Ecology, distribution and habitat suitability analysis of the North African Sengi (*Petrosaltator rozeti,* Macroscelidea, Afrotheria) in Tunisia

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Abstract

The North African Sengi (*Petrosaltator rozeti* syn. *Elephantulus rozeti* (Duvernoy, 1833)) is a small mammal endemic to the Maghreb area, and is one of the least studied mammals in North Africa. Little is known about its status, habitat preference, and distribution across large areas of its range. This work provides a detailed geographical and ecological distribution of the species in Tunisia based on 200 surveyed sites throughout the country with 103 positive occurrence records. We also used species distribution modelling to assess the habitat suitability of the species. *Petrosaltator rozeti* showed a heterogeneous bioclimatic niche, with a presence in the semi-arid, arid and Saharan bioclimatic zones. But the species' distribution seems to be limited to the main mountain ranges of Tunisia. This was also confirmed by habitat suitability modeling where the elevation was the most informative predictor variable. Our work also show some first recorded ecological traits, confirms the rock-dwelling specialist nature of the species and debate its endemism to mountain ecosystems.

Key words: *Petrosaltator rozeti*, rock-dwelling specialist, distribution modelling, mountain species, North Africa.

1 INTRODUCTION

With the global decline in biodiversity, gaps in knowledge about species occurrence and in their potentially suitable habitats must be rapidly filled for better conservation (Ahmadi et al. 2020; Hody and Kays 2018). The North African sengi (*Petrosaltator rozeti* syn. *Elephantulus rozeti* (Duvernoy, 1833)) is endemic to the Maghreb area and only found in Morocco, Algeria, Tunisia and Libya (Rathbun 2015). This species is the only representative of Macroscelidea in North Africa, and it is believed to have diverged from its closest relatives 16 Ma ago (Heritage et al. 2020). All other sengi species are distributed further south, from Somalia to South Africa (Douady et al. 2003; Nyari et al. 2010). Recently, the North African sengi has undergone a radical phylogenetic change and is now placed in a monotypic genus (Dumbacher et al. 2016). Like other Macroscelidea, the species is primarily insectivorous (Rathbun 1979; Wester 2010). This animal has its specialist ectoparasites and endoparasites (Beaucournu and Launay 1990; Orecchia et al. 1964). However, little is known about their status, ecology, habitat preference, and distribution across large areas of their range and data are sparse. Recent records of the North African sengi come principally from the west part of its distribution from Morocco (Aulagnier 2017; Denys and Bouarakia 2020) and Algeria (Ahmim 2019). To our knowledge, no new study dedicated to this species in eastern part of the species distribution is available. Data on this species from Libya date back to Hufnagl (1972) while the most recent update of sengi occurrence in Tunisia dates back to Gharaibeh (1997) who collated historical records from Blanc (1935), Chaignon (1904), Heim de Balsac (1936), Joleaud (1927), Joyeux and Baer (1928), Kock (1980), Lataste (1887), Trouessart (1905), Vesmanis (1979) and added his own occurrence records. The continuity between Moroccan, Algerian, Tunisian and Libyan populations is unknown and the presence of two subspecies (*P. r. rozeti* and *P. r. deserti*) is not clearly defined (Corbet and Hanks 1968; Dumbacher et al. 2016). Its ecological niche is not yet well-defined, which hampers a thorough assessment of its conservation status. For example, the species shelters among boulders and rock crevices associated with ridges and mountains (Cuzin and Seguignes 1990; Rathbun 2009). It is unclear to what extent this species is restricted to rocky environments, whether this species is endemic to rocky habitat (rupicolous/rock-dwelling) in the broad sense or strictly to rocky mountain ecosystems (mountain endemic) (Kotler et al. 199; Mares and Lacher 1987; Nicolau and Edwards

2023). A rupicolous/rock-dwelling animal can be generalist and be found where the habitat is rocky (plains, valleys, hills, mountains, rocky outcrops, human constructions). In this case, the macrohabitat can be of any type and the presence of the animal is associated with rock structures within these habitats (Diedericks and Daniels 2014; Fitzsimons and Michael 2017; Metallinou et al. 2015; Maswanganye et al. 2017; Sauthier et al. 2016). A mountain endemic animal is a species that can naturally only be seen in mountainous areas (Drovetski et al. 2013; Gliwicz et al. 2006; Osuna et al. 2020; Merckx et al. 2015; Rice 2008). Due to climatic or vegetation cover characteristics of high altitude habitats, mountains constitute a refugia zone for many species (Brighenti et al. 2021; Brito et al. 2014; Demos et al. 2014; Himes and Kenagy 2010). For mountain rupicolous/rock-dwelling species, the complexity of structured rocky environments offered by these geological features are specifically selected (Rodhouse et al. 2010). Screes, ravines and steep cliffs constitute the preferred landform for these animals. Boulders, cracks and rock crevices provide the animal with natural shelters where it can hide from environmental adversity (Andino et al. 2014; Brito et al. 2014; Sakiyama et al. 2021). Despite being part of the Mediterranean hotspot of biodiversity, the mountains of North Africa have a low level of endemism, particularly for mammal species, compared to lowlands (Aulagnier 2017, Gharaibeh 1997). This is probably due to the moderate elevation of the majority of the mountain systems and a relatively young formation for the main mountains of North Africa such as the Atlas (Babault et al. 2008; Lamotte et al. 2009). This has led to a smaller number of specialized mountain species than higher or older mountain formations in other regions (Amori et al. 2019; Camacho-Sanchez et al. 2019; Hu et al. 2017; Shrestha et al. 2022). North African sengi may be one of the few mammals endemic to the mountains of the Maghreb region, but the lack of habitat requirements data does not allow a good assessment of this endemism. Rathbun (2009) noted the scarcity of biogeographical research on sengi species in general and Brito et al. (2014) remarked on the considerable knowledge gaps in species ranges and ecological requirements in North African mammals. This is even more accentuated in elusive species such as sengi. New revisions in other sengis biogeography have shown an expansion of their known distribution and added undocumented ecological affiliations (Heritage et al. 2020). In this work, we provide a detailed geographical and ecological distribution of the North African Sengi in Tunisia. We added habitat suitability analysis to define the species potential range and try to understand its ecological requirements in North African ecosystems.

2 Materials and methods

2.1 Study area

Tunisia is a Mediterranean North African country and part of the Maghreb region. Tunisia's climate is principally Mediterranean, influenced by the Sahara Desert. Significant differences occur in the topography, vegetation, rainfall and temperature across the country (Slimani et al. 2007; You et al. 2016). It can be divided into three major natural regions ; the northern, central, and southern zones. Moving from north to south, the bioclimatic zones are Humid, Sub-humid, Semi-arid, Arid, and Saharan (Nouira 1996).

North Tunisia (between latitude 37°20′ N and 35°44′ N) has a humid and cold climate compared to the south of the country. It is separated from the central zone by a branch of the Atlas Mountains called the Dorsal. Average annual rainfall reaches a maximum of 1500 mm in the northwest. It is characterized by dense Mediterranean evergreen forest in the Humid bioclimatic zone. Maquis shrublands occupy Sub-humid area and degraded land (Debazac 1954). The limit between the northern and central zones is characterized by dry mediterranean forests and shrubs that occupy the Semi-arid zone. Being the extreme eastern part of the Atlas moutains range, the Dorsal is composed of a series of the country's highest peaks: Châambi (1544 m a.s.l.), Semmama (1314 m a.s.l.), Zaghouan (1295 m a.s.l.) and Sidi Abderrahman (637 m a.s.l.) arranged in a southwest-northeast transect from Kasserine to Cap Bon. The central zone (between latitude 35°44′ N and 34°19′ N) has an arid climate with hot summer. It is located between the Dorsal mountain chain and a series of large salt lakes (Chotts). This region receives between 200 and 400 mm of rainfall per year and the dominant natural vegetation is principally dry forest on the mountain peaks and degraded steppes on the plains (ROSELT/OSS CT7, 2004). Southern Tunisia (between latitude 34°19′ N and 30°13′ N) has and arid/Saharan climate with extreme temperature in summer. The Dhahar mountain chain divides the south-east and south-west. It is a calcareous plateau of 400-600 m in elevation. To the east, the Jeffara-Ouaraa, which is a large plain made up of crusted Quaternary deposits, stretches between the mountains and the littoral zone. Rainfall increases from 100 mm in the lowlands to 200 mm at high elevations. The area's natural vegetation consists primarily of degraded Mediterranean steppe and desert vegetations with more patchy shrubs in higher elevations. The Sahara Desert occupies the south-west to the exteme south of the country and receives <100 mm of annual rainfall. It is a xeric zone dominated by sand dunes and sparse vegetation adapted to dry climates (You et al. 2016).

