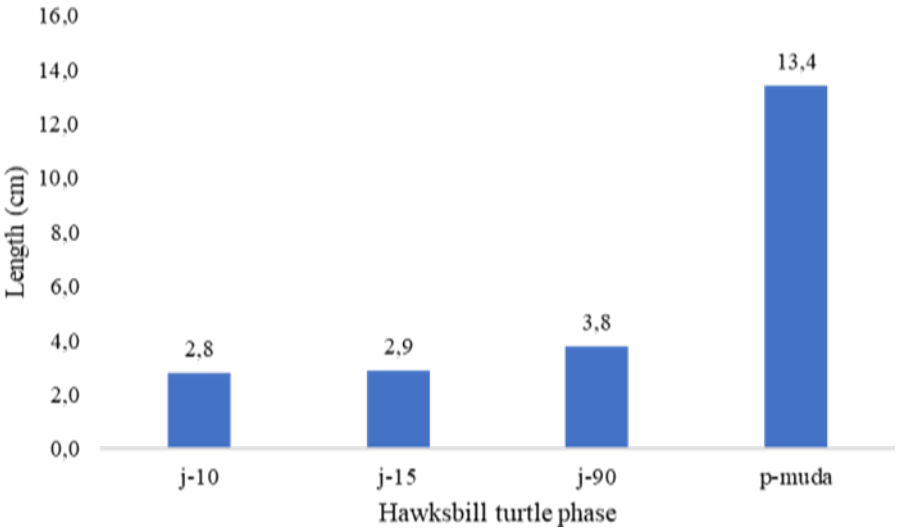

Fig. 3. Comparison of morphometric variations in head length (HL) by life stage in TNKpS.

Morphometric measurements of head length (HL) were conducted on 30 juvenile hawksbill turtle samples and 9 juvenile turtle samples. Figure 4 shows the average HL of 10- day-old juveniles at 2.8 cm, 15-day-old juveniles at 2.9 cm, 90-day-old juveniles at 3.8 cm, and 13.4 cm for young turtles.

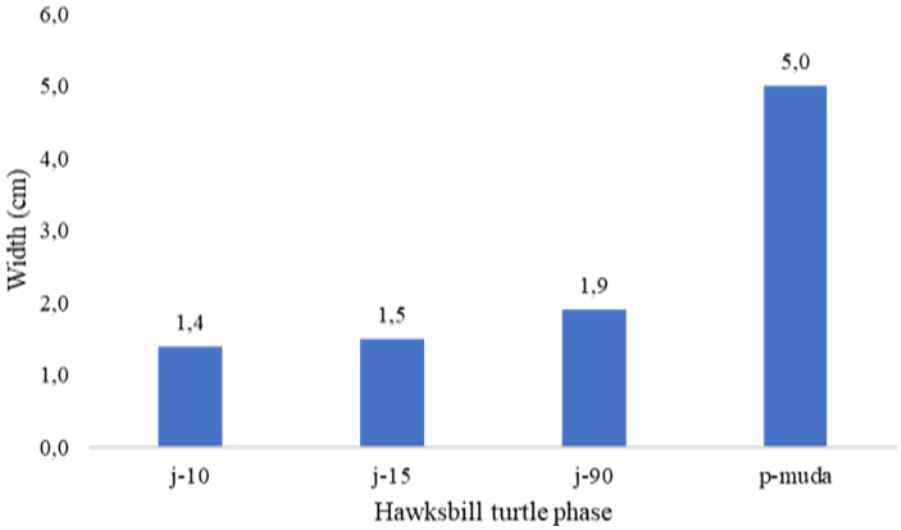

Fig. 4. Comparison of morphometric variations in head width (HW) by life stage in TNKpS.

Morphometric measurements of head width (HW) were conducted on 30 juvenile hawksbill turtle samples and 9 juvenile turtle samples. Figure 5 shows the average head circumference (HW) of 10-day-old juveniles at 1.4 cm, 15-day-old juveniles at 1.5 cm, 90-day-old juveniles at 1.9 cm, and young turtles at 5.0 cm.

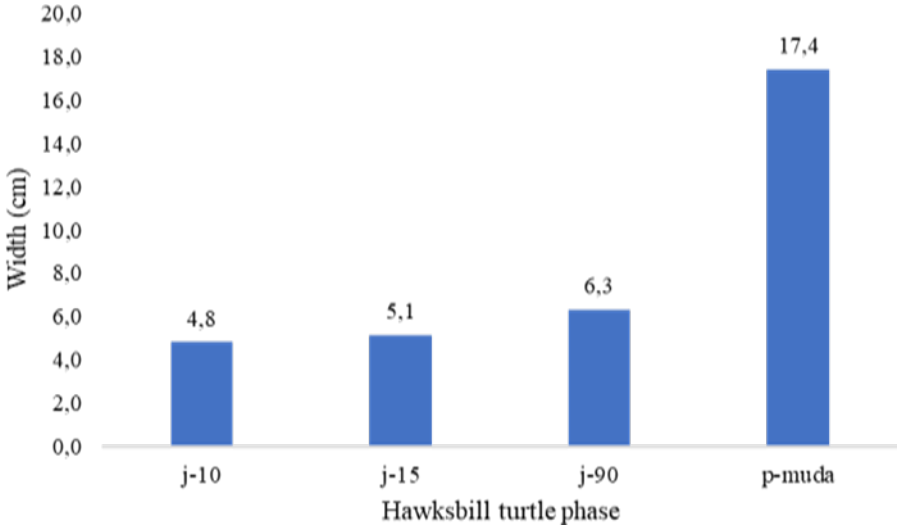

Fig. 5. Comparison of morphometric variations in head circumference (HC) by life stage in TNKpS.

Morphometric measurements of head circumference (HC) were conducted on 30 juvenile hawksbill turtle samples and 9 juvenile turtle samples. Figure 6 shows the average HW of 10-day-old juveniles at 4.8 cm, 15-day-old juveniles at 5.1 cm, 90-day-old juveniles at 6.3 cm, and young turtles at 17.4 cm.

