Physiological and Behavioral Effects of Climate Change on Wildlife: An Introduction and Overview

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A Senior Thesis submitted in partial fulfillment
of the requirements for graduation
in the Honors Program
Liberty University
Spring 2020

Acceptance of Senior Honors Thesis

This Senior Honors Thesis is accepted in partial fulfillment of the requirements for graduation from the Honors Program of Liberty University.

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Abstract

Planetary environmental system changes have been recorded and documented for several decades. Fluctuations that were first noticed in atmospheric carbon-dioxide levels have now extended into global pattern changes. Climatic variations that were initially non-threatening variabilities have since been observed creating significant biological influences. The results and evidence of the effects of worldwide environmental climate change on wildlife and biotic environments are worth examining because of the impacts it has on the planet. These climatic effects extend from changes in distribution and diversity patterns of terrestrial mammals to sea-life impacts and recovery trends. Possible wildlife benefits may include increased humidity and precipitation. Biological trends and predictions convey a view into the potential outcome of the planet.

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Climate Change

The climate has been observed by scientists to be changing ever since the analysis of global temperatures was first recorded (Callendar, 1938). Not long after then, scientists began closely monitoring global temperatures and atmospheric gas composition to identify any changes in the climate. In recent years, the topic of *Climate Change* has become one of the most highly discussed topics in not only science, but in politics as well. Climate change is often misrepresented as the rise in global temperature, however, it is much more diverse than that.

Climate change is the long-term change in typical climate patterns within either a localized region or the entire planet. This change can include a multitude of aspects within a climate such as the change in average temperature (higher or lower), a change is atmospheric gas composition, or even a difference in the annual magnitude of precipitation (Encyclopedia Britannica, 2020). Most notably, the rise in global temperatures has been linked to the increase in gaseous CO_2 in the atmosphere (Callendar, 1949). This relationship between CO_2 gas and temperature has been known for over a century (Arrhenius, 1896). In fact, the analysis of Antarctic ice cores has shown that the earth has been following the principles of this relationship for thousands of years (Fig. 1).

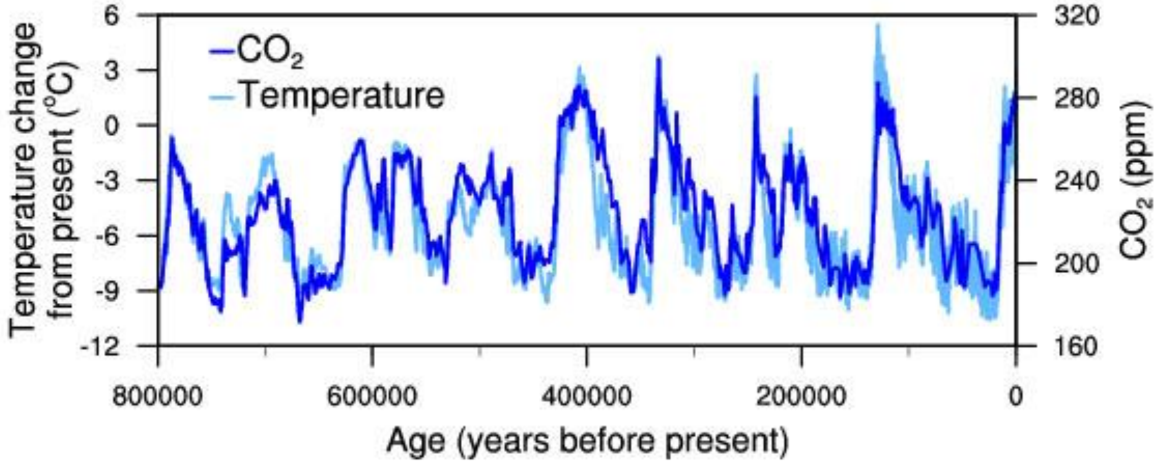

Figure 1. Historical (based on a geological old Earth) changes in carbon dioxide (dark blue) and global temperatures (light blue) from EPICA Dome C ice core in Antarctica (Temperature Change, n.d.).

The relationship of temperature and atmospheric CO_2 gas is not the issue. Where scientists find worry is with the great increase in atmospheric CO_2 within the last few decades. The CO_2 measured in the climate has vastly increased within the last few decades (Fig. 2). This increase in CO_2 is concerning as average global temperatures are thought to follow the rise of CO_2 and reach levels which the earth has never experienced before. Just as the average global temperatures of the earth have closely followed the atmospheric CO_2 gas in the past, global temperatures are expected to do the same in the future.

