NAT. CROAT. | VOL. 35 | No 2 | 0 - 0 | ZAGREB | December 31, 2026

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original scientific paper/izvorni znanstveni rad
DOI 10.20302/NC.2026.35.40

IMPACTS OF THE ANTHROPOGENIC ACTIVITIES ON THE MEDITERRANEAN STRIPE-NECKED TERRAPIN *MAUREMYS LEPROSA LEPROSA* (SCHWEIGGER, 1812) IN NORTHERN MOROCCO

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Taybi, F.A., Piscart, C., Hajji, L. & Mabrouki, Y.: Impacts of the anthropogenic activities on the Mediterranean stripe-necked terrapin *Mauremys leprosa leprosa* (Schweigger, 1812) in Northern Morocco. Nat. Croat., Vol. 35, No. 2, _____, 2026, Zagreb.

Freshwater ecosystems in North Africa are experiencing significant degradation, which is occurring at an accelerated pace and becoming increasingly concerning due to the expansion of human activities, combined with the effects of climate change and increasing drought frequency and intensity. A key objective in developing management and conservation plans for freshwater species is to enhance our understanding of their natural history and ecological requirements. *Mauremys leprosa leprosa* (Schweigger, 1812) is a medium-sized freshwater turtle, endemic to the western Mediterranean area. To date, the ecology of the Mediterranean pond turtle remains poorly understood, with significant knowledge gaps persisting, particularly in North Africa. The aim of this study is to investigate its ecological requirements and thereby improve our understanding of its distribution and habitat preferences in northern Morocco, by studying the effects of aquatic pollution on the sex ratio and sexual size dimorphism across 51 localities. Furthermore, this study aims to update the known distribution range of this species and provide new occurrence records, and to offer insights into the ecological plasticity and the conservation status of the species in the northern part of the country. *Mauremys leprosa leprosa* was frequently observed across a wide range of water quality parameters, showing a high occurrence and abundance even in degraded environments. Apart from the biased sex ratios noted in polluted waters, our observational data did not reveal an immediate negative correlation between water quality deterioration and turtle abundance or body size. This high association with anthropized areas suggests that the species might exploit certain habitat alterations, likely due to increased food availability, although potential sublethal or long-term physiological impacts remain to be fully investigated. Notwithstanding its ecological plasticity, the species continues to face significant challenges in the habitat, including roadkill, excessive freshwater extraction from aquifers, and the

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increasing frequency and severity of droughts. Effective conservation strategies addressing these multiple and interacting threats are therefore crucial to ensure the long-term conservation of the *M. l. leprosa* population in the northern Morocco.

Keywords: Freshwater turtles, desiccation, behavioural plasticity, ecological requirements, water pollution, North Africa

Taybi, F.A., Piscart, C., Hajji, L. & Mabrouki, Y.: Utjecaji antropogenih aktivnosti na mediteransku prugastovratu kornjaču *Mauremys leprosa leprosa* (Schweigger, 1812) u sjevernom Maroku. Nat. Croat., Vol. 35, No. 2, _____, 2026, Zagreb.

Slatkovodni ekosustavi u sjevernoj Africi doživljavaju značajnu degradaciju koja se odvija ubrzanim tempom i postaje sve više zabrinjavajuća zbog širenja ljudskih aktivnosti u kombinaciji s učincima klimatskih promjena i sve većom učestalošću i intenzitetom suša. Ključni cilj u razvoju planova upravljanja i očuvanja slatkovodnih vrsta jest poboljšati naše razumijevanje njihove biologije i ekoloških zahtjeva. *Mauremys leprosa leprosa* (Schweigger, 1812) je slatkovodna kornjača srednje veličine, endemska za područje zapadnog Mediterana. Do danas je ekologija ove kornjače slabo proučena, s još uvijek prisutnim značajnim prazninama u znanju, posebno u sjevernoj Africi. Cilj ove studije je istražiti njezine ekološke zahtjeve i time poboljšati naše razumijevanje njezine rasprostranjenosti i preferencija staništa u sjevernom Maroku, i to proučavajući učinke onečišćenja voda na omjer spolova i spolni dimorfizam veličine na 51 lokalitetu. Nadalje, ova studija ima za cilj ažurirati poznato područje rasprostranjenosti ove vrste i pružiti nove zapise o pojavljivanju te ponuditi uvid u ekološku plastičnost i status očuvanja vrste u sjevernom dijelu zemlje. Vrsta *Mauremys leprosa* često se opaža u širokom rasponu parametara kvalitete vode, pokazujući visoku učestalost i brojnost čak i u degradiranom okolišu. Osim pristrano bilježenih omjera spolova uočenih u onečišćenim vodama, naše promatranje nije otkrilo neposrednu negativnu korelaciju između pogoršanja kvalitete vode i brojnosti kornjača ili veličine tijela. Ova visoka povezanost s antropiziranim područjima sugerira da bi vrsta mogla iskoristiti određene promjene staništa, vjerojatno zbog povećane dostupnosti hrane, iako potencijalni subletalni ili dugoročni fiziološki utjecaji tek trebaju biti u potpunosti istraženi. Unatoč svojoj ekološkoj plastičnosti, vrsta se i dalje suočava sa značajnim izazovima u staništu, uključujući stradanja na cestama, prekomjerno crpljenje slatke vode iz vodonosnika te sve veću učestalost i jačinu suša. Stoga su učinkovite strategije očuvanja koje se bave ovim višestrukim i međusobno djelujućim prijetnjama ključne za dugoročno očuvanje populacije *M. l. leprosa* u sjevernom Maroku.

