Postprint: Bird Abundance Distribution Patterns in the Jingfu Temple Area of the Beijing Western Hills

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Abstract

Analysis of species abundance patterns is of great significance for understanding community structure. This study employed the broken-stick model to conduct fitting analysis on the species abundance relationship of bird communities in the Jingfusi area of the Western Hills of Beijing, and used rank correlation analysis to perform correlation coefficient tests on the model. The results show that: (1) the abundance pattern model of the bird community in this area is significantly correlated with the broken-stick model, and the broken-stick model can well fit the abundance pattern of the bird community in this area; (2) the bird abundance distribution pattern possesses dual temporal and spatial attributes; (3) at the monthly scale, January is significantly different from other months, while differences among forest communities are not significant; (4) at the seasonal scale, winter is significantly different from spring and autumn, deciduous broad-leaved forest is significantly different from coniferous-broadleaved mixed forest, while differences between coniferous forest and deciduous broad-leaved forest, and between coniferous forest and coniferous-broadleaved mixed forest are not significant; (5) at the annual scale, inter-annual variation differences are not significant.

Full Text

Preamble

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Bird Abundance Distribution Patterns in the Jingfu Temple Area of Beijing Xishan

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Abstract

The analysis of species abundance patterns is fundamental to understanding community structure. This study employed the broken stick model to investigate the quantitative relationships between species and abundance in the bird community of Jingfu Temple in Beijing Xishan, with model fit assessed using rank correlation analysis. The results demonstrated that: (1) The bird community structure in this area was significantly correlated with the broken stick model, which could effectively fit the abundance patterns of the local bird community; (2) Bird abundance patterns exhibited both temporal and spatial variation; (3) The abundance pattern in January differed significantly from other months, while no significant differences were observed among forest communities on a monthly basis; (4) Winter abundance patterns differed significantly from those in spring and autumn, with significant differences between deciduous broad-leaved and coniferous-broadleaved mixed forests, though neither deciduous broad-leaved nor coniferous-broadleaved forests showed significant seasonal differences from coniferous forests; (5) No significant annual differences were detected.

Keywords: bird community; abundance pattern; broken stick model; forest community

Introduction

In biodiversity research, beyond species diversity indices, species relative abundance models serve as essential tools that utilize mathematical and statistical methods to describe species abundance distributions [1] and form the basis for applying certain diversity indices [2-3]. Species abundance patterns result from continuous interactions among multiple species within a community and reflect the mechanisms of species relationships and community assembly [4-6]. While diversity indices provide quantitative characterization of community structure, abundance pattern analysis offers deeper interpretation of community properties, with both approaches complementing each other [3]. Abundance patterns not only represent a more intuitive manifestation of community characteristics than diversity indices [7] but also serve as fundamental criteria for determining species conservation priorities and hold significant importance for biodiversity conservation and management.

To better analyze abundance patterns, researchers have constructed various models based on ecological principles, including niche-based models such as the geometric series model, overlapping niche models, and the broken stick model [5,9-10], as well as statistical models like the log-series and log-normal distribution models [3,8]. Although some statistical models demonstrate good fit, they often fail to elucidate species interaction processes and community assembly mechanisms [5-6].

Bird research plays a vital role in ecological conservation and biodiversity protection. China possesses rich avian resources, with bird species comprising 13.1% of the world' s total. While studies on bird community composition, dynamics, and biodiversity in China are well-established [11], few have interpreted bird communities from the perspective of abundance patterns. The Xishan area features abundant vegetation that provides natural habitat for forest birds, resulting in rich avian species diversity. Previous research has investigated the biodiversity and interspecific associations of bird communities in this region [12-13]. This study examines bird abundance patterns in the Jingfu Temple area of Beijing Xishan using abundance pattern models, providing a theoretical basis for bird species diversity research and conservation.

1. Methods

1.1 Study Area and Bird Survey Methods

Study area details and bird survey methodologies are described in references [12-13].

