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Phenology and population structure of the Mediterranean stripe-necked terrapin *Mauremys leprosa* (Schweigger, 1812) in the Reghaïa Lake (northern Algeria)

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The Mediterranean stripe-necked terrapin is a freshwater turtle widely distributed in southwestern Europe and northwestern Africa, but whose natural history is little known. In this study we investigated the ecology of a population in northern Algeria (Reghaïa Lake Ramsar Reserve), with special emphasis on its phenology, demographic structure and diet, based on capture and recapture methods. Our results indicated that there is a short inactivity period in January and possibly the activity is also reduced during the month of August. The best Jolly-Seber model indicated that the population within the survey station had a minimum size of 653 specimens. The population contained a higher proportion of males (0.68 - 0.76) and a proportion of juveniles between 0.02 - 0.16. Females were larger and relatively heavier than males. Analysis of stomach contents showed that *M. leprosa* feeds with high frequency on aquatic arthropods. Specifically, we found insects: Diptera (Chironomidae, Culicidae, Dixidae, Syrphidae), Heteroptera (Corixidae, Notonectidae) and Coleoptera (Dytiscidae), crustaceans (Branchiopoda, Ostracoda), plant matter (*Typha angustifolia*), fish (*Gambusia holbrooki*), and unidentified materials.

Key words: Algeria; demographics; diet; predation.

The Mediterranean stripe-necked terrapin *Mauremys leprosa* is one of two species of freshwater turtles native to northwest Africa (Schleich *et al.*, 1996). The ecology of this species has been studied in the Iberian Peninsula, where it is described as a generalist in its use of habitats and trophic resources (Segurado & Figuereido, 2007; Pérez-Santigosa *et al.*, 2011). In Spain and Morocco, the species occupies all types of freshwater habitats, including rivers, intermittent streams, lakes, artificial reservoirs and coastal marshes (Keller, 1997; Gómez-Cantarino & lizana, 2000; Naimi *et al.*, 2012). In Algeria, *M. leprosa* appears in all the north of the country, in regions with Mediterranean climate, although it also penetrates marginally in the Sahara (Doumergue, 1901; Schleich *et al.*, 1996). Despite being relatively common

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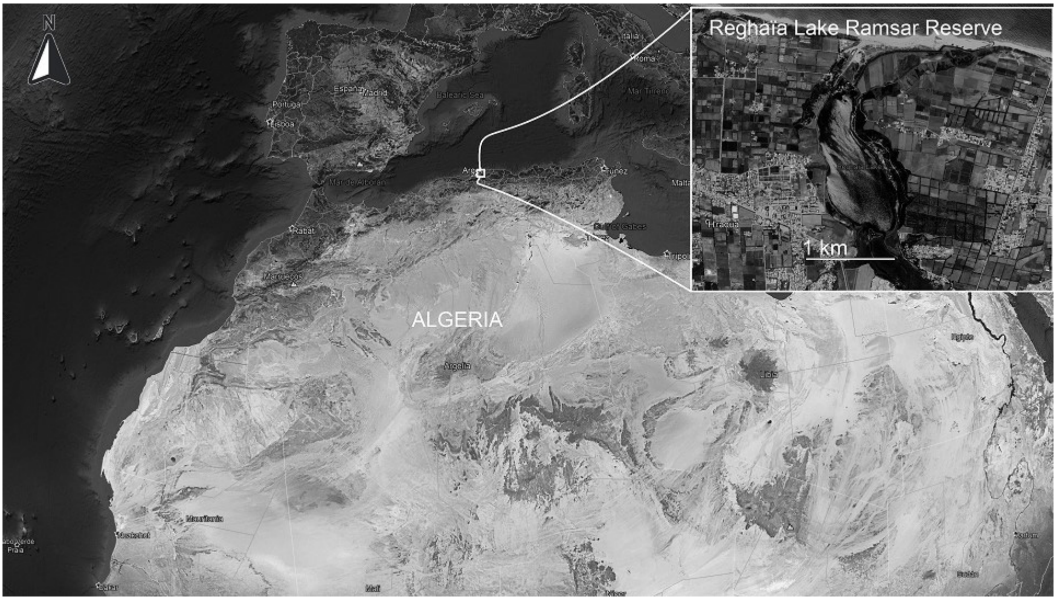

