

草地生境破碎化对蝗虫暴发及其天敌昆虫多样性影响的研究概述



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摘要: 草地生境破碎化导致草地生境大小、连通性和结构发生变化, 是草地生物多样性降低的主要原因之一, 其对于蝗虫暴发及其天敌昆虫多样性降低有潜在影响。该文采用文献计量法对国内外相关文献进行统计分析, 重点概述草地生境破碎化对蝗虫暴发及对其天敌昆虫多样性的影响, 并对提升天敌昆虫控蝗能力、减缓蝗虫激增及增加天敌昆虫多样性进行展望。

关键词: 草地破碎化; 蝗虫暴发; 天敌; 多样性; 文献计量分析

Review of impacts of grassland fragmentation on grasshopper outbreaks and natural enemy insect diversity

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Abstract: Grassland habitat fragmentation leads to changes in the size, connectivity, and structure of grassland habitats, which is one of the primary causes of the decline in grassland biodiversity. The fragmentation has potential impacts on locust outbreaks and the reduction of their natural enemy insect diversity. This paper employs bibliometric analysis to statistically examine relevant domestic and international literature, with a focus on summarizing the effects of grassland habitat fragmentation on locust outbreaks and their natural enemy insects. It also provides perspectives on enhancing the control capacity of natural enemy insects, reducing locust population outbreaks, and increasing the diversity of natural enemy insects.

Key words: grassland fragmentation; locust outbreak; enemy; diversity; bibliometric analysis

草地是世界上主要的植被类型之一, 覆盖了 $4.9 \times 10^7 \text{ km}^2$ 的广阔区域, 约占陆地表面的40%, 遍布世界各地, 为大量生物提供了栖息地(刘学琴,

2022), 是生态系统中极为重要的一部分, 具有巨大的生态和经济价值(Liu et al., 2022)。生境破碎化又称景观破碎化, 是一种景观动态变化, 指原来连续

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分布的自然生境在人为活动和自然干扰的情况下,被分隔成许多面积较小且不连续生境斑块的过程(Fahrig, 2003; 张圣昕, 2020)。生境的丧失通常与生境破碎化同时发生(刘红玉等, 2007),被认为是世界范围内生态系统退化的主要原因(Polus et al., 2007; Wilson et al., 2016)。而草地生境破碎化是当今全球范围内普遍存在的生态问题,放牧及滥垦滥伐等人类不合理土地利用方式和气候变化,造成我国草原面积持续减少,生境破碎化严重(王雪娇和肖海峰, 2018; 曹亚苏等, 2023)。此外,草地生境破碎化对生物多样性、生态平衡和生态系统功能有深远影响(Herkert, 1994; Collinge, 2000; DeCock et al., 2023),如草地生境破碎化直接影响草地植被,降低当地的植被多样性,甚至造成草地生境丧失(Soops et al., 2005; Kimberley et al., 2021),而多样化的植被组成又是蝗虫及其天敌昆虫的重要栖息场所,因此草地生境破碎化可能间接影响既定区域内蝗虫-天敌昆虫的多样性变化(Grass et al., 2018; Pernat et al., 2024),进而影响生态系统的稳定性(Gonzalez et al., 2011; Riva & Fahrig, 2023)。

蝗虫是世界性的农牧业重大害虫,给人类生产和实践带来极大为害(Sun et al., 2016; 魏笑佳等, 2021),全球范围内常年暴发蝗灾的面积达 $5\times10^7\text{ km}^2$,全球范围内有超过500种蝗虫为害牧场和农作物,其中主要害虫大约有50种(Zhang et al., 2019; 李朝, 2022)。天敌昆虫在蝗虫防控中扮演着非常重要的角色,对维持蝗虫种群数量和生态系统平衡具有重要意义(Lomer et al., 2001; Sánchez-Zapata et al., 2007)。蝗虫天敌主要包括寄生蝗卵的蜂类、寄生蝗蝻或成虫的蝇类昆虫,捕食蝗卵的芫菁类和蜂虻类昆虫,捕食蝗蝻或步甲、虎甲、螳螂和蠼螋等成虫(胡奇和张龙, 2007),天敌通过抑制蝗虫的种群增长来防止蝗灾引起的生态系统失衡(Branson et al., 2006; 秦兴虎等, 2015)。利用天敌对蝗虫进行生物防治,可以减少化学农药对环境的污染,维持草地生态系统的平衡并保证草地生态的良性发展(Lomer et al., 2001; 张礼生和陈红印, 2014)。

