STUDIES ON THE GROWTH OF THE DESERT TORTOISE *(TESTUDO SULCATA)* IN SUDAN: CHANGES IN MORPHOMETRICS AND BODY WEIGHT FROM HATCHING TO ONE YEAR (0+)

Z. N. MAHMOUD AND D. A. EL NAIEM

Department of Zoology, Faculty of Science, University of Khartoum, Khartoum, Sudan.

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ABSTRACT

Changes in morphometrics and body weight during growth was deduced from observations of individual *Testudo sulcata* of known age. A strong positive correlation was found to exist between plastron width (r = 0.97), carapace length (r = 0.94), carapace width (r = 0.94), body weight (r = 0.99) and plastron length. Changes in morphometrics and body weight during growth in their first year of life has been investigated. The tortoises increased in size at a rate of 1.3764×10^{-3}mm day^{-1} (plastron length), 1.0992×10^{-3}mm day^{-1} (plastron width), 1.5273×10^{-3}mm day^{-1} (carapace length), 1.4206×10^{-3}mm day^{-1} (carapace width) and 5.4519×10^{-3}g day^{-1} (body weight). The values of the intercept (a), regression coefficient (b) and instantaneous growth rate (K) were calculated for *T. sulcata* and from similar growth data in the literature. Their relation to morphological changes in tortoises and turtles have been discussed.

INTRODUCTION

Current ideas on reptiles life histories suggest that individuals exhibit a series of growth rates during their lives as a function of the source of energy and costs of growth, activity and reproduction (Gibbons, 1968; Wilbur, 1975; Andrews, 1982). This discontinuity in the rate of growth and the endangered status of many reptilian species make identification of growth rates an important area of research, especially in the early stages of the life history.

Although growth, morphometrics and the relative growth of a part in relation to that of the entire organism in many chelonian species have been studied in detail (see Cagle, 1950; Gibbons and Semlitsch, 1982; Meek, 1982; Long, 1984; Mahmoud, El Naeem and Hamad, 1986), early growth has received less attention and none of the published work (King, 1964 on *Testudo gracea*, Blackwell, 1968 on *Kinixys homeana*, Cloudsley-Thompson, 1970 on *T. sulcata*, Tryon and Hulsey, 1977 on *Clemmys muhlenebergi*, Bienefield, 1979 on *Hydromedusa tectifera*, Davis, 1979 on *Geochelene carbonaria*, Peters and Finne, 1979 on *Geochelone gigantica*, Brown, Marvey and Wilkins, 1982 on *Erelmohelys imbricata* and Inskeep, 1984 on *Cuora ambainensis*) has rigorously been quantified. From these data, relative growth rates were calculated and correlations were estimated by Linear regression. This paper describe some aspects of the early growth (O+) in *Testudo sulcata* from hatching to one year after hatching.

MATERIAL AND METHODS

MAINTENANCE

Newly hatched *T. sulcata* (16 from the same clutch) were kept in an enclosure (1.3 x 1.3 x 2m) wired on the top and back with a shut of glass for viewing on the front. The enclosure contained a shallow concrete pool (0.3 x 0.3m). Food was offered every other day and readily accepted. It consisted of *Medicago sativa* and *Vicus bengalensis*. During February, 1987 the tortoises were unable to feed. This was probably due to a bacterial infection of the mouth. Treatment consisted of a daily dose of 1ml of Rivocllin (Rivopharm, Switzerland) administered orally for one week. The mouth condition responded well, and the animals then began to gain weight rapidly once more.

MEASUREMENTS

Each individual was marked in a coded pattern by filling the marginal scute to produce slight notches in the bones. To aid recognition, dark marker paint was placed on the notched marginal scute and renewed mostly at the time of measurement. Records for each individual were kept. These consisted of age, weight in g, (measured with a Mettler balance sensitive to 0.1g), and four linear measurements: plastron length (PL) (greatest length measured at the midline), plastron width (PW) (maximum width along the midline) carapace length (CL) (greatest length measured along the midline) and carapace width (CW) (maximum width along the midline). These measurements were made with a calibrated tape, accurate to 1mm.