1.2 Selection of Abundance Metrics

Abundance measurement includes absolute and relative abundance. Absolute abundance refers to absolute values such as species counts and frequencies, while relative abundance represents a species' contribution to total community abundance, also termed relative importance percentage [14-15]. May [19] proposed that relative abundance across different species represents a more technical aspect of community patterns. Relative abundance can similarly be used to fit various species abundance models [16-18]. Therefore, this study employed relative abundance as the metric for fitting bird abundance distributions, calculated as:

$$A = N \ / n \times 100$$

where A is the relative abundance of species a, N is the number of individuals of species a, and n is the total number of individuals at the sample site.

1.3 Common Abundance Pattern Models

Common abundance pattern models fall into two categories: statistical models (e.g., log-normal and log-series models) and niche models (e.g., geometric series model, niche preemption hypothesis, and broken stick model).

The log-normal model, introduced by Preston [20], represents a log-normal distribution form for species abundance research. The log-series model, proposed by Fisher et al. [21] during insect species abundance studies, predicts the frequency of species with r individuals as $f = \alpha x / r$ ($r = 1,2,3,4,\cdots$), where α represents community characteristics reflecting diversity and x is a sample plot-related parameter.

The geometric series model, also known as the niche preemption model originally proposed by Motomura and later studied by Whittaker [22-23], calculates the expected proportion of abundance for the ith species as $P = K(1\text{-}K)^{-1}$, where K is a parameter and i represents observed community species number.

The broken stick model, also termed the random niche hypothesis, was proposed by MacArthur [24]. The expected proportion of individuals for the ith species is $P = (1/S)\ (1/j)$ from j=i to S, where i is the observed community species number and S is total species number.

1.4 Data Processing

Relative abundance was calculated for each species. Using species rank from common to rare as the x-axis and relative abundance as the y-axis, ecological model fitting diagrams were constructed. The Vegan package in R (http://mirror.bjtu.edu.cn/cran/) was used to calculate correlations between observed and model values. SPSS 19.0 performed rank correlation analysis to test model fit. Spearman' s rank correlation coefficient R, a non-parametric test, was calculated using the expression [25]:

$$R = [\ (X - \bar{X})(X - \bar{X})]\ /\ \sqrt{}[\ (X - \bar{X})^2\ (X - \bar{X})^2]$$

where X and X represent ranks of i and j in sample k. Curve slope parameters were calculated to analyze abundance pattern changes, with the slope at point x of the regression equation representing the rate of change at that point.

2. Results and Analysis

2.1 Model Fitting and Selection

Twelve monthly abundance datasets were fitted using log-normal distribution, log-series, geometric series, and broken stick models. Mean deviation values were obtained for each model. Among statistical models, the log-normal distribution model showed a deviation of 0.174, while the log-series model deviated by 0.404, indicating the log-normal model better described local abundance patterns. Among niche models, the geometric series model deviated by 0.103, while the broken stick model deviated by only 0.063, demonstrating its superior fit.

Niche models tend to reveal mechanisms underlying community abundance patterns, whereas statistical models primarily provide description. The slope of geometric series model fitting lines represents community complexity [7], while broken stick model curve slopes reflect community evenness trends [27]. As niche models more intuitively demonstrate community structure, this study selected the broken stick model as the primary model for analyzing local abundance patterns.

2.2 Monthly-Scale Analysis of Bird Abundance Patterns

Following bird phenology, data from 12 months were processed as one biological year. In the coniferous forest (Platycladus orientalis) model fitting tests, correlation coefficients (r) between observed and predicted values were 0.982, 0.866, 0.918, 0.982, 0.975, 0.909, 0.960, 0.979, 0.892, 0.974, 0.976, and 0.860, with all T-test P-values < 0.01, indicating highly significant correlations. This demonstrates that the broken stick model appropriately fits bird abundance patterns in coniferous forests, where species distributions are relatively sparse with weak interspecific competition and substantial niche differentiation, consistent with the random niche hypothesis. *Pica pica* (Eurasian magpie) emerged as the dominant species with greatest relative abundance, occupying most niches with clear dominance, while *Parus major* (great tit) and others showed smaller relative abundances.

