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Aspect of Population Structure of the European Pond Turtle (*Emys orbicularis*) in Lake Yayla, Western Anatolia, Turkey

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ABSTRACT.—Our main objective was to establish the population size, density, body size, and sex ratio of a local *Emys orbicularis* population. We examined the population structure of *E. orbicularis* in Lake Yayla, Buldan (Denizli), Turkey, using capture-recapture methods. The population consisted of 54% males, 42% females, and 4% juveniles. The adult sex ratio was significantly skewed in favor of males. Using the Jolly program, the population size was estimated at 1,462 (95% CI = 1,161–1,763), corresponding to a density of 81 turtles per hectare of optimal habitat. Females were larger than males. In carapace length, the Lake Yayla population resembles other small-sized populations inhabiting the southern parts of the species' range. The conservation status of the Turkish populations and their main threats are also discussed.

Throughout its range, the European Pond Turtle (*Emys orbicularis*) is considered ''endangered'' and requires special protection (Fritz and Andreas, 2000). Causes of its decline include pesticide use, habitat loss and alteration, and agriculture (Fritz, 2001, 2003). *Emys orbicularis* is protected by the Bern Convention and criteria of the IUCN Red List of Threatened Animals (Lower Risk/Threatened; IUCN, 2006). Furthermore, the species is protected in many European countries (e.g., Schneeweiss, 1998; Zuffi and Ballasina, 1998; Mitrus, 2005).

The population ecology of European populations of *E. orbicularis* has been studied by many authors during the last two decades (see review in Fritz, 2003); however, very little information is available on Asian populations. In Turkey, information about the ecology of the species is primarily based on anecdotal observations made during taxonomic studies (Taşkavak and Reimann, 1998; Ayaz, 2003). Only two ecological studies in Turkey have been conducted so far (Auer and Taşkavak, 2004; Ayaz et al., 2007).

The objectives of our study were to establish the population size, density, body size, and sex ratio of a population of *E. orbicularis* situated at a higher altitude than other populations from western Anatolia and to evaluate the main factors that endanger Turkish populations.

MATERIALS AND METHODS

Study Site.—Lake Yayla is situated on the Süleymanlı Plateau on the northern slope of Mount Sazak, approximately 8 km west of Buldan, Denizli (38°03′N, 28°46′E, 1,150 masl). The lake surface area is nearly 50 ha, surrounded by a 100-ha black pine (*Pinus nigra*) forest, which is under federal protection (Fig. 1). Climatic conditions in the study area are mainly continental, with a mean annual temperature of 13.6°C and annual rainfall of 452 mm (data from the nearest meteorological station at Güney).

The mixed woodland surrounding the lake includes black pine (*Pinus nigra*), oak (*Quercus* sp.), and juniper (*Juniperus* sp.). The lake is fed by small streams, water melt, and rain. The water level drops drastically, especially in summer, because of a decrease in spring waters and monthly rainfall. The maximum depth of the lake is 110 cm, and the surface water temperature ranges from 9–22.7°C (Ustaoğlu et al., 2003). In the center of the lake, aquatic vegetation consists of *Eleocharis palustris* and *Carex elata*. *Potamogeton natans*, *Polygonum amphibium*, *Ranunculus saniculifolius*, *Elatine alsinatrum*, and *Ceratophyllum submersum* densely cover the water surface in the littoral zone. Some of these plants also encircle parts of the shoreline.

