Research Progress on Driving Factors of Species Diversity of Grassland Insects

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Abstract. Insect species diversity is an important part of biodiversity in grassland ecosystems and a key link in the food chain. It plays an important role in maintaining the function and stability of grassland ecosystems. Studies have shown that grassland insect species diversity is closely related to grazing (strength, combination), climate (light, temperature, precipitation, atmosphere), plant diversity (type, height, coverage, biomass), but the specific mechanisms of grazing, climate, and plant diversity affecting grassland insect species diversity are not clear, especially how different grazing intensity and different grazing combinations drive insect diversity, and how specific grazing mechanisms affect insect species diversity have not been resolved. Moreover, there are few reports on the specific mechanisms of the effects of climate and plant diversity on insect species diversity. This paper collected and compiled 906 research papers on grassland insect species diversity and its driving factors at home and abroad, which is the future grassland insect species diversity. The research pointed out the direction and further explored the changes of grassland insect species diversity under the influence of grazing, climate, vegetation community and other driving factors in grassland ecosystem, and revealed for the first time the “grazing-plant-soil-grass insects” interaction between the two.

1. Introduction
Grassland insects are an important part of species diversity in grassland ecosystem, which play the role of consumers (herbivores, omnivores and carnivores) or decomposers (saprophagous insects) and play a key role in maintaining ecological stability (Belovsky 2000). The species diversity of insects in grassland is closely related to climate change, grazing conditions, vegetation communities, human activities, etc. The change trend of species diversity of insects is different during grazing of large herbivores. Different grazing and precipitation treatments have a strong impact on the diversity of grassland plants and insects (Zhu 2018). For example, the diversity of LEPIDOPTERA (moths and butterflies) decreased during grazing (Littlewood 2008, Vogel 2007), while the diversity of Diptera (flies) (Barragán 2014) and Coleoptera (beetles) (Yadamsuren 2015) increased.

Plant community plays an important role in insect species diversity. Plants provide food resources for herbivorous insects, and at the same time provide a suitable environment for insect life behavior. Some scholars have identified plant community as the main factor affecting insect species diversity in grassland ecosystem (Moreira 2016, Scherber 2010). There are two main mechanisms to control insect diversity based on the upward effect of plant communities: resource concentration hypothesis (root 1973)
and resource specialization hypothesis (Strong 1984), and both of them think that grassland insect diversity is positively correlated with vegetation communities. Insects, as the largest biological community on the earth, have gradually declined in species diversity, and the decline rate of insect species diversity is obviously faster than that of vertebrates or plants (Thomas 2004), which is mainly caused by human activities and climate change (Tittensor et al. 2014). Moreover, the protection of biodiversity has always been a hot issue concerned by insect researchers. Although there are a lot of researches on the driving factors of grassland insect species diversity, the researchers are limited to simulation or ecological investigation, and have not created actual economic value. On the basis of collecting and sorting out 906 literatures on species diversity and driving factors of grassland insects at home and abroad, this paper analyzed the research trend of grassland insects in the 34 years from 1985 to 2019, predicted the future research direction, further discussed the change law of species diversity of grassland insects under the influence of driving factors such as grazing, climate, vegetation community and human activities, and revealed the interaction law of "grazing-plant-soil-grassland insects" in the ecosystem.

2. Effects of grazing on insect species diversity in grassland

Grazing research on grassland insect species diversity mainly focuses on grazing intensity, grazing methods, grazing groups, and grazing seasons. Studies on the impact of grazing on grassland insect species diversity have both positive effects (Joern et al. 2005, Woodcock and Pywell 2010) and related conclusions (Pöyry et al. 2004, Krueck and Tscharntke 2002a, Krueck) and Tscharntke 2002b), and some believe that grazing has no significant impact on insect species diversity (Bestelmeyer and Wiens 2001, Hofmann and Mason 2006). Differences in grazing methods, intensity, and seasons cause insect abundance to decrease (González-Megías et al. 2004, Joern 2005, Littlewood 2012), increase or not change (Cagnolo et al. 2002, Ryder et al. 2005, Debano 2006, and GARCíA et al. 2009). Zhu Hui et al. have repeatedly proved that insect species richness has a clear relationship with plant diversity, grazing intensity, and grazing methods (Zhu et al. 2012, Zhu et al. 2015). The effects of grazing activities on the diversity of grassland insect species are divided into direct and indirect effects. They all affect the non-biological environmental factors, nutritional resources, and trophic level interspecific relationships of insects (Van et al. 2015). Indirect effects Research has increased, gradually shifting to the interaction mechanism of grazing combinations, grazing livestock, environment and grassland insect diversity (Burkepile et al. 2017, Liu et al. 2015).

