

ASPECTS OF THE POPULATION ECOLOGY OF *MAUREMYS CASPICA* IN NORTH WEST AFRICA

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ABSTRACT

Field observations have been made on a North African population of *Mauremys caspica leprosa*. Measurements on 73 animals has provided information on population structure and morphometrics. In a sample of 67 terrapins measured in September carapace lengths ranged from 22-186mm although the majority (59.7 per cent) were below 80mm. Body masses ranged from 4-906g but most animals (71.6 per cent) were below 100g. Females grow larger than and outnumbered males by 2.12:1, terrapins above one year outnumbered hatchlings by 4.15:1. Equations have been produced relating growth annuli (age) to carapace length. These indicate that females grow faster than males but that males outlive females. A general equation predicts that large animals (>200mm C. length) may attain at least 26 years in field populations. Younger animals predominated in the population and 68.1 per cent were aged less than seven years. Equations defining the relationship between body mass and the principal dimensions of the shell have indicated sexual dimorphic trends in shell morphometry during growth. *M. caspica* were found with leeches, shell damage and algal growth on the carapace.

INTRODUCTION

The striped-necked terrapin *Mauremys caspica* is a well known emydid of the Mediterranean region where it is found as three subspecies, *M.c. caspica*, *M.c. rivulata* and *M.c. leprosa* (see Busack and Ernst, 1981). Although certain aspects of the ecology of *M. caspica* in Israel (Gasith and Sidis, 1983; 1984; 1985. Sidis and Gasith, 1985) and North Africa (Meek, 1983) have been described, there is little information on the age structures, and life spans of *M. caspica*. The absence of information concerning these important life history attributes may in part be a result of difficulties involved in long term field studies of a species known to attain a relatively long life span (Bouler, 1977). Growth annuli on the shell can be used to age individuals in certain chelonians (Bruce Bury, 1979) but *M. caspica* is an aquatic species often living in flowing water where the annuli may be worn smooth rendering direct counting difficult or impossible. Therefore, methods for aging terrapins in these circumstances would be a useful tool in order to add to the understanding of their population dynamics. This paper is partly about an attempt to develop a method for aging *Mauremys caspica*; it is also about population structure and morphometrics. The most westerly occurring race of *M. caspica* is *M.c. leprosa* which ranges over southern France, Spain and North Africa (Arnold, Burton and Ovenden, 1978; Street, 1979). The observations in this paper are concerned with this subspecies and were made on a population found near the south western most limits of the species range in North Africa.

METHODS

Measurements on 67 *M. caspica* were made in September 1981 with six animals measured for body mass and carapace length in May 1980. The population was found at an irrigation channel which flowed through a desert area in southern Morocco. The channel originated from a dam which lay 2km southwest of the study site. An area of approximately 1km of the channel was sampled, which was about 1m deep and 2m wide with the water pH 7.2. The channel was man-made being constructed of concrete but sand from the surrounding area had blown into and settled on the concrete base providing a growth medium for clusters of pond weed (*Potamogeton sp*): three *M. caspica* were observed feeding on this plant. Terrapins were relatively easy to locate here since the water was clear and only small areas colonized by the *Potamogeton*. Animals were collected by hand after entering the water and moving against the current. They were then marked with Tippex fluid for future identification.

BODY MEASUREMENTS

Carapace length. A straight line between the leading edges on the nuchal and supracaudal scutes.

Plastron length. A straight line between the leading point on the junction between the gular scutes and the base of the anal notch.

Shell height. A straight line from the base of the plastron to the highest point on the carapace.

Carapace width. A straight line between the furthest points on the marginals.

Body mass. This was measured by using a set of pan balance scales.

Growth annuli. Determined by counting the number of annuli on the coastal scutes with each distinct annulus regarded as one years growth.

Discernible annuli were found in 22 terrapins (6 males, 12 females, 4 unsexed) with 32 animals with indistinct annuli. The remaining captures (13) were hatchlings with no complete rings (i.e. <1 year). Thus 35 terrapins could be aged directly.

