Research Paper

A Study on the Impact of Human Activities on Biodiversity in Severe Cold Region Urban Residential Areas with Consideration of Regional Climate Characteristics

A Case Study of Harbin, China

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Abstract

The unique regional climate of severe cold region shapes human activities patterns within urban residential areas and exerts significant impacts on urban biodiversity. Investigating how human activities in severe cold region urban residential areas affect biodiversity in the perspective of regional climate, provides scientific evidence for the planning and construction of biodiversity-friendly cities. Based on field survey in October–November 2024, this study used birds as indicator species of biodiversity to conduct a birds and human activities survey in 465 residential areas of Harbin. By contrasting seasonal with non-seasonal human activities, statistical analyses were applied to reveal the effects of seasonal activities on urban biodiversity, and corresponding optimization strategies were proposed. Results indicate that: (1) Seasonal resident's activities influenced by regional climate significantly enhanced bird diversity. Traditional resident's activities in severe cold region such as outdoor storage during autumn and winter provided supplementary food resources for birds, but autumn vegetable drying suppressed both bird abundance and diversity. (2) Non-seasonal resident's activities showed differentiated effects: residents' vegetable gardens, and garbage points significantly increased bird abundance, while intensive bird feeding and bird keeping reduced diversity. (3) Based on seasonal characteristics of resident's activities, optimization strategies were proposed. This study identified unique types of resident's activities shaped by regional climate in severe cold region urban areas, quantitatively revealed their relationships with urban biodiversity, and provided insights into fostering positive interactions between human activities and urban biodiversity.

Keywords

Severe cold region, Regional climate, Urban residential areas, Urban biodiversity, Human activities

1. Introduction

The conservation of urban biodiversity has emerged as a global imperative amidst rapid urbanization and the consequent loss of natural habitats (Leveau, L.M. et al. 2012; Dong, X. et al. 2025). Human activities, as the dominant force driving urban construction and habitat alteration, exert significant influences on ecosystems, often leading to fragmentation and ecological stress (Fahrig, L. 2003; Deng, J.S. et al. 2009; Banks-Leite, C. et al. 2020). However, abundant studies emphasize that human activities occurring within urban residential areas hold particular significance for urban ecology. As the fundamental units of urban renewal and the primary spaces for daily human living, urban residential areas play a paradoxical yet vital role. They serve not only as the regions where humans most frequently encounter urban wildlife but also function as essential habitat patches that align with the dispersal distances of common urban species (Cao, S. et al. 2023). Consequently, exploring how human activities within urban residential areas influence urban biodiversity is indispensable for fostering biodiversity-friendly cities.

Within urban residential areas, the relationship between human activities and urban biodiversity is dynamic and multifaceted. Unlike the static built environment, human activities act as fluid ecological filters that can either support or suppress biodiversity. Activities such as supplemental feeding (Greig, E.I. et al. 2017) or the creation of community gardens may provide critical resources (Goddard, M.A. et al. 2010), while others, like intensive greening maintenance or construction disturbances, may sever ecological connectivity (Aguilera, G. et al. 2019). However, current research often overlooks the specific behavioral mechanisms behind these effects. A detailed investigation into the types and intensities of these activities is needed to understand their true impact.

Regional climate has been overlooked when assessing how human activity affects urban biodiversity. China is a country with extreme cold climate. The climate can be expected to affect how humans interact with their surroundings. In accordance with China's Building Climate Zoning Standards (GB50178—93), there are five Zones (climate) for urban areas in China. One such zone is referred to as “Severe Cold Region”. The cities within the Severe Cold Region have long, bitterly cold winters; they remain covered in snow until well into spring; and undergo rapid freezing and thawing throughout the season (Kalle, R. et al. 2018; Jiang, C. et al. 2024). The aforementioned seasonal factors lead to an array of unique human activity patterns within the Severe Cold Region, which have direct ecological consequences (Liang, S. et al, 2025). The climatic characteristics of these regions determine (1) when and how quickly plants can grow, (2) where they can be grown, and (3) how these plants can create habitats for bird species within the area. Furthermore, the geographic locations within the Severe Cold Region will soon experience a large influx of both seasonal and non-seasonal activities, and thus have the potential to create many new, heterogeneous bioclimatic zones and ecological relationships. As humans continue to adapt to the harsh climatic conditions of the Severe Cold Regions, they will likely alter their behaviors and patterns of interaction with their environments and increase their level of ecological influence across the region.

