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Effects of climate change on butterfly species

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Abstract. In recent decades, climatic change has grown to one of the most concerned problems in the society. Species across the globe have been responding to climate change. In this article, butterflies' responses across the globe towards climate change are mainly focused on. Butterflies are sensitive to climate change due to their species interaction, high mobility and links with specific habitat conditions. They also have a wide distribution, covering all continents but Antarctica. Climate change impacts biodiversity and affect butterflies' various behaviors. This article has discussed butterflies' organismal responses, range shifts, alterations of phenology behaviors and species interaction. After analyzing studied data, it is shown that climate change has led the genetic revolution of certain mountain butterfly species to extinction. Warming climate has increased voltinism in European butterflies and has created mismatches in trophic interaction via driving mountain butterflies towards the summits. It is also studied in the article that warming night temperatures effect oviposition and life span of Finnish Glanville fritillary butterflies. The effect of disturbed El Nino/La Nina frequency due to climate change on tropic butterfly abundance has also been mentioned. Climate change has also affected monarch migration and population via shifting host plant distributions. By diving deep into the specific response butterflies have towards climate change, a more developed view on the effects of climate change could be gained. This is aimed for finding solutions to better preserve biodiversity.

Keywords: Climate Change, Butterfly Species, Response, Species Extinction, Biodiversity

1. Introduction

Climate change is casting notable impact on species across the globe. Species have been responding to climate change. In this article butterflies' responses towards climate change have been specifically studied. Butterfly is a kind of specie under the classification of Lepidoptera order, Amphiesmenoptera superorder and Insecta. Butterflies has wide distributions across the globe. Their distribution covers a wide range of landscapes, including all continents but Antarctica. There are about 17,500 species of butterflies in the world. Butterflies are effective indicators to climate change. They play vital roles in nature, for they make up a diverse group in the ecosphere, functioning with multiple identities such as pollinators, herbivores, and easy meals for insect-eaters [1]. In this article butterflies' organismal response, population and migration, phenological responses and alteration in trophic interactions have been studied. Climate change affects butterflies in various means. It has been pointed out that climate change post threats to butterflies' survival via threatening genetic evolution and driving range shifts. The relationship between El Nino/La Nina effects and regional butterflies has also been studied. By reviewing the different aspects butterflies are affected by climate change, a more vivid and advanced view into how climate change has specifically affected each butterfly species studied could be gained. This helps us gain a

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developed and systematic view on how butterflies have made short-term responses towards recent climatic change and how some species have made evolutionary adaptations. Only in this way can effective solutions with the aim of preserving biodiversity as well as saving endangered species emerge and develop.

Although studying butterfly is a common climatic responses topic, studies which combine and integrate these records to show a developed picture of climate change effects on butterfly species is rare. Studies have been done, studying specific butterfly species on a regional scale basis. In this article, how climate change has affected various butterfly species across the globe is clearly presented. Butterflies' organismal responses, population shifts, phenology response and species interactions have been focused on, covering specifically butterflies' genetic revolution, oviposition behavior, phenology, voltinism and species trophic interactions. The effect of disturbed El Nino/La Nina frequency due to climate change on tropic butterfly abundance has also been mentioned. The range of butterflies chosen in this article are also global and thus convincing, including representative species, such as small blue butterflies in UK, mountain butterflies in the Alps region, various tropic butterfly species and monarch butterflies which represent species that possess typical migratory behaviors.

The aim of this paper is to present the various impacts of climate change on butterfly species, to analyse species responses to increased temperatures and to suggest implications for biodiversity conservation. Firstly, the main focus is on organismal responses, evolutionary adaptations, range shifts, phenological and trophic interactions in butterflies. The different specific responses of butterflies to climate change are then analysed.

2. Butterfliy characteristics

Butterflies are common animals all over the world. Butterflies, together with other insects including moths and skippers, constitute Lepidoptera, an insect order under the class of Amphiesmenoptera superorder and Insecta. Butterflies are nearly worldwide in their distribution. Their distribution covers a wide range of landscapes, including all continents but Antarctica. Different butterfly species have adapted well to nearly all types of environments. Most butterflies have grown to get accustomed to specific ecological niches across the globe. However, each specie's habitat sites choices are rather restricted, for most of them are harnessed to limited amounts of herb species, more often to an exclusive and unshared section of the herb. Consequently, due to butterflies' unique tendency in confining themselves to certain fixed geological terrains, their population is rarely rich when it comes to multiple different kinds of ecological domains. There are about 17,500 species of butterflies on the planet. In equatorial areas, butterfly species diversification reaches a far greater magnitude than that in elsewhere. While the number of lepidopteran populations is bigger in the tropics, certain numbers of butterfly species that populate around the polar vegetations exist. For lepidopterans, their life circle consists of four dominant stages, starting with egg, larva, pupa, and ending with adults eventually. Larvae and adult butterflies feed on plants extensively, usually relying on a fixed segment of a particularly interaction-associated vegetation.

