# The Impact of Climate Change on Animal Behavior: The Arctic Marine and Monterey Bay Ecosystems

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## Abstract

Climate change affects ecosystems worldwide and the entire biosphere. Although the effects of climate change have been well researched, comparisons of its effects on animal behavior across ecosystems are lacking. This study compared the changing behavior of marine mammals in the Arctic marine ecosystem to that in the Monterey Bay ecosystem to narrow this gap. The Arctic marine ecosystem provides habitat for thousands of species, including polar bears, seals, fish, whales, and many species of algae. The Monterey Bay ecosystem, a marine ecosystem located in northern California, is home to hundreds of species of kelp, sea otters, seals, sea lions, seagulls, and other animals. This study highlights the similarities and differences in the migration, predation, distribution, and reproductive behavior of selected animals in response to climate change. This study focuses on species central to each ecosystem: sea otters, seals, and dolphins in Monterey Bay and polar bears, seals, and whales in the Arctic. By accounting for the effects of climate change on animal behavior, predictions were made based on the connection between similar behavioral patterns of the two ecosystems. Through comparing the Arctic marine ecosystem and the Monterey Bay ecosystem, scientists can gain an in-depth understanding of the changes in animal behavior due to climate change across wide geographies and suggest a new method of observing the impact of climate change globally to enable more accurate ecosystem predictions.

Keywords: ecology; marine biology; marine ecosystems; climate change; the Arctic; Monterey Bay; behavioral ecology; animal behavior

## Introduction

The effects of climate change on various environments and changes in animal behavior have been thoroughly observed. In most of the world, climate change has destroyed animal habitats, removed food sources, and caused many more harmful events, as demonstrated by melting ice caps and intensifying storms (1). Changing environments cause some animals to become unfit for their habitat, forcing them to either adapt or migrate elsewhere. Many species acclimate to their new environment in situ, behaving differently to survive in unfamiliar habitats. These behavioral changes in various species also affect how they interact with each other (2). The

chain effects caused by climate change ultimately lead to major shifts in flora and fauna populations and significant alterations to ecosystems.

The impact of climate change can be seen all over Earth, affecting biomes worldwide. Numerous studies have been conducted on the various negative effects of climate change (e.g., 1; 3; 4). When climate change affects animal behavior, it causes chain effects that also impact humans. Furthermore, environmental change can become a major factor when considering the impacts of climate change. Climate change is not only a threat to the planet but also to animal and human lives. Increasing amounts of greenhouse gases exert many negative impacts on the biosphere, such as rising sea levels, melting ice, escalating extreme weather, and global warming (1). Studying climate change allows scientists to find methods to slow the process of global warming and protect the planet.

Additionally, the study of animal behavior reveals the reasons behind species interactions and animal responses to the environment. Scientists should be able to understand how animals survive and the process of evolution in nature. Studying animal behavior allows for a deeper understanding of instincts and adaptation when facing challenges. As climate change and other challenges prove to be a threat to animal survival, their behavior may change so that they can survive. Behaviors previously beneficial in an environment can become maladaptive, leading to a population die-off if they are not adjusted. Behavioral changes drastically transform interspecies relationships and ecosystems, as any shift in the behavior of a species can lead to a larger chain of reactions (2).

Climate change and animal behavior are closely connected through their mutual effects. A small shift in the climate of an ecosystem may force an organism to change its behavior entirely so that they are better suited to the environment. Environmental changes due to climate change force animals to adapt to or avoid these new challenges to their lifestyle. Not only do these migrations or adaptations affect interactions between different species, but also within the same species. Additionally, changes in animal behavior mediate climate change and the environment. When a species alters its behavior, these species can cause extreme environmental changes when the combined impact of these changes is a major consequence in their ecosystem. Climate change and animal behavior affect each other in many different ways and can harm the environment and permanently damage the biosphere (2).

This paper reviews the literature on climate change and animal behavior and their close relationship in the Arctic and Monterey Bay ecosystems. This research emphasizes the importance of observing the connection between climate change and changes in animal behavior and the major similarities in animal reactions to a changing environment in these ecosystems. Moreover, the differences between the responses of organisms in the two ecosystems allow for further understanding of the mechanism behind changes in animal

behavior and pave the way for potential predictions of changes in animal behavior in other ecosystems.

