Effect of Climate Change on Arctic Fox (Vulpes/Alopex Lagopus)

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Abstract. Under the context of climate change, global warming, arctic regions are undergoing a rapid pattern transformation. This paper investigates the link between global warming and arctic fox (Vulpes/Alopex lagopus). This paper focuses on changes in environment. This paper deals briefly on the consequences of climate change and its impacts on various ecosystems in arctic regions. By the in-depth study of the arctic fox traits and compare between regular patterns and features after climate change, it's clearly to see how much extent the arctic fox is influenced by climate change. This research focus on different characteristics of arctic fox, which are habitat and distribution, coat color change, changes in diet and diseases related to arctic fox cause by climate change. Those are the direct factors that allow people to recognize how climate change is affecting the Arctic fox. This research not only study the direct climate change impacts, as well as the interaction between species. Climate changes in arctic ecosystems alter the ordinary interactions between species in a large extent. The changes in habitats competition and predatory relationships are caused by the species interaction straightforward by the influence of global warming. By analyzing the arctic fox in a broader aspect, people can have a better understanding the challenges that arctic species facing and how arctic fox adapt to new environment successfully. After people become more aware of the severe situation among arctic, they can gain more valuable insights of arctic species adaptations and make effective solution in conservation and protection. Knowing the adaptations of arctic fox is essential for conservation strategies, preservation of arctic biodiversity and maintenance of ecosystem stability.

Keywords: Arctic, arctic fox, red fox, global warming, diet, habitats, sea ice, Rabies.

1. Introduction

In recent years, climate change affect ecosystems and species in worldwide. As the one of the pole regions of earth, arctic regions including arctic ecosystems and its species are especially vulnerable to climate change and global warming. Increasing in the rate of global warming accelerates the changes general pattern of arctic regions. Starting from about the year 2000, the difference of average temperature rises at a significant rate. In nowadays, the average temperature after climate warming in arctic is two times more than the average temperature in 2000. By studying how arctic species deal with rapid transformation of climate, the basic foundation of protecting arctic species is made. This research takes Arctic fox as an example to illustrate the genetic and behavioral adaptive responses to climate warming. Through the correspondence between the ecosystems that arctic fox live in and the variation occurs in arctic fox species, a more targeted and effective solution which contribute to long-term preservation and conservation of species survival is formed.

Global warming has always been a much-discussed theme in biology and ecology. Scholars from different countries have studied in the broader and narrow insights of how climate change the world, from different angles such as the tropics regions, polar regions, diseases, and physiology. In recent years, many scholars have proven the cataclysmic effects of losing in sea ice, drastic fluctuation in species population dynamics are the consequences of climate warming. Arctic fox are facing challenges of unstable diet, loss of habitats and heat up of habitats competition between species and so on. The population of rodents which arctic fox feeding on fluctuate drastically, as well as their competitor red fox leads to habitats competition. This research not only investigate the climate impact on arctic fox but also other species in arctic. Like arctic fox, fish and other mammals are all facing the problems of diet. With temperature increase drastically, fish population have less food resource availability whatever their food is shrimps, plankton organism or other fish. Habitats of arctic fox are devastated by the effects of accelerating temperature rising, as well as other species. Increasing in ocean temperature cause fish population abandon their original habitats and further cause the mismatch between migration between time and food. This is less common among arctic fox species but typical in cetacean.

This paper briefly introduces general effects of global warming on ecosystems and species other than arctic fox. The correlation between environment changes and arctic fox characteristics is echoed around in this paper. To demonstrate the extent of how arctic fox is influenced, this paper discussed the regular live pattern of arctic fox and the significant differences amidst regular and after are shown.

2. Climate Change in Arctic

Climate change is always concerned and discussed in the various researches related to life science. Understanding the climate change in arctic leads to a better comprehension of effects on different species. This research discussed the general climate change which refers to the phenomenon of getting warmer and its effect in arctic, including the impact of global warming on diverse ecosystem and difficulties brought to arctic species.