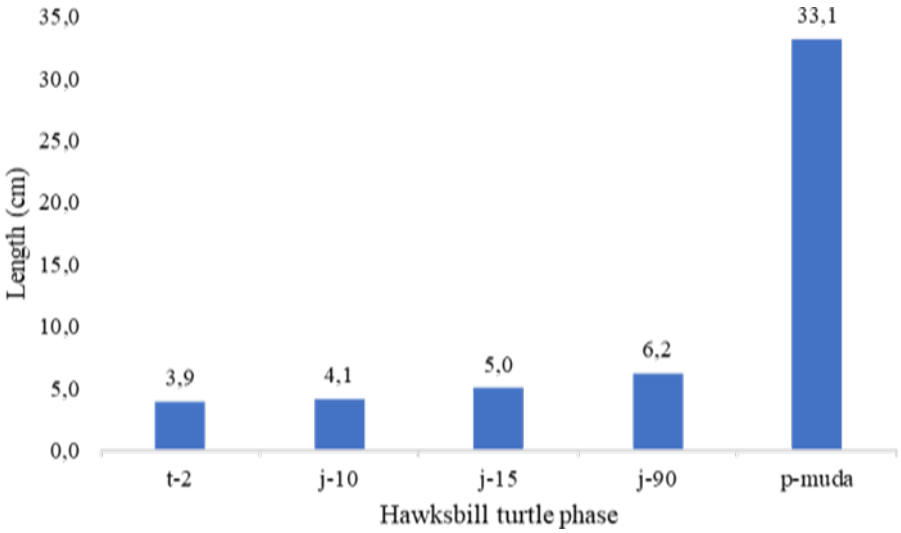

Fig. 6. Comparison of morphometric variations in straight carapace length (SCL) based on life stage in TNKpS.

Morphometric measurements of straight carapace length (SCL) were conducted on 15 hatchling samples, 30 juvenile hawksbill turtle samples, and 9 juvenile turtle samples. Figure 7 shows the average SCL of 2-day-old hatchlings at 3.9 cm, 10-day-old juveniles at 4.1 cm, 15-day-old juveniles at 5.0 cm, 90-day-old juveniles at 6.2 cm, and young turtles at 33.1 cm.

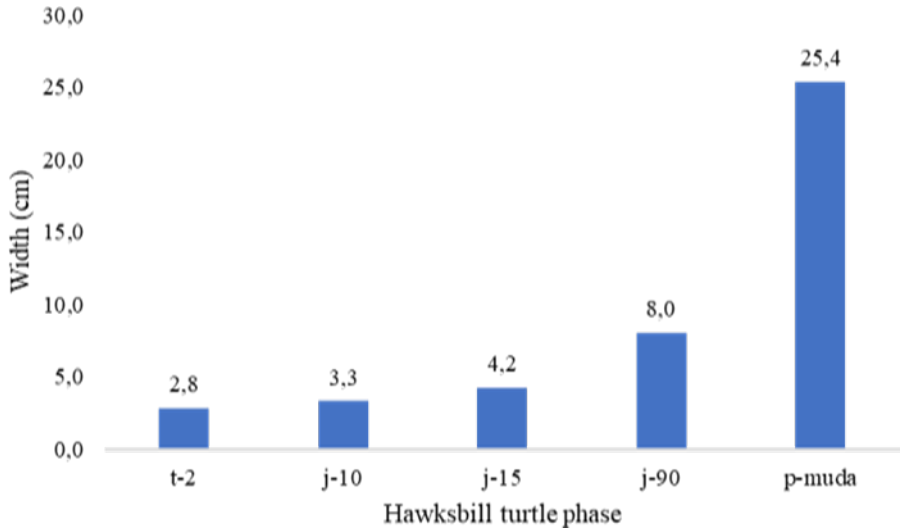

Fig. 7. Comparison of morphometric variations in straight carapace width (SCW) based on life stage in TNKpS.

Morphometric measurements of straight carapace width (SCW) were conducted on 15 hatchling samples, 30 juvenile hawksbill turtle samples, and 9 juvenile turtle samples. Figure 8 shows the average SCW size of 2-day-old hatchlings at 2.8 cm, 10-day-old juveniles at 3.3 cm, 15-day-old juveniles at 4.2 cm, 90-day-old juveniles at 8.0 cm, and young turtles at 25.4 cm.

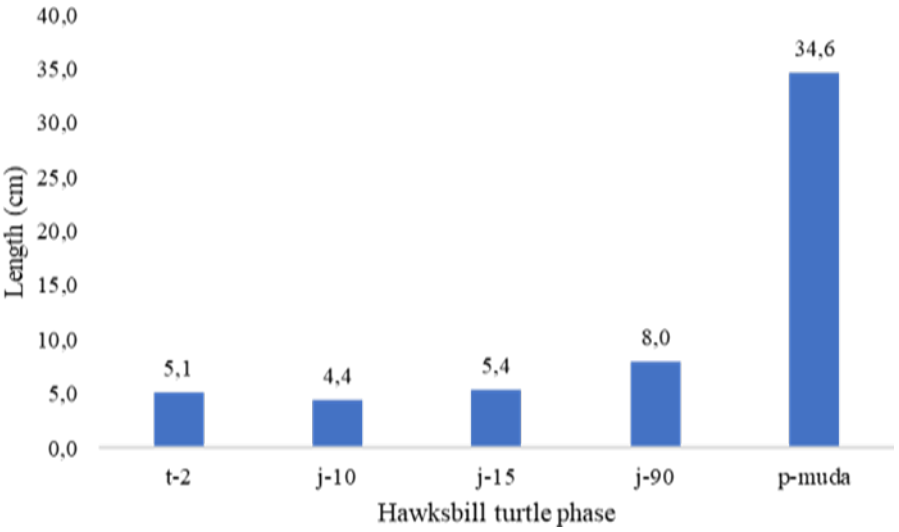

Fig. 8. Comparison of morphometric variations in curved carapace length (CCL) by life stage in TNKpS.

Morphometric measurements of curved carapace length (CCL) were conducted on 15 hatchling samples, 30 juvenile hawksbill turtle samples, and 9 juvenile turtle samples. Figure 9 shows the average CCL size of 2-day-old hatchlings at 5.1 cm, 10-day-old juveniles at 4.4 cm, 15-day-old juveniles at 5.4 cm, 90-day-old juveniles at 8.0 cm, and young turtles at 34.6 cm.

