AS PART OF MSc in BIODIVERSITY, CONSERVATION, & MANAGEMENT

Species distribution modelling using GIS: identifying potentially suitable habitat for *Iberolacerta cyreni*'s under future climatic scenarios

Abstract

Climate change threatens global biodiversity especially species with limited dispersal or adaptive ability, like reptiles. The carpetane rock lizard *(Iberolacerta cyreni)* is a particularly vulnerable endemic species found within the Iberian Peninsula. This project predicted the extent of suitable habitat and Natura 2000 coverage for *I. cyreni* in future (2050 & 2070) climate scenarios using a bioclimatic envelope species distribution modelling (SDM) approach in GIS. Results showed an overall increase in suitable habitat, assuming unlimited dispersal, yet only one scenario (2050 RCP 2.6) had suitable habitat still present in the original range, suggesting species will have high pressure to disperse. Natura 2000 coverage decreased in all but one scenario ranging from 19.4% to 57.2%. SDMs can provide useful generalizations; however, climate-only analyses omit several biotic factors that could influence species distribution and suitable habitat. Additionally, it is essential to interpret maps conservatively and consider all assumptions involved in producing them.

Introduction

Species Distribution Modelling

Species distribution modelling (SDM) is a technique that relates species occurrence data with environmental parameters using species-environment relationships to gain ecological and evolutionary insights. SDMs have been used extensively since the 1990's with the introduction of Geographical Information System (GIS) mapping, which allowed for faster and more effective analysis of spatial data (Guisan & Thuiller, 2005). SDMs have been used to better understand driving factors in species distribution, manage and protect species in protected areas, and assess or predict species invasions and proliferations (Corsi, de Leeuw, & Skidmore, 2000; Guisan & Thuiller, 2005). These models can also be used to predict future species distributions and suitable habitat under potential future climate change conditions (Guisan & Thuiller, 2005; Richard G.

Pearson & Dawson, 2003). However, SDMs function under several assumptions that should be considered including an equilibrium between species and their environments, and that environmental factors can be accurately sampled and projected into the future (Elith & Leathwick, 2009). Regardless, climate SDMs can provide useful initial approximations, within limits, of how species may react to climate change (Richard G. Pearson & Dawson, 2003). The resulting information can be used to better manage protected area systems, such as Natura 2000, or to inform efforts to prevent extinctions (Kati et al., 2014).

Natura 2000

Natura 2000 (N2k) is a transnational network of protected areas founded by the European Union (EU) that closely aligns with the goals of the Convention of Biological Diversity (CBD) (Kati et al., 2014). It is the largest network of protected areas in the world and covers about 17.9% of EU land territory (Kati et al., 2014). The network contains about 27,000 sites financed through EU initiatives (Kukkala et al., 2016). According to Kukkala et al. (2014), all vertebrate species' distributions identified in EU nature legislation are covered at least partly by N2k. Additionally, the N2k system has a strong EU legal framework and have strict policies for delisting a site, suggesting N2k sites are likely to remain stable and persist into the future (European Commission, 2017; Hlad, Miklič, & Ogorelec, 2004). Although these sites are extensive, many sites are predicted to lose climate suitability (Araújo et al., 2011). For these reasons, the N2k protected areas system is an interesting group of sites to investigate how well future predictions of suitable habitat might be protected.

Carpetane Rock Lizard (Iberolacerta cyreni)

Nearly 40% of reptile in Europe are classified as Threatened (19.4%), Critically Endangered (4.3%), Endangered (7.9%), or Vulnerable (7.1%) (Cox & Temple, 2009). Reptiles are considered the most vulnerable taxonomic group to climate change (Carey & Alexander, 2003; Gibbons et al., 2000; Wake, 2007). Although habitat loss and fragmentation are the leading causes for European reptile decline, climate change may have negative synergistic effects (Cox & Temple, 2009). Climate is thought to be a leading factor for reptile species distribution; major changes in past reptile species distribution were caused by shifts in climatic conditions, though limited by geographic barriers and life-history traits (Le Galliard et al., 2012). This is most likely due to the limitation thermoregulation places on their physiology and behavior (Aguado & Braña, 2014).

Temperature and precipitation, in particular, are thought to be important for reptile performance and survival (Guisan & Hofer, 2003; Le Galliard et al., 2012).

The carpetane rock lizard is an IUCN endangered, endemic reptile with a small range in the central mountains of Spain (Figure 1) (Pérez-Mellado, Cheylan, & Martínez-Solano, 2009). It is found in the Sierra de Bejar, Sierra de Gredos, La Serrota, and Sierra del Guadarrama occurring in rocky, damp habitat at altitudes between 1,300 and 2,500 meters (Aguado & Braña, 2014; Pérez-Mellado et al., 2009). These are protected, at least partly, by the N2k sites Sierra de Gredos (Habitats Directive ES4110002) and Sierra de Gredos y Valle del Jerte (Habitats Directive ES4320038). *I. cyreni* is mainly threated by habitat loss and fragmentation from the creation of ski resorts and roads as well as climate change (IUCN, 2017; Pérez-Mellado et al., 2009). These rock lizards are especially vulnerable to climate change because they: (1) live in the mountains and thus cannot migrate to higher or colder places, (2) are cold-adapted ectotherms which means they have narrow optimal temperatures, (3) live in the Iberian mountains which are predicted to experience higher temperature changes and risks of drought (Carvalho, Brito, Crespo, & Possingham, 2010; Ortega, Mencía, & Pérez-Mellado, 2016). Although adapted to the cold montane environment, *I. cyreni* may not have the behavioral plasticity or evolutionary mechanisms to buffer the effects of climate change (Aguado & Braña, 2014; Klaus Henle et al., 2008). Because *I. cyreni* is vulnerable to climate change and is currently within coverage of N2k sites, it is a good model to give insight into how lizards will respond to respond to climate change and whether N2k sites could effectively protect their habitat.