文献计量是图书情报学重要的研究领域之一,能够帮助研究人员快速了解行业动态,并做出决策(Chen et al., 2009)。为寻求新的草原蝗虫治理策略,采用文献计量法对国内外相关文献进行统计分析,重点概述草地生境破碎化对蝗虫暴发及对其天敌昆虫多样性的影响,并对提升天敌昆虫控蝗能力、减缓蝗虫暴发及增加天敌昆虫多样性进行展望,以

期为草地蝗虫生态防治提供支撑。

1 数据与方法

国内文献来自中国知网(China National Knowledge Infrastructure, CNKI)数据库,检索时段为1979年1月1日—2024年3月20日,采用主题、全文和摘要进行AND连接的方式进行高级检索,在检索式中利用“-”将容易被误检到的关键词“草地贪夜蛾”及“草原毛虫”剔除,即以“草地+草原-草地贪夜蛾-草原毛虫”进行主题检索,以“破碎化+丧失+碎片+隔离+斑块+生境异质(精确)”进行全文检索,以“昆虫天敌+天敌昆虫+蝗虫(精确)”进行摘要检索,以“多样性(精确)”再次进行全文检索,共检索到93篇中文文献(刘艳琪和班丽萍, 2021; 杨鼎等, 2022)。英文文献来自美国科学信息所创建的核心合集数据库(Web of Science Core Collection, SCI-C)中的科学引文索引扩展(Science Citation Index Expanded, SCI-EXPANDED)数据库,检索时段为1979年1月1日—2024年3月20日,采用TS=(grassland OR steppe) AND TS=(fragmentation OR habitat loss OR habitat isolation OR patchy habitat OR semi-natural) AND (TS=(grasshopper OR locust) OR TS=(natural enemy insect OR parasitism OR predation AND (grasshopper OR locust))) AND TS=(diversity OR biodiversity)进行高级检索,共检索到149篇英文文献。

利用可视化软件CiteSpace 6.3.R1 Basic(Chen, 2013)对CNKI及SCI-EXPANDED中检索的文献进行关键词突现和年度发文趋势分析,采用R4.2.4的bibliometrix软件包(Aria & Cuccurullo, 2017)对SCI-EXPANDED中检索的文献进行世界发文量分析。