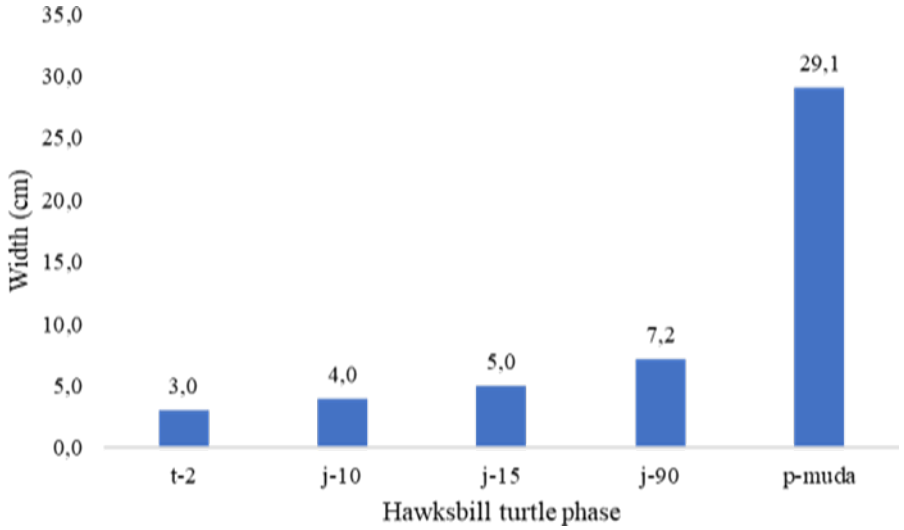

Fig. 9. Comparison of morphometric variations in curved carapace width (CCW) by life stage in TNKpS.

Morphometric measurements of curved carapace length (CCW) were conducted on 15 hatchling samples, 30 juvenile hawksbill turtle samples, and 9 juvenile turtle samples. Figure 10 shows the average CCW of 2-day-old hatchlings at 3.0 cm, 10-day-old juveniles at 4.0 cm, 15-day-old juveniles at 5.0 cm, 90-day-old juveniles at 7.2 cm, and young turtles at 29.1 cm.

3.1.2 Morphometric variations in hawksbill turtles Part B (limb, tail, and weight)

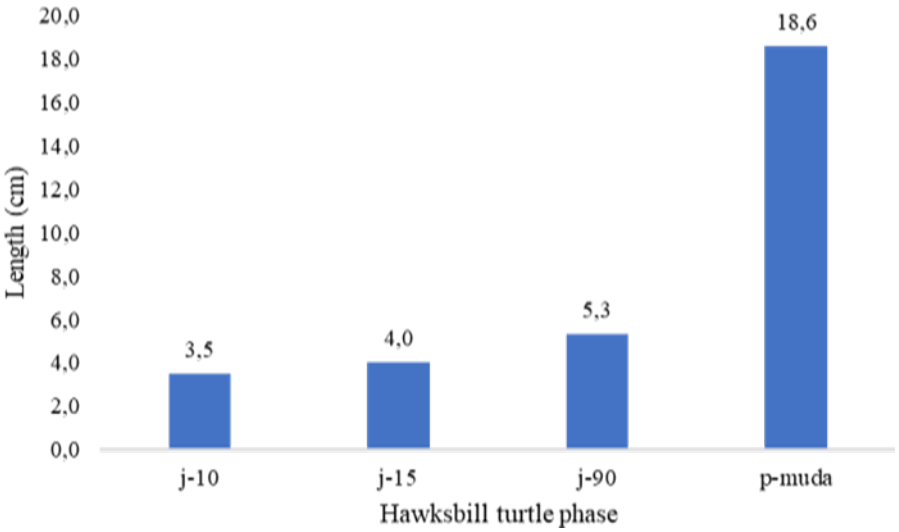

Fig. 10. Comparison of morphometric variations in front limb length (FLL) by life stage in TNKpS

Morphometric measurements of front limb length (FLL) were conducted on 30 juvenile hawksbill turtle samples and 9 juvenile turtle samples. Figure 11 shows the average length of the front limb length (FLL) for 10-day-old juveniles at 3.5 cm, 15-day-old juveniles at 4.0 cm, 90-day-old juveniles at 5.3 cm, and young turtles at 18.6 cm.

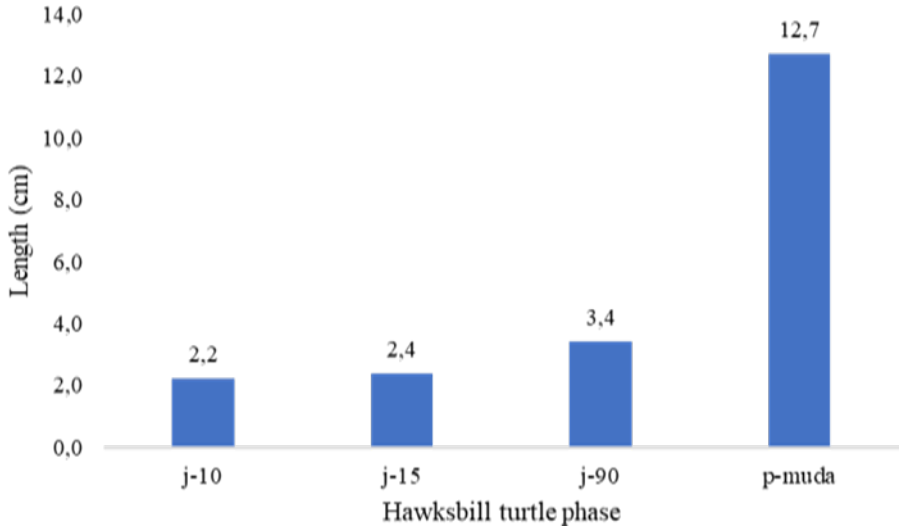

Fig. 11. Comparison of morphometric variations in hind limb length (HLL) by life stage in TNKpS.

Morphometric measurements of hind limb length (HLL) were conducted on 30 juvenile hawksbill turtle samples and 9 juvenile turtle samples. Figure 12 shows the average length of the HLL for 10-day-old juveniles at 2.2 cm, 15-day-old juveniles at 2.4 cm, 90-day-old juveniles at 3.4 cm, and young turtles at 12.7 cm.