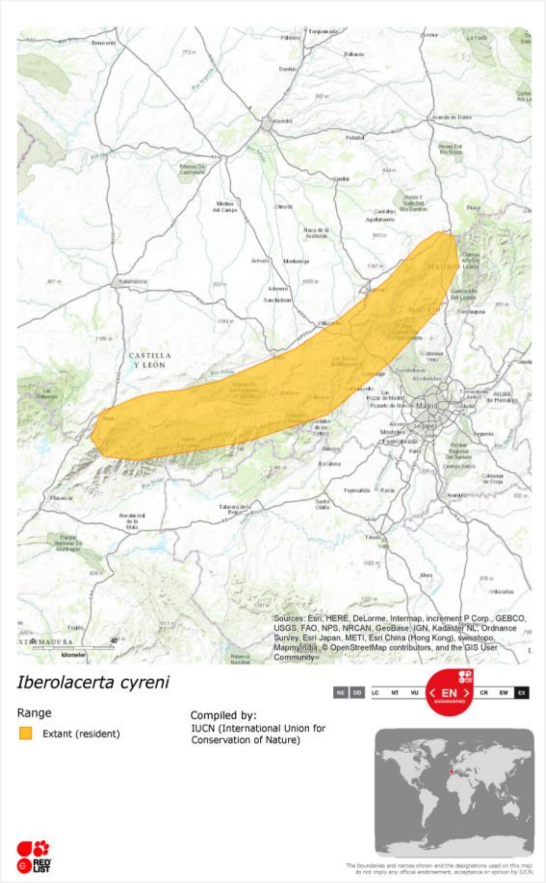


Figure 1: Distribution of *Iberolacerta cyreni* (IUCN, 2017)

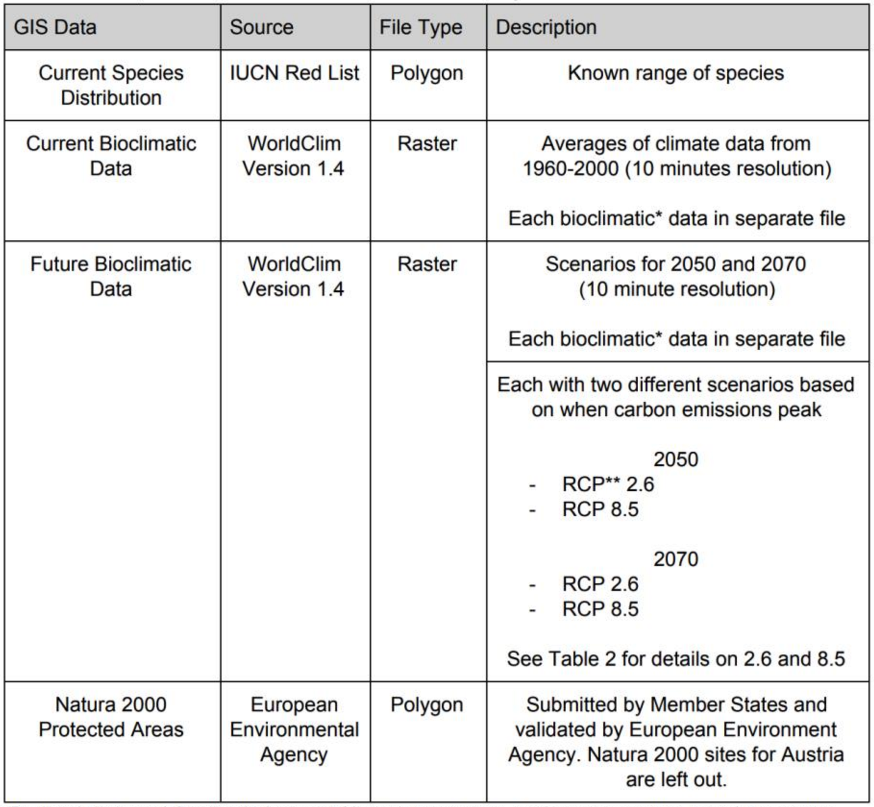
Project Objectives

This project aims to: (1) identify potentially suitable habitat for *I. cyreni* under different climatic scenarios using SDM in GIS, and (2) quantify how effectively N2k could protect *I. cyreni*’s habitat. The first was achieved using a bioclimatic envelope approach where current preferred climate variables were analyzed and then projected into future climatic models. The second objective was analyzed using area of overlap between predicted suitable habitat in different climate scenarios and the N2k protected area network. This study models potentially suitable habitat, not species distribution and should not be interpreted as such. Although climate SDMs have been used extensively to predict future species distributions, no study has modelled future suitable habitat and N2k coverage of it for *I. cyreni* to my knowledge.

Methods

GIS data on current species distribution, climate scenarios (present and future), and N2k sites were collected from the listed sites (Table 1). The future climatic data was divided into two years, 2050 and 2070. Within each year, two scenarios were chosen: RCP 2.6 and 8.5. These were chosen to represent “best case” and “worst case” scenarios of future bioclimatic conditions (Table 2) (Meinshausen et al., 2011). RCP 2.6 assumes that CO_2 emissions peak between 2010-20, meaning global mitigation techniques occur and are effective, while the RCP 8.5 scenario assumes no mitigation targets and CO_2 emissions continue to increase steadily (Riahi et al., 2011). Data for N2k included SCI (Sites of Community Importance), SPA (Special Protection Areas), and SAC (Special Areas of Conservation). SACs and SCI are both part of the Habitats Directive and overlap. One set of these variables was deleted using the select feature in the attribute table to avoid duplicates. All files were projected into WGS Mercator using geoprocessing and data tools.

Table 1. Description and sources of GIS data used in project

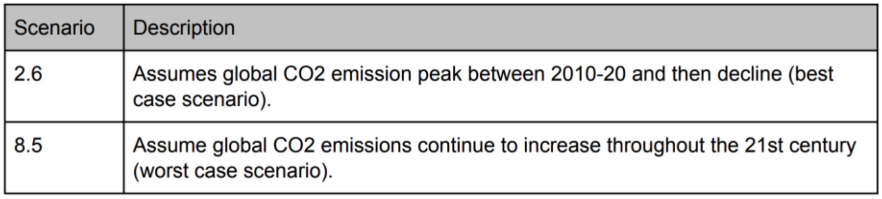


GIS Data	Source	File Type	Description
Current Species Distribution	IUCN Red List	Polygon	Known range of species
Current Bioclimatic Data	WorldClim Version 1.4	Raster	Averages of climate data from 1960-2000 (10 minutes resolution) Each bioclimatic* data in separate file
Future Bioclimatic Data	WorldClim Version 1.4	Raster	Scenarios for 2050 and 2070 (10 minute resolution) Each bioclimatic* data in separate file
			Each with two different scenarios based on when carbon emissions peak 2050 - RCP** 2.6 - RCP 8.5 2070 - RCP 2.6 - RCP 8.5 See Table 2 for details on 2.6 and 8.5
Natura 2000 Protected Areas	European Environmental Agency	Polygon	Submitted by Member States and validated by European Environment Agency. Natura 2000 sites for Austria are left out.

*Bioclimatic data used: Bioclimatic data used: Minimum temperature, maximum temperature, annual temperature, minimum precipitation.

** RCP (Representative Concentration Pathway)

Table 2. Description of future bioclimatic data scenarios based on Meinshausen et al. 2011.



