The Impacts of Climate Change on Insects Abundance in Four Types Climates

Hanshuo Shen[1,†,a], Sirui Wang[2,†,b], Xinyuan Wang[3,†,*,c] and Kaiming Zhang[4,†,d]
[1]*VAIE Academy of Innovation an d Excellence, Suzhou, 215000, China*
[2]*Hefei. No1. High school, Hefei, 230601, China*
[3]*Life sciences, Nanjing University, Nanjing, 210023, China*
[4]*Zhengzhou Foreign Language School, Zhengzhou, 450001, China*

[†]*These authors contributed equally*

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Abstract: Global warming has a negative effect on plants, animals, fungi in various ways. Owing to the critical benefits insects produce, including food source, pollination, capture of pests and current environmental situation, insect traits, it is necessary to reveal the impacts of climate change on insects in different climates. This study investigates the impact of climate change in four climates (polar climate tropical rainforest climate, tropical savanna climate and marine climate) on abundance of insects. According to the results, the tendency of abundance declines dramatically, especially in tropical climate and marine climate. The reason why insects are influenced by climate change are multiple, including offspring, genetic, behavioral, phenological and environmental elements. These results shed light for severe insects abundance decrease in different climates, which will continue to affect insects in the future, and it is of vital importance to pay attention to it.

1 INTRODUCTION

Global temperature rises drastically on account of climate change, where the most obvious impact is the decrease of the biodiversity around the world. Previously, insects are the main factors in the life-form chain. There is a general consensus among scientists that the global climate is changing at an unprecedented rate, with many regions experiencing warming trends, frequent high temperature extremes, and shifts in precipitation patterns (A Eskildsen, PCL Roux, RK Heikkinen, TT Høye, WD Kissling, J Pöyry, M Wisz, M Luoto 2014, Baranov, Viktor 2020). An increase of 0.61 °C in global average temperature is recorded since the beginning of the twentieth century (i.e., comparing the years 1850–1900 and 1986–2005, 5–95% CI is 0.55–0.67 °C) (A Eskildsen, PCL Roux, RK Heikkinen, TT Høye, WD Kissling, J Pöyry, M Wisz, M Luoto 2014, Brooks DR, Bater JE, Clark SJ, Monteith DT, Andrews C, 2012). Besides, the predicted warming of 2–6 °C by 2100 (A Eskildsen, PCL Roux, RK Heikkinen, TT Høye, WD Kissling, J Pöyry, M Wisz, M Luoto 2014, C García-Robledo, C. S. Baer, 2021) has direly increased the need to understand the impacts of climate change. Without any doubt, plenty of species will go to extinction in this dynamic process.

Insect abundance is an extremely plentiful or over sufficient quantity or supply. Global warming expanded the environment that are suitable for insects to survive, i.e., it leads to pests' survival rate increase. Additionally, with the temperature increase, plant reproduction, and hence plant abundance, may also decline as a result of decreased synchrony between plants and pollinators. If, for example, some plants are now flowering early relative to the timing of their pollinators, as has been reported in some cases (Carpaneto GM, Mazziotta A, Valerio L.Distrib. 2007, Deepa S. Pureswaran, Alain Roques, Andrea Battisti, 2018), insect populations are particu-larly responsive

[a] https://orcid.org/0000-0001-8605-9780
[b] https://orcid.org/0000-0001-6061-0167
[c] https://orcid.org/ 0000-0002-8414-4508
[d] https://orcid.org/ 0000-0003-3629-5990

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to climate change because of their sensitivity to temperature, short generation times, and high flight capacity. Observations of insect herbivory on an oak lineage during Quaternary climate change indicates that there was higher damage during warm and wet periods (A Eskildsen, PCL Roux, RK Heikkinen, TT Høye, WD Kissling, J Pöyry, M Wisz, M Luoto, Dirzo R, Young HS, Galetti M, Ceballos G, Isaac NJB, Collen B., 2014,). Consequently, it caused some insects species population decrease. Moreover, the consequence of its increase causes the insect abundance decline to a deadly level. With the loss of insects' habitats and the reduction of food source, the diversity of insects decreased. At present, previous researches mainly focus on general researches. However, there are few papers focus on particular climate characteristics.