## Literature Review

### *Monterey Bay Ecosystem*

The Monterey Bay ecosystem in northern California serves as a habitat for hundreds of species, including sea otters, seals, and dolphins (Figure 1). This marine ecosystem is located on the central coastline of California and has a submarine canyon, kelp forest, and estuaries. Monterey Bay has fairly warm summers and cold winters, with sea surface temperatures averaging around 14 °C (5). Human fishing, boating, surfing, and increased pollution impact the region and threaten organisms in the area. Moreover, due to climate change, the sea surface temperature in Monterey Bay is rising rapidly (6). Storm winds, particularly during the winter storm period, are intensifying, the sea level is rising, and seawater is becoming more acidic (7). These factors all contribute to shifting animal behavior throughout the ecosystem, as many species are forced to adapt to their new environment.

Because of the rising seawater temperature and sea level, many species have altered their migration patterns. Marine mammals in the Monterey Bay region have shifted their distribution patterns in response to an increase in warmer waters of the Pacific Ocean. The density of marine mammals in Monterey Bay increases as the water temperature rises (8). Throughout the Pacific Ocean, marine mammals, particularly those with limited thermal tolerances, have declined in population. Since most marine mammals cannot adapt quickly to a changing environment, those who survived the effects of the change to their habitats due to climate change had to adapt by changing their living and migratory habits.

### *Species in Monterey Bay*

In the Monterey Bay ecosystem, sea otters (*Enhydra lutris*), seals (*Pinnipedia* spp), and dolphins (*Lagenorhynchus obliquidens*), the species examined in this paper, are integral to the food web. These three mammals are the major species in this ecosystem, with otters being the keystone species. Sea otters, seals, and dolphins adapt their behavior to changing environments in unique ways to combat the effects of climate change.

Sea otters in the Monterey Bay ecosystem have increased diet and prey selection variations due to climate change. Due to the fluctuation of a consistent food source, specifically sea urchin populations, otters in the Monterey Bay area show increasing individual variability in diet

choices. Many otters have sought alternative food sources, and some have demonstrated extreme inter-individual variation in their diets (9). Furthermore, their presence in Monterey Bay sharply increased as water in the bay warmed after 2002. Because otters prefer warmer climates, as Monterey Bay's sea surface temperatures increase, the populations of sea otters in Monterey Bay also increase (8). As a result of climate change, sea otters in the Monterey Bay ecosystem must alter their diets and living patterns to survive, and their behavior has changed in response to the warming seas. Thus, sea otters must spread more sparsely in the northern Pacific Ocean, causing them to have an increased habitat range.

In the Monterey Bay region, seals, similar to sea otters, have an increased habitat range due to the warming of the northern Pacific Ocean. Similar to sea otters, elephant seals (*Mirounga angustirostris*) and harbor seals (*Phoca vitulina*) demonstrated a notable increase in their populations in the Monterey Bay region. However, the fur seal (*Arctocephalinae* spp.) Pacific Ocean population decreased (8; 10). Fur seal pups are born later and are significantly smaller due to chain effects from rising sea levels. The rising sea level leads to displaced storm and weather patterns, thereby altering the foraging trips of female fur seals and changing their breeding grounds into an environment that is much more hostile to birthing seal pups (11). Harbor seals have also adapted to melting ice in northern latitudes by dispersing broadly while breeding to access resources more easily (12). All three species of seals have been affected by climate change, and their behavioral patterns have changed, whether in migration, location, or birthing.

Moreover, Pacific dolphin (*Lagenorhynchus obliquidens*) populations in Monterey Bay have declined. Initially, many dolphin species populations in Monterey Bay increased drastically around 1999; however, their regional densities began to decline after 2002. Large groups of dolphins moved into the bay in search of prey, such as squid, and left when the population density of such prey declined (8). The densities of Pacific white-sided dolphins in the Monterey Bay ecosystems are directly related to the temperature of the water, causing their populations to increase with the warming of bay water (13). Dolphins have been forced to shift their living and predatory habits to adjust to changing environments. As more dolphins migrate into the Monterey Bay area, they affect the species they surround, particularly those they prey on.

