Exploring the Future of the Barbastella Barbastellus with a Species Distribution Model

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Abstract

The Barbastella Barbastellus(or Western Barbastelle) bat is a near threatened bat species which resides in Western Europe. A better understanding of its potential suitable habitats and distribution will aid in its conservation and to prevent habitat loss. We used a SDM(species distribution model) to predict the suitable habitats for the species using available occurrence data from GBIF, and then used environmental variables predictors(all nineteen bioclimatic variables, land cover, and elevation) to show habitats suitability and how climate change impacts the organism. The SDM showed that isothermality, temperature seasonality, mean temperature of wettest quarter, precipitation seasonality, and precipitation of coldest quarter had the biggest impacts on habitat suitability for the Barbastelle. Out of all these environmental variables, precipitation seasonality had the biggest impact on the species, and this was a negative relationship. So overall, the environmental effects of temperature and precipitation had the biggest impact on the Barbastelle. The SDM predicted the current suitable habitat for the bat is 1,330,846 square kilometers, and its future suitable habitat will be 1,050,913.6, undergoing a loss of 279,932 square kilometers, showing changes in temperature and precipitation. The SDM showed that the current suitable habitat range mainly occurred in the Western European areas around the Southern United Kingdom, France, Northern Spain, Western Germany, and countries around this area. The SDM then showed that in the future most suitable habitat loss would occur in the Southern areas of its current suitable habitat(Southern France and Spain). The SDM predicted that the suitable habitat for the Barbastelle would go northward, since most of its Southern habitats would disappear. In conclusion, this study recommends combat climate change which affects both precipitation and temperatures otherwise major parts of the Barbastella Barbastellus habitat would disappear.

Introduction

The Barbastella barbastellus, also known as the Barbastelle bat is a rare species of vesper bats. This bat has short, broad ears and a pug-shaped nose. It is commonly found in parts of Europe, especially Britain. It primarily lives in abandoned buildings, hollow trees, rock crevices, and caves. It prefers to live away from human activity in these habitats. This nocturnal creature plays a crucial role in keeping insect populations under control.

The Barbastelle bat is vulnerable to climate change like many other bats due to rising temperatures and changes in precipitation weather. The Barbastelle bat likes to keep its roosting spots in caves and tree hollows where the climate is humid and cool. Increasing temperatures and dry weather can disrupt their habitat. Also, temperatures should be stable year round and shouldn't vary by much otherwise it can disturb their roosting habitats. There should also be year round precipitation for the Barbastella Barbastellus. Higher temperatures can also disrupt their hibernation which causes them to lose more energy for the winter. Also with more climate change, there are more storms which can ruin their roosting habitats too. This bat is also vulnerable to human activity such as deforestation because of the destruction of their roosting sites. The bat likes to hunt its food(specifically moths) in tall forests and wet meadows. Lights and pesticides from human development are also harming the bats. The pesticides reduce their prey and indirectly poison the bats. The light pollution also delays a bats emergence from their roost, leading to smaller foraging times and less food. Also, However with more human development and deforestation, the bat is losing its environment causing further population decline. Not only that, but these bats are considered low reproductors because they only give birth to one or two pups a year. This means their population increases gradually, but with climate and environmental change their population has declined by 99% in the past several hundred years and is still on the decline.

Methods

Data Collection

I obtained occurrence records of Barbastella Barbastellus from Global Biodiversity Information Facility (GBIF) [https://doi.org/10.15468/dl.ms549b]. The GBIF is database and data infrastructure supported by multiple national governments, aimed at providing open-access biodiversity data for the public and the science community. The total number of occurrences for Barabastella Barbastellus downloaded is 125,955. These occurrences are found mainly in Western Europe such as France, United Kingdom, Switzerland, Spain, etc. The timeline of the sightings for this species ranges from 1700 to 2025. I then filtered to keep only occurrences with coordinates. The latitudes range from 29 to 63 and longitudes range from -18 to 21.

