

次生林不同类型森林边缘的鸟类物种 丰富度及个体多度比较

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摘要: 边缘效应对动物的分布及行为会产生一定的影响, 在鸟类生态学研究已证实某些鸟类在森林内部和森林边缘区域存在着物种丰富度和个体多度的差异。于 1999 至 2001 年的春夏季, 在吉林省左家自然保护区对阔叶林/农田边缘、阔叶林/灌丛边缘及阔叶林/针叶林边缘 3 种不同类型边缘地带的鸟类物种丰富度及个体多度进行了比较研究。结果表明, 不同年间鸟类物种丰富度无显著变化, 但个体多度存在着一定的波动。不同类型森林边缘的鸟类物种丰富度存在着一定的差异, 阔叶林/灌丛边缘的鸟类物种丰富度最高, 而阔叶林/针叶林边缘的鸟类物种丰富度最低。鸟类个体多度的总体趋势在 3 种不同类型的边缘差异不显著, 但存在种间差异, 灰椋鸟、灰头啄木鸟和喜鹊在阔叶林/农田边缘的个体多度最高, 斑啄木鸟、黄胸鹀、三道眉草鹀和日本树莺在阔叶林/灌丛边缘的个体多度最高, 而沼泽山雀、冕柳莺和山鹪鹩在阔叶林/针叶林边缘的个体多度最高。

关键词: 鸟类; 边缘类型; 边缘效应; 物种丰富度; 个体多度

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Comparison of bird species richness and individual abundance among different forest edges

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Abstract Edges may affect the organisms by causing changes in the biotic and abiotic conditions from some distance into the forest, such as increased amounts of sunlight, high wind speeds, and larger fluctuations in temperature and humidity. A bird species may respond to one or combination of these changes in the landscape as a result of different biological mechanisms. Also, edge effects may affect distribution and behavior of some bird species. Early studies in avian ecology have reported that there were differences of species richness and individual abundance between forest interior and forest edges. We compared the effects of three forest edges which were broadleaf/farmland, broadleaf/shrub and broadleaf/conifer edges on bird species richness and individual abundance in Zuoji Natural Reserve, Jilin Province during spring and summer seasons from 1999 to 2001.

Our study site, approximately 87km² in size, was located in Zuoji Nature Reserve and included the Tumengling Mountains and Zhujia Mountains ranging from the eastern Changbai Mountains to the western plain (126°42'~126°58'E, 44°12'~45°08'N). Elevation at the site ranged from 200m to 500m above sea level. The climate is east monsoon, characterized by hot, dry summers and cold, snowy winters. Mean year temperatures ranged from 9 to 11 °C. The vegetation within the study area was quite diverse, although the forest type was secondary forest. The seven tree species mainly present on the study area were Mongolian oaks (*Quercus mongolica*), dahurian birches (*Betula davurica*), manchurian linden (*Tilia manschurica*), Korean larches (*Pinus koraiensis*) and masson pines (*Pinus massoniana*). In the study area, Dahurian rose (*Rosa dahurica*), Korean

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rose (*Rosa Doreana*), and sakhalin honeysuckle (*Lonicera maximowiczii*) dominated the shrub layer

For comparison of edge type effects, we selected 3 kinds of forest edges and on 2 criterions: (1) the adjacent patch size $> 10\text{hm}^2$; (2) The length of every forest edge $> 300\text{m}$. In total, sixteen study sites were chosen for this study including 6 broadleaf/fam land, 5 broadleaf/shrub and 5 broadleaf/conifer edges. By using terrain map and GPS, we determined the position and length of those transect lines. We selected count points on each transect line in every 100m interval. We acquired 53 count points on broadleaf/fam land edges, 46 on broadleaf/shrub, and 41 on broadleaf/conifer edges. Birds were sampled using point counts and systematic observations. Counts were done between 6:00 and 10:00 am, avoiding mornings with strong winds or rains. Each point count lasted for 10 min. All individuals observed within 50 m of point-count station were recorded. Each study site was sampled 10 times from April to July, 1999 to 2001. Because of short distances between transects and stops, individual birds may have been recorded more than once. As such, point recordings may not all be considered independent. So, we did not record birds flying above the canopy and took care not to double count individuals. The order in which the transects were walked was varied systematically to avoid bias related to time of day. Four observers divided into three visit groups and observers were rotated sequentially so that each plot was surveyed approximately the same number of times by each observer.

For analysis, we used one-way ANOVA for effects of forest edge types on bird richness and individual abundance. Data were tested for normality using normal probability and tests of skewness and kurtosis. When data were not normally distributed and could not be transformed to achieve normality, nonparametric statistics were used. We used square root or arcsin to transform for those data. Significant ANOVAs at an alpha level of 0.05 were followed by post hoc tests. We used Fisher's least significant difference (LSD) for ANOVA. We used presence/absence program to test the frequency of bird occurrence at each type of forest edge. Statistical analyses were performed using SPSS11.0 package.