3. Butterfly responses towards climate change

3.1. Organismal response

3.1.1. Threats to genetic structures. Butterflies, especially those who habit in mountainous areas, have evolved differently due to continuous climate change effects. Butterflies' genetic structures have been altered by climatic inconstancy. Some possess earlier root origins and thus may be affected more intensively. Some possess recent roots, and thus may be hit as hard by climate change. For mountain butterflies, they have made genetic evolutions in response to climate change [2]. Genetic evolutions play vital roles in butterfly groups, for the structural and behavioral adaptions they evolve are critical to the entire population cluster survival. Climatic changes have threatened the genetics uniqueness of quite a large

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number of mountain butterflies. Schmitt T. et al. analyzed various populations of a representative mountain butterfly called Erebia manto to study genetic groups [1, 2]. To analyze genetic populations effectively, SDMs (species distributional models) have been utilized. The Erebia manto butterflies have mainly evolved genetic groups in the following mountainous regions: Pyrenees, Vosges, Alps and southern Carpathians. Among all six distribution sites, the Vosges one exhibited the greatest split from other sites. It can be indicated that this is partly a result of their ancestorial origin which may date back to earlier times. The great severance caused by climatic change could trigger serious maladjustment of butterflies towards the changing environment, leading to species disappearing in the worst scenario. Butterflies in the Pyrenees region and southern Carpathians also encounter genetic split of high magnitude. In the contrary, three groups in the Alps region don't exhibit a magnificent evolution in their genetic structure. This may indicate that they are of a relatively more recent genesis. Majority of mountain Erebia manto is negatively affected by climate change. Their genetic structures have shown to be severely threatened by climatic warming. Climate change may cast catastrophic effect on these species. According to reliable technologies, it is persuasively predicted that Vosges races of Erebia manto may face the danger of extinction in the succeeding decades of developing climatic warming. Not only Vosges root, but also the southern Carpathians and Pyrenees roots might probably disappear in the future.

3.1.2. Oviposition. Climate change influences butterflies from a variety of aspects. It affects butterflies' population evolution, timing of reproduction, abundance of eggs, site preferences, and other behaviors such as flying performance and so on. Take the Oviposition behavior and timing of emergence of Cupido minimus for example. According to the study of Ashe-Jepson E. et al. Cupido minimus, also known as small blue butterfly, has high and specific requirements for its host plants [3]. Small blue butterflies consume a particular herb called Anthyllis vulneraria. They must lay only one egg on each plant individual, otherwise their larvae would perform cannibalism, competing against one another to make sure of sole existence. Small blue butterfly populations are highly restricted to develop intensively. While feeding on Anthyllis vulneraria exclusively, they are restricted to oviposit singly on each herb individual. If they lay more than one egg on a flora, the larvae will perform cannibalism, eventually decreasing population size. Thus, small blue butterflies are extremely sensitive to temperature changes, for climate change may cast effects on Anthyllis vulneraria flowering times, consequently influencing various aspects including reproduction, egg abundance, egg quality and adult emergence. According to the study, after using extensive data, results show that adult butterflies' oviposition behaviors, including reproduction frequency and site choices has remained relatively same across the timespan. It is notable that eggs are emerging in greater numbers. Egg abundance is shown to be especially higher on certain host plants. Egg abundance has grown to become higher on flowerheads that were taller than surrounding shrubs. The surrounding vegetations are also generally of a higher altitude. Clearly, butterfly species produce more eggs on taller plants. To better conserve small blue butterfly populations and biodiversity, taller Anthyllis vulneraria should be arranged among taller shrubs. This implied conservation solution could possibly encourage butterfly oviposition to a greater scale. In this way, fierce competition in the specie groups could be significantly reduced, thus improving for larval survival.

Climate change also have effect on choice of oviposition sites. Global warming is influencing wild life on Earth. Sometimes climate change effects species negatively. It casts threat to their survival via altering their behaviors. For butterflies, they can be affected to change their oviposition site choices. This may cast threat to their population well-being for it effects the quality of butterfly offspring. Global temperature is rising. According to recent reports, temperatures turn out to rise at a faster speed at night than daytime. Experiments have been done in the study of Elena Rosa et tal [4]. In the experiment, the responses of Melitaea cinxia towards increasing temperature during night times are studied. The responses of both male butterflies and female butterflies have been tested. It is evaluated whether the choice on oviposition sites based on traits such as habitat situation and flora surroundings has been affected by temperature related properties during night time. Night-time thermal factors play vital roles in Melitaea cinxia survival. Females Melitaea cinxia has particular preference for laying eggs. They favor open locations for conducting reproduction. Nevertheless, results show that females are not heavily affected by temperature changes. Females show same interests in choosing open areas for oviposition. As they go through various thermal fluctuations during night times before they exhibit oviposition behavior, their interest for open spaces and general oviposition practices have remained steady. In the experiment, as female and male Melitaea cinxia get displayed under warm temperature circumstances during night, their life span and the survival of their offspring are affected differently. For females, warm conditions endured at nights did not threaten their survival. In the contrast, male life span has been notably shortened. For females, the success rate of the hatching of their eggs have shown to be brought down due to temperature warming. At the same time, while simulated climate change has shortened male adult butterflies to a certain degree, males are proven to sire eggs in larger clutches. Also, the success rate of the eggs they sired has also increased due to simulated temperature change. Thus, it may be indicated that climate change could make adult Melitaea cinxia butterflies live shorter lives, while boosting the survival quality of their offspring. This may suggest butterfly oviposition and reproduction strategies in response to threatening climatic warming.

