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农田-荒地边缘地带中蝗虫边缘反应分析

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摘要：探讨了中华蚱蜢等 10 种蝗总科昆虫对农田-荒地的边缘反应。研究发现，就同一边缘而言，有些物种的多度在靠近边缘时上升，而有些物种则下降。从科的水平上分析的结果与从物种水平上的分析有差异。为了更精确的了解边缘对蝗虫的分布格局的影响，从物种水平上对其进行分析是很有必要的。
关键词：农田-荒地；边缘地带；蝗虫；边缘反应；多度

Analysis on the edge responses of grasshoppers to the edge zone between fieldland and wasteland

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Abstract: With the advance of biodiversity and landscape research, the studies on edge effect has enter a new phase since the concept of edge effect came into being, and the study on the response of creature to edge effect has become a hot research topic too. The creature responses to edge effect are diverse because they are affected by creature themselves, natural conditions and many other factors. As a result, Sisk and Margules have divided the creature responses to edge effect into six types: habitat generalist, habitat generalist edge exploiter, habitat generalist edge avoider, habitat specialist, habitat specialist edge exploiter, habitat specialist edge avoider. Grasshopper as one group of the important insects, the study on the response of them to field edge would help us to grasp their distribution patterns precisely and hence offer some of basic theory on the analysis on grasshoppers' edge response and its intensity.

This study was carried out in Ningshan in the south slop of Qinling mountain (N 32°27′～33°29′, E 108°25′～108°30′, Altitude 800～1000m); The annual mean temperature is 12.3℃. The annual average rainfall is 905mm, It belongs to montanus mesotherm moist climate. The soils of the study area are montane brown soil and montane dark brown soil, and there are different vegetation types in field, wasteland and edge zone, field major vegetation: *Zea mays*, *Glycine max*, *Arachis hypogaea*, *Ipomoea batatas* ect, Wasteland major vegetation: *Artemisia argyi*, *Artemisia capillaris*, *Rosa multiflora* ect. Edege zone major vegetation types: *Plantago major*, *Artemisia capillaris*, *Bothriochloa ischaemum*, *Stipa krulovii*, *Artemisia argyi*, grass and so on.

The data were collected from July to August in 1999. There were 10 2m wide belts which were sampled in the vertical direction to the edge, and there was a 10m space between each two belts, 11sample quadrats that 2m width and 5m length in each belts. The specific sample scheme are presented in Fig1. The collected specimen were poisoned to death, identified and counted at once and brought those who can not be identified at the spots to lab.

The abundance of each species of grasshopper is calculated by the grasshoppers number in each $10m^2$

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sample quadrats which are apart from the edge for a distance. That is $A=1/10\sum ni$ (A: abundance; ni: the amount of each species in $10m^2$ quadrat).

A, B, C, D, E represent 5 sample quadrats of wasteland in Fig2,Fig3. The distance apart from the edge decrease progressively in alphabetical order; Edge represents edge zone, F, G,H,I,J represent 5 sampal quadrats in the field , and the distance apart from the edge increase progressively in alphabetical order.

There were 10 species of grasshoppers were collected from field, wasteland and edge, they were *Acrida cinerea* Thunberg , *Atractomorpha sinensis* Bol. , *Chorthippus chinensis* Tarb. , *Oedaleus infernalis* Saussure. , *Trilophidia annulata* (Thunberg) , *Celes skalozubovi* Adelung , *Oxya chinensis* (Thunberg) , *Oxya hyla intricata* (Stal.) , *Shirakiacris shirakii* (I. Bol.) , *Patanga japonica* (Bol.). The abundance changes with the distance apart from the edge, and there are 5 types of response in the field-wasteland ecosystem in according to Sisk and Margules's criterion. *Acrida cinerea* Thunberg and *Atractomorpha sinensis* Bol. are habitat generalist edge exploiteres. *Chorthippus chinensis* Tarb. , *Oxya chinensis* (Thunberg) and *Oxya hyla intricata* (Stal.) are habitat specialists. *Shirakiacris shirakii* (I. Bol.) is habitat specialist edge exploiter . *Oedaleus infernalis* Saussure and *Celes skalozubovi* Adelung are habitat specialist edge avoideres. *Patanga japonica* (Bol.) is habitat generalist .