In total, we recorded 71 bird species and 11029 individuals in the study period, but 42 species entered our analyses. Our results showed there were no differences of bird species richness when all types combined. Also this tendency was in broadleaf/conifer and broadleaf/shrub edges ($\chi^2 = 2.96$, $df = 2$, $p = 0.23$; $\chi^2 = 5.42$, $df = 2$, $p = 0.07$, respectively). However, there were significant differences of bird species richness on broadleaf/fam land edges ($\chi^2 = 7.05$, $df = 2$, $p < 0.05$). Individual abundance seems fluctuate among years when all data combined ($\chi^2 = 6.14$, $df = 2$, $p < 0.05$). But there were no significant difference individual abundance on broadleaf/conifer edges ($\chi^2 = 1.55$, $df = 2$, $p = 0.42$). The results of ANOVA indicated that there were significant differences of bird species richness among three types of edges ($F = 4.02$, $df_1 = 2$, $df_2 = 27$, $p < 0.05$). Broadleaf/shrub edges included more species than the others. The results of multi-comparison indicated that the species of broadleaf/fam land edges significantly differed from those of broadleaf/shrub edges ($p = 0.032$) and broadleaf/conifer edges ($p = 0.015$). However, we did not find the same tendency between broadleaf/shrub and broadleaf/conifer edges ($p = 0.73$). There was no significant difference of individual abundance among three types of edges ($F = 0.58$, $df_1 = 2$, $df_2 = 123$, $p = 0.56$). White-checked Starlings (*Sturnus cineraceus*) and Common Magpies (*Pica pica*) occurred frequently on broadleaf/fam land edges. Great Spotted Woodpecker (*Picoides major*), Yellow-breasted Buntings (*Emberiza aureola*) and Japanese Bush Warblers (*Cettia diphone*) occurred frequently on broadleaf/shrub edges. March Tits (*Parus palustris*), Eastern Crowned Warblers (*Phylloscopus coronatus*) and Forest Wagtails (*Dendronanthus indicus*) occurred frequently on broadleaf/conifer edges.

Key words: birds; edge types; edge effect; species richness; individual abundance

由于自然事件的影响和人类活动的干扰, 越来越多的大片森林破碎成彼此孤立的“森林岛屿”^[1, 2]。这种破碎化模式不但减少了有机体原有栖息地的面积, 还在森林景观中增加了许多的边缘^[3, 4]。森林边缘的微气候特征和植被结构特点通常会导致鸟类或其它有机体物种丰富度和个体密度产生变化, 这种现象称为边缘效应^[5~7]。近几十年来, 人们对边缘效应进行了广泛的研究。有些研究认为边缘栖息地对动物的生存和扩散是有积极作用的, 尤其对多数的雉科鸟类, 这种积极作用更大^[7]; 但大多数研究认为边缘效应对动物的生存是有消极作用的^[6, 8~10], 尤其对狭布种的影响较大; 也有的研究表明, 边缘效应对某些个体几乎不产生影响^[11]。造成研究结果的不一致主要有两方面原因, 即方法的不一致和研究区域的差别。方法的差异是人为因素, 通过统一和规范化可以达成一致。然而, 区域的差别是自然因素, 不同的区域其景观结构和功能过程均有差异, 另外, 生存于不同区域的生物物种有着不同的演化过程和进化历史, 所以它们对边缘的反应也不尽相同。

国外有关边缘效应对鸟类群落影响方面的研究多集中在原始森林的各类边缘上^[6, 7, 10, 12, 13], 而对次生林边缘的鸟类群落研究较少^[14], 我国尚未见有关此方面的报道。由于次生林生态系统与原始森林生态系统在结构和功能上均存在着较大的差异, 因此两种生态系统中鸟类的组成和个体行为特点具有一定的差别, 鸟类对边缘的敏感性也存在着差异^[15]。本文以我国东北部天然次生林边缘地带的鸟类群落为研究对象, 验证是否不同边缘类型对鸟类物种丰富度及个体多度产生影响。

