Modelling the future distribution of *Lasiommata megera*

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Date: 11-12-2017

Introduction

Lasiommata megera, common name the wall brown, is a species of Lepidoptera, the butterflies. It is a member of the large clade Satyrinae, the browns, which itself is a part of the large family Nymphalidae, the brush-footed butterflies. The species is a common inhabitant of grassland habitats, preferring to inhabit varied, flower-rich sites with many warm, open spots, as the species is a thermophile (Stip et al, 2014). According to literature, it is widely distributed across Europe and western Asia, being limited by the Atlantic in the west, the Altai Mountains in the east, the Sahara and Middle East deserts in the south, and the boreal forests of Scandinavia and Russia in the North (Bos, 2006). In GBIF, its distribution is less wide and biased towards certain areas, especially the British isles, the Benelux and Scandinavia (Fig.1). This reflects a high interest in butterflies in these areas, leading to better coverage. In the eastern part of *L. megera*'s distribution however, coverage is lacking. Furthermore, the species has declined heavily in western Europe (Stip et al, 2014), which has led to shrinkage in distribution not reflected in GBIF.

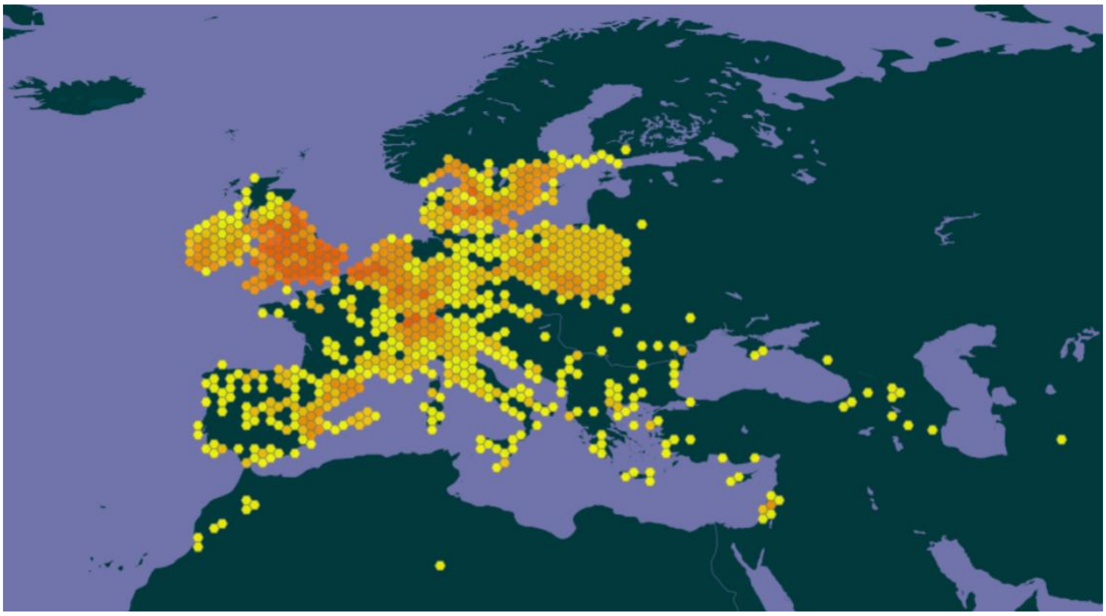

Figure 1: Distribution of Lasiommata megera from GBIF

Methodology

To model the future distribution of *Lasiommata megera*, the following was done. Distribution data of the species was downloaded from GBIF. Furthermore, bioclimatic variables at 5 minutes resolution were downloaded from WorldClim, for both the present and 2050 from the GCM HadGEM2-AO.