3.1.3. Range shifts—butterflies. Driven to the Summits.Climate change cast notable impacts on butterfly range shifts behaviors. According to reliable sources, it has been recorded that various butterfly species that habitat in the eastern Alps regions have shifted towards higher altitudes. [5]. Because of climate change, it is recorded that mountain butterflies are moving to higher altitudes on a more frequent basis. Butterflies have been driven towards the summits due to climatic changing across a large time span. They have been continuously shifted for six decades. Mountain butterflies have conducted elevational shifts most intensively in current times. Maximum altitudinal range shifts are detected recently, while the detection of the shallowest elevation changes is limited to time intervals previous to the year of 1980. Butterflies are fragile in the face of climatic changings. They are very delicate organisms when it comes to climate change. There are multiple factors to their sensitivity, including their high mobility and particularly exclusive relationships with host plant species. The interaction between mountain butterflies and their host plants is vital for their population continuation, for each butterfly species may rely exclusively on its host vegetation for reproduction. It is pointed out that flora species in the Alps have responded to climate change in a homogeneous approach. Flora herbs are reported to be driven towards higher elevations. The range shifts of butterfly host herbs can create large scale geological mismatching, thus effecting trophic interactions between lepidoptera species and flora ones negatively.

Consequently, the range alterations may lead to severe spatial mismatches. Lepidoptera species in the Alps may be forced to get separated from their host plant species. The inconsistency caused by climate change harms the continuation of butterfly population groups, for it also separates them from fitting habitat circumstances. Climatic change causes interruption in various aspects. It greatly interrupts trophic associations between different species. Various trophic levels along the food chain, such as parasitic relations, can be notably fluctuated. The interruption can cause big trouble for lepidoptera survival, for the mountain butterflies studied exhibit exclusive preference over certain particular habitat landscapes as well as host vegetation to provide nutrition for offspring to grow successfully. Many butterfly species perform such exclusive links between they themselves and their host plant species. They can be confined to a specific natural habitat and a specific type of larval plant at the same time. For example, the fritillary Euphydryas intermedia habitats only in the open spaces in mountain forests. They are fragile to climate change because they also have restrictive requirements for oviposition sites on which they lay their eggs. Euphydryas intermedia adults and larvae feed on Lonicera coerulea singly. Lonicera coerulea can only be found in the open spaces of mountain forests.

4. Population response

Carrying those outstanding characteristics described above, aptamers have been worth noting as anti-viral diagnostic and therapeutic tools. In Wandtke et al.'s review [9], RNA and DNA aptamers have been broadly designed for the last five years for a wide range of viruses, from Ebola, Zika, and Dengue to HIV, HPV, influenza, and Norovirus. For anti-viral screening and biosensing, aptamers are prominent

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in detecting low loads of viruses and distinguishing close-related antigens compared to the nasopharyngeal or oropharyngeal swab samples with RT-PCR or IgG/IgM antibody in serology tests [24]. For therapeutic neutralizations, virus entry disruption by blocking virus-host cell receptor attachment and viral replication inhibition are common and effective strategies in aptamer-based direct inhibition [21].

4.1. El Nino/La Nina Effects on tropical butterfly population size

El Niño events are common climatic patterns that affect various species in the world. In an El Niño event, the surface of tropical Pacific Ocean is heated up. Trade wings emergence around equatorial regions is also affected. El Niño significantly disturbs circulation in aerosphere and circulation related with oceans. This may cast notable impact on regional to global overall climate. The variation and modification between temperate El Niño and cool La Niña activities are known as the El Niño-Southern Oscillation in general. El Niño/La Niña effects are the most vital elements which contribute to the strongest climatic fluctuations [6]. There is a close relationship between El Niño phenomenon and global climate change. El Niño phenomenon is a direct reflection to climatic evolution, for frequency of El Niño/La Niña occurrence often comes with major climatic evolution events [7]. El Niño/La Niña has significant impacts on rainfall of the western hemisphere. Consequently, it also affects a wide variety of wild life, those habitat in the tropical zones in particular. Studies have been conducted to determine tropical butterflies' responses towards El Niño/La Niña changes. Maja Kajin via adopting capture-mark-recapture technology for about ten years, the population growth of Nessaea hewitsoni has been assessed [7]. Nessaea hewitsoni are tested for their monthly and seasonal population responses. Butterflies are captured and analyzed in three separate time intervals. Their population responses are tested before, during and after El Niño phenomena. As it turns out, the general population size of this tropical butterfly is not affected. Nevertheless, a delay in El Niño caused female lepidoptera to move.