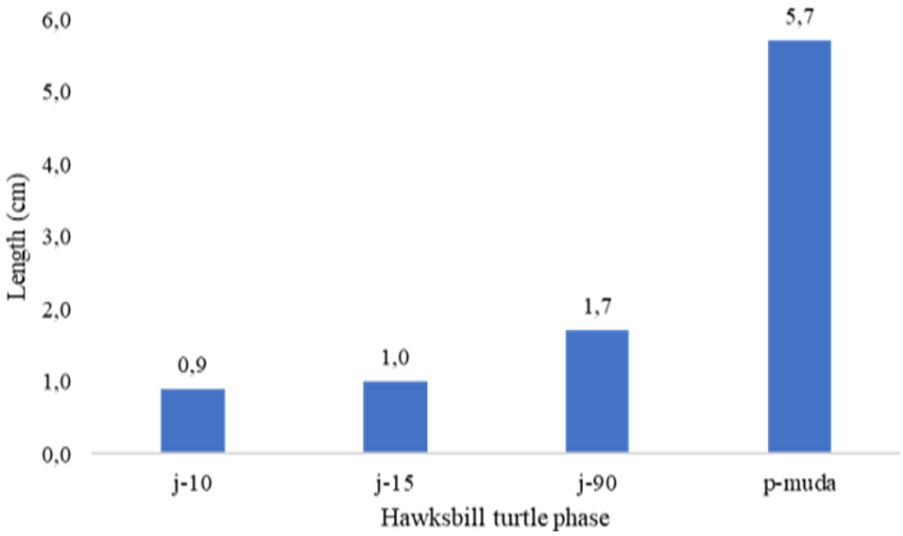

Fig. 12. Comparison of morphometric variations in total tail length (TTL) based on life stage in TNKpS.

Morphometric measurements of total tail length (TTL) were conducted on 30 juvenile hawksbill turtle samples and 9 juvenile turtle samples. Figure 13 shows the average TTL of 10-day-old juveniles at 0.9 cm, 15-day-old juveniles at 1.0 cm, 90-day-old juveniles at 1.7 cm, and 5.7 cm for young turtles.

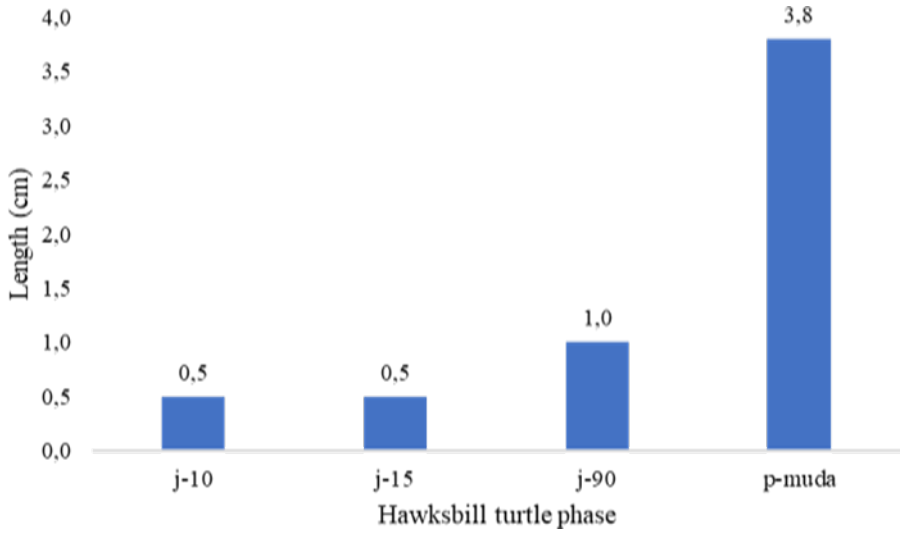

Fig. 13. Comparison of morphometric variations in cloaca-tip-tail length (CETL) based on life stage in TNKpS.

Morphometric measurements of cloaca tip tail length (CETL) were conducted on 30 juvenile hawksbill turtle samples and 9 juvenile turtle samples. Figure 14 shows the average CETL size of 10-day-old juveniles at 0.5 cm, 15-day-old juveniles at 0.5 cm, 90-day-old juveniles at 1.0 cm, and young turtles at 3.8 cm.

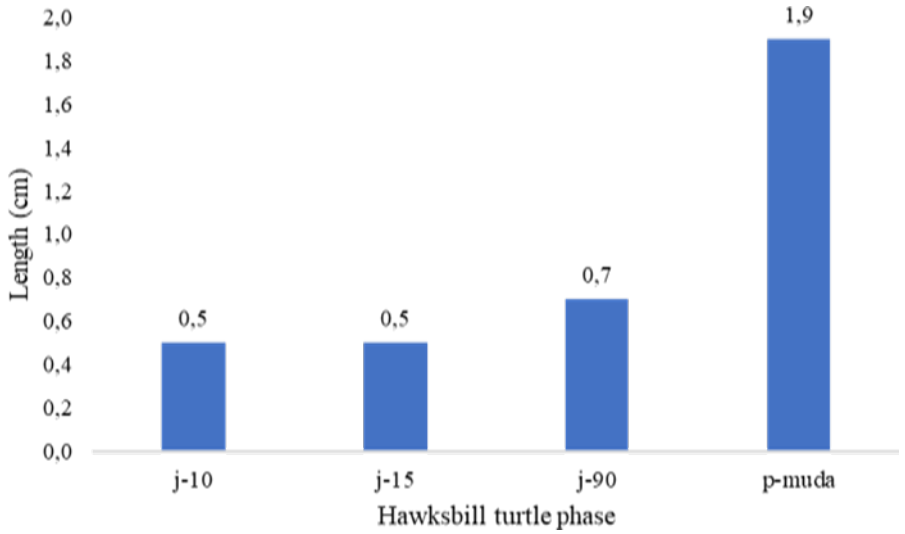

Fig. 14. Comparison of morphometric variations in the length between the tip of the plastron and the cloaca (PCL) based on life stage in TNKpS.

Morphometric measurements of the length between the tip of the plastron and the cloaca (PCL) were conducted on 30 juvenile hawksbill turtles and 9 juvenile turtles. Figure 15 shows the average PCL size of 10-day-old juveniles at 0.5 cm, 15-day-old juveniles at 0.5 cm, 90-day-old juveniles at 0.7 cm, and 1.9 cm for young turtles.