In coniferous-broadleaved mixed forest tests, correlation coefficients (r) were 0.756, 0.921, 0.978, 0.941, 0.980, 0.942, 0.969, 0.990, 0.930, 0.945, 0.945, and 0.945. Most T-test P-values were < 0.01, though March showed $P > 0.05$. March falls in early spring/winter when bird numbers are lower than other months. Additionally, cultural heritage excavation work conducted near the survey site during this period negatively impacted bird surveys, resulting in smaller datasets that prevented ideal curve fitting. The random niche hypothesis remained applicable, with *Parus major* occupying most niches as the dominant species. Small forest birds like *Parus venustulus* (yellow-bellied tit) and *Phylloscopus proregulus* (Pallas’ s leaf warbler) increased in proportion.

In deciduous broad-leaved forest tests, correlation coefficients (r) were 0.961, 0.977, 0.977, 0.964, 0.976, 0.956, 0.922, 0.951, 0.975, 0.901, 0.966, and 0.955, with all T-test P-values < 0.01, showing highly significant correlations. Species distribution followed the random niche hypothesis with weak interspecific competition, high niche differentiation, and low overlap. Small birds represented by *Parus major* occupied most niches as dominant species.

Slope is a crucial parameter in abundance curves, intuitively reflecting change rates. Most regression equations showed significant correlations (R), with only mixed forest showing non-significant correlation ($P > 0.02$), though F-test P-values were < 0.01. Monthly slope variations were greatest in coniferous-broadleaved mixed forest, followed by coniferous forest, with deciduous broad-leaved forest showing minimal change. ANOVA revealed no significant overall monthly differences, but multiple comparisons showed significant differences between January and other months, with extremely significant differences in some cases. No significant differences existed among forest communities monthly.

2.3 Seasonal-Scale Analysis of Bird Abundance Patterns

Seasons were defined according to bird phenology: spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). In coniferous forest seasonal model fitting tests, correlation coefficients (r) between observed and predicted values were 0.902, 0.950, 0.980, and 0.917, with all P-values < 0.01, indicating highly significant correlations. The broken stick model appropriately fits seasonal-scale abundance patterns in coniferous forests. *Corvus macrorhynchos* (large-billed crow) showed greatest relative abundance as the dominant species, with weak interspecific competition and relatively uniform niche distribution consistent with the random niche hypothesis.

In coniferous-broadleaved mixed forest tests, correlation coefficients (r) were 0.908, 0.958, 0.958, and 0.962, with all P-values < 0.01. *Parus major* showed greatest relative abundance, occupying most niches as the dominant species, with *Phylloscopus inornatus* (yellow-browed warbler) also prominent. Dominant species varied seasonally: winter dominant was *Cyanopica cyanus* (azure-winged magpie), spring and autumn dominants were *Parus major*, while summer showed multiple co-dominants.

In deciduous broad-leaved forest tests, correlation coefficients (r) were 0.959, 0.984, 0.984, and 0.983, with all P-values < 0.01. *Corvus macrorhynchos* showed greatest relative abundance as the dominant species, with *Aegithalos caudatus* (long-tailed tit) also prominent. Seasonal dominants varied: winter and spring dominants were *Parus major*, autumn dominant was *Parus major*, while summer showed multiple species with similar abundances.

Seasonal slope variations were greatest in coniferous-broadleaved mixed forest, followed by coniferous forest, with deciduous broad-leaved forest showing minimal change. Bivariate ANOVA with season as fixed factor and forest type as random factor showed no significant overall differences and no significant interaction. Multiple comparisons revealed significant differences between winter and spring/autumn, but no significant differences among spring, summer, and autumn. With forest type as fixed factor and season as random factor, overall differences were significant with no significant interaction. Deciduous broad-leaved forest differed significantly from coniferous-broadleaved mixed forest, while coniferous forest showed no significant differences from either other type.