Acrida cinerea Thunberg and *Atractomorpha sinensis* Bol. belong to the same type of edge response, However, with further analysis, we found there are still some differences between them, and *Acrida cinerea* Thunberg can live in more one of habitats. The adaptation of them in wasteland increases with the distance apart from the edge decreased, and it reached the highest point near the edge. In contrast, *Atractomorpha sinensis* Bol. can live in both field and wasteland in which the abundance was same too, which indicated that the responses of *Atractomorpha sinensis* Bol. were "equal".

The responses of *Chorthippus chinensis* Tarb. , *Trilophidia annulata* (Thunberg) , *Oxya chinensis* (Thunberg) and *Oxya hyla intricata* (Stal.) to the edge zone showe no difference. They all live only in field, wasteland or edge zone. *Trilophidia annulata* (Thunberg) live only in field and edge zone, the other three species live only in wasteland or edge zone. The abundance of them increase in their habitat and decrease with the decrease of distance toward the habitat edge. They all have little environmental tolerance and can not stand the natural condition of neighboring spots. As a result, they all live in some specified place . In the edge zone ,as for the specific natural condition (such as space and food), there were some of them distributed reluctantly and their abundance decreased sharply, too. These four species of grasshoppers tend to live in interior of the habitat and not the edge area in which grasshoppers lived with difficulty. By the way, *Oxya chinensis* (Thinberg) and *Oxya hyla intricate* mainly live and distribute in the wasteland which the grass family was the best food for them. However the vegetation in field are not fit for them. *Shirakiacris shirakii* (I. Bol.)can live only in wasteland and edge zone . However, there are some differences between *Shirakiacris shirakii* and the four species of above. The abundance of *Shirakiacris shirakii* (I. Bol.) is higher in edge zone than that in wasteland, which predictes that the natural condition of edge zone is better than that in wasteland. That is to say, *Shirakiacris shirakii* is much likely to live in the edge of wasteland than to live inside. Edge zone is a better and ideal ecotone for *Shirakiacris shirakii*. because of its the complex food and changed microenvironment suitable to them.

Oedaleus infernalis Saussare and *Celes skalozubori* Adelung can only live in wasteland and can not live in edge zone as the field-wasteland edge concerned. They had narrow adaptation range. Though there were something fit for eating in edge zone, they lived only in one habitat, because the microenvironment changed greatly.

Patanga japonica (Bol.) has no obvious selectivity and propensity to the inner or edge of the habitat. They had extensive adaptation and can live in field, wasteland and edge zone that are equal, ideal and undisturbed for them. The individuals can crossover the boundary among habitats. According to Francisco. J. Ayala's treatise, the responses of this species that had strong resistance and extensive adaption to the space is: the space is detected, equal and benign.

To sum up , the responses of difference species are different, which is not only because of the grasshoppers behavior characteristic and genetic property but also because of difference in food. A certain quantity of food resource was necessary for grasshoppers to survive and reproduce. The food habits of different species have changed greatly in the long natural selection and evolution process, which caused deviation in habitat selectivity of various grasshoppers. Comparatively speaking, Euryphagous grasshoppers distribute in a large area and stenophagous grasshoppers distribute in a small one. Consequently, the differences in vegetation of habitats as well as that in food habits, which bring about the difference in habitats selectivity. The various responses of creatures to the edge zone were, in the final analysis, decided by the natural conditions, survival capability, competitive ability, adaptation, regulation and so on.

