The impact of climate change on the prospects for transcontinental two-way invasion of reptiles between Europe and America

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INTRODUCTION

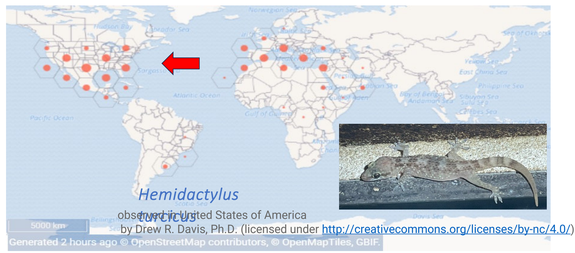
The emergence of invasive reptile species poses a significant threat to European and American ecosystems, exacerbated by the impacts of climate change. Interesting phenomena include the transcontinental movement of reptile species, such as the *Hemidactylus turcicus* lizards from Europe and Asia to America and, conversely, the introduction of *Trachemys scripta* turtles from America to Europe. These instances highlight the dynamic nature of global reptile dispersal and the potential for novel ecological interactions across continents. Understanding the mechanisms driving these transcontinental movements is crucial for predicting and managing future invasions, particularly in the context of climate change, which may facilitate the spread of invasive species to new regions. Investigating the ecological impacts of these transcontinental introductions provides valuable insights into the interconnectedness of ecosystems and the challenges posed by biological invasions on a global scale.

MATERIALS & METHODS

Databases were created for *Trachemys scripta* turtles from America, *Hemidactylus turcicus* commonly found in the Mediterranean region, including Southern Europe and Asia and *Emys orbicularis from Europe*, using available points of registration of the target species using data published in literature, GBIF dataset and original field records. We used the 'ntbox' package in R to avoid errors due to spatial autocorrelation.

Using **Species Distribution Models** based on WorldClim datasets (CRU-TS 4.06; Harris et al., 2020) (current, 2050), we determined probabilistic models of distribution for the 3 species. We identified the major environmental drivers of species-specific distribution and potential overlaps for identifying priority areas for future conservation initiatives.

GIS modeling was used to explore the potential distribution of each species, using Maxent v3.3.3 software with 25 replicates (Phillips 2005). The area under the receiver operating characteristic (ROC) curve (AUC) was used for assessing the discriminatory capacity of the models: AUC>0.85 is considered excellent. We carried out separate modelling for each set of factors and for each species. Logistic output format was used to describe the relative probability of presence, which is a continuous habitat suitability (HS) range between 0 (unsuitable) and 1 (the most suitable).



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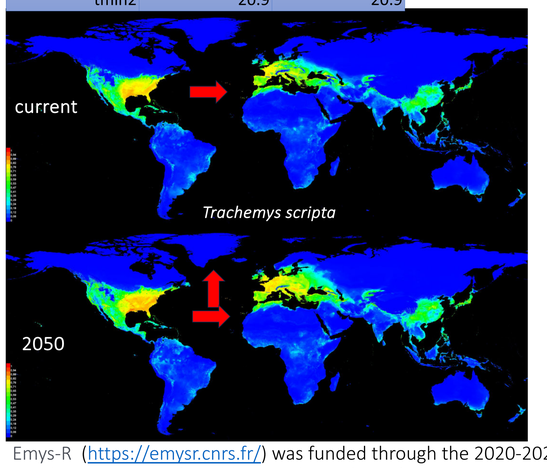
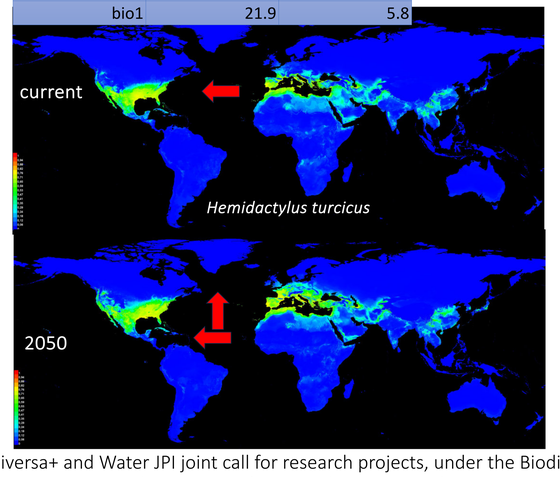
Variable	Percent contribution	Permutation importance
bio1	25.3	8.7
tmin2	20.9	20.9