ASSESSING SEX

Terrapins were sexed by the position of the cloaca on the tail which is located in a more posterior position in males. Males may also have a more concave plastron.

PHYSICAL CONDITION

Records were made of major shell damage, flaking scutes and the presence of algal growth or leeches on the shell. Some of these were photographed for later analysis.

METHOD OF ANALYSIS

From inspection of the data it was apparent that both age related and relative growth could be described as a logarithmic process and subsequently regression analysis was applied to the data after transformation to logarithmic form (Sokal & Rohlf, 1981). Age related growth can be described by the equation,

$$\log y = \log a + b \log x$$

where age y is determined from the length of the carapace x ; a and b are constants. This can be rewritten as,

$$y = ax^b \quad (\text{model 1})$$

which treats age y as dependent on the length of the carapace x .

When determining relative growth where no variable can be truly regarded as independent (although body mass represents the whole animal this measurement may be subject to error (Schmit-Neilson, 1984)) values of y and x can be related by,

$$y/y_0 = (x/x_0)^b \quad (\text{model 2})$$

where y_0 and x_0 are the geometric means of y and x respectively. The values of y_0 and x_0 have the same values in the two regression models but a and b may be different. The intercept can be calculated as,

$$a = y_0 x_0^{-b}$$

with b the exponent for either regression model. When there is a high correlation between y and x the models produce only slightly different exponents. A model (2) exponent can be derived from a model (1) by,

$$b_2 = (1/r)b_1$$

where r is the correlation coefficient, b_2 the exponent in model (2) and b_1 the exponent in model (1) (Alexander, Jayes, Maloiy and Wathuta, 1979). Therefore if, for example, r has a value of 1.0, the two methods are in agreement. Lines representing model (2) equations on the graphs in this paper have been calculated from,

$$y = [y_0/(x_0^b)]x^b$$

using the constants from the appropriate equation. The various shell dimensions have been analysed in arithmetic form using regression analysis and the relationships described by,

$$y = mx + b$$

where y and x are related by the slope m and the y intercept b .

Confidence intervals have been calculated for all equations at $n-2$ degrees of freedom using the t -distribution (Bailey, 1981). For b in the allometric equations or m in the regression equations they are the $\pm$ type but for y_0 in the allometric equations they are the $x/\div$ type. Tests for significant differences between equations or significant departures from geometric similarity have been made using the t -distribution at $n-2$ degrees of freedom by the method described by Bailey (1981).

RESULTS

POPULATION STRUCTURE

Size frequencies based on carapace length and body mass are shown in Fig. 1. The distributions were skewed towards smaller animals with 59.7 per cent having carapace lengths below 80mm and 71.6 per cent less than 100g body mass. Females had longer carapace lengths (range 49-186mm, $\bar{x} = 97.1$, S.D. = 37.9) than males (range 54-149mm, $\bar{x} = 82.06$, S.D. = 22.5) and also attained greater body mass (range 17-906g, $\bar{x} = 198$, S.D. = 230) than males (range 23-536g, $\bar{x} = 103$, S.D. = 118). Analysis of the population size structure showed that there was no significant difference ($P > 0.1$) in the lengths of the carapace or body mass between males and females up to 7 years. However, there was a significant increase in female carapace lengths ($F(1,20) = 7.43$, $P < 0.025$) and body mass ($F(1,20) = 4.32$, $P < 0.1$) above 7 years. Hatchling terrapins (i.e. animals with no complete growth rings) had carapace lengths from 22-32mm ($\bar{x} = 26.9$) and body masses from 4-7g ($\bar{x} = 5.5$). In general, the population sample favoured females by 2.12:1 with adults and subadults outnumbering hatchlings by 4.5:1.

AGE MODELS

There is a highly significant correlation between the number of growth rings on the costal scutes and carapace length in males ($r = 0.96$) and females ($r = 0.97$). Fig. 2 is a graph of the data plotted on logarithmic coordinates, Table 1 the allometric equations derived from the measurements. The equations for males and females have each been calculated using the information from unsexed juveniles on the assumption that at this stage no differences exist in the relationship.

