

FIRST DATA ON THE POPULATION STRUCTURE, GROWTH
RATE AND ONTOGENETIC ALLOMETRY OF THE TORTOISE
TESTUDO HERMANNI IN EASTERN STARA PLANINA
(BULGARIA)

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Abstract

The size-and-age composition of *T. hermanni* population in the Eminska Mountain – the easternmost part of the Balkan Range (Stara Planina), strongly suggests that this population is slowly declining: only 18.6% of the population are animals under 10 years; the size class 161–180 (32.4%) mm and the age class of 16 – 20 years (28.4%) dominate in the population. The sex ratio is approximately in parity (57.6% males: 42.4% females). Males dominate in the smaller size classes, and there are only females in the largest size classes. The carapace length of the hatchlings varies from 32.5 to 40 mm, the body weight – from 10 to 17 g. The linear growth is described by the equation of von Bertalanffy $L = 287(1 - e^{-0.0436(t+3.26)})$. Similar growth parameters are determined in some populations of Greece and France. Regressions of the tortoise body weight (W, g), carapace width (Wd, mm), and carapace height (H, mm) on the carapace length (L, mm) are described by the equations: $\ln W = -3.7452 + 2.0939 \ln L$; $\ln Wd = 0.3635 + 0.8792 \ln L$, and $\ln H = -0.2151 + 0.9088 \ln L$, respectively. At the same carapace length, the females have greater average weights and average heights, and smaller average widths than the males.

Key words: size and age composition, sex ratio, growth, condition, allometry

Introduction. Although only a few decades ago *Testudo hermanni* species was found almost anywhere on the territory of Bulgaria, nowadays its occurrence is very limited and its abundance drastically reduced. Now it is protected by the Biodiversity Protection Law and in international aspect it is registered into the Bern Convention and into the IUSN Red List. The investigations on the species in Bulgaria until now refer mainly to its occurrence and relative abundance, evaluated by the inquiry method [1].

For the first time in Bulgaria IVANCHEV [2] made systematic observations of one population in the region of Eminska Mountain. Our aim was to study the size, age, sexual composition, growth pattern, condition and ontogenetic allometry of *T. hermanni*



Fig. 1. Location of the study area

population in Eminska Mountain – the easternmost part of the Balkan Range (Stara Planina) (Fig. 1). The mountain comprises a territory of approximately 80 km².

Material and methods. The terrain studies, the hatchlings in different conditions and the measurements following them were made in the period between 2003 and 2006. Totally 102 adult and subadult specimens were examined. But for the different analyses a different number of specimens was used. In addition, the growth rate and the ontogenetic allometry were traced out during the first 175 days of the life of 53 specimens, hatched out in incubators, and of 14 specimens, hatched out in natural nests. The temperature in incubator No 1 was 31–33 °C, and in incubator No 2 – 28–29 °C. The humidity in both incubators was 60–80%. The measured dimension parameters were: straight carapace length (L), median width (Wd), and maximum height (H). The field techniques and ageing were based on the methods described by STUBBS et al. [3].

The parameters of von Bertalanffy's equation were calculated after the method of HOHENDORF [4] and the parameters of Ford-Walford equation – by RICKER [5].

Results and discussion. 1. POPULATION STRUCTURE. The size–frequency distribution of the sample is shown in Table 1. The size classes of 141 – 160 mm, 161 – 180 mm, and 181 – 200 mm (26.5%, 32.4%, and 16.7%, respectively) dominate in the population. There is a clear sexual dimorphism, in which females are on an average

larger than males (183 ± 3.7 mm: 158 ± 1.7 mm). The characteristic feature of the population structure is the lack of juveniles. Only 10 animals (9.8%) of the population sample are juveniles and 19 animals (18.6%) are under 10 years old. The age classes of 11–15 years, 16–20 years, and 20–25 years (25.5%, 28.4%, and 20.6%, respectively) dominate in the population. The characteristics of the size–age composition of *Testudo hermanni* population and the very unfavourable juveniles–adults ratio strongly suggests that this population is slowly declining. The most apparent cause of the decline is the anthropogenic factor. The Eminska Mountain is situated in close proximity nearness to one of the most popular and lively sea resorts in Europe – Sunny Beach.