Ključne riječi: slatkovodne kornjače, isušivanje, plastičnost ponašanja, ekološki zahtjevi, onečišćenje vode, Sjeverna Afrika

Ethics approval and consent to participate: The sampling of turtles for the current research was per-formed in accordance with the legislation of Morocco and was approved by Mohamed Premier University, (Oujda, Morocco).

INTRODUCTION

Freshwater ecosystems are among the most threatened on Earth (MCRAE *et al.*, 2017), particularly in the Mediterranean region, where water resources are scarce. This phenomenon is even more pronounced in North Africa (Moreno-Dodson *et al.*, 2022; MABROUKI *et al.*, 2026; TAYBI *et al.*, 2026). The prevalence of a semi-arid climate and the occurrence of drought periods contribute to this scarcity (TAYBI *et al.*, 2020). Furthermore, the degradation of freshwater ecosystems, resulting from a range of human activities, including the alteration of channels and the construction of impoundments, has also contributed to this problem, these activities have affected the hydrology and benthic habitat (BRAUTIGAM, 1999; MUTIN, 2000; BENSAAD *et al.*, 2017; MABROUKI *et al.*, 2018, TAYBI *et al.*, 2019). A significant number of freshwater species are facing a reduction in their distribution area and an increased risk of extinction due to a combination of factors, including pollution, habitat destruction, the introduction of invasive

species, and poaching (DAVIDSON, 2014; DUDGEON *et al.,* 2006; STRAYER, 2010; REID *et al.,* 2019; SANDERS *et al.,* 2023).

Freshwater turtles constitute an integral component of the fauna of aquatic ecosystems (ERNST & BARBOUR, 1989; FRITZ, 2001). Although the majority of freshwater turtles are in decline worldwide (STANFORD *et al.,* 2020; WOINARSKI *et al.,* 2023), other species possess characteristics that may prove advantageous in highly perturbed environments (GERMANO, 2010; ROE *et al.,* 2011). Consequently, certain species may actually benefit from human-induced changes to their environment (EL HASSANI *et al.,* 2019). These capacities include high tolerance to physiological stressors, high behavioural plasticity and the ability to survive in extreme environmental fluctuations (POLO-CAVIA *et al.,* 2008; POLICH, 2016; CHESSMAN, 2019).

The Mediterranean pond turtle *Mauremys leprosa* (Schweigger, 1812) is a good example of a freshwater animal that is resilient and resistant to pollution, and is often the only aquatic vertebrate to survive in the most degraded habitats (BERTOLERO *et al.,* 2017). This resistance is supported by a variety of phenotypic and physiological strategies. Despite its high tolerance to environmental degradation, physiological responses to pollutants have led to its use as a biological model for assessing water quality (HÉRITIER *et al.,* 2017; SLIMANI *et al.,* 2018). *Mauremys leprosa* is an endemic Mediterranean species belonging to the family Geoemydidae. It is a small to medium-sized freshwater turtle with a carapace length of up to 210 mm in males and 240 mm in females (PALACIOS *et al.,* 2015), with a wide distribution in North Africa, the Iberian Peninsula and southern France (MARAN, 1996; GÓMEZ-CANTARINO *et al.,* 2000; NAIMI *et al.,* 2012). Two subspecies are present in North Africa: *M. leprosa leprosa* and *M. leprosa saharica* (FRITZ *et al.,* 2006; VERÍSSIMO *et al.,* 2016). In Morocco, the first subspecies is found in the northern and north-eastern regions, extending to the Atlas Mountains. The second subspecies is found in the southern territories of the Atlas Mountains (MARAN, 2010; MARTÍNEZ *et al.,* 2020; TOLEDO *et al.,* 2021). In certain areas in Morocco, *M. l. leprosa* coexists with the European pond turtle *Emys orbicularis* Linnaeus 1758 and with non-native freshwater turtle species, predominantly the red-eared slider *Trachemys scripta* Schoepff, 1792 (LAGHZAOUI *et al.,* 2020; TAYBI *et al.,* 2023).

Despite a few studies in some parts of Morocco, and several studies having been carried out on its ecology and the alteration of its habitat (i.e., SLIMANI *et al.,* 2018; EL HASSANI *et al.,* 2019; LOULIDA *et al.,* 2018; LAGHZAOUI *et al.,* 2020), the ecology and population structure of the Mediterranean pond turtle are still poorly understood in many regions of the country, particularly in northern Morocco. In this context, the present study aims to elucidate the ecological requirements of *M. l. leprosa* and to evaluate the effects of organic pollution on its populations across a broad geographical area in northern Morocco. Specifically, we assess the influence of aquatic pollution on population abundance, sex ratio, and the sexual dimorphism index of *M. l. leprosa*. Furthermore, we seek to identify the principal threats affecting its populations in order to inform and strengthen conservation strategies throughout its distribution range.