2.2 Sampling methods and data collection

To establish the geographical distribution of the North African sengi in Tunisia, we tried to cover all bioclimatic zones and ecosystems, including coastal plains, forests, agricultural fields, mountains, steppes, pastures, deserts and sebkhas (Figure 1). These habitats were covered despite prior studies not recording the species in several of these environments to ensure that our study was not biased by what we know about the species. Through searching all available habitats, we can estimate the species' preferred habitat. Presence-absence surveys are the best cost-effective approaches when monitoring large areas, especially for sparse, rare, or difficult-to-detect species (Pollock 2006). Field data were collected from single-day trips, with a total of 200 sites visited from 2017–2021 (Figure 2). We employed active searching for sengi presence using a combined opportunistic and systematic sampling method at all sites, as it is more accessible and effective for yielding maximum results (Barba et al. 2010). We collected opportunistic sengi encounters without distinction, including literature records, captured animals, observed animals, or deceased animals. This approach additionally allowed us to gather information on the activity of the animals. Systematic sampling with line-transect searching commenced at sunrise and continued until late at night, with occasional breaks, along approximately 4 km of predefined routes chosen randomly at each site. The search effort varied depending on accessibility, visibility, and weather conditions at each site. This sampling was conducted for presence-absence monitoring rather than population abundance estimation; minor biases in search effort could be tolerated (Navarro and Diaz-Gamboa 2015). We searched for sengis by looking in favourable environments, including stones piles, under scrub, under rocks and in rock crevices and ruins of human settlement. Once the animal is disturbed, it retreats into the nearby shelter making its capture easier. We used thick gloves to catch specimens under rocks for safety reasons (these shelters are sometimes shared with venomous animals). This work was under ethical approval according to an approved animal use protocol (Sikes et al. 2016). All captured sengi were released in the same place where they were caught. In total, 800 km of active searching was undertaken and 52 specimens were captured with a capture rate of 0.06 sengi/km. Visual detections only were also used in cases where it was impossible to capture the animal due to inaccessibility in rough terrain. Being the only Macroscelidea in North Africa,

identification of the North African sengi was easy based on its unique morphology (Corbet and Hanks 1968). We used two principal external characteristics to identify this species, namely: large ears that protrude from adjacent fur, and a long, tubular and flexible snout (Figure 3).
To consider the species as being present at a site, we required at least one of the following criteria to be met: the capture of a specimen, observations of the animal or literature record. The geographic coordinates and characteristics of the biotope frequented by this species were also noted in order to identify their ecological affinities. We used Emberger Climate Index to define the five bioclimatic zones (humid, sub-humid, semi-arid, arid and Saharan) with their five winter variants (cold, fresh, temperate, hot and very hot) that characterize the Mediterranean climate in Tunisia. The climatic data was taken from the closest meteorological station of each concerned station. These data are freely available and freely accessible on www.meteoblue.com.

2.3 Species distribution modelling

Sengi distribution maps were drawn using Global Mapper 19, Arc GIS 14 and Corel Draw X7. To evaluate the current habitat suitability for *P. rozeti*, we produced distribution models under present climatic conditions, elevation and vegetation cover of Tunisia using a distribution modeling approach. We compiled known occurrence records from the literature as well as our own extensive fieldwork. We filtered this dataset to include only records that were separated by a distance of at least 2 km using Quantum GIS v. 3.22.16, as distribution models perform better when geospatially correlated observations are removed (Boria et al. 2014; Brown 2014).

The environmental layers used were downloaded from the WorldClim version 2.0 database (Fick and Hijmans 2017). Seven climatic variables were selected *a priori* based on the known ecology of the species: annual mean temperature (BIO1), mean diurnal range (BIO2), isothermality (BIO3), mean temperature of wettest quarter (BIO8), mean temperature of coldest quarter (BIO11), annual precipitation (BIO12) and precipitation seasonality (BIO15). These variables are ecologically important for the sengi because temperature and seasonality affect sengi' prey activity. Besides, the North African sengi is known to torpor in cold/winter temperature and when food is scarce (Lovegrove et al. 2001; Seguignes 1983). We additionally included elevation and land cover (DIVA-GIS 2023) as explanatory variables. Predictor variables were re-sampled to 30 arc-second (1 km^2) resolution and were tested for autocorrelation in ENMTools 1.3 (Warren et al. 2010;

Warren and Seifert 2011), with variables that were correlated (r ≥ |0.7|) removed from the modelling process (Brown 2014; Chalghaf et al. 2016; Elith et al. 2011). Species distribution modelling was performed in MaxEnt version 3.3.3 k (Phillips et al. 2004, 2006; Phillips and Dudík 2008). We used default settings, a logistic output format, 10-fold cross-validation to estimate errors around fitted functions and a maximum of 500 iterations. We varied the regularisation multiplier between one and five to constrain MaxEnt and prevent over-fitting of the model, with model performance assessed using the area under the receiver operating curve (AUC) value (Breiner et al. 2015; Marmion et al. 2009; Warren and Seifert 2011). The AUC value varies from 0 to 1, with models having an AUC value ≥0.7 considered to be robust (Marmion et al. 2009).

3 Results

3.1 Distribution of the North African Sengi in Tunisia

From 200 sites visited, we collected 103 occurrence records of North African sengi (17 records from the north, 46 from the central region and 40 from the south) which represent 51% of the sites visited. Our database includes new records and verification of previous site records from Gharaibeh (1997). Using a combined opportunistic and systematic sampling method allowed us to achieve maximum results, especially given the difficulty in capturing specimens of this species. Observations without capture constitute the primary dataset in this work, with 162 individuals observed (75% of encounters) and only 52 captured (25%). In many sites, our staff was unable to catch the sengi due to its quick escapes in sloping rocky environments. Additionally, our nighttime searches yielded no results in the majority of sites, with no signs of sengi activity. Only three specimens (1% of encounters) from two sites (Ain Snouber and Oued El-Khil) were observed outside of their shelters after the crepuscular period.

In the North, this species is present in the rocky mountains of Zaghouan, Siliana and Kef governorates. Based on our field observation, this species can be found at elevations ranging from 300-1300m a.s.l., where it seemed to prefer south facing slopes. Dense Mediterranean shrublands, several rocky outcrops and patchy forest-like structures characterize this northern part of its habitat (Figure 4). The vegetation is dominant by holm oak (*Quercus ilex*), olive tree (*Olea europea*), carob (*Ceratonia siliqua*), Atlas cypress (*Teraclinis articulata*) and lentisk pistachio (*Pistacia lentiscus*). Individuals were generally found close to rocky crevices, with quick forays into open areas.

In the central region, the North African sengi occupies almost all the mountainous western part to the Algerian border from 400-1500m a.s.l. This part of the country is more arid than the northern part, with dry forest at higher elevations of Aleppo pine (*Pinus halepensis*) and Phoenician juniper (*Juniperus phoenicea*), open environments with Alfa (*Stipa tenacissima*) vegetation on the steppes, and degraded farmlands, pastures and unexploited plots at lower elevations. The soil is dry with many rocky outcrops, screes and ravines. The species appears to feed on Aleppo pine seeds - piles of hollow pinecones which were frequently found in front of and around sengi shelter entrances. In steppe environments, the sengi is found on piles of stones where it can be seen basking or under boulders. The animal often visits shrubs where it appears to feed on their fruits. At some sites (e.g., Djebel Bouhedma), the species has been observed feeding on fruits of *Searsia tripartita*, a species of sumac shrub abundant in North African arid areas (Idm'hand et al. 2020).

The presence of North African sengi is also confirmed in the south-west of Tunisia from the mountain formation bordering Chott Djerid from the north (Fejej Mountains) and the south (Tebaga Mountains) shared between Touzeur, Kebili and Gabes governorates. In the south-east, almost all specimens have been collected on the Dhaher mountainous region from 250-600m a.s.l. the present study allows extension of its range southwards to the Libyan border. In its southern habitat range, this species has been found on steep cliffs, screes and boulders in dry Ouadi and plateau. The vegetation consisting of degraded steppes (*Stipagrostis sp.*) and perennial thorny desert plants like *Astragalus armatus*, *Artemisia herba-alba* and *Ziziphus lotus* in lower elevations and steppes of Alfa (*Stipa tenacissima*), relict shrub vegetation with Phoenician juniper and lentisk pistachio at higher elevations. The landscape is exposed and water, if present, is temporary and rare. The environment is degraded with clear vegetation, even at high elevations, since this sector of Tunisia is overgrazed over its entire extent (Aidoud et al. 2006). Some individuals that we found live in the same environments occupied by gundi (*Ctenodactylus gundi*) colonies. Based on our observation, the two species seem to tolerate each other and share shelters. Choumowitch (1954) reports that the sengi's main diet in this region is constituted of the spiny seeds of mountain clover (*Medicago arabica*) and piles of seed hulls of this species were found around the entrances of sengi shelters (Gharaibeh 1997). We were not able to observe this selective behaviour despite the fact that many seed shells were found around sengi shelters by us on numerous occasions. In these arid environments, vegetation cover is not dense enough for the species to hide under and their activity is limited to the vicinity of rocky structure where they can rapidly hide.

3.2 Bioclimatic niche of the North African Sengi in Tunisia

Petrosaltator rozeti showed a moderate bioclimatic range in Tunisia, with presence localities from the Semiarid, Arid and Saharan bioclimates, being absent from stations within the Temperate and Humid bioclimatic zones (Figure 5). The species occupies areas from the Sahara in the south with 0-100 mm of annual precipitation to the Semi-arid (400-500 mm), from a cold climate 16-17°C to a hot climate >21° of annual average temperature. Nevertheless, the ecoclimatogram of the species showed a more accentuate occurrence in cool winter regions (inland) within this bioclimates. We found the animal only in sites with minimum temperatures of the coldest month ranging from two to 7°C.