All the grasshoppers that have been studied are classified as five families. There are one species in Pyrgomorphidae, Acrididae ,Arcypteridae separately, therefore, the analytical results at species level are as same as that of family level. There are seven species in Catantopidae and Oedipodidae. Fig5 shows that the grasshoppers of Catantopidae can live in various habitats. Their abundance increases opposite to edge and decreased sharply near the edge. In the field, their abundance is lower than that in wasteland and it has little change with the distance from field to edge, which conceal the response of each species in this family. *Oxya hyla intricate*(Stål.), *Oxya chinensis* (Thunberg) and *Shirakiacris shirakii*(I. Bol.) are habitat specialist when they were analyzed at species level, but not at family level. The grasshoppers of Oedipodidae tended to live in the wasteland and edge zone. Their abundance increase towards edge, which make known that they even more tended to live in the edge zone where is regarded as a passageway that contributed to the exchange of material, energy and information. The responses of each species of grasshoppers in Oedipodidae showe no differences, and it is the characteristic of habitat specialist, In the studied area, the grasshoppers of Oedipodidae can only live in field and edge zone and are not found in neighbor area, which are decided by the habited environment and are limited by their food pattern in the most. To Mills' opinion, the edge zone was a barrioer for moving, which limited the distribution of Oedipodidae in the nearby ecosystem. The characteristics of Oedipodidae edge responses are mainly decided by their abundance amplitude. There were three species in Oedipodidae , they were *Oedaleus infernalis* Saussure , *Celes skalozubovi* Adelung and *Trilophidia annulata* (Thunberg). The abundance and dominance of the former two species were low and the latest species is dominant one among them. The edge response characteristic of Oedipodidae relate closely to their life form. *Trilophidia annulata* (Thunberg) is one of epigaeic species and tend to live in the bake and sunny area, as a result, their abundance is high in field.

The edge response of one species is different when you analyze them in different taxonomic ranks, As Peter, J. Neville said : we must point out the taxonomic rank in which we would analyzed when you studied the response of creature. He put forward the concept of "canceling-out effect" which means that the truth of the edge response would be disguised and show that the abundance would not change essentially in different habitats and edge zone. To this study, it shows that Oedipodidae has not "canceling-out effect", however, Catantopidae has a faint one, which means that "an canceling-out effect" would appear on high

taxonomic rank. So to speak, the result analyzed at family level is only an addition to that at species level. Therefore, it is important to be sure the taxonomic rank at species or subspecies level, which is a important principle to decide the edge response exits or not in the practice, and it is very significance to analyze the restoration of interfered ecosystem and the trend of creature occupied habitat.

It is not difficult to find that not all of the grasshoppers are agriculture pest by analyzing the response of different species to same edge. *Acrida cinerea* Thunberg , *Atractomorpha sinensis* Bol. , *Thilophidia annulata* (Thunderg), *Oedaleus infernalis* Saussure, *Patanga japonica* (Bol.) distributed only in field and harmed crops to some extend. Through the analysis above, we know that the selectivity in their habitat is different, the abundance of some species is high in the edge of habitat which is a passageway of material, energy, and information changed. Therefore, in pest control, the stress should be put in the edge of habitat. However, some species tend to live inside the habitat, and the edge zone is their distributed barrier. So the control should be put in inner habitat.

Key words: field-wasteland; edge zone; grasshopper; edge response; abundance

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自从边缘效应这一概念产生以来,随着生物多样性和景观生物学研究的深入,对边缘效应的研究也进入了一个全新的阶段。生物对边缘的反应成为边缘效应研究中新的热点。生物由于自身及外界条件等诸多因素的影响,对边缘的反应是多样化的。对此,Sisk 和 Margules[1]曾将生物对边缘反应类型的不同划归为 6 种。它们分别是:栖息地广布种(Habitat generalist),利用边缘的栖息地广布种(Habitat generalist edge exploiter),逃避边缘的栖息地广布种(Habitat generalist edge avoider),栖息地特异种(Habitat specialist),利用边缘的栖息地特异种(Habitat specialist edge exploiter),逃避边缘的栖息地特异种(Habitat specialist edge avoider)。蝗虫作为重要的昆虫,对其在农田-边缘中的反应进行研究,有助于更详细和准确地把握其分布格局,从而为蝗虫的边缘效应及其强度的分析和其防治工作的开展提供一定的理论基础。

1 研究地区概况

研究地区设立在秦岭南坡宁陕县境内。位于北纬 32°27′～33°29′,东经 108°25′～108°30′之间,海拔 800～1000m 之间;年平均气温 12.3℃ 。年平均降水量 905mm,属秦岭南坡山地温带湿润气候。研究样地内的土壤类型有山地棕壤、山地暗棕壤。农田、荒地及其边缘地的主要植被类型分别是:农田为玉米、大豆、甘薯、花生等;荒地为艾蒿、茵陈蒿、野蔷薇、白茅菜等;边缘地为车前草、白羊草、克氏针茅、艾蒿、茵陈蒿、禾本科杂草等。