1 研究区域和工作方法

1.1 研究区域

野外工作是在吉林省左家自然保护区进行的。左家自然保护区位于吉林省东部长白山地向西部平原过渡的丘陵地带。地理坐标为 126°04′E, 44°14′N, 研究区域总面积为 87km², 平均海拔高度 200~500m, 保护区内主要生境是山地次生杂木林。平均林龄为 50~60a, 其中重要乔木 11 种, 尤以蒙古栎 (*Quercus mongolica*)、白皮柳 (*Salix matsudana*)、黑桦 (*Betula dahurica*)、油松 (*Pinus tabulaeformis*) 为多。树木平均高度为 15~20m, 平均树冠高度为 4~7m, 乔木平均胸径为 25~35cm。灌木以刺玫 (*Shchizendara davoraca*)、关东丁香 (*Syringawolfi*)、榛 (*Corylus heterophylla*)、蓝靛果忍冬 (*Lonicera caerulea*) 为主。草本植物以菊科 (Compositae)、禾本科 (Gramineae)、毛茛科 (Ranunculaceae)、莎草科 (Cyperaceae) 植物为主。除天然次生林外, 本区还有人工林、草甸、农田、水库和林间空地等生态景观。该地区属温带大陆性季风气候, 四季分明, 夏季与冬季温差较大。全年平均气温在 9~11℃, 无霜期为 176d, 年平均降雨量为 550~720mm。

1.2 研究方法

为了比较研究, 在研究区域内选择 3 种类型的边缘: 阔叶林/农田边缘、阔叶林/灌丛边缘及阔叶林/针叶林边缘。确定调查边缘的标准有 2 点: (1) 相邻异质性斑块的面积大于 10hm² (2) 边缘的长度大于 300m。如果相邻异质性斑块的面积小于 10hm² 或边缘的长度小于 300m, 边缘效应易与斑块的面积效应混淆。由于研究区内的针叶林多为人工培育而成, 树龄差异较大, 因而在选择阔叶林/针叶林边缘时只选择成熟或接近于成熟的针叶林边缘为研究地点。运用地形图和植被图共选择符合上述要求的森林边缘共 16 处, 其中阔叶林/农田边缘 6 处, 阔叶林/灌丛边缘和阔叶林/针叶林边缘各 5 处。运用地形图和 GPS 确定各边缘的长度和样线位置, 边缘的长度的测定以直线距离为标准样线^[16], 在每条样线上以 100m 为间距, 确定若干个截点, 每个截点作为一个标准样点。其中, 阔叶林/农田边缘类型共包括 53 个样点, 阔叶林/灌丛边缘类型包括 46 个样点, 阔叶林/针叶林边缘类型包括 41 个样点。由于每个样点共计调查 10 次, 因此总调查样本量为 1400 个, 其中阔叶林/农田边缘、阔叶林/灌丛边缘和阔叶林/针叶林边缘分别包括 530 个、460 个和 410 个调查样本量。由于调查方法和过程具有重复性, 另外, 对照样本的数量和样线长度不完全相等, 因此在本研究中采用 Bondel 等介绍的无距离限制的可重复点样法进行鸟类数量和物种数调查^[17]。在被选样点区域内, 海拔范围为 280~329m, 地形比较平坦, 植被类型为针叶林、阔叶林和针阔混交林, 因此在本研究中, 没有对由海拔、地形、植被等因素引起的鸟类物种分布及密度差异进行分析。在破碎化森林景观中, 尽管斑块的面积效应及隔离度效应也会对鸟类物种分布及密度产生一定的影响^[18-20], 但在本研究中确定边缘的 2 个标准在一定程度上避免或减弱了面积效应及隔离度效应对本实验造成的误差。

鸟类调查的具体方法是每个样点停留 10min, 记录 50m 内观测到的鸟类物种和每个物种的数量。于 1999 至 2001 年的 4~7 月, 连续 3a 对 16 处确定的森林边缘地带鸟类物种和个体多度进行了调查, 每个样点调查 10 次。调查的时间为 6:00~10:00, 调查时不记录高飞于树冠之上的鸟类物种, 为了尽量减少实验误差, 下雨和大风的天气不进行调查。另外, 为了降低天气和温度等生态因子的差异而产生的误差, 3 个对比组之间的调查同时进行, 即将调查人员分为 3 组, 在同一时间内调查阔叶林/农田边缘、阔叶林/灌丛边缘和阔叶林/针叶林边缘的鸟类群落组成。为了减少观测经验引起的误差, 每组观测人员对 3 种不同类型的森林边缘进行轮流调查。