Our project was created to address the above deficiencies in existing literature. The project included (1) survey fieldwork and qualitative data collection to identify the ways that human behaviors are affected by the extreme climatic conditions in the Severe Cold Region; (2) to quantitatively assess the impact of seasonal (and non-seasonal) human behaviors on avian abundance and diversity within the Severe Cold

Region; and (3) develop spatial planning and design strategies for biodiversity-friendly residential areas in severe cold region cities.

2. Methodology

2.1 Study Area and Sampling

The main urban area of Harbin (116°27′– 116°43′ E, 45°42′ – 45°50′ N) has an annual mean temperature of about 3.5 °C and is located in Severe Cold Region of China. The city has a very long winter season that lasts from November until March with record low temperatures of -38 °C as well as an average winter temperature of -14.6 °C. The city has been identified as a major migratory and breeding stop for migratory birds in the Northeast Region of Asia (Tong, X. 2020; Rahman, F. et al. 2025). There are many resident species of common birds, as well as summer visitor species found in parks, lakes, and housing developments located in the urban area of Harbin (Dong, Y. et al. 2025) .

The research used a stratified random sample approach to identify 465 representative residential areas in the primary urban area of the city of Harbin (Figure 1). The process took two steps. First, the study area was divided into eight separate regions, each having their own individual building densities. Next, for each region, the researcher randomly selected an equal number of residential areas from each density category (total of 465 areas). Subsequently, the researcher confirmed that the sampled residential areas accurately reflected the overall region. Through this process, the researcher was able to identify residential areas that represented many different periods of history (over 25 years old, 15-25 years old and less than 15 years old). In addition, the sampled residential areas represented a variety of different types of residential developments (including low-rise, high-rise and mixed-use).

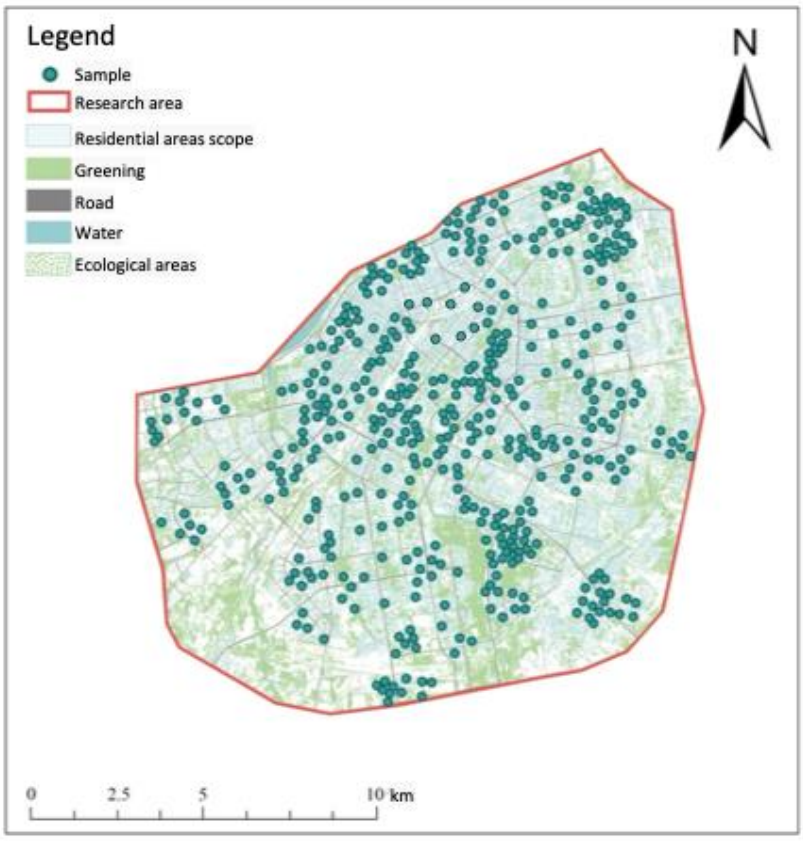


Figure 1 Study area and samples. Source: Authors.

