Advances in Research on the Effects of Grazing on Grassland Insect Diversity: Postprint

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Date: 2017-11-10T00:00:00+00:00

Abstract

In grassland ecosystems, grazing by large herbivores represents a crucial management approach that exerts a key driving influence on grassland biodiversity. Insects constitute an essential component of biodiversity in grassland ecosystems, playing a pivotal role in food web structure, ecosystem function, and stability. Previous research has demonstrated a close relationship between large herbivores and insects, with grazing impacts on grassland insect diversity being positive, negative, or neutral, contingent upon grazing management regimes, insect taxonomic groups, and grassland types. Grazing inevitably influences insect diversity significantly through direct mechanisms (herbivory, trampling, or excreta deposition) or indirect pathways (alterations in plant community composition or vegetation structure). While current research on the effects of large herbivore grazing on grassland insect diversity is extensive, certain limitations persist regarding systematic, in-depth, and longitudinal investigation. This paper, based on a comprehensive review of domestic and international studies concerning grazing effects on grassland insect diversity, proposes future research directions aimed at elucidating patterns of insect diversity variation under grazing management and providing theoretical guidance for developing long-term, effective scientific management strategies to sustain grassland insect diversity.

Full Text

Preamble

ACTA ECOLOGICA SINICA
Vol. 37, No. 21, November 2017
DOI: 10.5846/stxb201608181686

Effects of Grazing by Large Herbivores on Insect Diversity in Grasslands

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Received: 2016-08-18; Online publication date: 2017-07-11

Abstract

In grassland ecosystems, grazing by large herbivores represents an important management practice that plays a key role in driving biodiversity dynamics. Insects constitute a vital component of biodiversity in grasslands, influencing food web structure, ecosystem functioning, and stability. Numerous studies have demonstrated close relationships between large herbivores and insects, yet the effects of grazing on grassland insect diversity remain inconsistent—ranging from positive to neutral to negative—depending heavily on grazing management strategies, insect guilds, and grassland types. Grazing influences insect diversity through both direct pathways (foraging, trampling, and deposition of feces and urine) and indirect pathways (alteration of vegetation structure and plant community composition). While growing evidence shows that large herbivores can significantly affect insect diversity and abundance, further research is needed to enhance the systematic rigor, depth, and long-term continuity of studies examining insect diversity responses to grazing. This paper reviews current knowledge on how large herbivore grazing affects grassland insect diversity, identifies key knowledge gaps requiring additional investigation, and aims to improve understanding of insect diversity changes under grazing disturbance. The findings provide theoretical guidance for developing scientifically sound, long-term management strategies to conserve insect diversity in grazed grassland ecosystems.

Keywords: large herbivores; grazing; grassland; insect diversity; mechanisms

Funding: National Natural Science Foundation of China (31400345, 31230012); Fundamental Research Funds for the Central Universities (2412015KJ015); Open Project of Key Laboratory of Vegetation Ecology, Ministry of Education (130028636)

1 Effects of Grazing on Grassland Insect Diversity

Extensive research has confirmed that herbivore grazing significantly impacts insect communities, though results remain inconsistent. Compared with ungrazed areas, some studies report lower insect diversity and abundance in grazed plots [14–16], while others demonstrate increases [17–18]. Researchers have recognized

that these divergent outcomes likely reflect variations in grazing intensity, with most investigations focusing on intensity-dependent effects [19]. Many studies show that insect diversity and abundance increase with grazing intensity, peaking at moderate grazing levels [20–23]. However, the relationship is complex and varies across insect taxa. For instance, grazing reduces diversity of grasshoppers [27], moths [28], and butterflies [29], while increasing diversity of beetles [30] and flies [31]. Lepidopteran larvae, as herbivorous insects, suffer severe food resource depletion after large herbivore foraging, leading to reduced survival and reproduction rates [32], which consequently decreases their diversity. Conversely, dung beetles and blood-feeding flies that utilize livestock feces and blood as food resources increase in abundance under grazing [33]. Large herbivores also elevate tick populations [34] but reduce flea numbers [35].

Grazing method further influences insect diversity. Mixed grazing by two or more large herbivore species promotes greater insect diversity than single-species grazing [10], with different insect taxa responding distinctly to these management approaches [11]. Rotational grazing supports higher grasshopper species richness than continuous grazing [24]. Seasonal timing also matters—spring grazing reduces grasshopper abundance compared to autumn grazing [25], likely due to the biological and ecological characteristics of grasshoppers.