Figure 1: Map of the study region.

and widespread in much of the aquatic ecosystems of northern Algeria (Escoriza & Ben Hassine, 2017), little is known about the natural history of this species, except for some brief, old reports (e.g. Doumergue, 1901). This could have negative implications for species conservation at the regional level, particularly taking into account the significant level of alteration that wetlands have suffered in northern Algeria, and other parts of the Maghreb (Britton & Crivelli, 1993; de Belair & Samraoui, 1994). Improving knowledge of the natural history of the species is one of the priorities when developing management and conservation plans for the wild populations of reptiles (Cox *et al*., 2006). The aim of this study is to investigate the ecological requirements of this freshwater turtle, fulfilling part of the knowledge gap. Here we provided new data on the phenology, population structure, and diet of the *M. leprosa* in northern Algeria.

MATERIALS AND METHODS

The Ramsar reserve of Reghaïa Lake is situated 30 km to the east of Algiers, close to the Mediterranean coast (Fig. 1). Ramsar reserves are wetlands of international relevance, particularly for migratory and aquatic birds (Samraoui & Samraoui, 2013). The climate of the region is of type *Csa* (Koppen classification), with mild winters and summers (average temperatures of January: 11.5ºC and August: 26.1ºC; Kriticos *et al*., 2012). Given the importance of this reserve for the reproduction of several threatened birds (Metna *et al*., 2016), surveys were carried out at single station to reduce interferences with the bird nesting activity. Turtles were captured during the day with a dipnet (Lagler, 1943), between 11:00–16:00hr, after being detected visually around the shoreline. Additionally, we also surveyed the shoreline, to find destroyed nests or turtle remains, including fragments of shell or bones embedded in mammalian predator feces (ANDERSEN, 1954). Tracks and mammalian feces observed were assigned to species based on DAHLSTRÖM & CUISIN (2009). Surveys included a single monthly sampling between the years 2017–2018, including winter months.

Turtles captured were marked by notches on the marginal scutes, following a standardized code that allows individual identification (CAGLE, 1939). Specimens were also examined for wounds or injuries, measured with a digital caliper (straight line carapace length; 0.01 mm precision), and weighted with a digital balance (0.1 mg precision). Specimens were sexed based on secondary sexual characters: the preanal width of the tail and its length (MUÑOZ & NICOLAU, 2006). In our study population, those specimens with a carapace length greater than 90 mm were classified as adults, like other populations of *M. leprosa* (KELLER, 1997).

The diet was investigated in 32 adult and juvenile specimens captured during the second year of sampling (from April 2018 to November 2018). Stomach content was obtained by flushing (PÉREZ-EMÁN & PAOLILLO, 1997). The items found in the stomach were classified into large taxonomic groups (Subphylum or Class): insects, crustaceans and fish (animal matter), and plant matter. Most of the items were very fragmented or partially digested, and identification at a finer taxonomic resolution was very difficult. However, when possible, these items were classified at finer level. Invertebrates were classified following TACHET *et al.* (2000).

We evaluated two demographic parameters: sex ratio and proportion of juveniles (RAMOS *et al.*, 2009). The sex ratio was calculated as relative male proportion (male / male + females; KELLER, 1997). Other metrics to assess the sex-ratio were proposed in turtles (LOVICH & GIBBONS, 1990; LOVICH, 1996; LOVICH *et al.*, 2014), but we used the relative male proportion because it facilitated the comparison with previous studies on *M. leprosa*. To assess whether the proportion of sexes differed from parity, we used the single proportion test (NEWCOMBE, 1998). This test evaluated whether an observed proportion differs from a theoretical one, determining the statistical significance with the sample size (NEWCOMBE, 1998). Capture-recapture data were used to estimate population size, using an open population Jolly-Seber model. This model assumed that the probability of capture was equivalent among the different individuals that constitute the study population (NICHOLS, 1992). The Jolly-Seber model estimates the probability of capture (p) and apparent survival (phi), depending on an occasion (t) or along the entire sampling period (.). The optimal model was determined using the Akaike Information Criterion corrected for small sample sizes (WHITE & BURNHAM, 1999). The goodness-of-fit was assessed using the RELEASE function, implemented in the MARK package (WHITE & BURNHAM, 1999). Population size was calculated based on the formula n/p, where n is the number of specimens caught on period, and p is the probability of capture (WHITE & BURNHAM, 1999).