2.1. Effect of Climate Change on Arctic Ecosystem

Global warming is always the focus of most attention. Arctic is a polar region of the earth, the extreme north region. As such a special region, the changes in the environment will be magnified in the Arctic. Climate warming in arctic regions will be fast as two or three times the rest of regions due to the sea ice loss, which is the direct effect of global warming in the Arctic. In arctic, sea ice is the basis of habitats constructions for most animals, so when global warming occurs in arctic regions, normally follow by a decline in the extents and thickness, less snow, altered nutrition distribution, freeze-thaw events and so on, all led to the changes in arctic ecosystems [1]. Different types of arctic ecosystems will be discussed in this section of the climate change of the Arctic system. In the terrestrial ecosystems, researchers in high altitudes of arctic zones indicate that mortality and breeding potential in arctic herbivores are negatively influenced by warmer temperatures and Rain on snow events [2]. Large herbivores shift from woodland to higher arctic altitude due to their ability to cope with different environments. In fresh water ecosystem, the effect of climate change is terrestrial catchments and aquatic ecosystems are experiencing an increase in temperature and productivity. For marine ecosystem, the most direct and observable effect of climate change deceasing in sea ice. Increasing in temperature cause the ice extents to decrease in a large extent, which is a severe trouble to various marine species in arctic [3].

2.2. Challenges Faced by Arctic Organisms

Increasing in sea surface temperature, rising in sea levels and changing in ocean circulation, drastically affect the cetacean species [3]. On one hand, due to the climate change, the livability of hatchlings of each species and habitats and food availability are seriously threatened by global warming. Challenges faced cetaceans in the arctic marine ecosystem are tightly related to global warming. The marine heatwave damaged 36% of seagrass meadows which further influence the fish stocks. The lower prey availability means a reduction in food source availability. On the other hand, the cold adapted species is unbearable to warmer. For instance, arctic cod can't reproduce efficiently when there's an increase in 4°C [4]. Whenever the adult animals can't find sufficient foods and can't successfully reproduce, the abortion rates and neonate mortality will have a high possibility of occurrence. Moreover, global warming on arctic may affect the crucial events of arctic species. Many marine animals are migratory, based on temperature and food resource [3]. So, a potential challenges cause of global warming is the mismatch between food source and migratory timing. As well as in the marine ecosystem of the arctic, species in terrestrial ecosystem greatly influenced by global warming. Lichens and mosses are especially sensitive to light sensitivity [5]. By going through the warmer climate and warmer tundra, the cover of riches and mosses are reported to reduce. Further influence the habitat and migration of caribou in North America.

3. Population of Arctic Fox

A small fox that categorized in the family of Canidae, native to the arctic regions. Arctic fox is one of the most characterized species in arctic tundra regions. As an arctic species, it's crucial for arctic fox to tolerate high temperature difference of 90-100°C between the outside environment and the core's internal temperature [6].

3.1. Distribution and Habitats of Arctic Fox

Nowadays, the arctic fox is mainly distributed in all kinds of tundra regions (Fig. 1), extending from the sub-arctic mountain tundra which located in central Fennoscandia, cross most of the arctic tundra in Eurasia and North America, and almost all the large Arctic and sub-arctic islands [7]. In past centuries, a typical era is the last glacial maximum (LGM), which is the last glacial coldest period. In this period of time, Ice sheets covered much of North America, Northern Europe, and Asia. Permanent ice covered approximately 8% of Earth's surface and 25% of the land mass area [8]. During this period, the majority of central and northeastern Eurasia were inhibited by large parts of arctic fox populations. However, for recent, as the consequences of the warmer climate, the arctic fox are forced to confine in the tundra regions in the northern hemisphere [9]. Increasing in temperature in arctic tundra interacts with the behavior of other plant species, further alter the habitat distribution of arctic fox in a detectable trend.

Figure 1. Nowadays distribution of arctic fox. https://portals.iucn.org/library/node/8500

3.2. Life Histories, Reproductive Strategies, and Habitats of Arctic Fox

In arctic fox species, each couple is monogamous and its mating season occurs during the months of February through May, yearly. Arctic foxes are distributed on two types of tundra: inland and coastal tundra and are adapted to two different ecosystems within their habitats., respectively, are costal foxes and lemming foxes [10]. They have diverse reproductive strategies. First is the lemming arctic fox which is specialized on cyclic rodents. Reproduction of arctic fox largely depends on the food resource availability. Arctic fox is meat-eating animals that relies on typical rodent species, the lemming, which strongly determine the reproductive events of arctic fox. In the abundance of lemming population, arctic foxes have substantial dietary reserves and they breed off springs up to 19 young [7]. However, hardly no litters are born when there are fewer lemming population. Another ecotype within the range of distribution is coastal foxes, which located in the inland or coastal areas without a significant role of rodent species [10]. Arctic fox inhibition in this ecosystem has a relatively stable reproductive frequency but fewer than lemming arctic fox does. Foxes in this archetype reproduce four to five cubs per litters, and up to 11 cubs per litters.

