Effect of climate change on the distribution of Caribou and Canis Lupus in North America

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Abstract

Background

Caribou refers to the North American subspecies of Rangifer tarandus, also known as the Reindeer in Europe and Asia. North American populations of caribou primarily inhabit the tundra and boreal forest ecosystems, presently ranging from Alaska across most of northern Canada. The gray wolf (Canis Lupus) is the primary predator of caribou, and is found in much of the same habitat as the caribou. On the other hand, caribou's main food, especially during winter when other food sources are not available, is fruticose deer lichen (Cladonia rangiferina), and it is also found in much of the same habitat. Because arctic environments and the species inhabiting them are particularly vulnerable to the effects of climate change, the natural distributions of the caribou, the gray wolf and the reindeer lichen are expected to change in the near future due to the adverse effects of climate change. To analyze the effect of climate change, climate data variables such as temperature and precipitation, are measured at present time and by using climate models to predict the conditions in 2070.

Results

Using maximum entropy (Maxent) species distribution modeling, we examine the current distribution of Rangifer tarandus, Canis Lupus and Cladonia rangiferina

on the continent of North America, predict the possible distribution in 2070, and attempt to explain the various factors that influence the distribution of caribou, gray wolves and reindeer lichen. The results show us that the suitable habitat area of the Caribou shrinks by quite a lot, while the habitat of the gray wolves and the lichen remain almost the same.

Conclusions

The main conclusion that we can make is that the distribution of caribou will shrink due to the effects of climate change, even though food sources such as Cladonia Rangiferina will still be available. While the results of the habitat change of gray wolf are inconclusive, we have to consider what the lesser numbers of Caribou, the gray wolf's main food, will mean for the distribution of gray wolves in North America. However, it is important to note that the analysis of these species' distributions only took into account the effects of climate change based on climatic variables. Other anthropogenic factors such as increased human activity in the arctic and tundra regions are also likely to have an impact on many arctic species, including caribou and grey wolves.

Keywords

Caribou, Raindeer, Canis Lupus, Gray Wolf, Reindeer lichen, Cladonia rangiferina, Maxent, Climate change.

1 Introduction

Our research involved three species: Reindeer lichen (Cladonia rangiferina), caribou (Rangifer tarandus), and gray wolves (Canis lupus), which can all be found in similar ecosystems, including boreal forests and tundra. We chose to focus on these species' distributions in North America specifically, as they all also exist on other continents, most notably in the northern latitudes of Europe and Asia, where similar ecological conditions are found. These three species are also integrally connected as part of a food web: lichen makes up a substantial part of the caribou's diet, especially in the winter months when other vegetation is not available as a food source. Wolves are one of the main predators of caribou, especially at northern latitudes where other prey is not as

common.

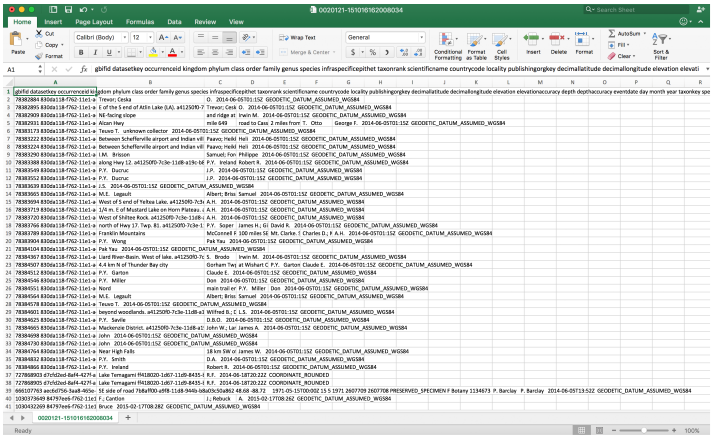
We chose to investigate the potential effect of climate change on these species because they inhabit an ecosystem that is very vulnerable to climate change. Air temperatures in the Arctic have been warming on average at twice the global rate, with the strongest warming in the winter and spring. Precipitation in the arctic has also been slowly increasing, but the overall trend is less clear than for temperature [3]. Arctic climate change is expected to have a direct impact on species such as caribou, which have evolved specifically to thrive in cold climates. In addition, climate change could have significant effects on the food web, which is why we decided to investigate the caribou's primary food source and predator as well.