Fieldwork.—Nine surveys were conducted between 21 May and 22 August 2005 by four people each (using hand capture and dip nets), between 1000–1200 h and 1400–1600 h within approximately 17-m peripheral littoral zone of the lake. The sampling area included almost 18 ha (36%) of the lake area. Outside of this zone, the water

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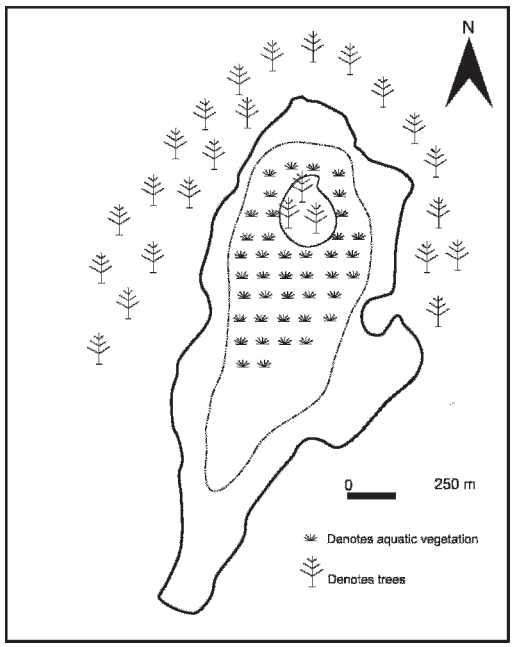

FIG. 1. Lake Yayla. Continuous line shows border of the lake, outside of noncontinuous line shows sampling area, 18 ha, approximately 36% of the lake (modified from Ustaoğlu et al., 2003).

was deeper, generally lacking suitable food items and was not frequented by the turtles. An interval of at least one week (9–12 days) separated the surveys to facilitate the redistribution of the individuals (Gibbons, 1988). Each turtle was permanently marked for future identification by filing notches in marginal scutes (Cagle, 1939) and then released. Sex was determined by using secondary sexual characters (e.g., iris color and plastral concavity) as described in Fritz (2001, 2003). The exact age was difficult to determine by counting annular rings (Sexton, 1959); therefore turtles were classified as either juvenile (carapace length $\leq$ 110 mm for males) or adult (>110 mm). The carapace length (CL) and plastron length (PL) of each individual was measured using a calliper to the nearest 0.1 mm; body mass (BM) was recorded to the nearest 10 g using 1.5-kg Pesola scales.

Data Analysis.—We used the Jolly program (Pollock et al., 1990) to estimate population size (N), capture probability (p), and survival rate (Φ) for each survey period. Model A, the general Jolly-Seber model with time-dependent capture and survival probabilities (Jolly, 1965), was used after goodness-of-fit tests implemented in Jolly suggested a good fit ($\chi^2_{13} = 192.8$, $P < 0.001$). Because the distribution of data was not significantly different from the normal distribution (Kolmogorov-Smirnov test, $P > 0.05$), CL, PL, and BM were compared between the sexes with parametric t-tests. The significance level was set at $\alpha = 0.05$.

RESULTS

A total of 1,216 individuals (659 males, 504 females, and 53 juveniles) was caught within the littoral zone of the lake, with 356 marked individuals (29%) recaptured. Mean capture efficiencies were calculated at 135 specimens/day and about 34 specimens/sampling hour. Of captured turtles, 54% were males, 42% were females and 4% were juveniles. The overall sex ratio was 1.31 : 1 (659 males : 504 females) and male-biased ($\chi^2_1 = 20.7$, $P < 0.001$). Females were larger and heavier than males (Table 1; CL: $t_{503} = 32.9$, $P < 0.001$; PL: $t_{503} = 43.2$, $P < 0.001$; BM: $t_{503} = 37.9$, $P < 0.001$).

Population size was estimated to be 1,462 ± 154 (95% CI = 1,161–1,763). Approximately 83% of the mean estimated population for the entire lake was marked. Mean capture probability (p) and mean survival ratio (Φ) were 0.142 ± 0.014 (0.157–0.211) and 0.817 ± 0.043 (0.732–0.902), respectively (Table 2). Capture probabilities and survival ratios were lower in the second, third, and fourth samplings. The population density was 81 turtles/ha (95% CI = 64–98); however, this estimate refers only to the sampled 17-m littoral zone of the lake (18 ha, approximately 36% of the whole lake area, see Fig. 1). Mean body mass was 379.80 g (range = 15.2–750.7), leading to a biomass estimation of 31 kg/ha (range = 1.2–60.9).

