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BIOLOGY OF THE GREEN TURTLE *CHELONIA MYDAS* (LINNAEUS) IN THE GULF OF MANNAR AND PALK BAY

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ABSTRACT

This paper deals with various aspects of the biology of the Green turtle *Chelonia mydas* of Mandapam region caught during 1971–1976. The major food items observed in the stomachs are sea grasses *Halophila ovalis, Thalassia testudinum* and sea weed *Gelidiella acerosa*. The relationships or morphometric measurements with plastron width, which is used here as standard measurement, showed linear regression with best correlations. The relationship of carapace length (straight) with other body measurements were also examined.

The plastron width-weight relationship for 316 turtles were worked out. The regression coefficients of the same for the subadults (weighing less than 71 kg), males and females were found to differ significantly. Females greatly outnumber males in all the years. Plastron length and weight frequencies for females and males were analysed.

Using annual weight frequencies for six years from 1971 to 1976, the modals were traced. The mean weights of individual age groups were converted to plastron width and a von Bertalanffy curve was fitted. The growth parameters were determined as $L \infty = 92.2241$ cm, $K = 0.2037$ and $t_0 = -0.2965$ years. It is found that the highest weight increment, 18.64 kg, is in the 7th year of age and highest plastron width, 15.2 cm, in the 2nd year.

INTRODUCTION

THE GREEN TURTLE *Chelonia mydas* (Linnaeus (family Chelonidae), precious and beautiful protected reptilian wildlife (Sundaram, 1972; Jayal, 1977) constitutes about 89% of the five species of marine turtles caught in the Gulf of Mannar and Palk Bay, the other four protected species being Hawksbill turtle *Eretmochelys imbricata* (Linnaeus) (family Cheloni-dae), Olive ridley turtle *Lepidochelys olivacea* (Eschscholtz) (family Chelonidae), Loggerhead turtle *Caretta caretta* (Linnaeus) (family Chelonidae) and Leatherback turtle *Dermochelys coriacea* (Linnaeus) (family Dermochelidae) (Fischer, 1978; Murthy and Menon, 1976). The availability of turtles is more in the Gulf of Mannar than in the Palk Bay (Jones and Bastian Fernando, 1973). They occur in abundance in the Gulf of Mannar near the coral reefs which extend from Rameswaram down to Cape Comorin (Chari, 1964). The Green turtles are also found in large numbers in the coastal waters of the Bay of Bengal and Arabian Sea from Nagapattinam to Quilon, in Laccadive Islands (Shanmughasundaram, 1968) in the Andaman Islands and on the Rangoon Coast (Acharji, 1950). Maxwell (1911) stated that there was a regular trade of these cheloniaus between Calcutta and the Andaman Islands. In the Nicobar Islands, these animals were extensively killed by 'pegging' and consumed by the local inhabitants (Acharji, 1950). As per Port office records the turtles were exported to Sri Lanka from 1945 to 1966 from Pamban and Keelakkarai. The turtle meat, shells and oil were exported to U.S.A., U.K., Germany, Bahrain, Singapore, Netherlands and Belgium. The turtle fishing has been practised for ages on

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the south eastern of shores the Indian Peninsula particularly around Krusadai Island (Kuriyan, 1950). Deraniyagala (1939) and Carr (1952) had given a good account on the Green turtles of the Gulf of Mannar and the Palk Bay. The Green turtles are found between the northern and southern 20°C Isotherms where average temperature of surface water in coldest month is above 20°C (Hirth, 1971).

The literature available on growth rate and age of maturity is very fragmentary. There is no satisfactory method of determining the age of Green turtles. In the present study food and feeding habits, morphometric relationship, plastron width-weight relationship, sex ratio and age and growth are dealt with.

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Material and Methods

The stomach contents of nine Green turtles collected from Keelakarai and one from Vedalai were analysed. Turtles meant for transporting to Tuticorin from Mandapam Camp, Mandapam, Pamban and Rameswaram railway stations and turtles landed at Keelakarai, Vedalai, Chinnapalam and Rameswaram landing centres were used for morphometric studies and length-weight relationship. The plastron width was measured between two marginals, perpendicular to the median axis, having the greatest straight line distance. The other measurements were taken as followed by Frazier (1971). The weight data of the turtles observed at landing centres as well as the data collected from the booking records of the above railway stations for six years from 1971 to 1976 were used for age and growth studies.

Briefly the analysis consisted of (1) transforming the data into usable form by (a) calculating plastron width-weight relationships using functional regressions (Ricker, 1973), (b) converting weights to plastron width which is used in this area as a standard measurement for marketing and (c) grouping the weights, year wise; (2) separating age groups from the frequency distributions and estimating their mean plastron widths; (3) setting up the progressions of mean plastron widths and corresponding age structures and (4) fitting von Bertalanffy growth model to the progressions of mean plastron widths.

