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POPULATION STRUCTURE AND MORPHOMETRICS OF THE EUROPEAN POND TURTLE (*Emys orbicularis* (LINNAEUS, 1758)) AT LAKE TONGA, ALGERIA

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A total of 100 specimens of *Emys orbicularis* were collected and marked at Lake Tonga (northeastern of Algeria) during 3 consecutive years (2013, 2014, 2015). Most of the turtles inhabit a canal where they remain throughout the whole activity season (March to October) and where they overwinter as well. Carapace Length (CL) and body weight (BW) were measured for each individual of *E. orbicularis*. The size of the turtles of our population was more similar to those of northern European populations than to the Mediterranean populations; females were significantly larger than the Spanish and Italian populations. The population size was calculated as 108.50 and the density as 8.63 turtles/ha. From 6.52 to 12.77% of the population were juveniles. The adult sex ratio was slightly in favor of males (males:females = 1.12, $P < 0.005$).

INTRODUCTION

The European Pond Turtle, *Emys orbicularis* (Linnaeus, 1758) is one of the most widely distributed water turtle species ranging from Northwestern Africa in the west to the former Aral sea in the east, and from the Latvia in the north to the Turkish-Syrian border in the south (Fritz 2001, 2003). Populations of the European pond turtle are considered endangered in several parts of their range (Servan, 1999; Fritz and Andreas, 2000). The populations of the species are threatened by destruction and disappearance of their habitats, pesticide use, habitat loss and alteration, and agriculture (Fritz, 2001, 2003). The population ecology of European populations of *E. orbicularis* has been studied by many authors during the last two decades (Fritz, 2003). However, very little information is available on Maghreb populations (Fahd et al., 2009; Donaire et al., 2011). Phylogenetic studies have suggested that the eastern Algerian and Tunisian pond turtles represent an undescribed distinct subspecies (Fritz and Havaš, 2007; Stuckas et al., 2014). However, their population structure and morphometrics remains unknown (Fritz, 1993). In this paper, we study the population structure (age structure, population size, density and sex ratio) and morphological parameters (size structure and weight) of an Algerian population of *E. orbicularis*. The study took place at Lake Tonga, in the National Park of El Kala, Algeria, in a region where *E. orbicularis* has never been studied before even if it may represent an important geographical refuge for the north-African subspecies of this chelonian. We compare our results to other populations in the Mediterranean and in Europe.

MATERIAL AND METHODS

Study area. This study was carried out in the National Park of El Kala, in north-eastern Algeria. The study area is a part of the north-eastern Algerian Tell (De Belair, 1990). The climate is Mediterranean (Seltzer, 1946; Toubal, 1986) with moderate rainfall concentrated during winter months. Total annual rainfall was about 630 mm, and the mean monthly rainfall was about 52 mm. The study was carried from March to August in 3 consecutive years (2013 – 2015) in the “Canal Messida” situated in the north of Lake Tonga (36°53'N 8°31' E). The lake is about 2500 ha with a shallow water body covered by extensive vegetation beds of emergent and floating-leafed plants. It represents one of the most important freshwater areas of northeastern Algeria

Figure 1 Location of Lac Tonga with major vegetation types and study area.

the redistribution of the individuals (Gibbons, 1990). From 2013 to 2015, a total of 100 European Pond Turtles were marked by notching its marginal scutes particularly the 1^{st} notching. On every specimen, before the release of the individual, a digital caliper (precision ± 0.1 mm) with the same measurement criteria as in Stubbs and Swingland (1984). Body mass of the turtles was measured using a digital balance (precision ± 1 g). Sex was determined by secondary sexual characters (e.g., plastral concavity and tail length) (Servan et al., 1989). Turtles of less than 12 cm were considered too small to be sex reliably and were classified as juveniles.

Statistical analyses. Population size was estimated using capture-mark-recapture procedures. This method consists in the capture of a certain number of individuals within a natural population, their marking and releasing to the capture point, during a “first capture survey.” Then, after a period with no surveys, a “second recapture survey” is done. Population size (N) was determined by Lincoln-Petersen-Bailey formula (1951) for small sample sizes ($m : 9$ 20):

Figure 2 General view of the Tonga Lake; b, view of the Messida canal. Photo by S. Fediras.