MATERIALS AND METHODS

Field surveys

Field surveys were conducted between 2014 and 2021 at 51 sampling sites spread over a large area in the northern part of Morocco, encompassing different biogeographical zones separated by major geographical barriers, such as the Middle Atlas and the Rif Mountains (Fig. 1). The study area covers different environmental conditions and types of water bodies

including estuaries and streams, irrigation canals, lagoons, ponds and brackish and saline marshes, with a particular focus on protected areas such as Ramsar sites and sites of ecological and biological interest (known as SEBI or SIBE).

The abundance of *Mauremys leprosa leprosa* was monitored at 51 study sites, each of which was surveyed once. The level of pollution at each site was characterised using a three-category variable: unpolluted (U), moderately polluted (M), or polluted (P).

In addition to active visual surveys, the turtles were captured using hoop-shaped traps baited with sardines. The same methodology and level of effort were applied at each site. The traps were firmly attached to the vegetation on the shores, plastic bottles were used as floats to avoid the risk of drowning. Upon capture, each individual was sexed, weighed to the nearest 0.1 g and then measured using a calliper to the nearest 1 mm. The sex of the turtle was determined by concavity of the plastron and the position of the cloaca. The plastron is concave in males and flat in females, and the cloaca is located well outside and just at the margin of the carapace in males and females, respectively.

Estimates of sexual maturity are best when based on primary sexual characteristics (e.g. the ability of females to produce eggs or males to produce viable sperm). By basing our sexual maturity criteria on secondary sexual characteristics, our samples may have included immature individuals, but this would be consistent across the different study sites. Turtles measuring less than 80 mm in length were deemed too small for sexing and were thus categorized as juveniles. Following the taking of measurements, all turtle specimens were released at their point of origin. Additionally, during the sampling process, we documented instances of scavenging behaviour and cases of turtle mortality resulting from human activities, including roadkill and deaths in anthropogenic structures.

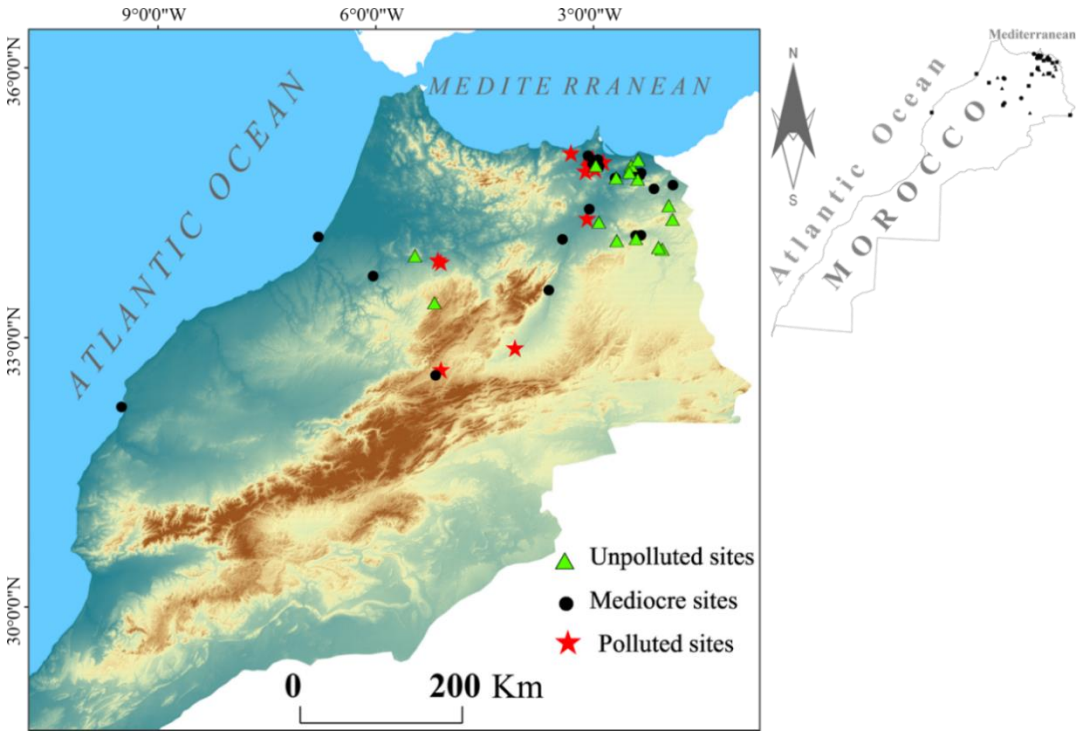


Fig. 1. The studied sites in northern Morocco where *Mauremys leprosa leprosa* was present.

Environmental data

Physico-chemical parameters such as pH, electrical conductivity, and dissolved oxygen concentration were measured directly in the field with portable equipment (WTW, MPP350). Water temperature was obtained using a mercury thermometer with a sensitivity of 0.1° C, and flow speed was measured by recording the time taken for a floating body [cork stopper] to cover a minimum distance of one meter. Elevation was calculated using a GPS device (Garmin eTrex 10). Other parameters including biological oxygen demand, ammonium, sulphate, and orthophosphate concentrations were measured in the laboratory in the laboratory from water samples collected int the field.