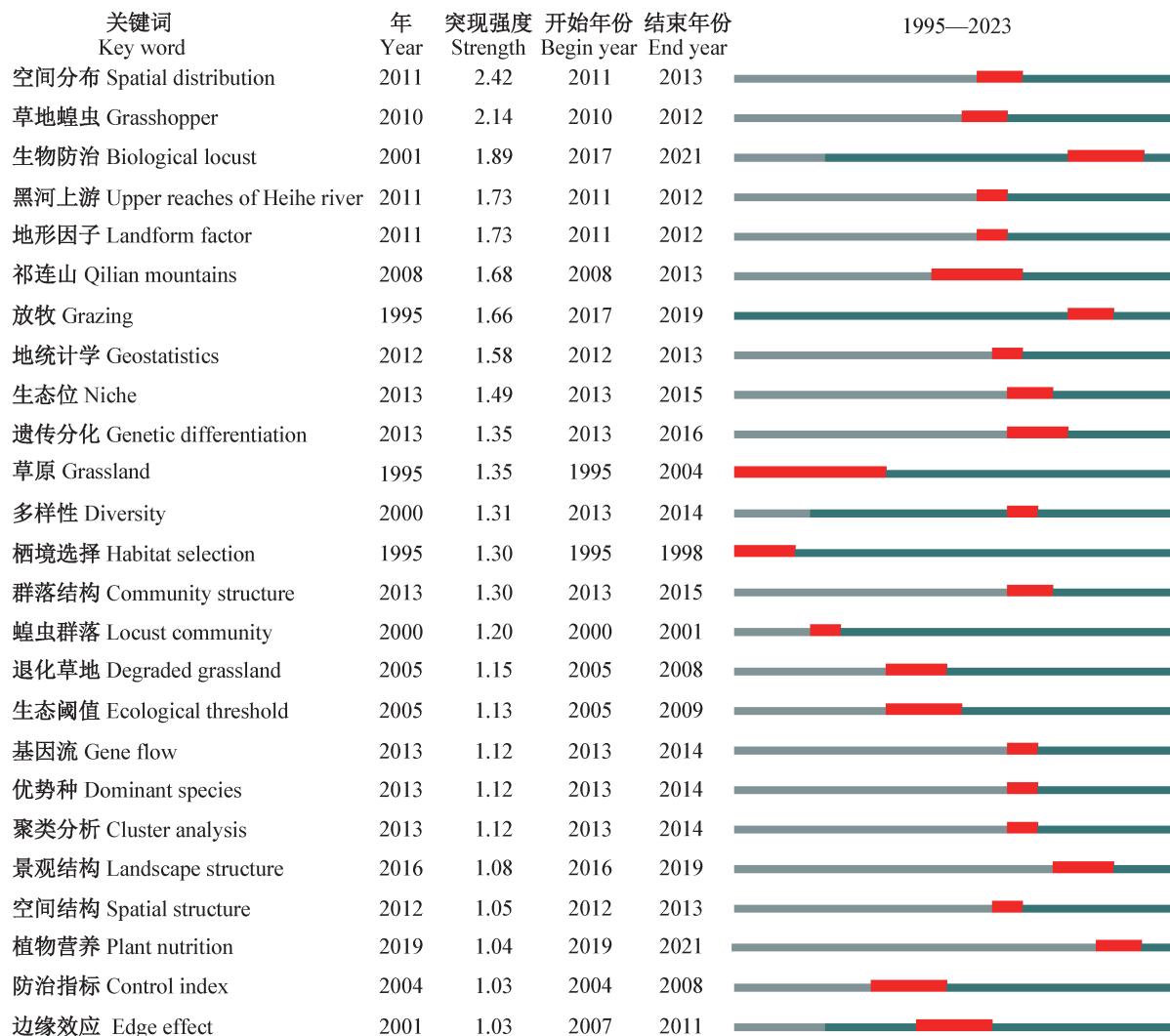
2 草地生境破碎化对蝗虫暴发及其天敌昆虫多样性影响的研究现状

2.1 国内的研究趋势分析

关键词突现结果显示,1979年1月1日—2024年3月20日国内关于草地破碎化生境对蝗虫暴发和天敌昆虫多样性影响的研究热点与科学发展趋势排名靠前的25个突现关键词分别为空间分布、草地蝗虫、生物防治、生态位、遗传分化、草原、多样性、栖境选择、群落结构、蝗虫群落、退化草地、生态阈值、基因流、优势种、边缘效应、黑河上游、祁连山、地统计学、聚类分析、景观结构、空间结构、地形因子、放牧、

植物营养及防治指标(图1)。早在1995年,与生境破碎化有关的草原及栖境选择等研究就被重视,并持续了较长时间,空间分布的突现强度最强,为

2.42,2011—2013年该词的引用量激增,成为了当时的研究热点,而生物防治和植物营养是近年来的研究热点方向(图1)。



关键词:作者文章中的实际关键词;年:突现关键词第1次出现的年;突现强度:关键词引用的暴发强度或者激增程度;蓝色线段:突现关键词的起始时间,蓝色线段越长表示该关键词持续时间越长;红色线段:关键词成为学术研究热点的特定短暂阶段;灰色线段:关键词未出现时段。Key word: Actual terms used in the authors' articles; year: the year when the keyword first exhibited a citation burst; burst strength: the strength or degree of the citation burst or sudden increase in references for the keyword; blue lines: the starting time of the keyword, the longer the blue segment, the longer the duration of that keyword; red lines: the specific ephemeral stages at which the keyword became a hotspot of academic research; grey lines: the periods when the keyword does not appear.

图1 基于CNKI数据库的1995—2023年草地生境破碎化对蝗虫暴发及天敌昆虫多样性影响相关文献的引用最强烈的前25个关键词

Fig. 1 Top 25 keywords with the strongest citation bursts of impacts of grassland fragmentation on the grasshopper outbreak and diversity of natural enemy insects from 1995 to 2023 based on CNKI database

自1983年,国内学者就开始对草地生境破碎化影响蝗虫暴发及天敌昆虫多样性有了初步认识,但2000年以前年发文量很少,年均发文量低于1篇,2000年以后发文量呈逐年增加的趋势,2010年左右