2.2 Data collection

The research involved gathering information about the number of different species of birds in 465 different residences during August 2023 and again between October 4 – November 17, 2024. Although this timeframe represented the end of a breeding season for many birds and the beginning of their autumn migration into Harbin, it also offered favorable conditions for completing an exhaustive database; specifically, Avian activity was at a peak, and both numbers of birds and species had stabilized, making it easy to identify the birds. All surveys were completed under clear or partly cloudy skies with no rainfall and dry ground; each residence was surveyed within the three-hour time window following dawn and before dusk (Bibby, C.J. et al. 2000; Arévalo, C. et al. 2022). In order to reduce the potential for chance errors due to inconsistent observing times, all sample residential areas were randomly assigned for each survey.

Each of the sample study areas was divided into squares measuring 100m by 100m, or 1 hectare. One to three squares from each area were chosen as representative of the type of habitat that would be surveyed based on the following criteria. In addition, observation points were created by placing a counting location in the middle of each square to facilitate accurate bird counts. Second, the observation area was defined as a 50-meter radius centered on the sample point. Each observation session lasted 10 minutes, during which bird species, numbers, behaviors, and perching locations observed or heard within the sample area were recorded using methods such as photography or videography. Concurrently, human activities data was documented, including storage activities, human feeding incidents, and the presence of urban renewal

actions. Finally, record 10 minutes of clearly audible bird songs, which may include faint ambient background noise, for acoustic signature analysis.



Figure 2 Panorama of No. 13 sample residential areas. Source: Authors.

2.3 Indicators calculation

A comprehensive indicator system was established to quantify the relationship between human activities and urban biodiversity (Table 1). Bird Abundance (B) and Simpson's diversity index (D) were used as metrics for biodiversity, ensuring a comprehensive reflection of the survival status of urban species in urban residential areas in severe cold regions (Liu, Q. et al. 2025; Zorzal, R.R. et al. 2021).

Human Activities indicators were categorized into seasonal and non-seasonal types, reflecting the dominant influence of the Severe Cold Region climate. Given the inherent difficulty in directly quantifying certain spontaneous or behavioral human activities (e.g., outdoor storage, vegetable drying), these indicators were operationalized as binary variables, where the presence of the activity was coded as 1 and its absence as 0. This binary approach was applied to all seasonal activities (drying autumn vegetables, outdoor window storage, exterior wall insulation, paving renovation) and spontaneous non-seasonal activities (human bird feeding, keeping birds, window sill greenery). Furthermore, Population density data was sourced from China's Third National Population Census. Other quantitative spatial indicators, specifically the number of garbage points and resident vegetable gardens, were quantified by counting the occurrences within a strict 50 meters radius surrounding the observation point.

For each observation point, Bird Abundance (B) was calculated as the total number of individual birds of all species recorded within the 50 m radius during the 10-minute observation session. Simpson's diversity index (D) was computed as $D = 1 - \Sigma(n_i/N)^2$, where n_i is the number of individuals of the ith species and N is the total number of individuals across all species at that point; values approach 1 as community evenness and richness increase. Where multiple observation points fell within the same residential area, point-level values were averaged to obtain a single B and D value per residential area. Bird identifications were cross-checked against the 10-minute acoustic recordings, and only birds observed using the residential area (foraging, perching, nesting or moving through the canopy) were included; high fly-overs were excluded.

	Indicators	Calculation method
Seasonal Human activities	Dry autumn vegetables	Binary variables, 1 is yes, 0 is none
	Window sill storage	
	Residential areas renewal behavior	Binary variables, 1 is yes, 0 is none, including exterior wall insulation, paving renovation

Non-seasonal Human activities	Population density	Population density within 100 meters, calculated based on world population data from the seventh census
	window sill Greenery	Binary variables, 1 is yes, 0 is none
	Human keeping birds	
	Human feeding birds	
	Outdoor balcony	
	Number of garbage points	The number of garbage points opened within a radius of 50m of the survey point
	Residential vegetable garden area	The total area of residents' vegetable gardens within a radius of 50m of the survey point
	The number of residents' vegetable gardens	The number of residential vegetable gardens within a radius of 50m of the survey point

Table 1 Human activities indicators and calculation methods. Source: Authors.