Results and Discussion

Food and feeding habits

Stomach contents of ten Green turtles were analysed (Table 1) for their preference of food items. The mean weight of the food items of the ten stomachs were as follows: *Halophila alis* 134.8 gm, *Thalassia testudinum* 170.3 gm, *Gelidiella acerosa* 208.4 gm, *Cymodacea* sp. 97.4 gm, sea grass stems and rhizomes (unidentifiable 89.2 gm' *Sargassum* sp. 30.3 gm, *Hypnea* sp. 16.9 gm, *Ulva reticulata* 6.2 gm and other species of sea weeds such as *Dictyota dichotama, Solieria robusta, Halimeda macroloba, Pockockiella variegata, Caulerpa fergusonii, C. sertularioides, C. microphysa* and *Chaetomorpha* sp. 18.1 gm and squid (*Loligo duvauceli*) egg mass and sponge 246.3 gm. The mean percentage occurrence of the above food items is given in the Table 1. Index of preponderence is worked out by multiplying the mean weight of the items and the percentage of the items. The major food items are the sea grasses *Halophila ovalis, Cymodacea* sp. *Thalassia testudium* and the sea weed *Gelidiella acerosa* which altogether form 75.6%. One male green turtle's stomach contained squid (*Loligo duvauceli*) egg mass constituting 92.5% (2462.3 gm) and a blue synthetic (polyvinyl) yarn of 40 cm length and in another female turtle a bit of

TABLE 1. *The stomach content analysis of ten green turtles examined at Keelakkarai and Vedalai. The stomach content items are given in weight (gm) and percentage of total content in parentheses. Occurrence index, weight index and the index of preponderance of food items are also given.*

Date	Sex	Plastron width in cm	Weight in kg	Empty stomach weight in gm	Stomach contents in gm	Items of stomach contents									
						Halophila	*Thalassia*	*Cymodacea*	Sea grass stems and rhizomes	*Gelidiella*	*Sargassum*	*Hypnea*	*Ulva*	Other sea weeds	Squid (*Loligo duvauceli*) egg mass and sponge
11-2-73	♀	47.8	23	112	405					405.0 (100)					
19-4-73	♀	63.2	58	456	1325	86.1 (6.5)				1192.5 (90)		15.9 (1.2)	30.5 (2.3)		
20-6-76	♀	41.4	13	70	211	210.6 (99.8)							0.4 (0.2)		
19-9-76	♀	65.2	67	326	999	458.5 (45.9)		2.0 (0.2)		176.8 (17.7)		152.9 (15.3)	30.0 (3.0)	178.8 (17.9)	
19-12-76	♀	52.5	32	414	488	484.0 (99.2)		1.0 (0.2)					1.0 (0.2)	1.0 (0.2)	1.0 (Sponge) (0.2)
20-3-77	♀	59.8	51	182	515	17.0 (3.3)	497.0 (96.5)							1.0 (0.2)	
19-6-77	♀	89.0	154	581	983	91.4 (9.3)			891.6 (90.7)						
11-9-77	♀	88.1	151	694	1311		1206.1 (92.0)	104.9 (8.0)							
18-12-77	♀	77.6	110	583	1279			865.9 (67.7)		309.5 (24.2)	103.6 (8.1)				
5-2-78	♂	75.3	101	893	2662						199.7 (7.5)				2462.3 (92.4) (squid)
Mean weight		65.9	76	431.10	1017.90	134.8	170.3	97.4	89.2	208.4	30.3	16.9	6.2	18.1	246.3
Mean % of weight						26.4	18.9	7.6	9.1	23.2	1.6	1.7	0.6	1.8	9.3
Occurrence index in % (Oi)						20.0	6.7	13,3	3.3	13.2	6.7	6.7	13.3	10.0	6.7
Weight index in % (Wi)						13.2	16.7	9.6	8.8	20.4	3.0	1.7	0.6	1.8	24.2
Index of preponderance % of $\frac{Oi \times Wi \times 100}{Oi \times Wi}$						25.8	10.9	12.5	2.8	26.4	2.0	1.1	0.9	1.8	15.8

sponge 0.2% (1 gm) also was found. It is derived from the mean weight of stomach content and turtles, that the stomach content is 1.34% of the weight of turtle. Hirth (1971) has given an elaborate list of food items of green turtles of Western and Eastern Hemispheres. Deraniyagala (1939, 1953) gives *Cymodacea, Thalassia, Halophila* and algae as the food items of green turtles in Sri Lanka waters.

Morphometric relationships

Fifty eight female turtles having a mean size of 46.4 cm (plastron width) within the range of 35.2 and 79.6 cm were measured for the morphometric relationships. The relationships of head width, plastron length, carapace width (curved) and carapace length (curved) with plastron width were found out by linear regression by the least square method. The *a* and *b* regression values are given in Table 2. The regressions on carapace length (curved) with carapace width (curved), plastron length, plastron width and head width were also found (Table 2). The correlation co-efficient *r* found for the above regressions shows the best correlations for all the regressions (Table 2).

The mean values of those ten turtles was 50.16 cm carapace straight length within the range of 40.4 and 64.5 cm. Two regressions on carapace length (straight) with carapace width (curved) and carapace width (straight) with carapace width (curved) were fitted (Table 2). The 'r' values showed the best relationship. By using the above regression values two graphs were drawn for converting plastron width to other measurements (Fig. 1) and from other measurements to carapace straight length (Fig. 2). Frazier (1971) gives the relationships of carapace straight length with carapace curved length and carapace straight width with carapace curved width for males and females of the Aldabra Atoll Green turtles as follows:

Males: Curved length = 0.9743 (straight length) + 7.006 cm

Females: Curved length = 1.0212 (straight length) + 3.693 cm

Males: Curved width = 1.0734 (straight width) + 11.562 cm

Females: Curved width = 1.4378 (straight width) + 15.091 cm.