In the past, rich insect abundance brings plenty of benefits to human. Flowering plants attract not only bees but also predatory and parasitic insects that primarily feed on plant-feeding insects and supplement their diets with pollen and nectar. For instance, specific flowering plant species, including shrubby false buttonweed (Spermacoce verticillata), partridge pea (Chamaecrista fasciculata) and white Pentas lanceolata attract the Larra wasp (Larra bicolor), a parasite of mole crickets in the southeastern United States (Doi, H., O. Gordo, and I. Katano 2008). Besides, some other insects can provide food to other animals, or some particular species can capture pests avoid the damage of crops. To protect the insect species is a meaningful and crucial way to protect the food source of the crops, and it also keep the biodiversity in a high level. If human beings do not pay enough attention to the insect abundance decrease, when their population decline to a warning level, it will cause harmful consequence to ourselves and the whole earth ecosystem. Therefore, it is necessary to analyze the insect abundance. This study discusses and compares the effects of insect abundance in different climates including polar climate, tropical rainforest climate, tropical savanna climate and marine climate.

2 IMPACTS OF CLIMATES

This study discusses four different types, which are polar climate, tropical rainforest climate, tropical savanna climate and marine climate, climates' corresponding effects to the insect abundance.

2.1 Polar Climate

Polar climate, mainly located in northern part of Eurasia, America and Antarctic, is the typical climate in the high latitude zone. Opposite to tropical rainforest climate, polar climate is featured with severe cold temperature as well as desiccation. Compared to tropical and temperate zone, insects biomass in polar area is apparently less, but it makes up more than sixty percent in terrestrial animal diversity (Adam G.Dale, 2020) and can obviously affect polar ecosystem in different ways. Unfortunately, compared to plant and vertebrate, research about insects in polar climate are not extensive (Emma Coulthard, John Norrey, Chris Shortall, W. Edwin Harrisb, 2019). The most common insect species in polar climate are flies and mosquitoes.

While global warming is happening everywhere around the world, temperature in polar climate has risen three times than that in other regions (Hulde´n L, Albrecht A, Itamies J, Malinen P, Wettenhovi J, 2000), causing serious trouble to the local ecosystem, including insects. Insects are the indispensable part of the polar climate food web, influencing plants and vertebrates in various ways (Field CB, 2014, Fonty E, Sarthou C, Larpinz D, Ponge J 2009). Faced with extreme climate change, plasticity may be the most important factor for insects to deal with variable thermal conditions (Forrest, J. R. K., and J. D. Thomson, 2011).

Firstly, global warming may help some insects expand their range of movement. The main reason is that some insects species have high thermal plasticity to handle extreme temperature (Franzén M, Johannesson M. J, 2007), e.g., between 1992 and 1999,2002 and 2009, the range of 56 species of Finnish butterfly have moved 54.5km northward (Geena M. Hill, Akito Y. Kawahara, Jaret C. Daniels, Craig C. Bateman, Brett R. Scheffers, 2021). Biting insects have also expand northward (Gillespie, Mak , et al. 2019). While change on the range of different insects species is different, such kind of dramatic change like Finnish butterfly does not happen frequently (Geena M. Hill, Akito Y. Kawahara, Jaret C. Daniels, Craig C. Bateman, Brett R. Scheffers, 2021).

In addition, climate change in polar area have resulted in the decline of insect abundance. At Zackenberg, North East Greenland, from 1996 and 2014, seven of the fourteen muscid species have been found to have a dramatic decline in their abundance, some even decline more than eighty percent (Field CB, 2014) as shown in Fig. 1. Climate change is also a factor in the extinction of some butterflies and moths in Sweden and decline of macrolepidopterans in Finland in the past 50 years before 2000 (Graham H. Pyke, James D. Thomson, David W. Inouye, Timothy J. Miller, 2016, Helen Nnoli, Rosina Kyerematen, Samuel Adu-Acheampong & Julian Hynes, 2019).