1.3 数据分析

在数据分析过程中, 首先对收集的原始数据进行整理和正态分布检测。运用 Skewness-Kurtosis test 检测数据是否符合正态分布, 如果不符合则对数据进行平方根或正弦转换。对转换后仍不符合正态分布的数据则运用 Kruskal-Wallis 法对其进行非参数分析。对符合正态分布的数据运用单因素方差分析 (One-way ANOVA) 检测是否分布在不同类型边缘的鸟类物种及个体多度存在着差异。在进行方差分析时运用 Fisher's least significant difference (LSD) 的方法对每两组的均值进行比较, 用 *t* 检验对均值比较的结果做显著性分析, 显著性水平为 0.05。由于研究工作在不同年份进行, 因此必须对丰富度及个体多度的年间差异进行检测。在检测鸟类物种丰富度和个体多度的年间差异性时, 将某一边缘类型 3 年中统计的物种丰富度及个体多度分别合并计算, 运用卡方检验的方法两两比较每一种边缘类型的鸟类物种丰富度和个体多度是否存在年间差异。为了便于比较, 采用 MacNally 介绍的方法计算出每一种鸟在每个样点出现的频率及每一种鸟在每种类型的森林边缘出现的频率^[21]。方差分析和卡方检验运用 SPSS11.0 统计软件进行分析, 对鸟类物种在每个样点上出现的频率及在每一种类型森林边缘出现的频率运用 presence/absence 统计软件进行分析。仅在 1 种边缘类型观测到的鸟类物种及每个样点观测到的个体数少于 10 的鸟类物种, 由

于样本量太小, 均不应用于分析之中。另外, 尽管观测到几种猛禽的数量符合分析条件, 但由于猛禽多高飞于树冠之上, 因此, 也不将猛禽应用于分析之中。

2 结果

3 年中共观测记录 71 种鸟类物种, 11029 个鸟类个体, 其中 42 种鸟类符合分析条件, 应用于方差分析之中(表 1)。对鸟类物种丰富度而言, 各边缘类型合并计算的总物种数在年间没有显著变化($\chi^2 = 1.33, df = 2, p = 0.51$; 图 1), 在阔叶林/灌丛边缘及阔叶林/针叶林边缘鸟类的物种数在不同年间也没有较大波动(阔叶林/农田边缘: $\chi^2 = 2.96, df = 2, p = 0.23$; 阔叶林/针叶林边缘: $\chi^2 = 5.42, df = 2, p = 0.07$)。但在阔叶林/农田边缘的鸟类物种数年间差异显著($\chi^2 = 7.05, df = 2, p < 0.05$)。对个体多度而言, 各边缘类型合并计算的个体多度在年份间差异显著($\chi^2 = 6.14, df = 2, p < 0.05$; 图 2), 在阔叶林/灌丛边缘及阔叶林/农田边缘鸟类个体多度的年间差异显著(阔叶林/农田边缘: $\chi^2 = 9.37, df = 2, p < 0.01$; 阔叶林/针叶林边缘: $\chi^2 = 8.08, df = 2, p < 0.05$), 而阔叶林/针叶林边缘鸟类个体多度的年间波动不明显($\chi^2 = 1.55, df = 2, p = 0.42$)。

表 1 不同类型森林边缘分布的鸟类物种及个体多度(Mean ± SE)