Environmental Variables

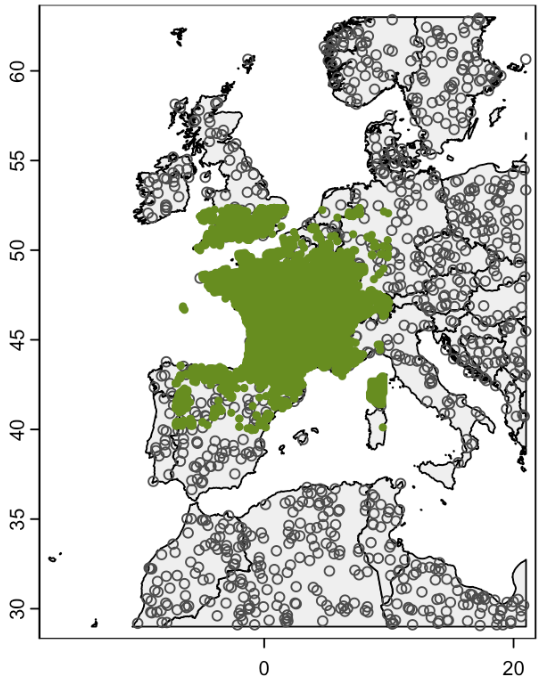
I acquired environmental variables representing the current climatic conditions from the WorldClim database (Fick and Hijmans, 2017) at the resolution of 2.5 arcmin. The environmental variables included: Bio1 = Annual mean temperature, Bio2 = Mean diurnal range (max temp – min temp) (monthly average), Bio3 = Isothermality (Bio1/Bio7) * 100, Bio4 = Temperature Seasonality (Coefficient of Variation), Bio5 = Max Temperature of Warmest Period, Bio6 = Min Temperature of Coldest Period, Bio7 = Temperature Annual Range (Bio5-Bio6), Bio8 = Mean Temperature of Wettest Quarter, Bio9 = Mean Temperature of Driest Quarter, Bio10 = Mean Temperature of Warmest Quarter, Bio11 = Mean Temperature of Coldest Quarter, Bio12 = Annual Precipitation, Bio13 = Precipitation of Wettest Period, Bio14 = Precipitation of Driest Period, Bio15 = Precipitation Seasonality (Coefficient of Variation), Bio16 = Precipitation of Wettest Quarter, Bio17 = Precipitation of Driest Quarter, Bio18 = Precipitation of Warmest Quarter, and Bio19 = Precipitation of Coldest Quarter. Using R software (R Core Team, 2023) and raster package (Hijmans, 2024), I trimmed the environmental variables so that the geographic range of environmental variables was contained with -18 to 21 longitude and 29 to 63 latitude; to get this information. The extent of the environmental variables covers and extends beyond the latitudinal and longitudinal ranges of Barbastella Barbastellus.

In addition, to project species future suitable areas, I acquired environmental variables representing future climatic conditions for the years 2061- 2080 under the model MPI-ESM1-2-HR and CMIP6 (Gutjahr et al., 2019) The future climatic raster layers were also trimmed using the sampling extent mentioned above. To avoid multicollinearity, we used Pearson correlation coefficient |r| > [0.7] as a threshold to remove highly correlated bioclimatic variables for both the current and future climatic variables.

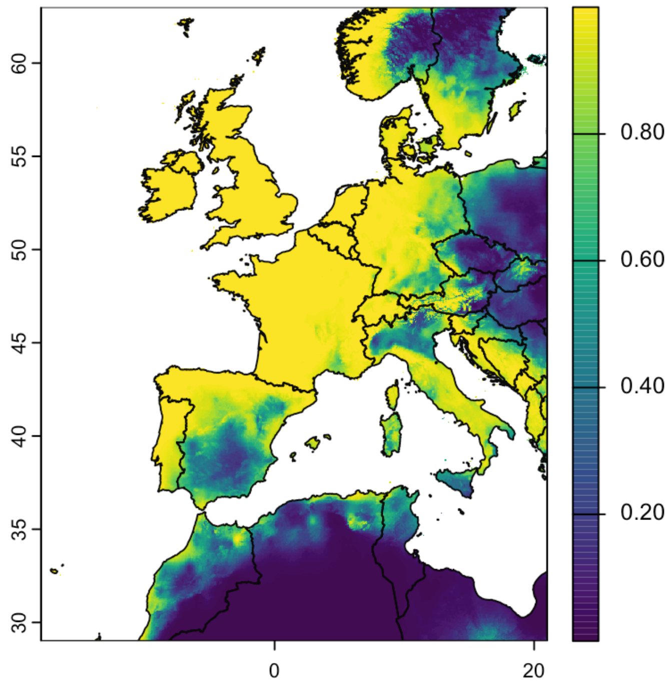
Modeling Strategy:

