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The Effect of Global Warming on Migration of Butterflies

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ABSTRACT

Certainly, global warming is one of the most important environmental problems of mankind today. Increased human activities, especially in the last few decades, like burning fossil fuels, increasing CO_2 emissions, deforestation, and other practices have exacerbated the global warming phenomenon. The increase in greenhouse gases leads to an increase in temperatures above the normal rate and this causes fires, droughts, sandstorms, high soil salinity, and fluctuations in precipitation. These changes in the environment affect not only humans but also all living organisms, including insects. Insects are the largest group of living organisms on earth. Therefore, one of the creatures that will be most affected by these changes is insects. Increasing temperatures, rising CO_2 levels, and changing rainfall patterns may affect the interaction between plants and insects. For example; the development of insects may accelerate, insect pests and insect-borne diseases, the number of generations in a year and winter survival may increase, the geographical distribution may expand, biological control of the pests may decrease, and as a result of all these, economic losses in crops may increase. Global warming may also affect the migration of insects, in particular, butterflies of which about 600 species have migratory behavior. This may be due to several factors, including the loss of the habitats on which the larvae feed, the nectar resources and the deterioration of their winter habitats, the adaptability and productivity problems in their new habitats, the attack of natural enemies, the disruption of migration signals and the change in wind patterns. In addition, the migration of butterflies may increase with the effect of global warming. Moreover, an increase in temperatures can also cause changes in butterfly morphology, e.g., a reduction in wing size that reduced their flight activity. In this review, we discussed the impact of global warming on butterfly migration.

1. Introduction

Insects are the largest group of living organisms on the earth's surface. They enter every ecosystem. Not all insects are considered pests. Some of them are useful like pollinators, bees, butterflies, and natural enemies (parasitoids, predators). Unfortunately, there is little interest in them while these organisms are affected by any changes that are occurring on earth. Today, the tangible effects of human activities such as the production and consumption of fossil fuels, industrial activities, deforestation, using of pesticides, and various chemicals are seen. Global warming, which was originally a natural event and not a problem, is warming the earth. Without it, the earth's temperature would be low and therefore life would be impossible. But some activities of humans have increased gases like carbon dioxide, nitrous oxide, and methane above their natural levels. These gases absorbed the infrared radiation emitted by the surface of the earth and became like a greenhouse. This greenhouse effect led to a sharp increase in temperature, the spread of fires, the occurrence of droughts and floods in different regions of the world, the occurrence of migrations of various species of humans, animals, and insects (Kweku et al., 2018).

Insects have migratory behavior and due to weather changes, they migrate either in search of food, when food decreases, or displacement begins. They affect the ecosystem and human life by breaking down organic matter, pollinating plants, and more during their migration (Jankielsohn, 2018). In this review, we discussed the importance of insects, especially butterflies, migratory behavior in insects particularly butterflies, then the impact of global warming on agriculture and insects in general, and also, we discussed the impact of global warming on butterfly migration based on previous studies.

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2. The Importance of Insects, Especially Butterflies

Insects are the largest group of living organisms on earth and very few of these insects are considered pests. Insects play a vital role in various ecosystems, for example, the movement of insects in and out of the soil increases the flux of N and P elements. Insects contribute to plant diversity through pollination, as two-thirds of all plant species depend on insects. Herbivorous insects are naturally controlled by predators and parasitoids. The order Hemiptera, Coleoptera, Diptera, and Hymenoptera are a large part of the predators and parasitoids. 4000 dung beetle species play an important role in the decomposition of manure (Jankielsohn, 2018). The role of butterflies is very important in pollination. They transport pollen to different places either through their mouthparts or the remnants of pollen grains on their legs or body. The migratory behavior of some of their species also helps with pollination and thus contributes to the restoration of damaged ecosystems by providing food. Moreover, an increase in the number of butterflies means an increase in the number of pollinators and an increase in the diversity of pollinated plants. They also contribute to the genetic variation of plants by collecting and distributing the pollen grain obtained from different plant species and spreading it to other plants. Since the plant that butterflies live on absorbs carbon dioxide, it is ingested by butterflies during feeding, thus removing carbon dioxide from the atmosphere. Butterflies are an ecological indicator of ecosystem health; more butterflies mean a better ecosystem. Butterflies respond to environmental stress; reproduction rates increase when the trophic level is low. They are considered more facilitated food for other animals such as birds and reptiles (Ghazanfar et al., 2016).