Table 1

Size, age, and sexual composition of *Testudo hermanni* in Eminska Mountain

Size classes mm	Age classes, years												N	%
	1–5		6–10		11–15		16–20		21–25		26–30			
	juv.	juv.	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		
61–80	5	1											6	5.9
101–120		3		1									4	3.9
121–140		1	1	2	1							5	4.9	
141–160			2	3	15	1			4		2		27	26.5
161–180					3	5	13	2	9			1	33	32.4
181–200							2	9	1	4		1	17	16.7
201–220						1		3		3		2	9	8.8
221–240												1	1	0.98
Total N	5	5	3	6	19	7	15	14	14	7	2	5	102	100
%	100	35.7	21.43	42.9	73.1	26.9	51.7	48.3	66.7	33.3	28.6	71.4		

The full adult sample sex ratio is 53 males: 39 females, and the differences (57.6%: 42.4% or 1: 0.85) are not significant ($\chi^2 = 2.1$, $P > 0.05$), i. e. the sex ratio is approximately in parity. The differences between males and females in different age classes are not significant, too. Males are significantly dominant (73.1%) only in the age class of 11–15 years ($\chi^2 = 5.5$, $P < 0.05$) (Table 1). There is a greater regularity of the changes in the sex ratio of different size classes. Males dominate in the smaller size classes: 141–160 mm and 161–180 mm (85.2% and 75.8%, respectively) ($\chi^2 = 13.4$, $P < 0.001$) and $\chi^2 = 8.8$, $P < 0.01$, respectively). Females dominate in the larger size class: 181–200 mm (82.3%) ($\chi^2 = 7.1$, $P < 0.01$) and in the other two size classes (201–220 mm and 221–240 mm) there are only female specimens.

2. GROWTH RATE. With the aim to determine the nature and growth rate of *T. hermanni*, first the linear growth (L, mm) was traced in 67 hatchlings in the course of 175 days (t , days). It was found out that the carapace length of the hatchlings (L_0) varied from 32.5 to 40 mm (mean 35.2 ± 0.33 mm), the body weight (W_0) from 10 to 17 g (mean 13.44 ± 0.15 g). Further growth is best described by the exponential function $\ln L = a + bt$: $\ln L_1 = 3.5524 + 0.0021t$; $\ln L_2 = 3.5732 + 0.0021t$, and $\ln L_n = 3.5442 + 0.0022t$ for the tortoises hatched out in incubators No 1 and No 2, and in natural nests, respectively. The differences in the growth of the tortoises, hatched out at different conditions, as well as in the values of parameters a and b in the three equations are not significant and unreliable. The values of L_0 in the three cases are about 35 mm, and of L_{180} – about 51 mm. The linear growth of *T. hermanni* from 0 to