To investigate the suitable habitat areas of Barbastella Barbastellus, we performed a multivariate generalized linear model (GLM). I randomly selected 10,000 pseudo-absence, or “background” points, within the range of the environmental variables (see section above). The number of 10,000 pseudo-absence points followed the recommendation by Barbet-Massin et al. (2012). After running the GLM model, I converted the continuous probability of habitat suitability to a binary response output (suitable = TRUE or FALSE). The suitability cut-off was equal to the threshold at which the sum of the model sensitivity (true positive rate) and specificity (true negative rate) is highest (Field et al. 1997; Liu et al. 2011). I then used five-fold cross validation to evaluate the trained GLM; in each cross validation, 80% of the occurrence data were training data, leaving the remaining 20% as testing data. We then evaluated the performance of GLM by calculating the Area Under the ROC Curve (AUC). We finally projected future suitable habitat areas for Barbastella Barbastellus in 2061-2080.

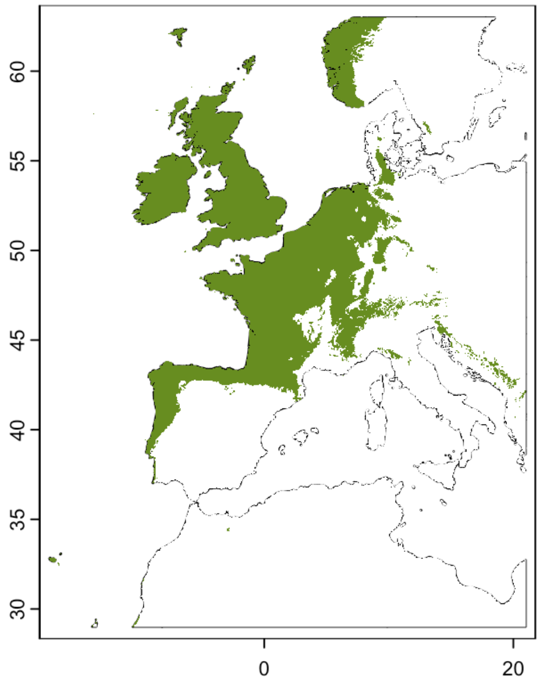
Results:



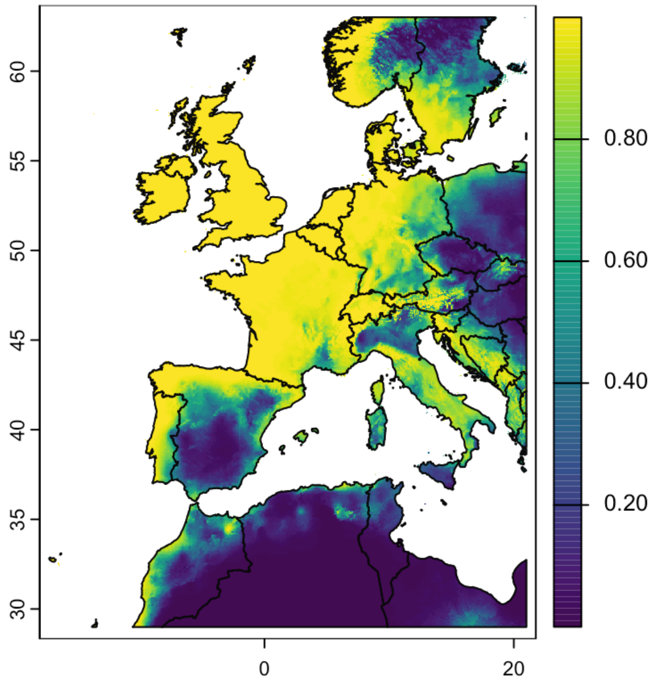
This is the background points figure generated. This contains the Pseudo-absence points (background points, black circles) vs. true presence points (green circles). The puseduo-absence points are points where the Barbastella Barbastellus is confirmed to be absent. The green points are the areas where the bat is confirmed to still exist. This shows that the Barbastelle resides in the Western European area.