3.3 Habitat suitability

We built species distribution models for *P. rozeti* based on the known presence localities. A regularisation multiplier of one resulted in over-fitting of the data, while a value of five reduced the specificity of the resultant models. We therefore used a regularisation multiplier of two for the final model, as it showed the greatest predictive power while limiting non-specific projection. The occurrence records used for modelling were fairly evenly distributed across the known range of this species, thereby precluding any spatial autocorrelation. The final model performed well, with an AUC value of 0.916 ± 0.005. Elevation was the most informative predictor variable, contributing 46.7 % and 48.6 % to the overall model and permutation importance, respectively. Mean diurnal range, mean temperature of coldest quarter and land cover were the next most important predictor variables, each contributing between 10 % and 15 % to the overall model.

The species distribution model revealed large but disjointed habitat suitability area for *P. rozeti* that perfectly overlaps the mountainous topography of the Dorsal and Dhaher mountain ranges (Figure 6). The model also shows generalized unsuitable habitat north of the Medjerda River, all low elevation zones (plains and Sebkha depressions), the coastal area and the Sahara. We can observe three principal patches of high habitat suitability in Tunisia: One from the northern part of the Dorsal (Zaghouan area) to the central part of the Dorsal that continues to the Algerian border, and isolated from the north by a network of permanent rivers such as the Medjerda, Meliane and Mellegue rivers. It is isolated from the south-east by the Kairouan and Sidibouzid plains, and from the extreme south-west by Chott El-Gharsa. The second suitable area is located in the central part of Tunisia between west Sfax, Sidibouzid and east Gafsa. This area is bordered by the coastal region (Sahel) in the east and Chott Djerid in the South. The third area is limited to the Dhaher mountains from Matmata to Dhehiba in southern Tunisia, and continues to the Libyan border. It is bordered on the east by the coastal Jeffara-Ouaraa plains and in the west by the sandy dunes of the Sahara.

4 Discussion

The good knowledge of the ecology, distribution and the limiting environmental factors of a given species are necessary for developing suitable conservation strategies (Guisan and Thuiller 2005). The present work provides the most detailed geographical, ecological and bioclimatic description of *Petrosaltator rozeti* range so far. However, it should be highlighted that our ecological study and distribution model only relies on data collected from Tunisia and thus should be considered a description of a part of the real biogeographical potentiality for the species, and not of the current ecological requirement in all its range.

4.1 Ecology

The North African sengi can be found from Semi-arid to Saharan bioclimatic zones and can live in Mediterranean forests, shrublands, steppes and desert biotopes. Within these habitats, we have noted some ecological traits that characterize *P. rozeti*:

Individuals were found in rocky habitats with stony substrates and nowhere else, despite our extensive fieldwork in other habitats. The species lives exclusively among rocky outcrops and screes with enough shelters which the animal can use to hide from predators. Shelters are principally rock crevices, piles of stones, and boulders. Our study confirms what has been put forward in previous research, namely that the animal has a rupicolous and rock-dwelling nature (Gharaibeh 1997; Rathbun 2009). Sengis are known to be habitat specialists and differences in habitat preference occur independently from phylogenetic affinity (Rathbun 2009). Heritage (2018) showed that the Western Rock Sengi (*Elephantulus rupestris*) and the Bushveld Sengi (*Elephantulus intufi*) do not use the same habitat or type of shelters despite their close phylogeny and that the former is rupicolous and shelters under boulders while the latter species is arenicolous and shelters under bushes.

The animal seems to be more diurnal than nocturnal. We observed specimens being active at all times of the day, and only rarely at night. Crepuscular activity was previously reported for most soft-furred sengis (Neal 1995; Rathbun 1979; Ribble and Perrin 2005; Woodall et al. 1989). Moreover we did not comfirm whether the North African Sengi lives in colonies or in pairs and interaction between individuals was rarely observed. The species seems to be more solitary than expected and we caught only solitary individuals or females with litter. However, we note a proximity of few meters between individual found by us in some stations. We think this is driven by the scarcity of shelters, which makes the species appear locally abundant. This search of shelters also obligate the sengi to cohabite with the common gundi (*Ctenodactylus gundi*) who covets the same spatial niche but not the same trophic niche. Nevertheless, based on our field observations, this social rodent provides protection from predators to the sengi who seems to take advantage of the colonies warning system (Gouat and Gouat 1989; Gouat 1991). The sengi take refuge when the gundi sentry gives the alert for the colony. In fact, the common name of the North African sengi in Tunisian local language is a diminutive of the name Gundi (*Goundi* in Arabic). The animal is called *Goundchya* or *Goundchaya* which means little gundi. Giant sengis have been observed interacting with insectivorous bird species in East Africa (Cordeiro et al. 2022), which leads us to believe that an interaction may occur between the North African sengi and gundi colonies. The interaction between these two species can be cooperative or commensal and additional research should be done in the future to approve this speculation.

Plants may constitute a large part of the North Africa sengi's diet in some areas with certain species preferred to others. We found literature and direct evidence of sengi foraging on at least three plant species depending their availability (Choumowitch 1954, this study). Seeds of pine trees were consumed in forest ecosystems, sumac shrub fruit were consumed in steppe ecosystems and mountain clover seeds were consumed in desert ecosystems. Furthermore, the species seems to gather and store seeds in its shelters, probably to build a food reserve. This explain the piles of seed hulls and hollow pinecones in front of shelter entrances observed during our fieldwork. Plants can be an additional nutritional source especially in winter when insects are scarce. The species' periodic consumption of vegetation materials in addition to their insectivorous diet has been explained as a vestige of their ancestors' herbivorous diet (Rathbun 2009). Other sengis like *Elephantulus edwardii* and *E. brachyrhynchus* was observed being nectar-feeding animals and may play a role as potential pollinators (Johnson et al. 2011; Wester 2010, 2011, 2015). It is possible that the vegetation structure and composition across the range of the North African sengi can explain in part its distribution as alimentation resource. In Tunisia, the habitat of *P.rozeti* overlaps with the range of many plant species like Atlas Cypress (*Teraclinis articulata*), Aleppo Pine (*Pinus halepensis*), Alfa (*Stipa tenacissima*) or Phoenician Juniper (*Juniperus phoenicea*) (Ben Mariem and Chaieb 2017; Caudullo et al. 2017). The association of this sengi with certain types of plants should be further studied in the future.

The species shares ecological similarities with well-studied moutain endemic and rock-dwelling small mammals. For example, basking behaviour is shared with rock hyrax (*Procavia capensis*) and gundi species (*Ctenodactylus sp.*). Food storage is shared with pika species (*Ochotona sp.*). Diurnal activity shared with gundis, pikas and hyrax (Brown and Downs 2007; Gliwicz et al. 2006; Honigs and Greven 2003; Kotler et al. 1999; Varner et al. 2023). Although these behaviours are not exclusive to moutain species, it appears that together they characterize the response of these animals to the harsh conditions of their habitats. Such behaviours are certainly accompanied by anatomical adaptations (Feijó et al. 2020; Mares and Lacher 1987). We think that adaptive anatomical features, not addressed in this work, may also help the North African sengi live in such challenging ecosystem. For example, we know that probably all sengis can see colors, which is an advantage for diurnal foraging (Thüs et al. 2020, 2023). Spurrier et al. (2023) showed a ressemblance between the feet of rock-dwelling mammals, adapted to the irregular surface of rocks. Further research into the biology of the North African sengi needs to be done.

4.2 Distribution and habitat suitability analysis

One of the most remarkable findings from this study is that the North African sengi not only prefers rocky ecosystems, but it is also a mountain species and a rock-dwelling specialist in Tunisia. This is revealed in the biogeographic patterns of the species observed through both direct sampling (presence-absence data) and habitat-modeling methods (presence-only data). All records of this species come from mountainous sampling sites and the species distribution modelling shows the importance of elevation in the probability of the species' presence. Elevation was the most informative factor to predict North African sengi distribution, more so than any bioclimatic variable or the vegetative cover. The habitat suitability area for this species significantly overlaps with the mountainous topography of the Dorsal and Dhaher mountain ranges. In addition, both methods show the absence of this species at low elevation sites (< 200m) while lowlands constitute a large part of the country's surface area. However, in Tunisia, the species is present in mid-altitude mountains with a presence in the Châambi moutain (country's highest peaks, 1544 m a.s.l). *P.rozeti* has been observed in Morocco at an altitude of 2700 m a.s.l. (Cuzin and Seguignes 1990). The North African sengi has a large but discontinuous range in Tunisia, both the sampling and habitat modelling show a patched presence zone for the species. We think that the occurrence of the species depends on the presence of mountains reliefs and structures (probably the availability of shelters). This may explain the patchy distribution area of the species, which coincides perfectly with the discontinuity of mountainous habitats in the country.