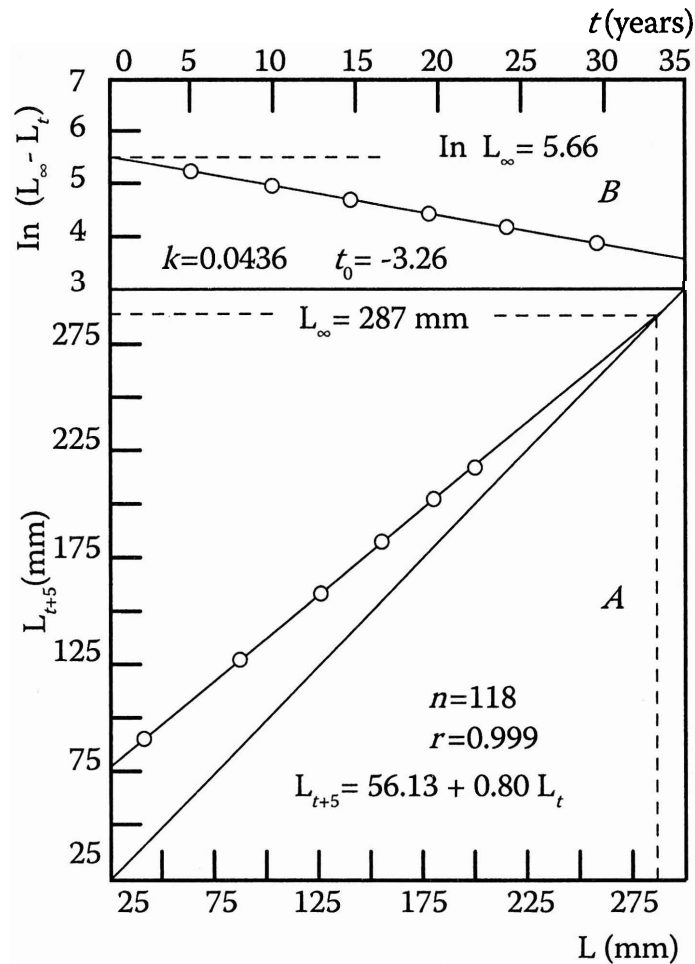


Fig. 2. Walford graph of carapace length growth of *T. hermanni* in Eminska Mountain. A - relationship between carapace length at age t years (L_t) and at age $t + 5$ years (L_{t+5}), calculated by the Plokhinskiy's equation ($L_t = 287 - 249.10^{-0.0189t}$). B - relationship between age (t) and $\ln(L_\infty - L_t)$. L_∞ , k , t_0 - parameters of von Bertalanffy's equation

30 years (t , years) is well described also by PLOKHINSKIY'S [6] asymptotic equation, ($L=287 - 249.10^{-0.0189t}$, $r = 0.98$, $n = 118$) and by the most frequently used in biology for this purpose von Bertalanffy's equation ($L= 287(1 - e^{-0.0436(t+3.26)})$, $r = 0.99$, $n = 118$). $L_{t+5} - L_t$ relationship is a straight line (Fig. 2). This fact proves the validity of von Bertalanffy's growth model for *T. hermanni*.

The females' growth rate ($\ln L= 4.0789 + 0.3997 \ln t$) is greater than that of the males ($\ln L= 4.3506 + 0.2587 \ln t$). However, the difference in the values of b in the equations for both sexes is not significant ($t = 1.34$, $P > 0.05$) because of the comparatively small number of studied specimens (53:39).

When comparing the studied population's growth with the growth of other populations of Mediterranean tortoise, i. e. with populations from Greece and France, some

Table 2

Linear growth rate of *T. hermanni* in different localities. L_0, L_6, L_{10}, \dots etc., mm – average carapace lengths calculated by equations or graphs at the same ages (0, 6, 10 ... etc., t , years)

Locality and author	Equation or graph	L_0	L_6	L_{10}	L_{14}	L_{18}
Epanomi, Greece [6]	$L = 21 + 12.9t, t_{\max} = 8$ yr.	21	98			
Keramoti, Greece [6]	$L = 26 + 11.5t, t_{\max} = 8$ yr.	26	95			
Alyki, Greece [6]	Graph, $t_{\max} = 30$ yr.	30	100	145	161	170
Alyki, Greece [6]	$L = 37 + 10.0t, t_{\max} = 8$ yr.	37	97			
Alyki, Greece [6]	$L = 38 + 10.9t, t_{\max} = 8$ yr.	38	103			
Eminska Mountain, Bulgaria	$L = 287(1 - e^{-0.0436(t+3.26)}),$ $t_{\max} = 30$ yr.	38	95	126	152	173
Kastoria, Greece [7]	Graph, $t_{\max} = 26$ yr.	40	90	125	160	187
Massif des Maures, France [8]	Graph, $t_{\max} = 30$ yr.	40	90	118	141	145
Kalamata, Greece [7]	Graph, $t_{\max} = 26$ yr.	42	115	155	162	164
Alyki, Greece [8]	Graph, $t_{\max} = 30$ yr.	43	99	133	156	166

very similar or even identical parameters were determined (Table 2): noticeable retardation of the growth rate's velocity after the 12th–13th year; sexual size dimorphism; similar growth rates of the Bulgarian and Greek populations from Kastoria and Alyki; the same L_6 values of the Bulgarian population and the population from Keramoti (Greece) – 95 mm, etc.

3. ONTOGENETIC ALLOMETRY. The regression of the tortoise body weight (W) on carapace length (L) of *T. hermanni* is best described by the power equation $W = aL^b$ (Fig. 3, Table 3). Although the relative rate of weight growth in relation to the length of juvenile specimens in the first 175 days ($b = 2.1484 \pm 0.1097$) is greater than that of the adult specimens ($b = 2.0939 \pm 0.1608$), (Fig. 3), this difference is not significant ($t = 0.26, P > 0.05$). It shows that in the process of its postembryonal development (ontogeny) the *T. hermanni* tortoise does not change very much its form (body proportions – length, height, width) and density in contrast to fishes, the values of whose slopes b in the juvenile period are much more different than those of adult individuals (for instance, see PROKES [11]).