TABLE 2. *Relationship of body measurements*

Body measurements	No.	'a' value	'b' value	+b	'r' value
Plastron width (x) vs carapace length (curved) (y)	58	−10.540	1.412	0.062	0.981
-do- (x) vs carapace width (curved) (y)	58	− 5.477	1.243	0.034	0.978
-do- (x) vs plastron length (y)	58	− 5.170	1.064	0.020	0.981
-do- (x) vs head width (y)	58	− 0.750	0.155	0.005	0.984
Carapace length curved (x) vs carapace width (curved)	58	4.233	0.872	0.043	0.988
-do- (x) vs plastron length (y)	58	3.026	0.749	0.050	0.994
-do- (x) vs plastron width (y)	58	8.899	0.682	0.035	0.981
-do- (x) vs head width (y)	58	2.092	0.106	0.023	0.971
-do- (straight) (x) vs carapace length (curved) (y)	10	7.440	0.941	0.188	0.988
Carapace width (straight) (x) vs carapace width (curved) (y)	10	−16.045	1.475	0.251	0.995

Some workers use straight carapace length as standard measurement. For finding out the relationship between straight length and curved length and between straight width and curved width of carapace ten turtles were measured.

The regression found out for carapace length (straight) with carapace length (curved) for ten turtles of the Gulf of Mannar is similar to the male turtles of Aldabra. The relationship of carapace width (straight) with carapace width

(curved) is more or less equal to the Frazier's regression values for females.

sexes were differentiated externally were pooled for the years 1972–1976 and the sex ratio is given

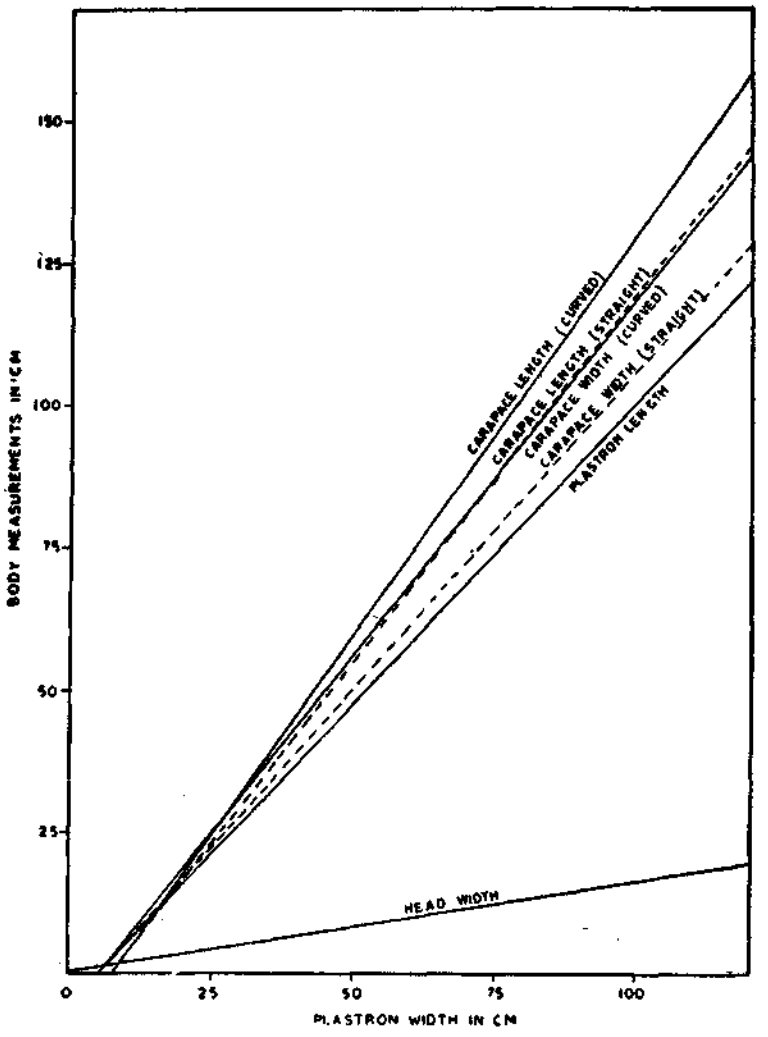

Fig. 1. Relationships of plastron width with head width, plastron length, carapace width (straight), carapace width (curved), carapace length (straight) and carapace length (curved).

Sex ratio

The sexes are differentiated by the external appearance of tail only; the tail of female barely reaches beyond the margin of carapace, but the tail of male reaches some distance beyond (Ingle and Smith, 1949). The individuals whose

in percentages for the corresponding plastron width and weight intervals (Fig. 3 a, b). It is seen that the sex differences are evident in adult turtles from the weight group of 71 kg and from the plastron width interval of 50 cm. The smaller turtles below the weight of 70 kg were females only by external appearance.

In Table 3 the data on the ratio of males to females above 71 kg groups against each year from 1972 to 76 are presented. It is seen that only in the year 1972 x^2 value of high significance with the females dominating were noted. In the weight interval-wise data presented in Table 4, the sex ratio obtained for 81–90 kg and 131-140 kg are found to show different degrees of significance. Of these the high significant deviation was for 131–140 kg range and above that range there is no male representation. The relevant data and the x^2 values for the different size groups are shown in Table 5 which indicates that in the 50, 55 and 60, 80 cm groups the females are more numerous whereas in the groups 70 and 75 cm the ratio is more or less equal without any significance. In the groups 85 and 90 cm there is no male representation.