There is a significant difference between the exponents in equation (1) for males and (2) for females ($t = 1.92$, 24 d.f., $P < 0.1$) indicating that females grow faster than males with a major departure at 5-7 years. Equation (1) predicts that the largest male in the field sample may have been >23 years, equation (2) that the largest female was >20 years. The maximum carapace

length for *M. caspica leprosa* is over 200mm (Arnold et al., 1978), equation (3) predicts that animals of this size would be at least 26 years.

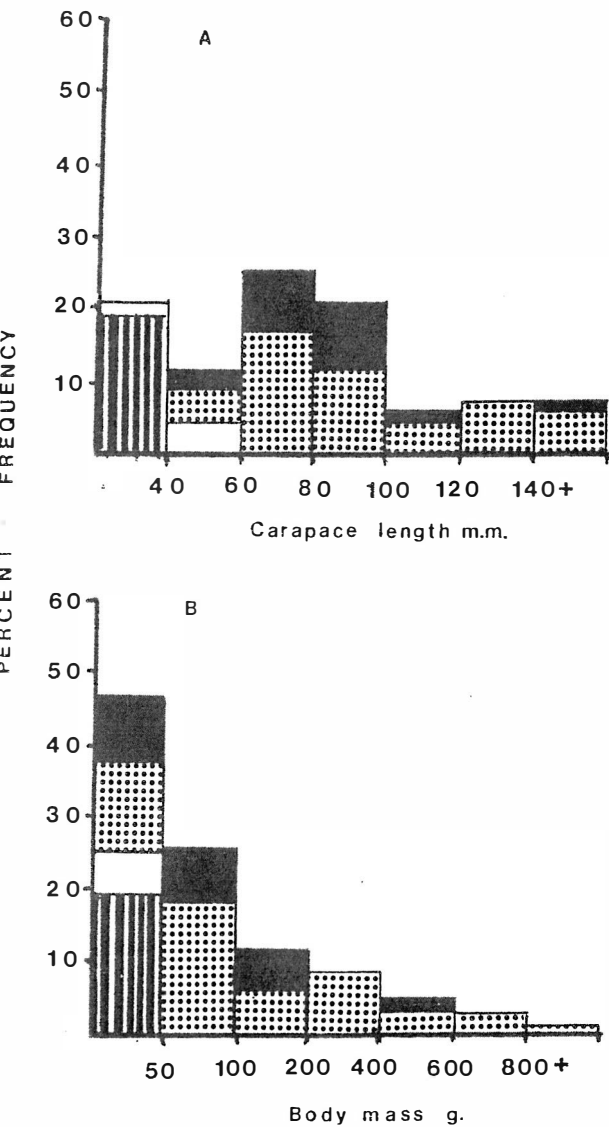


Fig. 1 Histograms of size frequencies of *M. caspica* carapace lengths (A) and body masses (B) expressed as percentages of the total sample in September (n = 67). Vertical bars represent hatchlings, open bars immatures, solid bars males and stippled bars females.