DISCUSSION

Population densities of *E. orbicularis* vary considerably, depending on the region (Fritz, 2001, 2003). Generally, population densities are high in southern Europe and in the center of the species' range. However, peripheral populations in central and northeastern Europe, northern Africa, as well as in southern and eastern Asia Minor are characterized by low to extremely low numbers. For instance, in Central Italy, C. Utzeri (pers. comm.) found an average population size of 22.7 individuals in seven ponds (Cordero Rivera and Ayres Fernández, 2004) and between seven and 11 individuals were counted in ponds of 0.0065–0.009 ha in Central France (Naulleau, 1991). Mosimann and Cadi's (2004) estimation for the population density of an introduced population near Geneva (Switzerland), however, was 64 individuals per hectare. Mazzotti (1995) estimated the population density in the Po Delta Region (northern Italy) as 6.13 individuals per hectare.

In some places in Azerbaijan, European Pond Turtles occur in large groups of 70–80 individuals

TABLE 1. Morphometric data of *Emys orbicularis* in Lake Yayla (means, standard errors of the means, minimum, and maximum).

	CL (mm)	PL (mm)	BM (g)
Juveniles ($N = 53$)	101.06 ± 1.58	96.37 ± 1.53	195.94 ± 6.39
	(38.1–109.3)	(34.1–107.1)	(15.2–250.8)
Males ($N = 659$)	124.91 ± 0.28	114.44 ± 0.27	317.85 ± 2.13
	(110.2–156.8)	(99.1–148.6)	(185.3–490.6)
Females ($N = 504$)	140.46 ± 0.40	134.19 ± 0.39	480.34 ± 4.05
	(115.3–166.6)	(105.3–158.9)	(240.1–750.7)

Note: CL: carapace length, PL: plastron length, BM: body mass.

(Alekperov, 1978). In some lakes of Stavropol district (southern Russia), estimated population densities ranged from 75–125 turtles per hectare (Tertyshnikov and Vysotin, 1987). In a pond situated between Koktebel and Pidgirne (Crimea, Ukraine), Kotenko (2004) estimated more than 112 individual per hectare. Auer and Taşkavak (2004) calculated the population density at Çukurköy (Western Anatolian) as 225 individuals per hectare. Ayaz et al. (2007) reported the densities of European Pond Turtles at Pazarağaç (Turkey) as 83 individual per hectare. However, one has to keep in mind that such estimates typically reflect only the densities in the preferred habitats of the turtles and not the actual densities per total surface area. Although this is also true for our estimate of 81 turtles/ha, it is obvious that Lake Yayla falls into the category with high densities from the central parts of the species' range.

The high density of *E. orbicularis* in Lake Yayla could be because it is the only turtle species there, and the peripheral littoral zone of the lake was quite rich in suitable foods. According to our 11 years of field experience, central Anatolian populations of *E. orbicularis* have distinctly higher densities than populations from the Aegean and Mediterranean regions. European Pond Turtles in the latter regions experience interspecific competition with *Mauremys rivulata* and other restrictive factors, contributing to the observed lower densities.

Some authors assume that survival rates of adults of both sexes are equal in turtles (Iverson, 1991; Congdon et al., 1993). However, mortality may differ for males and females (Wilbur, 1975). Because of our brief sampling period, we pooled males and females. Annual survival rate of adult individuals of some freshwater turtle species is very high, for example 0.96–0.98 for *Emydoidea blandingii* (Congdon et al., 1993, 2000) and 0.95 for *Kinosternon flavescens* (Iverson, 1991). Mitrus and Zemanek (2004) estimated survival rates for juvenile and adult *E. orbicularis* ranging from 0.80 to nearly 1.00 in Central Poland. The Lake Yayla population of *E. orbicularis* exhibits similar survival rate. We recorded a lower capture probability and survival rate between 31 May and 19 June, 2005 than in the other samplings. This fluctuation might be caused by seasonal and nesting activity of individuals.