(Fig. 1). The main plant species are common reed (*Phragmites australis* Cav.) and lesser reed mace (*Typha angustifolia* L.) with some admixture of common bulrush (*Scirpus lacustris* L.), branched burrhead (*Sparganium erectum* L.), and yellow iris (*Iris pseudoacorus* L.). The submerged and surface-floating vegetation of this lake is dominated by white water-lily (*Nymphaea alba* L.), pondweeds (*Potamogeton lucens* L.), and water-milfoil (*Myriophyllum verticillatum* L.) (Bakaria et al., 2009). The Mediterranean pond turtle (*Mauremys leprosa*) is another freshwater turtle which is also present in the study site.

Fieldwork. Only caught by hand method was used in this work because of the lack of traps especially fyke nets, ideal to catch turtles. The turtles were caught in an area of 5 ha of the entire canal. The coastal strip is inspected, and when a turtle is observed in the shallow area, we usually use a net to catch it. Four surveys sessions by one people were carried out. The session consist of the prospection of the canal from 10:00 to 16:00 h. Five in 2013 (from 21 March to 15 August), 6 in 2014 (from 27 March to 18 August), and three in 2015 (from 12 March to 24 August). An interval of at least two week separated the surveys to facilitate

(Cagle, 1939). Measures have been taken when turtles are disinfection of the lime, as well as scutes before and after the caught, seven morphometrical variables were measured (Fig. 3)

individual on the site of capture. Carapace length was measured

$N = M \frac{n+1}{m+1}$, where M is the sample of individuals that were captured, marked and measured during the first survey period, n is the number of individuals captured during the second survey period, and m is the number of individuals, captured during the second survey period, that were already marked.

Population density (d) was estimated as $d = N/a$ with N the mean population size and a the sampled area (5 ha).

Age was estimated by counting the number of growth annuli on the shell (Castanet, 1988; Germano and Bury, 1998).

Figure 3 Morphometrical variables of *Emys orbicularis* (for abbreviations see Table 3). Photo by S. Fediras

The exact age was difficult to determine on large old turtles by counting annular rings; therefore those turtles were classified as adults on class age superior to 10 years. We used the carapace length to estimate the growth rates, and placed this measure against the age of the various individuals (Barbault, 1973). The instantaneous growth rate (IGR) was expressed in mm per time unity (j) according to the following formula:

$$IGR = \frac{CL_2 - CL_1}{t_2 - t_1}$$

CL_2 and CL_1 are respectively the carapace lengths of the animal at the time t_2 and t_1 .

The growth rate estimates were generated from the turtle's

order to ensure that the growth inter-vals cover at least an entire growing season. All statistical analyses were done by the Excel software and Minitab® 15.1.30.0.

Data collected was used for the estimation of statistical description range (average, standard deviation, range), while the univariated statistics (t -test) was used to analyze the differences between genders.

RESULTS

Population size. During the period of the study from 2013 to 2015, a total of 100 individuals was captured. The number of individuals captured did not differ from one year to another, being 47 turtles in 2013 and 2014; and 46 individuals in 2015 (Table 1). The mean size of the population for the tree years is 46.66 individuals. Adults dominate the population with 87.23% (2013) to 95.74% (2014) of individuals caught for 4.26% (2014) to 12.77% (2013) of juveniles.

Density. The population density was estimated as 8.63 turtles/ha.

Sex ratio. The sex ratio was in favor of males 1.14:1 in 2014 and in favor of females 0.78:1 and 0.79:1 in 2013 and 2015, respectively. When the whole study period was considered, the sex ratio was found as 1.12:1 ($\div^2 = 25.06$, $P < 0.0001$) and it was male-biased.