In tropical areas, butterfly population size and lepidoptera diversity are closely associated with tropical rainfall [8-11]. According to Maja Kajin et al [7], strong rainfall post threats to Nessaea hewitsoni-survival, while the factors for their population abundance are widely diversified and no direct relationship between rainfall and population size is found. Nessaea hewitsoni possess shorter life span than other insects. This might be an indicator to its climate sensitivity. According to studies of Grøtan et al [12], butterflies have yearly periodic patterns for lepidoptera variety as well as population group resemblance, but not time intervals of reproduction. Grøtan et al [12] also announced that while species variety and butterfly abundance fluctuations exhibit annual periods, the total population in a group shows no evident periodicity. The temporary emigration of female butterflies also shows close association with El Niño, varying between years. Thus, although butterfly abundance and migration take place on a year-to-year periodic basis, population sizes may not necessarily be affected by El Niño.

Nevertheless, El Niño may affect herb growth, and butterflies heavily rely on their host plant species. According to studies of DeVries et al. [8] and studies of Walla et al. [9], tropical butterfly habitat more intensively in regions with higher host plant distribution density. During arid seasons, the standards and values of host plants declines significantly. To find high quality plants for oviposition, female Nessaea hewitsoni may be forced to start temporary migration. When there is no El Niño, the migration probabilities remain relatively consistent between male and female insects. However, when there is El Niño affecting rainfall, the probability value for female migration way exceeds that of male butterfly. This indicates female and male butterflies respond differently towards the climatic change of El Niño effects [13].

4.2. Expansions of asclepias host plants impact Migratory Monarchs

Monarch butterflies (Danaus plexippus) are commonly known species. They are mesmerizing lepidoptera and have been the subject of various researches. Monarch butterflies are persuasive representatives of migratory insects [14]. Generally, monarch groups experience two main annual migrations. In fall, adult monarchs move from northern United States and southern Canadian regions to central Mexico for hibernation purposes [15]. Once they reach Mexico, they remain inactive up until spring. In spring, from

February to March, adults of the consistent generation become reproductively dynamic and start migrating towards northern areas to oviposit in northern Mexico and southern America [16, 17]. Monarchs are closely dependent on their host vegetation species—milkweed. To find abundant milkweed for survival, generations and generations of monarchs keep migrating towards northern regions where the temperature is more moderate for high density milkweed emergence [18, 19]. Adult female monarchs show strong preference to lay eggs on particularly milkweed herbs. Meantime, their larval offspring are shown to grow up more successfully on milkweed plants in particular [20–22].

Migratory monarch butterflies rely heavily on host plant distributions. Thus, they may be highly sensitive to the fluctuation of host herb abundance driven by climatic change. The varying responses of milkweed species towards climatic change may essentially impact the continuation of monarch species. For example, via contrasting and comparing Fig. 1 and Fig. 2, it is predicted that the general distributions of Asclepias under climate change would have shifted northwards. The distributions of monarch butterflies would have also shifted northwards, as shown in Fig. 3 and Fig. 4. To be more specific, the population of Asclepias under severe climate change would has shrunken significantly (Fig 2). This affects monarch migration and population. The predicted distribution of monarch under severe climate change has shifted northwards more than that under moderate conditions (Fig 4). The monarch population under severe conditions would has also increased (Fig 4). It can be clearly indicated that females have diverging preferences over specific milkweed species for reproduction. For instances, female butterflies prefer Asclepias incarnata to Asclepias syriaca due to the differences in cardenolide concentrations [23]. What's more, it has been documented that Asclepias incarnata and Asclepias curassavica bear monarch larvae with higher success rate for survival. compared to the more common Asclepias syriaca [23, 24]. It is suggested that to reach optimal biodiversity, modifications of host plant species distributions can be done. For Asclepias syriaca and Asclepias incarnata, they should be limited to northern North America, while others such as Asclepias speciosa and Asclepias viridis ought to habitat broadly across North America. As most migratory monarchs migrate across North America, they can get particularly sensitive to alterations in host herb densities in summertime at which point they start breeding their offspring [19, 25]. To identify whether climate change post helpful or destructive influence on butterfly population, more specific and targeted aspects of different types of monarchs ought to be investigated in field observation [23, 24].