2.4 Annual-Scale Analysis of Bird Abundance Patterns

Historical survey data were compiled to obtain complete spring bird survey datasets for 2012 and 2013. Repeating the above procedures, correlation coefficients (r) for spring 2012 and 2013 model fitting tests were 0.952, 0.977, 0.891, 0.963, 0.933, and 0.896, with all T-test P-values < 0.01 and F-test P-values < 0.001, indicating highly significant correlations. Community species composition showed no obvious changes, with dominant species varying slightly. All three forest communities followed the random niche hypothesis. One-way

ANOVA of slopes with year as factor yielded $P > 0.05$, indicating no significant annual variation in abundance patterns across the three forest communities.

3. Conclusions and Discussion

3.1 Conclusions

The broken stick model effectively fits the quantitative relationships of bird communities in the study area. Analysis from temporal (monthly, seasonal, annual) and spatial (three forest communities) scales reveals that bird community abundance patterns possess dual temporal and spatial attributes. The fitted curves intuitively display community composition and bird distribution patterns. The model demonstrates that resource partitioning among bird species is random, with weak interspecific competition and non-overlapping niches.

Temporal-scale patterns: Analysis across three temporal scales shows that coniferous-broadleaved mixed forest exhibits the most pronounced abundance pattern changes, while coniferous and deciduous broad-leaved forests show moderate variation. Monthly analysis reveals significant differences between January and other months. Seasonal analysis shows significant differences between winter and spring/autumn, but no significant differences among spring, summer, and autumn patterns. Annual changes are not significant.

Spatial-scale patterns: Among the three forest communities, deciduous broad-leaved forest shows the highest bird richness, followed by coniferous-broadleaved mixed forest, with coniferous forest having the lowest richness. Coniferous and mixed forests show similar patterns, while deciduous broad-leaved forest differs significantly from mixed forest. Dominant species are primarily *Parus major* and *Corvus macrorhynchos*.

3.2 Discussion

This study supplements and enriches research on bird communities in the Xishan Jingfu Temple area from an abundance perspective. Similar to interspecific association patterns [12], bird community abundance patterns here exhibit dual temporal and spatial attributes. The broken stick model describes communities lacking extremely dominant species, where species are not particularly rich but are relatively evenly distributed across niches. This distribution conforms to the random niche hypothesis [24], where resource partitioning is random and niches do not overlap. The model has been widely applied in abundance pattern research, proving effective for both simple and complex communities [29]. While Zhang Jintun found poor fit for certain forest communities [28], others have successfully applied it to various forest types [17,30].

The study reveals that bird species and numbers change with seasons and vegetation zonation. Analyzing abundance patterns clarifies community structure characteristics including richness, evenness, and dominance. Human disturbance affects community structure and species composition [31], with birds responding through varying flight initiation distances [32]. During this study, cultural heritage excavation from March-April 2014 in the coniferous-broadleaved mixed forest survey area disrupted the original landscape, negatively impacting bird surveys and causing data gaps. This resulted in non-significant model fits for post-March data in mixed forests. Landscape structure critically influences biodiversity [33], and while recreational activities may reduce suitability for nesting birds, most species show no detrimental habitat effects [34]. Whether human activities impact bird community abundance patterns requires further investigation.