Age structure. Adults dominate the population of *E. orbicularis* in the study area (89%) for the three years

Tableau 1 Number of Individuals Captured Each Year and Estimation of Abundance Obtained by Lincoln Inde

	2013 ($n = 47$)		2014 ($n = 47$)		2015 ($n = 46$)	
	Session A	Session B	Session A	Session B	Session A	Session B
M	9	14	8	19	6	10
n	8	20	8	12	8	8
m	1	4	4	5	7	1
N	81	58.8	18	49.4	6.75	45
Average	69.9		33.7		25.88	

Note. 2013: Session A, capture March 28 – 31, recapture April 12 – 15; Session B: capture May 20 – 22, recapture June 26 – 30. 2014: Session A: capture March 27 – 30, recapture April 18 – 20; Session B: capture June 17 – 23, recapture July 08 – 14. 2015: Session A: capture March 12 – 14, recapture April 20 – 23; Session B: capture May 22 – 24, recapture July 08 – 11.

while juveniles are represented by a few individuals (11%).

Mean age of captured terrapins was 8.32 ± 2.73 years ($N = 100$). Ages classes between 5 – 6 and 9 – 10 years were represented by the same rate (21.0%). The individuals with age from 7 to 8 accounted for 27% of the population.

Individuals >10 years old, represented 23% of the population. Males are few represented in this age classes (6%), most of the individuals being females (17%). The age classes 1 to 4 (juveniles) accounted for 8% of the population.

Figure 4 Variation in population catch by sexes and ages for the three years (N = 140).

Figure 5 Age structure of the population of *Emys orbicularis* during three years (N = 100).

Figure 6 Size structure of the population of *Emys orbicularis* during three years (N = 100).

	2013	2014	2015	Total
The number of males	18	24	19	47
The number of females	23	21	24	42
Sex ratio (males:females)	0.78:1	1:1.14	0.79:1	1.12:1
χ^2	28.95	28.65	12.36	25.06
$P <$	0.0001	0.0001	0.05	0.0001

Tableau 2 Population Sizes and Sex Ratio of *Emys orbicularis* on the Study Area

Sexual dimorphism. Males and females differed significantly in terms of both carapace length (males: 130.65 ± 10.57 mm, range 110.01 – 161.20 mm; females: 151.00 ± 18.96 mm, range 110.10 – 179.67 mm; $P < 0.0001$ at t -test) and weight (males: 326.06 ± 110.13 g, range: 225 – 808 g; females: 548.40 ± 200.28 g, range 225 – 814 g; $P < 0.0001$ at t -test). For juveniles, the average carapace length and weight were respectively 91.41 ± 13.45 (69.03 – 110.36) mm and 144.84 ± 55.80 (88 – 225) g. From biometrical parameters, it is clearly seen that for all parameters, the average values were

higher in females individuals. The (t -test) shows statistically ($p < 0.0001$) differences between males and females for all variables (Table 3).

Size structure. All captured individuals of *E. orbicularis* were separated in six different size classes based on their carapace length (CL). Turtles were allocated into 20 mm size classes (length frequency distribution), where the first size class was from 60 – 80 mm, the second from 80 – 100 mm and till the last one, that was from 160 – 180 mm. First, altogether individuals of *E. orbicularis* were classified according to size. Adult males are better represented with classes of sizes between 120 and 140 mm (68.09%). In adult females, size class between 140 and 160 is represented with 40.48% of the size frequency. The typical size class for juveniles is 80 – 100

mm with 54.55% of the size frequency.

Growth. A relative constancy of the size of the individuals based on their weight is observed both in males ($r = 0.91$, $p < 0.0001$) and in females ($r = 0.95$, $p < 0.0001$) with a net increase of size and body weight in females (Fig. 7).

The analysis of the growth curve (Fig. 8) for the population revealed that it is more important in females than in males. The growth is quick during the early years and tended to decrease by the 12th year of life. More precisely, the growth of the males tended to slowdown and to eventually stop by age 10 – 11 years old. For female, the growth continues beyond 12 year-old.