2.4 Statistical Analysis and research framework

Initial descriptive statistics were performed on the collected bird diversity and human activity data, including occurrence rates for each binary activity variable and summary statistics for the continuous indicators. Because the bird abundance and Simpson's diversity values were not normally distributed (Shapiro–Wilk test, $p < 0.05$) and several explanatory variables were binary, Spearman's rank correlation (ρ) was employed to quantify the relationships between each seasonal and non-seasonal human activity indicator and the two bird diversity metrics. Correlation coefficients were considered statistically significant at $p < 0.05$ (two-tailed), and the strength of association was interpreted following standard conventions ($|\rho| < 0.2$ weak; 0.2–0.4 moderate; > 0.4 strong). Prior to analysis, the spatial independence of the residential-area observations was assessed using global Moran's I on both bird abundance and Simpson's diversity, which indicated no significant spatial autocorrelation across the 465 sample residential areas; pooled correlation analysis was therefore considered appropriate. All analyses were performed in Python.

In addition, our research strictly followed three distinct steps. The first step involved defining the comprehensive indicator system, including the selection of bird diversity metrics as response variables and the categorization of human activities into seasonal and non-seasonal explanatory variables. The second step comprised the extensive field surveys and acoustic monitoring conducted across the 465 residential sites in Harbin to collect the necessary data. The final step involved statistical correlation analysis to quantify the specific influence of human activities on urban biodiversity. The subsequent proposal of seasonal human activities management strategies for biodiversity conservation and enhancement.

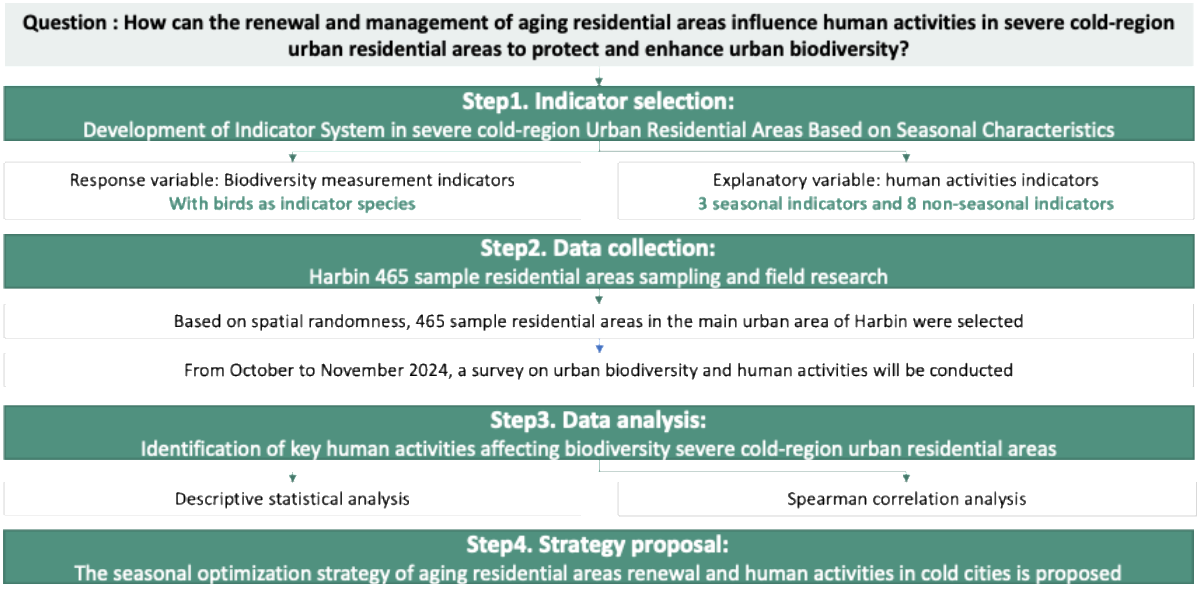


Figure 3 Research Framework. Source: Authors.