2.1. Direct influence of grazing on species diversity of grassland insects

Feeding, trampling and feces of livestock will directly affect the species diversity of insects (Kangle 1995, Chang Hong et al. 2013, Zhu Hui et al. 2017). Livestock accidentally ate or trampled some insects that inhabit vegetation and have poor mobility, thus reducing the number of such insects. Fecal urine can provide food resources for COLEOPTERA or Diptera insects, and the species richness of COLEOPTERA insect’s increases (Van et al. 2015, Gish et al. 2017). Urine can promote the number of termites and provide a large amount of salt for the reproduction of LEPIDOPTERA insects (Eldridge et al. 2017, Kas). Livestock manure provides food for COLEOPTERA insects, which can increase soil fertility after decomposition. Meanwhile, grazing accelerates the nitrogen cycle in soil, changes the physical properties of soil, changes the living environment of insects, and directly affects the activities of insects such as survival, reproduction and spawning (Schrama et al. 2013). There are very few insects in grassland ecosystem, and the direct impact of grazing on the species diversity may lead to the extinction of this species.

2.2. Indirect effects of grazing on species diversity of grassland insects

The indirect effect of grazing on insect species diversity is mainly caused by changing the habitat quality of insects during grazing. At present, the research in this field mainly focuses on the habitat quality such as plant diversity, food resources, soil environment and community structure (Li Xincheng 2019, Greenwood and MC 2001, Bakker et al. 2006) and the changes of soil environment, compensatory
growth of plants and nutrients after livestock eating and trampling (Olff and Ritchie 1998). Grazing animals' eating and trampling reduced plant height, resulting in spatial heterogeneity, which led to the increase of grassland surface temperature, which was beneficial to the oviposition development of insects such as butterflies and locusts (Bourn and Thomas 2002, Roy and Thomas 2003), and indirectly affected insect species diversity. Haddad et al. 2010) found that there was a strong positive correlation between arthropod richness and vegetation community during grazing. The diversity of phytophagous and omnivorous insects increased with the increase of plant diversity, and the insect diversity was more stable and abundant in the ecosystem with high and stable plant diversity (Ebeling et al. 2012). High-intensity grazing seriously reduces insect species diversity, while arthropods have the strongest response to grazing activities in the early growing season (Nickel and Hildebrandt 2003), and the partial eclipse of domestic animals will also increase the heterogeneity of vegetation. All these indicate that plants play an important guiding role in insect species diversity. Livestock can be used as a management tool (Moran 2014), controlling vegetation community and structure can indirectly protect insect species diversity in grassland, regulate grassland nutrition structure and maintain sustainable production in grassland.

2.3. Interaction of grazing on species diversity of grassland insects

The direct effect of livestock on grassland animals is far less than the indirect effect, but the special life history of some insects will make insects have interspecific specificity (Van et al.2015). The direct and indirect ways of grazing activities often occur simultaneously. For example, it has been found that sheep and locusts have different feeding habits, and the reciprocity can maintain and balance plant diversity. Other studies have found that reducing litter accumulation in cattle is beneficial to the stability of ant population richness, while increasing ants increases soil N content, which is beneficial to plant growth, which in turn improves cattle's feeding activities. The reciprocal relationship formed by the two regulates the structure and composition of plant communities together (Zhong et al. 2017, Zhong et al. 2014).

Grazing research on grassland ecosystem is not sufficient, especially lack of understanding and understanding of grassland animal species diversity (Li Xincheng 2019). Verdú found that reasonable grazing can protect insect species diversity and maintain the stability of ecosystem function [Verdú et al., 2007]. This study shows that grazing is of great practical significance to the study of species diversity of grassland insects. In the following work, it is necessary to analyze and study more influencing factors, such as environmental factors, interspecific relationships, grazing combinations and so on. By exploring the complex animal relationships in grassland ecosystem and the main influencing factors of grazing on grassland insect species diversity (Rosenblatt and Schmitz 2016), the interaction law between grassland insects and grazing in grassland ecosystem was revealed earlier.

