

Effects of climate warming on animals and their regulation of temperature

Jiarui Yu *

Environmental biology, University of Nottingham, Nottingham, UK

* Corresponding Author Email: 2576674375@qq.com

Abstract. Warming is the biggest and most serious of the environmental problems of the day, and it's a matter of survival for living things. Warming is causing metabolic disorders, oxidative stress, immunosuppression and even death in animals. In order to survive, animals have to learn to adapt to climate change, which can be reflected in behavioural and physiological changes, such as early migration of birds, changes in habitat location in response to temperature changes in metazoans, and even modulation of their liver size, corticosterone secretion and maternal effects).

Keywords: Metabolic disorders, oxidative stress, corticosterone, maternal effects.

1. Introduction

Climate change is a long-term change in temperature and weather patterns, which may be due to natural causes, but over the last two centuries, human activity has been the main cause of climate change, with gases produced by the burning of fossil fuels by humans increasing global temperatures, also known as warming. The effects of warming on animals are significant and are categorised into effects on growth and health.

2. Effects of climate warming on animals

Climate warming can have negative impacts on animal health, which may be direct or indirect. Direct effects include temperature-related disease and mortality, while indirect effects occur through more complex pathways, such as climate effects on microbial density and distribution, distribution of vector-borne diseases, and food and water shortage diseases [1].

2.1. Direct effects

The direct health effects of climate change are likely to be primarily due to higher temperatures and increased frequency and intensity of heat waves. These effects are produced by heat stress, which, depending on its intensity and duration, may lead to metabolic alterations, oxidative stress, immune suppression and death, thus negatively affecting the health of animals [1].

2.1.1. Metabolic Disorders

Thermostats respond to high temperatures by increasing heat loss and decreasing heat production to avoid elevated body temperatures. These responses include increased respiration and sweating rates and decreased food intake. For example, heat stress can cause lameness in cattle, which may be due to ruminal acidosis or increased bicarbonate output. Heat-stressed cattle eat less frequently during the cooler periods of the day, but the amount of food eaten per meal increases. Feeding is reduced during hotter periods of the day and increases when the ambient temperature is lowered, which can lead to acidosis. As the ambient temperature increases, the respiratory rate increases, progressing from panting to open-mouth breathing. Rapid loss of carbon dioxide can lead to respiratory alkalosis. Heat stress can also lead to metabolic diseases in cattle, as a reduction in feed intake coupled with an increase in maintenance energy expenditure may alter the energy balance, and ketosis occurs when the animal is in a state of severe negative energy balance, with a significant transfer of fat [1].

2.1.2. Oxidative Stress

Oxidative stress occurs as an imbalance between the production of a pro-oxidant substance and the antioxidant state, and its effects include alterations in life-history traits and reductions in whole-organism adaptations. Telomere wear and tear due to oxidative stress is a major cause of accelerated growth and reduced lifespan in animals. Telomeres are nuclear proteins that cover the end of each chromosome, and they help maintain genetic stability. Normally telomere sequences shorten after each cell division, whereas in harsh environments animals subjected to cellular oxidative stress may have shortened telomeres, resulting in reduced lifespan and reduced survival [2].

2.1.3. Immune Suppression

Heat stress alters the immune function of animals and makes them susceptible to infectious diseases. Depending on the duration of exposure, heat stress can enhance or suppress an animal's immune function [3]. Immunosuppression promotes the development of infections, which impairs reproductive efficiency and may compromise animal welfare and increase the use of antimicrobials. Increased use of antimicrobial drugs may lead to the development of antimicrobial resistance in microorganisms. On the other hand, climate change may introduce new or re-emerging pathogens and disease vectors [1].

2.1.4. Death

Climate warming has made extreme weather more intense and frequent. High temperatures may lead to heat stroke, heat exhaustion, heat cramps and eventually organ dysfunction in animals. These heat-induced complications occur when the body temperature rises 3 to 4 °C above normal [1].

2.2. Indirect Effects

Weather and climate change may affect the biology and distribution of vector-borne infections. For example, changes in temperature, global wind, precipitation patterns and changes in relative humidity in temperate climates will positively affect insect reproduction and their population densities. As a result, some tropical diseases, especially those transmitted by insects, may move from their natural endemic basins to other countries. Another mechanism through which climate change may alter livestock and human health is represented by the favorable effects that high temperatures and moisture may exert on growth of mycotoxin-producing fungi. When animals consume large quantities of contaminated feed, mycotoxins may cause acute disease episodes. Finally, parasitic disease is the other examples of how climate change is affecting animal health. Some parasites complete a significant portion of their life cycle outside the host's body, making their survival and development vulnerable to climate change [1].