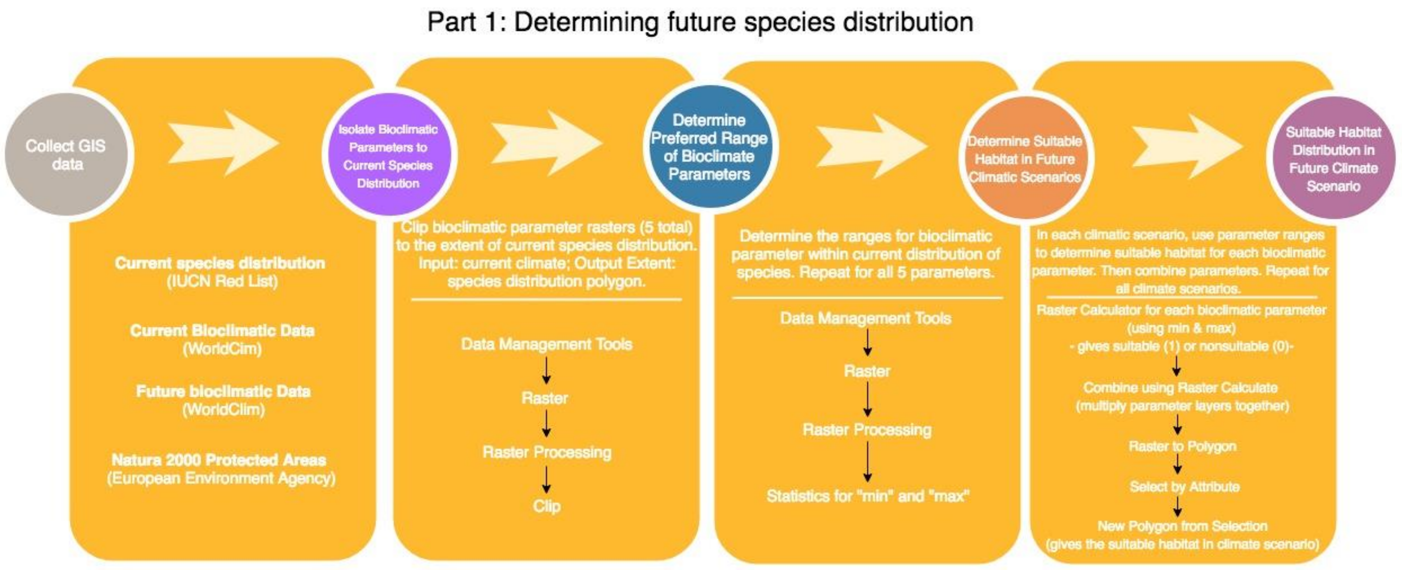
Scenario	Description
2.6	Assumes global CO2 emission peak between 2010-20 and then decline (best case scenario).
8.5	Assume global CO2 emissions continue to increase throughout the 21st century (worst case scenario).

The first step in developing a climate SDM is to create a bioclimatic envelope by determining the species preferred range of environmental variables within the current distribution (Figure 2, Part 1). Because *I. cyreni* is not well studied, climatic factors were chosen based on parameters important more widely to reptiles and the lizard family: temperature and precipitation (Le Galliard et al., 2012). The specific temperature and precipitation bioclimatic parameters used in this project (Table 3) were chosen because previous SDM studies on reptiles used similar parameters (Carvalho et al., 2010; Guisan & Hofer, 2003; Iverson, Prasad, Matthews, & Peters, 2008; Kearney & Porter, 2004; Raxworthy et al., 2003). Next, the preferred ranges of each parameter were recorded using the “Clip” and “Statistics” feature on the current climatic data within the original species distribution (Figure 2, Part 1; Table 3).

Raster Calculator was used on each individual parameter in future scenarios (2050 & 2070 each with RCP’s 2.6 & 8.5) and combined to identify all locations within the range of the species’ preferred climatic conditions from Table 3 (Figure 2, Part 1). Maps were created for each scenario. Only Europe habitat area was considered because it is unlikely that *I. cyreni* could disperse farther (Gibbon et al., 2000; Opermanis et al., 2012). An analysis of possibly suitable habitat for current climate data was also calculated and mapped. This was done in order to get a better understanding of how current species distribution compares to potential habitat using the bioclimatic data technique. In addition, the overlap between the two scenarios within both 2050 and 2070 was mapped. The area of overlap was calculated using the geoprocessing tool “Intersect” and then “Calculate Geometry” in the attribute table. The overlap between Natura 2000 and the predicted suitable habitats in each scenario for *I. cyreni* was isolated by using the “Clip” tool for each climate scenario (Figure 2, Part 2). The area of overlap was then calculated using “Calculate Geometry” in the attribute table.

Table 3: Bioclimatic parameters used to create the bioclimatic envelope

Bioclimatic parameters	Max	Min
Annual Mean Temperature	13.33 °C	8.04 °C
Max Temperature of Warmest Month	27.91 °C	21.34 °C
Min Temperature of Coldest Month	-1.39 °C	-4.88 °C
Annual Mean Precipitation	989 mm	351 mm
Precipitation of Driest Month	23 mm	12 mm