Using Rstudio, the following variables were selected: isothermality, temperature seasonality, mean temperature of the wettest quarter, mean temperature of the warmest quarter, and precipitation seasonality. Since *Lasiommata megera* is a thermophile, it is dependent for its activity on high temperatures in the months when it flies. Since these months are also the warmest of the year, the variable mean temperature of the warmest quarter was chosen. Unfortunately, annual mean temperature was correlated with mean temperature of the warmest quarter, and thus had to be dropped, despite likely being an important variable for the species. Isothermality was chosen since it represent the day night oscillations relative to the annual range. This could be important for *Lasiommata megera* because it prefers sites with a high variation in temperatures, especially with high peaks. Temperature seasonality could be important for the same reason, although seasonal change seems to have less influence. Lastly, *L. megera* has no clear preference in precipitation patterns, although presence of water in the soil does have an influence, due to poor nutritional value of hosts plants on dry soils. Moreover, in pupa phase it is vulnerable to very wet or dry conditions. Thus, precipitation seasonality was also chosen. Mean temperature of the wettest quarter was only selected due to it having no correlation to another variable, and has no known relevance to the species.

Subsequently, a species distribution model for both present and future was made with the program MaxEnt. Default MaxEnt settings were used. Finally, maps of the distribution were created in Rstudio.

Model output

The model was reliable, with an AUC of 0.782. The most important variable driving the distribution pattern is the temperature seasonality, with mean temperature of the warmest quarter being second. The other three variables contribute relatively little to the pattern (Table 1).

Table 1: variable importance table

Variable	**Percent contribution**	**Permutation importance**
Temperature seasonality	53.6	64.7
Mean temperature of the warmest quarter	28.5	14.1
Precipitation seasonality	8.9	4.1
Isothermality	6	11.2
Mean temperature of the wettest quarter	3	5.8

For the present, this was the distribution map produced by the model (Fig. 2).

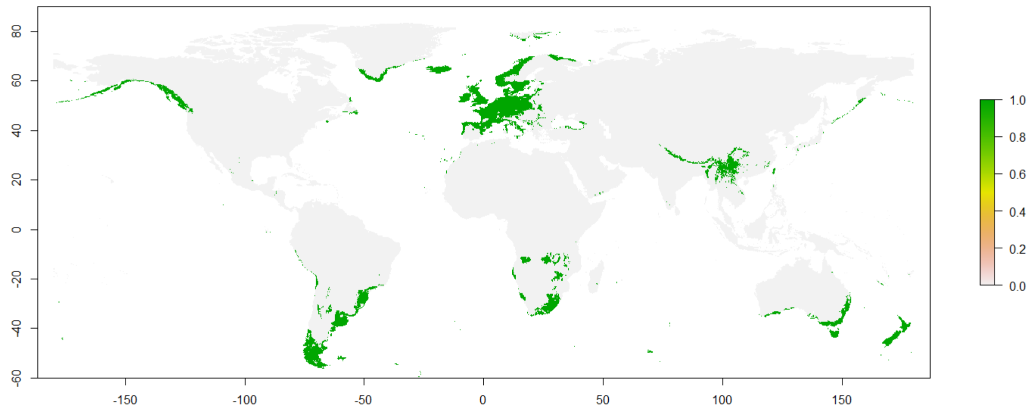

Figure 2: Map of present distribution

For the future, this was the distribution map produced by the model (Fig.3).

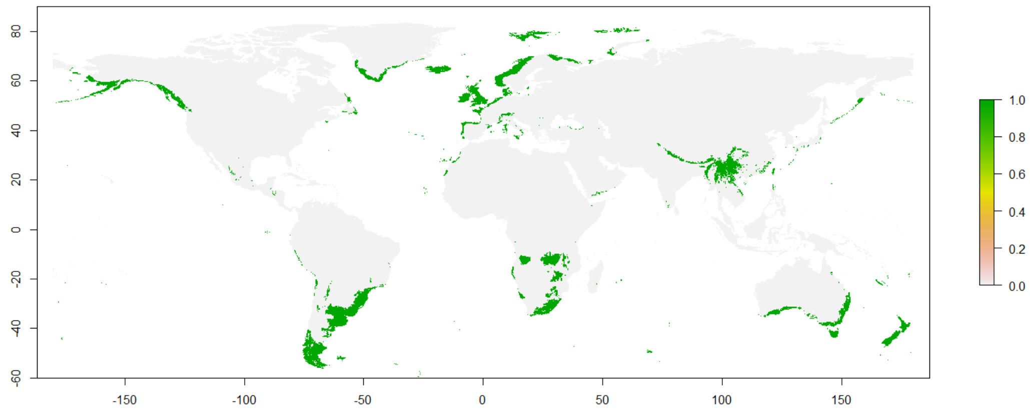

Figure 3: map of future distribution

This is the map of expected distribution change for the world (Fig.4).