Parameter	Males (N = 47)	Females (N = 42)	t	p
Carapace length CL, mm	130.65 ± 10.57 (110.01 – 161.20)	151.00 ± 18.96 (110.10 – 179.67)	1.988	<0.0001
Carapace height CH, mm	49.07 ± 5.54 (41.02 – 65.14)	63.33 ± 9.06 (41.23 – 80.37)	-9.058	<0.0001
Carapace width CW, mm	103.27 ± 7.48 (90.12 – 125.75)	118.02 ± 15.31 (90.31 – 142.31)	3.591	<0.0001
Plastron length PL, mm	114.24 ± 10.43 (99.03 – 150.40)	140.60 ± 19.37 (98.10 – 168.91)	-8.393	<0.0001
Plastron PWA, mm	68.56 ± 6.63 (59.01 – 92.30)	86.44 ± 13.81 (59.05 – 108.88)	-17.876	<0.0001
Plastron PWB, mm	59.43 ± 5.58 (49.17 – 76.50)	73.60 ± 9.96 (51.14 – 89.45)	-14.171	<0.0001
Body weight BW, g	326.06 ± 110.13 (225 – 808)	548.40 ± 200.28 (225 – 814)	1.988	<0.0001

Tableau 3 Biometrical Data (Mean ± SD, range); t-Test (t) and Level of Significance (p) Between Males and Females ($\alpha = 0.05$)

The instantaneous growth rate of five turtles (2 males, 2 females, and 1 juvenile) that were recaptured in multiple years during the study period (Table 4) indicated that the mean IGR for the males (24.392×10^{-3} mm/day) corresponded to an average growth rate of 8.90 mm/year. For females, the mean IGR was 26.218×10^{-3} mm/day, i.e., a growth rate of 9.57 mm/year. For the juvenile, the IGR is (49.632×10^{-3} mm/day) corresponded to a growth rate of 18.12 mm/year. As expected, the growth of juveniles is two times faster than that of males and females. These values confirm the growth curve that is quick in early years. These values also indicate that the growth of females is greater than that of males.

Sex	Time intervals between two recaptures (No. of days)	CL, mm		IGR, mm/day
		at t_1	at t_2	
Juvenile	1088	69	123	0.0496
Female	788	151	168	0.0216
Female	348	158.26	169	0.0309
Male	1086	106	137	0.0285
Male	1087	120	142	0.0202

Notes. CL, carapace length; IGR, instantaneous growth rate.

Tableau 4 Individual Growth of Five Recaptured Individuals of *Emys orbicularis* at the Study Area

DISCUSSION

Density. the density of our population (8.63 turtles/ha) is close to the one found in the Po Delta Region (northern Italy) with 6.13 individuals/ha Mazzotti (1995). Important densities were reported for Turkey where 81 turtles/ha were found at Lake Yayla (Ayaz et al., 2007) and up to 225 turtles/ha at Cukurkoy (Western Anatolian) (Auer and Taskavak, 2004). In

Figure 7 Linear regression of body weight (BW) on carapace length (CL) for *Emys orbicularis* captured during 3 years (N = 100).

other regions, there were much higher densities, such as in La Selva County (north-eastern Spain) where estimated density is 1030.60 individuals/ha (Ramos et al., 2009). It should be noted that the lack of traps especially fyke nets, ideal for catching turtles is the main cause of the low number turtles captured. Fyke nets are adapted to a site with deep water, more efficient in terms of catch because of larger. The catch by hand is very difficult and time-consuming (Woodbury, 1956). We estimate that only 10% of the observed turtles were caught during the capture-recapture sessions. However, it is necessary to combine these two methods (hand caught and trapping), since none, used alone, gives a complete description of the structure of the population (Servan, 1986; Ream and Ream, 1966). They are biased by the behavior of different age groups (Ream and Ream, 1966).

Body size. Sexual dimorphism is related to differences in history strategies of both sexes (Olivier, 2002). When smaller males could be advantaged in their mobility and/or search for sexual partners; females tend to a larger size which can be correlated with the clutch size (Olivier, 2002). We found that females were larger than males in size as in most *Emys orbicularis* subspecies (Zuffi et al., 1999; Fritz, 2001, 2003; Ayres and Cordero, 2001). Also in Algerian, pond turtle population, females (151.00 mm of length and 548.40 g of weight) are larger than males (129.43 mm of length and 321.21 g of weight). The plastron width is significantly higher in females than in males, and especially the posterior part of the plastron ($p < 0.0001$, t -test). Considering that there is a positive correlation between the numbers of laid eggs and female size (Mitrus and Zemanek, 1998; Zuffi et al., 1999), as in most *Emys orbicularis* subspecies (Zuffi et al., 1999; Fritz, 2001, 2003). The body sizes vary depending on latitude and environmental factors (Fritz, 2001, 2003) with the populations in the southern area tending to be smaller (Fritz 1998; Keller et al., 1998). Similar observations with respect to latitude were made also in *Chrysemys picta* (Moll, 1973; Iverson and Smith, 1993).