### *Arctic Marine Ecosystem*

The Arctic Ocean provides a home for thousands of species, including polar bears, seals, and whales, the species this paper will focus on. This ecosystem is in the northernmost body of water in the world and is covered with glaciers while receiving precipitation as snow (14). As time passes, more and more humans enter the region for residency, tourism, and fishing. Consequently, pollution in the area increases, and marine traffic in this ecosystem affects the

migration and behavior of animals. However, as a consequence of climate change, ice in the Arctic marine ecosystem melts, and the temperature of seawater is rising rapidly. Since 1980, more than 50% of permanent ice in the Arctic ecosystem has been lost and is decreasing by 13% per decade (15). As a result, the zooplankton population has declined, altering their consumers' behavior and the rest of the food web (4). With so many changes to their food sources, many species must change their behavior to survive.

Northward distribution shifts are forcing the positions of food sources to change and introduce new predators into the Arctic region. Furthermore, with the changing prey distribution, predators must adjust their migration patterns' timing and destinations to improve their chances of survival (16). Because so many marine mammals are migrating north, their new behavior will alter species interactions within the ecosystem and cause chain effects in all species in the Arctic marine ecosystem. Additionally, the melting sea ice in the region is shifting migration patterns as the literal shape of the ecosystem is changing.

*Species in the Arctic*

Polar bears (*Ursus maritimus*), seals (*Pinnipedia* spp.), and whales (*Cetaceae* spp.) are the three major species in Arctic marine ecosystems. These three animals are tertiary consumers and play an integral role in the food web of the Arctic marine ecosystem. Tertiary consumers are frequently keystone species and help control the population of other species and maintain a balance in the food webs of ecosystems. Marine mammals are often tertiary consumers in marine ecosystems. In particular, polar bears are the keystone species of the Arctic marine ecosystem and are therefore imperative to study. Although many Arctic marine mammals are ill-equipped to adapt quickly to climate change, these three species must do so to survive. By analyzing these species, we hope to understand how major predatory species adapt to the effects of climate change.

More of the polar bear population in the Arctic Ocean's southern Beaufort Sea has begun to stay onshore for longer because of melting sea ice. From 1986 to 2013, the average distribution of polar bears on the shore increased from 5.8% to 37% (17). Polar bears spend much of their time on sea ice; however, with the diminishing amount of sea ice due to global warming, polar bears in the southern Beaufort Sea have become more dependent on their terrestrial habitat. These polar bears risk interacting with humans to access more food on land, as climate change has destroyed much of their water habitat (17). However, polar bears have gradually adjusted their land use behaviors in response to their melting habitat in the sea.

Similarly, various species of seals in the Arctic area are poised to migrate further north as the Arctic climate continues to warm. Harp (*Pagophilus groenlandicus*), hooded (*Cystophora cristata*), ribbon (*Histriophoca fasciata*), and spotted seals (*Phoca largha*), among others, rely on

sea ice to give birth to young; without sea ice, their populations are likely to decline (3). The dependence of seals on ice masses for parturition is changing and as the amount of ice on the seas is waning, seals must migrate further north or face the threat of declining reproduction rates (18). Seal populations have slowly decreased over the past century with the shift to a warmer climate. Seals are not organisms that typically migrate or move long distances; however, they must survive the rapidly warming climate of the Arctic marine ecosystem.

The North Pacific gray whale (*Eschrichtius robustus*) population has altered its migration pattern times and reproduction rates in response to major shifts in its environment due to climate change. While the amount of sea ice is reduced by global warming, whales in the Arctic marine ecosystem, including gray whales, are likely to travel further north and stay longer. In places such as the Bering Sea, many whales remain in the northern areas of the sea all year instead of migrating back south once summer is over (3). Due to this change in distribution and shifted migration schedule, whales will also have to adjust their reproduction times accordingly. These location changes may delay or even prevent whales from reproducing as usual. As a repercussion of the dramatic influence of climate change throughout this ecosystem, whales have had to completely shift their migration and living behaviors to combat habitat destruction in the ocean.

## Comparative Analysis

While Monterey Bay and the Arctic are thousands of kilometers apart, there are still parallels in how animals adjust their behavior to the effects of climate change. However, due to the unique features of each ecosystem, there are also differences in their responses. In the Monterey Bay ecosystem, marine mammals must contend with shifts in prey populations, changes in water temperature, and the rising sea level. Sea otters, seals, and dolphins have changed their living, eating, and breeding habits; therefore, they may adjust to the effects of climate changes in the habitat. Marine mammals in the Arctic marine ecosystem are severely affected by climate change, as evident from the responses of the populations of these three species to the melting sea ice. Polar bears, seals, and whales have altered their migration and reproductive patterns, among other behavioral patterns, to adapt to their rapidly changing environment.