STASTISTICAL ANALYSIS

Regression analysis of plastron length as well as other morphometric measurements, and body weight were carried out in accordance with the following equation.

$$X = a + bY$$

where:

Y is the plastron length in mm; a = the intercept and b the regression coefficient of the morphometric measurement in mm or body weight in g.

Relative growth rates, measured as rate of increase per day, were calculated from the formula (Brody, 1945).

$$K = \frac{LnX_i - LnX_o}{t_i - t_o}$$

where:

K, is the instantaneous relative growth rate

X_o and X_i are the morphometric measurements or body weight at the beginning and end of the age interval t_o to t_i Ln, is the base of the natural logarithm.

RESULTS

Relative Growth

The reliability of using either plastron length or carapace length as criteria for the measurement of growth in *T. sulcata* was tested by plotting the two parameters against each other. The linearity of the points (Fig. 1) suggest either parameter can be used to assess growth.

Growth in plastron width and carapace width was investigated in relation to plastron length. The linearity of the points and the regression analysis show a high correlation between PW, CL, CW and the lengthening of the plastron (Fig. 1; Table 1) where 88, 88 and 94 per cent of the points respectively, were accounted for.

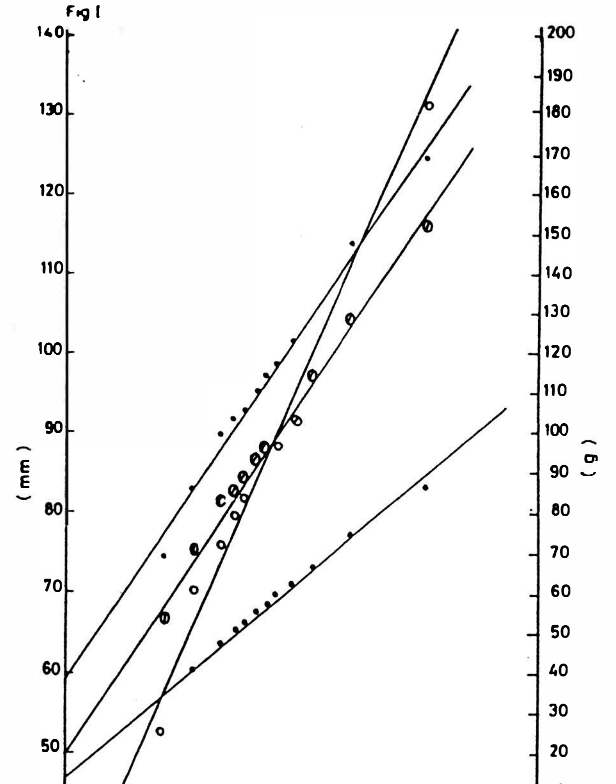

Fig. 1 Relationship between, plastron width (●——●), carapace length (Ø——Ø), carapace width (o——o), body weight (O——O) and plastron length in O+ *T. sulcata*.