We also were interested in evaluating possible intersexual differences in carapace length, and the body mass index

Table 1: Survey and demographic parameters for *Mauremys leprosa* in the Reghaïa Lake Ramsar Reserve. Sex ratio: mean sex ratio (males/males+females) per year. Proportion of juveniles: mean relative frequency (juveniles/total captures) per year.

	2017	2018
Total unique specimens	98	50
Sex ratio	0.677	0.762
Proportion of juveniles	2.04%	16.00%

(BMI, g/cm^2; PETZNEK *et al.*, 2002), and seasonal variation in BMI (comparing the BMI of a given season relative to the mean BMI of others seasons). The carapace length was used to calculate a size dimorphism index (SDI = (mean size of largest sex / mean size of smallest sex) −1, if females are larger; LOVICH & GIBBONS, 1992). The statistical significance of these differences was assessed by Student's-t tests, conducted using the package PAST vs. 3.0 (HAMMER *et al.*, 2001).

RESULTS

We captured 148 specimens. The sex ratio was biased toward males (0.677), and the difference was statistically significant during the year 2017 (z = 3.366, P = 0.0008) and 2018 (z = 3.677, P = 0.0002). The proportion of juveniles was variable, ranging between 2 - 16% (Table 1). Mutilations in the hindlimbs were observed in 14.9% of the captured specimens. Captures showed a bimodal pattern, being higher during spring, and autumn. No captures were made during January, July and August 2017 and January, February, June and August 2018, despite attempts to do so.

An open capture-recapture model was conducted using only the data obtained in 2017, because recaptures were too low in 2018. RELEASE goodness-of-fit tests indicated that the model followed the assumptions ($\chi 2 = 1.27$, df = 4, $P = 0.87$). The best model was phi(.) p(t), in which apparent survival remained constant during the sample period but the probability of capture was time-dependent (Table 2). This model allowed an estimate of the mean probability of capture (0.089) and the minimum population size for the survey station and the year 2017 (98 / 0.15 = 653 specimens).

Morphological comparisons showed that females had larger carapace sizes, and BMI than males, with SDI = 0.05 (Table 3). The BMI showed intrannual variation, particularly in both sexes after winter, and in

Table 2: Jolly-Seber model candidates used to estimate population size of *Mauremys leprosa* in the Reghaïa Lake Ramsar Reserve. Phi = probability of apparent survival; p = probability of capture; AICc = Akaike Information Criterion corrected for small sample sizes.

Model	Phi	p	AICc	Delta AICc	AICc Weight
Phi(.)p(t)	1.0	0.00–0.15	157.54	0.00	0.79
Phi(t)p(.)	0.00–1.00	0.09	160.45	2.90	0.18
Phi(t)p(t)	0.00–1.00	0.00–0.94	164.20	6.65	0.03
Phi(.)p(.)	0.05	0.09	177.61	20.06	0.00003

	Males	**Females**	*t*	**P**
n	96	42		
Carapace length (mm)	174.6	184.1	1.96	0.051
BMI	3.68	4.81	5.98	0.00000002
SDI		0.05		

Table 3: Sexual dimorphism in the population of *Mauremys leprosa* in the Reghaïa Lake Ramsar Reserve, assessed with t-Student tests. *n* = number of specimens; BMI (Body Mass Index) = g/cm^2. SDI (Size Dimorphism Index).

Table 4: Seasonal variation of the Body Mass Index (BMI) in a population of *Mauremys leprosa* in the Reghaïa Lake Ramsar Reserve, assessed with Student's t-tests. *n* = number of specimens; BMI = g/cm^2. $\text{BMI}_{\text{season}}$= BMI mean seasonal value; BMI_{out} = BMI mean year value (excluding $\text{BMI}_{\text{season}}$).