Table 3 Comparison of body weight variations by life stage in TNKPs

Sample	Weight-h2 (gr)	Weight-j10 (gr)	Weight-j15 (gr)	Weight-j90 (gr)	Weight-y.turtle (gr)
1	12,00	13,26	22,76	62,30	1150
2	13,17	15,16	22,16	70,07	3750
3	11,76	16,14	23,57	60,18	3450
4	13,21	16,90	25,78	76,23	3450
5	11,77	16,25	24,44	84,08	4250
6	12,90	16,24	21,88	59,75	3100
7	13,09	15,98	24,23	79,31	2700
8	12,87	14,49	20,36	57,26	5000
9	13,76	12,26	19,01	41,52	3750
10	12,72	14,13	23,08	50,00	
11	11,82				
12	13,15				
13	12,23				
14	13,96				
15	13,06				
Average	12,76	15,08	22,73	64,07	3400

Body weight measurement was conducted on 15 samples of hatchlings aged 2 days (t 2), 30 samples of juvenile hawksbill turtles aged 10 days (j 10), juvenile aged 15 days (j 15), juvenile aged 90 days (j 90), and 9 samples of young turtle phase (p young). Table 4 indicates that body weight increases with age. The average weight indicates for hatchlings aged 2 at 12.76 grams, juvenile aged 10 days at 15.08 grams, juvenile aged 15 days at 22.73 grams, while juvenile aged 90 days at 64.07 grams, and young turtle at 340.0 grams.

Table 4 Result of the calculation of the relationship between straight carapace length and weight of the hawksbill turtle in TNKpS.

Phase	n	a	b	r	R^2	Growth Pattern
t-2	15	11,726	0,0617	0,035	0,001	Negative allometric
j-10	10	0,678	2,1919	0,617	0,381	Negative allometric
j-15	10	0,782	2,0870	0,844	0,712	Negative allometric
j-90	10	0,145	2,9898	0,969	0,940	Allometrik negative
p-muda	9	1,171	2,2692	0,969	0,938	Allometrik negative

Description: Hatchling aged 2 days (t-2), juvenile aged 10 days (j-10), juvenile aged 15 days (j-15), juvenile aged 90 days (j-90), young turtle (p-muda).

3.2 Result of correlation analysis of straight carapace length and weight of hawksbill turtles

Growth observation on hawksbill turtles can be seen from the correlation of straight carapace length and weight. Hawksbill turtles in the Turtle Conservation Center SPTN Region I Pulau Kelapa and SPTN Region II Pulau Harapan consist of 3 life phases. The life phases of hawksbill turtles include hatchlings, juveniles, and young turtles. The results of the correlation of straight carapace length (SCL) and weight of hawksbill turtles can be seen based on the following figure. Observations show a varying pattern according to the growth phase of the turtles. The results of linear regression tests and the coefficient of determination

(R^2) illustrate the strength of the relationship between length and weight that differs in each life phase.

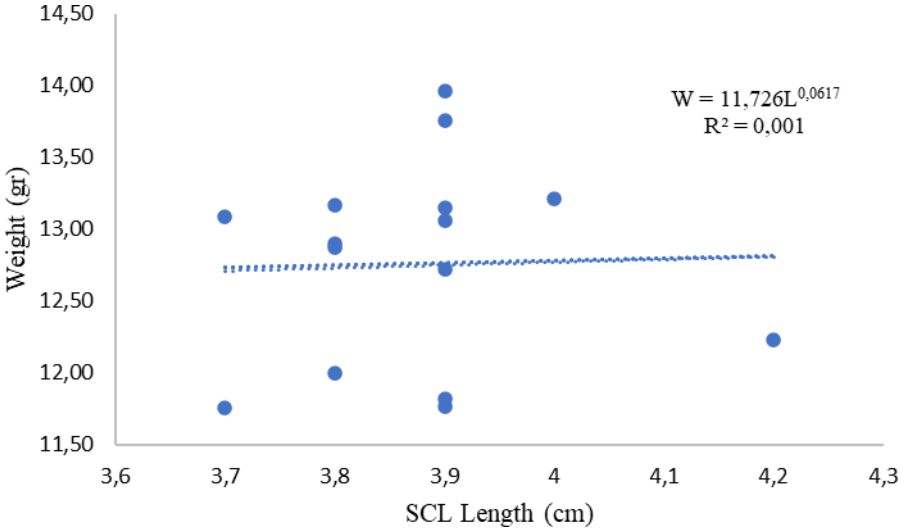

Fig. 15. Correlation between straight carapace length (SCL) and weight of 2-day-old hatchlings in TNKpS.

The results of the calculations on 15 samples of 2-day-old hatchlings can be seen in Appendix 9, with straight carapace lengths ranging from 3.7 to 4.2 cm and weights ranging from 11.76 to 13.96 grams, resulting in a correlation value as shown in Figure 16. The results indicate the equation $W = 11.726L^{0}.0617$ with (R^2) 0.001, which means the relationship between straight carapace length and weight is very low.

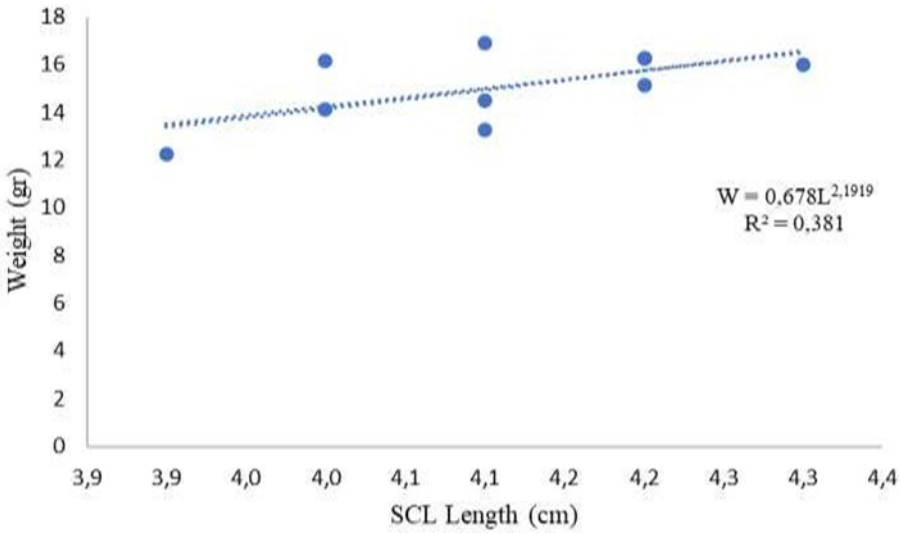

Fig. 16. Correlation between straight carapace length (SCL) and weight of 10-day old juveniles in TNKpS