Whether impacts of climatic changes on monarch migration could be realized depends extensively on butterfly distribution in response to milkweed arrangements. Meanwhile, present migration routes may undergo shifts due to milkweed identification. The relationship between butterfly range modifications and host vegetation is also based on whether the ecological phenology of monarch butterflies correspond well to that of Asclepias in future climatic conditions [26]. Monarch migrations and population size may encounter notable alterations under future climatic change.

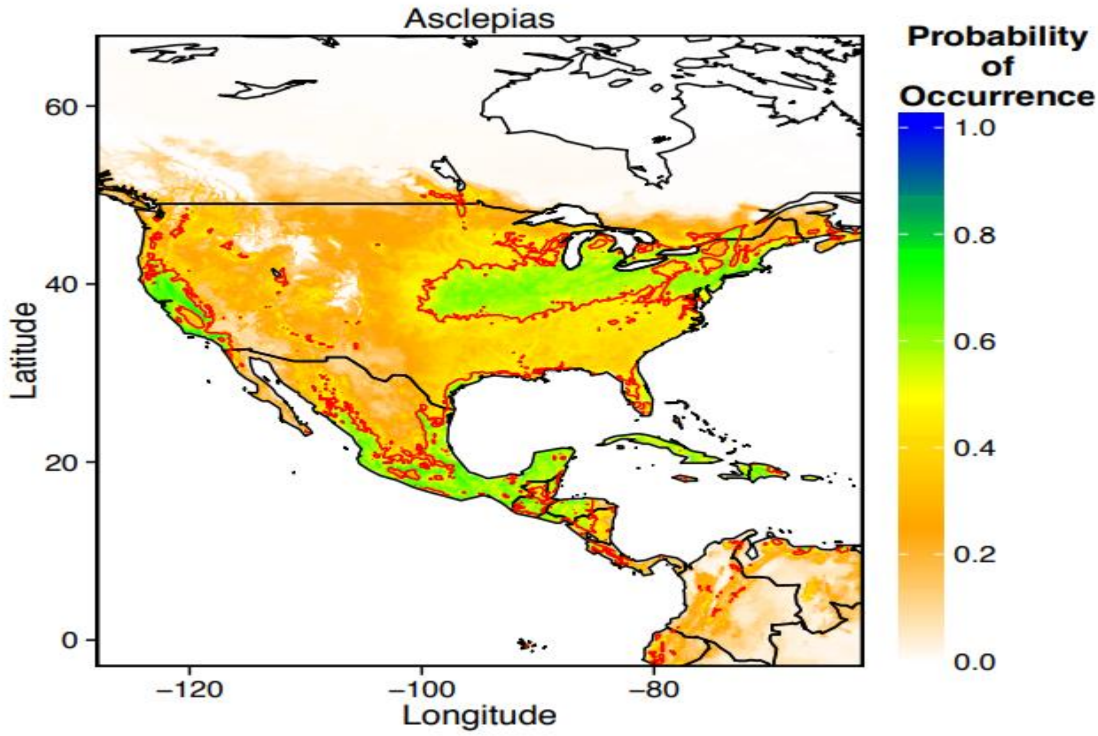

Figure 1. MaxEnt predictions of current Asclepias distribution without any spatial filtering [14]

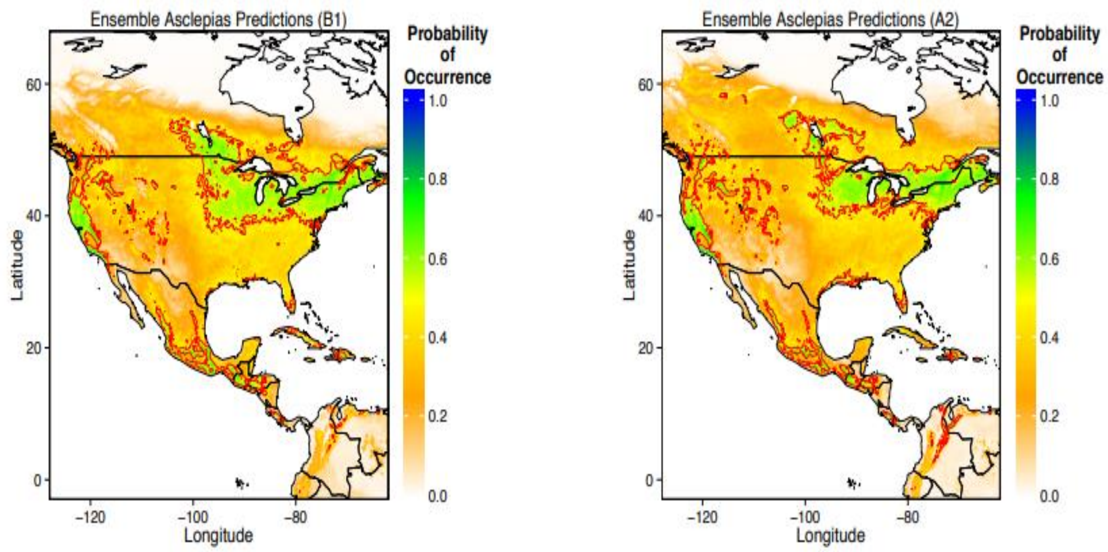

Figure 2. Predicted distribution of milkweed species under two climatic change scenarios without spatial filtering. (B1 under moderate climate change conditions; A2 under severe climate change conditions) [14]