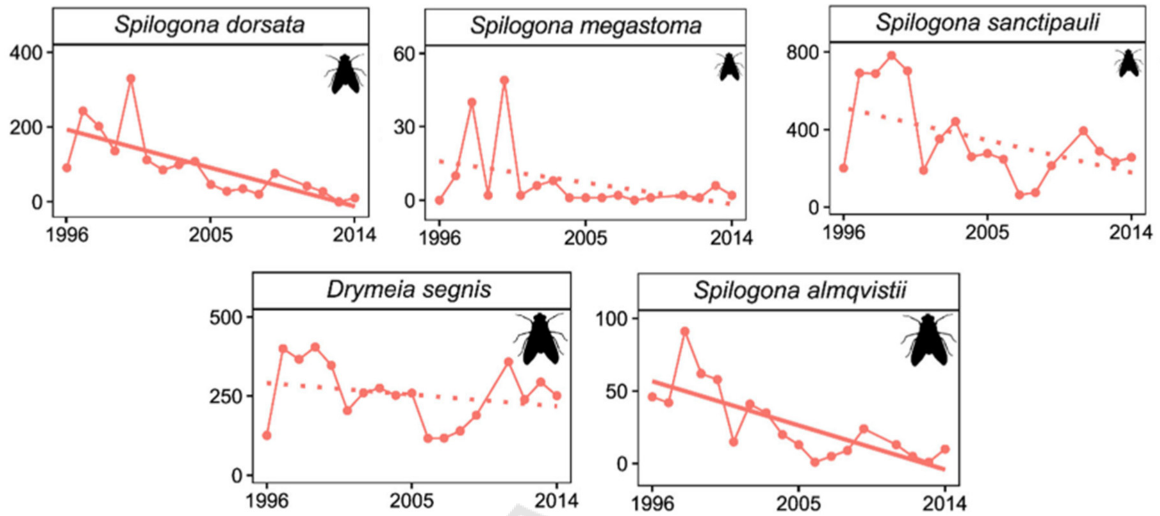


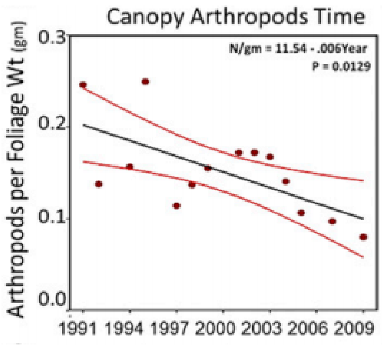
Figure 1: Interannual variation in abundance of 5 muscid fly species(frequent flower visitors) caught in pitfall traps at Zackenberg. The size of the fly silhouette indicates body size of the species. Solid lines represent significant trends ($p<0.05$) while dashed lines are non-significant (Field CB, 2014).

2.2 Tropical Rainforest Climate

Tropical rainforest climate, mainly located in Africa, America and Asia, is one of the most frequent climate in low latitude area, with apparently high average temperature and high rainfall all year around. Tropical rainforest climate provides more than half of the habitats for plants, animals as well as fungi. Insects are one of the most critical parts of ecosystem and its biomass is much larger than other animals in tropical rainforest climate (Hodkinson, I. D. 2013). There are various species of insects in the climate, mainly containing aquatic insects, ants, beetles, bees, butterflies.

It is known that global warming has influenced variety of species in many ways in different climates, including plants richness, development and distribution as well as insect abundance, range, reproduction and metabolic rate (Hulde´n L, Albrecht A, Itamies J, Malinen P, Wettenhovi J, Hye, T. T, 2000, Jonathan A. Walter, Anthony R. Ives, John F. Tooker, Derek M. Johnson, 2018). However, most studies were carried out in temperate zone and mid-to-high latitudes, only few research cared about insects abundance in tropical zone (Emma Coulthard, John Norrey, Chris Shortall, W. Edwin Harrisb, 2019). Since tropical climate have a narrow range of temperature, animals especially insects, which are ectothermic organisms, have more risks to be influenced by temperature rise (Hulde´n L, Albrecht A, Itamies J, Malinen P, Wettenhovi J, 2000, Koltz, A. M., L. E. Culler, 2021). It is important to pay attention to those species with higher risks in tropical climate since they play critical roles in the whole rainforest ecosystems.