4. Impact of Climate Change on Arctic Fox

As arctic regions are experiencing rapid transformation caused by climate change, being an arctic species, the arctic fox has high level of vulnerability to climate change. So it's important to delve into how arctic fox adapting this. By analyzing the genetic variability, the investigation of coat color changes and discoveries of factors that determine survival, this research provided a better understanding the adaptive strategies of arctic fox.

4.1. Coat Color Variation of Arctic Fox

Arctic fox usually has two color types which are white and blue. White foxes have their fur in brownish-grey in summer and blue fox remains charcoal all year round, for the purpose of camouflaging in habitats. Though the blue morph had a lighter color in summer, it's still much darker than the color of white fox in the summer [7]. The coat color of arctic fox changes seasonally to blend within their surrounds and protect them from predators. The MC1R gene, a specific type within is the MC1R/agouti control, plays a significant role in the synthesis of pigment and altering fur color. Mutations in the blue fox's MC1R gene affect its function, resulting in turning darker even in the absence of a natural ligand. This unique trait allows the blue fox to maintain dark fur throughout the whole year, making it an advantageous camouflage in low-snow environments [11].

Within global warming, the snow cover duration decline and arctic fox are exposed to low-snow environments in most of the time. Blue fur will better match the background environments color and consequently arctic fox tends to enhance the frequency of showing in blue [12].

4.2. Changes in Habitats Distribution

Being an arctic species, the arctic fox is sensitive to increasing in temperature. A shift in habitat distribution is adaptive strategies used by most species. Habitats distribution of arctic fox largely affected by environment variability. The changes in climate warming in arctic biota cause the habitats of arctic fox in a general trend of shifting to norther areas. Previous researchers extracted with mitochondria deoxyribose nucleic acid (mtDNA) from Pleistocene, in Europe today. By comparing with the locations where same type mtDNA found in modern days, a general tendency shifting north is exhibited [9]. Impact of climate warming on habitat are listed, whenever there is a temperature plunge, the movement of habitats produces a stark contrast. During the little ice age, a time period where the temperature globes decreased in 2°C, there was a cooling in north atmosphere. A sudden decrease in atmosphere induces frequent sea ice grounding which refers to a transmission that grounded ice transforms to freely floating ice. This event promotes arctic fox to migrate from Greenland and other arctic regions back into Iceland [13]. A tendency that migrate from the arctic circle to regions outside the boundary of arctic regions.

By experiencing a drastic increase or decrease in arctic temperature, this is the direct factor that causes a shift in arctic fox habitats. Climate change, in other words, global warming didn't only affect Arctic fox species, but also the red fox (Vulpes vulpes). There's a close connection between red fox and arctic fox, which for example in low altitude in Finnish Lapland and Greater Prudhoe Bay area in Alaska, and increase in the construction of red fox always accompanied by a decline in arctic fox (Fig. 2). So as global warming alters the habitats of red fox, it indirectly causes a shift in habitats of arctic fox. An indirect way to influence the habitats is by altering the habitats arrangement of red fox. Global warming has less effect on red fox species instead it favor red fox, compared to arctic fox, elevating of the red fox's competitiveness threaten the habitats arctic fox. Red fox weighs heavier than arctic fox about 60% [14]. Red fox is the main competitor and hunter for both infantile and adult arctic foxes either wherever the habitats are [5].

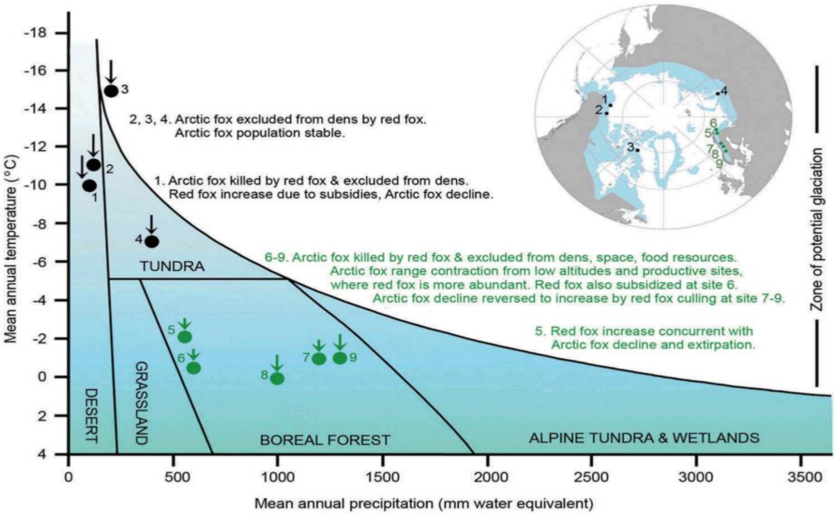

Figure 2. The interaction between species and effects on arctic fox at different sites.
https://www.tandfonline.com/doi/full/10.1080/17518369.2017.1319109