Our investigation used MaxEnt to establish distributions for all three species, based on location data found online. By comparing these distributions to current climate data, MaxEnt can predict a distribution of these species in 2070, using future climate data obtained from climate models. Since arctic climate change will mainly be affecting temperature and precipitation, we chose similar climate variables that we thought would be most likely to affect our three species. Although we only considered climate related variables, MaxEnt showed that the distribution of caribou was likely to decrease in the near future, which in turn might have significant effects on other species, including grey wolves.

2 Methods

We gathered the caribou and gray wolf current data from vertnet.com, and the Cladonia rangiferina data from gbif.org (Global Biodiversity Information Facility). From the downloaded datasets in .tsv format, only the latitude and longitude coordinates were used to create the current distributions of all three species. These distributions were also filtered to only consider location data for North America, as all three species can also be found elsewhere with similar ecosystems, such as Eurasia. (Figure 1)

In order to predict the distribution of each of our three species of interest in the year 2070, we used maximum entropy modeling (MaxEnt). We used current global climate data as well as future global climate predictions obtained from worldclim.org.



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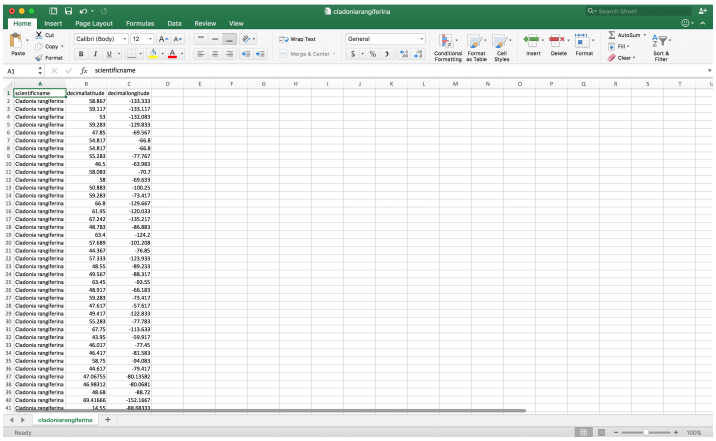

Figure 1: Cladonia rangiferina data

We decided to use the following four climate variables: Annual Mean Temperature, Precipitation Seasonality, Precipitation of Driest Quarter and Precipitation of Warmest Quarter.** These variables should account for the main differences in climate between now and 2070, and should therefore have an impact on the possible distributions of all three of our species. The climate data was downloaded from worldclim.org in raster format, which was then converted to Ascii (.asc) format using the ArcGIS software. We chose to download data for 2.5 arc-minute resolution, which gives detailed data for a small area while keeping the file size manageable. For the future climate data, we chose to download data from the BCC-CSM1.1 climate model, following the RCP85 trajectory. The RCP projection simply allows to control for the amount of greenhouse gas emis-

sions [4]. So RCP85 represents one of the more pessimistic, but realistic, greenhouse gas emission scenarios, where emissions continue to rise throughout the 21st century, which could happen if nations do not take policy action to mitigate their emissions. Once all the input data was correctly obtained and formatted, we ran MaxEnt and obtained the results in the 'raw' format, which is the simplest output format, and just shows the results of the Maxent model for where the species is more suitable to live in.

3 Results

MaxEnt results are shown in the form of maps that indicate the suitability for where each species is likely to be able to live. Figure 2 shows the present distribution, and Figure 3 shows the future distribution for reindeer lichen (Cladonia rangiferina). It is clear that most of the continent of North America (except for some parts of Mexico) is habitable for Cladonia rangiferina, and even in 2070, the distribution does not change too much.