鸟类物种 Bird species	边缘类型 Forest type			p
	阔叶林/农田	阔叶林/灌丛	阔叶林/针叶林	
	Broadleaf/farm land	Broadleaf/shrub	Broadleaf/conifer	
山斑鸠 <i>Streptopelia orientalis</i>	15.37 ± 9.56	22.03 ± 10.85	8.49 ± 3.64	0.365
三宝鸟 <i>Eurystomus orientalis</i>	6.35 ± 2.70	2.14 ± 1.02	3.46 ± 1.18	0.804
戴胜 <i>Upupa epops</i>	22.65 ± 8.86	13.60 ± 4.77	9.90 ± 3.28	0.335
斑啄木鸟 <i>Picoides major</i>	64.18 ± 22.70	135.26 ± 41.09	88.62 ± 19.97	0.027
小斑啄木鸟 <i>Picoides minor</i>	27.77 ± 8.06	18.20 ± 9.00	19.36 ± 5.14	0.282
灰头啄木鸟 <i>Picus canus</i>	86.30 ± 17.05	69.87 ± 19.34	61.85 ± 23.34	0.612
山鸫 <i>Dendronanthus indicus</i>	4.31 ± 1.95	7.94 ± 5.11	30.08 ± 9.42	0.032
白鸫 <i>Motacilla alba</i>	24.38 ± 7.86	12.30 ± 4.17	7.65 ± 6.31	0.155
树鹊 <i>Anthus hodgsoni</i>	5.32 ± 1.66	6.83 ± 2.18	8.06 ± 1.78	0.891
北灰鸫 <i>Muscicapa dauurica</i>	6.86 ± 1.07	1.36 ± 0.42	4.33 ± 0.98	0.322
棕头鸦雀 <i>Paradoxornis webbiana</i>	16.12 ± 5.47	10.75 ± 4.06	11.30 ± 5.15	0.772
红胁蓝尾鸫 <i>Tarsiger cyanurus</i>	7.83 ± 2.05	31.24 ± 11.08	17.66 ± 7.38	0.067
北红尾鸫 <i>Phoenicurus aureus</i>	41.07 ± 14.39	20.44 ± 9.06	12.95 ± 5.48	0.073
灰背鸫 <i>Turdus hortulorum</i>	9.39 ± 1.65	8.54 ± 2.03	15.40 ± 6.99	0.662
斑鸫 <i>Turdus naumanni</i>	3.56 ± 1.71	7.94 ± 1.35	6.64 ± 1.55	0.407
日本树莺 <i>Cettia diphona</i>	43.06 ± 11.74	98.29 ± 20.50	5.18 ± 2.03	0.001
暗绿柳莺 <i>Phylloscopus trochiloides</i>	9.36 ± 1.92	15.22 ± 4.67	22.39 ± 7.04	0.098
极北柳莺 <i>Phylloscopus borealis</i>	5.58 ± 1.04	3.21 ± 1.08	6.88 ± 1.66	0.751
黄腰柳莺 <i>Phylloscopus proregulus</i>	0.00 ± 0.00	7.18 ± 2.96	6.30 ± 1.94	0.055
巨嘴柳莺 <i>Phylloscopus schwarzi</i>	36.29 ± 7.06	17.21 ± 6.55	19.27 ± 5.60	0.106
冕柳莺 <i>Phylloscopus coronatus</i>	0.00 ± 0.00	4.43 ± 1.90	10.66 ± 5.83	0.017
银喉长尾雀 <i>Aegithalos caudatus</i>	3.83 ± 1.12	4.99 ± 0.98	5.66 ± 1.54	0.715
沼泽山雀 <i>Parus palustris</i>	9.67 ± 4.10	21.02 ± 9.43	49.88 ± 10.65	0.024
大山雀 <i>Parus major</i>	62.11 ± 9.05	80.54 ± 12.60	56.23 ± 6.53	0.117
普通鸫 <i>Sitta europaea</i>	11.59 ± 5.31	10.60 ± 4.39	7.41 ± 3.50	0.804
黑枕黄鹂 <i>Oriolus chinensis</i>	49.26 ± 13.33	33.55 ± 6.98	28.08 ± 6.75	0.877
红尾伯劳 <i>Lanius cristatus</i>	22.53 ± 7.59	31.07 ± 8.22	14.81 ± 5.50	0.232
喜鹊 <i>Pica pica</i>	101.24 ± 13.30	53.61 ± 8.87	29.63 ± 4.62	0.005
松鸦 <i>Garrulus glandarius</i>	16.32 ± 6.30	9.17 ± 4.22	20.67 ± 7.54	0.505
灰棕鸟 <i>Sturnus cineraceus</i>	124.84 ± 26.80	70.22 ± 29.31	55.97 ± 22.30	0.016
树麻雀 <i>Passer montanus</i>	4.33 ± 1.51	8.12 ± 6.30	7.06 ± 2.90	0.775
燕雀 <i>Fringilla montifringilla</i>	10.33 ± 2.98	3.24 ± 1.03	2.10 ± 0.86	0.370
金翅雀 <i>Carduelis sinica</i>	62.18 ± 18.50	33.34 ± 15.99	23.61 ± 15.20	0.094
黄雀 <i>Carduelis spinus</i>	19.29 ± 5.72	9.60 ± 8.56	6.44 ± 1.15	0.062
白腰朱顶雀 <i>Carduelis flammea</i>	8.83 ± 2.69	5.85 ± 2.07	11.23 ± 3.65	0.626
长尾雀 <i>Uragus sibiricus</i>	6.22 ± 1.35	11.30 ± 3.94	1.98 ± 0.55	0.072
白眉姬鹀 <i>Ficedula zanthopygia</i>	15.63 ± 6.80	12.67 ± 5.64	11.37 ± 3.88	0.449
白腹蓝姬鹀 <i>Cyanoptilia cyaneolana</i>	5.23 ± 1.20	6.18 ± 1.77	1.57 ± 0.43	0.440
黄胸鹀 <i>Emberiza aureola</i>	28.06 ± 9.15	89.35 ± 9.24	11.70 ± 6.93	0.014
黄喉鹀 <i>Emberiza elegans</i>	50.63 ± 11.08	39.94 ± 8.80	69.75 ± 17.99	0.063
灰头鹀 <i>Emberiza spodocephala</i>	20.14 ± 7.36	17.82 ± 6.54	4.96 ± 1.45	0.079
三道眉草鹀 <i>Emberiza cioides</i>	70.56 ± 18.27	56.66 ± 9.07	18.20 ± 8.05	0.056