2 调查方法与数据分析

2.1 调查方法 在与边缘垂直方向上共取 10 条宽 2m 的样条带,样条带间的间隔为 10m,每一样条带上设置 11 个样方。在农田荒地及边缘地带所设定的样方面积均 2m (宽)×5m (长)。样方间的间隔为 5m。具体取样方案见图 1(示两条样条带)。采集工作在 1999 年 7～8 月份间进行。采集时将昆虫标本毒死后进行鉴定和计数,对于暂不能鉴定的蝗虫带回实验室进行鉴定。

2.2 数据分析方法 每一种蝗虫的多度以每 $10m^2$ 的样地中物种的个体数计[2]。其多度值以距边缘一定距离 10 个样方中个体平均数表示。即多度$=1/10\Sigma ni$(ni 为每 $10\ m^2$ 样方内每一物种的个体数)。

3 结果分析

图 2 中,A、B、C、D、E 分别代表荒地中 5 个代表性样地,其距边缘距离按字母顺序递减;Edge 代表边缘地带,F、G、H、I、J 则分别代表农田中 5 个代表性样地,其距边缘距离按字母顺序递增。

3.1 从物种水平上对蝗虫边缘反应的分析 在农田、荒地、边缘处共采集到 10 种蝗虫。它们分别是:中华蚱蜢(*Acrida cinerea* Thunberg),短额负蝗(*Atractomorpha sinensis* Bol.)、中华雏蝗(*Chorthippus chinensis* Tarb.),黄胫小车蝗(*Oedaleus infernalis* Saussure)、疣蝗(*Trilophidia annulata* (Thunberg))、赤翅蝗(*Celes skalozubovi* Adelung)、小稻蝗(*Oxya hyla intricata* (Stal.))、中华稻蝗(*Oxya chinensis* (Thunberg))、长

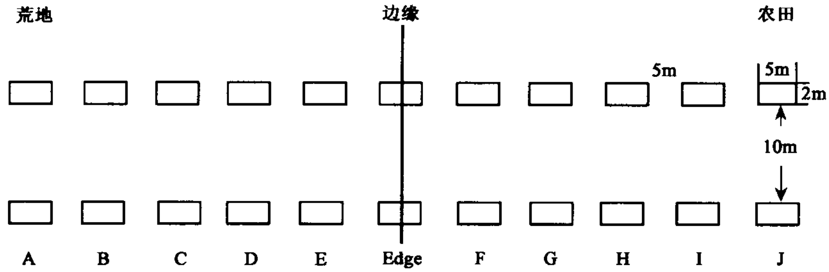

图 1　调查取样方案

Fig. 1　The sampling design of the survey

翅素木蝗(*Shirakiacris shirakii* (I. Bol.))、日本黄脊蝗(*Patanga japonica* (Bol.))。其多度随距边缘距离的变化而变化的情况见图 2。根据 Sisk 和 Margules 的划分标准,在农田-荒地生态系统中有五种类型的边缘反应。其中中华蚱蜢和短额负蝗属于利用边缘的栖息地广布种;中华雏蝗、小稻蝗和中华稻蝗属于栖息地特异种;长翅素木蝗属于利用边缘的栖息地特异种;黄胫小车蝗和赤翅蝗属 于逃避边缘的栖息地特异种;日本黄脊蝗则属于栖息地广布种。

中华蚱蜢和短额负蝗属于同一种边缘反应类型,但是进一步分析可以看出二者仍具有一定的差异。中华蚱蜢能在一种类型以上的栖息地中生存,但是其在荒地中的适应性明显地比在农田中的高。因此,与农田栖息地相比,中华蚱蜢更喜生活于荒地中,且其多度在荒地中随着距边缘距离的降低而升高,最终在近边缘处达到了最高。而短额负蝗与其不同,短额负蝗虽亦能在农田和荒地中生存,但是其适应性在两种类型栖息地中基本一致。这表明短额负蝗对农田、荒地这两种类型的环境空间的反应是"均等的"(图 2)。