	Season	**$\text{BMI}_{\text{season}}$**	**BMI_{out}**	*t*	**P**
Males	Winter	3.82	3.63	0.86	0.389
	Spring	3.57	3.79	-1.11	0.269
	Summer	3.78	3.66	0.33	0.740
	Autumn	3.76	3.66	0.45	0.652
Females	Winter	5.34	4.79	1.24	0.222
	Spring	4.57	4.87	-0.94	0.351
	Summer	4.31	4.89	-0.95	0.346
	Autumn	4.97	4.73	0.76	0.453

females in summer, but these differences were not statistically significant (Table 4). In the study of the diet, the stomach content of 32 specimens was examined. Of these, 59.4% were empty, with a lower proportion of empty stomachs (28.6%) in the summer than in spring (66.7%), and autumn (69.2%). At our study site, *M. leprosa* frequently preys on aquatic insects, while other items (plant matter, fish, Crustacea) appear with lesser frequency (Table 5). The items that could be identified at a finer taxonomic resolution were fragments of *Typha angustifolia* (plant), fragments of crustaceans (Branchiopoda and Ostracoda), and fish (*Gambusia holbrooki*). We could also identify some groups of insects: Diptera, larvae of Syrphidae (genus *Eristalis*), larvae, pupae, and adults of Culicidae, and Dixidae, and larvae of Chironomidae; adults of aquatic insects: Corixidae (*Sigara*), Dytiscidae, and Notonectidae (*Anisops*), and adults of terrestrial insects: Formicidae, and honey bees (genus *Apis*) (Fig. 2). During the terrestrial surveys around the lagoon, we found four destroyed nests, and 46 turtle shells with 52.2% showing signs of biting by carnivore mammals. Also, we found 13 scats of *Canis anthus* containing fragments of *M. leprosa* carapaces near the nests and shells observed.

DISCUSSION

This study is the first to investigate the ecology of *M. leprosa* in Algeria, and describes its phenological cycle. Our results suggested that the Reghaïa Lake Ramsar Reserve possibly harbors a large population of this terrapin, even using conservative estimations. The population of *M. leprosa* from Reghaïa contained a high proportion

	Items	Males	Females	Juveniles
n		23	3	6
Empty%		60.9	33.3	66.7
Full%		39.1	66.7	33.3
	Insecta larvae	55.5	50.0	50.0
	Insecta adult	22.2	50.0	50.0
	Crustacea	22.2	50.0	50.0
	Fish	11.1	0.0	0.0
	Plant	33.3	50.0	50.0

Table 5: Results of stomach flushing in 32 specimens of *Mauremys leprosa* in the Reghaïa Lake Ramsar Reserve. Empty% = proportion of specimens with empty stomachs; Full% = proportion of specimens with plant/ animal matter in the stomach; *n* = number of specimens.

of adult individuals (84.00–97.96%), and of these, males predominated (67.7–76.2%). A very similar demographic structure was reported in other populations of *M. leprosa.* KELLER (1997) reported a proportion of adults / sub-adults of 94.3%, and a sex ratio biased toward males of 61.8%, during five years of surveys in Doñana National Park (southwestern Spain). However adult sex ratios are a variable parameter in wild populations of freshwater turtles (LOVICH *et al.*, 2014). For example, ratios biased toward both males or females have been observed in the other Mediterranean species, *Emys orbicularis* (MAZZOTTI, 1995; KELLER, 1997; RAMOS *et al.*, 2009). In general, those species in which there is a marked sexual dimorphism, the sex of smaller size is usually demographically dominant (LOVICH *et al.*, 2014). The analysis of sexual dimorphism showed that females are larger and have a higher relative weight than males, similar to that reported in southwestern Spain (MUÑOZ & NICOLAU, 2006). Sexual dimorphism is also a variable trait in chelonians (LOVICH & GIBBONS, 1992; AGHA *et al.*, 2018), and in the case of *M. leprosa*, it varies throughout the Moroccan range of the species. This variation is possibly attributable to local climate conditions (LOVICH *et al.*, 2010). In females, mean carapace length was similar to those described in other populations of *M. leprosa* (LOVICH *et al.*, 2010). However, the SDI value (0.05) was lower, because of the relatively large size of males in the Reghaïa Lake Reserve.