The cause and the severity of climate change are both highly discussed points within many fields. What is generally not debated is that the climate is continually changing and that the changes that are observed are the product of many effects experienced by biotic environments. The changing climate has large effects on many parts of earth's abiotic environments. The large abiotic changes include the increase in global temperatures, the warming of the oceans, the shrinking of ice sheets, an increase in sea level rise, ocean acidification, and an increase in severity as well as frequency of extreme storms (Levitus et al., 2017; Nerem et al., 2018; Pacific Marine Environmental Laboratory (PMEL), n.d.; Ramp-Up, 2018; Temperature Change, n.d.). All of these changes have significant impacts on the biotic life that share the environment which is drastically changing.

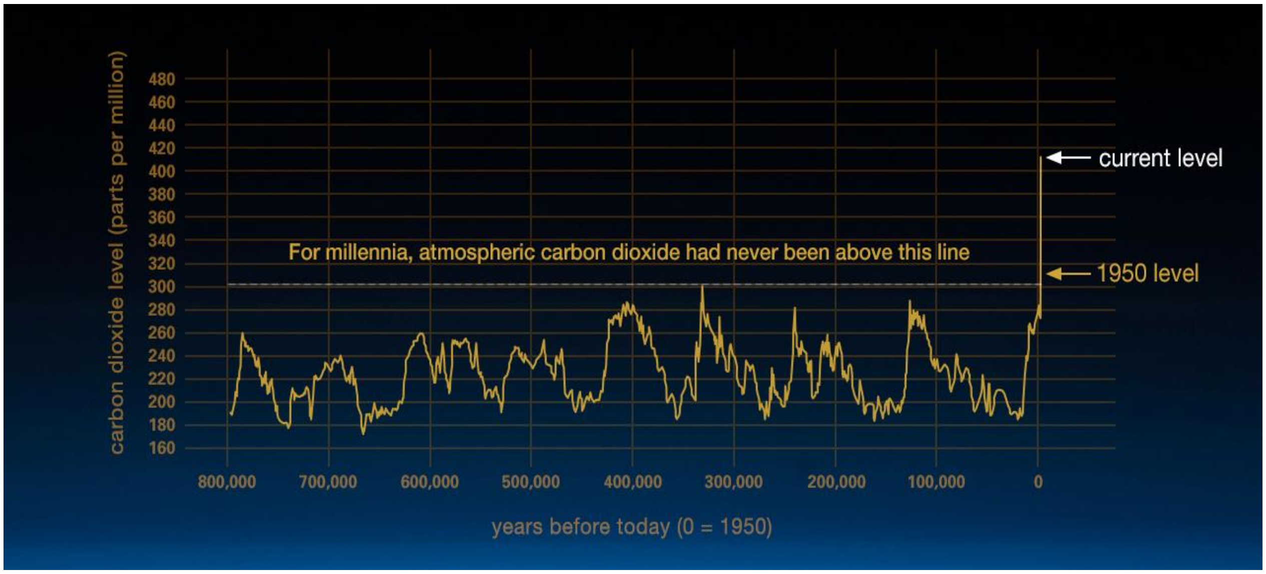

Figure 2. Carbon dioxide levels measured in ice cores and direct atmospheric measurements (Shaftel, 2020).

The effects of the temperature, precipitation, and atmospheric gas on animal behavior extend to the breeding tendencies, migration patterns, predator-prey interactions, and distribution ranges of terrestrial organisms (Haest, Hüppop, Pol & Bairlein, 2019; Harmon & Brandon, 2013; Chen et al., 2011; Schmitz & Barton, 2014). The behavioral tendencies of an organism influence the species' survival (Alcock, 2009). The innate behaviors, as well as learned characteristics, of a terrestrial animal are the result of the influence of the species in the environment (Averós et al., 2012). Understanding the changes in a species' behavior is an effective approach at managing a species' population (Berger-Tal et al., 2015). The current behavior of many organisms is changing. This change is highly related to alterations in the climate (Broitman, Szathmary, Mislan, Blanchetter & Helmuth, 2009; Daufresne & Boët, 2007).

Although the abiotic effects and the causes of climate change have been well studied, research investigating the influence climate change has on biotic life is not as prevalent. Additionally, a large overview of the effects that climate change has on wildlife is missing in literature. Therefore, the physiological effects as well as behavioral impacts that climatic changes have on wildlife, which includes organisms in both terrestrial and aquatic environments, will be explored.