### *Similarities between the Arctic marine ecosystem and the Monterey Bay Ecosystem*

To survive rapid climate change, marine mammals in both ecosystems have changed their behavior in various ways to survive in these new environments. The species examined do not change their behavior easily; however, they have adjusted their migrational, distribution, and predation habits, among others, to face the new challenges that climate change presents to them in their environment.

Both ecosystems face the threat of rising sea levels, warming of the sea surface, and habitat destruction. Melting ice in the northern Pacific Ocean and the Arctic Ocean threatens the habitat of species such as seals and polar bears. Seals in the Arctic marine region and Monterey Bay require ice to reproduce; therefore, the declining ice in the two areas reduces the population of seals (11; 3). The diminishing amount of sea ice also affects polar bears' distribution and predation behavior in the Arctic marine ecosystem (17).

Predators in both ecosystems shifted their food sources and thus had to change their behavior. The changing climate in both ecosystems has altered many interspecific relationships and species interactions throughout the food web. Sea otters, dolphins, and polar bears have all encountered changes in their food sources and have adapted their diets to their new environment. Due to climate change, sea urchin populations in Monterey Bay have fluctuated, and sea otters have shifted their predation behaviors accordingly to compensate for their unreliable food sources (9). Furthermore, dolphins have adjusted their distribution patterns to search for more abundant prey, and their densities in the Monterey Bay area have increased (8). Similarly, polar bears have changed their distribution patterns on land and in the sea in the Arctic marine ecosystem to access more prey.

Species in both ecosystems are declining because of the effects of climate change on their environments. Globally, organisms of all six species are noticeably decreasing in population. The chain effects of their behavioral changes can be seen throughout the trophic structure of each ecosystem in many negative ways. These marine mammals have altered their behavior in many ways to adapt to climate change. However, climate change occurs in similar ways in both ecosystems. Specifically, changing migration and distribution due to habitat destruction and rising sea levels were prevalent in these six species. Predation, reproduction, and dietary behaviors are also shifting. The species residing in these two ecosystems respond similarly to climate change and adjust the corresponding parts of their behavior to adapt.

*Differences between the Arctic marine ecosystem and the Monterey Bay Ecosystem*

Although the two ecosystems share many similarities in their topographical features and species, changes in species behavior are not always parallel because of climate differences between the two ecosystems.

In the Arctic marine ecosystem, ice is a major part of many animal habitats, and the melting affects their migration, reproduction, and other patterns. In contrast, the Monterey Bay ecosystem does not face this issue because its location is significantly more southern. Because of this difference in habitat, animals in the Arctic marine ecosystem contend with habitat loss

and alter their distribution, migratory habits, and reproductive patterns. In both ecosystems, seals have changed their reproductive behavior in different ways. In Monterey Bay, seals spread over icy areas in the northern Pacific Ocean, and seals in the Arctic Ocean migrated further northward to access more ice (12; 18). Since Monterey Bay is farther away from the northern sea ice and seals cannot migrate large distances, they must compensate for their lack of ice by spreading sparsely across the available ice. In comparison, the seals in the Arctic marine ecosystem are significantly closer to the northern sea ice; therefore, they can migrate far more easily to access this ice.

The effects of climate change on both ecosystems appear to modify different types of behavior. While the three species in the Arctic marine ecosystem have mainly changed their migration patterns, the living and eating patterns of the three species have changed in Monterey Bay. In the Arctic marine ecosystem, whales have changed their migration habits, seals have changed their migration and reproductive habits, and polar bears have changed their distribution patterns. In comparison, in the Monterey Bay ecosystem, sea otters have mainly changed their predation behaviors, seals have changed their reproductive behaviors, and dolphins have changed their predation behaviors (Table 1). Although climate change manifests itself in similar ways in the two ecosystems, the types of behaviors the animals alter in response vastly differ.