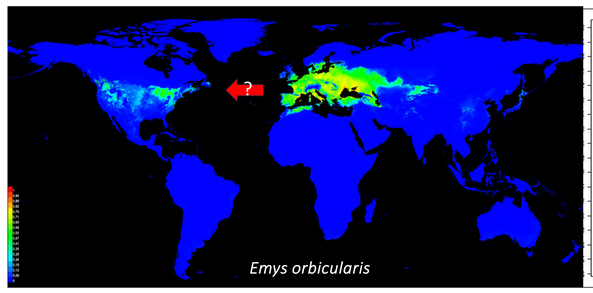
Variable	Percent contribution	Permutation importance
tmin2	29.3	20
bio1	21.9	5.8

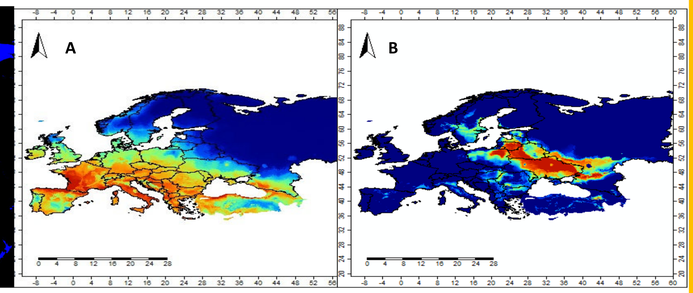


RESULTS

As a result of GIS modeling, reliable SDM models (AUC over 0,8) were obtained. It was revealed that these species *T. scripta and H. turcicus* have great prospects for spreading both in Europe and in America. In the future, their range is expected to significantly increase, which is associated with global warming. The main factors limiting their distribution are the minimum temperature of February (tmin2) and the annual temperature (bio1) (more than 20% contribution). For these two exotic species, which are kept by exotic animal enthusiasts, widespread distribution is also associated with anthropogenic structures, and they are most often found in populated areas. The main problems are related to the impact of these species on the local fauna. Thus, the turtle *T. scripta* is widespread in water bodies where the native turtle *Emys orbicularis* is found and competes quite strongly with it, especially in Western Europe. However, in the near future, this species is expected to move eastward in Europe and expand its range. With climate change and the reduction of water bodies due to decreased precipitation and their pollution, native species will be quite vulnerable. Multiple Regression Analysis indicates a significant increase in the correlation coefficient between native and invasive species, signaling potential shifts in ecological dynamics. However, certain regions in the northeast of the European pond turtle's range remain promising for conservation efforts, devoid of invasive species.

Variable	Percent contribution	Permutation importance
bio1	33.4	15.7
bio15	21.7	9





Based on Multiple Regression Analysis, models outcomes for *E. orbicularis* : A - area of intersection of current promising habitats for the native European pond turtle *E. orbicularis and T. scripta*; B - area of current promising habitat for *E. orbicularis*, without invasive *T. scripta* (current).

Conclusions

Our study has shown that widespread reptile species can be an effective model for studying transcontinental invasions. And that these species will expand their range in the near future and may compete with the local fauna. Therefore, it is important to focus conservation efforts on areas without invasive species, such as in Eastern Europe, the Baltic countries, and Ukraine. Climate change plays a key role in the distribution of invasive species in Europe and America. Using GIS modeling, we emphasize the need for proactive management and conservation strategies to protect biodiversity and ecosystems. This requires joint efforts from researchers, policymakers, and stakeholders.

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