Concerning the northern part of Tunisia, our sampling yielded no occurrence records north of the Dorsal mountains despite extensive field effort. The species is absent even in rocky ecosystems of Khroumourie and Mogods mountain range, which forms the highest structural unit in northern Tunisia (Riahi et al. 2010). Three hypotheses can be advanced to explain this absence: (i) the northern part of Tunisia has the highest annual precipitation and the coolest climate with extremely low temperatures and snow in winter at high elevations. Humid and Temperate bioclimatic zones characterize this part of the country. We suggest that the absence in northern areas may reflect the limit of climatic tolerance capacity of the species. The Maghreb region, in its northern part is more similar to Europe than the rest of the African continent (Bons and Geniez 1996). Additionally (ii), denser vegetation structures (high surface cover of canopy and sub-canopy layers) in the norther mountainous region of Tunisia (especially in Khroumourie) may limit the ecological fitness of the species and explain its absence. Tree shading blocks solar radiation, thereby preventing basking behaviour, which seems to be important for the sengi in its daily thermoregulation. The absence in regions with closed canopy cover has been noted in another rock-dwelling mammal, the northern pika (*Ochotona hyperborea*), in Japan for similar reasons (Sakiyama et al. 2021). Alternatively (iii), geographical isolation by the Medjerda River is also a possible explanation. Walker et al. (2003) showed that rivers could act like a barrier and affect the distribution of rock-dwelling species. The Medjerda is a perennial river that originates in Algeria and flows eastwards to the Mediterranean Sea through the gulf of Tunis. This completely separates the northern regions from the rest of the country. The first and second hypotheses seem more accurate since even our habitat suitability model shows an absence of sengi in the north. Species distribution models like ours do not include geographic barriers (like water bodies) in the predicted occurrence probability (Aliaga-Samanez et al. 2020).

However, the ecology, distribution and habitat suitability show that *P. rozeti* is an obligate macrohabitat (mountains) and microhabitat (rock-dwelling) mammal, at least in Tunisia. Previous research does not specify the mountain specialist pattern in *P. rozeti*. Habitat suitability models created by Nyari et al. (2010) for this species show a continuous and larger area in North Africa than expected. This is probably due to the use of only bioclimatic parameters in the predictability models without including the elevation, an important factor for the species. Cuzin and Seguignes (1990) describe the species as present from the coast up to highlands in the Atlas Mountains. This discrepancy between our results and those of previous research can be explained by the fact that in some parts of Morocco (and probably also Algeria), the Atlas Mountains are in direct contact with the coast (Ellero et al. 2012), which is not the case in Tunisia. More research on the distribution of this species across its range would help to define its bioclimatic niche and habitat choice. Furthermore, the two presumed subspecies of this species are distinguished by their distributions, with *P. r. rozeti* occuring north of the Atlas Mountains and *P. r. deserti* occuring south of this mountain range (Corbet and Hanks 1968; Dumbacher et al. 2016). If we deem this separation to be correct, only *P. r. deserti* is present in Tunisia as suitable habitat for this species only exists south of the Atlas Mountains. This is also noted by Gharaibeh (1997) who tried to identify morphometric differences between populations from northern and southern Tunisia, but without success.

Interestingly, the habitat suitability model shows a discontinuity in the distribution of the North African sengi across Tunisia. We posit that northern populations that live in the Dorsal Mountains are probably continuous with the Algerian populations of this species, while the southern populations that live in Dhaher Mountains are probably continuous with the Libyan populations. Between these two groups, Chott Djerid, a big salt lake depression that bisects Tunisia from west to east, can be a geographic barrier limiting the dispersal of individuals, especially considering the rupicolous nature of this species. This can separate the south-Tunisian-Tripolitan population form the Atlas Mountains population. We know that the use of habitat suitability modelling can give us an idea of gene flow between metapopulation (Wang et al. 2008).

4.3 Conservation measures

In the context of global biodiversity crisis (Ceballos and Ehrlich 2002), there is an urgent need to determine the ecology and biogeography of elusive species like sengis. This can guide the conservation priority towards some species. The North African Sengi lacks national and international protection laws. The species is listed "Least Concern" on the IUCN Red List of Threatened Species and it is not protected in Tunisia. In this work, we show that the North African sengi is endemic to specific habitats with a fragmented distribution. *Petrosaltator rozeti* is one of the few mammals specialized in the rupicolous ecosystems of North Africa. Many rock-dwelling mammals are rare, elusive or on the verge of extinction making studies like ours necessary (Nutt 2005). There is no evidence for a decrease in the total distribution of this species in Tunisia, but that does not mean that this species is not in decline. Its habitat is safe from large-scale anthropogenic activity like urbanization, agriculture and pollution, but is still ravaged by many other threats like wildfire, mining and overgrazing. The species is endemic to mountainous ecosystems and these areas therefore have to be protected. Helpfully, human populations in Maghreb do not consume the species and it is rarely hunted. In other parts of Africa, sengis are threatened by bushmeat activity (Fitzgibbon et al. 1995). Nevertheless, concerning its specialist habitat choices, local extinction can occur in isolated mountains (Beever et al. 2003; Walker et al. 2003; Wilcox 1980).

5 Conclusion

Overall, this study provides new insights by revising the biogeography and adding undocumented ecological traits of an elusive small mammal, *Petrosaltator rozeti*. In Tunisia, its distribution and suitable habitat are limited to the country's main mountains ranges, while it is absent in the lowlands and the northernmost mountains. Its ecology shows that the species depends on rocky habitats and does not exist anywhere else. Certain behaviours help the species to cope with the harsh geographic/climatic conditions generally observed in mountainous regions such as limited surface availability, cold winter and fluctuating temperatures between day and night. Given the scarcity of the spatial niche in the sloping surface of its habitat, the species occasionally shares shelters with other moutain species. Seeds storage strategies, torpor, basking and diurnal activity are probably also a response to mountain environment. Further investigations are needed, including all known records of the species within its global distribution in habitat suitability modelling, to confirm the moutainous habitat preference throughout its range. Indeed, elevation must be taken into account in the modeling.

Figure 1. Landscape of sampling sites representing different habitat types available in Tunisia. Mediterranean forests and shrublands (A) Feija National Park and (B) Djebel Serj, scrublands and steppes (C) Kalaat Sinan and (D) Bouhedma National Park, arid mountains (E) Tameghza and (F) Matmata, desert habitat (G) Douiret, and Saharan habitat (H) Grand Erg Oriental. (Photos © Zaher Kammoun).

Figure 2. Map of bioclimatic zones in Tunisia showing sampling sites.

Figure 3. Main extern characters used to identify the North African sengi (*Petrosaltator rozeti*) observed and captured during this study. Long tubular snout (1, 2, 3, 5, 7, 9) and a large ears that protrude from adjacent fur (4, 6, 8).

Figure 4. Distribution of the North African sengi (*Petrosaltator rozeti*) in Tunisia (left). New distribution data are indicated by simple yellow circles, while literature records obtained from Gharaibeh (1997) are indicated by yellow circles with black dot. Small map shows the continuity of the mountains range (dark gray) outside the country's borders. Close up of the sengi habitat showing landform and vegetation cover (right) in its northern (**A**), central (**B**) and southern distribution range (**C**).

Figure 5. Ecoclimatograms of the North African Sengi in Tunisia determined within minimum convex hull in relation to the Mediterranean bioclimates. The presence localities (n = 103) blue dots are showed within all sites visited (n = 200). Qemb: Emberger quotient, Tmin: minimum temperatures of the coldest month. The continuous lines separate the principal bioclimates.

Figure 6. Predicted distribution of the North African sengi (*Petrosaltator rozeti*) in Tunisia as estimated by Maxent according to climate, elevation and land cover variables. Warmer colours indicate areas with higher probability of presence, while colder colours indicate areas with lower probability of presence.

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Tables

Table 1. Records of *Petrosaltator rozeti* in Tunisia. Positive presence records are highlighted in blue. Obs = specimen observed and Cap = specimen captured.