The capture patterns suggest intrannual variations of the activity of this species. During the months of January and August no specimens were captured, indicating a significant decrease of the species' activity during the periods of mid-winter, and mid-summer. These observations mirror those of DOUMERGUE (1901), who indicated that the Algerian populations went into aesti-

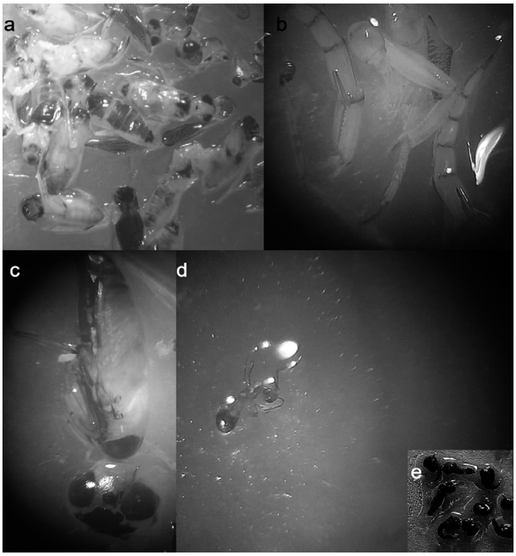

Figure 2: Items found in the stomach contents of *Mauremys leprosa* from the Reghaia Lake Ramsar Reserve: a) Corixidae; b) Dytiscidae; c) Notonectidae; d) Formicidae; e) Culicidae. (Photos: B. Bakhouche).

Figure 3: Examples of predation and/or scavenging of *M. leprosa* in Reghaïa: a) a nest predated by jackals (*Canis anthus*); b) jackal feces containing bone remains of *M. leprosa*; c and d) partially devoured carapaces (Photos: B. Bakhouche).

vation following stream desiccation. However, a large part of the marshes of Reghaïa do not experience a significant surface regression in summer. This suggests that the decrease in captures could be attributable to lesser activity, at least during the hours of the surveys (11:00–16:00). The decrease of the BMI after winter in both sexes could be consequence of lower activity during this period, while the decrease observed in summer in the females (but not in the males), is possibly related to oviposition (May-July in Morocco; NAIMI *et al.*, 2012). However, these intrannual differences in the BMI did not show statistical significance, so caution is advised in associating variation in the BMI with the phenology of this population.

Diet was similar to the results of previous studies conducted on *M. leprosa* (e.g. PÉREZ-SANTIGOSA *et al.*, 2011). In the Reghaïa Reserve, stomach contents showed that *M. leprosa* feeds on arthropods frequently: insects (adults and larvae, mainly aquatic species but also terrestrial), and bentho-nektonic crustaceans. However, some plant material, and occasionally fish were included. We did not detect the presence of Gastropoda in the diet, despite their observations in the diet of Spanish populations of *M. leprosa* (PÉREZ-SANTIGOSA *et al.*, 2011). Gastropods are well represented in the reserve, so their absence in the diet of turtles is perplexing. *Mauremys leprosa* preys on hard-bodied carnivorous insects, such as water beetles (Dytiscidae), and backswimmers (Notonectidae), as a top predator in this aquatic ecosystem.

During the shore surveys we found several damaged empty shells and bone/carapace fragments of turtles in mammalian feces. However, it is impossible to conclude whether these specimens were depredated or died from other causes and were then scavenged. In the reserve, occasional events of 'mass mortality' of turtles were observed, and although the causes are not completely known, they could be caused by rapid salinity changes in the water (but see NASRI *et al.*, 2008). These episodes of mass mortality could be exploited opportunistically by predators. However, 14.9% of the specimens showed healed wounds in the limbs attributed to jackals (*Canis anthus*), wild boars (*Sus scrofa*) or brown rats (*Rattus norvegicus*). During the shore surveys, some destroyed nests were also found, occasionally with feces or tracks of jackals, suggesting that this canid is also a predator of *M. leprosa* nests. This behavior is known in these opportunist canids, which frequently prey on turtle nests in the Mediterranean region, including marine species (BROWN & MACDONALD, 1995).

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