Quite surprisingly, the size of the individuals of our population was more similar to the size of northern European populations than to the size of the Mediterranean turtles. Females were significantly larger than the Spanish and Italian populations and smaller than the French, German and Polish populations (Table 5). A possible explanation come from Phylogenetic studies which suggested that the eastern Algerian pond turtles represent an undescribed distinct subspecies (Fritz and Havaš, 2007; Stuckas et al., 2014). The environmental effect (phenotypic) also seems to play, but within the limits imposed by the genotypic effect (phylogenetic constraints) (Lombardini and Cheylan, 2004).

Sex ratio. In an animal species, the sex ratio is a very important ecological factor, which influences the dynamics of populations (Girondot and Pieau, 1993). According to Fisher (1929), the optimum primary sex ratio should be 1:1, but several studies have shown the existence of unbalanced sex ratios (Gibbons, 1990). In the Emydidae family, this ratio varies. Such variations are due to sampling errors (Bury, 1979), mortality rate (Girondot and Pieau, 1993), or different behavior between sexes (Kofron and Schreiber, 1987; Dodd, 1989) influencing capture. Valdeón (2006) in Navarra obtained preliminary data with a sex ratio 1:1. Ayllon et al. (2010) in Cuenca (Spain), find a sex ratio biased towards males (3.6:1) and it is the case for other Iberian populations (Keller, 1997; Cordero-Rivera and Ayres-Fernandez, 2004; Segurado et al., 2005; Ayres and Cordero, 2001). This is the case of our population during 3 years, when the total number of males was higher than females and the sex ratio was biased for males (1.12:1). Inversely, very variable sex ratio values have been measured in Italian samples of *Emys orbicularis*, between 1:1 and 1:2.4 (Mazzotti, 1995; Zuffi and Gariboldi, 1995; Mazzotti et al., 2007).

Age structure. The maximum age was 16 years for a male caught in 2014 and 14 years in two females caught in 2015. Auer and Taskavak (2004) reported maximum age almost identical to the one found in our study (i.e., 16 years). In Doñana, data estimated at 28 to 29 the maximum age for males and females respectively (Keller et al., 1998). The age structure of the

population is quite common in chelonians, with a majority of adults and a small percentage of juveniles. However, we did not capture hatchlings in the site. This may be explained by the threatened factor, where juveniles stay more hidden in the vegetation and do not show up very often. This is the case for the population of Camargue Gardoise (Lyet and Cheylan, 2002) and the Ebro Delta in Spain (Bertolero, 2000). This mainly reflects different behavior between adults and juveniles (Ayres and Cordero, 2007). It is possible that the aquatic habitats were used differently by adults and juveniles (Olivier, 2002). Finally, it is possible that bias is due to the capture method since hatchlings are smaller and therefore difficult to detect and our sampling was carried by hand. Predation pressure can also be a cause of low numbers of hatchlings, extremely vulnerable because of their soft shells.

Figure 8 Growth of carapace length of *Emys orbicularis*.