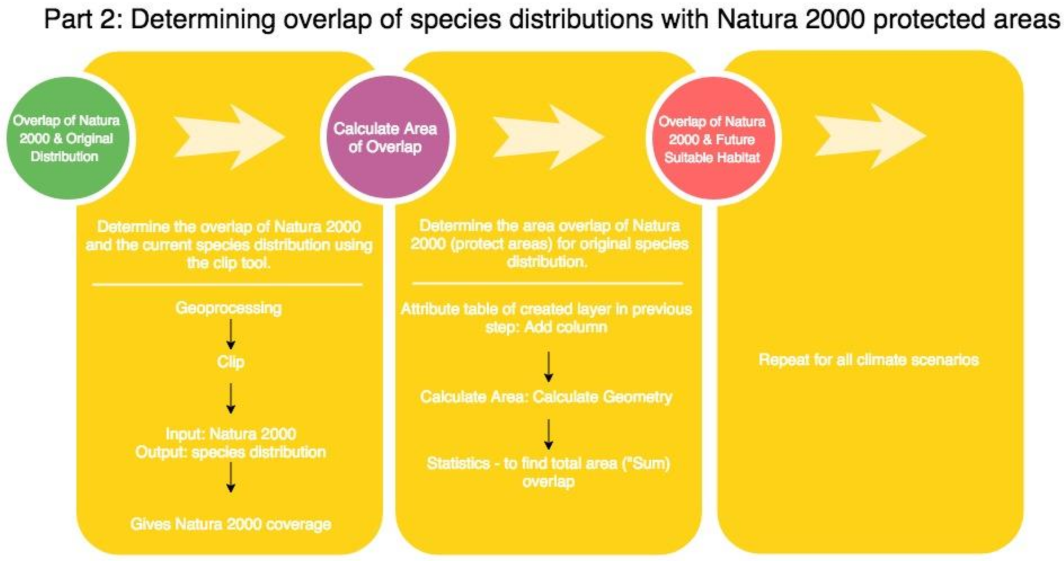


Figure 2: Workflow and tools used in GIS to complete the project

Results

I. cyreni's current distribution covered an area of about 11,425 km^2. Using the species preferred environmental parameter ranges, maps of the predicted suitable habitat were generated for each climatic scenario (Figures 3, 4, 6, 7). Additionally, analysis using the same environmental parameter ranges was used to determine potential suitable habitat under current climate data (Figure 9). The areas calculated using spatial analysis for each scenario and current suitable habitat are listed in Table 4. Overall, the area of predicted suitable habitat increased compared to both current species distribution and predicted current suitable habitat for all scenarios. Scenario 2050 RCP 2.6 is the only future climatic scenario in which there was still any suitable habitat within *I. cyreni*'s current range. Between the two 2050 emission scenarios, the RCP 8.5 scenario had a more restricted potential habitat than RCP 2.6 with a difference of 504,117 km^2 (Figure 5). However, there was an overlap of 235,430 km^2 between the two scenarios. Similarly, the 2070 RCP 2.6 scenario predicted habitat was 99,590 km^2 greater than that of the 2070 RCP 8.5 scenario though the difference was less than the difference between scenarios in 2050. The overlap between 2070 RCP's 2.6 and 8.5 was 201,278 km^2 (Figure 8). The area covered by the 2050 RCP 2.6 was 397,320 km^2 greater than the 2070 RCP 2.6 scenario; however, the difference between 2050 and 2070 RCP 8.5 scenarios was much smaller (7,207 km^2) with the 2070 scenario having a slightly larger area coverage. Additionally, the locations of suitable habitat predicted in both 2050 and 2070 RCP 8.5 scenarios had an overlap of 420,782 km^2 (Figure 10). That is 80.3% of the 2050 RCP 8.5 scenario and 79.2% of the 2070 RCP 8.5 scenario.

Table 4: Area coverage of predicted species suitable habitat in current and future climate scenarios

		Area (in km^2)
Potential suitable habitat (current)		236,900 km^2
2050		
	RCP 2.6	1,027,974
	RCP 8.5	523,857
2070		
	RCP 2.6	630,654
	RCP 8.5	531,064

To analyze how well N2k might protect *I. cyreni*'s habitat, N2k coverage was calculated for each climate scenario (Table 5). Originally, N2k covered 8,107 km^2 of *I. cyreni*'s current distribution which is about 71%. The percent coverage by N2k of the predicted suitable habitat was also calculated in Table 5 by dividing the N2k coverage by the areas listed in Table 4. N2k had poor coverage of the potential current suitable habitat with only 25.7% coverage. Between both 2050 and 2070 scenarios, there was better coverage in the RCP 2.6 scenarios with 88.7% in 2050 and 57.2% in 2070. Similarly, the RCP 8.5 had a better habitat coverage for both years with 38.1% in 2050 and 19.4% in 2070. For both RCP's 2.6 and 8.5, 2070 climate scenario had a lower suitable habitat coverage by N2k. Overall, the coverage of N2k decreased for future climatic scenarios compared to an original 71% coverage of original *I. cyreni*'s distribution with the exception of 2050 RCP 2.6.

Table 5: Area overlap between Natura 2000 sites and predicted species distribution in future climate scenarios

		Area (in km^2)	Percentage of predicted suitable habitat
Potential suitable habitat (current)		61,084	25.8%
2050			
	RCP 2.6	911,948	88.7%
	RCP 8.5	199,481	38.1%
2070			
	RCP 2.6	360,785	57.2%
	RCP 8.5	102,939	19.4%