Length-weight relationship

The calculated equation derived from the logarithmic transformation of plastron width versus the whole weight of 316 turtles is log W-3.4924 Log PW-4.5495 where W is weight in kilogram and PW is plastron width in cm. The plastron width-weight curve fitted for all the turtles (Fig. 4) showed closer resemblance with the observed values. Hirth and Carr

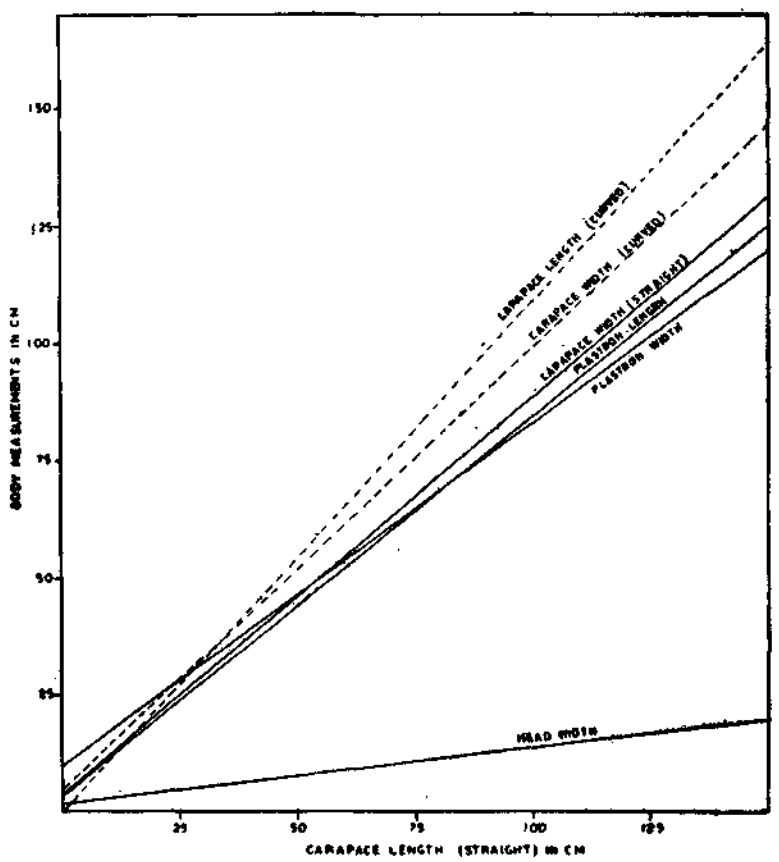

Fig. 2. Relationships of carapace length (straight) with head width, plastron width, plastron length, carapace width (straight), carapace width (curved) and carapace length (curved).

(1970) found that the carapace length and weight relationship of 19 female and 10 male turtles was $W = 0.005\ L^3$ (W is weight in pounds and L is carapace length in inches) 71 kg and above. Different regressions were calculated in respect of 4 groups *viz.* (1) below 71 kg, (2) above 71 kg, (3) females above 71 kg. and (4) males above 71 kg. Variance test was

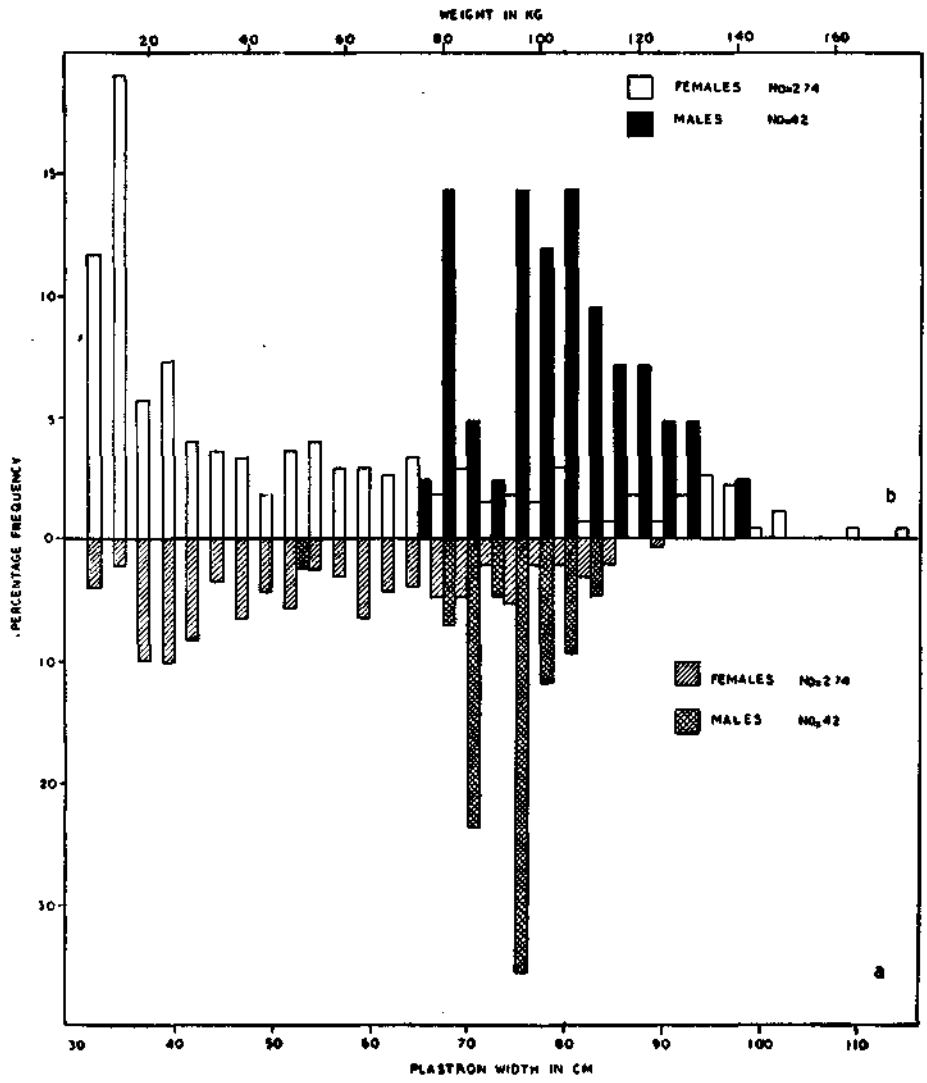

Fig. 3 a and b. Weight and length frequencies in percentage of males and females pooled for the years 1970-1976.

and indicated that there was no significant differences between males and females of the same size. The males whose sex could be determined by external characters weighed used for the regression coefficients and the results are presented in Table 6. The groups below 71 kg, females above 71 kg and males showed a significant difference ($F = 60.14$).