发文量最多,2018年发文量骤减,之后趋于平稳(图2)。

2.2 国外的研究趋势分析

2.2.1 关键词突现分析结果

1979年1月1日—2024年3月20日国外关于草

地破碎化生境对蝗虫暴发和天敌昆虫多样性影响的研究热点与科学发展趋势排名靠前的25个突现关键词分别为直翅目、生物多样性保护、响应、扩散、害虫防治、生态系统服务、丰富度、蝗科、生物多样性、寄生繁殖、灭绝、生物多样性丧失、破碎化、连通性、动态、集合体、景观、农业景观、栖息地质量、土地利

用、气候变化、农业环境计划、植物、森林及全球变化(图3)。早在1998年,生物多样性就被重视,直翅目昆虫的突现强度最强,为3.28,2020—2024年该词的引用量激增,同时是近年来很长一段时间的研究热点,而直翅目昆虫、栖息地质量、土地利用、生物多样性、响应及寄生繁殖也是近年来的研究热点(图3)。

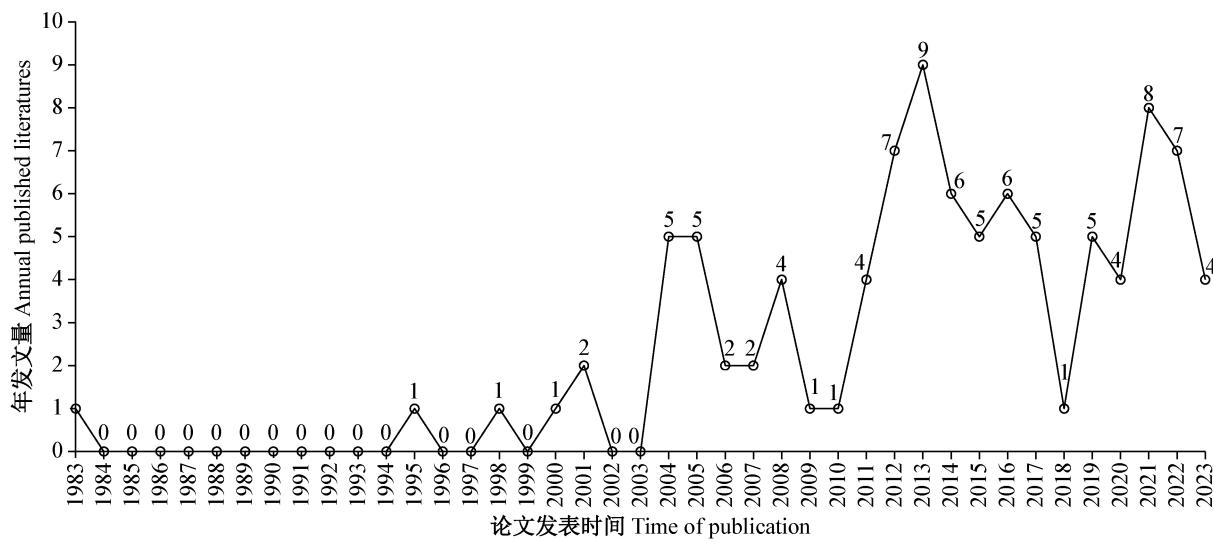


图2 基于CNKI数据库的1983—2023年草地生境破碎化对蝗虫及天敌昆虫多样性影响相关文献的年发文量

Fig. 2 Annual published literatures of impacts of grassland fragmentation on the grasshopper outbreak and diversity of natural enemy insects from 1983 to 2023 based on CNKI database

自1994年,国外就开始涌现与草地生境破碎化对蝗虫暴发及天敌昆虫多样性影响相关的文献,但1997年以前年发文量很少,年均发文量低于1篇,2000年以后年发文量呈逐年增加的趋势,2008年后的年发文量保持在较高水平,其中2022年左右发文量最多(图4),表明对草地生境破碎化引起的蝗虫暴发及天敌昆虫多样性影响的研究越来越重视,且侧重于蝗虫及天敌景观格局变化与多样性。

2.2.2 世界发文量共现分析结果

北美洲的美国和欧洲的德国、法国、瑞士和意大利等国家的发文量较高,其中美国的发文量最多,德国第2,法国第3,发文量分别为104、81和46篇。中国的发文量居第7位,为24篇(表1)。