方差分析的结果表明, 不同类型森林边缘的鸟类物种丰富度存在着一定的差异 ($F = 4.02, df_1 = 2, df_2 = 27, p < 0.05$; 表 2, 图 3), 物种丰富度均值比较的结果显示, 阔叶林/灌丛边缘的鸟类物种丰富度最高, 阔叶林/农田边缘次之, 而阔叶林/针叶林边缘的鸟类物种丰富度最低。多重比较的结果表明, 阔叶林/农田与阔叶林/灌丛、阔叶林/农田与阔叶林/针叶林边缘的鸟类物种丰富度差异显著 (显著性分别为 $p = 0.032$ 和 $p = 0.015$, 表 3), 但阔叶林/灌丛与阔叶林/针叶林边缘的鸟类物种丰富度没有明显差异 ($p = 0.73$, 表 3)。鸟类个体多度总的趋势在不同类型森林边缘上差异不显著 ($F = 0.58, df_1 = 2, df_2 = 123, p = 0.56$; 表 2), 但不同物种的个体多度在不同类型的森林边缘存在着一定的差异, 灰棕鸟和喜鹊在阔叶林/农田边缘出现的频率最高, 斑啄木鸟、黄胸鹀和日本树莺在阔叶林/灌丛边缘出现的频率最高, 而沼泽山雀、冕柳莺和山鹡鸰在阔叶林/针叶林边缘出现的频率最高 (图 4)。表明不同类型森林边缘对鸟类个体多度响应因种类不同而有所差异。

3 讨论

3.1 边缘效应的作用机理

边缘效应是生态学和保护生物学中非常重要的概念, 自从 Leopold 于 1933 年提出边缘效应的概念以来^[22], 许多生态学研究对边缘效应的理论内涵和作用机理进行了广泛的研究和探讨^[23, 24]。到目前为止, 有关边缘效应的作用机理有 3 种解释。第 1 种解释是加成效应, 每一种生物都占据着一定的生态位, 由于环境条件和资源的限制, 生物实际占有的生态位一般要差于理想生态位, 其间的差距使得生物潜在一种从实际生态位向理想生态位靠拢的趋势。由于边缘区域的环境异质性较高, 为边缘生物向理想生态位靠近提供了可能。边缘效应的结果给边缘地带的鸟类或其它物种提高实际生态位创造了条件; 第 2 种解释是协合效应, 某些生物对同一生态因子的利用强度与其它因子的现有水平有关, 边缘地带的各种因子并不是简单的叠加关系, 对特定种来说, 其固有的生态习性都是在长期的自然选择中进化而来的, 它们一旦与边界交互生态系统中的生态位相吻合, 各个因子就会产生协合的效应, 从而提高这些物种的生存适合度; 第 3 种解释是“集肤效应”, 生物的信息需求是生态系统有别于物理系统的主要特征之一, 边缘地带是多种“应力”交叉作用的地带, 信息量较丰富, 因而刺激了各子系统中信息需求高的种群甚至

外系统的种群向边缘区集结^[25]。本文并没有直接检测和验证边缘效应的作用机理和理论内涵, 但本文的结果表明, 同一区域内不同类型的边缘对鸟类物种分布及个体多度产生一定的影响。由此可以推断, 边缘的自身特性直接影响着边缘效应的作用机理

表 2 不同类型森林边缘分布的鸟类物种丰富度及个体多度单因素方差分析结果

Table 2 The results of One-way ANOVA of bird species richness and individual abundance among different types of forest edges					
项目 Item	离差平方和 Sum of squares	自由度 df	均方 Mean square	F 值	显著性 Sig.
鸟类物种丰富度 Bird species richness					
组间 Between groups	272.87	2	136.43	4.02	0.03
组内 Within groups	916.50	27	33.94		
鸟类个体多度 Bird individual abundance					
组间 Between groups	48.15	2	24.07	0.58	0.56
组内 Within groups	5151.71	123	41.89		

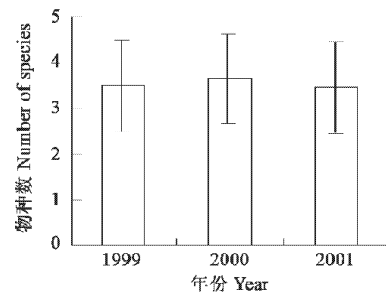


图 1 鸟类物种数的年间变化 (自然对数转换)

Fig. 1 Changes of bird species richness among years (ln transformed)