The group above 71 kg (mature) and the group below 71 kg (sexed as females based on external characters - immature or subsdults) showed significant difference (F=82.68) and the males and females above 71 kg groups also showed significant difference (F=32.1). It is observed from the curve of plastron width and weight that the males weighed less than the females after 75 cm (Fig. 5).

To test whether the length-weight regression coefficients of the three groups differed from 3, *t*-test was applied. It was seen that the regression coefficients of sub-adults and males differed significantly at 1% and females at 5% level from 3. The results are given below:

Groups of turtles	Regression Coefficient b	Standard Error of b	b–3	t value	Degree of freedom
Sub-adults (below 71 kg)	3.6591	0.0433	0.6561	15.10**	194
Males	1.5647	0.2425	-1.4353	5.13**	39
Females	2.8019	0.1004	-0.1981	1.97*	74

TABLE 3. *Chi-square test for the Green turtle above 71 kg*

Year of catch	Males	Females	χ^2	D.F.
1972	4	16	7.20**	1
1973	7	17	4.16*	1
1974	10	14	0.67	1
1975	16	17	0.03	1
1976	5	14	4.26*	1
Pooled	42	78	10.80**	1

** Significant at 1%
* Significant at 5%

Age and growth

Observed weights of 159, 177, 277, 175, 364 and 177 turtles for the years 1971 to 1976 respectively were converted to percentage weight frequencies for the corresponding years and given in the Figure 6. The modals were traced for individual year classes and presented in the same figure. The first modal value ranged from 8–13 kg (mid point): the average of six years first mode is 11.3 kg.

TABLE 4. *Chi-square test for different weight groups above 71 kg*

Weight interval in kg	Males	Females	χ^2	D.F.
71–80	7	14	2.33	1
81–90	3	12	5.40*	1
91–100	11	9	0.20	1
101–110	10	10	0.00	1
111–120	6	7	0.08	1
121–130	4	7	0.82	1
131–140	1	13	10.29**	1
141–150	—	4	2.00	1
151–160	—	—	—	—
161–170	—	1	0.50	1
171–180	—	1	0.50	1
Pooled	42	78	10.80**	1

TABLE 5. *Chi-square test for different plastron width groups above 50 cm*

Plastron width interval in cm	Males	Females	χ^2	D.F.
50–54.9	1	28	25.14**	1
55–59.9	—	16	8.00**	1
60–64.9	—	30	15.00**	1
65–69.9	3	24	16.33**	1
70–74.9	12	19	1.58	1
75–79.9	20	21	0.02	1
80–84.9	6	15	3.86*	1
85–89.9	—	6	3.00	1
90–94.9	—	2	1.00	1
Pooled	42	161	69.76**	1

Schmidt (1916) found that nine turtles initially weighing between 2.3 and 29 kg showed weight increase from 138 to 430 gm per month after 3.5 to 11 months in the ocean. His findings also suggest that Green turtles weighing about

TABLE 6. *Calculations for the analysis of variance to test the regression coefficients for the different groups of turtles*

Groups of turtles	Degrees of freedom	x^2	xy	y^2	Correlation coefficient 'r'	Regression coefficient 'b'	Degrees of freedom	Sum of squares	Mean square	F
Below 71 kg	196	1.2259	4.4821	16.8226	0.9870	3.6561	195	0.4356		
Females above 71 kg	76	0.0942	0.2640	0.8101	0.9557	2.8019	75	0.0703		
Males above 71 kg	41	0.0410	0.0630	0.1908	0.7172	1.5647	40	0.0942		
Total	313	1.3612	4.8091	17.8236			310	0.6001	0.0019	
							312	0.8330		
		Difference of testing among regression coefficients					2	0.2329	0.1164	60.142
Females	76	0.0942	0.2640	0.8101	—	—	75	0.0703		
Males	41	0.0410	0.0630	0.1908	—	—	40	0.0942		
							115	0.1646	0.0014	
Total	117	0.1353	0.3270	1.0009	—	—	116	0.2105		
		Difference of testing among regression coefficients					1	0.0459		32.097
Below 71 kg	196	2.2259	4.4821	16.8226	—	—	195	0.4356		
Female and Male	118	0.1367	0.3328	1.0084	—	2.4158	117	0.2105		
							312	0.6461	0.0021	
Total	314	1.3626	4.8149	17.8311	—	—	313	0.8173		
		Difference of testing among regression coefficients					1	0.1712		82.68

2.3, 5.5 and 9.1 kg are about 1-1.5, 2-2.5 and 3.3-3.5 years old respectively. He further postulated that a one-year-old green turtle is about 27 cm in carapace length and a two-year old 17.8 cm in carapace length per year (Hirth, 1971).

