Effect of climate change on the distribution of Caribou (Rangifer tarandus)

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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.

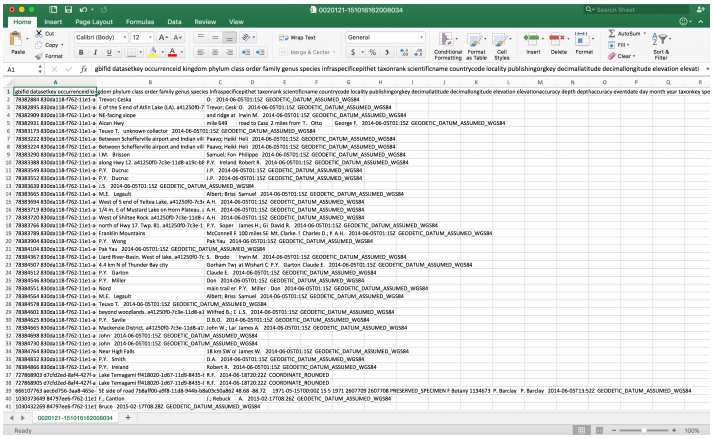
Our investigation used MaxEnt to establish distributions for all three species, based on location data found online. By comparing these distributions to current climate data, MaxEnt can predict a distribution of these species in 2070, using future climate data obtained from climate models. Since arctic 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. 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



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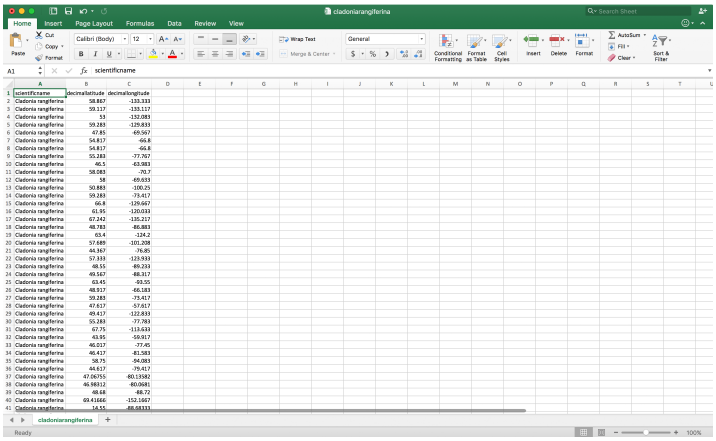

Figure 1: Cladonia rangiferina data

trajectory. The RCP projection simply allows to control for the amount of greenhouse gas emissions [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.

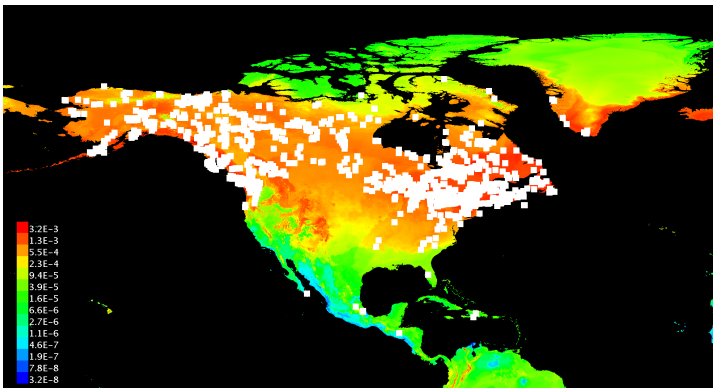

Figure 2: Distribution of Cladonia Rangiferina in North America

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, whereas the southern portion of the US is less suitable.

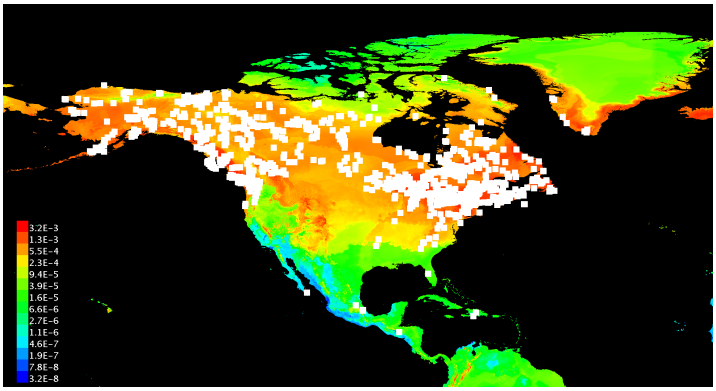

Figure 3: Distribution of Cladonia Rangiferina in North America

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. However, some of the reported locations of caribou seem highly unlikely, such as the Yucatan peninsula in Mexico, or Florida.