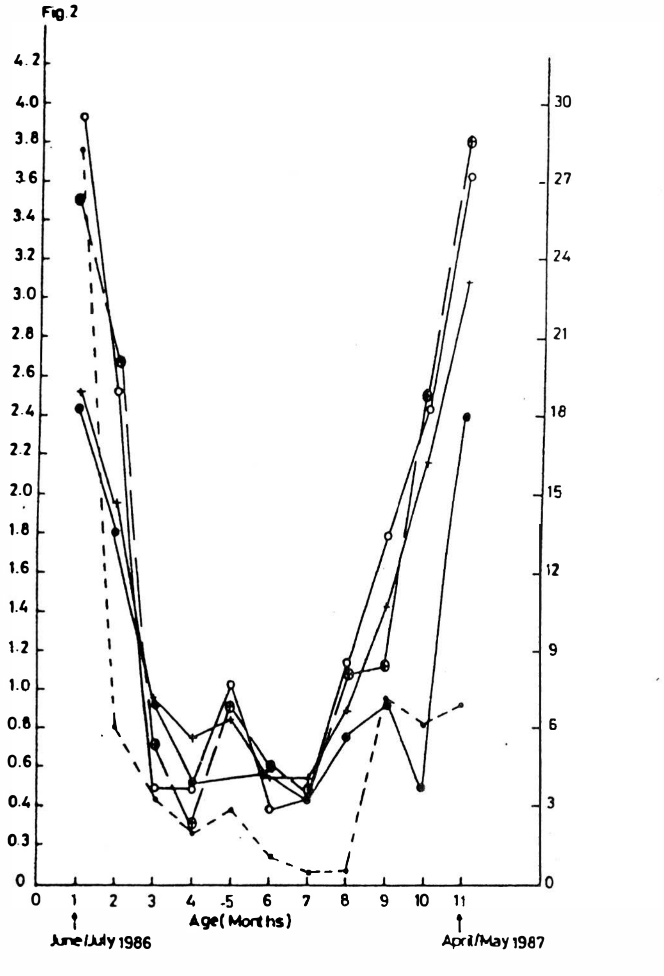

Fig. 2 Instantaneous relative growth rate of plastron length (+——+), plastron width (●——●), carapace length (o——o), carapace width (⊕——⊕), and body weight (●------●) between when first measured in June, 1986 and last measured in May, 1987 as a function of age in O+ *T. sulcata*.

Parameter	Intercept (a)	Regression coefficient (b)	Correlation coefficient (r)	r^2
Carapace length	-8.8351	1.4757	0.94	88
Carapace width	-3.3556	1.5284	0.94	88
Plastron width	14.8838	0.8121	0.97	94
Body weight	-201.64338	4.5262	0.99	98

TABLE 1: Results of the regression analysis of some morphometric measurements (mm) and of body weight (g) on plastron length (mm) of *T. sulcata*.

The regression between plastron length and body weight (Fig. 1) expressed by the equation:

$W = 201.6438 + 4.5262 \times PL$

indicates that body weight increased relatively faster than plastron length, because the regression coefficient (b) is greater than 1 (Table 1). The correlation is very highly significant and 98 per cent of the points are accounted for.

The plot of the monthly instantaneous relative growth rates (Fig. 2) shows that carapace length and width had a greater overall relative rate of growth than plastron length and width. However, the inconsistency in this trend throughout the year is probably due to the formation of a carapace of the same shape.

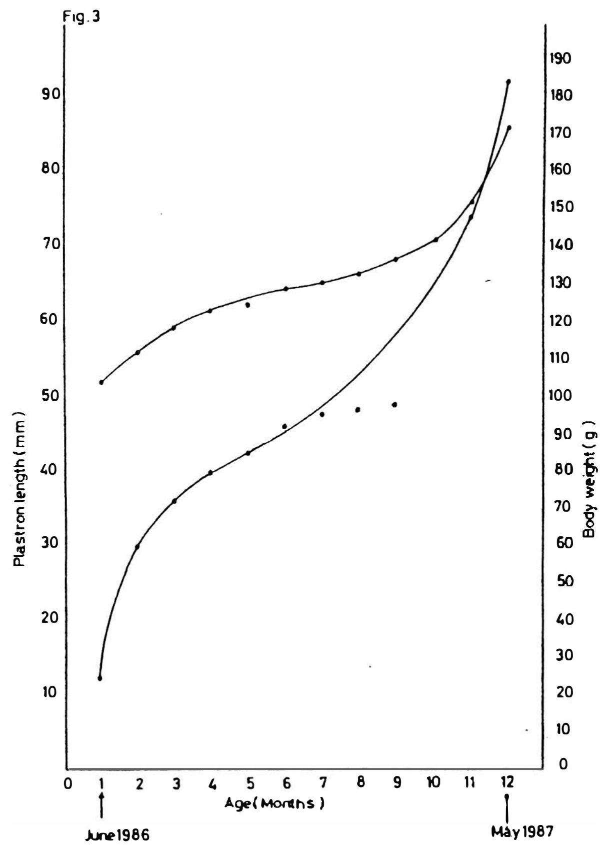

Fig. 3 Relationship between plastron length (o——o), body weight (●——●) of O+ *T. sulcata* and time in months during June 1986 and May 1987.