The results of morphometric measurements on 10 samples of 10-day-old juveniles can be seen in Appendix 10 with a straight carapace length ranging between 3.9 - 4.3 cm and a weight ranging between 12.26 - 16.9 grams producing a correlation value as in Figure 17. The results show the equation $W = 0{,}678L2{,}1919$ with $(R2)$ 0.381 Figure 17 Correlation between straight carapace length (SCL) and juvenile weight 17 10 days in TNKpS which means that the length of the carapace is straight and the weight has a low relationship.

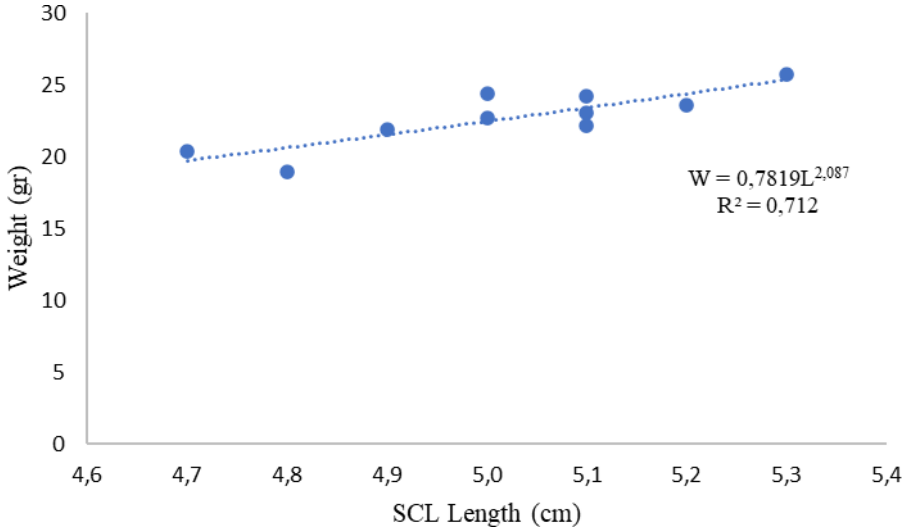

Fig. 17. Correlation between straight carapace length (SCL) and weight of 15-day-old juveniles in TNKpS.

The results of morphometric measurements on 10 juvenile samples aged 15 days can be seen in Appendix 11 with a straight carapace length ranging between 4.7 – 5.3 cm and a weight ranging between 19.01 – 25.78 grams producing a correlation value as in Figure 18. The results show an equation $W = 0{,}7819L2{,}087$ with $(R2)$ 0.712 which means that the straight carapace length and weight have a strong relationship.

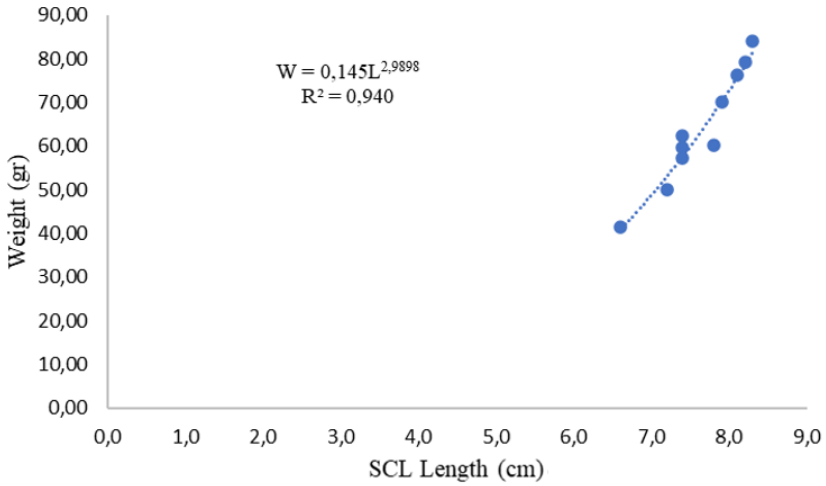

Fig. 18. Correlation between straight carapace length (SCL) and weight of 90-day-old juveniles in TNKpS.

The results of morphometric measurements on 10 juvenile samples aged 90 days can be seen in Appendix 12 with a straight carapace length ranging from 6.6 – 8.3 cm and a weight ranging from 41.52 – 84.08 grams producing a correlation value as in Figure 19. The results show an equation $W = 0{,}145L2{,}9898$ with ($R2$) 0.940 which means that the straight carapace length and weight have a very strong relationship.

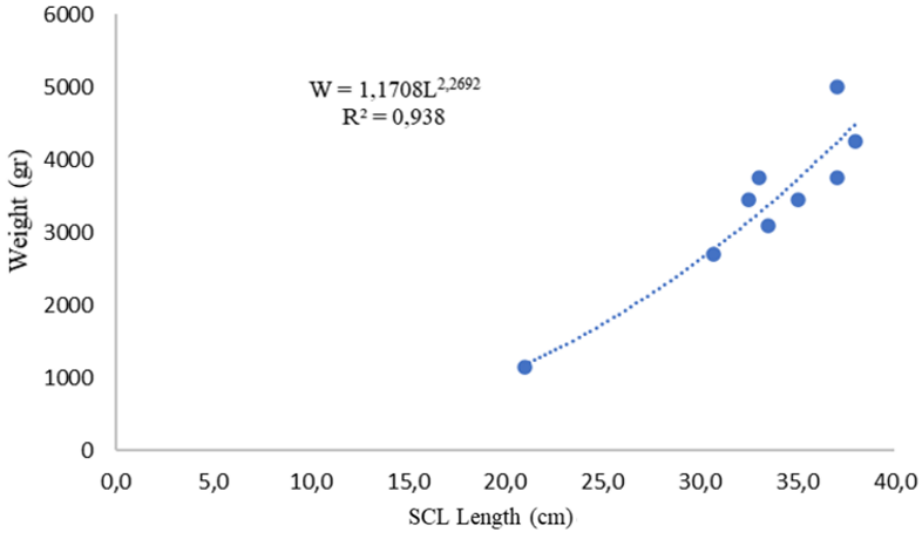

Fig. 19. Correlation between straight carapace length (SCL) and weight of young turtles in TNKpS.