Terrestrial Environments

The long-term effects of climate change on ecological systems are causing a rise in attention due to the uncertainty of how the biological systems will manage with the Earth's changing climate. The Earth is experiencing many changes abiotically that have direct effects upon terrestrial ecosystems and biotics life. These abiotic changes include a rise in global temperatures, fluctuations in annual precipitation, and the frequency and severity of extreme storms (National Oceanic and Atmospheric Administration (NOAA), n.d.; PMEL, n.d.). Ecologically, these factors are influencing terrestrial ecosystems by physically changing habitats. The terrestrial ecosystems are at an increased vulnerability due to the direct interactions many organisms have with the climate. The complexity of the responses from organisms which inhabit these changing habitats adds great difficulty to understanding this problem. Much is still unknown about how the interactions that occur within the ecosystems will respond to the shifts of a changing climate. However, an increasing number of recent studies have explored how organisms are physiologically and behaviorally affected by climatic changes. Physiological changes experienced by terrestrial organisms have been documented in the changes in body temperature, metabolic efficiency, and respiration. The alterations in terrestrial animals' behavior is most noted in their breeding behaviors, migratory patterns, predator-prey interactions, and distribution ranges.

Species vary in their ability to adapt appropriately to abiotic changes within the environment in which they reside (Freeman et al., 2018; Janzen, 1994). However, a drastic change in this environment either means decreased reproductive success in some species or a change in how a species functions. Generally, a species will adapt either physically, through natural selection, or behaviorally to fit the changes experienced in the environment (unless it is a generalist species). Many of the current climate changes which are experienced today influence behavioral adaptations for animal species (Hoffmann & Sgrò, 2011). When a change occurs in the species' environment, the species can collectively relocate to a place which better fits its needs (discussed later in behavioral changes), be forced to decrease its geographic distribution based on remaining suitable habitat, or physiologically change as a species.

The problem with the changing climatic temperature is not that it is simply increasing, but rather that the increasing temperature has negative physiological effects on the organisms in the system. Species face the problems of both death by heat exhaustion as well as long-term effects that may lead to the extirpation of a species from the diminished physiological performance at increased temperatures (Somero, 2009). For temperature tolerant species, the increased temperature is not much of a problem. However, temperature sensitive species living near their physiological limits deal with a much greater problem as their species may not be able to adapt quick enough to be able to survive the increased environmental temperatures (Hoffman & Sgrò, 2011). As a result, these species may face extirpation.

Physiological Effects

Development. Climatic changes in temperature have been observed to affect populations of reptiles (Janzen, 1994) and birds (Göth & Booth, 2005). Many terrestrial organisms such as some reptiles have sex determinate properties which are temperature dependent during the embryonic phase. These physiological changes may affect the sex structure of populations of these organisms. For example, painted turtle populations have been observed with differing sex ratios within multiple populations due to a change in temperature among sites (Refsnider, Milne-Zelman, Warner & Janzen, 2014). As a result, improper ratios of these species may develop and cause population instabilities (Grayson et al., 2014).

Body temperature. Increased atmospheric CO_2 has a physiological impact on animals. Increased CO_2 levels have been observed decreasing heart rate and body temperature as well as increasing respiratory frequency in rodents (Soholt et al., 1973). These effects could prove to have a negative impact as increasing respiratory frequency can be a signal of added stress on the bodies of the animals (Gaughan, Holt, Hahn, Mader & Eigenberg, 2000).

Survival of an organism can be based upon the relative humidity of the environment. Differences in humidity affected by climatic variations may also decrease body temperatures in some organisms (Kay, 1975). These changes observed in organisms by climatic based humidity changes can have great effects on an ecological system. Some of the effects can be beneficial. the positive relationship of leaf litter and humidity increases the abundance and mass of frog populations (Oliveira, Pralon, Coco, Pagotto & Duarte Rocha, 2013).

Well understood in the scientific community are the effects of environmental temperature on the body temperature of the organisms. The physiological impact is highly dependent on the sensitivity of the species (Calosi, et al., 2007). Some insect species in the tropics are projected to be greatly affected by the relatively small climate warming in that region due to the high heat sensitivity of the insects (Deutsch, et al., 2008). These insect species are pressed to decrease their thermal sensitivity or face extirpation in their resident area. Many species of aphids are sensitive to high temperatures and cannot tolerate a short-term increase in temperature. High temperatures shock the physiology (respiratory and nervous system) of aphids which results in subsequently decreasing their reproduction and survival rates (Schmitz & Barton, 2014). The deteriorating effects experienced by the species can influence the species to adapt to the increased temperature through microevolution.

Metabolic efficiency. The effects of temperature play a role in a species' resource consumption. An increase in environmental temperature can decrease the amount of feeding performed by a species (Rall et al., 2012). Decreased feeding is linked to several detrimental effects on a species. Lower feeding rates are linked to a lower species fitness (Meyer, 2000). Additionally, feeding rates are related to reproductive success in many species. Therefore, a decrease in feeding will produce a lower reproductive rate for that species (Grinsted, Deutsch, Jimenez-Tenorio & Lubin, 2019).