The impact of Global warming on insects in tropical rainforest climate have been studied in some regions, revealing that the general decline of insect abundance in tropical rainforest climate. In Puerto Rico's Luquillo rainforest, global warming has caused biomass of arthropods decline for over fifty percents in the past thirty years, including walking stick population and the canopy arthropods (Kris Sales, Ramakrishnan Vasudeva, Matthew E. Dickinson, Joanne L. Godwin, Alyson J. Lumley, Łukasz Michalczyk, Laura Hebberecht, Paul Thomas, Aldina Franco & Matthew J. G. Gage, 2018) as illustrated in Fig. 2. In La Selva, a lowland wet forest in Costa Rica, the larvae of insects like Cephaloleia species cannot develop as normal if temperature rise to more than 30℃ (Lister, B. C. , A. Garcia, 2018), which have existed in recent years and taken challenge to the local insects species because of the excess of insects species thermal limits. There must exist the decline of insects abundance in other region in tropical rainforest climate, but till now few studies have been conducted.



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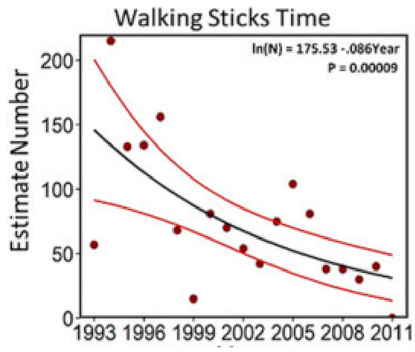

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Figure 2: Trend lines of the abundance of canopy arthropods and walking sticks in the Luquillo forest from 1991 to 2011. (A) Linear regression of the total number of canopy arthropods captured per foliage weight against the period when the samples were taken. (B) Quasi-Poisson regression of total number of walking sticks against the period when the population was sampled (Kris Sales, Ramakrishnan Vasudeva, Matthew E. Dickinson, Joanne L. Godwin, Alyson J. Lumley, Łukasz Michalczyk, Laura Hebberecht, Paul Thomas, Aldina Franco & Matthew J. G. Gage, 2018).

2.3 Tropical Savanna Climate

The distribution area of this type is in the alternating control area of equatorial low-pressure belt and trade wind belt. Regional climate temperature is high. Low rainfall and dry climate lead to a general decrease in insect abundance.

Taking termite as an example, its abundance declines in the Tropical Savanna Climate, which is a warming climate is expected to increase the variability of future precipitation on African savannas. Therefore, some areas will get more rain and others will get less. In the Kruger National Park in South Africa, termites tend to nest in areas that are not too wet or dry, but well drained on the slopes of savanna hills across the border called seeplines. Seepline is formed where groundwater flows through sandy porous soils, and where clay is abundant. Generally, woody trees prefer well-drained areas on hillsides, while grass dominates the wet areas below. These conditions can affect the growth of plants, which can affect the entire local ecosystem. The researchers considered the relationship between mound density, size and location and vegetation type. The characteristics of vegetation and termite mounds on dry, intermediate and wet African savannas, and argued that precipitation, altitude, hydrology and soil conditions determine whether an area will be dominated by grass or woody vegetation, as well as the size and density of termite mountings. Besides of monitoring vegetation, the advantage of monitoring termite mounds is that termite mounds are closely linked to soil and hydrological conditions, making it easier to map slope leakage lines. In addition, vegetation cover varies greatly between the dry and rainy seasons, while mounds are unaffected by these fluctuations (M Franzén, M. Johannesson, 2007).

2.4 Marine Climate

Marine climate is a combination of weather and atmospheric activities over many years on the ocean. Atmospheric circulation facilitates the exchange of heat and water between north and south or between east and west, making the climate subject not only to the nearby Marine environment, but also to other non-marine environments. Some Marine insects have declined in abundance.

Taking Shannon as an example, our analyses revealed a decline in the total abundance of insects by 81.6% over the past 42 years (-477 individuals/year slope estimator; Fig. 3a), whereas species richness (Fig. 3b), Shannon's diversity (Fig. 3c), and evenness (Fig. 3d) increased in a nonlinear way: Initially all 3 metrics increased until 1989/1990 by 21.3%, 28.3%, and 24.8%, respectively (seen from Fig. 3), and then started declining by 10.5%, 4.3%, and 1.9%, respectively. Our GLS models revealed that the decrease in abundance is paralleled by increasing temperature. The increases in Shannon's diversity, species richness, and evenness are concomitant with increasing temperature and changes in discharge pattern (Matthew L. Forister, Emma M. Pelton, Scott H. Black, 2019).