中华雏蝗 、疣蝗、小稻蝗和中华稻蝗对边缘的反应类型是一致的,这 4 种类型的蝗虫只能在农田或荒地及边缘地带生存,其中疣蝗只能在农田和边缘地带中生存,其他 3 种蝗虫则只能在荒地或边缘地带中生活。4 种蝗虫的多度在栖息地内部较高,且随着距边缘的距离减少而下降。这些蝗虫只具有较窄的环境耐受力,它们的个体只能在某一种类型的斑块中生活,而不能够忍受邻近斑块的环境条件。这些物种对环境条件的要求相当苛刻,不同斑块环境条件的异质性决定它们只能忍受某一种斑块条件,且生活于其中。边缘条件(如空间、食物等)的特殊性,使得这些物种只能勉强生活于其中,从而造成其多度急剧地降低。这四种类型的蝗虫更倾向于生活在栖息地内部,而非边缘地带。值得一提的是,小稻蝗和中华稻蝗适宜于在荒地中而非农田中生活,主要是由于农田的植被类型不适合这两种稻蝗取食;而在荒地中,由于其植被是由紧贴地表的禾本科杂草组成,是稻蝗的理想食物。所以,这两种稻蝗在此调查区中主要分布在荒地中(见图 3)。

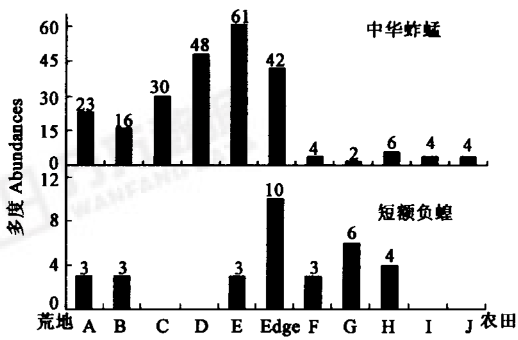

图 2　中华蚱蜢和短额负蝗的多度

Fig. 2　Abundances of *Acrida cinerea* Thunberg and *Atractomorpha sinensis* Bol.

长翅素木蝗虽只能在荒地及边缘中生存,但与中华雏蝗等四种类型蝗虫有所不同。长翅素木蝗的多度在边缘处比在荒地中的要高。边缘从而表现出比荒地更优越的特性,这就说明与荒地内部相比而言,长翅素木蝗更倾向于生活在栖息地边缘。边缘复合性的食物和变化了的微观环境更适于长翅素木蝗的生存,与栖息地内部相比,是较理想的生态场所(见图 4)。

黄胫小车蝗和赤翅蝗只能在农田中生活。就此调查和农田-荒地边缘而言,黄胫小车蝗和赤翅蝗在边缘地带中都不能够生存。这种类型的蝗虫的适应范围很窄,适应性差,故虽然边缘地带中有些食物与农田

中的某些食物相同，但由于微观环境的剧烈改变而引起蝗虫行为的变化，使得黄胫小车蝗、赤翅蝗只能在一种类型的栖息地内部生存（见图 4）。

日本黄脊蝗能够在荒地、农田和边缘处生活。由图 4 可以明显地看出，日本黄脊蝗对栖息地类型、栖息地内部或边缘没有明显地选择性或倾向性。日本黄脊蝗的适应性广，其个体可以成功地跨越斑块间的界限，适应边缘已经变化了的而不同于栖息地内部的环境，它们把这种类型栖息地看作是近乎均质的，环境变化幅度小而对其生存没有显著影响的理想之所。据 Francisco J. Ayala 等人[3]的论述，这种耐力强、适应广的物种对空间的反应结果是：空间是细致的、均匀的、良性的。

综上所述，不同种类蝗虫对边缘的反应是不同的。这种反应上的迥然差异，除部分与蝗虫自身行为特点和遗传特征有关外，更大程度上来自于食性上的差异。一定量的食物资源是蝗虫生存和繁殖所必需的。在长期自然选择进化过程中，不同种类的蝗虫食性发生了很大改变，而正是这种食性上的差异造成了蝗虫在栖境选择上的偏差。相对而言，广食性蝗虫种类分布范围较广泛，而狭食性蝗虫种类的分布范围就相当有限了。因此，栖境所提供的植被类型的差异，亦即蝗虫食性上的差别就造成了不同种类蝗虫栖境选择上的差异。就每种蝗虫在边缘和栖息地内部上差异而言，归根结底，这是由自然界环境条件、蝗虫自身的生存能力、竞争能力、及对环境的适应和调节能力等因素所决定，从而使得生物表现出千差万别的边缘反应。