3. Results

3.1. The spatial distribution of biodiversity metrics

Across the 465 sample residential areas in Harbin, bird communities showed marked variation in both abundance and diversity. Using birds as indicator species, we quantified biodiversity with two metrics: bird abundance and Simpson's diversity index. Both metrics varied substantially among residential areas, indicating strong spatial heterogeneity in biodiversity within the severe cold region. Some residential areas supported relatively species-rich and abundant bird assemblages, whereas others were dominated by only a few common species (Figure 4). Notably, the abundance distribution of bird populations exhibits high skewness, with only a few dominant species accounting for the vast majority of observation records.

Residential areas within sub-zones adjacent to the Songhua River and large urban green spaces exhibit relatively favorable bird community indices, though these show some fluctuation and demonstrate distinct spatial heterogeneity. Within residential areas near the Songhua River and large urban green spaces, bird community indices are favorable. Moran's I test results indicate no significant spatial autocorrelation.

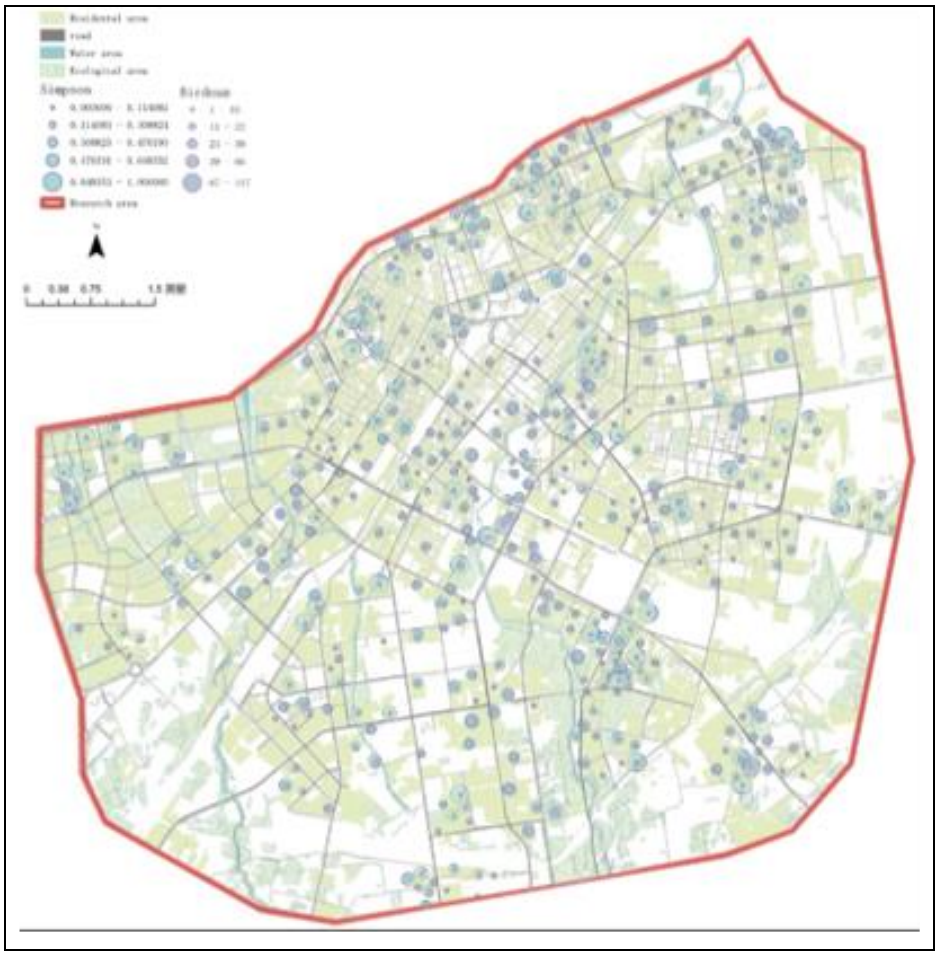


Figure 4 Spatial distribution of bird diversity metrics. Source: Authors.

3.2. Descriptive analysis of human activities in residential areas of Harbin

Descriptive statistics revealed that human activities that are typical of severe cold regions are widely distributed across residential areas in Harbin. Among seasonal activities, drying autumn vegetables and window-sill storage were particularly prevalent: 63.7% of the 465 residential areas exhibited drying of autumn vegetables, and 69.3% showed outdoor or window-sill storage behaviors related to using low outdoor temperatures as an extended “refrigerator”. Residential areas renewal activities, including wall and balcony insulation retrofits and pavement renovation, occurred in 26.3% of the sample residential areas.