3 草地破碎化诱发蝗虫暴发的潜在原因

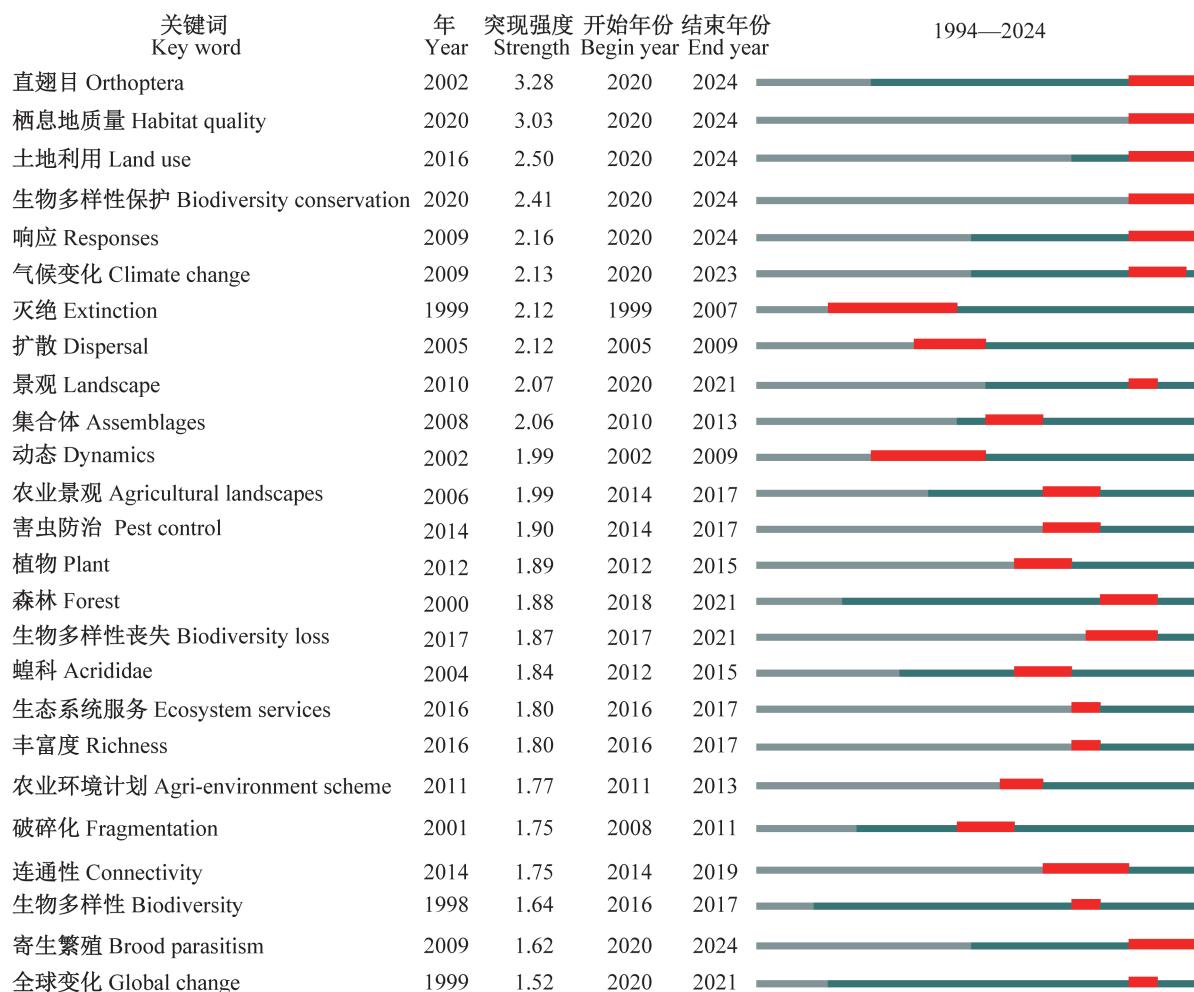
资源集中假说认为多样性生境会干扰害虫寻找寄主作物的嗅觉和视觉判断,减少其迁入率,增加其迁出率(Andow, 1991; 初炳瑶等, 2020; 闫雪影等, 2023),多样化的植物组成也会影响害虫的交配、产卵及转移等行为,最终降低其对寄主植物的为害。因此,草地破碎化诱发蝗虫暴发的潜在原因有3个:

第一,草地破碎化直接引起植被结构变化,进而增加了被蝗虫为害的风险。如西藏玛旁雍错湿地周边的植被被严重破坏,导致蝗虫灾害频发(徐志高等, 2010; 董文霞等, 2013)。第二,草地破碎化会影响蝗虫的迁徙和扩散模式,容易导致蝗虫在局部地区出现大规模暴发,甚至造成不可逆的修复(Despland et al., 2004; Zhao et al., 2020)。如刘缠民(2000)通过2年3次的采样试验发现,林中草地被毁坏后,生境的隔离和封闭被打破,进而造成林中草地与林外草地隔离减少,最终导致蝗虫种类增加,密度增大,对草地的为害也加重。第三,草地破碎化进一步破坏了生境的连通性和稳定性,削弱了自然屏障功能,这些变化大幅增加了蝗虫在局部区域的大规模暴发风险。如一些过度放牧和开垦严重的地区,蝗灾发生越来越频繁(Rösch et al., 2013; Guan et al., 2021; Ríos et al., 2022)。

长期以来,农牧交错区的耕作制度复杂,再加上人为破坏和过度放牧,该区生态脆弱,易暴发蝗灾(张付旭等, 2007),因为在农牧交错区修建蓄水池、更改河道、建设道路及开发农田可能导致山脉、河流等自然障碍物减少或消失,一方面蝗虫更容易跨越

原本的地理障碍,扩散到新的区域,另一方面缩小蝗虫迁徙过程中的障碍物,并加速蝗虫的迁徙速度,增大了扩张范围(Ma et al., 2012; Cease et al., 2015; Wang et al., 2020)。如2020年沙漠蝗*Schistocerca gregaria*在巴基斯坦和印度暴发,但喜马拉雅山脉的高海拔环境条件为限制沙漠蝗种群继续扩张提供了重要的自然屏障,因此,未在我国大面积暴发(Liu et al., 2021)。此外,草地破碎化会导致草原植被的分布不均匀,形成了资源聚集和资源贫乏的对

立区域(Cojoc et al., 2016; Yan et al., 2022),对于一些蝗虫来说,这种资源分布可能为它们提供了更适宜的生存和繁殖环境,从而引起蝗虫暴发。如农田侵占引起草地破碎化,而农田中的作物和水源等(Richards et al., 2009; 朱昌伟,2021)适合蝗虫聚集,进而可能成为蝗虫大规模迁徙的终点,进而导致草地蝗虫暴发(亓东明,2014; Shi et al., 2018; 曹雅忠等,2022)。



关键词:作者文章中的实际关键词;年:突现关键词第1次出现的年;突现强度:关键词引用的暴发强度或者激增程度;蓝色线段:突现关键词的起始时间,蓝色线段越长表示该关键词持续时间越长;红色线段:关键词成为学术研究热点的特定短暂阶段;灰色线段:关键词未出现时段。Key word: Actual terms used in the authors' articles; year: the year when the keyword first exhibited a citation burst; burst strength: the strength or degree of the citation burst or sudden increase in references for the keyword; blue lines: the starting time of the keyword, the longer the blue segment, the longer the duration of that keyword; red lines: the specific ephemeral stages at which the keyword became a hotspot of academic research; grey lines: the periods when the keyword does not appear.

图3 基于科学引文索引扩展数据库的1994—2024年草地生境破碎化对蝗虫暴发及天敌昆虫多样性影响相关文献的引用最强烈的前25个关键词

Fig. 3 Top 25 keywords with the strongest citation bursts of impacts of grassland fragmentation on the grasshopper outbreak and diversity of natural enemy insects from 1994 to 2024 based on SCI-EXPANDED database