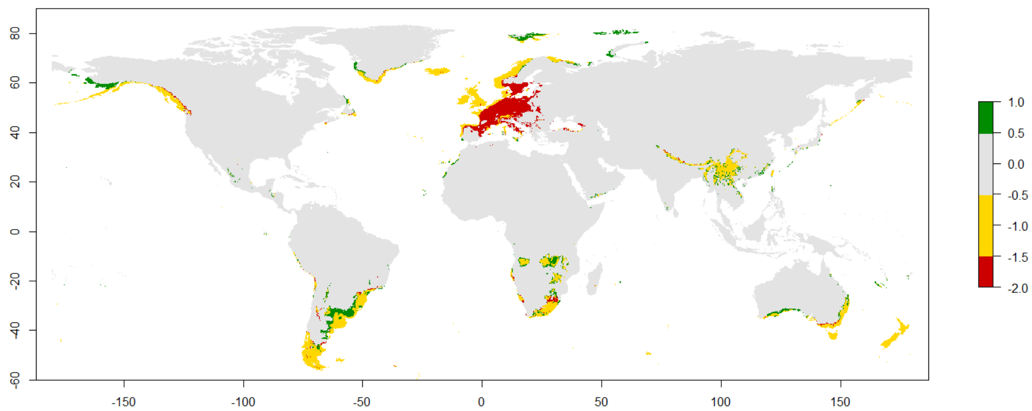

Figure 4: Expected distribution change in the world by 2050. Red is lost, yellow is remaining suitable, and green is gained

This is the map of expected distribution change focusing on its present distribution (Fig.5).

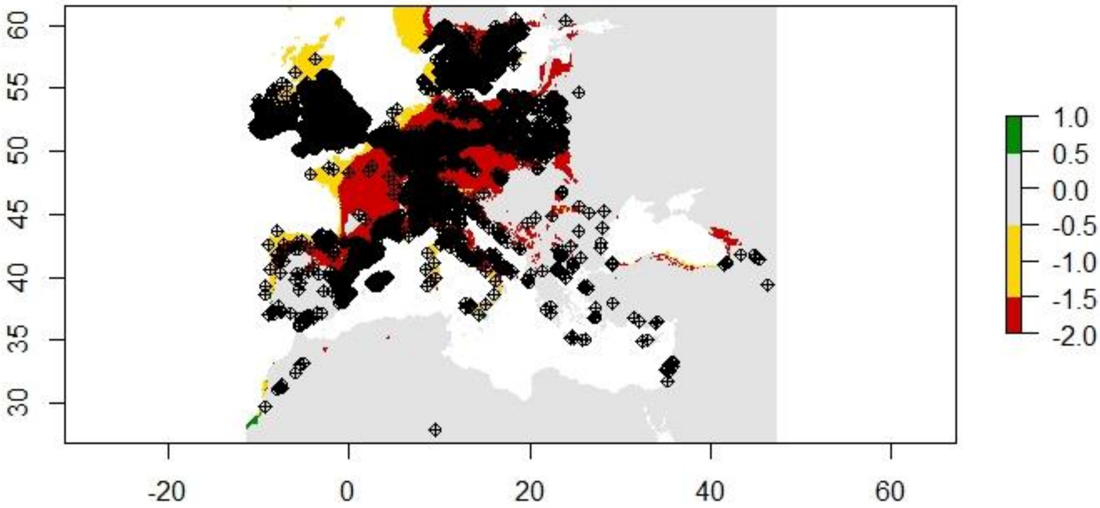

Figure 5: Expected distribution change in area of current distribution by 2050. Red is lost, yellow is remaining suitable, and green is gained. Black dots indicate records from GBIF.