Furthermore, an increase in environment temperature can have a negative effect on the energetic efficiency of a species. A decrease in energetic efficiency is due to the increase in metabolic rate of an animal as the temperature increases. Metabolic increase due to temperature lies in the indirect adaptation of organisms synthesizing resources quickly in order to maximize resources during a warm season (Clarke & Fraser, 2004). Monotonic increase of resting heartrates in individuals is observed with the increase in temperature (Clarke, 2006). The increase in heartrate in an organism is a homeostatic response to the environmental change. However, the biological effect of the temperature increase is unhealthy long-term for the animal.

Fluctuations in a changing climate's environmental humidity has also been recorded affecting biological systems. Humidity has a large influence on the evaporative water loss of an organism which is a vital component to a species' survival (Cooper & Withers, 2008). For example, many amphibians including lungless salamanders require moisture for cutaneous respiration and depend largely on humidity to regulate body temperature (Galindo, Cruz & Bernal, 2018). Therefore, any atmospheric moisture changes that occur in an organism's habitat can have vital effects on the species' survival.

Although not much research has been conducted on the effects of changing humidity on fauna outside of amphibians, literature presents findings on how humidity of an environment can affect plant life. Relative humidity can affect the functioning and productivity of a plant based on its ability to adapt to the environment. Cacti have been observed decreasing the intake of CO_2 in the presence of a high relative humidity (English, Dettman, Sandquist & Williams, 2010). Similar results may be produced in a changing climate where humidity levels can reach extremes.

Plant life is vitally important to animals as it is the primary production in the food chain. Less abundant plant life results in a reduced amount of food for herbivores which means a reduction in herbivores and ultimately lower carnivore population numbers. However, biological impact is observed at the primary level of resource consumption as plants are changing due to changing climates. Some Mediterranean grasses have been observed altering their water-use efficiency to compensate for the changing precipitation levels in their environment (Ladrón de Guevara et al., 2015). For many grasses, dryer climates result in the reduction in size of the plants. The reduced size is due to the significantly decreased leaf-level photosynthesis, water use efficiency, and movement of H_2O and CO_2 through the stomata when the grasses were exposed to dryer climate (Connor & Hawkes, 2018). The decrease in plant efficiency ultimately results in a reduced net CO_2 production of the plant. Since the movement of CO_2 is one of the main factors in an ecological system, the reduced production of the gas results in an overall lower state of productivity for that ecosystem.

Respiration. As mentioned above, one of the main driving forces in the changing of a climate is the increase of atmospheric CO_2. The production of this gas affects ecosystems at the base of the production level by disrupting the physiology of plants. The increase of atmospheric CO_2 has been shown to increase carboxylation rates and stomatal closure in the vast majority of plants (Medlyn et al., 2015). The effects of this gas can be beneficial to most C_3 plants as it is the main component in a plant's growth process (Wong, 1979). However, increased CO_2 can increase radiative heat from the plant (Zhu et al., 2017). This production of CO_2 can lead to the increase of temperature in an environment and produce negative effects on photosynthesis through vegetation-climate feedback. This feedback occurs when plants react to increased CO_2 levels by closing their stomata (respiratory vents) and decreasing transpiration (Zhu et al., 2017). As a result, plants will not open their stomata and continue transpiring until a reduction in atmospheric CO_2 occurs.

Additionally, an excess amount of precipitation can also provide differing physiological results among organisms. Inhibition of water usage has been observed in plants experiencing extreme levels of precipitation. Additionally, the net flux of CO_2 and water within a plant is greatly decreased in a high precipitation environment (Connor & Hawkes, 2018). This diminished productivity of the plants caused by increased precipitation relates to an overall decreased success rate in an ecosystem (Fay et al., 2008). Therefore, extreme precipitation causes a less efficient and therefore less productive plant system which in turn, can create several differing results of carbon cycling.

Behavioral Effects

Breeding. The changes in the climate can affect the breeding of a species greatly without interfering physiologically with the organism. The process at which the changing climate affects the breeding of a species can be related behaviorally in many aspects. Most notably, the interactions between some songbird species has been greatly affected (Harmon & Brandon, 2013). The change in atmospheric temperature affected by the changing climate has altered the seasonal location of many breeding grounds for countless species of birds. This transformation of breeding grounds has influenced birds to breed at different times, both later and earlier depending on the effects on the breeding grounds (Harmon & Brandon, 2013). For example, decreasing snowfall has allowed for more herbivorous elk to occupy breeding grounds of birds and forage on the breeding and nesting habitat of the birds, greatly decreasing quality nesting options (Martin & Maron, 2012). As a result, the bird population has decreased due to the poor nesting foliage, allowing for more predatory opportunities. Breeding behavior in pronghorns has also been affected by climate change. The increase in harsher weather killed 75% of male pronghorns which included the entire ≥5-year-old age group. The less experienced pronghorns altered their behavior to a harem-defense system in which males no longer held breeding territories. The effects of the system change ultimately created tired females in the population which resulted in a population decrease (Byers & Kitchen, 1988).