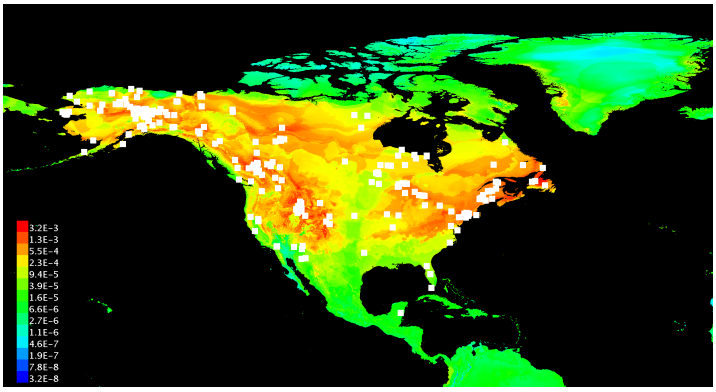

Figure 4: Distribution of Caribou in North America

This might be due to errors in reporting the location, or it might be location data from caribou found in zoos. The amount of suitable habitat for caribou seems to shrink across the entire continent, so overall we predict that due to climate change, especially

warming in the near-arctic region, caribou will have less suitable habitat in the future.

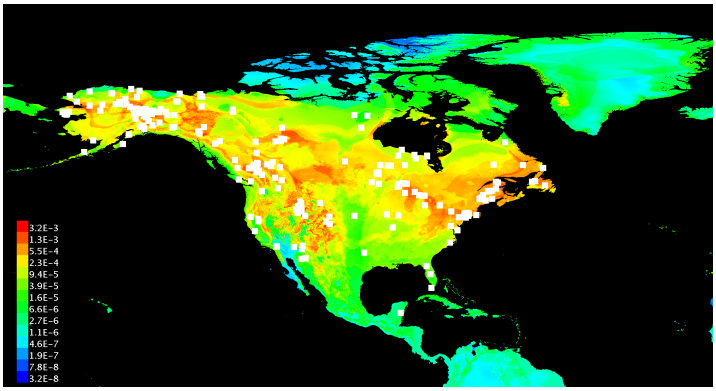

Figure 5: Predicted Caribou habitat for year 2070

Figures 6 and 7 show the current and future distribution of grey wolves. Their current suitable habitat covers much of the continent, and even in 2070 it appears that they would not be affected too much by climate change, as there is only a slight decrease in suitability in some areas of the continental US. Overall, it seems that grey wolves should still be able to live across North America, as they are able to live in varying climate conditions.

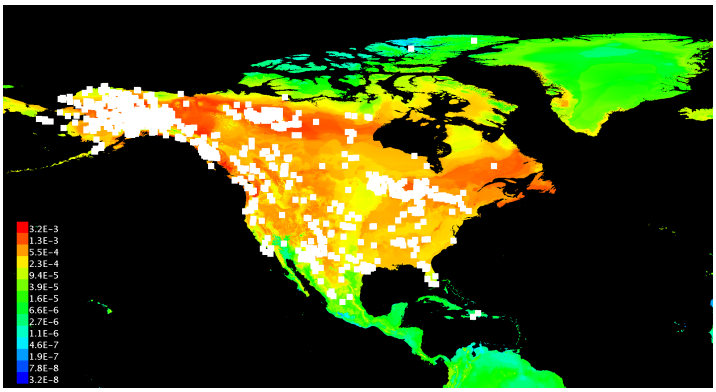

Figure 6: Distribution of Canis Lupus in North America

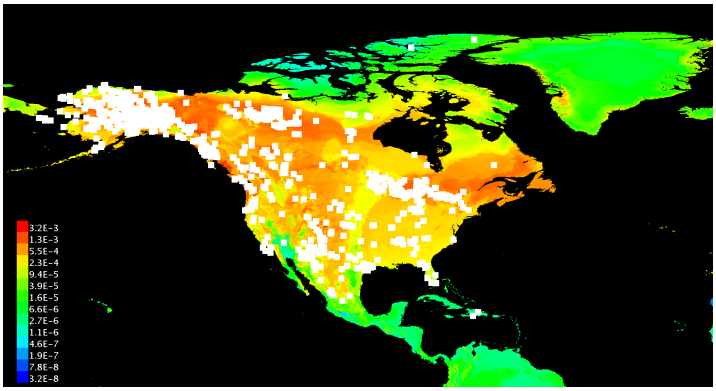

Figure 7: Predicted Canis Lupus habitat for year 2070

4 Discussion

Our results showed that reindeer lichen and grey wolves are unlikely to be affected very much by climate change, probably due to the fact that they can thrive in many different climatic conditions. However, caribou are specialized to live in cold climates, and so climate change is more likely to impact them, as seen by the fact that their suitable habitat decreases substantially.