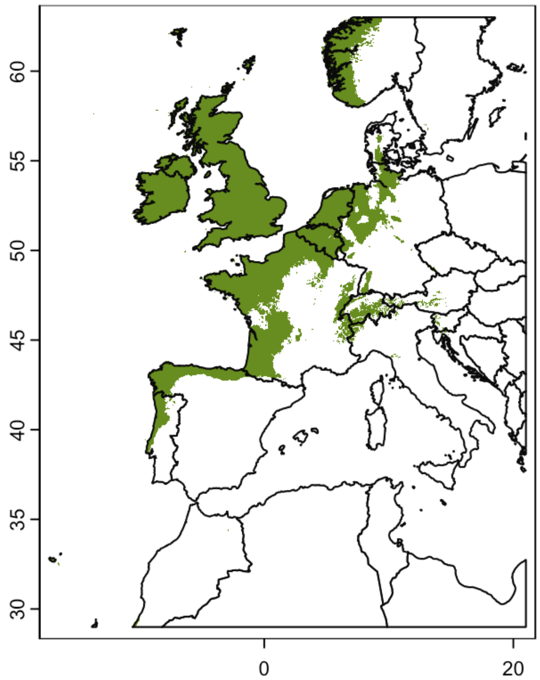
This is the generalized linear model's prediction on species suitable habitat based on current climatic variables. This is represented as a heatmap and the color shows the probability of the Barbastella Barbastellus' presence (0 to 1). This is continuous because it shows how likely we would be to expect the bat's presence/abscence.



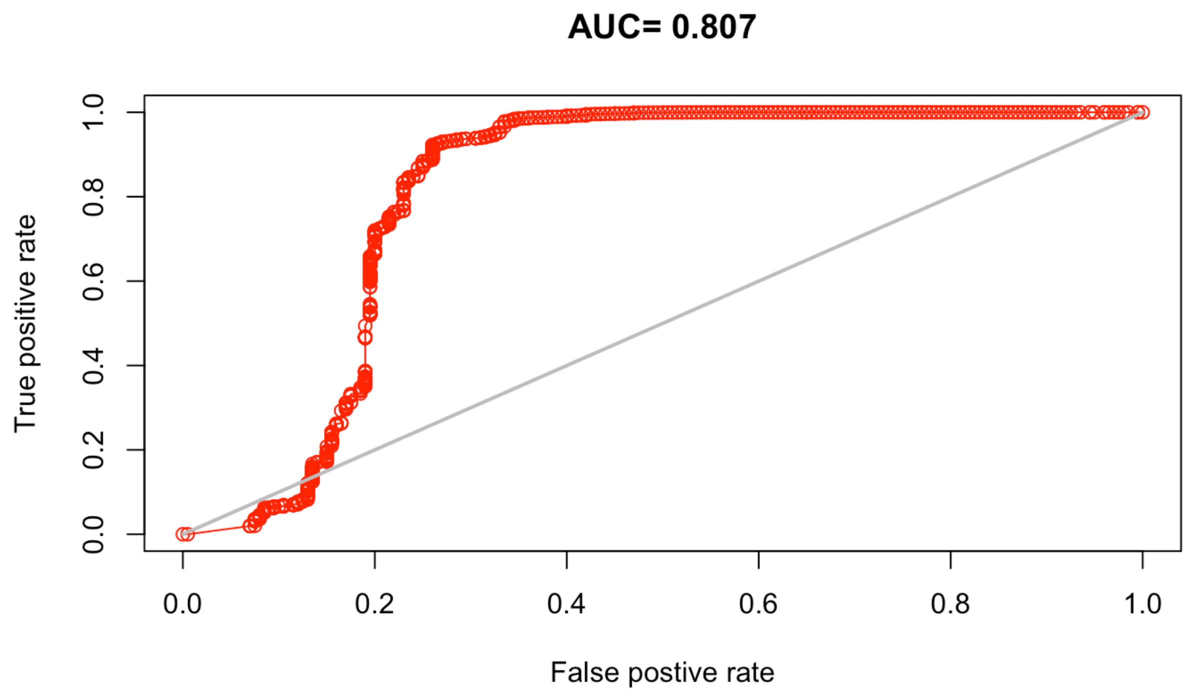
This shows the current suitable area as a binary where green means that the Barbastella Barbastellus is a completely suitable habitat and the white means the habitat is not completely suitable.