**Table 1. Types of Behavioral Changes in the species studied**

| Ecosystem | Species | Behavioral Change |
|---|---|---|
| ***Monterey Bay*** | *Sea Otters* | Diet, distribution |
| | *Seals* | Reproduction, dispersal |
| | *Dolphins* | Predation, distribution |
| ***Arctic marine*** | *Whales* | Migration, distribution |
| | *Seals* | Reproduction, migration |
| | *Polar Bears* | Distribution, predation |

The two ecosystems also show differences in species density in response to climate change. Monterey Bay is witnessing an increase in the densities of its species, while the Arctic sees a decrease in its densities (19; 18; 3). The Arctic's melting ice causes many species to migrate further north in search of more abundant ice in colder climates. However, the diminishing habitat of species living on ice causes the population of such species to decline. Furthermore, seals in the Arctic, which require ice to give birth, also decrease in population as their necessary surroundings for parturition decrease. Comparatively, due to increasing temperatures in the Monterey Bay region and the northern Pacific Ocean, sea otter and dolphin population densities increase in this ecosystem as more organisms move into the bay, searching for warmer waters and more prey.

## Discussion

In the years to come, climate change will likely continue to affect animal behavior. Within the Monterey Bay region, many species may migrate in greater densities into the bay, potentially overpopulating the area and eventually causing the population of these species to decline. This may lead to negative consequences for the Monterey Bay fishing industry. Other species might have sought more habitats further north and migrated further north. Overall, climate change will greatly affect the migration behavior of the species in the Monterey Bay ecosystem and their distribution patterns. The Arctic marine ecosystem is also likely to show an overall decline in species density. Due to habitat destruction, organisms in the Arctic marine area will continue to shift their migration patterns to adapt to their changing climate, potentially leading to altered predation habits and reproduction rates. With different species distributions, food sources change, leading to new species interactions. Moreover, reproduction rates have decreased, as observed in research on seals in Monterey Bay (3). Human-animal interactions will become more frequent as populations decline due to climate change. In summary, this study has demonstrated that climate change has drastically affected the lifestyles of many species, and ultimately the lifestyles of humans, and it will continue to do so unless prevented.

This study was constrained by the limited research on the Monterey Bay area, especially the effects of climate change on animal behavior in the region. Moreover, the scope of the study was limited as only three marine species were chosen for each ecosystem. The species was chosen to highlight the rising dangers of climate change effects on marine ecosystems; however, many more comparisons can be made at the ecosystem level. Additionally, because of the many differences between the Arctic marine ecosystem and the Monterey Bay ecosystem, such as the discrepancy between the size and species count, it is significantly more difficult to compare the two ecosystems.

Future researchers should consider more species from the existing literature to address the limitations in this study. They could also select a larger variety of species beyond marine mammals and predators and potentially include microorganisms or plant life in marine ecosystems. A larger scope would provide more evidence supporting the drastic effects of climate change. Scientists could also look at food webs rather than individual species or select the most threatened species in ecosystems. Limitations regarding insufficient research in the Monterey Bay region could be solved by performing field experiments in Monterey Bay or behavioral experiments along the Pacific coast. Future scientists may study different regions and connect them with research to better understand the similarities that larger regions share to gain a deeper understanding of migration patterns and other behavioral changes in animals.

Changing animal behavior affects ecosystems and organisms worldwide. An overall shift in the behavior of certain species, particularly keystone species, may cause chain effects throughout the biosphere, affecting other animals and humans. Furthermore, by studying changes in animal behavior, scientists can better understand our ecological system, and the various impacts of climate change on the world. Scientists can also form more accurate predictions and conclusions regarding the comprehensive impacts of climate change on our environment and the future ways in which climate change will affect humans and animals.

## Conclusion

This study aimed to examine the threat of climate change to ecosystems worldwide while focusing on its severe impact on animal behavior, particularly in marine mammals. Furthermore, this study identified overarching behavioral signatures of climate change. By comparing two unique marine ecosystems, this study highlights similar behavioral adjustments that demonstrate the consequences of climate change. The effects of climate change are evident in the behavioral adaptations that have appeared in species throughout the Arctic marine and Monterey Bay ecosystems. Research has shown that species in both ecosystems have altered their migration, distribution, predation, and reproductive patterns to adapt to their rapidly changing environment. While there are key differences between the two ecosystems, similarities in species' behaviors show the effect climate change has on marine mammals. As the impact of climate change worsens, more and more species' populations in the world continue to decline and struggle to respond to climate change. Ideally, this initial analysis will inform future research and underline the importance of considering animal behavior in changing ecosystems.

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