There is not a significant difference either between the value of b for the individuals hatched out in incubator no 1 ($b = 1.8192 \pm 0.1952$) and in incubator No 2 ($b = 1.9259 \pm 0.0527$) ($t = 0.55, P > 0.05$); between the values of b for the individuals hatched out in incubator No 2 and those hatched out in natural nests ($b = 1.6409 \pm 0.3497$) ($t = 0.8, P > 0.05$); between the values of b for males ($b = 2.8754 \pm 0.5940$) and females ($b = 2.0497 \pm 0.2043$) ($t = 1.31, P > 0.05$). In comparison to the population of *T. hermanni* in Alyki, Greece [10], the population in the Eminska Mountain has bigger mean weights at the same carapace length (Table 3). Besides, when analysing the length–weight relationships of *T. hermanni*, we determined the same regularities and characteristics as in fishes [12, 13]. The weight/length ratio, like every morphological proportion ratio of the organisms, is genetically programmed. Chances in living condition could provoke variations in this ratio only within a certain range under a continuous genetic control. We also determined in tortoises the inverse relation between intercepts a and slopes b in equations $W = aL^b$ ($b = 1.3969 - 0.4275 \ln a, r = -0.99, n = 18$). Therefore, it is suggested that the average weight, computed according to equation $W = aL^b$, at the same round length values can be used as a condition factor for different populations and samples.

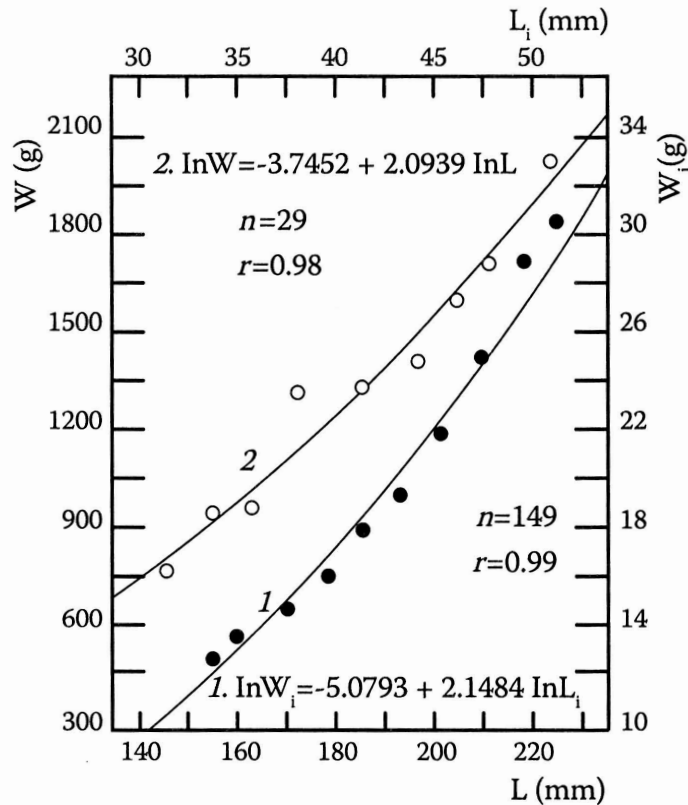


Fig. 3. Regressions of average tortoise weight of specimens at age 0 to 175 days, hatched out in incubators (W_i , 1) and average tortoise weights of the specimens at age 1 to 25 years, hatched out in natural nests (W , 2) on average carapace length (L_i and L , respectively)

Regression of the average carapace width (Wd) on the average carapace length (L) is also best described by the power equation $Wd = aL^b$ (Fig. 4). The correlation rate between Wd and L is extremely high ($r = 0.99$). The differences in slope b of the regression $\log Wd - \log L$ straight lines for the tortoises hatched out in incubators (i) and those hatched in natural nests (n) are not significant ($t = 1.84$, $P > 0.05$). However, the differences in the slopes of those lines for males and females are significant ($t = 3.2$, $P < 0.01$). The mean width of female tortoises (138.3 ± 2.7 mm) is significantly greater than that of the males (127.5 ± 1.18 mm) ($t = 3.36$, $P < 0.01$). In spite of this, at the same length value the width is greater in males compared to that of females.