3.2 从科水平对蝗虫边缘反应分析 所研究的蝗总科的蝗虫隶属于 5 个科，其中锥头蝗科（Pyrgomorphidae）、剑角蝗科（Acrididae）和网翅蝗科（Arcypteridae）皆只有一种蝗虫，故从科水平上和从物种水平上进行分析的结果是一致的。其他 7 种蝗虫则分别隶属于斑腿蝗科（Catantopidae）和斑翅蝗科（Oedipodidae）。从图 5 可以看出，斑腿蝗科的蝗虫可以利用不同类型的栖息地。在荒地中，斑腿蝗科的蝗虫的多度随着距边缘距离的降低而增加，在边缘处，其多度急剧下降，在农田中，其多度比荒地中的低得多，且随着距边缘距离的变化没有明显地波动。这一结果掩盖了其组成种类的各自的边缘反应。从物种水平上分析时，小稻蝗、中华稻蝗与长翅素木蝗都只是栖息地特异种，而在科水平上进行分析时，这种特征被掩盖了。由图 5 还可以看出，斑腿蝗科的蝗虫更适宜于在荒地和边缘处生活，且随着距边缘距离的降低，其多度呈上升趋势，从而得知斑腿

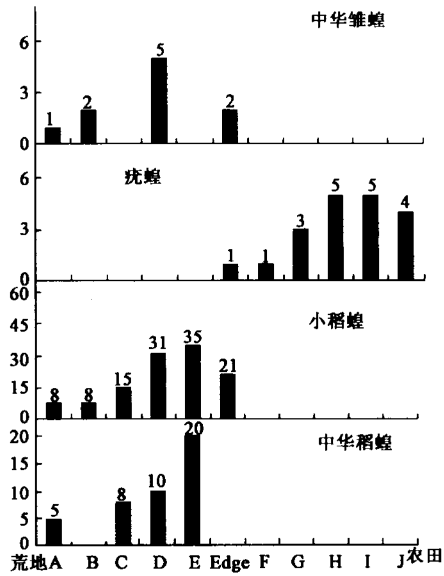

图 3 中华雏蝗、疣蝗、小稻蝗和中华稻蝗的多度

Fig. 3 Abundances of *Chorthippus chinensis* Tarb.、*Trilophidia annulata*（Thunberg）、*Oxya hyla intricata*（Stål.）and *Oxya chinensis*（Thunberg）

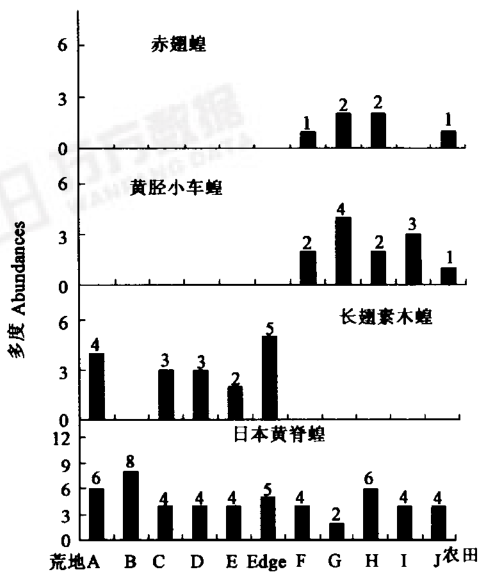

图 4 长翅素木蝗、黄胫小车蝗、赤翅蝗和日本黄背蝗的多度

Fig. 4 Abundanec of *Shirakiacris shirakii*（I. Bol.），*Oedaleus infernalis* Saussure，*Celes skalozubovi* Adelung and *Patanga japonica*（Bol.）