Several non-seasonal human activities were also common. Window-sill greenery was present in 51.4% of the residential areas, while resident-initiated vegetable gardens occurred in 31.7%. Human feeding of birds or other animals was recorded in 32.8% of the residential areas, and humans keeping cage birds occurred in 23.8%. In addition, the survey documented outdoor balconies, varying numbers of garbage points within a 50 m radius of the survey points, and differences in population density and vegetable-garden area and number among residential areas.

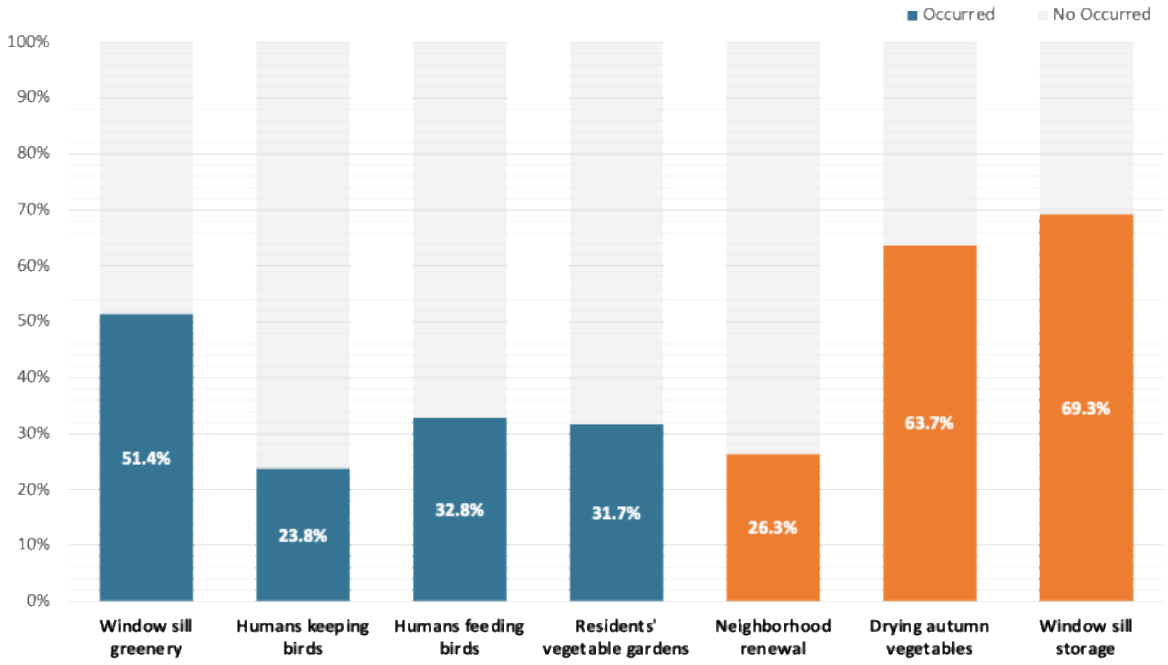


Figure 5 Overlay of occurrence rates for human activities. Source: Authors.

3.3. Correlation analysis of human activities and biodiversity

3.3.1 Seasonal activities

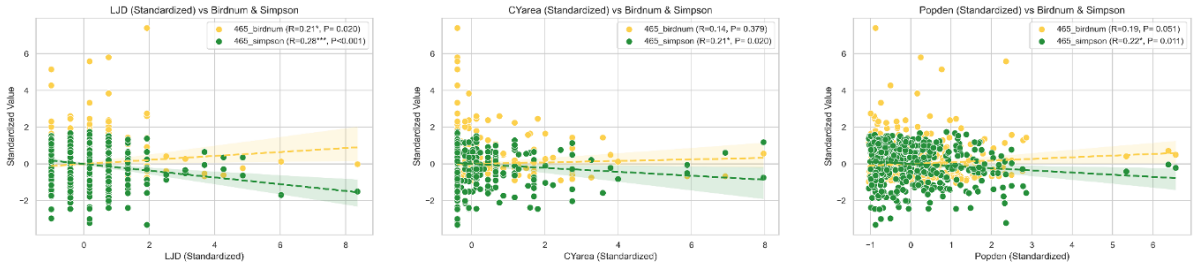
The correlation analysis results showed that seasonal activities influenced by severe cold regional climate have distinct effects on bird abundance and diversity (Figure 6). Outdoor storage behaviors significantly increased bird abundance but did not favor high bird diversity. Residential areas with outdoor or window-sill storage tended to support larger numbers of individual birds but were often dominated by a limited set of synanthropic species. Drying autumn vegetables showed a negative association with bird diversity. Despite the expectation that dried vegetables might provide additional food resources, the correlation analysis indicated that residential areas with extensive autumn vegetable drying exhibited lower Simpson's diversity values. Residential renewal behaviors, including wall and balcony insulation and pavement replacement, significantly increased bird abundance but were associated with reduced bird diversity, suggesting that these interventions may favor only a subset of tolerant species.