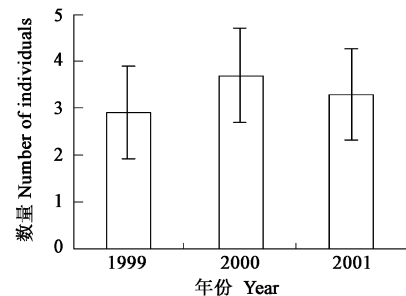


图 2 个体多度的年间变化 (自然对数转换)

Fig. 2 Changes of individual abundance (ln transformed)

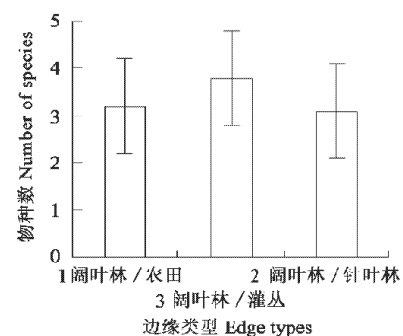


图 3 不同类型边缘的鸟类物种数 (自然对数转换)

Fig. 3 Bird species richness on different types of edges (ln transformed)

1. Broadleaf/farm land; 2. Broadleaf/conifer 3. Broadleaf shrub; 下同 the same below

表 3 同类型森林边缘分布的鸟类物种丰富度均值多重比较结果(L SD)

Table 3 The results of Post hoc multiple comparisons on bird species richness among different types of forest edges (L SD)		平均差	标准误	显著性
组别 Groups		Mean difference	Std. error	Sig.
阔叶林/农田 Broadleaf/farm land	阔叶林/灌丛 Broadleaf/shrub	- 5. 90	2. 60	0. 032
	阔叶林/针叶林 Broadleaf/conifer	- 6. 80	2. 60	0. 015
阔叶林/灌丛 Broadleaf/shrub	阔叶林/农田 Broadleaf/farm land	5. 90	2. 60	0. 032
	阔叶林/针叶林 Broadleaf/conifer	- 0. 90	2. 60	0. 732
阔叶林/针叶林 Broadleaf/conifer	阔叶林/农田 Broadleaf/farm land	6. 80	2. 60	0. 015
	阔叶林/灌丛 Broadleaf/shrub	0. 90	2. 60	0. 732

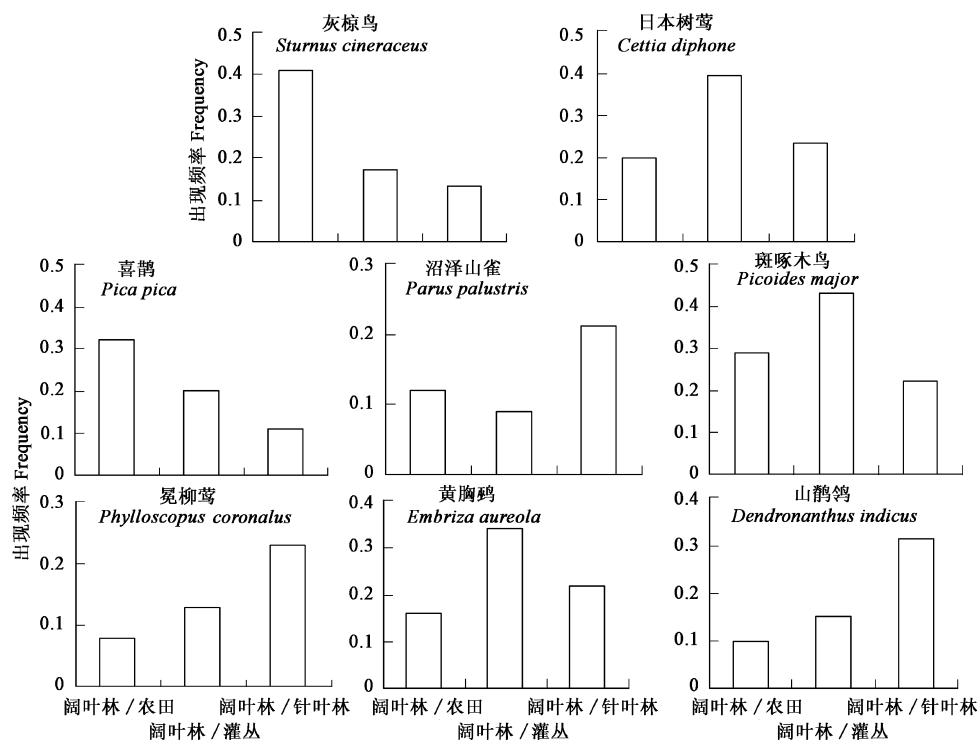


图 4 鸟类在不同类型边缘出现的频率($p < 0.05$)