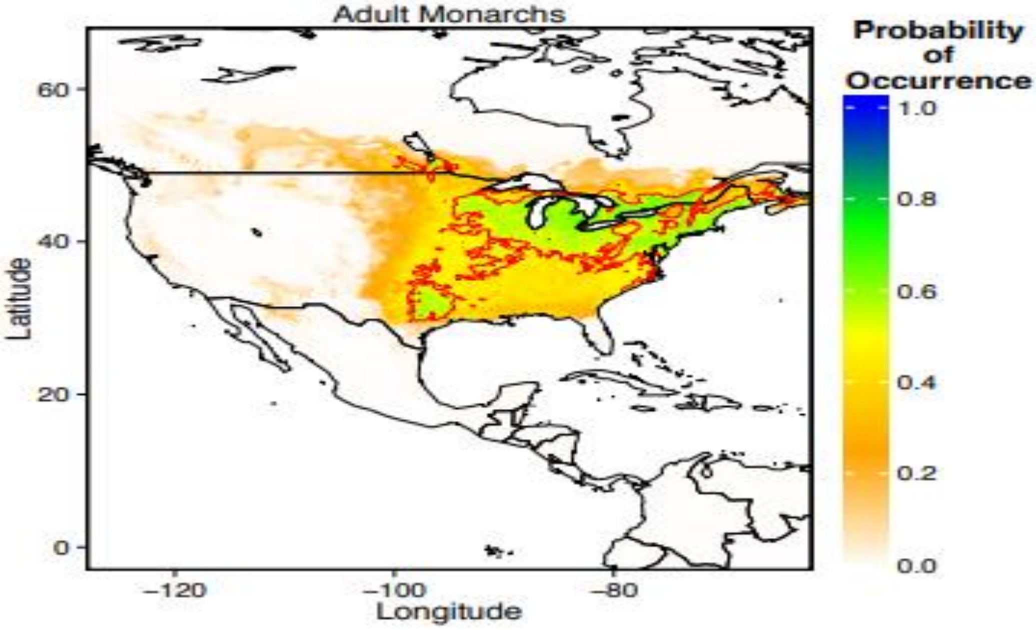

Figure 3. MaxEnt predictions of current monarch distribution without any spatial filtering [14]

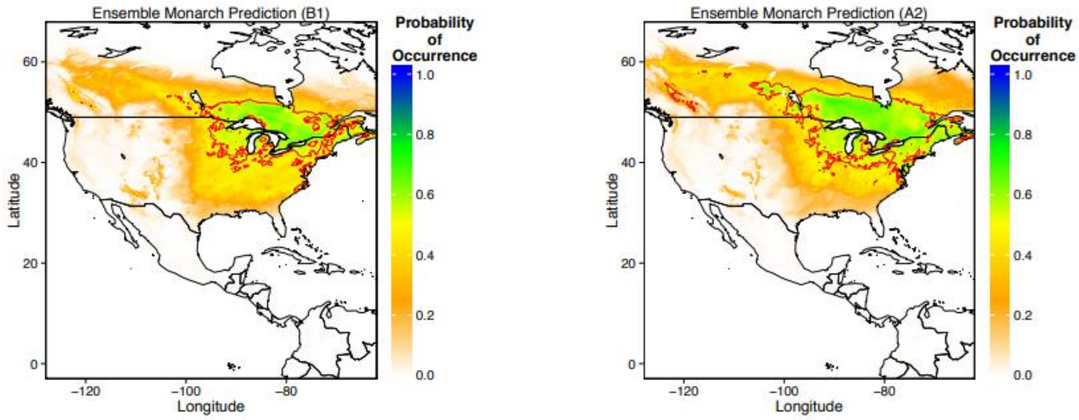

Figure 4. Predicted distribution of adult monarchs under two climate change scenarios without spatial filtering. (B1 under moderate climate change conditions; A2 under severe climate change conditions) [14]