3. Migratory Behavior in Insects, Particularly Butterflies

In insects, migration is a movement in a given direction and distance. This may be long-range and seasonal. The main reason for migration is to provide sustainability of the species or organism for upcoming generations by dispersing their offspring to different places and times under different environmental conditions (Holland et al., 2006). The large geographic range is thought to help conserve the species from extinction. However, migratory species face many threats, for example, due to habitat destruction and human predators that have led to the extinction of a common migratory species such as the Rocky Mountain locust (*Melanoplus spretus* (Orthoptera: Acrididae)). Many migratory species have morphological, physiological, and behavioral characteristics that enable them to migrate. An internal biological clock enables them to migrate. Migration occurs in all insect species, but they vary in distribution, even within the same group there are differences (Ramesh, 2018). Migration occurs in pollinators, herbivores, predators, pests and insects that transmit human and plant diseases. Insect migration is imperceptible due to their small size and lack of mass aggregation compared to vertebrates. During migration insects have some strategies for example, their movement is enhanced and foraging and reproductive activities are reduced. Migration occurs pre-reproductively in adult insects. Since migration pre-reproductive, reproductive ability and ability to colonize are at or near maximum. They live in habitats that are temporary. In these habitats, population increase and therefore more colonization occur. Migratory insects influenced by environmental factors and adapted to prevailing conditions. Migrations are either daily or seasonal (long distances). In the northern hemisphere, movement occurs in the spring to north to provide food during the summer and south in the fall to provide food after the winter season. In some species, the migration occurs in one direction and they never turn back, like the Red Admiral butterfly (*Vanessa atalanta* (Lepidoptera: Nymphalidae)) and Painted Lady butterfly (*Vanessa cardui* (Lepidoptera: Nymphalidae)). They fly out of the Mediterranean Sea in summer, breed and die. Their offspring fly south in the fall and die resulting in offspring returning again (Dingle, 1972).

4. The Impact of Global Warming on Agriculture and Insects

Global warming has affected every life cycle on the planet. The reason is humans and the first affected are humans too. Also, agricultural production was affected because it directly depends on weather and climate factors. Any changes in precipitation rates, water resources, temperature, and CO_2 concentration affect agricultural production. Northwest India suffers from deteriorating soil fertility, rising salinity, changing water table, and irrigation water quality. South America, North Asia, and Central Asia experienced increases in precipitation. Since groundwater recharge and soil moisture can change, droughts and floods can occur (Allen et al., 2004). Rising temperatures lead to drought and thus slow down or destroy plants growing and this reduces overall agricultural production. A 100 mm decrease in precipitation reduces growth by 0.35% (Gupta et al., 2021). The quantity and quality of forage are also affected by temperature rise and therefore livestock is not spared from the effects of global warming. With climate change due to drought and rainfall, pest and disease patterns may vary according to this alteration. When the global temperature increases, the reproductive cycle of insects increases, increase in the species and numbers of insects, which means an outbreak of pests that leads to an increase in the use of harmful pesticides (Aydinalp and Cresser, 2008; Sangle et al., 2015).

Increasing temperatures, rising CO_2 levels, and changing rainfall patterns may affect the interaction between plants and insects. For example; the development of insects may accelerate, insect pests and insect-borne diseases, the number of generations in a year and winter survival may increase, the geographical distribution may expand, biological control of the pests may decrease, and as a result of all these, economic losses in crops may

increase. Global warming has caused pollinators to move some distances, leading to an increase in the food security issue, and hence farmers have been forced to grow specific crops to compensate for the lack of pollination. For instance, rising temperatures have led to a decline in large areas of coffee and chocolate acreage due to a lack of pollinators (Robinet and Roques, 2010).