Other physicochemical parameters were analyzed, but only at sites where *M. l. leprosa* was present. Two water sample replicates from each site were taken in 500 ml polyethylene bottles. Water samples were preserved with 2 ml of concentrated hydrochloric acid (pH = 2). According to ISO 5667-6 (1990), ISO 5667-2 (1991) and ISO 5667-3 (1994) standards, they were transported in a cooler at a low temperature (approximately 4 °C) to minimize metabolic activities. Sulfate (SO_4^{2-}), biological oxygen demand after 5 days (BOD_5), phosphate (PO_4^{3-}) and nitrate ($N\text{-}NO_3^-$) were measured in the laboratory. These variables were determined according to AFNOR standards (1997) and RODIER *et al.* (1996).

The sites were divided into three groups according to their level of pollution: unpolluted (16 sites), poor quality (21 sites) and polluted (14 sites). This classification is mainly based on BOD_5 concentrations, as recommended in the Moroccan freshwater standards report (ABHM, 2012):

Unpolluted sites have a BOD_5 concentration of less than 6 mg/L.
Poor quality sites have a BOD_5 concentration between 6 and 10 mg/L.
Polluted sites have a BOD_5 concentration greater than10 mg/L.

A visual assessment of anthropogenic pressure was also carried out at each site, taking into account factors such as the quality of riparian vegetation and river substrate.

Statistical Analysis

The effect of pollution on the abundance of *Mauremys leprosa leprosa* was analysed using a generalised linear model (GLM) based on a negative binomial distribution. This was chosen in order to adequately model count data exhibiting high overdispersion, for which a standard Poisson distribution was unsuitable. Additionally, the sex ratio was analysed using a generalised linear mixed model (GLMM) of the binomial family, with site included as a random effect to account for the non-independence of the data. For all models, estimated marginal means (EMMs) and their 95% confidence intervals were calculated to visualise and interpret the predictions. Post hoc multiple comparisons were then performed to identify differences among the three disturbance levels, with p-values adjusted using Tukey's test for abundance and Holm's sequential method for the sex ratio, and a significance threshold set at 5%. All analyses and graphical representations were performed using R software (version 4.5.2) and the glmmTMB, emmeans, multcomp and ggplot2 packages. The statistical significance threshold was set at 5%. We calculated a sexual dimorphism index (SDI) by dividing the average size of the larger sex by the average size of the smaller sex and then subtracting one from this ratio (LOVICH & GIBBONS, 1992). Only turtles exhibiting obvious secondary sexual characteristics were included in our analysis (juveniles were excluded).

RESULTS

A total of 748 specimens of *M. l. leprosa* were captured and examined from 51 localities (Tab. S1 in supplementary material). The freshwater turtle exhibited a widespread distribution across highly variable physico-chemical conditions. Our findings show a strong association of *M. l. leprosa* with degraded and organically enriched localities (Tab. S1), where high population counts were sustained. More specifically, the species shows a wide tolerance of environmental parameters. The species has been found in sites with BOD_5 concentrations ranging from 0.49 to 96.5 $mg{\cdot}L^{-1}$; orthophosphate concentrations ranging from 0.005 to 6.78$mg{\cdot}L^{-1}$; nitrate concentrations ranging from 0.08 to 102.95$mg{\cdot}L^{-1}$ and sulfate concentrations ranging from 34 to 639 $mg{\cdot}L^{-1}$. The species also tolerates a wide range and temporal variability in electrical conductivity. It has been observed in highly mineralized waters, such as those in Lake Sidi Boughaba (a Ramsar site on Morocco's Atlantic coast), with a maximum of 30,340 $\mu s.cm^{-1}$, and in weakly mineralized freshwater, with a minimum of 213 $\mu s.cm^{-1}$, at Ain Sfa (a perennial spring in the Oriental region of Morocco). *Mauremys leprosa leprosa* has been recorded in both hypoxic and highly oxygenated waters. The lowest concentration of 0.5 $mg{\cdot}L^{-1}$ was observed downstream of a wastewater plant effluent in the Marchica lagoon, while the highest concentration of 12 $mg{\cdot}L^{-1}$ was recorded at Dardoura River, an affluent of the Marchica Lagoon. Finally, the turtle was observed in water temperatures ranging from 18 to 28°C and in waters with a neutral pH in the majority of cases, with a pH between 4.5 and 8.8.

The estimated average abundance of *M. l. leprosa* varied significantly between the three types of site. The highest abundances were recorded in poor-water quality sites, followed by mediocre and unpolluted sites (Fig. 2). In addition, we found a significantly higher proportion of males on polluted sites (Tab. 1) than in unpolluted and Mediocre sites ($P<0.001$ and 0.036, respectively).

The weight distribution of males and females showed an almost identical pattern in the three types of site (Fig. 3). The polluted sites showed a wider range of weights than the other types of site. Male specimens weighed between 550 and 1030 g, while females weighed between 830 and 1200 g (Fig. 3, Tab. 1).