N°	Stations. Locality	GPS COORDINATES	*Presence/absence*	References	Habitat
1	Bizert Nord	37°19'23.5"N 9°50'23.8"E	-	Present study	Plain Forest
2	Douar Menara. Bizert	37°19'27.0"N 9°41'18.5"E	-	Present study	Plain shrubland
3	Rimel Forest. Bizert	37°13'47.9"N 10°00'54.3"E	-	Present study	Plain Forest
4	Ghar El Meleh. Bizert	37°10'13.1"N 10°09'12.9"E	-	Present study	Mountain forest
5	Ghammareth. Tunis	36°55'10.4"N 10°17'27.3"E	-	Present study	Plain Forest
6	Borj Touil	36°56'32.4"N 10°08'09.9"E	-	Present study	Mountain shrubland
7	Sidi Thabet	36°53'21.9"N 10°03'40.0"E	-	Present study	Mountain shrubland
8	Tbourba	36°49'20.3"N 9°48'27.4"E	-	Present study	Agricultural field
9	18km south of Mateur	36°53'23.6"N 9°36'04.8"E	-	Present study	Agricultural field
10	Boukournine National Park	36°41'54.5"N 10°21'08.4"E	-	Present study	Mountain forest
11	Djebel Rassas	36°36'41.7"N 10°19'57.8"E	-	Present study	Mountain shrubland
12	Djebel El-Bhalil. Hammamet	36°30'25.0"N 10°29'07.2"E	-	Present study	Mountain forest
13	Djbal Sidi Zid. Mournag	36°28'17.1"N 10°18'34.3"E	-	Present study	Mountain forest
14	Rtiba. Nabeul	36°53'13.8"N 10°44'24.8"E	-	Present study	Plain Forest
15	Djbel Hammamet	36°26'47.4"N 10°37'01.8"E	-	Present study	Mountain shrubland
16	Manzel Horr road	36°43'38.4"N 10°56'10.9"E	-	Present study	Agricultural field
17	El Jabouza, Djebel Sidi Abedrahman	36°45'35.3"N 10°41'32.0"E	-	Present study	Mountain forest
18	Dar Chichou Forest. Nabeul	36°57'16.5"N 10°58'33.5"E	-	Present study	Plain forest
19	Kelibia	36°50'19.8"N 11°06'57.5"E	-	Present study	Agricultural field
20	Djbel Haouaria, Nabeul	37°03'58.8"N 11°01'44.2"E	-	Present study	Mountain shrubland
21	Hamem Zeriba, Zaghouan	36°21'01.6"N 10°10'50.5"E	+ (3 obs, 1♀ cap)	Present study	Mountain shrubland
22	El Mheris, Zaghouan	36°21'54.9"N 10°09'51.8"E	+ (1♀ cap)	Present study	Mountain shrubland
23	Djebel Zaghouan	36°22'41.8"N 10°08'09.4"E	+ (2 obs)	Present study; Vesmanis, 1979; Kock, 1980	Mountain forest
24	North West Fahes	36°23'27.5"N 9°52'08.9"E	+ (2 obs)	Present study	Mountain forest
25	South Zaghouan	36°21'35.3"N 10°07'16.8"E	+ (1♀♀2♂♂ cap)	Present study	Mountain shrubland
26	Mhedhba, Zaghouan	36°17'10.4"N 10°08'11.7"E	+ (1 obs)	Present study	Mountain forest
27	South West Fahes	36°18'14.2"N 10°03'09.5"E	+	Gharaibeh, 1997	Mountain forest
28	Djebel Fkerine, Zaghouan	36°12'20.2"N 9°57'44.8"E	+ (2♀♀1♂♂ cap)	Present study	Mountain shrubland
29	Enfidha. Sousse	36°08'03.0"N 10°25'09.2"E	-	Present study	Plain shrubland
30	Medjez Elbeb, Beja	36°37'52.0"N 9°38'04.7"E	-	Present study	Agricultural field
31	Oued Zarga, Beja	36°41'16.3"N 9°27'35.9"E	-	Present study	Agricultural field
32	Tibar, Beja	36°31'51.6"N 9°06'57.9"E	-	Present study	Plain Forest
33	Beja	36°45'21.6"N 9°08'45.0"E	-	Present study	Plain Forest
34	Sejnan Forest	37°05'53.4"N 9°09'50.0"E	-	Present study	Mountain forest
35	Cap Serrat	37°12'40.7"N 9°11'50.4"E	-	Present study	Plain forest
36	Sidi Mechreg	37°10'16.6"N 9°09'42.6"E	-	Present study	Plain forest
37	Est de Tabarka	36°57'04.4"N 8°44'05.8"E	-	Present study	Plain forest
38	Beni Metir	36°43'42.4"N 8°46'18.0"E	-	Present study	Mountain forest
39	Zaouit Sidi-Bou-Zaaroura. Fernana	36°40'29.7"N 8°42'08.0"E	-	Present study	Mountain forest
40	Amdoun	36°49'18.6"N 9°06'01.3"E	-	Present study	Agricultural field

41	Jandouba	36°31'20.8"N 8°47'21.7"E	-	Present study	Mountain forest
42	Bir Saad Ben Mannsour, Ghardimaou	36°28'25.1"N 8°27'08.3"E	-	Present study	Agricultural field
43	Ghardimaou Forest, Jandouba	36°25'51.6"N 8°26'34.8"E	-	Present study	Mountain forest
44	Feija National Park, Jandouba	36°29'55.6"N 8°14'38.4"E	-	Present study	Mountain forest
45	Sakyet Sidi Toussef	36°14'14.9"N 8°21'28.0"E	-	Present study	Mountain shrubland
46	Hammam Mellegue	36°10'48.8"N 8°31'52.8"E	-	Present study	Mountain shrubland
47	Ain Meddis. Kef	36°12'08.1"N 8°45'09.6"E	-	Present study	Mountain shrubland
48	Kef Forest	36°11'25.3"N 8°41'07.9"E	-	Present study	Mountain forest
49	Abida. Kef	35°59'25.9"N 8°43'55.6"E	-	Present study	Mountain forest
50	Seress	36°01'24.4"N 8°58'39.6"E	-	Present study	Mountain forest
51	Boussalem	36°33'10.0"N 9°02'39.7"E	-	Present study	Mountain forest
52	El Krib	36°18'25.4"N 9°08'18.7"E	-	Present study	Mountain forest
53	Touborsouk	36°28'31.5"N 9°15'47.7"E	-	Present study	Plain Forest
54	Ain Snouber, Zaghouan	36°06'45.0"N 9°49'20.4"E	+ (4 obs)	Present study	Mountain shrubland
55	Ain El-Merja, Zaghouan	36°06'24.3"N 9°48'30.1"E	+ (3 obs)	Present study	Mountain shrubland
56	3km North Sebikha	35°57'42.1"N 10°05'29.4"E	-	Present study	Agricultural field
57	Sebikha, Kairouan	35°55'52.2"N 9°56'14.3"E	-	Present study	Agricultural field
58	East Sebikha	35°55'33.1"N 10°01'45.9"E	-	Present study	Agricultural field
59	Sidi Messaoud, Kairouan	36°03'09.0"N 9°49'48.3"E	+ (1 obs)	Present study	Mountain shrubland
60	Ksar Lemsa, Kairouan	36°01'19.9"N 9°39'58.8"E	+ (1♀ cap)	Present study	Mountain shrubland
61	El-Sarj National Park	35°55'43.4"N 9°34'09.5"E	+ (4 obs)	Present study	Mountain forest
62	Oueslatia, Kairouan	35°52'57.0"N 9°29'54.9"E	+ (2 obs)	Present study; Gharaibeh, 1997	Mountain forest
63	Makthar, Seliana	35°51'53.3"N 9°10'31.7"E	+	Vesmanis, 1979; Kock, 1980	Mountain shrubland
64	2km North Tejerouine	36°02'55.7"N 8°36'58.5"E	-	Present study	Mountain shrubland
65	Tejerouine, Kef	35°59'38.0"N 8°29'42.3"E	-	Present study	Mountain shrubland
66	South Tejerouine	35°59'50.9"N 8°36'44.3"E	-	Present study	Mountain shrubland
67	Manzel Salem, Kef	35°52'29.9"N 8°27'51.3"E	+ (4 obs)	Present study	Mountain shrubland
68	Kalaat Sinan, Kef	35°44'12.4"N 8°26'42.0"E	+ (1♂ cap)	Present study	Mountain forest
69	Thala, Kasserine	35°35'10.4"N 8°44'37.0"E	-	Present study	Mountain forest
70	Rouhia	35°37'57.4"N 9°11'57.2"E	-	Present study	Mountain shrubland
71	Djbal Sidi Ali, Kasserine	35°37'48.8"N 8°59'36.7"E	+ (1 obs)	Present study	Mountain shrubland
72	West Thala, Kasserine	35°33'02.2"N 8°37'57.7"E	+ (2 obs)	Present study	Mountain forest
73	Djebel Cherichira, Kairouan	35°37'17.8"N 9°46'53.3"E	+ (1 obs)	Present study; Vesmanis, 1979; Kock, 1980	High steppes
74	Sousse	35°48'50.6"N 10°31'57.1"E	-	Present study	Agricultural field
75	Jemmel, Mestir	35°38'17.2"N 10°43'47.7"E	-	Present study	Agricultural field
76	Manzel Fersi, Mestir	35°32'43.5"N 10°52'44.7"E	-	Present study	Agricultural field
77	Mahdia	35°30'36.5"N 11°01'35.8"E	-	Present study	Agricultural field
78	Kssour El Seff. Mahdia	35°23'28.8"N 11°01'26.1"E	-	Present study	Agricultural field
79	Sebkhet El Jem	35°08'53.6"N 10°50'38.9"E	-	Present study	Sebkha
80	Hibra , Mahdia	35°10'30.1"N 10°13'12.7"E	-	Present study	Plain shrubland
81	Hibra route	35°09'45.0"N 10°14'28.9"E	-	Present study	Plain shrubland
82	Jelma	35°14'15.2"N 9°25'24.2"E	-	Present study	Agricultural field
83	Aïn Dumrir, 30km NE Sbeitla	35°25'24.5"N 9°17'36.3"E	+	Gharaibeh, 1997	Mountain shrubland
84	Djebel Meghila National Park	35°20'13.3"N 9°09'54.5"E	+ (1 obs)	Present study	Mountain shrubland
85	Oued Al Msahel, Sbeitla	35°22'01.2"N 8°56'55.8"E	+ (1♂ cap)	Present study	Mountain shrubland
86	Foussana	35°18'35.9"N 8°45'03.4"E	+ (1 obs)	Present study	Mountain shrubland
87	Near Djebel Meghila, Kasserine	35°16'25.0"N 9°08'33.5"E	+ (1 obs, 2♀ cap)	Present study	Mountain shrubland
88	Djebel Elkhachem, Sidi Bouzied	35°02'56.4"N 9°53'56.8"E	+ (1 obs)	Present study	High steppes
89	Ouled Hafouz, Sidi Bouzid	35°00'49.7"N 9°51'20.9"E	+ (4 obs)	Present study	High steppes
90	Agareb, Sfax	34°49'30.3"N 10°11'47.5"E	+	Kock, 1980	High steppes
91	Sfax	34°44'22.4"N 10°40'58.4"E	-	Present study	Agricultural field
92	El Abbassia, Kerkennah Island	34°43'22.8"N 11°14'17.6"E	-	Present study	Island
93	East Sidi Bouzid	34°57'58.4"N 9°44'18.0"E	+ (1♀ cap)	Present study	High steppes
94	Rgueb, Sidi Bouzid	34°52'48.1"N 9°38'60.0"E	+ (2♀ cap)	Present study	High steppes
95	Mzara, Sbeitla	35°07'02.4"N 9°07'32.4"E	+ (1 obs)	Present study	High steppes
96	Djebel Semmama, Sbeitla	35°19'10.4"N 8°51'24.9"E	+ (2♀♀1♂♂ cap)	Present study	Mountain shrubland
97	Near Khanguet El-Jazia, Sbeitla	35°04'28.7"N 9°05'56.2"E	+ (12 obs, 2♀ cap)	Present study	Mountain shrubland
98	East Kasserine	35°12'05.4"N 8°52'34.9"E	+ (1 obs)	Present study	Mountain shrubland
99	South Djebel Chaambi, Kasserine	35°11'44.7"N 8°43'05.7"E	+ (5 obs, 2♀♀1♂♂ cap)	Present study; Blanc, 1935; Kock, 1980	Mountain forest
100	Henchir El-Talla, Djebel Chaambi	35°12'17.5"N 8°38'32.8"E	+ (2♀ cap)	Present study	Mountain forest