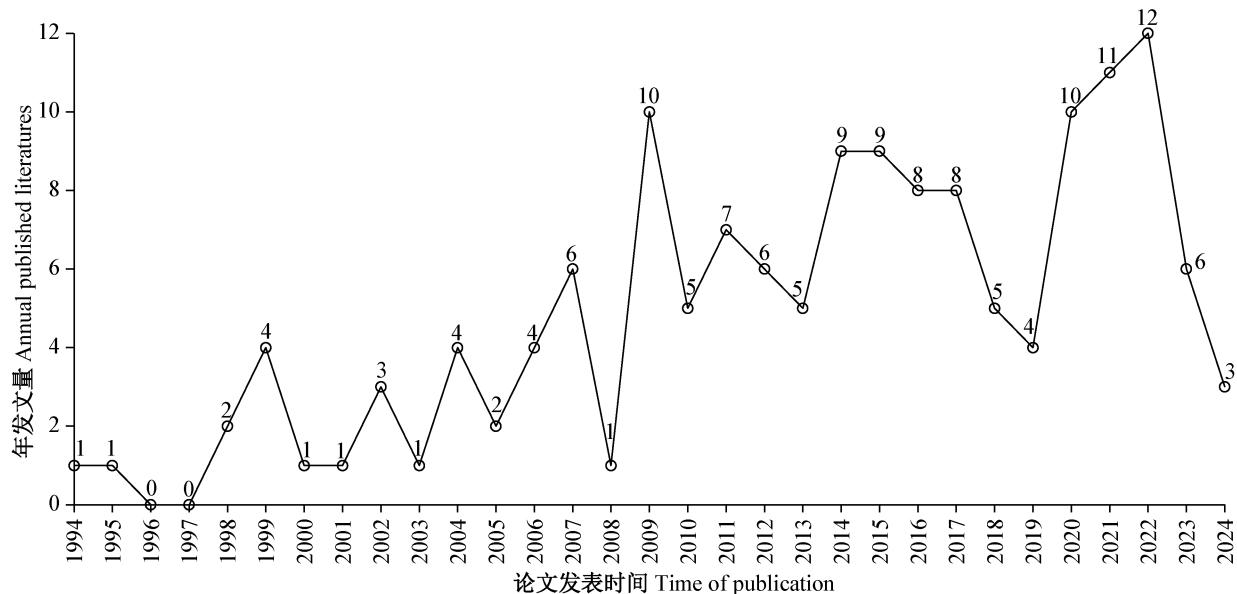


图4 基于科学引文索引扩展数据库的1994—2024年草地生境破碎化对蝗虫及天敌昆虫多样性影响相关文献的年发文量

Fig. 4 Annual published literatures of impacts of grassland fragmentation on the grasshopper outbreak and diversity of natural enemy insects from 1994 to 2024 based on SCI-EXPANDED database

表1 1994—2024年草地生境破碎化对蝗虫暴发及天敌昆虫多样性影响的发文量前10位的国家

Table 1 Top ten countries by the number of publications on impacts of grassland fragmentation on of grasshopper outbreak and the diversity of natural enemy insects from 1994 to 2024

序号 Serial number	国家 Country	大洲 Continent	发文量 No. of publications
1	美国 United States	北美洲 North America	104
2	德国 Germany	欧洲 Europe	81
3	法国 France	欧洲 Europe	46
4	瑞士 Switzerland	欧洲 Europe	37
5	意大利 Italy	欧洲 Europe	33
6	匈牙利 Hungary	欧洲 Europe	27
7	中国 China	亚洲 Asia	24
8	南非 South Africa	非洲 Africa	24
9	英国 United Kingdom	欧洲 Europe	21
10	奥地利 Austria	欧洲 Europe	18
11	捷克 Czech Republic	欧洲 Europe	18
12	其他国家和地区 Other countries and regions	其他大洲 Other continents	93

4 草地破碎化诱发蝗虫天敌昆虫多样性降低的潜在原因

蝗虫天敌主要包括寄生性昆虫及捕食性昆虫。鞘翅目昆虫是蝗虫的主要捕食性天敌,主要取食蝗卵(Umbers et al., 2015; Zhang et al., 2024),其中最常见的是步甲,其对环境变化非常敏感,常作为人为干扰环境下的生境指示物种(Lövei & Sunderland, 1996; Wei et al., 2020)。蝗虫寄生性天敌主要包括一些蝗卵蜂属的卵寄生蜂及蜂虻科等昆虫(Thomas, 1999; Dangerfield et al., 2001),它们在调

节蝗虫种群和控制蝗虫灾害方面发挥着重要作用(徐超民等,2021)。生境破碎化会影响捕食者的生长、发育、繁殖及觅食等习性(Kruess & Tscharntke, 1994),进而减弱天敌对害虫的制约作用,进而增加害虫暴发的可能性(张永生,2018; Landis et al., 2000)。如典型草原生境较荒漠草原生境的破碎化程度高,而典型草原中鞘翅目步甲的多样性较荒漠草原生境中鞘翅目步甲的多样性低,推测生境破碎化条件下植物群落和当地小气候变化显著影响了步甲对栖息环境的适应性,进而影响了步甲的多样性(Wei et al., 2020)。此外,Collinge(2000)发现,在破