This is the future continuous suitable habitat for the Barbastella Barbastellus. It predicts the probability of the Barbastelle's presence in a certain area as a decimal.



This is the future predicted suitable habitat map for the Barbastella Barbastellus. The green area is the complete habitat area for the Barbastelle, and the white is the area which is not completely habitable.



This is the Area under the receiver operator curve(ROC). An AUC with a value of 0.807 means the model has a strong ability to differentiate between the positive and negative classes. When the model has a false positive rate of around 0.15, there is a sharp increase in the true positive rate showing its accuracy.

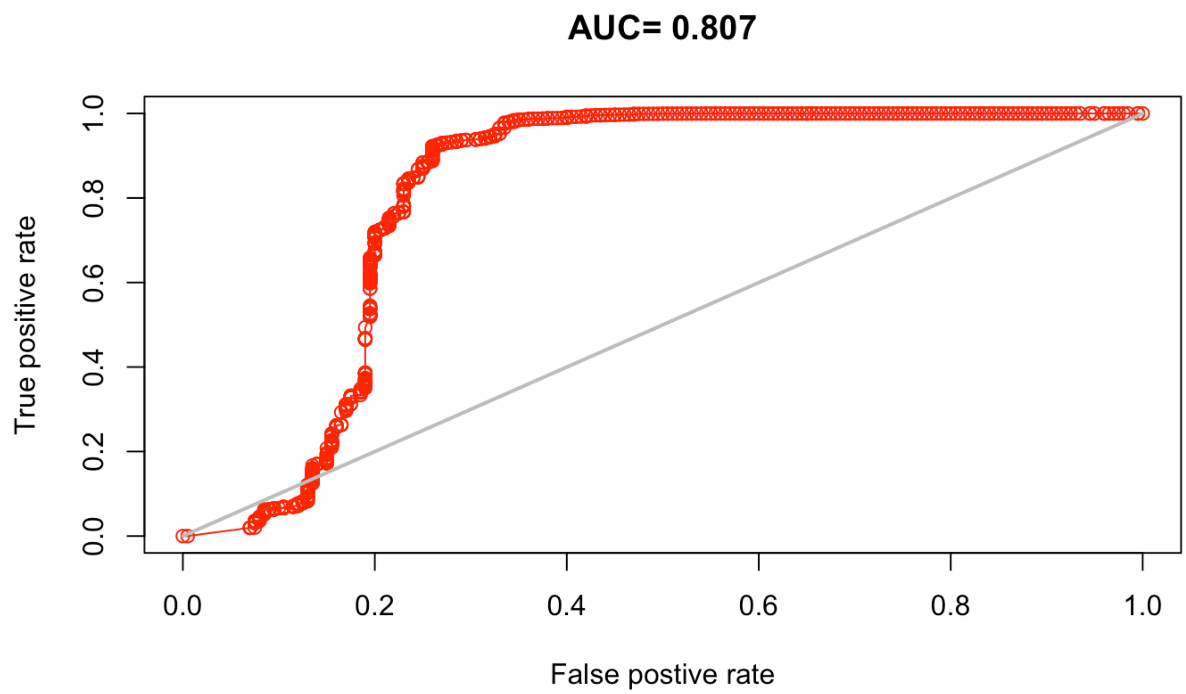
	np	na	prevalence	auc	cor	pcor	ODP
1	22116	200	0.99103782	0.80666825	0.66556042	0	0.00896218

This is the evaluation of the generalized linear model variables shown.