The results of morphometric measurements on 9 samples of young turtles aged 2.5 years to 3 years can be seen in Appendix 13 with a straight carapace length. Ranges from 21.0 – 38.0 cm and weighs between 1150 – 5000 grams produces a correlation value as in Figure 20. The results show the equation $W = 1{,}1708L2{,}2692$ with ($R2$) 0.938 which means that the straight carapace length and weight have a very strong relationship.

3.3 Discussion of morphometric variation of hawksbill turtles

Morphometric measurements of head length (HL) in the juvenile phase start at around 2–3 cm at 10 days of age, increase to 3 cm at 15 days of age, then 3.5–4.3 cm at 90 days of age, and finally 9–15.7 cm in the young turtle phase. Research by [5] analyzed the skulls of green sea turtles (C. mydas), comparing the size of juvenile and adult individuals. They found that changes in the skull, particularly relative head length and width, reflect adaptations to shifting dietary patterns during development. This suggests that the progressive increase in head length (HL) from juvenile to young turtle stages is not only due to general growth but also ecological adaptations leading to improved foraging efficiency.

Head circumference (HC) measurements showed a significant jump from 4.5 – 4.9 cm at 10 days of age, 4.9 – 5.3 cm at 15 days of age, to 6 – 6.5 cm at 90 days, and finally 13.5 – 20.1 cm in the juvenile turtle phase. Head width (HW) also showed a consistent increase from 1.3 cm at 10 days of age, to 6.0 cm in the juvenile turtle phase. In line with the study of [6] on adult hawksbill turtles in Bulukumba waters, which included head measurements and reported significant differences between age classes and described exponential growth throughout the juvenile and juvenile turtle phases. The proportional increase in head size with growth demonstrates the role of head width in ecology and jaw strength in line with the pattern of increasing head width (HW) from the juvenile to the juvenile turtle phase.

Morphometric measurements of straight carapace length (SCL) and straight carapace width (SCW) increase with age. Straight carapace length (SCL) increases from a range of 3.8 – 4.2 cm in 2-day-old hatchlings to 21.0–38.0 cm in the juvenile turtle phase, while straight carapace width (SCW) increases from 2.5–2.9 cm to 14.5–29.5 cm. Growth reflects healthy development and structural adaptations to support swimming activities and body protection. The morphometric growth of hawksbill turtles can be greatly influenced by dietary factors and protective habitat. Research by [7] examined the effect of feed type on the growth of hawksbill turtle hatchlings at Tikus Emas Beach, Sungailiat, Bangka. Results showed that different feed compositions significantly varied the increase in parameters such as straight carapace length (SCL) and straight carapace width (SCW).

Measurements of curved carapace length (CCL) and curved carapace width (CCW) showed an increase with age, reflecting measurable and consistent growth in hawksbill turtles. Research by [8] showed that variations in feed composition between lemuru and seaweed significantly affected the curved carapace length (CCL) and curved carapace width (CCW) of hawksbill turtle hatchlings. Research shows that carapace width growth continues to follow the increase in length proportionally.

The length of the forelimbs (FLL) and the length of the hindlimbs (HLL) in hawksbill turtles show negative allometric growth, where the growth in the length of the forelimbs and hindlimbs is slow compared to the body growth. Morphometric data from the 10-day juvenile phase showed that the FLL ranged from 3.0 to 4.0 cm, increasing to 3.7 to 4.1 cm at 15 days of age, and reaching 4.5 to 5.9 cm at 90 days of age, while the juvenile turtle phase had an FLL between 12.0 and 23.0 cm. HLL measurements for the 10-day juvenile phase ranged from 2.0 to 25 cm, increasing slightly to 2.0 to 2.8 cm at 15 days of age, then 3.0 to 4.0 cm at 90 days of age, and reaching 9.0 to 17.5 cm in the juvenile turtle phase. This is in line with the results of research by [9] which documented similar FLL and HLL ranges in hawksbill turtles caught by catch in Sambas Waters, West Kalimantan, and showed that limb growth accelerated with age.

Tail morphometrics in hawksbill turtles show clear growth with age, with total tail length (TTL) increasing from 0.8–1.0 cm in 10-day-old juveniles to 4.5–7.0 cm in the juvenile phase. Meanwhile, the length from the cloaca to the tip of the tail (CETL) increases from 0.4–0.5 cm in 10-day-old juveniles to 2.5–5.0 cm in young turtles. Similarly, the length between the plastron and the cloaca (PCL) grows from 0.4–0.5 cm to 1.0–2.5 cm. [10] study in northwestern Mexico measured total tail length (TTL) along with curved carapace length (CCL) and found juveniles had tails longer than 5 cm. This consistently indicates sexual dimorphism and a transition to maturity.

Analysis of the body weight of hawksbill turtles (E. imbricata) shows an increase with age, from hatchling to juvenile. The weight of 2-day-old hatchlings ranges from 11.76 to 13.96 grams, then increases to 12.26 to 16.90 grams in 10-day-old juveniles, and reaches 19.01 to 25.78 grams at 15 days. At the age of 90 days, the juvenile body weight increases drastically to reach 41.52 – 84.08 grams. In the young turtle phase, body weight jumps to 1150 – 5000 grams. This increasing pattern indicates a healthy and progressive growth process. Research by [7] treated hawksbill turtle hatchlings with different feed treatments for 12 weeks. The group fed lemuru fish reached a weight of 211.8 grams, while the group fed pellets reached 95.3 grams. This confirms that adequate nutrition and age are important factors in supporting the rate of body weight growth of hawksbill turtles in conservation settings.