5. Voltinism

Global warming boosts voltinism of butterflies in Europe. Climate change is reshaping spatial distributions, major migrations and phenology of a variety of wild life. For insects like butterflies, they are ectotherms and their metabolic rate can be directly altered by temperature fluctuations [27]. Thus, in seasonal cycles, many insect species encounter an earlier start and elongation of seasonal periodic duration [27]. However, from a long-term perspective, concerning impacts from both ecological and evolutionary perspectives, the importance of generation number and breeding efforts may exceed that of temporary seasonal variations. The number of generations is also called voltinism. An additional generation every unit time interval may cast significant on accelerating population growth [27]. Florian Altermatt [27] used a persuasive database which could be dated backtrack to the mid-nineteenth era, notable alterations in the voltinism of lepidoptera species such as butterflies and moths in Central Europe have been observed. It has been shown that the frequency to produce second and subsequent offspring generations have increased for a large proportion of multi-voltinism species, particularly under a moderate temperature since the year of 1980. Of the 263 species studied, 44 of them have been perceived to increase voltinism after the year of 1980. Fluctuations in butterfly voltinisms can lead to notable ecological consequences. Fluctuations in voltinism cause outbreaks of insects, including various species of pests that may cast destructive impacts on agricultural and forestry developments.

6. Species interaction

Climate change can cast notable and sophisticated impacts on wild life on Earth. By being involved in intricate interactions within various organismal communities, climatic fluctuations can profoundly influence species interactions, eventually shrinking species' population size. Butterflies are delicate insects which respond sensitively towards climatic changes. Climate change can affect butterfly interaction with their host flora species, causing mismatches and substantially threatening population continuation. Despite direct and immediate effects of climatic fluctuations on butterfly species, indirect impacts via intermediate species also exist, such as in host-plant interconnections. Butterfly and its host vegetation species are sensitive to temperature fluctuations. Meanwhile, the ecosystems in which they habitat are close ones, meaning butterfly and herb species are restricted in migration sites. [28]. The theory such that climatic fluctuations is going to probably confine the habitat shifts of a type of mountain butterfly in the Alps has been confirmed. It is tested that climate change may shrink butterfly population and range shifts via affecting host plant distribution [29]. To test for direct and indirect impacts climate change have towards butterfly species, simulations have been conducted to assess whether the distribution of a butterfly has been altered with or without host plants alterations. Climate change can disrupt species interactions, eventually casting a negative effect on biodiversity.

7. Conclusion

Climate change is closely associated global biodiversity, triggering species' response actions. Butterfly species across the globe have made various responses towards climatic change. Various butterfly behaviors have been altered by climate change, including oviposition site choices and migration range shifts. Climate change is also an important element in the evolution of butterflies' genetic structures and population growth. It directly impacts butterfly distribution via effecting host plant species. Climate change is threatening mountain species' genetic evolution to extinction. It effects small blue butterflies' and Finnish Glanville fritillary butterflies' oviposition behaviors. The temporary emigration of tropic butterflies is strongly correlated with El Niño, while mountain butterflies in eastern Alps have been driven to higher elevations, decoupling species interaction and mountain biodiversity. Migratory monarch butterflies are delicate species and they are fragile to climate-driven changes in host plant abundances. Global temperature warming boosts voltinism of butterflies in Europe. In the future, to better adapt to climate change and protect biodiversity, conservation methods associated with the relationship between butterfly and host plants species should be invested on. By diving deep into the response butterflies have towards climate change, a better developed view on the impacts of climatic change can be gained. The results may also imply possible implications for effective solutions to better preserve biodiversity and save endangered species.

References

[1] M. S. Crossley, O. M. Smith, L. L. Berry, R. Phillips-Cosio, et al. Recent climate change is creating hotspots of butterfly increase and decline across North America. Glob. Chang. Biol., 27(12):2702-2714.