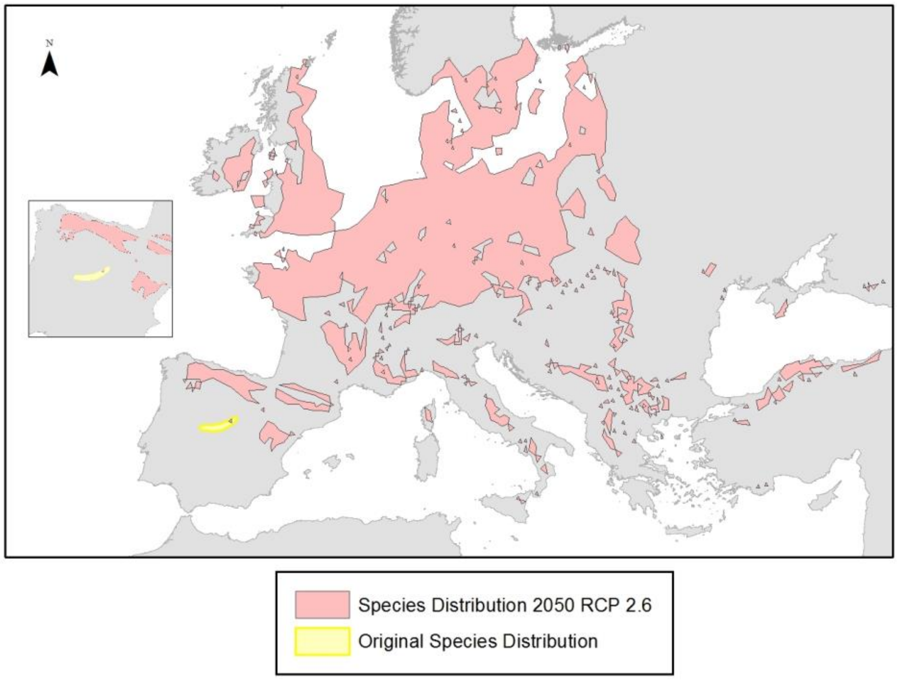


Figure 3: Predicted suitable habitat for *I. cyreni* in 2050 RCP 2.6 scenario

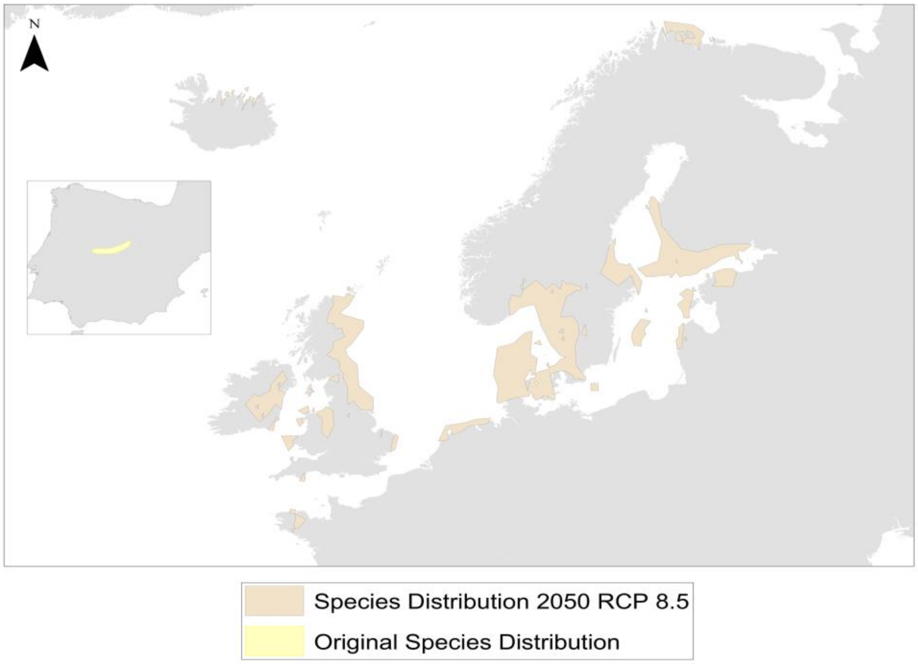


Figure 4: Predicted suitable habitat for *I. cyreni* in 2050 RCP 8.5 scenario

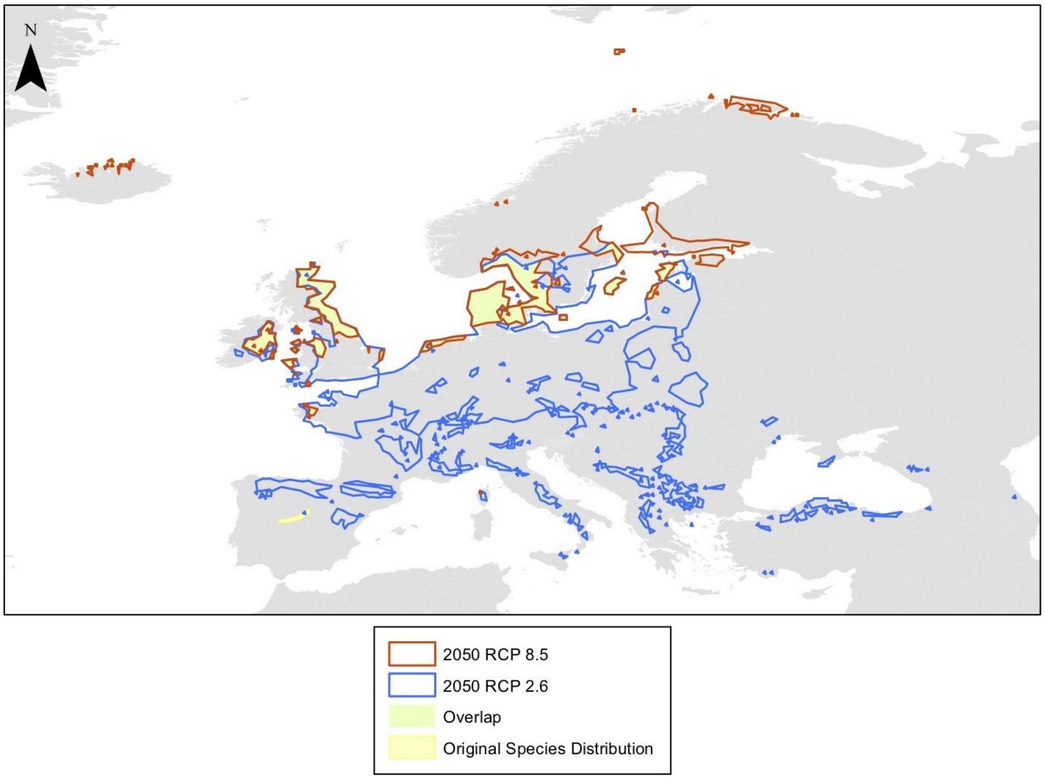


Figure 5: Comparison of predicted suitable habitat for *I. cyreni* in 2050 scenarios (RCP 2.6 and 8.5)