Area	Sex	N	CL, mm	BW, g	References
Germany (north eastern)	Females	31	182.8	—	Schneeweis, 1998
	Males		160.3		
Poland (central)	Females	38	182.7	—	Mitrus and Zemanek, 2000
	Males		171.8		
Germany (north eastern)	Females	22	173 (143 – 197)	—	Farkas et al., 1998
	Males	21	159 (131 – 178)		
West Poland	Females	33	171 (137.90 – 198.50)	790.66 (438 – 1380)	Najbar et al., 2006
	Males	28	154.40 (133.30 – 185.50)	554.2 (345 – 815)	
Southern France (Camargue)	Females	183	163.3	744.6 (670 – 1092)	Olivier, 2002
	Males	130	145.4	436.7 (286 – 670)	
Western France	Females	50	159.7	—	Duguy and Baron, 1998
	Males		149.5		
France (Brenne)	Females	210	154	—	Servan, 1988
	Males		142		
Hungary	Females	978	155	—	Balazs and Gyorffy, 2006
	Males		130		
Hungary	Females	97	152	—	Farkas et al., 1998
	Males		135		
Algeria (El kala)	Females	68	151.00 (110.10 – 179.67)	548.40 (225 – 814)	Current study
	Males	61	130.65 (110.01 – 161.20)	326.06 (225 – 808)	
Corsica	Females	151	147.5	—	Lombardini and Cheylan, 2004
	Males		134.3		
France (Aquitaine)	Females	1471	144	—	Priol, 2009
	Males		131		
Donana (southern Spain)	Females	778	142.6	—	Keller et al., 1998
	Males		138.9		
Italy (Emilia-Romagna)	Females	126	137.6	—	Zuffi and Gariboldi, 1995
	Males		112.5		
Ebre delta (Spain)	Females	24	137.4	—	Bertolero, 2001
	Males		119.6		
Southern France (Gers)	Females	63	137	—	Parde et al., 2000
	Males		130		
Turkey	Females	1216	135.4	—	Ayaz et al. 2008
	Males		128.5		
Central Italy	Females	25	131.7	483.4	Zuffi et al., 1999
	Males	45	125.9	233	
Sardinia (Italy)	Females	24	125.2	—	Schulze and Fritz, 2003
	Males		117.9		
East Spain (Valencia)	Females	161	124.39 (80.7 – 156)	338 (84 – 631)	Bataller et al., 2008
	Males	113	119.15 (89.9 – 158.4)	279 (114 – 428)	
Northwestern Spain	Females	115	122.6	352.6	Ayres and Cordero, 2001
	Males	66	136.4	408	
Italy (Calabria)	Females	84	121.4	—	Tripepi and Zuffi, 2002
	Males		108.2		
Italy (Latium)	Females	33	121.2	—	Rovero et al., 1999
	Males		112.8		
Pô delta (Italy)	Females	127	119.5	—	Mazzotti, 1995
	Males		111.2		
Southern Italy	Females	43	119.9 (97 – 152)	297.6 (142 – 600)	Fattizzo, 2008
	Males	26	109.2 (90 – 128)	199.6 (120 – 300)	
Turkey (Central Anatoly)	Females	94	119.1	—	Taskavak and Reimann, 1998
	Males		105.4		

Females
Males

Tableau 5 Average Carapace Lengths (CL) and Average Body Weights (BW) of the Algerian Population Compared with Various European Populations (in decreasing order of carapace length of females)

Size structure. In our population juveniles are few the three years, especially with the class size between 60 – 120 mm. This rate is higher in other populations such as Doñana, Spain (20%) (Keller, 1997) and Brenne, France (30%) (Servan, 1989). Braitmayer et al. (1998) found 12% juveniles in Menorca. This percent can be very low in some population as in

Çukurköy (western Turkey) where the rate is only 1.9%. The major difference between males and females is the size over 160 mm which is more represented in females with an average percent of 38% and with only 5.56% in males.

Growth rates. The only juvenile recaptured has a much higher growth than adults with 19.8% of growth rate. The growth trajectories are characterized by a faster growing period at the youth age and a slow growth trajectory probably after reaching the sexual maturity. The growth is much pronounced in female than male, which can explain the difference in body size between the two sexes.

The first results obtained from this work will constitute a basis for more studies on the reproduction strategy, the behavior and the use of the space in order to obtain details of the movements and to verify the zones actually used by the individuals and to highlight the corridors used. This species is not yet protected in Algeria despite its presence in a National Park and on a site Ramasar, it is often a victim of the operations of clearing the channel which can put the population at risk. Laying sites are also frequently devastated by clearing operations at the lake dykes. The disturbance is also a threat since the site is a touristic area and very frequented especially during the summer. It is, therefore, essential to involve the public, in particular, the users of the wetland (fishermen, farmers, etc.) and tourists in a process of preserving a species that is still vulnerable by the fragility of these habitats. It seems necessary that the various actors involved in wetland conservation, including Chadli Bendjedid University, the management of El Kala National Park, the services of Forests, Hydraulic Services and the services of Agriculture Collaborate to establish long-term conservation strategies for this species.

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