It is not just the breeding times of birds that has been affected by the changing climate. Anuran breeding dates in North America have been observed trending to earlier dates due to the earlier seasonal change of their environment. Anuran species such as the Cascades frog and Western toad have showed trends towards earlier breeding with the increase in environmental temperature (Blaustein et al., 2001). Although literature is not sure on the cause of the relationship between earlier breeding and anuran populations, it is concerned with this effect as climate change could contribute to population declines (Blaustein & Wake, 1995).

Migration. The effects that a changing climate have on the migration patterns of biology has been discussed greatly in literature. This is due to the relatively large effect that the climate has on the migration of animals as well as the ease of detecting these occurrences. Temperature, precipitation, and wind have large contributions to the migration of terrestrial animals. In a climate that is changing, each one of these aspects can have drastic influences on the typical migration of an animal (Haest et al., 2019). The changes seen in a climate have been observed having a strong influence upon life stages and annual cycles of migratory animals (Parmesan & Yohe, 2003).

Climatic changes in temperature and precipitation have a staggering influence upon the naturally occurring migration of many animals (Haest et al., 2019; Sexton, Phillips & Bramble, 1990). The influence of a changing climate can affect the migration of animals either directly or indirectly. Direct influences can be seen as an increase in storms creating difficult flight paths of many types of migrating birds (Lain et al., 2017). The influence of storms can have a large effect on birds based upon the quantity as well as severity of these storms, affecting bird migration timing in both cases. Birds have the ability to delay their migratory dates if a storm is detected (Streby et al., 2015). This delaying increases survival but ultimately may have negative effects on bird populations if it occurs regularly. Storms also influence a species' migration due to the threat of staying in the affected territories (Boyle et al., 2010). A species can be directly affected by the presence of a storm and even drive the occurrence of migration.

Indirect effects are observed upon the environment of the animal as it readies for migration. Fluctuations in temperature and precipitation affect the natural growth of plants which therefore advances the timing of the migration of birds (Menzel, et al., 2006). The effects of plant growth experienced by migrating birds are also a large influence upon migrating mammals as they rely greatly upon plants for grazing during large migration trips. The change in plant phenology ultimately influences the reproductive success of large migrating mammals due to the inconsistency in foraging (Post & Forchhammer, 2007).

Predator-prey interactions. Changing abiotic factors in an environment can have a significant impact on the life-cycle timing of a predator-prey interaction (Schmitz & Barton, 2014). Specifically, interactions between predators and prey have been observed being affected by a changing climate due to the increase in temperature of an environment. For example, a temperature increase physiologically alters the hunting behavior in the predatory ladybird beetle allowing for faster hunting reactions and skills (Frazer & Gilbert, 1976). Although an initial physiological change occurs in the predator, the change in speed and striking distance of the predator alters the predatory interactions between the prey and predator by increasing predator rates forcing the prey to change behaviorally. The changes in the predator-prey interactions are generally influenced by the predator which therefore pressures the prey to change behaviorally to survive. Such changing interactions between a predator and a prey are common within a temperature changing environment. Implications of energetic inefficiencies suggest a stabilization of predator-prey oscillations with the result of potential predator starvation despite abundant resources (Vucic-Pestic et al., 2011). This disruption in a balanced system can lead to the crashing of a species and potentially the whole ecological system. Additionally, some species can have a greater effect on the surrounding abiotic environment than others. Known as *ecosystem engineers*, these animals have daily tendencies which result in drastic effects on the habitat (Louw, Haussmann & le Roux, 2019). Due to the large influence that ecosystem engineers have on the habitat, many more species can be affected if the ecosystem engineer varies from its typical hunting/ foraging behavior. For example, the foraging and movement of gazelles in the Arava desert are known to break the soil crust creating patches of moist soil for antlions and plant species (Shanas et al., 2018).

