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PRELIMINARY RESULTS ON HABITAT MODELLING AND DETECTION DOGS TO FIND AN ENDANGERED SPECIES: HERMANN'S TORTOISE *TESTUDO HERMANNI* IN SOUTHERN LAZIO

SUMMARY

The Hermann's tortoise *Testudo hermanni* is one of the most endangered reptiles in Europe. In the Italian Peninsula, knowledge gaps on the current distribution of the species can hinder its conservation. Serious challenges arise from species' habitat structure, elusive behaviour and low population densities. Sampling effort can be guided by habitat modelling to plan a habitat-specific stratified survey, while species detectability can be greatly improved using specially trained dogs. In this study, we modelled the climatic and land cover suitability for *T. hermanni* in southern Latium, in particular the Volsci Mountains, the Pontine Plain and the Cape Circeo, where the persistence of viable populations is currently uncertain. Two dogs were trained to detect the species using three captive individuals. Except for the high mountain areas, the entire study area showed high suitability. The dogs demonstrated 100% sensitivity and accuracy in semi-natural conditions. Our preliminary results showed the suitability of the study area for *T. hermanni* and the potential increase in species' detectability with detection dogs.

Key words. Habitat suitability, detection dogs, detectability, Testudinata, Reptilia.

RIASSUNTO

Risultati preliminari sull'uso di modelli dell'habitat e di cani da ricerca per trovare una specie in pericolo: la Testuggine di Hermann Testudo hermanni *nel Lazio meridionale.* La testuggine di Hermann (*Testudo hermanni*) è uno dei rettili più minacciati d'Europa e in Italia peninsulare le lacune conoscitive sulla sua distribuzione possono ostacolarne la conservazione. Difficoltà nella raccolta dei dati distributivi derivano dalla struttura dell'habitat, dal comportamento elusivo e dalle basse densità di popolazione. Il campionamento può essere guidato dalla modellizzazione dell'habitat per pianificare un'indagine stratificata per l'habitat, mentre la rilevabilità delle specie può essere massimizzata con l'utilizzo di cani addestrati. In questo lavoro, abbiamo modellizzato l'idoneità climatica e di copertura del suolo per *T. hermanni* nel Lazio meridionale, in particolare i Monti Volsci, la Pianura Pontina e il promontorio Capo Circeo, dove la persistenza di popolazioni vitali è incerta. Ad eccezione delle zone di alta montagna, l'intera area di studio ha mostrato alta idoneità ambientale. Due cani sono stati addestrati per rilevare la specie utilizzando tre individui in cattività. I cani hanno dimostrato una sensibilità e un'accuratezza del 100% in condizioni semi-naturali. I risultati preliminari mostrano l'idoneità dell'area di studio per *T. hermanni* e il potenziale aumento della rilevabilità delle specie con cani da rilevamento.

Parole chiave. Idoneità di habitat, cani da ricerca, rilevabilità, Testudinata, Reptilia.

INTRODUCTION

Habitat destruction and illegal harvesting made the Hermann's tortoise, *Testudo hermanni* Gmelin, 1789, one of the most endangered reptiles in Europe (MAZZOTTI, 2004; ZENBOUDJI *et al.*, 2016). Its distribution is currently highly fragmented and the remaining populations showed marked declines (CORTI *et al.* 2014*:* ZENBOUDJI *et al.*, 2016). This is particularly true for Italy, where this species is considered Endangered by the IUCN national assessment (ANDREONE *et al.*, 2013; RONDININI *et al.*, 2013) and knowledge gaps on its current distribution hinder its conservation (MAZZOTTI, 2004; CHEYLAN *et al.*, 2010). A significant part of the species' range is found along the Tyrrhenian coast of Tuscany and Lazio, where viable populations are present (MAZZOTTI, 2004; CHEYLAN *et al.*, 2010). Filling the gaps is crucial to urgently planning conservation strategies needed to ensure the survival of the species.