References

[1] Biodiversity Research Principles and Methods. Beijing: Chinese Academy of Sciences Biodiversity Committee, 1994: 141-165. [2] Zhang J T. Advances in species abundance pattern research. Chinese Journal of Plant Ecology, 2003, 27(3): 412-526. [3] Chinese Academy of Sciences Biodiversity Committee. Biodiversity Research Principles and Methods. Beijing: China Science and Technology Press, 1994. [4] Pielou E C. Ecological Diversity. New York: Wiley, 1975. [5] Tokeshi M. Species abundance patterns and community structure. Advances in Ecological Research, 1993, 24: 111-186. [6] Tokeshi M. Niche apportionment or random assortment: species abundance patterns revisited. Journal of Animal Ecology, 1990, 59(3): 1129-1146. [7] Hoagstrom C W. The unified neutral theory of biodiversity and biogeography: Stephen P. Hubbell. Annals of the Entomological Society of America, 2005, 98(2): 241-242. [8] He J S. Neutral theory in community ecology. Chinese Journal of Plant Ecology, 2006, 30(5): 868-877. [9] Wu C Z, et al. Fitting study on relative abundance models of bird species in Jiangshi Nature Reserve, Fujian. Chinese Journal of Eco-Agriculture, 2004, 12(2): 36-39. [10] Chen Z L, Guan W B. Interspecific association analysis between Parus major and other bird populations in Beijing Xishan area. Acta Ecologica Sinica, 2013, 33(20): 6614-6633. [11] Jia L L, Guan W B. Bird community diversity in ancient Platycladus orientalis forest at Jingfu Temple, Beijing. Journal of Beijing Forestry University, 2013, 35(5): 46-55. [12] Whittaker R H. Community and Ecosystem. 2nd ed. New York: Macmillan, 1975: 135-168. [13] Whittaker R H. Evolution of species diversity in land communities. In: Hecht M K, Steere B W N C, eds. Evolutionary Biology. New York: Plenum Press, 1977, 10: 1-67. [14] Molles Jr M C. Ecology: Concepts and Applications. Dubuque, IA: WCB/McGraw-Hill, 1999. [15] Wu C Z, et al. Fitting study on relative abundance models of Tsoongiodendron odorum community in Wanmulin Reserve, Fujian. Journal of Tropical and Subtropical Botany, 2001, 9(3): 235-242. [16] González-Estrada E, Fawcett R H, Herrero M. Integrating models of relative abundance of species with the dry-weight-rank method for the botanical analysis of forest understory vegetation. Grass and Forage Science, 2002, 57(2): 171-183. [17] May R M. Theoretical Ecology. Oxford: Blackwell Scientific Pub., 1976. [18] Preston F W. The commonness, and rarity, of species. Ecology, 1948, 29(3): 254-283. [19] Fisher R A, Corbet A S, Williams C B. The relation between

the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology, 1943, 12(1): 42-58. [20] Whittaker R H. Dominance and diversity in land plant communities. Science, 1965, 147(3655): 250-260. [21] Whittaker R H. Evolution and measurement of species diversity. Taxon, 1972, 21(2/3): 213-251. [22] MacArthur R H. On the relative abundance of bird species. Proceedings of the National Academy of Sciences of the United States of America, 1957, 43(3): 293-295. [23] Legendre P, Legendre L. Numerical Ecology. 2nd ed. Amsterdam: Elsevier Science, 1998: 194-198. [24] Zhang J T. Interspecific association indices and hierarchical pattern models in Pistacia chinensis communities. Journal of Beijing Forestry University, 2007, 43(3): 118-121. [25] Zhang J T. Species abundance distribution analysis of artificial vegetation in Antaibao opencast mine. Chinese Journal of Applied and Environmental Biology, 1999, 5(6): 573-583. [26] Ma K P, et al. Studies on plant community diversity in Donglingshan area, Beijing. Acta Ecologica Sinica, 1997, 17(6): 573-583. [27] Zhang J T. Studies on species abundance relationships of several forest community types in New York State, USA. Acta Phytoecologica Sinica, 1999, 23(6): 481-589. [28] Zhao H F, et al. Preliminary study on bird species diversity in typical degraded ecosystems in the upper Minjiang River. Journal of Sichuan Forestry Science and Technology, 1999, 19(3): 399-507. [29] Wu C Z, et al. Impact of human activities on species diversity of forest plant communities in Mount Tai. Journal of Shandong Agricultural University, 2003, 9(1): 42-58. [30] Li X H. Study on urbanization impacts on bird communities and bird adaptability. East China Normal University, 2007. [Dissertation] [31] Forman R T T. Landscape ecology and biodiversity protection. Chinese Journal of Nature, 1999, 21(3): 31-37. [32] David N B. The effects of human activity on forest bird communities. Journal of Applied Ecology, 1990, 27(1): 265-279. [33] Palomino D, Carrascal L M. Impact of recreation on forest bird communities: non-detrimental effects of trails and picnic areas. Acta Zoologica Sinica, 2007, 53(1): 54-63.

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