101	West Djebel Chaambi	35°08'36.2"N 8°33'57.9"E	+ (1♂ cap)	Present study	Mountain forest
102	Darnayah, Feriana	35°07'13.3"N 8°25'14.0"E	+ (1 obs)	Present study	Mountain forest
103	Djebel Khcham El Kalb, Feriana	35°04'47.2"N 8°36'43.5"E	+ (8 obs)	Present study	Mountain forest
104	South Bouchebka, Feriana	35°05'51.4"N 8°23'11.4"E	+ (1 obs)	Present study	Mountain shrubland
105	Djebel Salloum, Kasserine	35°04'38.1"N 8°55'52.3"E	+ (3♀ cap)	Present study	Mountain shrubland
106	Djebel Karoub Kasserine	35°02'18.1"N 9°02'36.0"E	+ (5 obs)	Present study	High steppes
107	Henchir El-Khima, Djebel Salloum	35°02'25.6"N 8°51'15.4"E	+ (1 obs)	Present study	High steppes
108	Hassi El-Ferid, Kasserine	34°59'20.9"N 8°45'24.7"E	+ (2 obs)	Present study	High steppes
109	Feriana	34°57'38.2"N 8°30'49.7"E	+	Lataste, 1887; Joleaud, 1927; Kock, 1980	High steppes
110	Djebel Sidi Aïch, Kasserine	34°46'57.9"N 8°51'52.9"E	+	Kock, 1980	High steppes
111	Majel Bel Abess, Kasserine	34°43'17.9"N 8°25'29.3"E	+ (1♀ cap)	Present study	Mountain desert
112	South Bir Ali Ben Khlifa, Sfax	34°40'08.3"N 10°03'38.5"E	-	Present study	Plain Steppes
113	Gandoul, Sfax	34°37'40.6"N 10°03'46.2"E	-	Present study	Plain Steppes
114	Oued Leben, Sfax	34°37'03.8"N 10°00'47.8"E	-	Present study	Plain Steppes
115	East Bouhedma	34°29'36.7"N 9°38'34.1"E	+ (1♀ cap)	Present study	High steppes
116	Djebel Bouhedma	34°30'15.9"N 9°37'01.0"E	+	Trouessart, 1905; Kock, 1980	High steppes
117	Bouhedma National Park	34°28'57.4"N 9°36'42.2"E	+ (16 obs, 2♀ cap)	Present study	High steppes
118	West Bouhedma	34°28'46.6"N 9°27'02.2"E	+ (1 obs)	Present study	High steppes
119	Menzel Bouzaiene, Sidi Bouzid	34°36'19.3"N 9°18'45.6"E	-	Present study	Plain Steppes
120	Djebel Orbata, Gafsa	34°24'46.5"N 9°15'54.1"E	+ (7 obs)	Present study	High steppes
121	Gafsa	34°26'26.9"N 8°45'48.4"E	+	Chaignon, 1904; Heim de Balsac, 1936; Kock, 1980	Mountain desert
122	East Gafsa	34°22'08.4"N 8°54'21.9"E	+ (1 obs)	Present study	High steppes
123	Oum-Larays, Gafsa	34°32'31.1"N 8°20'56.6"E	+ (1♂ cap)	Present study	Mountain desert
124	Edoughra, Gafsa	34°30'46.4"N 8°33'46.4"E	+ (2♀♀1♂♂ cap)	Present study	Mountain desert
125	Djebel Ben Younes, North Gafsa	34°28'05.6"N 8°43'38.5"E	+ (2 obs)	Present study; Blanc, 1935; Kock, 1980	Mountain desert
126	North Metlaoui, Gafsa	34°21'59.5"N 8°24'04.0"E	+ (1 obs)	Present study	Mountain desert
127	Metlaoui, Gafsa	34°20'24.8"N 8°20'41.8"E	+ (3 obs)	Present study	Mountain desert
128	Rdeyef, Gafsa	34°23'01.4"N 8°06'48.1"E	+ (1 obs)	Present study	Mountain desert
129	Tamerza, Touzeur	34°21'37.1"N 7°53'41.9"E	+ (2 obs)	Present study; Gharaibeh, 1997	Mountain desert
130	Chebika, Touzeur	34°18'57.0"N 7°59'44.9"E	+ (1 obs)	Present study; Vesmanis, 1979; Kock, 1980	Mountain desert
131	North Chebika, Touzeur	34°19'43.8"N 7°56'32.1"E	+ (1♀ cap)	Present study	Mountain desert
132	Skhira, Sfax	34°17'38.8"N 10°05'28.7"E	-	Present study	Plain Steppes
133	Zagrata, Gabes	34°11'06.4"N 9°48'44.6"E	-	Present study	Plain Steppes
134	Manzel Habib, Gabes	34°07'26.5"N 9°38'00.5"E	+ (2 obs)	Present study	Mountain desert
135	South Manzel Habib, Gabes	34°05'58.8"N 9°26'42.7"E	+ (1 obs)	Present study	Mountain desert
136	Dghoumes National Park	34°04'01.2"N 8°30'26.7"E	+ (1 obs)	Present study	Mountain desert
137	Dguech, Touzeur	34°00'13.5"N 8°13'54.0"E	+	Vesmanis, 1979; Kock, 1980	Mountain desert
138	Nefta (route P3)	33°52'22.8"N 7°47'22.0"E	-	Present study	Desert plain
139	Chott Djerid, Touzeur	33°51'52.8"N 8°14'18.8"E	-	Present study	Sebkha
140	Kebili Oasis	33°41'15.3"N 8°57'45.9"E	-	Present study	Oasis
141	EL Qalaa, Kebili	33°29'37.3"N 8°59'53.0"E	-	Present study	Desert plain
142	Douz Oasis, Kebili	33°28'39.5"N 8°56'25.1"E	-	Present study	Oasis
143	Faouar, Kebili	33°21'35.9"N 8°40'30.9"E	-	Present study	Oasis
144	East Kebili	33°42'21.3"N 9°12'09.2"E	+ (1♀ cap)	Present study	Mountain desert
145	Oued Batoum, Hamma	33°44'05.0"N 9°31'44.1"E	+ (4 obs)	Present study	Mountain desert
146	West Hamma	33°46'53.3"N 9°39'34.4"E	+ (1 obs)	Present study	Mountain desert
147	40Km East of Douz, Kebili	33°31'35.7"N 9°28'10.6"E	-	Present study	Sahara desert
148	El Hamma, Gabes	33°53'19.9"N 9°47'09.5"E	-	Present study	Oasis
149	15Km South East of El Hamma	33°48'36.4"N 9°52'04.5"E	-	Present study	Desert plain
150	Gabes	33°50'48.5"N 10°07'30.7"E	-	Present study	Oasis
151	Teboulbou, Gabes	33°50'48.9"N 10°08'27.6"E	-	Present study	Desert plain
152	Mareth, Gabes	33°38'52.0"N 10°18'08.1"E	-	Present study	Desert plain
153	Beni Zelten, Gabes	33°36'02.6"N 10°08'17.8"E	+ (1♂ cap)	Present study	Mountain desert
154	Matmata	33°32'26.2"N 9°50'47.9"E	+	Joleaud, 1927; Joyeux and Baer,	Mountain desert