Testudo hermanni is a highly elusive species due to its slow movements, cryptic coloration, habit to stay sheltered for long periods and the density of its habitat (JEAN-MARIE *et al.*, 2019). Moreover, low population densities resulting from fire-induced habitat destruction can further reduce its detectability (COUTURIER *et al.*, 2011; TANADINI & SCHMIDT, 2011). As a result, the efficacy of visual censuses is highly reduced, jeopardising surveys' success for this species (JEAN-MARIE *et al.*, 2019). The limitation of human eyesight in detecting elusive species can be overcome by the use of detection dogs (DEMATTEO *et al.*, 2019). Dogs have a high olfactory capability which has been used to detect the presence of many cryptic tortoises in the United States, South Africa, Southeast Asia and Europe (COUTURIER *et al.*, 2011; DEMATTEO *et al.*, 2019; JEAN-MARIE *et al.*, 2019).

A further problem to be solved when studying rare species is how to comprehensively cover the study area with the available human resources (MARTA *et al.*, 2019). Stratified, habitat-specific random sampling can ensure the collection of unbiased information on the distribution of species in a study area by sampling all suitable habitat types (MARTA *et al.*, 2019). This method can account for the spatial availability and typology of different resources and has proven to be particularly appropriate for rare and elusive species whose ecology is well-known (MARTA *et al.*, 2019).

The presence of suitable conditions for the species can be modelled using bioclimatic envelopes (GUISAN *et al.*, 2017) and habitat suitability models (RONDININI *et al.*, 2011). In the first case, also known as climatic niche models, the presence of species is correlated to climatic variables known to influence its distribution through specific algorithms, subsequently, the study area is classified according to the species-climate relationships found (GUISAN *et al.*, 2017). In the second case, the land cover categories are classified as suitable by expert assessment using the habitat requirements of the species (RONDININI *et al.*, 2011). The results of these techniques can be combined to identify areas suitable for both climatic and land cover conditions (BAISERO *et al.*, 2020) and used to design a stratified sampling strategy (GUISAN *et al.*, 2017; MARTA *et al.*, 2019).

In this study, we modelled climatic and land cover suitability for *T. hermanni* in southern Lazio, a highly suitable and still subsampled portion where viable populations are hypothesized to be present. We used this model to plan a survey with stratified, habitat-specific sampling using trained detection dogs.

METHODS

Study area

The study area is located in southern Lazio (central Italy), it includes the Volsci Mountains, the Pontine Plain and the Cape Circeo (Fig. 1, Box) and is characterized by Mediterranean climate and habitats. For the northern part of the Volsci Mountains, the Lepini Mountains, both historical and recent evidence of *Testudo hermanni* are available (ANGELINI *et al.*, 2020). On the central and southern parts of the Volsci Mountains, there are some scattered records dating to the 90s (RUFFO & STOCH, 2005). For the entire mountain range, recent records are scarce, with only 5 observations on the Lepini Mountains in the last 5 years (ANGELINI *et al.*, 2020) and one observation on the Aurunci Mountains in 2020 (GBIF.ORG, 2021). Frequent fires and illegal harvesting by locals (as reported by local people themselves, pers. comm.) may have led to low population density or even local extinctions. The species is considered to be present in Cape Circeo, however the latest records date back to the mid-80s and could refer to individuals escaped from captivity (RUFFO & STOCH, 2005; VIGNOLI *et al.*, 2017).

Species data

The presence of the species in its range was obtained through the Global Biodiversity Information Facility (GBIF.ORG, 2021) for its entire range (Fig. 1).

We have removed the points with geospatial problems and, to avoid spatial clustering, those closest to 1 km (resolution of climatic variables) for a total of 1776 occurrences. A further 18 points for southern Lazio were obtained from RUFFO & STOCH (2005) and ANGELINI *et al.* (2020) (Fig. 1, Box).