Fig 4 Frequency of birds occurred on different types of edges

和效果,从而间接地影响着分布在边缘区域的动物种群动态和群落结构。

3.2 边缘及边缘效应的类型

Murcia 将森林景观中的边缘效应划分为 3 类^[15]。第 1 类是非生物效应,包括环境条件的变化,起因于临近结构相异的基质改变;第 2 类是直接的生物效应,包括物种分布和丰富度的变化,直接由边缘附近物理条件变化引起(例如通过干燥、风流、植被生长),这个变化取决于物种对边缘条件的生理耐受度;第 3 类间接的生物效应,主要包括物种相互关系的变化,例如捕食、竞争、巢寄生、放牧、生物授粉和种子扩散等。在鸟类生态学研究,人们往往把研究焦点集中在第 2 类和第 3 类边缘效应上^[3, 6, 10, 26],而忽略了第 1 类边缘效应。在某一区域内,对动物而言,不同类型的森林边缘在一定程度上可以反映环境条件的差异,在实际研究中运用对比的方法比较不同森林类型的边缘效应,所得结果会更加全面。

国外的相关研究将边缘分为 3 类^[7, 14, 27],为陡峭边缘(Abrupt edge)、过渡边缘(Intemmediate edge)及精细边缘(Subtle edge)。James 和 Warner 认为不同类型的边缘对鸟类的分布有着不同的影响,主要原因是不同的边缘类型有不同的植被结构特点和微环境特点,这些特点直接影响鸟类的巢位选择行为和取食行为,从而影响着鸟类的分布格局,同时他们认为,鸟类多样性与边缘结构的复杂程度关系较大,一般而言,边缘地域的组成结构越复杂鸟类的多样性越高^[28]。DeGraaf 调查了不同类型边缘的鸟类物种多样性^[29],发现斑块与边缘的过渡梯度越陡则鸟类的多样性越低,他列举了较陡的边缘(如森林/高速公路边缘,森林/矿区边缘)的鸟类多样性仅为精细边缘(如森林/高灌木丛边缘)的 48%。他对该现象的解释是某些边缘敏感种很容易觉察到陡峭边缘是一个不同于栖息地内部的独立体系,通过视觉效应限制了它们的领域行为。

在本研究中,阔叶林/农田边缘属于陡峭边缘,阔叶林/灌丛边缘属于过渡边缘,而阔叶林/针叶林边缘则属于精致边缘。各

边缘类型中的鸟类物种多样性不一样,证实了James和Wamer的观点。另外,在本研究中,分布在过渡边缘(阔叶林/灌丛)的鸟类物种丰富度最高,而多样性较低的是陡峭边缘(阔叶林/农田),与DeGraaf的结论基本一致。但对特定鸟类物种而言存在种间差异,灰椋鸟、灰头啄木鸟和喜鹊在阔叶林/农田边缘的个体多度最高,斑啄木鸟、黄胸鹀、三道眉草鹀和日本树莺在阔叶林/灌丛边缘的个体多度最高,而沼泽山雀、冕柳莺和山鹪鹩在阔叶林/针叶林边缘的个体多度最高。这种现象与不同鸟类物种的生活史特征及不同边缘类型的作用特点紧密相关,在左家自然保护区,喜鹊的巢址多选择在农田附近^[30],这可能是喜鹊在阔叶林/农田边缘的个体多度最高的原因之一,另外,在繁殖前期和后期喜鹊以植物的籽实为主,农田可以为喜鹊提供丰富的籽实资源;黄胸鹀和三道眉草鹀是典型的灌丛鸟类,在灌丛中筑巢和觅食,因此在阔叶林/灌丛边缘的个体多度较高;沼泽山雀、冕柳莺和山鹪鹩的食物以昆虫为主,尤喜食松毛虫,它们在阔叶林/针叶林边缘的个体多度较高,可能与食性有关。

不同类型边缘除对鸟类物种多样性和个体多度有一定的影响外,对鸟类的生存率、繁殖功效及某些行为也会产生一定的影响^[31]。一般而言,边缘地带鸟类物种多样性较高,但繁殖功效和生存率较低,这种现象被Gates和Gysel称为“生态陷阱(Ecological trap)”。以往的研究表明,生态陷阱现象在陡峭边缘比较明显,而在精细边缘并不明显,甚至没有^[27~29]。因此,在将来的相关研究中,除了研究动物在边缘的分布和数量外,还应该对生存率、繁殖功效及某些行为等内容进行探讨。另外,边缘效应受到斑块面积、斑块间隔离度、斑块的形状和研究尺度等因素的影响^[32],因此,探讨边缘效应的作用范围不能一概而论,要根据具体的景观特征、斑块特征及研究对象特征,设计合理的实验检测边缘效应。

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