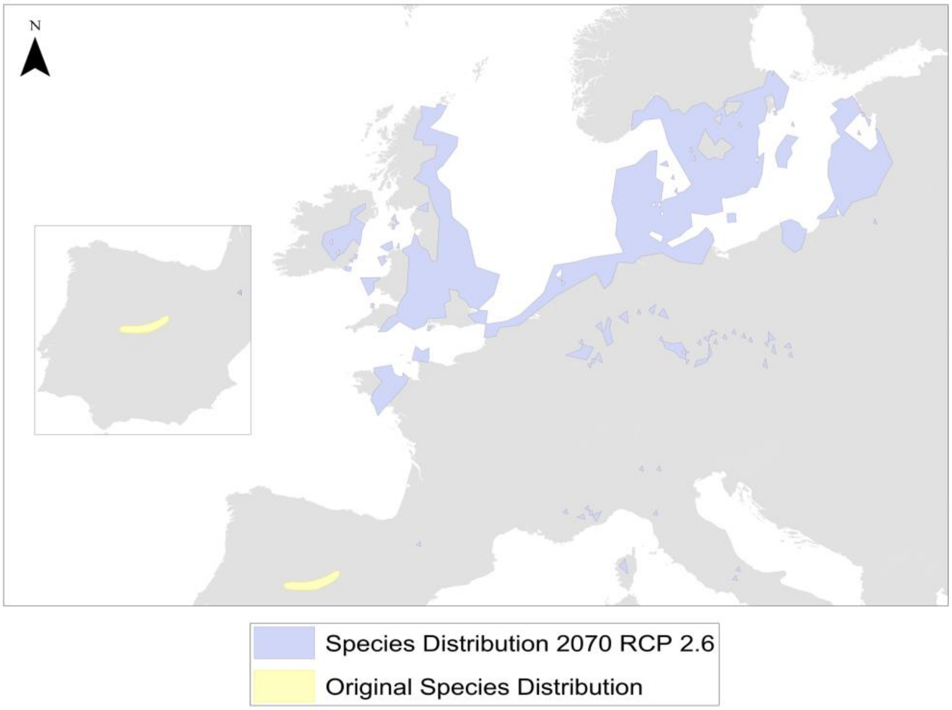


Figure 6: Predicted suitable habitat for *I. cyreni* in 2070 RCP 2.6 scenario

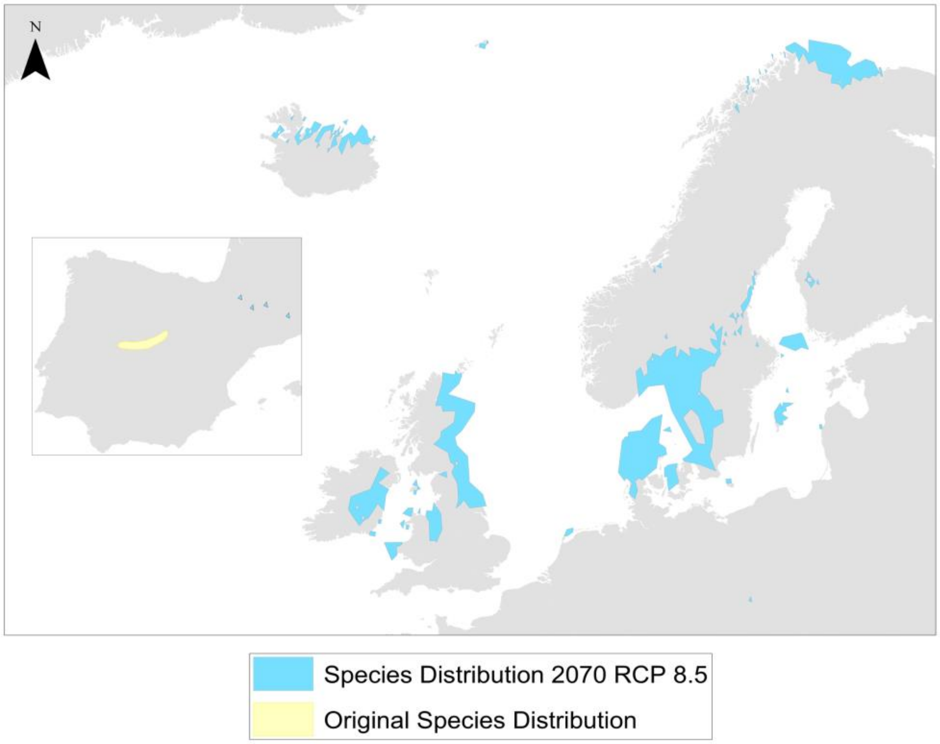


Figure 7: Predicted suitable habitat for *I. cyreni* in 2050 RCP 8.5 scenario

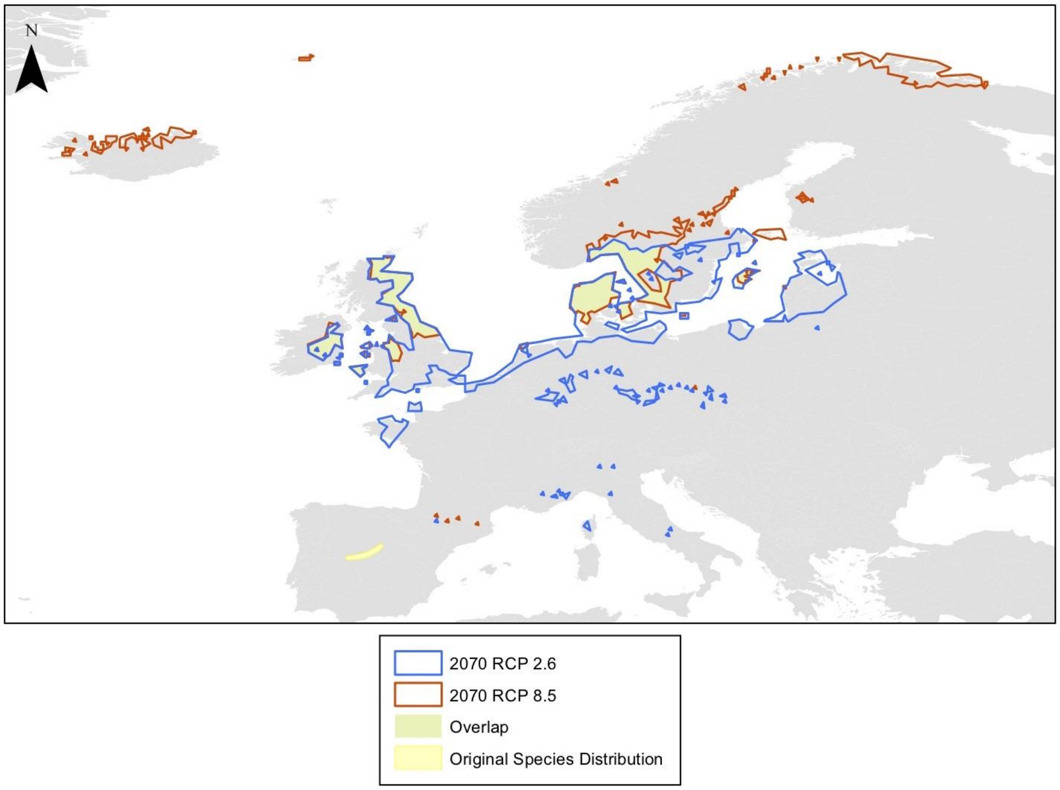


Figure 8: Comparison of predicted suitable habitat for *I. cyreni* in 2070 scenarios (RCP 2.6 and 8.5)

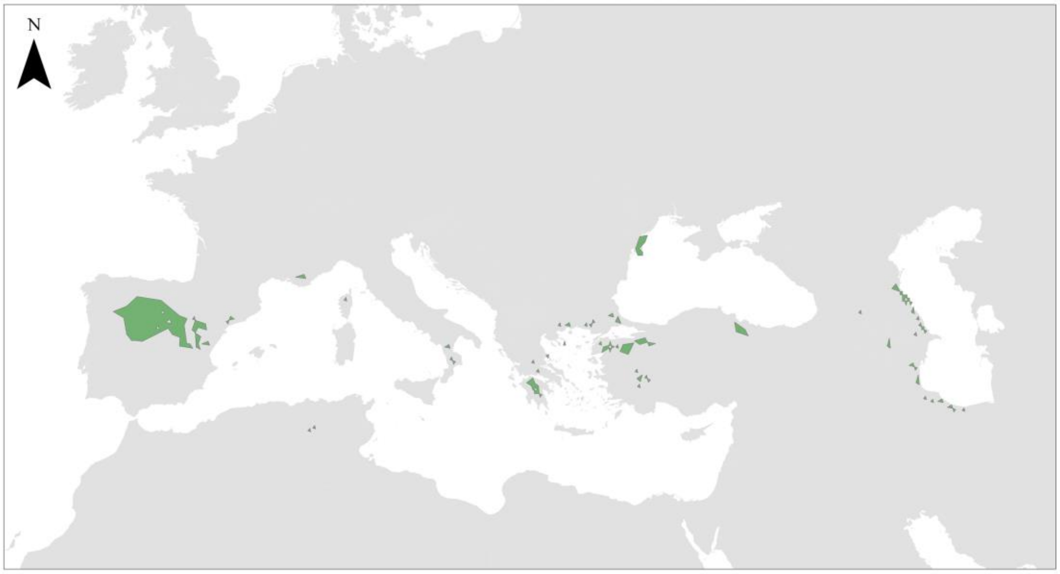


Figure 9: Potential suitable habitat for *I. cyreni* in current climate using preferred climate parameters.