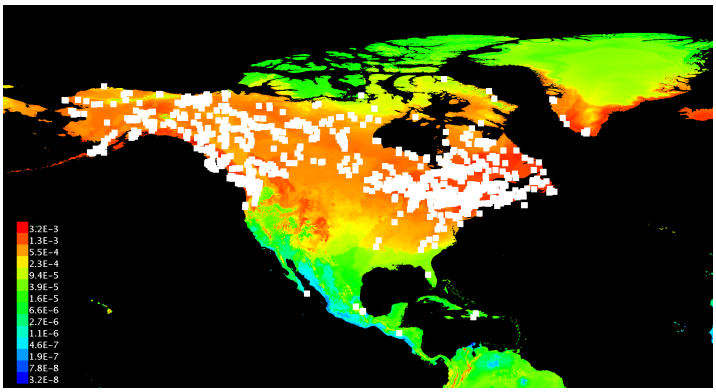

Figure 2: Distribution of Cladonia Rangiferina in North America

Cladonia rangiferina is a very hardy lichen, which can grow in varied conditions of temperature and precipitation. Unlike many plants, it is also well suited to very cold climates, which enables it to grow at high latitudes in the tundra ecosystem. By absorbing moisture directly from the air, it is also able to thrive in areas with low precipitation [6]. This can be seen in the map because much of Alaska, Northern Canada, and even coastal Greenland is seen as a suitable habitat for Cladonia rangiferina,

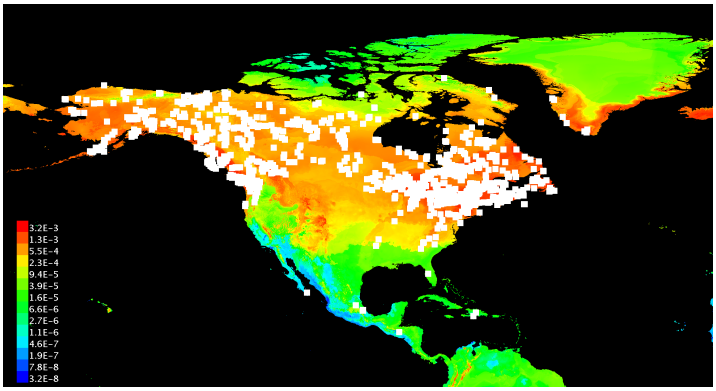

Figure 3: Distribution of Cladonia Rangiferina in North America

whereas the southern portion of the US is less suitable. By absorbing moisture directly from the air, it is also able to thrive in areas with low precipitation. (US Forest Service)

Figures 4 and 5 show the current and future distribution of caribou. We immediately notice that the amount of suitable habitat for caribou noticeably shrinks between now and 2070, which indicates that climate change will probably have a significant effect on the current habitat of caribou. [1] [2] [5]

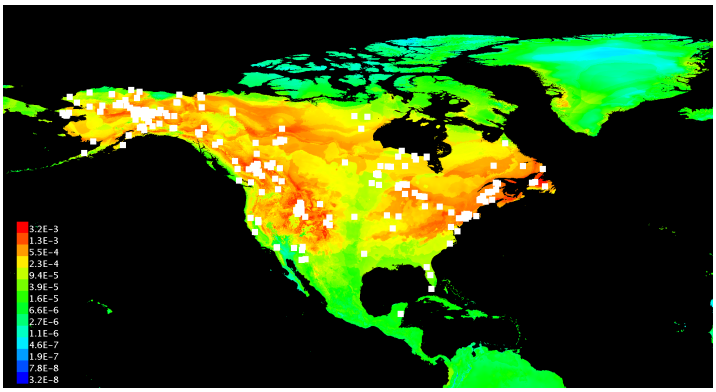

Figure 4: Distribution of Caribou in North America

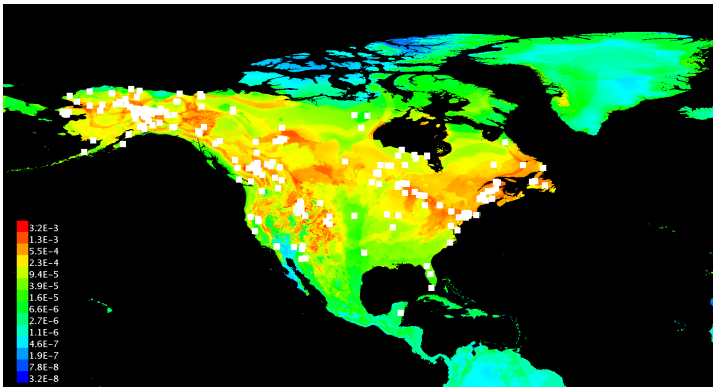

Figure 5: Predicted Caribou habitat for year 2070

4 Discussion

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