3. Effects of climate change on species diversity of grassland insects

The influence of climate (temperature, precipitation, light and atmosphere) on the individual development of insects can be divided into direct and indirect effects. The change of temperature, precipitation, light and gas will cause the change of species diversity of insects in grassland. Climate change mainly changes the temperature and precipitation of the ecosystem, which are the most important factors affecting the growth and development of insects (Bale et al. 2000), not only affecting the phenological period and life history of insects. In addition, it will also affect insect species diversity and easily increase the outbreak of phytophagous insects (Baldwin et al. 2014). With the increase of temperature, the flowering period and phenological period of plants are advanced, and the number of flower-visiting insects decreases due to lack of nectar (Hegland et al. 2010). Precipitation and high concentration of CO2 will directly destroy the living environment of insects and change the physiological metabolic function of insects (Hodkinson 2005). The increase of CO2 concentration changes the chemical composition of plants and indirectly affects herbivorous insects (Ge Feng and Chen Fajun 2006). The influences of climate factors on grassland insects are different. The influences of temperature, precipitation and light can directly change the living environment of grassland insects,
while the influences of atmosphere are usually caused by indirectly changing the characteristics of plants or insects.

3.1. Effect of temperature on species diversity of grassland insects
Temperature is the most important abiotic factor for phytophagous insects in climate, which directly affects the growth, reproduction and development of insects (Bale et al. 2002). The developmental threshold temperature and effective accumulated temperature of insects determine the growth and development rate of insects. Temperature change will change the life history strategy of insects (Guo et al. 2009). Under temperature stress, the activities of a series of respiratory metabolic enzymes in the body decrease, the metabolic capacity of insects decreases, and the activity capacity of insects decreases (Chen Juhong et al., 2018). With the increase of temperature, the species richness of insects increased (Hoover et al. 2012), and the number of moths increased greatly (Bale et al. 2002). On the contrary, the insects migrated to high altitude due to the warming of climate (Villalpando et al. 2009). Fan Meiling et al. (Fan Meiling et al. 2009) found through mathematical model fitting that temperature has an impact on generation time, reproductive rate and body weight of insects, which can link temperature with life history of insects and comprehensively simulate climate warming for biological control of pests.

3.2. Effects of precipitation on insect species diversity in grassland
Precipitation is an important ecological factor and a major factor in the growth and development of animals and plants, which plays a more significant role in arid and semi-arid ecosystems (Sponseller 2010). The change of precipitation will reduce the richness of plants, simplify the structure of grassland ecosystem, and lead to a decline in the number of insects (Dang Zhihao and Chen Fajun 2011; Zhu Hui 2012). The increase of precipitation simplifies the food web, reduces the diversity and quantity of insects, which leads to extreme environmental drought, and changes in the relationship between host plants and insects, which leads to the destruction of biodiversity and community stability (Suttle et al., 2007). The increase of precipitation will slow down the growth and development of insects and even lead to the extinction of insects (Xing Wenli 2017). For example, the reproductive development of locusts will be greatly affected by precipitation (Nestel et al. 2010). Climate change directly affects the phenological period and life history of insects, and the influence of climate factors on insect species diversity is usually the result of temperature, CO2 concentration, fertilization, etc. (Morsello et al. 2008). The research on the specific mechanism of climate change on grassland animal community function is limited by many factors, and the theoretical and applied research is not perfect, which needs further study (Wang et al. 2018).

4. Specific mechanism of plant diversity and insect species diversity
There is a close relationship between plants and insects, and plant community composition (such as vegetation height, coverage, richness and nutritional value, etc.) provides food resources or habitat environment for insects, and plays a decisive role in insect species diversity (Dong Zhaoke and Ge Feng 2012). In 2006, Bakker et al. (2006) found that the species richness of grassland animals is related to the vegetation structure and plant types of habitats, and the effects of insects on plants include feeding and parasitism. When plants are harmed by insects, defense or adaptation mechanisms will be generated, and insects will form anti-defense mechanisms (Qin Qiuju and Gao Xiwu 2005, Peng Lu et al. 2010). With the increase of plant species richness and insect species richness, plant biomass has a strong positive impact on insect richness (Perner et al. 2005). The species density and richness of grazing vascular plants increase, while the nutrient content of vascular plants is lower, which leads to the decrease of the richness of grassland insects (PÄyry 2006). The increase of plant height, coverage, gene diversity, species and productivity can provide more space for insects (Zhu Hui et al. 2008). For example, species richness of beetles, flies and HYMENOPTERA insects decreased, while species diversity of Hemiptera insects increased (Debano 2006).