The mean value of the first mode 11.3 kg is inferred as three years old to correspond with

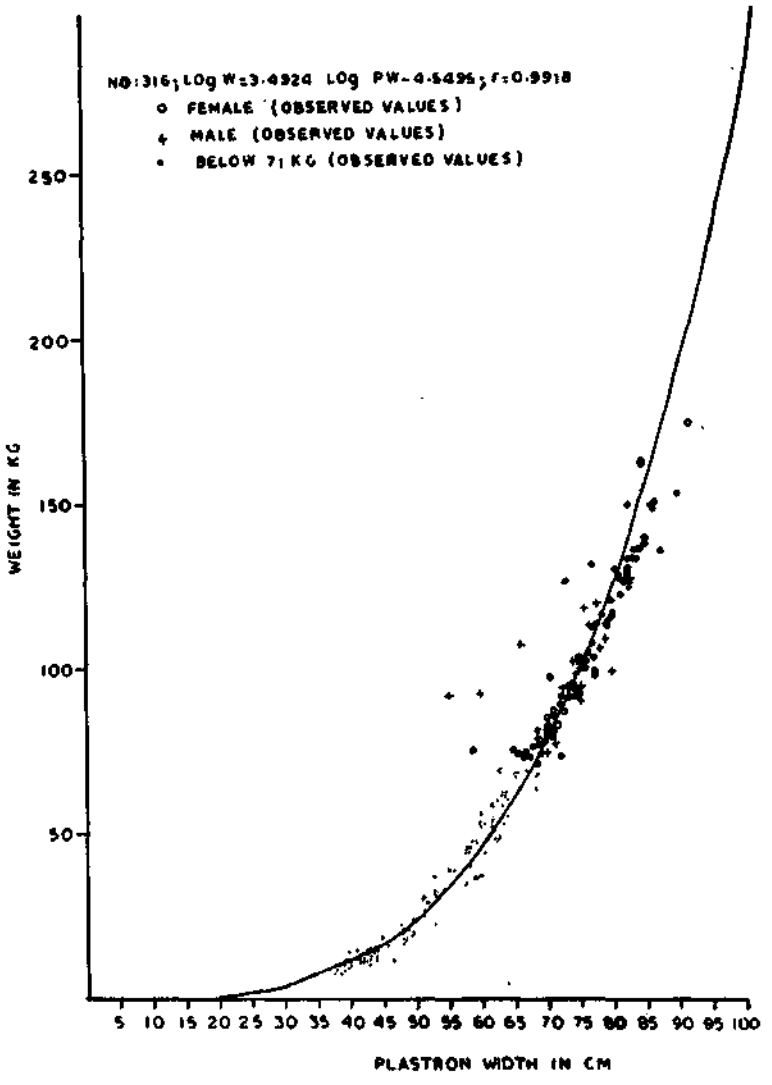

Fig. 4. Plastron width and weight relationship common to all green turtles observed.

is about 35 cm long. Moorhouse (1933) estimated that one-year-old turtles are 20.3 cm long. According to Ingle and Smith (1949) growth rate in early year is about 3.2 kg or

the findings of the above authors. The mean values of the modals traced for the different age groups and corresponding year classes are given in Table 7. It is seen from the Table 7

TABLE 7. *The modal values of weight in kg for different year classes to the corresponding age groups and mean weight of age groups and the corresponding plastron width in cm*

Year Class	Age 3	4	5	6	7	8	9	10	11	12	13	14
1973	13											
1972	8	28										
1971	13	28	43									
1970	13	25	38	58								
1969	8	28	48	58								
1968	13	28	38	58	68	75						
1967		28	38	58	68	78	88					
1966			43	58	68	—	98	98				
1965				65	78	83	—	108	118			
1964					83	—	105	113	118	135		
1963						93	—	—	128	138		
1962							113	—	128	143	158	
1961								123	138	143	—	173
1960									138	148	—	—
1959										158	163	—
Average weight in kg.	11.3	27.5	39.4	59.2	73.0	82.3	101.0	110.5	128.0	144.2	160.5	173.0
Corresponding plastron with in cm.	40.20	51.86	57.48	64.60	68.58	70.98	75.26	77.23	80.56	83.35	85.94	87.80

that the turtle attains a weight of 59.2 kg in 6th year, 101.0 kg in 9th year, 144.2 kg in 12th year and 173.0 kg in 14th year. From the plastron width-weight relationship of all the turtles (log W=3.4924 Log PW – 4.5495) the mean weights of different age groups were converted to plastron width and were presented in the same Table.

K is a constant expressing the rate of change in length increments with respect to t, and t_0 is the hypothetical age at O lengths, is used in this study. The growth curve was plotted by fitting regression of $L_t + 1$ on L^t by the least square method. The parameter estimated are $L_{\infty} = 92.2241$ cm, $K = 0.2037$ and the average (t_0 for the years 3–14 = 0.2965 year (t_0 is found