Absolute Growth

When the mean plastron length and mean body

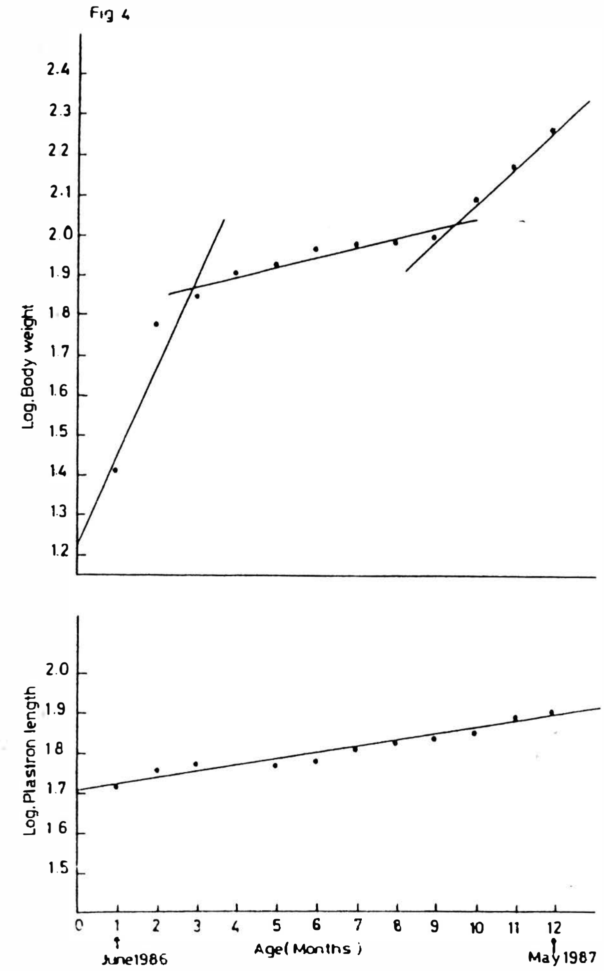

Fig. 4 Relationship between the growth in plastron length (o——o), body weight (●——●) and time (months). The growth modes are represented by the regression lines.

weight were plotted against age on a linear scale, a sigmoid growth pattern was obtained (Fig. 3). The plot of the logarithmic value of the mean plastron length and the mean body weight against age, straighten the curve for plastron length (Fig. 4).

A separate regression line has to be calculated for each of the three growth modes obtained for body weight (Fig. 4 and Table 2). The points of intersection of the regression lines were observed to lie between days 84 and 282 after hatching. The three regression were highly significant ($P<0.01$) and most of the points were accounted for by the three lines.

Parameter	Intercept (a)	Regression coefficient (b)	Correlation coefficient (r)	r^2
Plastron length	1.7153	0.0154	0.97	94
Body weight				
First growth mode	1.2346	0.2241	0.94	88
Second growth mode	1.8091	0.0226	0.96	92
Third growth mode	1.2338	0.0856	0.99	98

TABLE 2: Results of regression analysis for the relationship between plastron length (X, log mm) and body weight (X, log g) with age (Y, months) in *T. sulcata.* The regression following the equation.

$Y = a + b \log X$, where a and b are constants.

Species	No. of animals	Duration t_0 -t_1 in days	Body weight g. day^{-1} 10^{-3}	Plastron length mm day^{-1} 10^{-3}	Plastron width mm day^{-1} 10^{-3}	Carapace length mm day^{-1} 10^{-3}	Carapace width mm day^{-1} 10^{-3}	Reference
Geochelone carbonaria	15	76	5.69	—	—	2.01	—	Davis, 1979
Geochelone gigantica	8	96	8.37	3.54	2.72	3.92	—	Peters and Fine, 1979
Kinixys homeana	3	95	13.25	—	—	—	—	Blackwell, 1968
Testudo gracea	5	12	5.72	2.43	—	—	—	King, 1964
T. sulcata	1	18	10.30	—	—	2.41	1.31	Cloudsley-Thompson, 1970
T. sulcata	16-9	365	5.45	1.38	1.09	1.53	1.42	Present work
Clemmys muhlenbergii	2	367	6.36	—	—	2.36	—	Tryon and Hulsey, 1977
Hydromedusa tectifera	7	122	7.27	—	—	2.36	2.22	Benefield, 1977
Eretmochelys imbricata	103	365	—	—	—	8.93	—	Brown *et al.*, 1986
Curo amboinenisis	1	199	5.52	—	—	1.86	1.98	Inskeep, 1984

TABLE 3: Calculated Instantaneous growth rate (k-value) for some chelonians (present work and literature)

Growth in the weight of hatchling *T. sulcata* per unit time was characterised by an initial fast growing period at a rate of 11.46 x 10^{-3}g day^{-1} until about August, followed by a slow growing rate of 1.50 x 10^{-3}g day^{-1} until about February and a fast growing rate of 5.13 x 10^{-3}g day^{-1} by the time when the animals are one year old (Table 2 and 3). The growth in plastron length followed the same trend and during these period a rate of 1.52 x 10^{-3}mm day^{-1}, 0.65 x 10^{-3}mm day^{-1} and 1.85 x 10^{-3}mm day^{-1} was computed.