The final GBIF dataset of Barbastella Barbastellus contains 123547 rows of records with coordinates. The GLM species distribution model also includes 5 bioclimatic variables after excluding the highly correlated variables.

Variable Name		Bioclimatic Variable	Description
wc2.1_2.5m_bio_3		BIO3 – Isothermality	(BIO2/BIO7) (* 100)
wc2.1_2.5m_bio_4		BIO4 – Temperature Seasonality	Standard deviation *100
wc2.1_2.5m_bio_8		BIO8 – Mean Temperature of Wettest Quarter	Average temperature of the wettest quarter
wc2.1_2.5m_bio_15		BIO15 – Precipitation Seasonality	Coefficient of Variation
wc2.1_2.5m_bio_19		BIO19 – Precipitation of Coldest Quarter	Total precipitation in the coldest quarter

The model shows an AUC value of 0.807, which indicates that there is an 80.7% chance the model will indicate a positive class above a negative class which is considered good.

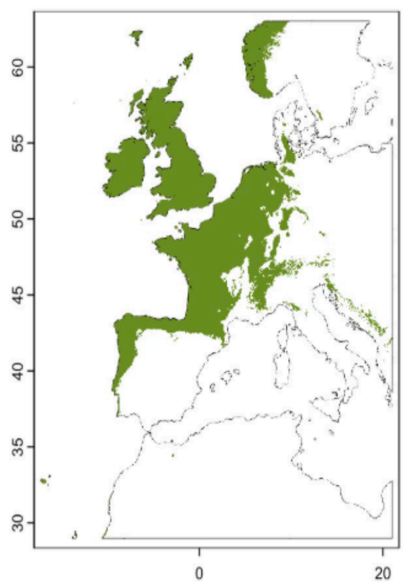


The GLM model output shows that the precipitation of the coldest quarter, and the isothermality shows significant positive correlation to predicting species presence, and temperature seasonality, mean temperature of wettest quarter, and precipitation seasonality show significant negative correlation to species presence .

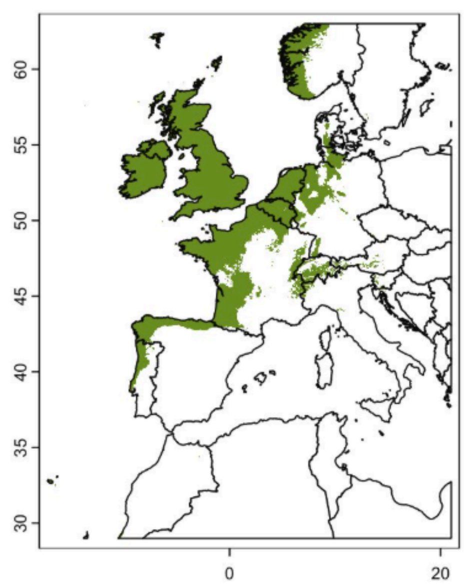
	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	16.2670902	0.91906294	17.6996476	4.22E-70
wc2.1_2.5m_bio_3	0.03842619	0.01144143	3.35851415	0.00078363
wc2.1_2.5m_bio_4	-0.0199134	0.00096056	-20.731019	1.82E-95
wc2.1_2.5m_bio_8	-0.054036	0.01328583	-4.0671945	4.76E-05
wc2.1_2.5m_bio_15	-0.1178516	0.00353321	-33.355389	6.09E-244
wc2.1_2.5m_bio_19	0.01010372	0.00082271	12.2810332	1.15E-34

The comparison between current and future suitable habitat area reveals that habitat area may decrease from 1330845 square km to 1050913.6 square km in 2061-2080, undergoing a loss of 279932 km2.