The regression of the average height (H) on the average carapace length (L) is also described by the power equation (Fig. 4). The correlation rate between H and L is also very high ($r = 0.99$). The difference in the slopes b of the regression $\log H - \log L$ straight lines for the tortoises hatched out in incubators (i) and in natural nests (n) (0.0084) is not significant and unreliable ($t = 0.08$, $P > 0.05$). The difference (0.0738) in the slopes b of those lines for male and female individuals (0.0738) is also not significant ($t = 0.5$, $P > 0.05$). In spite of this, the mean height of females ($H = 92.04 \pm 1.81$ mm) is significantly greater than that of males ($H = 80.04 \pm 0.64$ mm) ($t = 6.25$,

Table 3

Average weight of *T. hermanni* from different localities and sexes calculated at the same carapace length ($L = 140, 160, \dots$ etc., mm) ($W_{140} W_{160} \dots$ etc., g). Values of W were calculated by the equation $\ln W = \ln a + b \ln L$ for every single locality and sex

Locality and author	Equation	W_{140}	W_{160}	W_{180}	W_{200}	W_{220}	r	N
Alyki, Greece [9] ♂	$\ln W = -3.1031 + 2.7199 \ln L$	542	780	1074	1430		0.96	746
Alyki, Greece [9] ♀ + ♂	$\ln W = -3.1160 + 2.7290 \ln L$	551	793	1093	1457		0.97	1465
Alyki, Greece [9] ♀	$\ln W = -3.0636 + 2.7103 \ln L$	556	813	1209	1490		0.98	361
Eminska Mountain, Bulgaria, ♂	$\ln W = -3.3420 + 2.8754 \ln L$	676	961	1310			0.84	10
Eminska Mountain, Bulgaria, ♀ + ♂	$\ln W = -1.6265 + 2.0939 \ln L$	736	974	1247	1555	1899	0.98	29
Eminska Mountain, Bulgaria, ♀	$\ln W = -1.5259 + 2.0497 \ln L$	746	981	1249	1551	1855	0.93	19

$P < 0.001$). The relative growth rate of carapace height towards the carapace length in adult specimens ($b = 0.9088 \pm 0.0255$) is significantly greater than the velocity in juvenile individuals, hatched out in incubators ($b = 0.7359$) ($t = 2.64, P < 0.01$). This difference, however, is not significant with regard to the juvenile individuals hatched out in natural nests ($t = 1.88, P > 0.05$). At the same length value the height of females is greater than that of males.

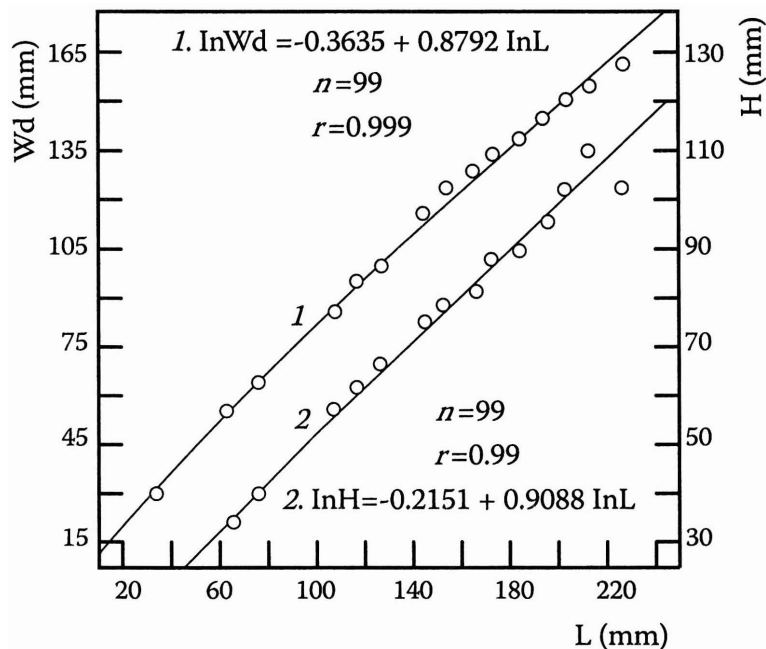


Fig. 4. Regressions of average carapace height (1, H) and average carapace width (2, Wd) on average carapace length (L)

To the best of our knowledge there are no investigations on carapace length – carapace width and carapace length – carapace height relationships of *T. hermanni* in order to compare the obtained results with ours.

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