DISCUSSION

During the growth of newly hatched *T. sulcata* a strong positive correlation was found between plastron length and other morphometric measurements (Table 1). Similar findings have been reported between plastron length and carapace length in young hatchling *Platemys platycephala* ($r = 0.99$) by Ernst and Lovich (1986) and in adult of *Gopherus agassizi* ($r = 0.99$) by Medica, Bury and Turner (1975). They have also been calculated from the data of Peters and Finne (1979) in one year old *G. gigantica* ($r = 0.93$). Plastron length can therefore be used as the independant variable in relative and absolute growth studies, due to its relatively constant rate of growth. Ernst (1977) and Ernst and Lovich (1986) stated that straight line carapace measurement includes much hidden growth masked in its curvature.

Mathematical models based on plastron length could be misleading if differences in plastron length between males and females exist. Although plastron length dimorphism has been demonstrated in several chelonian species (Berry and Shine, 1980; Branch, 1984), the clearest sex discrimination functions (tail length and anal region measurements) failed to distinguish the sex of O+ *T. sulcata* (Mahmoud and Mustafa, 1987). In the present study all of *T. sulcata* examined were small in size (under 106mm plastron length) and can only safely be classified as juveniles. Therefore, the plastron length is clearly a useful measurement for describing the growth of O+ *T. sulcata*.

The present study showed that in *T. sulcata* the body weight increases relatively faster than plastron length ($b > 1$, Table 1). The calculated regression coefficient values (b) showed that the O+ old tortoises tend to increase more in weight than in length when compared with O+ old turtles (Table 4). This might be due to relatively faster growth of tortoises as that they become dome-shaped with increase in size, while turtles tends to remain flat. Similar observations have

Species	Intercept (a)	Regression coefficient (b)	Correlation coefficient (r)	Reference
Tortoises:				
Geochelone carbonaria	−125.7299	2.9536	0.98	Davis, 1979
Geochelone gigantica	−150.3738	3.7163	0.91	Peters and Finne, 1979
T. sulcata	−224.0133	4.8143	0.97	Present work
Turtles:				
Hydromadusa tectifera	−23.1891	0.8578	0.99	Benefield, 1977
Clemmys muhlenbergii	−25.3801	1.0118	0.98	Tryon and Hulsey, 1977
Cure ambolmensis	−37.3781	1.2047	0.93	Inskeep, 1984

TABLE 4: Regression analysis of carapace length (mm) and body weight (g) describing the early growth in some chelonians.

been reported in *E. imbricata* by Brown *et al.* (1982). Mosiman (1958) and Long (1984) reported that the length of the flat soft-shell turtles had greater intercept values as opposed to other, more domed species. The same opinion hold true when the intercept value of *T. sulcata* (present study) and calculated values for tortoises and turtles (literature) are compared (Table 4).

In *T. sulcata* late summer and early winter account for the lower K-values during mid-August to mid-January. Medica *et al.* (1975) found that *G. agasszi* grew most rapidly during the spring (mid-April) and early summer (first week of July). However, the discrepancy of the K-value (present work and literature) is due to difference in the species, their zoogeography, the duration of the study and number of animals involved (Table 3).

Additional long term growth data are required to verify whether the fluctuation in K-value is due to seasonality and/or some physiological factors that need to be investigated. To cast light on these problems, records for the 1986 hatchling will continue and the 1987 hatchling are now studied in terms of the impact of environmental factors and food quality on growth of *T. sulcata.*

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REFERENCES

Andrews, R. M. (1982). Patterns of growth in reptiles. In *Biology of the Reptilia Vol.* **13D**, 273-320. (Ed) C. Gans. *Academic Press,* New York.