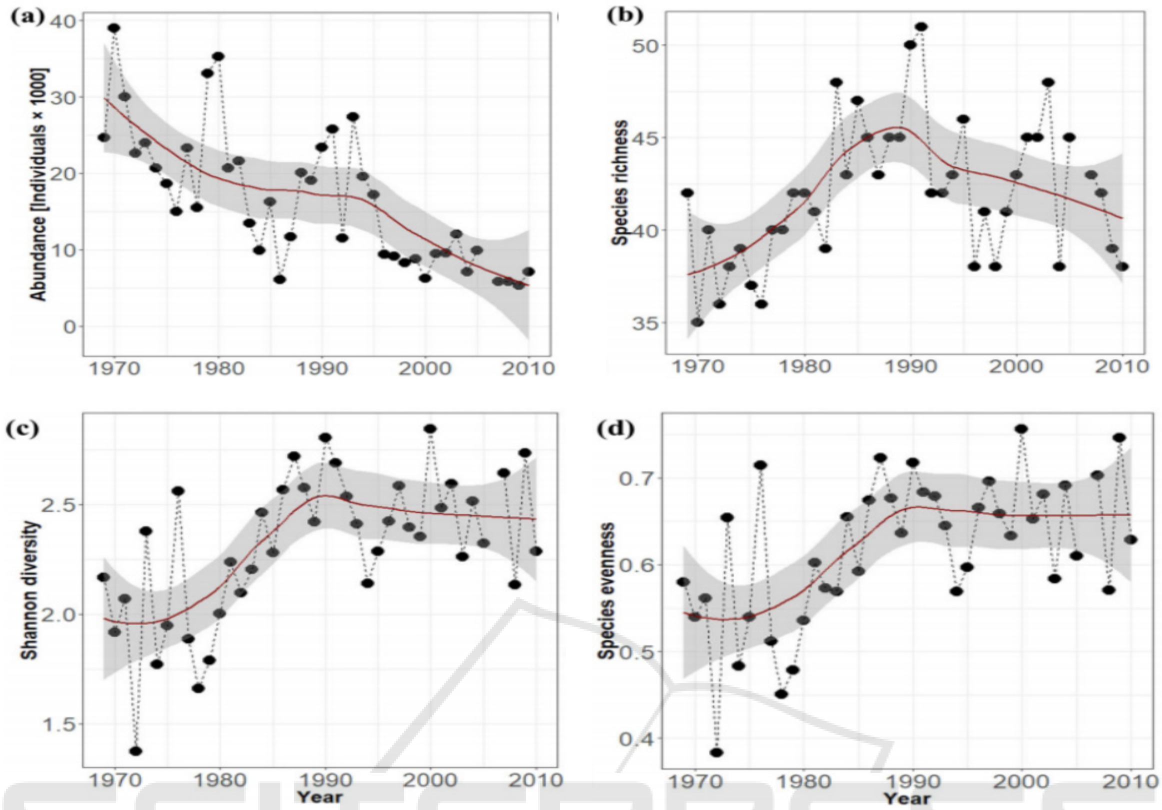

Figure 3: Changes in (a) overall abundance, (b) species richness, (c)Shannon's diversity, and (d) species evenness of the Breitenbach EPT community over time. (Matthew L. Forister, Emma M. Pelton, Scott H. Black, 2019).

Taking Chironomidae, Hydropsyche spp, Cloeon spp, and Cheumatopsyche spp as examples, the results of the current study in 2013/14 shows that the upper reaches of the river were dominated by four groups of insects, the Chironomidae 22%, Hydropsyche spp. 10% Cloeon spp. 9%, and Cheumatopsyche spp. 8%. From the results presented in article, the abundance of aquatic insects has substantially reduced from an average of under 3,000 individuals per square metre in 1970/71 to a little over 1,600/m2 in 2013/14, a reduction of 45%. Results of a one-way ANOVA of insect records between the two studies show no significant differences between diversity ($P < 0.05$), but abundance was significantly lower in the latter study ($P < 0.001$). The reduced abundance was evident across all 10 months spanning wet and dry seasons and most marked in the case of the dominant families, Ephemeroptera, Diptera and Trichoptera. It is suggested that reduced forest cover in the catchment area of the river and reduced nutrient inputs, combined with greater variations in flow swinging from spates to quickly reduced flows, are responsible for the reduced numbers of species, even as the diverse community of aquatic insects has been maintained. The altered conditions allow for shorter periods for insect populations to build up in stable conditions between extremes of flow (McKinney, A. M., P. J. CaraDonna, D. W. Inouye, B. Barr, C. D. Bertelsen, N. M. Waser, 2012).