The feeding behavior of insects will change the structure of plant community, the rate and direction of plant succession (Xu Rumei 2005). Plant productivity, vegetation structure and physical disturbance
of habitat are the factors interacting with plant diversity, and plant community plays an important role in arthropod community (Zhu et al. 2017). The maximum species richness of herbivorous insects always shifts to higher vegetation communities (lower disturbance and longer succession age) (Lawton 1983). Pyry observed that the maximum abundance of special butterflies and moths appeared in low vegetation areas (Pöyry et al. 2006). This is consistent with the prediction result of "dynamic equilibrium model" described by Huston's (Huston et al. 1996). As a potential predictor, plant diversity has a bottom-up impact on insect diversity (Haddad et al. 2009). Grazing causes the spatial heterogeneity of vegetation structure, which has a strong response to insect species richness, and changes the changing law between plants and insects.

5. Prospect

5.1. Specific mechanism and application of grazing livestock-vegetation community-insects

Grazing livestock, plants and insects are closely related, and the effects of livestock on insects include direct and indirect ones. Feeding, trampling and feces of livestock can directly affect the species diversity of insects, and can also change the habitat or food of insects indirectly by changing the height, species composition and heterogeneity of plants. The main relationships between insects and plants are feeding and parasitism, and there is an interspecific relationship. The competition between insects and plant niches will affect the relationship between livestock, plants and insects. Grazing activities will cause changes in spatial heterogeneity of plants, while changes in plant height, coverage and biomass will cause changes in insect habitats (Figure 1). In grazing ecosystem, the three factors always interact and influence each other. For this reason, climate, plants, grazing conditions and other influencing factors can be used to predict the species diversity of grassland insects. Understanding the composition of grassland insect species diversity can adjust the dynamic relationship between natural enemy insects and pests by changing the herd structure of pasture, which can be used to protect grassland and insect species diversity, improve the quality of pasture and improve the quality of grazing livestock.

![Figure 1. Specific influence mechanism of driving factors on insect diversity.](image)

Note: the direction of arrow represents the direction of action or influence

5.2. Prediction of future research direction of grassland insect species diversity

In this paper, 906 domestic and foreign literatures about grazing activities, climate change, vegetation community and other factors on grassland insect species diversity from 1985 to 2019 were searched
from CNKI and SCIE. From Figure 2, it can be seen that the number of research literatures about grazing activities on grassland insect diversity increased gradually from 1985 to 2019, and the research on climate and vegetation community on grassland insect diversity changed irregularly. In recent years, China has made great efforts to develop animal husbandry. The research on the impact of grazing on insect species diversity has great practical significance, and the published literature has gradually increased. At present, the global warming brings about temperature rise and air pollution, and the biodiversity in grassland ecosystem is greatly destroyed, which can be verified by simulation experiments. Although there are too many interference factors and the experiment is difficult, the research in this field has strong timeliness and can provide a large amount of basic data for the protection and prediction of biodiversity. The vegetation community is more concentrated under a certain vegetation group and then classified and verified. On the contrary, it is easier to control the change of grassland animal species according to grazing activities, which can fully realize the specific mechanism of "grazing-plant-soil-grassland insects" in this process and promote the rapid development of ecological animal husbandry.

Note: statistics from CNKI and Web of Science (SCIE) are conducted every 5 years, with a total of 906 literatures. Other factors mainly include inter-species relationship, altitude, soil and human activities of grassland insects.

5.3. Analysis on the research trend and direction of grassland insect diversity
Although the effects of grazing, climate, plant and human activities on grassland insect diversity have been understood, the effects on grassland insect diversity are the results of multiple driving factors, which are different from the results of single factor research. In order to have a more complete and in-depth understanding of the mechanism of driving factors of grassland insect diversity, and ensure the accuracy and reliability of the results, we should carry out experimental research on grassland insect diversity in a larger space-time scale. Secondly, as soon as possible, through experiments and statistical means, the dominant factors among the driving factors were explored, and the mechanism of grazing, climate, plant diversity and other driving factors on grassland insect diversity was expounded. The mechanism of "grazing-plant-soil-grassland insects" was combined with the technical concept of biological control to protect the biodiversity of artificial pasture or grassland. The establishment of relevant grassland natural enemy insect research institute is helpful to discover natural enemy insects with great control effect and wide application prospect on grassland, and can provide theoretical guidance for green prevention and control technology system of grassland pests, grassland ecological restoration and high-quality development of ecological animal husbandry.
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