				1928; Blanc, 1935; Vesmanis, 1979; Kock, 1980	
155	South East Matmata	33°30'47.9"N 9°57'48.6"E	+ (1 obs)	Present study; Gharaibeh, 1997	Mountain desert
156	Techine, Matmata	33°29'03.0"N 9°57'09.6"E	+ (1 dead specimen)	Present study	Mountain desert
157	West Matmata	33°25'57.4"N 9°48'07.8"E	+ (3 obs, 1♀ cap)	Present study	Mountain desert
158	Toujane, Gabes	33°28'31.7"N 10°08'23.5"E	+ (1 obs)	Present study; Gharaibeh, 1997	Mountain desert
159	Gourine, Medenine	33°36'52.9"N 10°29'36.6"E	-	Present study	Desert plain
160	Dhahret Adloun, Djerba Island	33°46'10.5"N 10°49'08.4"E	-	Present study	Desert plain
161	Gribis. Zarzis	33°33'05.2"N 11°00'18.1"E	-	Present study	Desert plain
162	Zerzis	33°33'20.4"N 11°01'26.2"E	-	Present study	Desert plain
163	Khalfalah. Zerzis	33°24'51.2"N 10°52'15.9"E	-	Present study	Desert plain
164	3km in route P19, Medenine	33°18'39.4"N 10°28'52.0"E	-	Present study	Desert plain
165	Kssar Halouf, Medenine	33°16'45.5"N 10°08'06.3"E	+ (1♀ cap)	Present study	Mountain desert
166	West Beni Khedache, Medenine	33°14'36.4"N 10°06'37.7"E	+ (3 obs)	Present study	Mountain desert
167	Beni Khedache, Medenine	33°15'29.6"N 10°10'54.5"E	+	Blanc, 1935; Vesmanis, 1979; Kock, 1980; Gharaibeh, 1997	Mountain desert
168	Oued Smar, Medenine	33°24’39.3"N 10°36’46.0"E	-	Present study	Mountain desert
169	Ksar Hadada	33°06'47.5"N 10°18'38.4"E	+ (1 obs)	Present study	Mountain desert
170	Kssar Ouled Boubaker	33°07'12.6"N 10°26'58.7"E	+ (2♀ cap)	Present study	Mountain desert
171	Bou Hmed, Medenine	33°18'01.6"N 10°39'58.8"E	-	Present study	Desert plain
172	Oued El-Khil, Tatatouine	33°09'22.1"N 10°19'16.7"E	+ (9 obs, 1♀ cap)	Present study	Mountain desert
173	Ghoumrassen North	33°05'23.1"N 10°22'53.7"E	+ (1 obs)	Present study	Mountain desert
174	Ghoumrassen	33°03'18.2"N 10°16'29.7"E	+ (1 obs)	Present study	Mountain desert
175	Ghoumrassen Village	33°03'26.9"N 10°21'55.6"E	+ (1 obs)	Present study	Mountain desert
176	Chobit Fadhal, Tataouine	33°07'19.0"N 10°08'09.3"E	+ (2 obs)	Present study	Mountain desert
177	Ksar Ghilane	32°58'38.3"N 9°38'03.2"E	-	Present study	Mountain desert
178	Djebil National Park	33°00'06.5"N 8°54'59.7"E	-	Present study	Sahara desert
179	North Guermassa	33°00'28.3"N 10°12'55.0"E	+ (1 obs)	Present study	Mountain desert
180	Guermassa, Tataouine	32°58'40.4"N 10°13'47.1"E	+ (2 obs)	Present study	Mountain desert
181	Tataouine	32°57'17.5"N 10°26'04.1"E	+	Blanc, 1935; Vesmanis, 1979; Kock, 1980	Mountain desert
182	Ksar Mkelba, Tataouine	32°55'31.9"N 10°24'43.6"E	+ (1 obs)	Present study	Mountain desert
183	Gatouffa, Tataouine	32°54'00.6"N 10°33'48.0"E	+ (3 obs)	Present study	Mountain desert
184	Ksar Bouhrida, Tatatouine	32°52'06.3"N 10°33'31.3"E	+ (1 obs)	Present study	Mountain desert
185	Chenini, Tataouine	32°52'21.9"N 10°19'49.4"E	+	Vesmanis, 1979; Kock, 1980	Mountain desert
186	North East Douiret, Tataouine	32°54'35.9"N 10°15'16.8"E	+ (2♀ cap)	Present study	Mountain desert
187	Douiret, Tataouine	32°51'58.1"N 10°17'43.5"E	+ (1 obs)	Present study	Mountain desert
188	Ben Guerdane	33°10'39.4"N 11°10'48.1"E	-	Present study	Desert plain
189	Sebkhet Adhilbate, Ben Guerdane	33°05'35.7"N 11°21'17.4"E	-	Present study	Sebkha
190	Sidi Toui National Park	32°43'35.7"N 11°13'34.8"E	-	Present study	Desert plain
191	Near Oued Dekouk National Park	32°35'41.1"N 10°23'41.4"E	+ (4 obs)	Present study	Mountain desert
192	South Bir Amir, Tataouine	32°28'35.9"N 10°12'24.8"E	+ (1♂ cap)	Present study	Mountain desert
193	West Bir Amir, Tataouine	32°21'43.9"N 9°52'03.8"E	+	Gharaibeh, 1997	Mountain desert
194	West Ramada, Tataouine	32°12'46.1"N 9°41'23.0"E	+ (2 obs)	Present study	Mountain desert
195	East Borj Bourguiba, Ramada	32°13'50.6"N 10°11'49.5"E	+	Gharaibeh, 1997	Mountain desert
196	Djebel Segdel, South Ramada	32°13'21.1"N 10°25'38.8"E	+	Vesmanis, 1979; Kock, 1980	Mountain desert
197	Dehiba (15Km North)	32°06'12.1"N 10°41'25.1"E	-	Present study	Saharan desert
198	North-West Dhehiba	32°03'54.4"N 10°30'42.2"E	+ (1♀♀2♂♂ cap)	Present study	Mountain desert
199	West Dehiba	32°02'40.6"N 10°31'37.5"E	+ (4 obs)	Present study	Mountain desert
200	Sanghar-Jabess National Park	31°52'46.4"N 9°48'27.0"E	-	Present study	Saharan desert

Figure 1. Landscape of sampling sites representing different habitat types available in Tunisia. Mediterranean forests and shrublands (A) Feija National Park and (B) Djebel Serj, scrublands and steppes (C) Kalaat Sinan and (D) Bouhedma National Park, arid mountains (E) Tameghza and (F) Matmata, desert habitat (G) Douiret, and Saharan habitat (H) Grand Erg Oriental. (Photos © Zaher Kammoun).

812x1104mm (38 x 38 DPI)

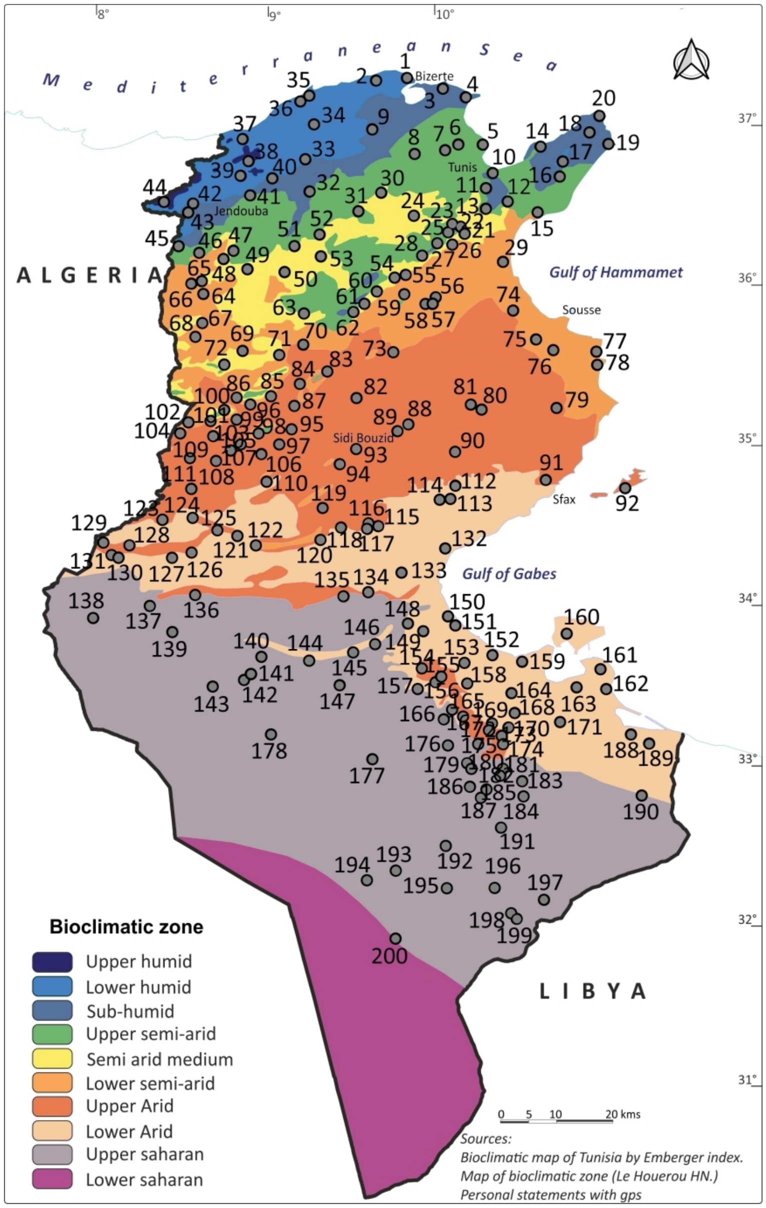

Figure 2. Map of bioclimatic zones in Tunisia showing sampling sites.