DOI: 10.54254/2753-8818/4/20220557

[2] T. Schmitt, J. C. Habel, D. Rödder, D. Loucy. Effects of recent and past climatic shifts on the genetic structure of the high mountain yellow-spotted ringlet butterfly Erebia manto (Lepidoptera, Satyrinae): a conservation problem. Glob. Chang. Biol., 20(7): 2045-61.
[3] E. Ashe-Jepson, A. J. Bladon, G. Herbert, G. E. Hitchcock, R. Knock, C. B. H. Lucas, S. H. Luke, E. C. Turner, Oviposition behavior and emergence through time of the small blue butterfly (Cupido minimus) in a nature reserve in Bedfordshire, UK. J. Insect. Conserv., 26(1):43-58.
[4] E. Rosa, M. Saastamoninen. Warm-night temperature alters paternal allocation strategy in a North temperate-zone butterfly. Ecol. Evol., 11(23):16514-16523.
[5] D. Rödder, T. Schmitt, P. Gros, Werner Ulrich & Jan Christian Habel. Climate change drives mountain butterflies towards the summits. Sci. rep., 11(1):14382.
[6] A. Timmermann, S. I. An, J. S. Kug et al. El Niño-Southern Oscillation complexity. Nature., 559(7715):535-545.
[7] M. Kajin, C. M Penz, P. J DeVries. Large-Scale Climate Effects Meet an Amazonian Butterfly: Which Population Parameters Respond to El Niño? Environ. Entomol., 46(6):1202-1211.
[8] S. Rodenhuis, et al. A multi-center prospective phase II study of high-dose chemotherapy in germ-cell cancer patients relapsing from complete remission. Ann. Oncol., 10(12): 1467-73.
[9] P. J. Devries and T. R. Walla. Species diversity and community structure in neotropical fruit-feeding butterflies. Biological Journal of the Linnean Society., 74: 1–15.
[10] V. Grøtan, R. Lande, I. A. Chacon, P. J. DeVries. Seasonal cycles of diversity and similarity in a Central American rainforest butterfly community. Ecography., 37: 509–516.
[11] A. Valtonen, F. Molleman, C. A. Chapman, J. R. Carey, M. P. Ayres, and H. Roininen. Tropical phenology: bi-annual rhythms and interannual variation in an Afrotropical butterfly assemblage. Ecosphere., 4: 1–28.
[12] V. Grøtan, R. Lande, S. Engen, B. E. Sæther, and P. J. DeVries, Seasonal cycles of species diversity and similarity in a tropical butterfly community. J. Anim. Ecol., 81: 714–723.
[13] R. R. Nemani, Climate-driven increases in global terrestrial net primary production from 1982 to 1999. Science. 300: 1560–1563.
[14] N. P Lemoine. Climate change may alter breeding ground distributions of eastern migratory monarchs (Danaus plexippus) via range expansion of Asclepias host plants. PloS. One., 10(2):e0118614.
[15] L. I. Wassenaar, K. A. Hobson, Natal origins of migratory monarch butterflies at wintering colonies in Mexico: new isotopic evidence. P. Natl. Acad. Sci. USA., 95: 15436–15439.
[16] L. P. Brower, Understanding and misunderstanding the migration of the monarch butterfly (Nymphalidae) in North America: 1857–1995. J. Lepid. Soc., 49: 304–385.
[17] P. A. Guerra, S. M. Reppert, Coldness triggers northward flight in remigrant monarch butterflies. Curr. Biol., 23: 419–423.
[18] H. A. York, K. S. Oberhauser, Effects of duration and timing of heat stress on monarch butterfly (Danaus plexippus) (Lepidoptera: Nymphalidae) development. J. Kansas. Entomol. Soc., 75: 290–298.
[19] Flockhart DTT, Wassenaar LI, Martin TG, Hobson KA, Wunder MB, Norris DR. Tracking multi-generational colonization of breeding grounds by monarch butterflies in eastern North America. P. R. Soc. B. 280: 20131087.
[20] C. S. Bartholomew, K. V. Yeargan. Phenology of milkweed (Asclepiadceae) growth and monarch (Lepidoptera: Nymphalidae) reproduction in Kentucky and ovipositional preference between common and honeyvine milkweed. J Kanas Entomol Soc. 2001;74: 211–220.
[21] A. DiTommaso, J. E. Losey. Oviposition preference and larval performance of monarch butterflies (Danaus plexippus) on two invasive swallow-wort species. Entomol. Exp. Appl., 108: 105–209.
[22] H. R. Matilla, G. W. Otis. A comparison of host preference of monarch butterflies (Danaus plexippus) for milkweed (Asclepias syriaca) over dog-strangler vine (Vincetoxicum rossicum). Entomol. Exp. Appl., 107: 193–199.

DOI: 10.54254/2753-8818/4/20220557

[23] D. T. Ladner, S. M. Altizer. Oviposition preference and larval performance of North American monarch butterflies on four Asclepias species. Entomol. Exp. Appl., 116: 9–20.
[24] L. Tao, A. R. Berns, M. D. Hunter. Why does a good thing become too much? Interactions between foliar nutrients and toxins determine performance of an insect herbivore. Funct. Ecol., 28: 190–196.
[25] D. T. T. Flockhart, J. B. Pichancourt, D. R. Norris, T. G. Martin. Unravelling the annual cycle in a migratory animal: breeding-season habitat loss drives population decline of monarch butterflies. J. Anim. Ecol., 84(1): 155-65.
[26] R. V. Batalden, K. S. Oberhauser, A. T. Peterson. Ecological niches in sequential generations of eastern North American butterflies (Lepidoptera: Danaidae): the ecology of migration and likely climate change implications. Environ. Entomol. 36: 1365–1373.
[27] F. Altermatt. Climatic warming increases voltinism in European butterflies and moths. Proc. Biol. Sci., 277(1685):1281-7.
[28] C. Navarro, A. Jose, et al. Climate change, phenology, and butterfly host plant utilization. Ambio. vol. 44 Suppl 1 (2015): S78-88.
[29] A. E. Cahill, M. E. Aiello-Lammens, M.C. Fisher-Reid, X. Hua, C.J. Karanewsky, R.H. Yeong, G.C. Sbeglia, F. Spagnolo, et al. How does climate change cause extinction? Proceedings of the Royal Society B: Biological Sciences 280: 20121890.