5. The Impact of Global Warming on Butterflies and their Migration

Climate affects directly and indirectly, either negatively or positively on the migration route of butterflies. The effects of climate change resulting from global warming on humidity and temperature systems disrupt migration signals. Migratory species are threatened because the habitats for their migratory route have been compromised. In North America, the monarch butterfly, *Danaus plexippus* (Lepidoptera: Nymphalidae) population has declined by 80% in the last decade and may even disappear forever. This is due to several factors including loss of the habitats the larvae feed on, nectar resources and degradation of their winter habitats, attack by natural enemies, and changing wind patterns. The nectar plants were affected by drought due to the lack of rain. When monarch butterfly fed on irrigated *Liatris mucronate* (Asteraceae), it stored 80 mg fat, while when fed drought-affected *Verbesina virginica* (Asteraceae), it stored only 40 mg (Chowdhury et al., 2021). Habitat types affect the migration of butterflies. In forests, migration is less than in meadows, but meadows have also been destroyed due to human activities and global warming (Hoyle and James, 2005). The annual migration of the monarch butterfly (*D. plexippus*) in eastern America is between the summer breeding areas (in the north of the United States and southern Canada) and between the winter sites in central Mexico. But its annual migration has been affected by the high temperatures. The fall migrations in the month of September and October are delayed by six days per decade, due to the high temperatures in these two months. This led to a decrease in the arrival of migratory numbers to winter sites in Mexico, which in turn affected the success of their migration and thus the destruction of these species (Culbertson et al., 2022). Studies indicated that the climate works in conflicting ways during the spring and summer. The influence of the climate in Texas affected the activities of butterflies in Ohio, while the climatic conditions in Ohio did not affect the migration and activities of butterflies. Average temperatures and spring rains in Texas led to the arrival and growth of a greater number of monarch butterflies (*D. plexippus*) in Ohio. Rising temperatures can sometimes make winters warmer. This has led to some butterflies expanding their range rather than being negatively affected by the deadly cold temperatures. The warmer temperatures have been beneficial for many European butterflies, including migratory ones (Zipkin et al., 2012). The migration of 75 species of butterflies has increased with climate change in Portland between 1982 and 2005. For example, Dark Sword-grass, *Agrotis ipsilon* (Lepidoptera: Noctuidae), and the beautiful Painted Lady, *Cynthia cardui* (Lepidoptera: Nymphalidae) were recorded 23 and 20 years, respectively in Portland between 1982 and 2005. An increase of 1°C in temperature resulted in an increase in migrating species by 14.4 ± 2.4. Global warming may also threaten the adaptation of migrant butterflies. It poses a threat to resident species that are less mobile and more specialized in habitat requirements (Sparks et al., 2007). In China, increasing the average temperature in the last decades led to an advanced peak and increased proportion of high ovarian development levels of first generation *Mythimna separata* (Lepidoptera: Noctuidae) females. They suggested that rising temperatures due to global warming may impact *M. separata* migratory status and cause damage in corn production (Chen et al., 2019). Rising temperatures led to a reduction in the wing size of *V. cardui*. The larvae of *V. cardui* were reared at three different temperatures, 22, 28, and 33°C. It was determined that as the temperature increased the wing size of the adults got significantly smaller. All larvae used in the experiment did not complete their transformation and died which were reared at 33°C. It's known that *V. cardui* is a migratory species and migrate from Africa to Europe annually. But smaller wings due to global warming could prevent *V. cardui* from making this journey (Kennelly et al., 2017).

6. Conclusion

It is thought that global warming will affect the butterfly life cycle and therefore their migration. Warm temperatures are beneficial for many butterflies. However, the average temperature rises above the normal level affected their development as well as disrupted the signals of natural migration. Also, nectar resources that are necessary for adult butterfly feeding have been adversely affected by drought. The habitats on which species depend on their migration route, including winter habitats, have been endangered, and the meadows that butterflies prefer more for migration have been destroyed. Rising temperatures due to global warming have also affected the development of butterflies. Above the average temperatures caused an increase in the metabolism of butterflies that led to development faster and sometimes even death. In addition, increasing temperatures caused butterfly wings to become smaller which may cause butterflies to be unable to migrate. On the other hand, global warming has increased the migration of some species of butterflies which are considered pests. Butterflies are an ecological indicator of ecosystem health. Thus, the effect of global warming on butterflies should be carefully studied and necessary precautions should be taken.

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