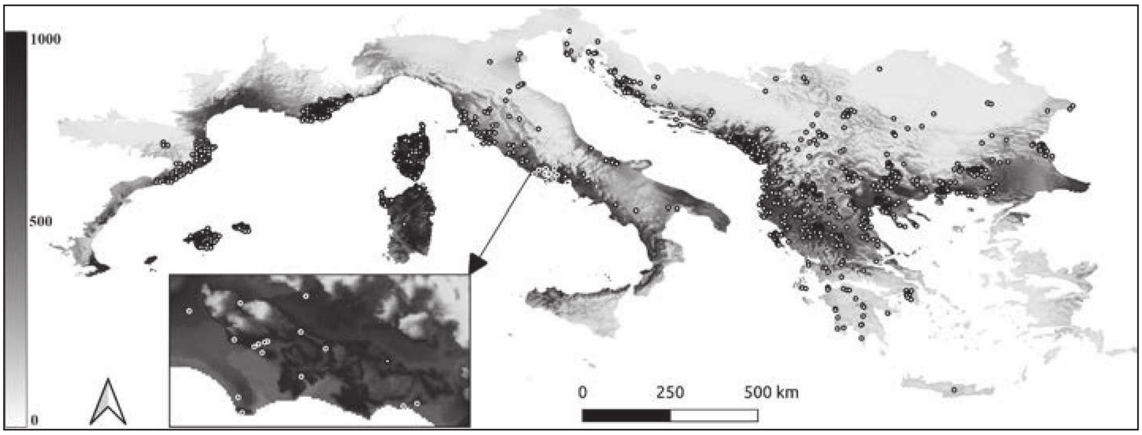

Fig. 1 — Climatic suitability for the entire range of *Testudo hermanni*. The study area is shown in the box. White dots represent occurrences obtained from GBIF while black dots occurrences from the literature.

Environmental data

We chose a set of bioclimatic variables with a resolution of 1 km based on the ecology of the species and physiologic constraints CHELSA (Climatologies at high resolution for the earth's land surface areas) data (KARGER *et al.*, 2017): temperature seasonality, the max temperature of the warmest month, precipitation seasonality and precipitation of the wettest quarter. All variables showed a Variance Inflation Factor value < 2 (GUISAN *et al.*, 2017).

We obtained land cover data from Corine Land Cover levels 4 and 5 of Lazio with a resolution of 1-hectare (REGIONE LAZIO, 2015). This land cover map provides a fine resolution description of the habitat types of the study area and an exhaustive representation of the vegetation factors that can influence the presence of the species.

Bioclimatic envelopes and habitat models

To avoid niche truncation, we used the entire range of the species to inform bioclimatic envelopes (GUISAN *et al.*, 2017). The background area was defined as the ecoregions (OLSON *et al.*, 2001) in which the species is present (Fig. 1). A number of pseudo-absences equal to the presences were randomly sampled in the background for five sets of pseudo-absences (GUISAN *et al.*, 2017). To build bioclimatic envelopes, we used Generalized Boosted Regression Trees from the biomod2 R package (Thuiller *et al.*, 2019). Models were replicated five times for each set of pseudo-absences for a total of 25 replicates. The dataset was randomly split into a training and evaluation dataset, containing 70% and 30% of the data, respectively. We used the Boyce index to evaluate the performance of the model (Di Cola *et al.*, 2017; Guisan *et al.*, 2017). Finally, we identified the suitability threshold that maximizes the sum of sensitivity and specificity (MaxSSS) (Guisan *et al.*, 2017).

Habitat models were obtained by an expert-based reclassification of land cover classes (Table 1). Species-habitat relationships have been identified from the literature (Mazzotti, 2004). To obtain a more conservative estimate of the available habitat, we focused only on highly suitable land cover classes (Table 1).

Table 1.
Land cover classes identified as highly suitable for *Testudo hermanni*

Code	Description
3223	Illyrian bushes with *Pistacia terebinthus* and *Paliurus spina-christi* or *Cercis siliquastrum* and *Pistacia terebinthus*
31311	Mixed woods with a prevalence of evergreen oaks
32312	High internal hill shrubland
32323	Shrubland with myrtle and mastic or olive and mastic
32324	Cyst, heather and rosemary or *Helichrysum litoreum* garrigue
311111	Coastal thermo-Mediterranean holm oaks
311112	Holm oaks with deciduous trees
311121	Cork oaks mixed with other evergreen trees on red soils or de-carbonated soils
311122	Cork oaks of sandy and arenaceous substrates with broadleaved oak or others

Survey design

To build a stratified, habitat-specific random sampling we overlaid a 1×1 km grid on the climatic suitability of the species and the habitat maps. Only cells containing a climatic suitability value equal to or above the MaxSSS threshold (≥ 430) and suitable land cover classes were retained for the survey. We obtained a final grid of 1694 cells offering suitable conditions (Fig. 2). We have selected 5% of cells per land cover class for a total of 84 cells in which the surveys will be performed.