Interpretation

Based on this model, large parts of *Lasiommata megera*'s distribution will become unsuitable, including Northern Africa, the Middle east, Central Asia, and Southern, Central and Eastern Europe (Fig.5). Parts of the Arctic will become suitable (Fig.4).Thus, *L. megera* is expected to shift northwards, relinquishing almost its entire inland southern and eastern distribution, and gaining area in the North, although likely limited by dispersal constraints. An already declining population in Northwest Europe in combination with a massive loss in habitat suitability in the aforementioned areas would make conservation of this species a priority.

Unfortunately, the model is not very useful. Already in the present, the area with suitable habitat according to the model does not fit the present distribution of *L. megera*. The model points out large parts of the species' southern and eastern distribution, such as the Balkans, North Africa, Central Spain, the Middle east and Central Asia, as unsuitable to begin with (Fig. 5). However, the climate in these areas is presently suitable for this species, as evidenced by stable population trends. In the Northwest, it points out Scotland, Iceland, Norway and parts of the Arctic as suitable (Fig.2), while the present distribution does not go north of approximately the line Stockholm-Oslo-Edinburgh. North of this line, the species is constrained by climate, as the species needs regular temperatures above at least 15 degrees Celsius in summer. Thus, the model underestimates the habitat suitability in south and east, while overestimating in north and west.

This misconception of the present distribution is likely due to the much better record in Northwest Europe (Fig.1), causing a bias towards the north and west. Moreover, in Northwest Europe, the oceanic climate is predominant. The difference between this climate and a continental climate depends for a large part on two variables selected for this model: precipitation and temperature seasonality, respectively the third most important and the most important one (Table. 1). Thus, the variables chosen exacerbate the bias effect, by effectively selecting on similar oceanic climates, mostly ignoring *L. megera*'s distribution in areas with a Mediterranean or continental climate. This bias towards coastal and highland regions with an oceanic climate can clearly be seen in figure 2.

For the future, this effect is even more amplified, as the distribution map shows almost the entire mainland Europe habitat as unsuitable, with only the coasts suitable (Fig.3). Furthermore, although many coastal regions in the Arctic are modelled to have a suitable climate in the future, this is unlikely in the short term; temperatures will need to rise with more than 5-10 degrees Celsius before these areas become suitable. Finally, central Europe is also unlikely to become unsuitable any time soon, since this species actually prefers very high temperatures, actively looking for spots with a local microclimate upwards of 40 degrees Celsius, and is only vulnerable to very long droughts.

Apart from the problems in estimating the climate suitability, the model also leaves out two very important factors. On the one hand, land use, and changes there in, which is an important driver for *L. megera'*s distribution, and likely the cause for the decline in Northwest Europe; and on the other hand dispersal constraints, since this species has limited dispersal capability above open water. Although it is a good flier, it needs to rest and warm up regularly, making a cross to Iceland or Greenland unlikely.

Nonetheless, it is important to note that in Northwest Europe, *L. megera* has indeed contracted its range to the coast. There is some clue that this is due to moderating effects on extremes in climate, for which the caterpillar and pupa are sensitive. However, in other parts of Europe, no such contraction has been observed. It is also likely that the species will spread North in the future, colonizing Scotland, parts of Scandinavia, and maybe in time, with help from a southern gale, Iceland. A possible future collapse in Southern and Southeast Europe due to desertification, since caterpillars are vulnerable to long droughts damaging the grasses upon which it feeds, is also possible. Thus, there is some truth in the model, but an improvement, focusing more on temperature variables, can be made.

References

Bos, F., Bosveld, M., Groenendijk, D., Van Swaay, C., Wynhoff, I., & Vlinderstichting, D. (2006). *De Dagvlinders van Nederland: verspreiding en bescherming;(Lepidoptera: Hesperioidea, Papilionoidea)*. Nationaal Natuurhistorisch Museum.

Stip A., WallisDeVries M.F. & B. Omon (2014). Beschermingsplan argusvlinder. Rapport VS2014.026. De Vlinderstichting, Wageningen.