3. How are animals adapting to the climate warming?

Animals must adapt to climate change in order to survive and reproduce, and the failure of species to respond adequately to new environmental conditions may lead to population declines or even species extinction. Animal thermoregulation of climate warming can be divided into two categories: behavioural and physiological.

3.1. Behavioural thermoregulation

3.1.1. Birds advance their spring migration in response to climate change

Within species or populations, advancement is typically most pronounced early in the season. Many studies in Europe show that the first arrival date was on average about 0.4 days⁻¹ year earlier, compared to an early arrival date of 0.1-0.2 days yr⁻¹ representing the mean or median migration date. This may reflect the greater influence of climate on early migrating individuals. Despite regional, species and population differences, in general, bird studies in North America and Australia are broadly similar to those in Europe [4].

3.1.2. Basking and seeking shade

Recent research suggests that, assuming body temperature equals ambient air temperature, the physiological sensitivities of tropical ectotherms may make them more sensitive to specific levels of climate warming than temperate ectotherms [5]. For example, behavioural thermoregulation in lizards, maintaining a position in the shade in the tropics and shuttling between sunlight and shade in temperate and continental regions, this consists of three distinct behaviours: 1) sitting passively on sunny surfaces. 2) sitting passively under the shade. 3) moving in and out of the shade or retreating underground. For many terrestrial ectotherms, performance is best at core temperatures above 20 °C, peaking around 30-35 °C, with the vast majority experiencing heat stress at temperatures above 40 °C. The majority of terrestrial ectotherms have been found to be able to survive in the sun. Another mechanism of behavioral thermoregulation in ectotherms is an altered daily and seasonal timing of activity. In temperate environments, climate warming may indeed increase potential activity time for many ectotherms. For tropical and desert taxa, however, potential activity may often be reduced and the potential for behavioral thermoregulation to buffer the impacts of climate warming on potential above-ground activity will be strongly contingent on the availability of shade [6].

3.2. Physiological thermoregulation

3.2.1. Modulate liver size and liver function.

The two temperate lizard congeners, *T. septentrionalis* and *T. wolteri*, achieved thermal acclimation of whole-organism metabolism through modifications to liver size and intensity, respectively.

T. septentrionalis, the widespread temperate–tropical species from a mid-latitude population, enlarged its liver size in response to cold acclimation, with few modifications to liver biochemical function. As the major site of metabolism, the larger livers in cool conditions could be achieved by some combination of enhancement of cell size and number, higher mitochondrial density, higher enzyme concentration, and more fuel storage, leading to upregulation of whole-organism metabolic rates. Decreasing metabolic rates in warming environments would help conserve energy, providing an advantage for lizards in a warming climate.

T. wolteri, the narrowly distributed temperate species collected from a high-latitude population, modulated liver function in response to warm acclimation, providing increased metabolic intensity and apparent shifts in fuel utilization without the corresponding increases in organ size. They modulate metabolic rate by modifying mitochondrial function [7].

3.2.2. Secretion of baseline corticosterone.

Baseline corticosterone in lizards declines seasonally during periods of intense heat waves, especially in population that are in the driest conditions. Low basal secretion of corticosterone may lead to decreased activity levels and reduced water loss under extreme climatic conditions. Behavioural modulation of water balance by reducing corticosterone secretion may represent an adaptive response to avoid overheating, dehydration and premature death when faced with extreme heat waves. Baseline secretion of glucocorticoids may be upregulated when individuals are exposed to non-optimal ambient temperatures to help individuals adjust their physiology (e.g. metabolic rate) and/or behaviour (e.g. behavioural thermoregulation) [8].

3.2.3. Maternal effects.

As a form of transgenerational plasticity, maternal effects play a critical role in shaping offspring phenotypes (e.g. growth and survival) in response to temperature change in lizards. Maternal effects modulate life-history trade-offs of offspring under a climate warming scenario. First, maternal behavioural thermoregulation plays an important role in responding to temperature variation or climate warming in ectothermic animals because effective thermoregulators may buffer the impact of extreme temperatures behaviourally, and thereby have time for intra- and inter-generation plasticity and evolutionary adaptation before they become extinct. Second, maternal effect may mediate oxidative stress, a potentially widespread mechanism underlying life-history trade-offs, to shape

offspring growth and survival. Third, maternal effects may mediate the trade-off via some physiological and molecular regulators such as epigenetic factors (DNA methylation, histone modification) and cytoplasmic and somatic factors (e.g. RNA, hormones) [9].

4. Conclusion

Human activities are becoming more and more frequent, and in the next decade or so, climate warming is expected to become more severe, which will be a threat to animals. Warming affects metabolism, oxidative stress and immune function, and animals will need to adapt both behaviourally and physiologically to warming in order to avoid the consequences of death or extinction.

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