Because MaxEnt only considers climate variables when modeling the distributions of these species, there are likely some discrepancies between where these species are actually found and where MaxEnt predicts them to be found. For example, according to the MaxEnt maps, grey wolves could live pretty much anywhere in North America just based on how suitable the climate is, yet there are definitely other factors that influence where wolves actually live. One such factor is the availability of prey, since wolves' actual habitat seems to be more affected by where their prey lives than by climatic or ecological factors [8]. We can also assume that human presence, or lack thereof, is another major factor in determining where wolves would live, as they tend to prefer remote areas, away from large human presence. Although climate change does not appear to

directly affect the distribution of grey wolves, it is possible that grey wolves would be affected indirectly. In our results we see the distribution of caribou shrink, especially in the Northern part of Canada, where caribou provide the main prey for wolves. This suggests that even if the climate could support large populations of wolves, there might not be enough prey, and so wolf populations might decrease or relocate to areas with more prey. In addition, if climate change leads to more human activity near the arctic (such as mining, fossil fuel extraction), it is likely that wolves will not be able to inhabit those regions.

Similarly, the distribution of reindeer lichen seems relatively unaffected by climate change. These lichens would also likely not be as affected by other factors, although a decrease in predation from caribou might actually lead to an increase in lichen. The current and future distributions of the lichen overlap with the distributions of caribou, which suggests that food availability would not be an issue for caribou, even if their suitable habitat changes, because they are likely to find Cladonia rangiferina in almost every possible habitat in North America. In addition, caribou diets include a variety of other plant species such as willow, lichen, forbs, and graminoids, depending on the seasonal availability [5].

Caribou themselves are most likely to be affected by climate change. Even though the MaxEnt map for present distribution indicates that a large portion of the continental US is climatically suitable for them, their actual distribution in the US (excluding Alaska) is limited to the Columbia Mountains, in between Idaho and Washington [7]. Human presence likely explains this discrepancy, as caribou avoid human activity as much as possible, staying several kilometers away from roads, railways, forestry activity, and oil or gas infrastructure [2]. This also explains why caribou are mainly found in boreal forest or tundra ecosystems of Alaska and Northern Canada, where there are

far fewer human activities.

One of the most dramatic changes in caribou suitability can be seen in the northern part of Canada, across Nunavut, the Northwest Territories, and Yukon. This corresponds to the habitat of the migratory tundra caribou ecotype, which differs from the more sedentary boreal caribou ecotype, the mountain caribou ecotype, and the Peary caribou, which inhabit the High Arctic [2]. Tundra caribou live in large herds, and migrate seasonally across the tundra, whereas the other ecotypes tend to be more sedentary and live in smaller groups.

The direct impact of climate change on caribou can be explained by examining the effect of temperature and precipitation on their lifestyle. The predicted increase in temperature from climate change can lead to many adverse effects for caribou, such as increased duration and intensity of insect harassment. In the summer months, caribou face harassment from swarms of mosquitos, warble flies, and nasal bot flies, and the young and sick animals are especially vulnerable to having their energy and fat reserves drained by insects. Insect activity starts when temperatures reach approximately 6°C, so earlier and warmer summers are likely to lead to increased insect harassment, which would leave caribou undernourished and weak heading into the winter months [1]. Another major effect of climate change will be in the spring, when winter snow starts to melt, and caribou start to feed on spring vegetation. Since climate change could lead to an earlier start to spring, abnormally early snow thawing and freezing could lead to food sources such as lichens being frozen under solid ice, and therefore inaccessible to caribou. It would also disrupt the caribou lifecycle, because the availability of spring growth in May/June and their nutrients generally coincides with when females begin to lactate and need the most energy and nutrients. Therefore, early snowmelt and early feeding could lead to a deficiency later on, when food sources are

most needed [1]. Finally, if precipitation increases during winter months, more snow cover could hinder caribou's mobility when migrating or escaping from predators, and make it harder to obtain snow covered food sources [1].

The distribution of caribou in 2070 is substantially smaller than the current distribution because of the adverse effects of climate change on the caribou's environment. Although not considered as part of our distribution model, indirect effects of climate change are likely to cause an even greater decrease in the potential habitat for caribou. Climate change may lead to an increase in competition from other species such as moose or deer, which could move northwards as temperatures warm up, potentially even bringing predators that follow them. However, the greatest effect of climate change on caribou might simply be caused by increasing human activity in caribou habitats.

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