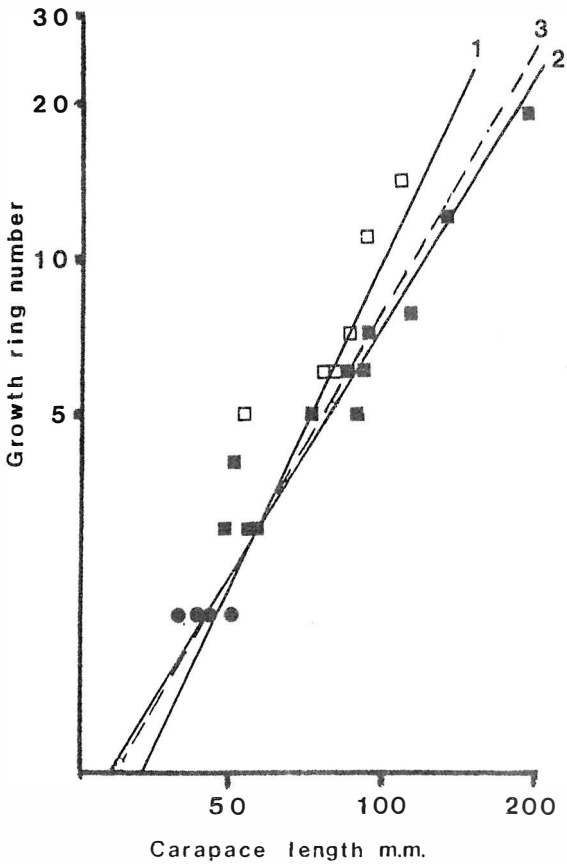


Fig. 2 A graph on logarithmic coordinates of growth ring number plotted against carapace length. The lines taken through the data are derived from the equations in Table 1. The symbols represent males (□), females (■) and unsexed juveniles (●). Sample sizes are given in the text.

AGE STRUCTURE

An important problem in presenting a valid statistical analysis of age structure was that many adults could not be aged accurately because of worn growth rings. Fig. 3b is a histogram of age frequencies of animals aged by direct counting (n = 35) with the age classes shown as a percentage of the total sample (n = 67). Fig. 3a shows these data in addition to terrapins aged by using equations (1) and (2) in Table 1. An obvious feature of the histograms is the high proportion of hatchling terrapins, but these

Eqn. No.	a	b	b ₂	r	n
(1) males	0.0009	2.03 ± 0.32	2.12	0.95	10
(2) females	0.0068	1.53 ± 0.21	1.57	0.97	16
(3) pooled	0.0057	1.59 ± 0.27	1.68	0.94	22

TABLE 1: Allometric equations of the form $y = ax^b$ relating the number of growth annuli on the costal scutes y with the length of the carapace x in mm from the exponent b and intercept a; 95 per cent confidence intervals have been calculated for b. Exponents for model 2 regression (b₂) are also given. The equations for males and females have been calculated by including the data from immatures.