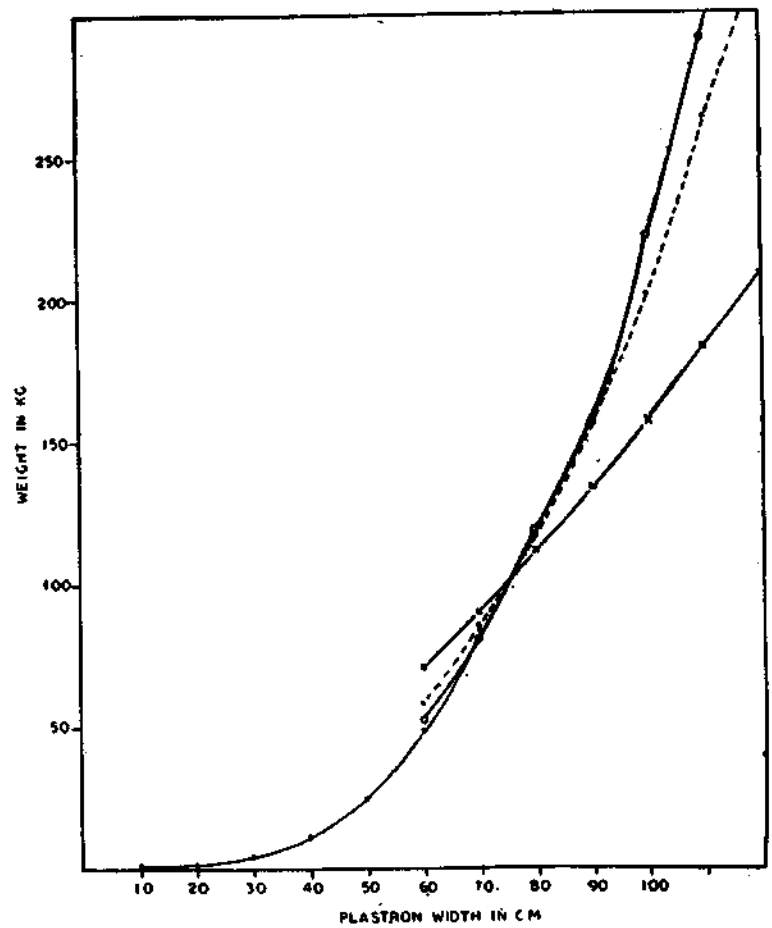

Fig. 5. Plastron width and weight relationships separately to the individuals below 71 kg (subadults), above 71kg (adults), females and males (N: 197 below 71 Kg Group ● — ● LOG W = 3.6561 LOG PW – 4.8242 r = 0.987; N: 119 above 71 Kg GROUP - - - LOG W = 2.4158 LOG PW – 2.5292 r = 0.890; N: 77 Females o—o LOG W = 2.8019 LOG PW – 3.2561 r = 0.956; N: 42 Males + — + LOG W = 1.5530 LOG PW – 0.9115 r = 0.717).

The expression of von Bertalanffy $L_t = L_{\infty}(1 - e^{-K(t-t_0)})$ where L_t is the length at age t in years, L_{∞} is the theoretical maximum length, by the equation $t_0 = t + \frac{1}{K} \log_e \frac{(L_{\infty} - l_t)}{L_{\infty}}$

It is seen from Fig. 7 that the calculated

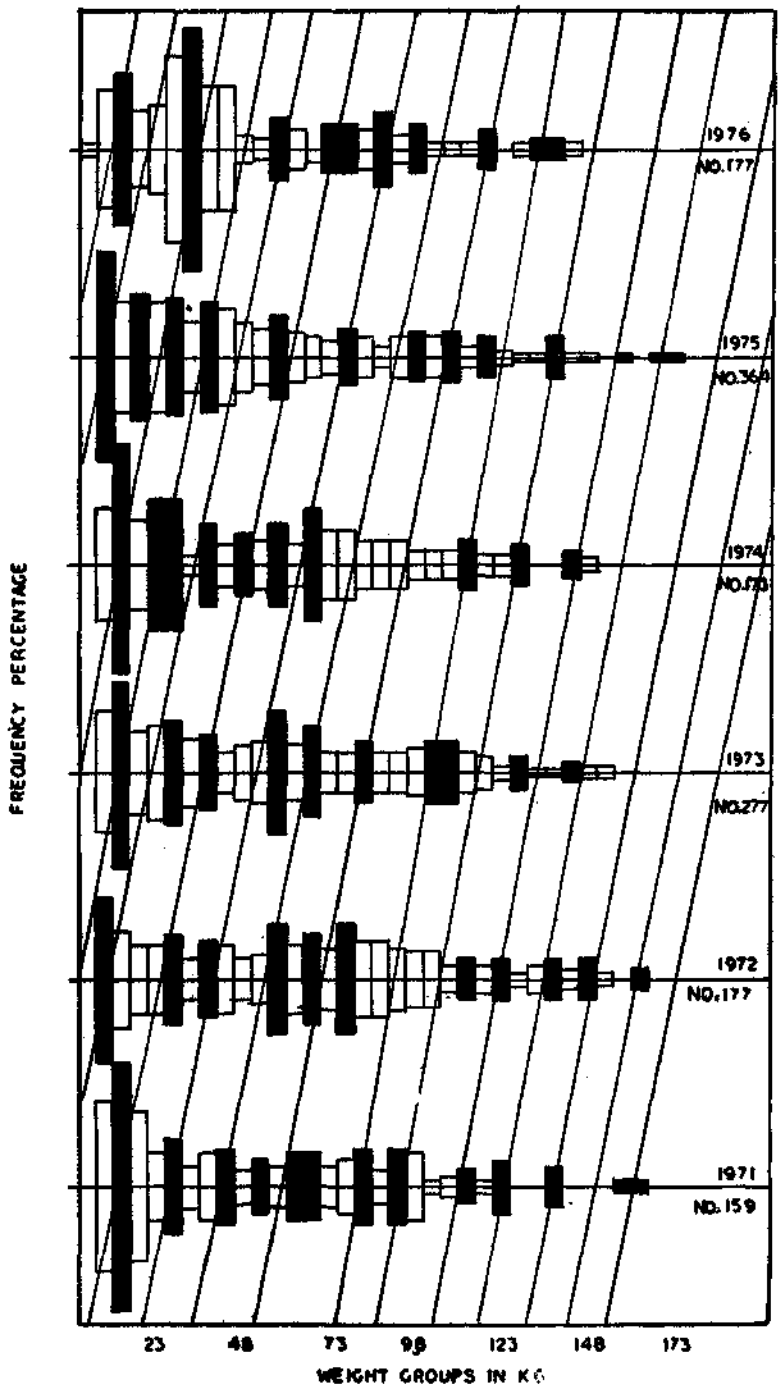

Fig. 6. Annual weight frequencies in percentage and modal trace for the years 1970–1976.