蝗科的蝗虫更易栖息于栖息地的边缘地带。边缘地在两栖息地间起着通道的作用，有利于不同栖息地的蝗虫进行物质、能量、信息交流。

斑翅蝗科的蝗虫对边缘的反应同其中每一物种的表现形式趋向一致，即表现出明显的栖息地特异种的特征（见图 5）。在所调查区域中，斑翅蝗科仅能生活于农田及边缘地带，而未出现在邻近的荒地中。这与栖息地中的环境有关，但更多的则可能来自于食性的限制。据 Mills[4]的观点，就斑翅蝗科的蝗虫而言，边缘地带是它们活动的障碍，限制其向邻近生态系统中扩散。斑翅蝗科中的黄胫小车蝗、赤翅蝗二者的多度低，优势度低，而疣蝗则是三者中的优势种，故斑翅蝗科对边缘反应的特征主要是由疣蝗的多度变化幅度来决定的。斑翅蝗科对边缘反应特征与疣蝗的生活型密切相关。疣蝗属于露地栖性蝗虫，尤喜栖息于裸地及阳光充足的地带[5]，而农田就是具备这样条件的理想之所，因此，农田拥有较高的多度。

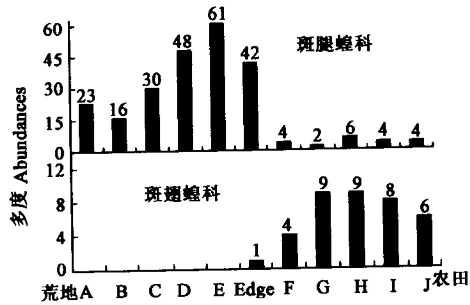

图 5　斑腿蝗科蝗虫和斑翅蝗科蝗虫的多度

Fig. 5　Abundances of grasshoppers in Catantopidae and grasshoppers in Oedipodidae

4　讨论

不同分类等级蝗虫对边缘反应的分析表明，从不同分类等级上所得到的结果是不同的。正如 Peter. J. Neville 等人[6]所指出的那样，基于这种分析结果的差异，在对生物的边缘反应进行分析时，必须明确指出是从哪种分类等级水平上进行分析。他们在从目的水平上对昆虫进行分析时，提出“抵消效应”（An cancelling-out effect）这一概念。所谓抵 消效应，顾名思义，即从科或目等高级分类阶元进行分析时，会掩盖原有的生物个体对边缘反应的真相，而表现为在不同栖息地之间和边缘，生物多度没有根本性的改变。而在此次分析中发现，斑腿蝗科有抵消效应存在，但是抵消效应的强度较弱，而在对斑翅蝗科蝗虫的分析中，就没有出现所谓的抵消效应，从科的水平上的分析只不过是从物种水平上进行分析的加和性体现而已，出现这种现象的可能原因是这种抵消效应要在更高的分类阶元中表现出来。因此，在实际工作中，为了在生态系统中检测如边缘效应这种因子的存在与否，将生物的分类等级确定到种或亚种水平上是很重要的。只有确保这一条原则，才能证明边缘效应存在与否。研究生物对边缘的反应类型，对于大范围的干扰后生态系统的恢复及生物占地倾向的分析在内的生态学研究具有广泛的意义。

通过对不同种类蝗虫对同一边缘类型反应的分析，不难发现，并非所有的蝗虫都是农业生产上的害虫。就所调查区域中 10 种蝗虫而言，仅有中华蚱蜢、短额负蝗、疣蝗、黄胫小车蝗、日本黄脊蝗等 6 种蝗虫在农田中分布，且对农作物具有一定的危害；并且由上面的结果分析可知，这 6 种蝗虫对栖息地的选择性是不同的。有的蝗虫种类在栖息地边缘处多度较高，这种类型的蝗虫将边缘作为相邻栖息地之间物质、能量、信息交流的通道。因此，防治时，应将防治中心放在栖息地边缘处；而有的蝗虫种类适宜于在栖息地内部生活，边缘对其来讲是其扩散的障碍，因此，防治时应将防治重点放在栖息地内部。综上所述，建议在实际生产中，应根据农田中主要的蝗虫种类，结合其边缘反应的特点，采取合理科学的防治对策，是搞好蝗虫防治工作的关键所在。

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