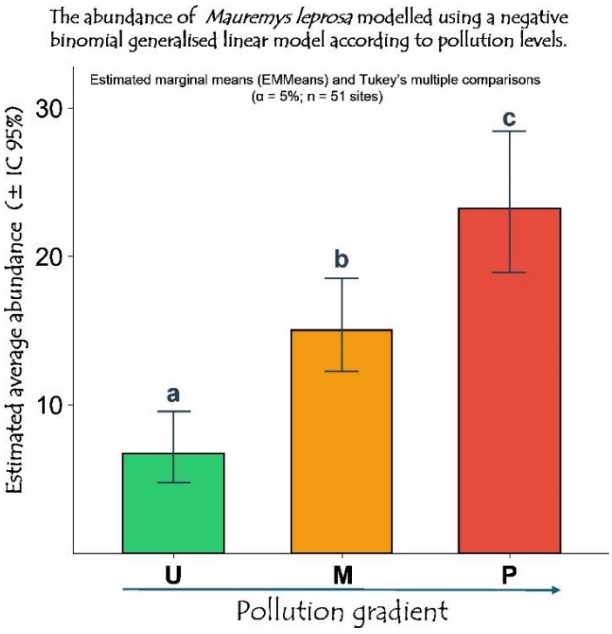


Fig. 2. The estimated average abundance is compared by site type, where: U: unpolluted sites; M: poor-quality sites; P: polluted sites. The letters above indicate whether there is a significant difference between sites in post hoc pairwise comparisons (sites with the same letter have no significant difference).

Tab. 1. Sex ratio (M: F) of turtles *Mauremys leprosa leprosa* of the 51 remote populations in northern Morocco.

	Unpolluted sites	Mediocre sites	Polluted sites
Males	52	178	210
Females	51	137	120
Total	103	315	330
Sex-ratio	1.02	1.30	1.74
Sexual Dimorphism Index	0.12	0.16	0.2

Tab. 2. Descriptive statistics for carapace length and body mass for sexed males and females from the localities studied. For each case, values are given as mean ± SD (sample size) and (min-max).

	Carapace length (mm)		Body mass (g)	
	Males	Females	Males	Females
Unpolluted sites	125.65 ± 12.05 (100 - 160)	140.47 ± 12.89 (107 - 164)	589.54 ± 52.56 (485 - 750)	739.24 ± 57.72 (586 - 850)
Mediocre sites	123.99 ± 14.85 (90 - 165)	143.45 ± 17.99 (90 - 190)	591.28 ± 64.69 (442 - 772)	751.34 ± 78.31 (512 - 949)
Polluted sites	161.1 ± 18.98 (116 - 224)	193.04 ± 20.46 (164 - 248)	752.75 ± 82.67 (556 - 1030)	967.20 ± 88.98 (836 - 1203)

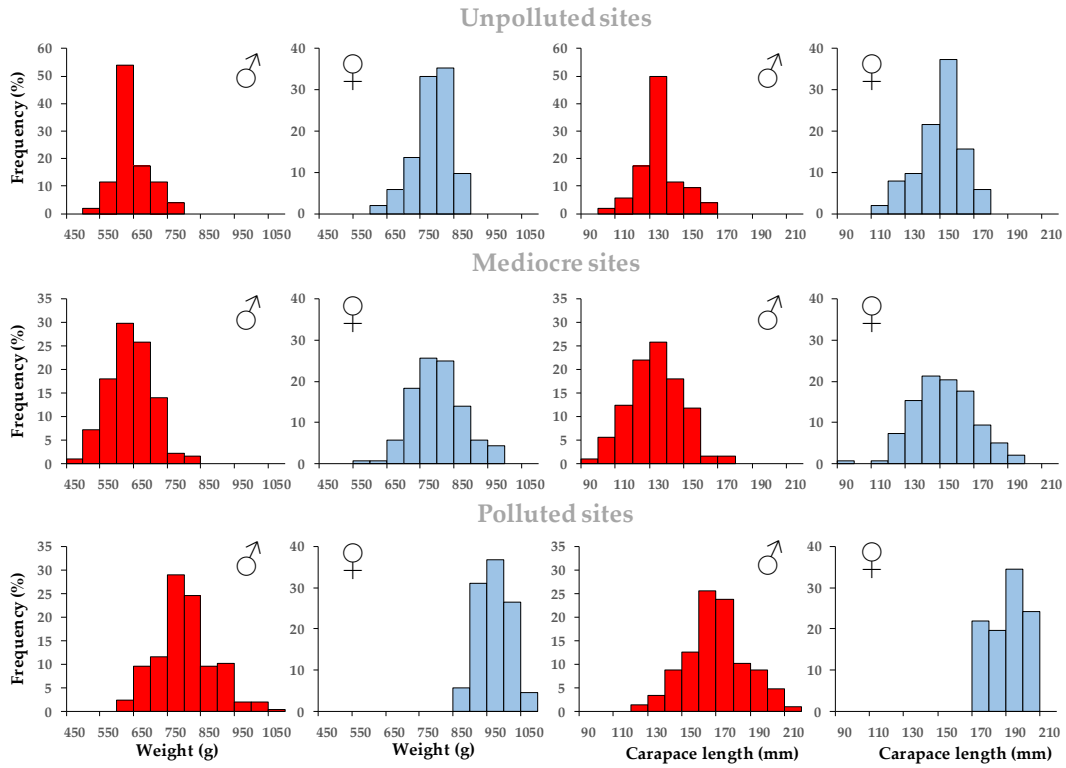


Fig. 3. Weight-frequency distributions of males and females *Mauremys leprosa leprosa* sampled during study period according to the type of site. Left histograms of each sex indicate weight classes and right curves represent size classes.