175x276mm (400 x 400 DPI)

Figure 3. Main extern characters used to identify the North African sengi (Petrosaltator rozeti) observed and captured during this study. Long tubular snout (1, 2, 3, 5, 7, 9) and a large ears that protrude from adjacent fur (4, 6, 8).

572x737mm (38 x 38 DPI)

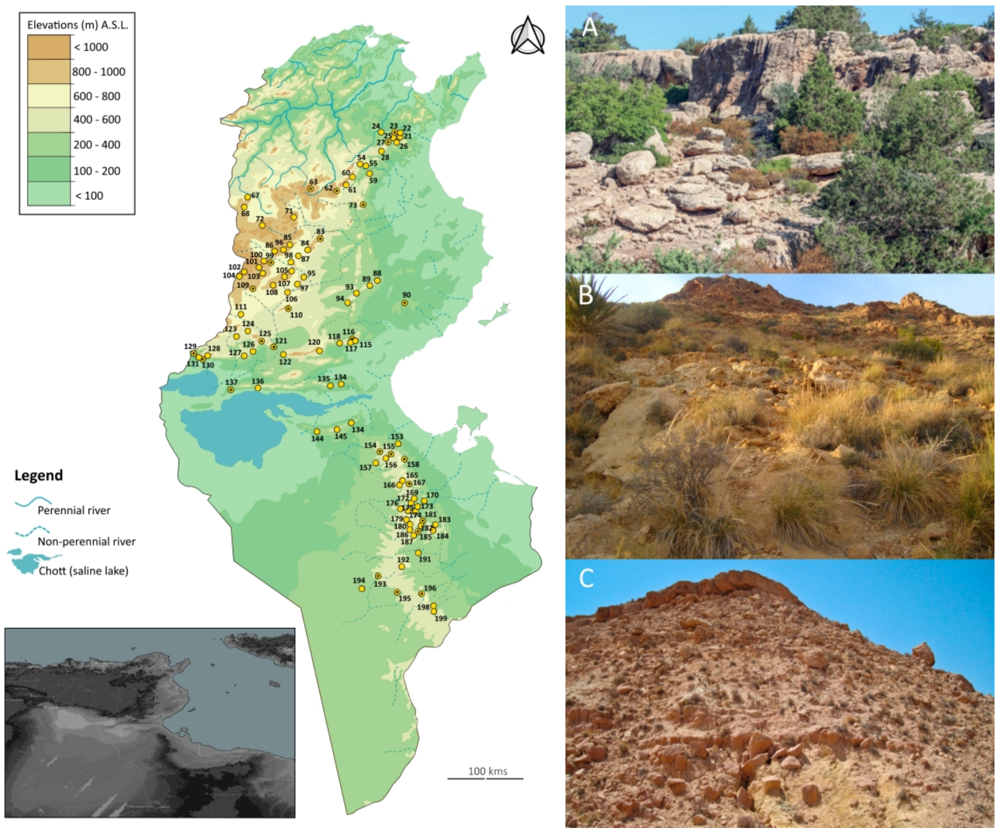

Figure 4. Distribution of the North African sengi (Petrosaltator rozeti) in Tunisia (left). New distribution data are indicated by simple yellow circles, while literature records obtained from Gharaibeh (1997) are indicated by yellow circles with black dot. Small map shows the continuity of the mountains range (dark gray) outside the country's borders. Close up of the sengi habitat showing landform and vegetation cover (right) in its northern (A), central (B) and southern distribution range (C).

2593x2133mm (38 x 38 DPI)

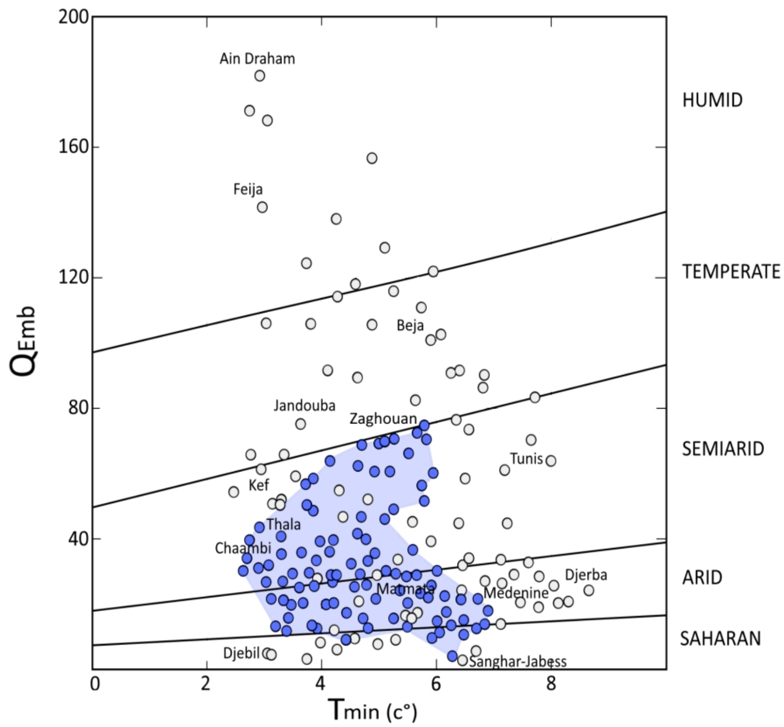

Figure 5. Ecoclimatograms of the North African Sengi in Tunisia determined within minimum convex hull in relation to the Mediterranean bioclimates. The presence localities (n = 103) blue dots are showed within all sites visited (n = 200). Qemb: Emberger quotient, Tmin: minimum temperatures of the coldest month. The continuous lines separate the principal bioclimates.

1572x1192mm (38 x 38 DPI)

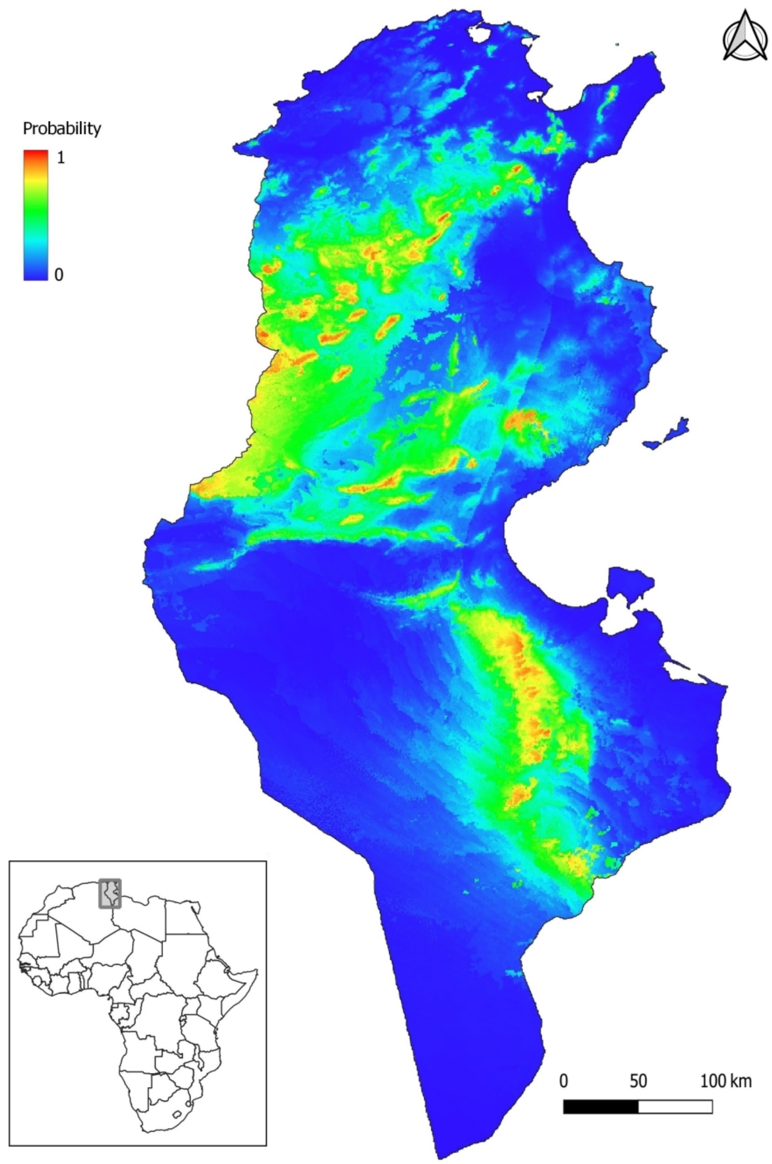

Figure 6. Predicted distribution of the North African sengi (Petrosaltator rozeti) in Tunisia as estimated by Maxent according to climate, elevation and land cover variables. Warmer colours indicate areas with higher probability of presence, while colder colours indicate areas with lower probability of presence.

202x296mm (300 x 300 DPI)