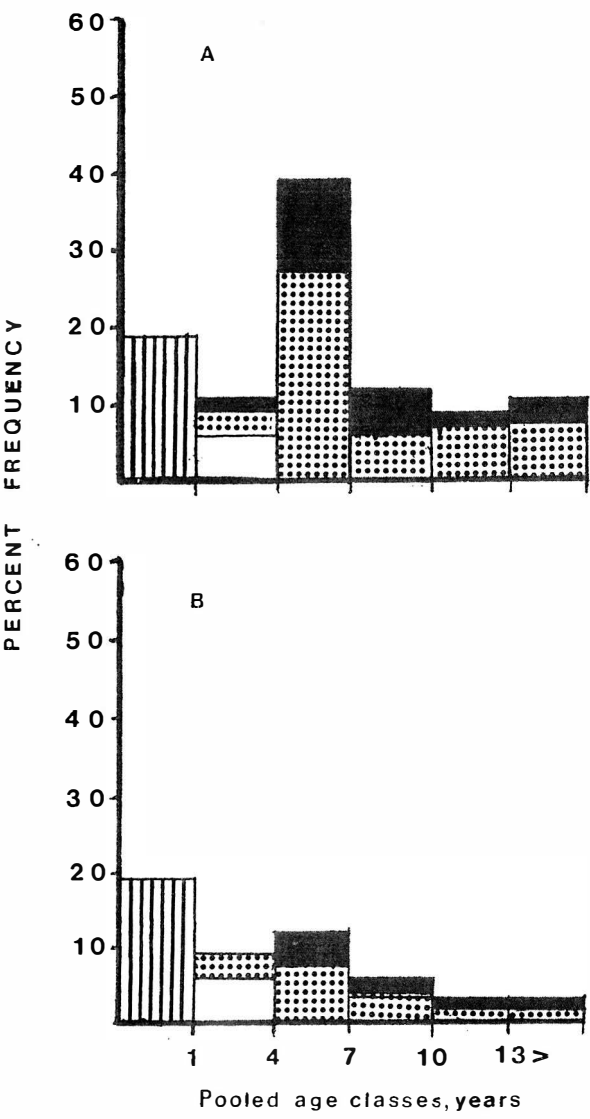


Fig. 3 Age frequency histograms of *M. caspica* expressed as percentages of the total number of animals in the September sample (n = 67). Fig. 3a is based on animals aged by direct growth ring count in addition to animals aged by equations (1) and (2) in Table 1. Fig. 3b is based only on animals aged by direct counting (n = 35) but with the cell sizes represented as per cent frequencies of the total sample (n = 67). Other details as for Fig. 1.

would probably not be expected to be present in such numbers at other periods of the year as a result of mortality. Therefore, it appears that the major age classes in this population were between 4-7 years. In Fig. 3a the majority of terrapins were below 7 years (68.1 per cent) although 10.4 per cent exceeded 13 years.

SHELL CONDITION

Examination of the shell in 67 *M. caspica* showed that eight individuals (11.9 per cent) had flaking scutes on the carapace. Flaking scutes are believed to result from algal growth but in fact no individuals with this condition had any signs of such growth, although growths of algae were observed in a further 4.5 per cent of the sample. Leeches (unidentified) were observed on the carapace, plastron and limbs of 4 (5.9 per cent) of terrapins. In only one animal was there serious shell damage. This involved three of the marginal scutes which were absent. Table 2 is a summary of these data.

MORPHOMETRY

Fig. 4 is a graph on logarithmic coordinates of body mass plotted against the shell dimensions; Table 3 gives allometric equations derived from the data. Exponents for model (1) and model (2) regression have been calculated but only model (2) equations will be discussed here since all the correlation coefficients for the data sets are high and therefore there is little difference between the two methods. It will be convenient to consider the calculated exponents in relation to a hypothetical animal maintaining geometric similarity during growth and therefore also its shape. This requires that the lengths of the corresponding elements are proportional to body mass^{0.33}, exponents above 0.33 imply that the linear dimensions are becoming relatively longer. If elastic similarity is to be maintained during growth (McMahon, 1973) an exponent of 0.25 is required, indicating relatively shorter elements with increasing size.

The exponents for carapace length are significantly higher than 0.33 (males $t = 3.2$, $P < 0.01$; females $t = 9.8$, $P < 0.001$) therefore the almost circular shell shape (i.e. length vs width) of hatchlings develops into a more elongate adult condition, as confirmed by the equations for shell width where the exponents are lower than 0.33. The height of the shell is not

	n	Flaking scutes	Shell damage	Algal growth	leeches
males	16	2	1	2	1
females	34	6	0	1	3
juveniles	4	0	0	0	0
hatchlings	13	0	0	0	0
per cent total		11.9	1.5	4.5	5.97

TABLE 2: Observations on the shell condition in *Mauremys caspica* from data on September captures (n = 67).

maintained during growth in males ($b = 0.29$, $t = 2.6$, $P < 0.02$) but in females, although the exponent is < 0.33 , there is no significant departure from geometric similarity ($t = 0.98$, $P > 0.1$) thus females have higher shells than males which is similar to the condition found in some other terrapins, e.g. *Chrysemys picta* (Iverson, 1982).

The relationship between carapace length and plastron length is shown in Fig. 5. A significant difference ($t = 2.5$, $P < 0.02$) has been found between the equations relating carapace length (x) in mm to plastron length (y) in mm in males,

$$y = 0.84 \pm 0.03X - 0.98 \quad (r = 0.99, n = 33) \quad (12)$$

and females,

$$y = 0.89 \pm 0.02X - 2.43 \quad (r = 0.99, n = 51) \quad (13)$$

and also between the equations relating carapace length (x) in mm to carapace height (y) in mm ($t = 2.23$, $P < 0.05$) in males,