3.4 Discussion of the correlation between of straight carapace length and weight of hawksbill turtles

The correlation between hatchlings at 2 days of age was very low, at 0.001. This indicates that in this early stage of life, carapace length has little correlation with weight. Research by

[9] showed that in the early stages of life, carapace length growth is faster than weight growth. This is quite normal because hatchling development is still influenced by energy reserves from the egg yolk, which have not yet been fully absorbed, and there has not yet been any accumulation of body mass from independent feeding activities. In the juvenile phase at 10 days of age, the correlation increased, although still in the low category, with a value of 0.381. This indicates the beginning of a slightly more consistent growth pattern between length and weight, possibly because the hatchlings began to actively feed and adapt to the conservation environment. Research by [13] showed that although there was an increase in specific growth rate, there was no significant difference between feeding treatments on hatchling growth. This indicates that other factors such as feed quality and environmental conditions also plays an important role in the growth of hawksbill turtles.

The juvenile phase at 15 days and 90 days old had values of 0.712 and 0.940, respectively, indicating a stronger correlation between straight carapace length and weight. This suggests that with increasing age and size, hawksbill turtle growth becomes more proportional between carapace length and weight. Research by [13] confirmed that a combination of feed with optimal protein and calcium content can increase the efficiency of hawksbill turtle morphometric growth during this phase. The correlation between the juvenile turtle phase and the age range of 2.5 to 3 years showed a very strong relationship with a value of 0.938. This indicates that the turtle's growth during this juvenile turtle phase is proceeding well, as can be seen in Appendix 14. Environmental factors and the availability of suitable habitat greatly influence the successful growth of hawksbill turtles. According to [14] the importance of habitat quality and bio-physical factors supporting the growth and survival of hawksbill turtles.

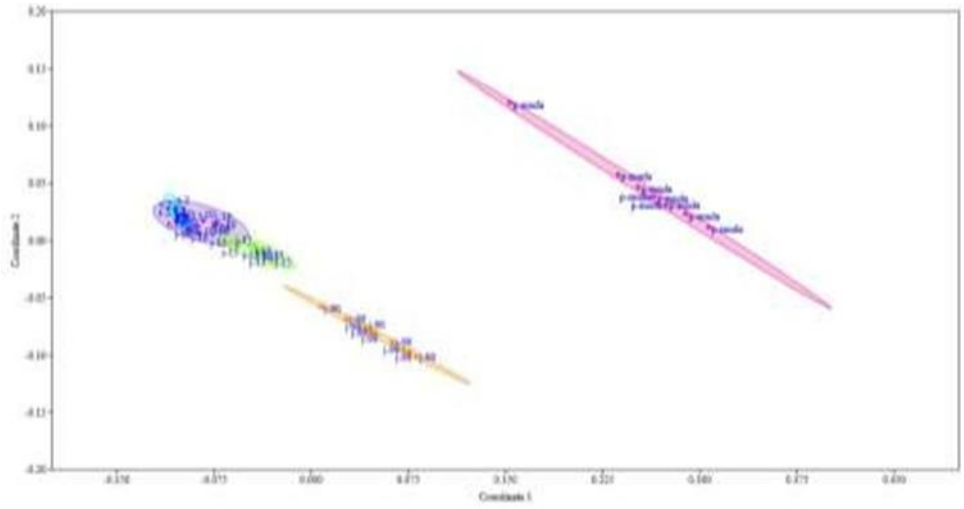

Fig. 20. Nmds analysis of straight carapace length (SCL) and weight based on age of hawksbill turtles in TNKpS

The results of the nMDS analysis in Figure 21 using the Bray-Curtis index indicate the presence of morphometric clustering of hawksbill turtles. 2-day-old hatchlings (t-2), 10-day-old juveniles (j-10), and 15-day-old juveniles (j-15) cluster tightly in the lower left corner. 90-day-old juveniles (j-90) begin to shift away from the hatchling and young juvenile clusters. Young turtles (p-young) form their own cluster far to the right. The nMDS plot with the Bray-Curtis index shows a clear growth pattern in hawksbill turtles based on two main morphometric variables, namely straight carapace length (SCL) and body weight. The

hatchling phase (t-2), 10-day-old juveniles (j-10), and 15-day-old juveniles (j-15) cluster very tightly, indicating that in the early stages of growth, variation between individuals is still low, and changes in carapace size and weight are not very different between individuals. At around 90 days (j-10), the clusters began to move away from the early phase clusters, indicating that growth between samples began to differ significantly, possibly due to variations in individual growth rates or the influence of the environment and diet that began to appear. Indonesian research by [7] stated that the type of food can affect the growth rate of hawksbill turtle hatchlings at Tikus Emas Beach, Sungailiat.

The group of young turtles (p-young) is separated significantly from the other clusters, indicating that this phase of size and weight increase has reached a level where individual morphometrics are very different from the initial phase as a whole. These findings align with research by [3] who reported that the growth rate of juvenile hawksbill turtles varies with size and population density in the Chagos Archipelago. The early juvenile period, at 10 to 15 days of age, is homogeneous in size and weight, but after passing a certain threshold of around 90 days, the growth process becomes more diverse, possibly due to differences in food intake and other factors. Research by [15] who analyzed the morphometrics of olive ridley turtle hatchlings in the Mentawai Islands, showed a homogeneous pattern in the early phase but developed into greater size variation with age.

3.5 Conclusion and suggestion

3.5.1 Conclusion

Hawksbill turtles (*E. imbricata*) in SPTN Region I, Kelapa Island, and Region II, Harapan Island exhibit negative allometric growth from hatchling to juvenile turtle stage. Measurement results show that carapace length and width increase with age, but body weight increases much faster. The correlation between straight carapace length and body weight also increases with age, starting from a very low correlation in 2-day-old hatchlings to a very strong correlation in juvenile turtles aged 2.5-3.5 years. There are three cohorts of hawksbill turtle growth in the turtle conservation center of SPTN Region I, Kelapa Island, and SPTN Region II, Harapan Island, TNKpS.

3.5.2 Suggestion

Long-term monitoring is necessary and consistency in the use of measuring instruments is required during morphometric measurements get a more complete picture of growth. Further research in-depth analysis can be done by observing the influence of feed nutrition and environmental quality parameters to optimize data and conservation strategies.

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