As the climate in Arctic becomes warmer, shrub encroachment occurs in arctic and tress and species start to develop to the north. Red fox follows the ecotypes which it belongs to and move norther. In a relatively low altitude, the habitat distribution will be mainly determined by the irruption of red fox. In this case, the habitats of arctic fox and red fox are in the same geographical regions, lead to an intense interaction between red fox and arctic fox [7]. In Fennoscandia, arctic fox will retreat to and construct habitats in higher altitudes to dodge from the presence of red fox. When the red fox being close to the habitats of arctic fox, arctic fox will waive the den and move to somewhere far away from red fox [14].

4.3. Change in Diet Characteristics of Arctic Fox

Within a decline in food source availability, finding food among snow is a challenge for arctic fox. So whether arctic fox will change their dietary structure? Therefore, this section discusses the food problems and alternative food among arctic fox.

Global warming will affect the arctic fox's behavior in the aspect of altering the food source availability. Main food sources for arctic foxes are rodent species, such as lemming, voles and other oceans-based seals. Under the condition of global warming, the cycle of population growth for lemmings and voles will come to be increasingly more unbalanced [7]. The ice melts and freezes, the repetition of those processes will cause the Freeze-thaw events and result in the formation of incrustation ice that makes the food plants unattainable. The lemming and voles themselves will have a problem of foraging, leading to the foraging problem in the arctic fox. Arctic fox is deemed as opportunistic forager in researchers. Under the case of global warming, arctic fox which is a terrestrial animal will transfer the main food source from rodents to marine species. A previous study shows that in arctic fox samples, a protein that derived from marine increased from 17% to 46% in the first two years of lemming populations decreasing [15]. A evidence pointing to that in the case of a decline in lemming population, diet is turning to the marine, cause much sea seal carrion is contained in it. The switching of main food resource is known as an alternative foraging behavior [16].

4.4. Change in Diet Characteristics of Arctic Fox

Global warming has a close relationship to the diseases spreading in arctic fox species, so this section explores how changing in climate influence the spreading disease among arctic fox. In the case of global warming, a consequence related it that arctic foxes are going more frequently to find substitute food recourses of lemming. So, when Arctic fox invest a large proportion of time foraging, they make contact to infected species and thus the chance of becoming rabid fox has increase [17].

A previous study set up a model to demonstrate the rabies dynamics among arctic fox, and it shows that the rabies infectious is cyclic and pronounced more seasonally. The number of rabid foxes is reported lower in summer and higher in winter. One explanation is relevant to the deterioration of sea ice in which it limited the ability for arctic fox to move in a large extent [18]. For arctic fox, they have capable of moving thousand kilometers per year on average [13]. The longest distance traveled by an arctic fox increases the possibility of interaction with rabid species which increases the chance of getting infected. However, global warming makes as an inverse result. A decreasing in arctic sea ice lowers the number of rabies infection, owing to the loss of sea ice acreage limits the ability for arctic fox traveling on long distance and make frequent contact with rabies pathogens.

5. Conclusion

The impact of global warming has been discovered over arctic regions. Increasing in temperature causes a decline in sea ice extent and thickness and a significant rise in sea temperature. In this case, arctic species are unable to reproduce successfully. The extremely high sensitivity to seawater makes organisms unable to adapt to the increase in seawater temperature. To blend in the environment that loss a huge amount of ice, arctic foxes have to adjust their coast color of showing blue more often. MC1R gene plays an essential role in this process. Large fluctuations occur among nutrition distribution threaten the foraging behaviors and mismatch between migration season and food availability. In the last coldest glacial period, arctic fox is distributed largely in the parts of central and northeastern Eurasia. However, in nowadays, the distribution of arctic fox shift to norther and higher altitude, this is because arctic foxes were trying search regions that match their adaptations that fit in the cold areas. At the same time, rises in red fox population and fierce competition between habitats induce arctic fox to retreat. Climate warming lead to the present of freeze-thaw events. Creating a layer of ice crust cause plants nutrients less accessible by rodents. The decline in rodent population makes arctic fox foraging become a handicap. In this situation, arctic fox distracts their preliminary prey from rodent species to sea species for substituents. Surprisingly, rabies, an infectious disease that is deadly to humans, has little effect on Arctic foxes. Ability to migrate in long distance of arctic fox is stint by the loss of sea ice extent, which makes rabies difficult to transmit.

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