碎化严重的生境中,天敌昆虫对蝗虫的捕食效率较低,究其原因可能是,破碎化的生境无法为天敌提供足够丰富和稳定的食物资源,进而使天敌昆虫的数量和活动受到限制。

生境破碎化不仅破坏草地的连续性,而且增大破碎化生境间的质量差异,进而影响土壤质量和植被结构等(Wiegand et al., 2005; Mortelliti et al., 2010; Ye et al., 2013),这些环境变化均可能会影响天敌昆虫的生存和繁殖条件。如中华雏蜂虻 *Anastoechus chinensis* 和苹斑芫菁 *Mylabris calida* 幼虫可捕食蝗虫卵,其成虫喜食花蜜或花,因此,通过种植开花植物等营造适宜天敌昆虫的生存和繁殖生境可达到防治蝗虫的目的(Thomas, 1999; 王广君等, 2021);在北美矮草草原中,个体较小的甲虫主要分布在草地生境,而大型甲虫更偏向于在粗砂灌木丛中生存,推测灌丛中地上植物生境可为大型甲虫提供食物及庇护生境(Stapp, 1997),因此,通过保护和改善灌木丛生境等为大型甲虫提供充足的食物和庇护场所以增强天敌昆虫的捕食能。生境破碎化还会改变土壤微生物组成,进而对天敌昆虫产生潜在危害(Kiesewetter & Afkhami, 2021; Zhou et al., 2023)。Rosenheim(1998)与王振平和严毓骅(1999)研究表明,细菌与噬菌体、线虫与噬线虫真菌等与天敌昆虫相互作用会降低天敌昆虫对蝗虫的防控效果。综上所述,生境破碎化对蝗虫天敌有潜在影响,且对不同天敌的影响强度是不同的,这主要取决于天敌对逆境的响应能力和所处的生境类型。

5 展望

目前关于草地蝗虫及天敌昆虫多样性响应生境破碎化的研究仍有限,相关研究仍需加强。害虫与天敌昆虫之间有跟随效应,此消彼长。在草地生境破碎化的背景下,天敌昆虫与蝗虫的关系可能会发生改变。例如,捕食性昆虫数量的急速下降可能会影响草食性昆虫的种群结构,从而影响整个昆虫群落的结构和稳定性,最终影响整个生态系统的平衡(van Emden & Williams, 1974; Rusch et al., 2010)。

生态管控在害虫生态治理中具有明显的优势(戈峰等,2017; 戈峰,2020)。通过维护草地生境的完整性和稳定性,人工建造和维护天敌昆虫的天然生境,同时人工培育和释放寄生性蜂类、蝇类及捕食性瓢虫类、缘蝽科及步甲和虎甲等天敌昆虫以提高草地蝗虫天敌的多样性。未来可进一步深入探讨,如何通过合理的生态管理措施减少人为干扰,提高

草地生态系统整体的生物多样性,从而抑制蝗虫的繁殖和扩散;也可以探讨在草地补播恢复生境中选种的多功能植被用于防治蝗虫,例如,引用蛇床草 *Cnidium monnieri* 等植物用于吸引瓢虫、草蛉以及食蚜蝇等捕食性天敌(杨泉峰等,2018; Zhang et al., 2022)。但要保证被引植物适合当地草原环境,能持久地增加天敌昆虫的栖息地,提高天敌昆虫的丰度。对于农牧交错区,采取针对蝗虫主要天敌昆虫的生态修复和保护措施,如恢复植被、改善栖息地结构、建立生态廊道等,从而实现草地生态系统的可持续发展和生态治理的目标(Clough et al., 2005)。

基于景观生态学原理,利用天敌昆虫对草地蝗虫进行管控时,要重视草地空间配置优化,强调生态系统中不同空间单元之间的联系和互动,积极寻找各地可允许破碎化的最低阈值,同时对天敌空间分布进行优化配置,使其在草地生境中形成良好的空间格局,提高天敌对蝗虫的控制效果;要加强草地生境多样性保护,倡导增加生境多样性以促进生物多样性和生态系统稳定,合理规划和管理草地生境,增加适宜天敌昆虫栖息和繁殖的生境类型和多样性,有利于提高天敌种群的丰度和多样性,从而增强对草地蝗虫的控制能力;因为蝗虫天敌昆虫如步甲在不同空间尺度可能会产生不同的效果,所以还要考虑草地破碎化的空间尺度(Wei et al., 2020)。

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