Distribution and habitat changes. Terrestrial organisms are currently experiencing shifts in range and distribution in response to the changes in the climate (Chen et al., 2011). Although precipitation, humidity, and gas composition all have an effect on the distribution of organisms, one of the large influences for behavioral distributions changes is due to the changes in temperature experienced in a changing climate (Parmesan & Yohe, 2003). In some species, the adaptation to a temperature change can occur quickly, while others are forced to modify behaviorally in the face of extirpation (Root, 1996). Many animal species have adapted very well to the climatic changes experienced throughout their species history (Harris, 1993). The changes experienced in the climate have pressured many species to seek cooler climates (Chen et al., 2011). However, not all animal ranges are being altered equally. The ranges of many species are expanding, some are shifting, and others are shrinking depending on the environmental stress under which they are surviving (Freeman et al., 2018). Generally, the distances moved by a given species are relative to the increase in temperature experienced by that group of organisms. For example, spiders, grasshoppers, butterflies, and ground beetles all migrate different distances when exposed to similar temperatures (Chen et al., 2011).

Animal ranges in recent years are expanding to greater latitudes as well as altitudes. Climatic changes are predicted to push species ranges on average 6.1 km per decade toward the poles while mountainous organisms are pressed to higher elevations at a rate of 11 meters per decade (Chen et al., 2011; Parmesan & Yohe, 2003). The range shifts that are affected by temperature are also influencing the size of a species' distribution. In terms of altitudes, the ranges of mountain dwelling animals are shrinking with the changes observed in environmental temperatures, suggesting the rise in temperature is pushing the range of these animals to higher elevations (Freeman et al., 2018).

Other distribution changes have been observed in animals as they seek different habitats to accommodate for the change in the climate. Terrestrial ectotherms rely heavily on their environment for the regulation of their metabolism. Due to this, many organisms experiencing a change in climatic temperature have altered their micro-habitats choice to adapt behaviorally (Kearney et al., 2009). Ectotherms needing low-shade environments for basking in tropical and temperate areas, where above-ground activity is prevalent, are all affected by the change in temperature as it alters their natural habitat selection to fit their metabolic needs.

Aquatic Environments

Aquatic environments are vitally important for supporting and maintaining life on Earth. Water covers roughly 71% of the earth's surface, providing enormous amounts of ecosystems and environments for life (United States Geological Survey, n.d.). Both freshwater and marine systems have their own distinct biological systems that are equally important to their respective habitats. From the macroinvertebrates hunted by freshwater trout to the diverse coral and cardinalfish interactions, each species is vital to the survival of that ecosystem and the surrounding environments. For example, extreme coastal storms can cause destruction to important land-protecting reefs (Lukoschek, Cross, Torda, Zimmerman & Willis, 2013). However, climate change disturbances can have severe effects on the ecosystems such as the coral reef (Webster, Holland, Curry & Chang, 2005). Multiple factors influenced by climate change are affecting marine and freshwater environments. The increase in ocean temperatures, severity and frequency of extreme storms, and ocean acidification are the major effects on aquatic environments observed by climate change (Levitus et al., 2017; Nerem et al., 2018; PMEL, n.d.). These climatic changes also greatly impact aquatic fauna.

Both physiological and behavioral changes are a result of the changing environment. From small krill that float throughout the oceans to large marine giants that consume the krill, climatic changes influence all parts of the organismal spectrum (Poloczanska et al., 2016; Trathan, Forcada & Murphy, 2007). Aquatic organisms inhabiting river systems are additionally vulnerable to the effects of climate change because they often live in suboptimal temperatures due to physical obstacles such as waterfalls or dams (Daufresne & Boet, 2007).

The physiological effects of aquatic organisms are diverse in their nature due to the large array of environmental factors which influence the functionality of the organisms. However, large topics within physiology arise due to the prevalence of natural observations. These issues are the changes observed in the development of aquatic organisms as well as the respiration of the organisms. The effects are largely due to major factors such as temperature.

Behavioral effects in aquatic organisms vary widely. This variation is due to the fact that slight disruption in the environment leads to impacts on large ecological structures (Eissa & Zaki, 2011; Williams, 2010). Species interactions, distributions, and timing of life-histories are among the many effects which the climate has impacted in aquatic environments in recent years (Mawdsley et al., 2009). Although many changes have been observed in aquatic animal behavior such as habitat migration, the largest changes observed have been in the feeding of the animals. Therefore, the largest behavioral changes observed in aquatic animals are foraging strategies, breeding patterns, and predator-prey interactions.

Physiological Effects

Developmental effects. Developmental effects of aquatic organisms due to climate change vary widely. This is in large part due to the large variability of animals in all marine and freshwater environments. However, one common theme in the realm of developmental changes due to the climate is the effects of rising ocean temperatures. As a general thought, practically all of an animal’s physiological processes are affected by its body temperature (Buckley et al., 2001; Somero, 2005). As a result, any climatic event which influences the temperature of the animal affects the way it functions physiologically.