$$y = 0.27 \pm 0.01X + 4.92 \quad (r = 0.98, n = 33) \quad (14)$$

and females,

$$y = 0.30 \pm 0.02X + 3.37 \quad (r = 0.98, n = 51) \quad (15)$$

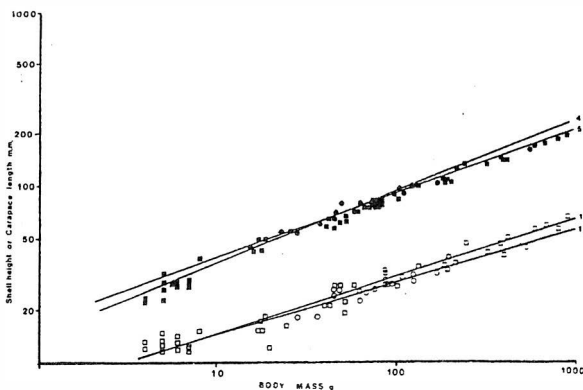


Fig. 4 A graph on logarithmic coordinates of body mass plotted against carapace length and shell height. The lines taken through the data represent equations given in Table 3. Solid symbols represent carapace length, open symbols carapace height; circles represent males, squares females.

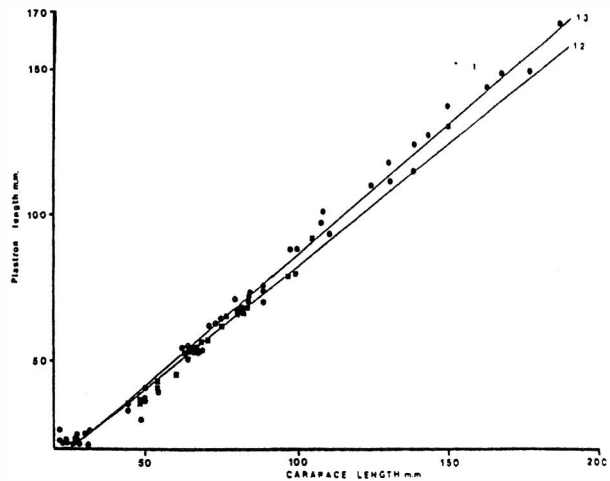


Fig. 5 A graph on arithmetic coordinates of carapace length plotted against plastron length. The lines represent equations given in the text. The square symbols represent males, circles females and juveniles.

However, no significant sexual dimorphic trends were evident from the relationship between carapace length and carapace width ($t = 0.58$, $P > 0.1$) with the pooled data defined as,

$$y = 0.63 \pm 0.2X + 9.66 \quad (r = 0.99, n = 67) \quad (16)$$

where y is the width of the carapace in mm and x the length of the carapace in mm.

DISCUSSION

The information in this paper indicates that in southern Morocco *M. caspica* has a potential long life span, females grow larger than males with sexual dimorphic trends in shell morphometrics. Fig. 3a suggests that the population had a high proportion of animals aged between 4-7 years. There are several possible explanations for this the most likely are: 1. sampling error; 2. if Fig. 3a does indeed

Eqn. No.	Shell dimensions	b_1	b_2	y_0	x_0	r	n
(4)	Carapace length (males)	0.38	0.41 ± 0.05	$48.14x / \div 1.06$	20.20	0.94	33
(5)	Carapace length (females)	0.38	0.38 ± 0.01	$62.67x / \div 1.04$	44.23	0.99	51
(6)	Plastron length (males)	0.39	0.39 ± 0.02	$40.08x / \div 1.02$	21.66	0.99	33
(7)	Plastron length (females)	0.39	0.39 ± 0.01	$53.13x / \div 1.02$	44.23	0.99	51
(8)	Carapace width (males)	0.31	0.31 ± 0.02	$40.69x / \div 1.02$	21.66	0.99	33
(9)	Carapace width (females)	0.31	0.31 ± 0.01	$51.01x / \div 1.02$	44.23	0.99	51
(10)	Carapace height (males)	0.28	0.29 ± 0.03	$18.52x / \div 1.02$	21.66	0.97	33
(11)	Carapace height (females)	0.31	0.32 ± 0.02	$23.04x / \div 1.02$	44.23	0.97	51