Dog training for species detection

Two dogs underwent the standard training protocol based on operant conditioning (DeMatteo *et al.*, 2019; Jean-Marie *et al.*, 2019) to learn to detect *T. hermanni* in the field without harming them. Three individuals of *T. hermanni hermanni* living in captivity, two males and one female were employed in the training trials, for which a specific handling authorization is not required. The training was conducted in a semi-natural area in May 2021. To ensure tortoises safety, they were placed in perforated paper boxes and dogs wore a muzzle (JEAN-MARIE *et al.*, 2019). An assistant randomly placed the tortoises in the boxes along with non-target odours (food, toys, etc…) unknown to the dogs and trainer (JEAN-MARIE *et al.*, 2019). To train the dogs to smell the tortoises they received a reward when they approached the box containing the tortoise. In a second phase, the special word "*cerca* (i.e., search for)" was used to indicate the beginning of the search for tortoises; when a tortoise was spotted the dogs stared at it without interacting whit the tortoise (JEAN-MARIE et al., 2019). The tortoises showed no visible signs of stress during training, which was repeated 10 times until both dogs successfully learned to detect the target odour. For both dogs, we measured accuracy, which is the proportion of all alerts that are correctly directed at a target, and sensitivity, which is the proportion of all targets that are adequately alerted (DEMATTEO *et al.*, 2019; JEAN-MARIE *et al.*, 2019).

RESULTS AND DISCUSSION

The bioclimatic envelope showed high performance (Boyce = 0.995). Climatic suitability in Europe was concentrated in the Balkans, Corsica, Sardinia, southern France, Catalonia, the Balearic Islands and central-southern Italy (Fig. 1). Lazio and the study area showed widespread climatic suitability for the species, with values below the MaxSSS threshold (430) only at high elevations (Fig. 1, Box). Suitable land cover classes largely overlapped with suitable climatic conditions, however, they were largely restricted to the Volsci Mountains and Cape Circeo (Figs 2 and 3). The remarkable presence of suitable conditions for the species in the study area confirmed its hypothesized ability to support viable populations (MAZZOTTI, 2004; CHEYLAN *et al.*, 2010).

The detection dogs were able to locate the tortoises and report their location without harming individuals. All dogs demonstrated 100% sensitivity and accuracy during training sessions without indicating untargeted odours. The transferability of the dog's performance from controlled conditions to the field cannot however be guaranteed due to several variables that could affect the detection (e.g., weather conditions, substrate, fatigue etc.). However, other papers report a significant correlation between training and field performance (DEMATTEO *et al.*, 2019). Our findings suggest the use of dogs specifically trained to search for wild *T. hermanni* as an effective and efficient tool for filling distribution gaps. In the summer and autumn 2021, we aim to carry out the designed stratified habitat-specific survey using trained detection dogs.