A changing climate has been observed in recent years having a significant influence on the developing aquatic organisms (Mawdsley et al., 2009). As discussed earlier, reptiles have temperature dependent sex determinate properties within the developmental stages of the embryos (Janzen, 1994). However, more uncommonly known is that the same characteristics exist in some fish populations (Ospina-Álvarez & Piferrer, 2008). Environmental temperature is affected by a changing climate which ultimately has an effect on the development of some fish populations by influencing the sex-determination in the species. These physiological effects are important as they may have an extended influence on the dynamic of the local population. For example, variabilities in climatic temperature may have an effect on the sex ratio of Bluegill Sunfish populations due to sex-determination within the species (Shen et al., 2016). This developmental disruption, as well as a pathogen increase, with the rise in water temperatures could be contributing to the decline in abundance of some species in the last four decades (Wedekind & Küng, 2010). Furthermore, life cycle shifts of many aquatic species due to temperature changes have been linked to a shift in earlier spawning. This shift in spawning has an effect on both the sex-determination of many fishes as well as the survival of the hatchlings (Barson et al., 2009).

The effects of temperature on the embryonic development are evident among many aquatic fish species. Warm temperatures produce shorter incubation times while colder environments facilitate the lengthening of embryonic development (Alderdice & Velsen, 1978). The effects of water temperature extend into fish physiology which affect the genes of many species. For example, different water temperatures have been observed affecting the genetic makeup of developing young of several fish species (Beachan, 1988). Additional developmental effects are due to climatic changes in recent years. Increased summer temperatures have been linked to the decrease in juvenile survival of many salmonids (Brannon et al., 2004). These effects driven by environmental temperature changes are all possible influences from a climate which is constantly changing in aspects including temperature.

Respiration. The effects of climatic changes on the respiration of aquatic animals historically has been largely overlooked in literature. Conversely, terrestrial organisms have had greater respiratory effects due to climate change when compared to other organisms. The greater effects observed in terrestrial organisms is because there are more factors which influence the respiratory system of these organisms such as the fluctuations in atmospheric gas composition (Eissa & Zaki, 2011; Rahel & Olden, 2008). The effects of changes in a climate are not primarily observed in aquatic environments since the climate, by definition, is the weather above the surface of land and sea. Most notably, the increase in ocean temperature can have effects upon survival of some animals due to incapabilities of high temperature respiration. Some organisms, such as pulmonate limpets, demonstrate a thermal limit to their respiration which can vary among species (Kankondi, McQuaid & Tagliarolo, 2018).

Climate change related effects are present in the influence it has on freshwater aquatic organisms as well. Endangered Asian freshwater fish have exhibited a poor thermal tolerance when exposed to high and low temperatures, showing a decrease in swimming performance when not in optimal temperatures (Zhou et al., 2019). These qualities will be exposed and threaten the survivorship of the species with the increase in temperature due to climate change.

Behavioral Effects

Breeding. Climatic changes in the atmosphere alter aquatic environments by reducing ice cover, increasing salinization, and altering flow regimes (Rahel & Olden, 2008). Due to the changing environments and habitat in which fish naturally inhabit, many fish species are forced to change habitat selection to a location with more security and stability (Sae-Lim, 2016). For example, some fish are adapting to fast flowing habitats to avoid the accumulation of discharge within a river system (Capra et al., 2017). Conversely, the increase in habitat selection may result in fish selecting more resilient breeding locations which in turn aids in the security of the developing fish. Specific influences of some climatic events directly affect fish populations in areas where seasonal events drive reproduction. Lacustrine fish respond to an earlier ice breakup date by breeding and spawning earlier and more frequently (Hovel et al., 2016). Effects of such shift in time and frequency of breeding leads to a changed size (physical proportions) structure of the population after the growing season (Hovel et al., 2016). However, literature suggests the ability of some fish to become tolerant to thermal water changes through the use of genetic variation (Barrett et al., 2011).

Breeding changes observed in fishes is not only due to direct influence from climatic changes. Some fish experience earlier breeding due to water temperature changes which influence earlier migration to breeding grounds. Consequently, earlier gonad maturation and spawning is triggered in these migrating fish (Genner et al., 2010). Marine fish populations do not always respond uniformly to the change in temperature of either the oceans or freshwater systems. As a result, fluctuations in fish population structures can be created from the differing water temperatures experienced by mature fish (Shen et al., 2016).