The sex ratio of a population near Izmir, Turkey (Taşkavak and Ayaz, 2006) was found to be balanced (1 : 1), whereas we observed a significantly male-biased sex ratio (1.31 : 1) in Lake Yayla. Similarly, male-biased sex ratios have been reported for populations of *E. orbicularis* in western Turkey (Auer and Taşkavak, 2004; Ayaz et al., 2007) and in many other

TABLE 2. Summary of estimates of survival (Φ) and capture (p) probabilities for the pooled data on male and female *Emys orbicularis*. The estimates are made under the Model A (Φ_t, p_t) of Program Jolly: Abbreviations: Φ_i = Probability that an animal survives from time i to $i + 1$; SE (Φ_i) = Standard error of survival rates; p_i = Probability that an animal alive at time i is captured in the i-th sample; SE(p_i) = Standard error of probability of capture and approximate 95% confidence intervals (95% CI).

Period	Date	Φ_i	SE (Φ_i)	95% CI	p_i	SE (p_i)	95% CI
1	21 May 2005	1.431	0.235	0.970–1.891	–	–	–
2	31 May 2005	0.600	0.120	0.365–0.835	0.070	0.017	0.037–0.103
3	10 June 2005	0.600	0.119	0.367–0.833	0.097	0.022	0.055–0.140
4	19 June 2005	0.494	0.086	0.326–0.662	0.094	0.021	0.052–0.136
5	30 June 2005	0.772	0.128	0.520–1.023	0.171	0.032	0.108–0.234
6	12 July 2005	0.694	0.124	0.450–0.938	0.187	0.035	0.119–0.255
7	23 July 2005	1.128	0.269	0.600–1.655	0.192	0.037	0.120–0.264
8	13 August 2005	–	–	–	0.184	0.044	0.097–0.271
Mean		0.817	0.043	0.732–0.902	0.142	0.014	0.157–0.211

localities as reviewed in Fritz (2001, 2003). Juveniles constitute about 4% of the marked individuals in our study. However, this value does not represent the actual population of juveniles. This considerably low proportion of juveniles can be attributed to the fact that they prefer to inhabit shallow waters with dense vegetation where they can easily find food and protection from predators and lead a more cryptic life (e.g., Zuffi, 2000; Mosimann and Cadi, 2004). In the present study, the habitats of adults were targeted, so that an underrepresentation of juveniles was expected.

Latitude and local environmental conditions are important factors that influence body size variation of *E. orbicularis,* with larger individuals occurring at higher latitudes (e.g., Rovero and Chelazzi, 1996; Zuffi et al., 1999; Fritz, 2001, 2003). Similar observations with respect to latitude were made also in *Chrysemys picta* (Moll, 1973; Iverson and Smith, 1993). In Turkey, however, a complicated pattern emerges; some populations of *E. orbicularis* from the Central Anatolian Plateau are large, with maximum shell lengths of approximately 200 mm, whereas other Central Anatolian populations and populations along the Aegean and Mediterranean coasts are small- to medium-sized (Fritz, 2001, 2003; Taşkavak and Ayaz, 2006). The carapace length distribution and mean values of the Lake Yayla population correspond with those of populations in the Aegean and Mediterranean regions. Mountainous habitats, like Lake Yayla, might act as negative constraints for growth (i.e., reducing the length of the activity period and limiting the time effort in searching for food). An additional limiting factor there also could be the continental climate, with a short active season and unfavorable conditions for a rapid growth rate (Zuffi et al., 2007).

Conservation

As yet, there are no detailed action plans for the protection of *E. orbicularis* in Turkey. Today, the major factors endangering the European Pond Turtle are the draining of wetlands for agriculture (e.g., former Amik Lake), illegal collecting and trade, the coating of main waterways with concrete (and, thus, disrupting the suitable nesting and feeding areas), urbanization caused by tourism, and heavy use of pesticides (unpubl. data, see also Atatür, 1995; Ayaz, 2005).

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