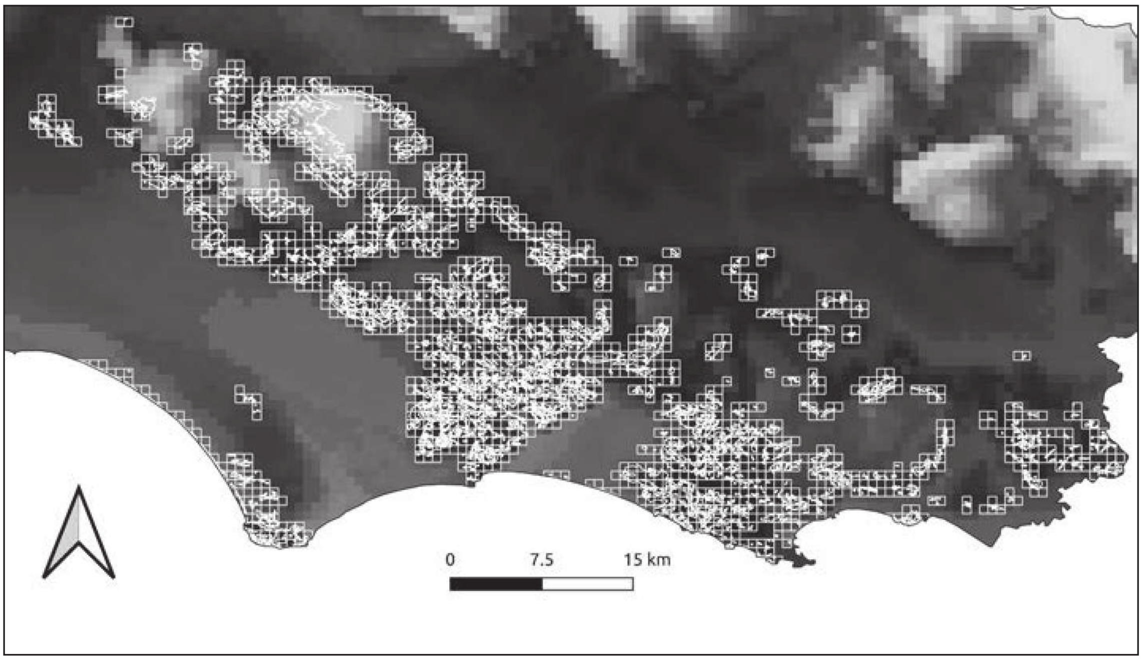

Fig. 2 — Stratified, habitat-specific sampling with a 1x1 km grid for *Testudo hermanni*.

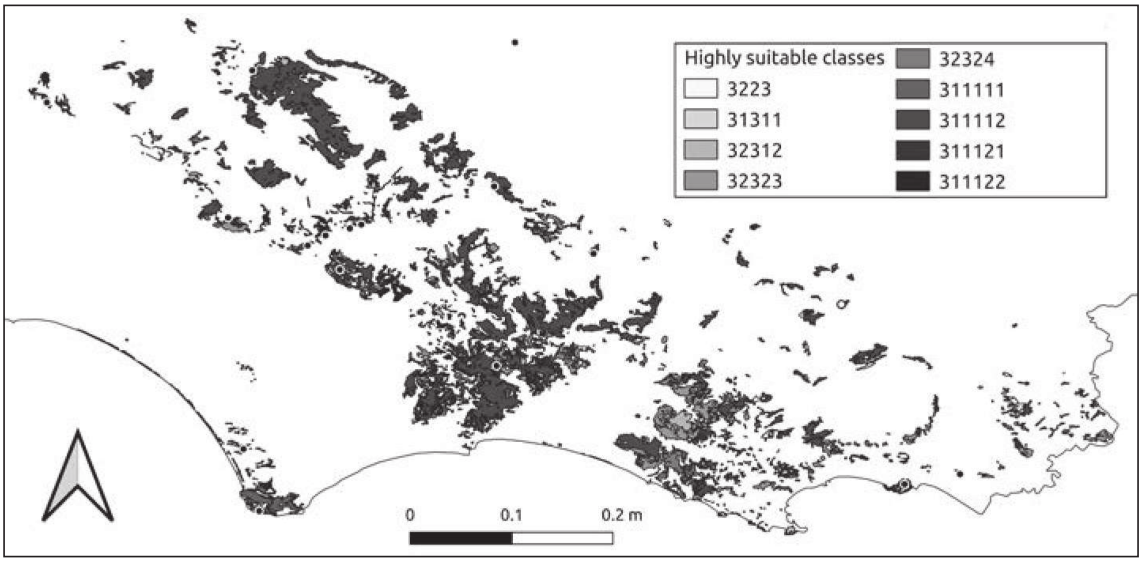

Fig. 3 — Habitat model showing the land cover classes identified as highly suitable for *Testudo hermanni*.

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