Foraging. Temperature changes in the climate have been indirectly influencing behavioral feeding habits of many aquatic organisms. Disruptions in upper trophic levels have been established due to several changing aspects as a result of an increase in temperature such as an increase in diatom blooms (El-Sayed & Van Dijken, 2007; Winder & Schindler, 2004). As a result, species must change their behavior to cope with altering food sources or face extirpation. Evidence has been provided linking temperature to the decreased productivity in lakes. The surface water warming influenced by climatic changes has disrupted the stability of lake water columns (O’Reilly, Alin, Plisnier, Cohen & McKee, 2003). A difference in the dispersion of traditional food locations, scarcity, and availability all influence the changing of behavior in aquatic organisms. As a result, these aquatic organisms are adapting behaviorally to the abiotic changes in the environment.

Temperature is not the only influence upon the production and dispersion of food resources which aquatic organisms utilize. Other climatic factors such as wind have drastic impacts on large physical structures in the ecosystem. Although increased temperature and precipitation can cause an increase in storm severity (Wasko, Sharma & Johnson, 2015), in other cases instabilities in climatic composition drive the production of weaker and less frequent wind movements. As a result, the lack of wind contributes to the reduced mixing of water columns which reduces nutrient-rich waters (O'Reilly et al., 2003). Ultimately, this climatic change leads to a change in aquatic organism foraging behavior to accommodate the change in environment.

Predator-prey interactions. The increase in both temperature and precipitation can have an effect upon the frequency and severity of storms (Wasko et al., 2015). This factor has an influence on the water systems due to the increased movement of water in those environments. The additional flow of water due to more precipitation and storms increases the turbidity of the water. The increase in turbidity has a significant influence on the predator-prey interactions of fish due to the reduced visibility in these environments (Chivers et al., 2013; Ferrari et al., 2010). The effects of the increased turbidity alters the quality of the fishes' recognition ability. This ultimately has an effect on the feeding of the fish, reducing its total prey consumed.

More significant effects of a changing climate are observed in the effects of temperature on predators. An increase in temperature influences predatory fish to make more attacks on prey (Grigaltchik et al., 2012). However, a threshold is held at a high water temperature which then actually decreases the frequency of attacks made by the predators. In both scenarios, the increase in environmental temperature has a significant effect on the interactions between the two fish which can ultimately influence the population dynamic in the ecosystem. Attack speeds of predatory fish maximizes with a rise in temperature while prey have reduced reaction distances (Allan et al., 2015). Both effects increase predatory rates. This scenario suggests that the increase in marine environment temperature influenced by climatic changes will have a negative effect on the population interactions of fish species. In other scenarios, the temperature fluctuations of a habitat influences the prey species more severely than the predator which again increases predatory rates in the species interaction (Broitman et al., 2009). In either case, climatic events which influence the physiological change in an organism’s body temperature affects the behavioral patterns of predator-prey interactions due to the multiple behavioral aspects in the relationship.

Conclusion

The physiological and behavioral changes occurring on wildlife have significant impacts on individual organisms. These organismal level changes are vital to the species since it must adapt to changing environments if it is going to survive (Hoffmann and Sgro, 2011). The result is that each organism faces unique challenges influenced by climate change.

However, the effects of climate change on terrestrial and aquatic fauna go beyond organismal level changes and extend into interspecific interactions (Schmitz & Barton, 2014). Alternatives for a species' survival may also be to permanently migrate or change environments to survive (Kearney et al., 2009). A combination of both cases is a derived scenario as predatory pressures can influence the migration of lower trophic level organisms to new environments (Bond et al., 2019). In any case, the changing interactions between animals within an environment alter the ecological dynamics of the ecosystem (Glaspie & Seitz, 2018). Therefore, the climatic and environmental changes that affect individual organisms have applied influences upon the larger ecosystem.

Not only do the influences of climate change affect individual organisms as well as biotic system interactions, they also have an influence upon the physical structure of the habitat. Many animals have interactions with the environment which can physically alter the habitat in which they reside such as ecosystem engineers. Many stable interactions within an ecosystem are directly or indirectly dependent on these interactions (Mourant et al., 2018). As a result, the influences of climate change may have effects upon ecosystem engineers which will then have drastic impacts upon the physical habitat of an ecosystem.

A large portion of how climate change affects wildlife is represented in literature, however many topics within this large area of research remain underrepresented. Within both terrestrial and aquatic areas, further studies should be directed toward the unique functions of all major systems in an animal's body. Most research, in general, is focused toward the metabolic processes or respiratory abilities. However, although it is understood that there are multiple ways in which an aquatic organism respires and that there is great variability in the quality of water that affects respiration, little recent research has been conducted on the effects of climate change on the physical respiratory systems of aquatic organisms. These areas offer opportunity for discovery within this field of science. Potential ecological advances lie within these unsearched areas of study.

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