Both sexes showed the same size trends in the three types of site and the size distributions overlapped (Fig. 3). The dominant sizes are 120 mm for males and 140 mm for females in unpolluted and poor sites respectively, and 160 mm for males and 180 mm for

females in polluted sites. The largest size cohort was found at polluted sites, with a size range of 116 to 224 mm for males and 164 to 248 mm for females (Fig. 3, Tab. 1).

The biometric analysis revealed a clear impact of environmental degradation on turtle growth. Individuals from heavily polluted sites (P) exhibited significantly higher carapace lengths and body masses compared to those from unpolluted (U) and mediocre (M) habitats (Fig. 4). By contrast, no statistically significant difference was observed between mediocre and unpolluted sites regarding the size and weight of individuals of the same sex. Across all categories, females remained consistently larger and heavier than males; however, these biometric values were highest at polluted sites, exceeding those measured in other habitats by a large margin.

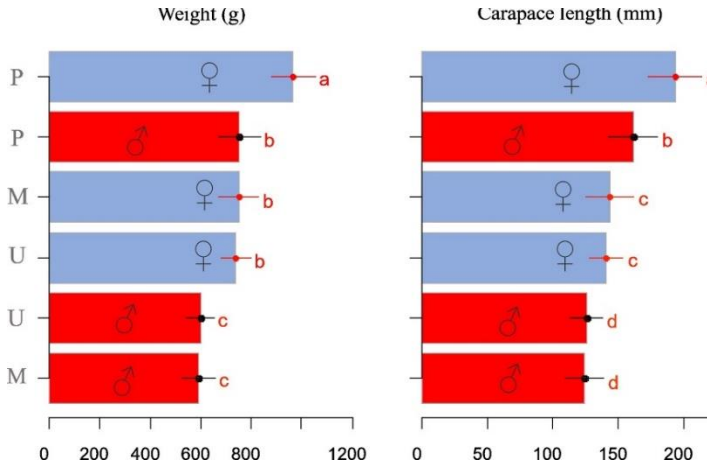


Fig. 4. Comparison of size and weight of *Mauremys leprosa leprosa* for both sexes in different habitats; with: P: Polluted sites; M: Mediocre sites; U: Unpolluted sites. The letters (a, b, c, d) indicate statistically significant differences based on post hoc pairwise comparisons. Subsets sharing the same letter are not significantly different from each other ($P > 0.05$).

We observed the scavenging behaviour of the aquatic turtle in isolated rural areas not connected to the waste collection network, where generally small populations collect household waste in a sort of small dump for incineration. Local children even throw their wastes into the river to attract the turtles (Fig. 5a, b). Several groups of turtles have been observed scurrying towards the organic waste freshly dumped by the local population to feed on a variety of plant and animal organic matter: heads, fish, animal carcasses and intestines (chickens and pigeons, for example).

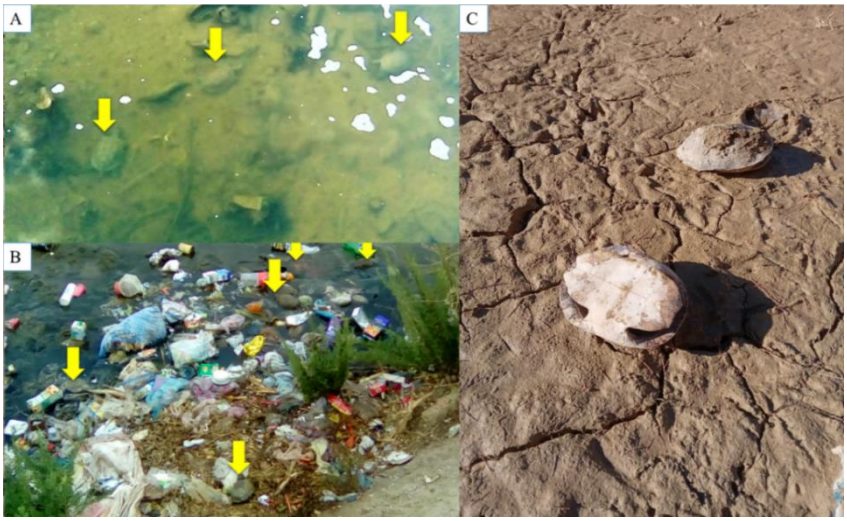


Fig. 5. *Mauremys leprosa leprosa* in heavily polluted waters (a). Scavenging behavior of the turtle observed in Selouane River (b). Dead turtles found in the dried-up ponds near Oujda (c)

During the field survey we found a total of 49 road kills, a high level of road mortality documented particularly in the rural areas of the northern region, the Bouareg plain and the Triffa plain (Fig. 6). As we did not actively search for road-killed animals, the road mortality rate could be much higher. Dead animals have also been found in human infrastructure such as water tanks and irrigation canals in the eastern region of Morocco, with a few individuals found alive, rescued and returned to the nearest aquatic ecosystem. Finally, we found animals that had died as a result of the drying up of the bodies of water where they live, such as the ponds on the Angad plain (Fig. 5c). Other environmental problems highlighted in the study area include the loss of breeding sites due to urbanisation and drainage of wetlands. In addition, the use of wetlands as embankments, high environmental pressure from livestock and the discharge of wastewater from nearby residential areas into wetlands were also identified.