Benefield, J. (1979). Hatching the Argentine snake-necked turtle *Hydromedusa tectifera* at San Antonio Zoo. *International Zoo Yearbook* **19**, 55-58.

Berry, J. F., Shine, R. (1980). Sexual size dimorphism and sexual selection in Turtles (Order Testudines). *Oecologia (Berl)* **44**, 185-191.

Blackwell, K. (1968). Some observations on the hatching and growth of the African tortoise *Kinixys homeans. British Journal of Herpetology* **4**, 40-42.

Branch, W. R. (1984). Preliminary observations on the ecology of the angulate tortoise (*Chersina angulata*) in the Eastern Cape Province, South Africa. *Amphibia-Reptilia* **5**, 43-55.

Brody, S. (1945). Bioenergetics and growth. New York, Reinhold.

Brown, R. A., Harvey, G. C. M. and Wilkins, L. A. (1982). Growth of Jamaican Hawksbill turtles (*Eretmochelys imbricata*) reared in capativity. *British Journal of Herpetology* **6**, 233-236.

Cagle, F. R. (1950). The life history of the slider turtle, *Pseudemys scripta* (Molbrook). *Ecological Monographs* **20**, 32-54.

Cloudsley-Thompson, J. L. (1970). On the biology of desert tortoise *Testudo sulcata* in *Sudan Journal of Zoology London*, **160**, 17-33.

Davis, S. (1979). Husbandry and breeding of the red-footed tortoise *Geochelone carbonaria* at the National Zoological Park, Washington, *International Zoo Yearbook* **19**, 50-53.

Ernst, C. M. (1977). Biological notes on the bog turtles, *Clemmys muhlenbergic Herpetologica* **33**, 241-246.

Ernst, C. H. and Lovich, J. E. (1986). Morphometry in the chelid turtle, *Platemys platycephala. The Herpetological Journal* **1**, 66-70.

Gibbons, J. W. (1976). Aging phemomena in reptiles. Experimental Aging Research Ed. by M. F. Ebas, B. E. Elef theriou and P. K. Klias pp. 454-475. EAR Inc. Bar Harbor, Maine.

Gibbons, J. W. and Semlitsch, R. D. (1982). Survivorship and longevity of a long-lived vertebrate species: How long do turtles live: *Journal of Animal Ecology* **51**, 523-527.

Inskeep, R. (1984). A note in the captive breeding of the box turtle *Curo amboinensis* (Daudin, 1802). *British Journal of Herpetology* **6**, 385-386.

King, J. M. B. (1964). Rearing young Mediterranean spur-thighed tortoises (*Testudo gracea*). *British Journal of Herpetology* **3**, 155-159.

Long, R. D. (1984). Interspecific comparisons of growth relationships in chelonians. *British Journal of Herpetology* **6**, 405-407.

Mahmoud, Z. N., El Naiem, D. A. and Hamad, D. M. (1986). Weight and measurement data on the grooved tortoise *Testudo sulcata* (Miller) in captivity. *Herpetological Journal* **1**, 107-110.

Mahmoud, Z. N. and Mustafa, S. E. (1987). Sexual size dimorphism, sexual selection and sex behaviour in *Testudo sulcata.* In preparation.

Medica, P. A., Bury, R. B. and Turner, F. B. (1975). Growth of the desert tortoise (*Gopherus agassizi*) in Nevada, *Copeia* **1975**, 639-643.

Meek, R. (1982). Allometry in chelonians. *British Journal of Herpetology* **6**, 198-199.

Mosiman, J. E. (1958). An analysis of allometry in chelonian shell. *Revue Canadienne de Biologie* **17**, 137-228.

Peters, V. W. and Finne, E. P. (1979). First breeding of the Aldabra tortoise *Geochelone gigantica* at *captivity* at Sydney Zoo. *International Zoo. Yearbook* **19**, 53-55.

Tryon, B. W. and Hulsey, T. G. (1977). Breeding and rearing the bog turtle *Clemmys muhlenbergii* at the Fort Worth Zoo. *International Zoo Yearbook* **17**, 125-130.

Wilbur, H. M. (1975). A growth model for the turtle *Chrysemys picta Copeia* **1975**, 337-343.