Grassland type introduces additional variation. Studies across different grassland types reveal inconsistent effects on grasshopper diversity: grazing decreases species richness in typical steppe and North American tallgrass prairie, but increases it in desert steppe and Chinese meadow steppe [11,14,27]. Research in semi-arid North American grasslands found no effect on grasshopper diversity [13]. These discrepancies likely stem from differences in plant community composition and climate conditions (temperature and precipitation) among grassland types, which interact with grazing to shape insect diversity responses.

[Figure 1: see original paper] Effects of large herbivore grazing on grassland insect diversity, and these effects strongly depend on different factors.

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2 Pathways of Grazing Effects on Insect Diversity

Large herbivore grazing significantly affects grassland insect diversity through multiple mechanisms. Understanding these pathways and their underlying processes represents a critical scientific challenge. As a major grassland management practice, grazing influences insect diversity both directly—through foraging, trampling, and excretion—and indirectly by altering plant community composition and structure [36].

2.1 Direct Pathways

Large herbivore foraging can unintentionally reduce insect populations by ingesting insects living on or within plant stems and leaves that cannot escape quickly

[37–38]. If such insects are rare in grazed habitats, foraging may cause local extirpation, reducing overall diversity. While this mechanism is theoretically sound, experimental validation remains limited, with most evidence derived from simulated herbivory studies showing increased insect mortality [39].

Trampling also significantly impacts insect diversity by compacting soil, altering soil bulk density and moisture content [40], and causing premature leaf drop. These changes affect oviposition site selection for insects that lay eggs in soil or on leaves [41–42]. However, experimental studies on trampling effects are scarce due to logistical difficulties in controlling foraging and trampling activities while monitoring insect responses.

Large herbivore feces represent another direct pathway affecting dung beetles and other saprophagous insects that occupy decomposer niches. Grazing promotes dung beetle diversity and abundance [43–44], though excessive grazing intensity can have negative effects [45–46]. Most studies attribute these changes to altered plant community structure rather than direct fecal effects. Theoretical mechanisms suggest that random defecation creates heterogeneous resource patches, but distinguishing fecal effects from vegetation effects remains methodologically challenging. Improved sampling techniques, such as trap-netting, are needed to accurately quantify dung beetle responses.

[Figure 2: see original paper] A conceptual framework of the mechanistic pathways by which large herbivore grazing directly and indirectly affects insect diversity [36].

2.2 Indirect Pathways via Plant Communities

Plant Community Composition. Large herbivores alter plant diversity, which cascades to affect insect diversity. Increased plant diversity generally enhances insect diversity [8,50–51], including for predatory and parasitic insects [8,52]. Grazing can increase grasshopper species richness by raising plant species richness in tallgrass prairie [14], though some studies show insect diversity changes independent of plant diversity responses [11]. Grazing also modifies plant functional groups—increasing graminoid cover benefits associated herbivorous insects [53], while reducing flowering forbs negatively impacts pollinators [54]. Additionally, grazing can alter plant nutritional quality, with heavy grazing promoting locust outbreaks by lowering plant nitrogen content [22] or, conversely, increasing insect performance through enhanced plant nutrition [55].

Plant Community Structure. Herbivory changes vegetation height and structural complexity, modifying microhabitat conditions critical for insects. Short vegetation increases soil temperature, benefiting grasshoppers and butterfly larvae [57–58], while dense vegetation provides thermal buffering and refuge from extreme conditions [59–60]. Taller vegetation offers more food resources and lower predation risk [61–62]. Large herbivores can increase vegetation heterogeneity through selective feeding [11], though some studies show homogenizing effects [63]. Recent work demonstrates that grazing modifies insect diversity

by altering plant height heterogeneity [11,64]. However, experimental evidence linking grazing-induced structural heterogeneity to insect diversity remains limited [65], and the scale-dependent nature of these effects (increasing homogeneity at small scales but heterogeneity at large scales) requires further investigation to understand fully how grazing influences insect diversity across spatial scales.

3 Discussion

Despite progress in understanding grazing effects on grassland insect diversity, inconsistencies persist due to variations in grazing intensity, management approaches, and focal insect taxa. Most studies have been conducted at local scales, while regional and global-scale investigations incorporating vegetation type, climate, and topography are needed for more robust conclusions. While many studies confirm that grazing affects insect diversity, the specific mechanisms regulating these effects remain unclear. The relative importance of direct pathways (foraging, trampling, feces) versus indirect pathways (plant composition, structure, heterogeneity) has not been resolved, requiring more experimental research. Furthermore, insects play crucial roles in grassland food webs, and understanding whether grazing influences insect diversity through top-down or bottom-up control represents an emerging research frontier. How insect diversity changes under grazing alter food web structure and ecosystem functioning will be a critical direction for future studies.

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Note: Figure translations are in progress. See original paper for figures.