TABLE 3: Allometric equations of the form $y/y_0 = (x/x_0)^b$ relating shell dimensions y in mm with body mass x in grammes. Exponents for model (1) (b_1) and model (2) (b_2) regression are given. The values of y_0 and x_0 are the geometric means of y and x respectively, r the correlation coefficient and n the number of observations on which the equations are based; 95 per cent confidence intervals for b and y_0 are also given. The equations for both males and females have each been calculated using the data from hatchlings and unsexed juveniles.

approximate reality then it may be that the population has a widely fluctuating recruitment and/or survivorship from year to year, possibly suggesting favourable breeding success between 1974-77; 3. the sample represented part of a migratory population which would imply that such behaviour is largely confined to certain age classes. Migratory behaviour has been observed in several species of freshwater chelonians (Bruce Bury, 1979) and could also explain the large difference in capture success between May when the number of sightings were low, and September when sightings were frequent. The high proportion of hatchlings recorded during the study period is probably dependent on season since although terrapins produce high numbers of eggs annually (6-8 in *M. caspica*: Pritchard, 1979) nest destruction and high mortality of the hatchlings due to the relatively soft shell, greatly reduces recruitment into the juvenile age class (Bruce Bury, 1979) and therefore a rather different size distribution might be expected to be found at other periods of the year.

A number of methods of aging terrapins in field populations have been developed. Several are based on the assumption that growth annuli are indicators of age in temperate species and have included counting plastron annuli (Sexton, 1959), plastron length and recent growth history (Wilbur, 1975) and the number of annuli on the left pectoral plate which was used to establish a relationship with plastron length in older individuals (Gibbons, 1968). In general, these methods take into account differential growth rates but inevitably all incur some degree of error. Although high correlations have been found for the information concerning carapace length and growth ring number in *M. caspica* it should be noted that the equations derived from the data are also based on the assumption that growth rings are age indicators. However given that this assumption is valid a useful statistic for determining the reliability of the equations and the subsequent error involved in their predictions are the confidence intervals attached to the exponents. These have values of 0.32 and 0.21 in the equations for males (1) and females (2) respectively which are errors of 15.7 and 13.6 per cent, although further error might be expected as a result of the observers counting error since some secondary rings with no annual deposition rate could have been inadvertently recorded with major annuli. This would be most likely to occur in older animals or in those showing greater shell wear.

Estimates of life spans for freshwater chelonians have indicated maximum ages of less than 30 and 35 years for *Pseudemys scripta* (Gibbons and Semlitsch, 1982) and around 40 years for *Chrysemys picta* (Wilbur, 1975) which are in approximate agreement with the age spans estimated for *M. caspica* in this paper.

Berry and Shine (1980) examined sexual size dimorphism in chelonians and observed that in most aquatic 'swimmers' females (as found here for *M. caspica*) attained greater size than males. To explain this they suggested that in addition to larger size enabling increased female fecundity, smaller males could also be actively favoured since it may allow for

increased mobility to locate females. Smaller males could also simply result from males devoting energy to locating females rather than to growth. Growth studies in chelonians have included a number of freshwater species (e.g. Dunson, 1967; Meek, 1982; Long, 1983; Iverson, 1982, 1984). These works have indicated a consistent trend towards a low profile shell design in highly aquatic species ($b > 0.33$). Iverson (1984) suggested that there may be an adaptive ontogenetic trimming of body mass in terrapins during growth by a reduction in shell height and width. The data presented here for *M. caspica* agree with this prediction, which might be expected since a streamlined shell design would have advantages for a mobile swimmer. However the trend is less evident in female *M. caspica* where there is a retention of a more bulky shape. This appears to be a further adaptation (in addition to attaining greater absolute size) to increase fecundity. A high exponent (0.41) relating shell length to body mass has been found for *Emys orbicularis* (Meek, 1982) a species often sympatric with *M. caspica* and with a similar general appearance and life style (Arnold et al., 1978).

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