Current Suitability



Future Suitability



Discussion:

The study found that the area of the Barbastella Barbastellus would undergo a loss of 279,932 square kilometers in 2061-2080. Its current suitable area is 1,330,846 square kilometers, and its future suitable habitat would be 1,050,913.6 square kilometers. The model generated coefficients of isothermality, temperature seasonality, mean temperature of wettest quarter, precipitation seasonality, and precipitation of wettest quarter. Isothermality and precipitation of the wettest quarter had a positive relationship with the Barbastella Barbastellus. Precipitation seasonality, temperature seasonality, and mean temperature of the wettest quarter had a negative relationship. Out of all these environmental variables, Precipitation seasonality (coefficient of variations) has the biggest impact among all of them. Also the AUC value generated was 0.807 showing that it was accurate in distinguishing negative and positive cases. There were 120,000+ observations of the Barbastella Barbastellus species showing that this would be accurate and enough data for the model. It is shown that the Barbastella bat lives mainly in the Western European area and most of its losses will mainly occur in France, Germany, and Spain. The heat maps show that

The future suitable habitat area is expected to shrink due to precipitation changes, urbanization, and temperature change. The bat had a positive relationship with precipitation of the coldest quarter, and the isothermality. This is because the organism prefers moister weather during the winter months, so it thrived when there was precipitation in the winter. Barbastella Barbastellus bats roost in moist, thermally buffered sites where humidity is important. Therefore, in the winter(coldest months) precipitation is vital for their hibernation. Areas with snow or light rain tend to support older, moist forest ecosystems — their key habitat. Also isothermality is important because this factor ensures thermal stability for hibernation, so reduces energy loss. With higher isothermality, the bats will have fewer fluctuations so they don't have to frequently arouse from torpor costing a lot of energy. However with climate change, isothermality is lowering because the temperature range from the day night cycle is becoming more and more extreme. Not only that but with deforestation, natural temperature buffer zones are getting removed, increasing day-night extremes. The bat thrives in habitats with less temperature seasonality. With winters that are too cold, they can be awakened from extreme temperatures costing valuable energy. The bats' prey(moths and other insects) can be disrupted by extreme temperature shifts further affecting the Barbastelle population. Also, Barbastellus prefers habitats with less precipitation seasonality, so they prefer environments where there is steady moderate to high precipitation year round. The Barbastelle feed mainly on moths which require a stable moist environment for their life cycles. Also in dry seasons, their roosts can become too dry causing the bats to abandon them for a moister site. Lastly, Barbastella Barbastellus prefer an environment with a lower mean temperature during the wettest quarter. This is because these bats prefer cool moist forest habitats, not tropical hot humid climates. So, climates with this type of weather occur in the Western European area in general where the wettest season tends to have an autumn climate, and temperatures remain cool. According to the future suitability image, the Barbastella Barbastellus habitat will shrink by around 308 thousand square kilometers. This is happening due to a mixture of climate change, deforestation, and their specific ecological preferences. First climate change increases temperatures and extremes of their habitats. Climate change introduces more extreme seasonal shifts such as hotter and dryer summers. There will also be less stable precipitation leading to a loss of roosting sites and a stable insect population for prey.

My findings can also be applied to organisms with similar glm statistics coefficients as the Barbastella Barbastellus. Organisms, especially other hibernating animals, which rely on steady yearly rainfall and temperatures not affected by seasonal changes will experience similar changes as the Barbastelle bats.Some limitations of this research are factors like other organisms. Another thing is that the AUC curve value is not the highest. It is reliable to use, but could be improved for increased accuracy. My findings can be used to inform studies and organizations about the importance of the ecological balance of a roosting site, managing forests, and preventing climate change. A stable temperature and precipitation pattern is very important for many species like the Barbastella Barbastellus so this information is useful for addressing ecological issues around this subject.

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