Fig. 6. Different specimens of *Mauremys leprosa leprosa* killed by road traffic in different parts of the study area of Northern Morocco.

DISCUSSION

The variations observed in the different populations studied can be attributed to the variability of the habitat and the diversity of environmental conditions although sampling problems cannot be ruled out. The phenotypic variations observed in body size could be primarily linked to environmental factors and phenotypic plasticity rather than definitive genetic differentiation, as populations in north-west Africa are frequently isolated from each other by intermediate arid lands, which might lead to a complex pattern of local variation in carapace size (BERTOLERO & BUSACK, 2017; LOULIDA *et al.*, 2023). In addition, several studies have shown that populations of the same taxon can show variations in their body size at maturity and in their growth rate in response to different environmental pressures. The most important biotic factors are variations in trophic resources (JORGEWICH-COHEN *et al.*, 2022; GAHMOUS *et al.*, 2022). The highest average body size and mass have been observed in highly disturbed habitats, particularly in the presence of domestic liquid waste. The inputs of effluent resources can improve food supply by creating a suitable ecological niche for prey throughout the year, which could be beneficial for the growth and overall biometric development of turtles (LE GAL *et al.*, 2023). However, it is crucial to note that high abundance or larger body sizes in the studied areas reflect an association with resource-subsidized habitats rather than definitive

physiological resilience, as potential chemical stress and hidden sublethal costs were not evaluated in this observational design.

A male-biased sex ratio was observed in the most polluted sites. This imbalance is consistent with the findings of LE GAL *et al.* (2023), who documented a similar male-skewed sex ratio downstream of effluent discharges and hypothesized an early-stage or primary sex ratio bias rather than sex-differential survival or recruitment. While high levels of habitat alteration and organic pollution can promote enhanced growth rates and denser turtle populations due to increased food availability, the observed male bias likely arises from distinct mechanisms. According to LE GAL *et al*. (2023), such an imbalance could be linked to altered environmental conditions at nesting sites, where modifications in vegetation cover or soil thermal profiles might influence temperature-dependent sex determination during incubation. Alternatively, the variation observed in the male-to-female ratio in our study could be partially influenced by the capture methodology. Although the trapping effort and methods were strictly standardized across all 51 locations, surveys were conducted progressively between 2014 and 2021. Variations in the specific season or time of day when a site was sampled might interact with the differential seasonal and daily activity patterns of sexed males and females, potentially affecting their respective catchability and trap response (LOULIDA *et al.*, 2023).

The wide geographical distribution of *M. l. leprosa* supports the hypothesis that this species is capable of thriving in a range of contrasting environmental conditions. The species exhibits a high degree of habitat plasticity and a broad ecological tolerance, allowing it to thrive in a wide variety of biotopes, including severely degraded ones. In the study area, the habitats of this species show considerable diversity, encompassing a range of water bodies from large permanent streams at high and low altitudes to reservoirs, springs and small temporary tributaries. In addition, they are found in high-altitude lakes, the brackish and saline waters of coastal marshes and lagoons, and semi-temporary rivers fed by a perennial spring or subterranean waters. This result is consistent with the existing literature on *M. l. leprosa*, which characterizes the species as plastic and capable of inhabiting a range of continental waters, including those that have been altered (MARAN, 1996; NAIMI *et al.*, 2012; BAKHOUCHE *et al.*, 2019; LE GAL *et al.*, 2023).

In North Africa, high densities of *M. l. leprosa* were already documented in highly degraded and polluted habitats (SLIMANI *et al.*, 2018; ATTIA EL HILI *et al.*, 2020; BAKHOUCHE *et al.*, 2019). A recent study carried out in Algeria has shown that the Mediterranean pond turtle can thrive in highly degraded and polluted conditions (GAHMOUS *et al.*, 2022). This phenomenon was demonstrated by measuring reproductive characteristics. Populations exposed to pollution have adapted so well that this has increased their reproductive capacity. Females living in highly degraded and polluted habitats had the largest body sizes of the species, enabling them to carry a greater number of eggs and larger eggs (GAHMOUS *et al.*, 2022). In Morocco, in a comparative study of populations on the slopes of the High Atlas, LOULIDA *et al.* (2018) showed that the Tensift population appears to be highly tolerant to organic pollution, with a high degree of inter-individual phenotypic variability. This was assessed by the use of multi-character fluctuating asymmetry (MFA), which involves a comparison of the right and left anatomical dimensions of bilateral characters in the plastral scales, carapace scales and limbs. In addition, the Plastral Formula (PF) was used to rank in descending order the lengths of the suture lines corresponding to each pair of plastral scales. This evidence supports the claim that *M. l. leprosa* exhibits high reproductive and growth