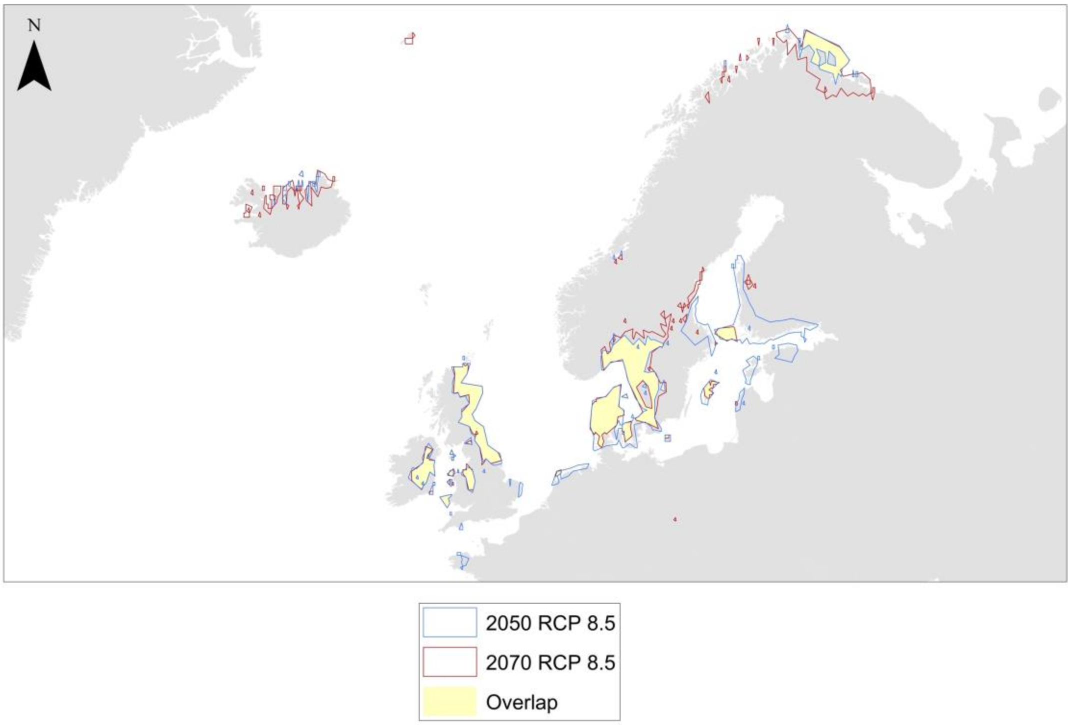


Figure 10: Comparison of predicted suitable habitat for *I. cyreni* in 2070 scenarios (RCP 2.6 and 8.5)

Discussion

The Iberian Peninsula is predicted to undergo rapid and extreme climate change with risks of drought and high temperatures (Carvalho et al., 2010; Ortega et al., 2016). Combined with intermediate mobility and habitat loss or land use change, climate change is expected to dramatically effect reptiles, especially those with restricted ranges such as *I. cyreni* (Guisan & Hofer, 2003; Le Galliard et al., 2012). Using SDM and a bioclimatic envelope approach, the suitable habitat for *I. cyreni* was predicted for future climatic scenarios and the percent coverage by Natura 2000 was calculated. In general, species distribution and habitat is predicted to contract for most species in SDM future climate analyses; however, models for reptile species have found mixed results (Carvalho et al., 2010). In this analysis there was an increase in suitable habitat both compared to the original species distribution area and the modelled current suitable habitat. Previous studies have shown that ectotherms benefit from warming temperatures (Araújo & Guisan, 2006; Le Galliard et al., 2012). Under the assumption of unlimited dispersal, it isn't surprising that *I. cyreni* would us benefit from warming temperatures. Although *I. cyreni* could adapt to increased temperature through evolutionary and behavioral mechanisms (Le Galliard et al., 2012), precipitation did limit its range. The Iberian Peninsula is predicted to experience drier conditions and drought which may explain the lack of modelled suitable habitat in *I. cyreni*'s current range in most scenarios especially in the higher emission scenarios (RCP 8.5). It is also interesting to note that the suitable habitat calculated using current climate change had a larger area than the IUCN current range. Fragmentation and habitat loss or perhaps unaccounted biotic interactions may account for the restricted range of the true species distribution. The increased suitable habitat may bode well for *I. cyreni*, but when coupled with other non-climatic factors – fragmentation, habitat degradation, human encroachment – this species is likely still threatened by climate change.

According to Carvalho et al. (2010), the next decade is critical for the survival of reptiles under climate change conditions which may explain why both 2050 and 2070 RCP 2.6 scenarios predicted a larger area of suitable habitat than the RCP 8.5 scenarios. In the RCP 2.6 scenario, emissions begin to drop after 2010-2020 (Meinshausen et al., 2011). The RCP 2.6 scenarios may have larger suitable habitat due to less extreme changes in temperature and precipitation. Conversely, RCP 8.5 scenarios had smaller areas of suitable habitat due to more extreme increases in environmental parameters. It is possible 2050 and 2070 RCP 8.5 scenarios had similar areas

(Figure 10) because factors such drought and temperature limit but don't vary largely between years. Although these maps may be good estimates, they lack important information including dispersal abilities. Additionally, restricting parameters push results toward the upper and lower ends of suitable habitat which may not be representative of actual distribution as species tend to be more densely found closer to mean preferred environmental parameter values (Austin & Gaywood, 1994; Wilfried Thuiller, Brotons, Araujo, & Lavorel, 2004).

The overall loss of coverage by N2k implied that climate change may severely impact our conservation efforts. N2k, like many other protected area systems, may be insufficient at protecting future habitat. Though N2k currently has full representation of species listed in the Habitats Directive (i.e. *I. cyreni*) (Araújo et al., 2011; Trochet & Schmeller, 2013), the range coverage is less impressive (Kukkala et al., 2016; Maiorano et al., 2015). N2k only covers about 33.6% of the total vertebrate directive species' ranges, but if sites were optimally selected could cover up to 60.3% (Kukkala et al., 2016). According to Araújo et al. (2011), N2k is not any more effective at retaining climate suitability for species than non-protected areas and most vertebrates and plants in Europe are expected to lose suitable climate within protected areas. Several studies point to the small size and dysconnectivity of sites as the main reasons for its ineffectiveness (Davis et al. , 2014; Halpin, 1997; Lawton et al., 2010). Small sites can have edge effects, which are especially harmful to reptiles (Martino, 2001). Creation of buffer zones could reduce edge effects, prevent encroachment of destructive human activity, and better connect N2k sites (Barzetti, 1993; Martino, 2001; Shafer, 1998). Connectivity of sites is also important to allow species to move in response to climate change (Henle et al., 2008; Sinervo et al., 2010). N2k's connectedness varies with some being less connected than the average protected area site in Europe (Mazaris et al., 2013).Thus, N2k site connectivity, size, and placement need to be reexamined for the N2k system to become more efficient at protecting species in the future.