curve fits the converted plastron for the mean weight of different ages. From the length-weight relationship (combined), age-weight relationship (Fig. 7) was obtained in this study. The mean weights of different ages also closely fit the weight-age curve. For L the corresponding weight is 205.3 kg and the corresponding age is 124 years. The most rapid growth in

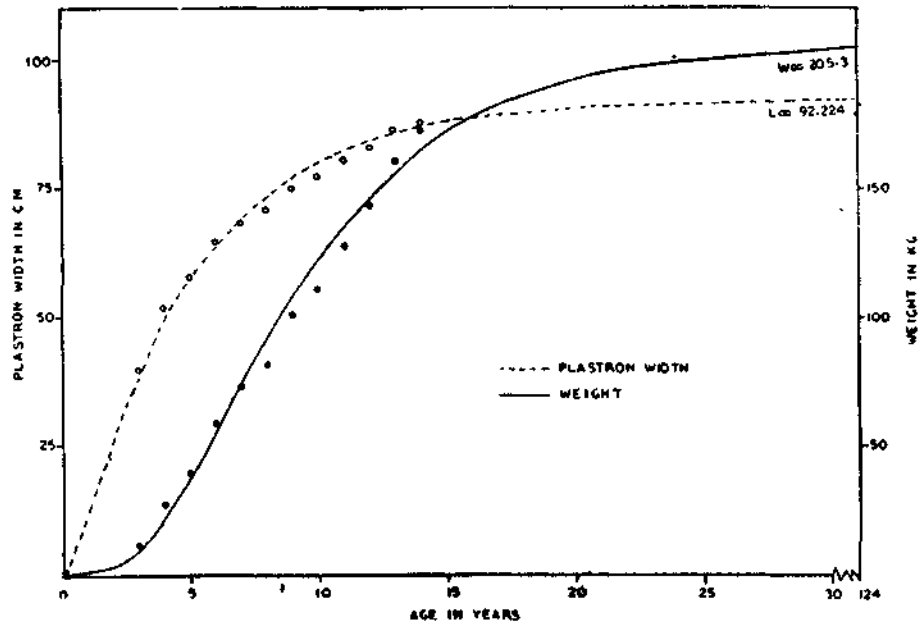

Fig. 7. von Bertalanffy growth curve in plastron width and corresponding curve in weight.

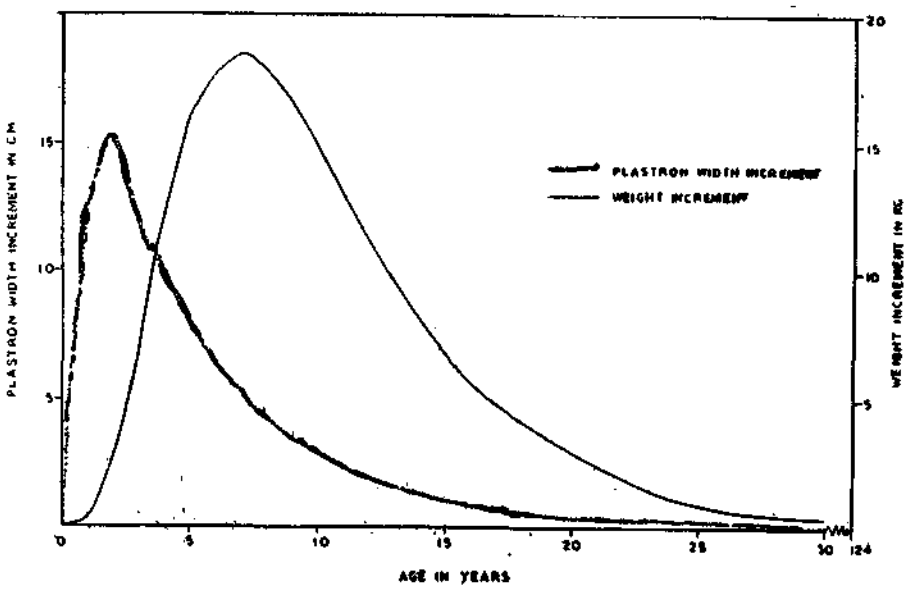

Fig. 8. Weight and plastron width increments for ages.

plastron width occurs in the age of two, the increment being 15.2 cm. The most rapid increase in weight occurs in the age of seven, the increment is being 18.64 kg (Fig. 8). The rapid growth in weight occurs between the ages 4 to 13 and the range of increment is between 10.0 to 18.64 kg.

At the seventh age the plastron width is 69 cm (=81 cm carapace straight length) and the weight is 74 kg. On observation the external sex differentiation is visible for males from 71 kg onwards. The maximum weight increment takes place in the 7th age. From this it is inferred that the first maturity takes place at the age of 7. According to Hendrickson (1958), Carr (1967), Harrisson (1962) and Ehrenfeld (1970), the Green turtles reach maturity from 4 to 6 years, at least six years, 5 to 7 years and 8 to 13 years respectively. Carr and Ogren, (1960), Hirth and Carr (1970) and Hirth (1971) have reported that the smallest nesting female recorded on the Tortuguero and Southern Yemen breeding beaches had carapace lengths of 69.3 and 78.1 cm respectively.

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