Reported faunal losses include aerial and ground-dwelling insects, freshwater and terrestrial species, and diurnal and nocturnal insects. Dirzo et al. analyzed more than 90 million occurrence records for four orders of UK insects: Coleoptera, Hymenoptera, Lepidoptera, and Odonata (Nicholls N. et al. 1996). All four orders showed declines of 30–60% in occurrence frequencies over the most recent four decades. For UK and Swedish Lepidoptera, similar rates of loss have been documented for both butterflies and moths (NSF News, 2010, Pamela H. Templer, Andrew F. Schiller, Nathan W. Fuller, Anne M. Socci, John L. Campbell, John E. Drake, Thomas H. Kunz, 2012). Dirzo et al. also found evidence of steep declines among orthopterans. Brooks et al. (Peter, Wadhams, Timothy, M., Lenton, Carlos, M., Duarte, Paul, Wassmann. 2012) concluded that three-quarters of UK carabids censused in their study had undergone population reductions of >30%. A similar rate of decline was documented for dung beetles in Italy (Pyke, G. H. , et al. 2016).

3 REASON

The abundance change in insects is a kind of direct manifestation induced by the climate change. This discussion talks about the reasons why the change in climate can cause the change in insect abundance. The offspring, genetic, behavioral, phenological, environmental factors are analyzed.

3.1 Offspring

The fertility of the insects, especially the male, would be reduced because of the rising global temperature, and it would also reduce the reproductive potential and lifespan of offspring (Roslin, T., H. Wirta, T. Hopkins, B. Hardwick,G. Varkonyi. 2013). The genotypes that are the most heat stable is also always the least fecund, i.e., selection for heat tolerance could greatly reduce population sizes (Seebacher F, White CR, Franklin CE. 2015). Additionally, the hotter climate can shorten development time, resulting in smaller but hard-surviving individuals (Shah, A. A. , et al. 2020).

3.2 Gene

Under the circumstance of climate change, alleles of insects will be hampered and lead to decreased fecundity and reduced dispersal (Seebacher F, White CR, Franklin CE, 2015).

3.3 Behavior

Camouflage or foraging time will be influenced since insects have to do some particular posturing. For example, some butterflies spread their wings to dissipate heat, but it is easier for predators to find the wing-stretched butterflies. Moreover, insects have to spend more time as well as more energy in order to thermoregulate or look for new optimal habitats (Seebacher F, White CR, Franklin CE. 2015).

3.4 Phenology

Insect's seasonal activity needs to change, and it will be more difficult to get thermoregulatory behaviors to synchronize (Srensen, M. H. , et al. 2019). It may cause a mismatch. For instance, the growing program of plants could be advanced, and the food supply will be a problem if the larva is not born earlier.

3.5 Environment

Taking soil freezing due to lower snow cover during winter will reduce the abundance of forest-floor arthropods, including adult beetles (Su T, Adams JM, Wappler T, Huang Y-J, Jacques FMB, Liu Y-S, et al. 2015). It is inferred that there is a kind of global trend of the change in insect abundance. Walter et al. (2018) argued that Time-series temporal trends and externally forced periodic behavior have occurred over many places (VASCONCELOS, et al. 2012). It indicates that the dynamics of those insects were truly affected by global change.

According to the study, the insect abundance has declined in tropical savannas, marine areas, polar regions, tropical rainforests. There are several climates on the earth, e.g., tropical savannas, marine areas, polar regions, tropical rainforests etc., but the mechanism by which climate change affects the insect abundance is difficult to relate to a specific climate system for analysis. The global changes brought about by climate change are obvious and universal, e.g., more CO_2 and higher global temperature. These changes are also universal and not limited to a specific place or climate. Therefore, for insects, the decline of heat-resistant genes and adult reproductive ability are universal. Only the environment change may be weakly associated with the specific climate. There is universality of the changes and the reasons for the changes.