performance in anthropized environments, where nutrient enrichment provides an overabundance of trophic resources. However, recent literature offers a more nuanced view: while these turtles can maintain high population densities and large body sizes due to additional resource subsidies, they remain exposed to the severe negative physiological impacts of chemical contaminants, such as heavy metal accumulation and oxidative stress (SLIMANI *et al.*, 2018; LE GAL *et al.*, 2023). In the same study area and later in 2019, EL HASSANI *et al.* demonstrated that morphological and physiological indices indicated that *M. l. leprosa* was able to adapt remarkably well to highly degraded and polluted habitats. The population density and body condition of the turtles were found to be higher in sewers. Stress markers, such as glucocorticoids, indicate that turtles have the capacity to respond to various stress factors. In addition, the researchers observed that reproductive parameters, including testosterone levels and vitellogenesis indices, were elevated in the polluted area.

Another feature that may have contributed to the success of *M. l. leprosa* is its behavioural and dietary plasticity. The diet of this species appears to be both opportunistic and omnivorous (ALARCOS *et al.*, 2008; PÉREZ-SANTIGOSA *et al.*, 2011). The Mediterranean pond turtle is a diurnal and nocturnal feeder, feeding both on land and in the water. The species is primarily carnivorous by preference, although it also feeds freely upon vegetation and has been reported ingesting various small animals and human waste (BERTOLERO & BUSACK, 2017). In addition, observations have shown that it is able to feed on vegetation without restriction (BERTOLERO & BUSACK, 2017). In Morocco, large populations have been found feeding even on wheat grains (BERTOLERO & BUSACK, 2017). Our results corroborate the observation that *M. l. leprosa* also displays necrophagous and scavenging behavior (BERTOLERO & BUSACK, 2017). A similar observation was recently made in Algeria (GAHMOUS *et al.*, 2022). This behavior is likely driven by the availability of large quantities of edible organic refuse in anthropized sites. Such household waste can provide high-quality nutritional resources that may be preferred over local, seasonal, and natural foods (HAFEEZ *et al.*, 2008, DITCHKOFF & MAYER, 2009; MAYER *et al.*, 2021). The availability of food from household waste and landfill sites can increase the abundance of wildlife populations, including reptiles, birds and mammals (NEWSOME *et al.*, 2015; SAIYAD *et al.*, 2015; MELLE *et al.*, 2022).

While the deterioration of water quality was not associated with a decline in the abundance or biometric parameters of *M. l. leprosa*, these observations should not mask potential sublethal effects. Instead, other anthropogenic pressures such as roadkill represent an immediate and documented source of mortality for its populations across a vast distribution range in northern Morocco, particularly in rural areas. A similar finding was recently documented in the amphibian populations of the same study area (MABROUKI *et al.*, 2019). Reptiles and amphibians represent one of the most endangered vertebrate species globally, with roadkill representing a significant threat, particularly in agricultural areas (HEIGL *et al.*, 2017). Some reptiles are attracted by the favorable microclimate on roads, while other species are particularly susceptible to roadkill due to their inability to move in response to an approaching vehicle (GLISTA *et al.*, 2008; BOUCHARD *et al.*, 2009; D'AMICO *et al.*, 2015). In addition to these factors, the drying up of aquatic environments, the excessive extraction of freshwater from aquifers, and the fragmentation and destruction of habitats represent major threats. These factors contribute to the temporary drying or permanent loss of wetlands, which can lead to the disappearance of many enclaves where species were previously present, as shown by the situation in the Iberian Peninsula (DASILVA, 2002; ARAÚJO & SEGURADO, 2008; TOLEDO *et al.*, 2021).

The Mediterranean pond turtle is currently classified as Near Threatened (NT) in the updated Red List of European reptiles (BOWLES *et al.*, 2025), whereas it was previously listed as Vulnerable (VU) in older assessments (COX & TEMPLE, 2009). Although the turtle is not considered an endangered species in Morocco, the blue-eyed subspecies of the Sahara faces significant threats, particularly the small isolated populations located on the northern periphery of the Sahara (MARAN, 2010; LOULIDA *et al.*, 2019). *Mauremys leprosa leprosa* is a protected species in Morocco under the Annual Haunting Decree, ministerial decree 582-62.3, November 1962 (BERTOLERO & BUSACK, 2017). However, despite this legislative protection, the species continues to face major challenges. These include excessive freshwater extraction from aquifers and the increasing impact of drought, which is a consequence of both anthropogenic activities and climate change. To ensure the long-term conservation of the *M. l. leprosa* population, it is essential to implement effective protection strategies that address these multiple threats.

ACKNOWLEDGMENTS

We would like to express our sincere gratitude to the editorial team and the anonymous reviewers for their constructive comments and precise suggestions. Additionally, we warmly thank the Master's students from Mohammed Premier University (Oujda, Morocco) for their invaluable assistance during the field surveys.

Received February 23, 2026

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