Although SDM for future climate scenarios may be useful approximations of suitable habitat for planning reintroductions or relocating reserves (Thuiller et al., 2004), the models have many assumptions which lead to uncertainty in results. First, climatic SDM assume that climate data is complete and accurate. Because climatic data cannot be measured at all locations across the globe, missing data is extrapolated using models which leads to uncertainty. Additionally, predicting future climate data also has several assumptions and uncertainties. For example, the RCP 8.5 scenarios are based on high population, moderate technology innovation, and little energy use improvements, yet these are calculated using a less than perfect methodology (Riahi et al., 2011). Improvements are necessary to better predict variables such as air pollution, land use, and land use change to incorporate in models (Riahi et al., 2011). Species range maps and polygons used in this project are another source of uncertainty. These range maps are usually created at least in part using museum and natural history collections (Graham, 2001; Ponder, Carter, Flemons, & Chapman, 2001) which can be incomplete or biased. Because range maps are created using presence and absence data (Maréchaux, Rodrigues, & Charpentier, 2017), sampling methodologies using in collecting current data on the species may also influence the polygons. However, because of limited resources, money and time, certain areas of known population habitation may be targeted in field sampling which can skew results (Corsi et al., 2000). Maps created from current point and historical presence data are then generalized to make a polygon which function more as a 'extent of occurrence' (Gaston & Fuller, 2009). Species distribution polygons are also subject to errors of omission (Rodrigues, Akacakaya, et al., 2004; Rondinini, Wilson, Boitani, Grantham, & Possingham, 2006) and especially commission (Hurlbert & Jetz, 2007; Rodrigues, Andelman, et al., 2004). In addition, range maps do not consider abundance or density of species and therefore assume all areas within the range map are equally important to the species and for its conservation which is rarely the case (Maréchaux et al., 2017). Thus, range maps of current species distribution should only be used to infer ranges at coarsest levels with a critical eye and caution (Hurlbert & Jetz, 2007; Loiselle et al., 2003). Due to these uncertainties, results from this project need to be interpreted conservatively.

Though holistically, it is possible for climate-only based models such as the one used in this project to make broad predictions of the impact of climate change for species where climate is a driving factor (Beerling, Huntley, & Bailey, 1995), it disregards several potentially important biotic parameters that could influence habitat distribution. For instance, vegetation and topography may play a role in predicting suitable habitat especially in the Iberian Peninsula where vegetation is threatened and will likely undergo major species losses. Vegetation loss is expected to have negative synergistic effects on amphibians and reptiles in the region (Carvalho et al., 2010). Similarly, organisms (i.e. *I. cyreni*) residing in higher altitude and rock environments may be influenced more by factors such as nutrient availability, water flows, refuges, or solar radiation on a finer scale (Guisan & Hofer, 2003). Other biotic interactions such as competition and predation (Guisan & Thuiller, 2005; Richard G. Pearson & Dawson, 2003), population dynamics (Peng, 2000), soil type (Pearson & Dawson, 2003), species ability to adapt (Elith & Leathwick, 2009), and physiology (Kearney & Porter, 2004) may also influence the distribution of species. Dispersal is another important aspect to consider when determining which suitable habitats may actually be inhabited by the species in future (A. J. Davis, Jenkinson, Lawton, Shorrocks, & Wood, 1998).Though this project's model does not include dispersal in its models, several SDM studies have begun to incorporate this factor. However, dispersal ability is unknown in several species including I. *cyreni*, and thus becomes difficult to model (Le Galliard et al., 2012). One approach is to model suitable habitat or species distributions using two extremes, zero or unlimited dispersal ability, to give the minimum and maximum ranges (Guisan & Thuiller, 2005). Others have tried modelling habitat fragmentation and dispersal events to better predict future species distribution (Iverson, Schwartz, & Prasad, 2004; Schwartz, Iverson, & Prasad, 2001). Therefore, models can be improved by including several of these factors and how those factors will change in future climates as well (Elith & Leathwick, 2009).

Additionally, SDM predictions can be improved by comparing several models and statistical calculations. Several new mutli-approach modelling techniques for species predictions have been developed including BIOdiveristy MODelling (BIOMOD) and Spatial Evaluator of Climate Impacts on the Envelope of Species (SPECIES) model. BIOMOD computes 4 modelling techniques for each species distribution prediction including: Generalized Linear Models (GLM), Generalized Additive Models (GAM), Classification and Regression Tree analysis (CART) and Artificial Neural Networks (ANN) (Thuiller, 2003). SPECIES uses ANN to create the bioclimatic envelope using observed species distributions and environmental variables (climate, soil type, etc.) while incorporating physiology to give a mechanistic basis as well (R. G. Pearson, Dawson, Berry, & Harrison, 2002). It is important to choose the model that best represents the species. Testing against historical data can be a good method to validate methods and determine which most accurately predicts for the specific species (Raxworthy et al., 2003). Using several methods prevents reliance on limited parameters and statistical analyses, however, models should still be interpreted with caution.

Conclusion

Changes in species distribution and suitable habitat will likely to be affected by climate change. The carpetane rock lizard, in particular, is predicted to be especially vulnerable to changes in temperature and precipitation expected in the Iberian Peninsula. This project found an overall increase in suitable habitat in future climates both in the “worst case” (RCP 8.5) and “best case” (RCP 2.6) scenarios. Though suitable habitat may increase, actual distribution will be impacted by other factors including dispersal which would limit its extent. The climatic model used also assumes the five temperature and precipitation variables chosen are the only factors determining *I. cyreni*’s suitable habitat and disregards biotic interactions. Ultimately, how much and which parts of predicted suitable habitat may actually be inhabited by *I. cyreni* in the future depends on its resilience, adaptive ability, and behavioral or physiological plasticity. In addition, this project found a decrease in Natura 2000 coverage which implies that N2k will not be effective at protecting future suitable habitat at least for this species. Policy makers need to focus on site management, creating larger and more connected sites, to increase the network’s resilience against climate change. Moreover, SDM has many limits and conservationists should attempt to compare several models and statistical analyses to develop the most accurate prediction. Regardless, climate-based SDM can provide useful generalizations of habitat and distribution which can be used in conservation planning and species protection.

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