4 DISCUSSION

This study makes a prediction of the situation of insect species in the future and argues the distribution of insects will be wider, periodic actions of insects will be earlier, and the total number of insects will be less if the climate keeps changing in the future.

The factors that influence insect abundance are more than climate change, such as habitat conversion, homogenization, invasive plant species and fragmentation, industrialization (Seebacher F, White CR, Franklin CE. 2015). Climate change is just one of the most influential ones. As the whole system works in a very complex way, it makes sense that the acclimation of insects will be different, and the response to the change in insect abundance will be different as well. All of those factors will affect the insect abundance and our prediction of the situation of insect species in the future. However, the associations that have been documented between stressors and insect responses point to causal relationships even though our knowledge of the mechanisms that underlie them are imperfect (Wagner, D. L., 2019), and it is still not convincing to prove a one-size-fits-all response of insects to global change. There might be some exceptions. One is that agricultural insects were more likely to be declining, while forest insects were more likely to be increasing (VASCONCELOS, et al. 2012). This is because that insect pests erupt periodically. Although the climate change dilute insects, the general amounts of forests insects still rise up. However, those agricultural ones are easier to be impacted by climate change, so their abundance diminishes. As a result, it is not objective and critical enough to assert that all the insect abundances of the world will just decrease, but it shows an overall downward trend.

In other words, there isn't enough knowledge about those factors. More scholars and volunteers are needed to join, i.e., biologists and entomologists can work out how these relative elements work and interact with each other and finally affect insect abundance at present and in the future.

It is concluded that in tropical savanna, marine areas, polar regions, tropical rainforest, the number of insects is declining. It is believed that at present, the insect abundance is changing worldwide, mainly because of climate change. The general trend of insect abundance is decreasing, but there could be exceptions. We also suggest that insect abundance will keep decreasing in the future. Since we haven't known enough about how homogenization, fragmentation, industrialization, and other elements will work on insect abundance, we are not sure about the future insects' circumstances. Nevertheless, there's no doubt that there is a change in insect abundance nowadays and we need to pay attention to it.

5 CONCLUSION

Depending on the background of the earth current environmental situation, which including the warm and cold cycle in the past; and compare to the previous research, it is indicated that research need to focus on particular climates. With the catastrophe caused by global warming, two detrimental effects on insects' abundance, concerning with insects survival rate and the decline of pollinator, are proposed. Additionally, because of the critical benefits which insect produce, including food source, pollination and the capture of pests, insects abundance in four different climate (polar climate, tropical rainforest climate, tropical savanna climate and marine climate) are revealed.

In polar climate, mainly located in northern part of Eurasia, America and Antarctic, some insects species have high thermal plasticity to handle extreme temperature, expanding their range of movement, while some species abundance have decline because of climate change. In tropical rainforest climate in Africa, America and Asia, due to the narrow range of temperature, it is easier for climate change to influence insects, which is ectothermic organisms and causing sharp decline of insects abundance. The savanna climate distribution area is the alternating control area of the equatorial low pressure belt and the trade wind belt. High regional oblique temperature, low rainfall, and dry climate lead to a general decrease in insect numbers. Marine climate is the combination of weather and atmospheric activity over many years on the ocean. Atmospheric circulation facilitates the exchange of heat and water between north and south, and between east and west, making the climate influenced not only by the nearby Marine environment, but also by other non-marine environments. The abundance of some Marine insects has declined dramatically.

Climate change impacts insects by offspring, genetic, behavioral, phenological and environmental elements. It is proved that climate change has a significant influence on insect abundance, and it will keep its influence in the future. Contemporarily, although there are a few exceptions that exist, the general number of insects decreases. Nonetheless, it is hard to predict the future situation of the number of insects because of the lack of study about the association between insects and climates as well as the complex working system of habitat conversion, homogenization and other factors that can affect insects. However, by analyzing the current situation, it is convincing that if the global temperature continues to increase, the overall trend of insect abundance is to increase. These results offer a guideline for the decrease and downtrend of insects abundance which belonging to different climate system, influenced by the climate change.

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