3.3.2 Non-seasonal activities

Our findings reveal that human feeding, resident vegetable gardens (both area and number), and the number of garbage points all showed significant positive correlations with bird abundance (Figure 6). Residential areas with more feeding sites, larger or more numerous vegetable gardens, and more garbage points tended to host higher numbers of birds overall.

At the same time, human feeding and bird-keeping behaviors were negatively associated with bird diversity. Residential areas where residents frequently fed birds or kept cage birds exhibited lower Simpson's diversity values. In particular, cage-bird keeping appeared to suppress certain territorial species

such as the Azure-winged Magpie (*Cyanopica cyanus*): residential areas with many kept birds had noticeably fewer individuals of this common severe cold region species than other areas. The number of garbage points showed a positive relationship with bird diversity as well as abundance, indicating that moderately distributed waste-related resources may provide additional foraging opportunities for a broader set of species.



(a) Number of garbage points **(b) Area of resident's vegetable gardens** **(c) Population density**

Figure 6. Visualization of bivariate correlation analysis results between some indicators and biodiversity metrics. Source: Authors.

4. Discussion

4.1. The effect of seasonal human activities on biodiversity

The findings highlight the dual role of seasonal human activities in severe cold regions as both resource pulses and disturbance sources for urban bird communities. Outdoor storage and residential renewal are strongly conditioned by the regional climate characteristics of Harbin, where long, cold winters and pronounced freeze–thaw cycles encourage residents to store goods outdoors and necessitate frequent pavement and insulation repairs.

The positive association between outdoor storage and bird abundance suggests that stored items, residual food and structural elements (such as crates and shelves) provide additional foraging opportunities and microhabitats for synanthropic birds. However, the lack of a corresponding increase in diversity implies that these resources primarily benefit a few generalist species capable of exploiting human-dominated niches, while more specialist or disturbance-sensitive species remain excluded. This pattern is consistent with the broader understanding that resource enrichment in highly artificial environments can reinforce biotic homogenization, favoring adaptable urban exploiters rather than supporting a diverse assemblage.

The negative relationship between autumn vegetable drying and bird diversity is particularly noteworthy. From a functional perspective, drying vegetables in autumn could be expected to supplement food resources at the onset of winter, when natural food availability declines sharply in severe cold region cities. Yet the correlation analysis suggests that, in practice, this activity reduces diversity. One likely reason is that the specific vegetables commonly dried in Harbin (such as Chinese cabbage and scallions) are not preferred foods for many bird species, limiting their value as a resource.

In addition, residents often actively drive away birds to protect their stored vegetables, thereby increasing disturbance around drying areas. The result is a local environment with frequent human presence, low resource diversity and a high probability of disturbance—conditions that favor only a narrow subset of highly tolerant species.

Residential renewal activities—including wall and balcony insulation retrofits and pavement replacement—also showed a mixed effect: they increased bird abundance while inhibiting diversity. On the one hand, construction sites and newly exposed substrates may temporarily provide bare soil, cavities and structural niches that can be exploited by some birds. On the other hand, such activities typically involve intensive human presence, noise and habitat simplification, which can displace sensitive species and reduce vegetation cover. Given that these renewal works recur every one to two years in many severe cold region residential areas due to freeze–thaw damage, their cumulative effect may be to maintain a chronically disturbed environment where only a few tolerant species can persist.

4.2. Non-seasonal human activities and synanthropic bird assemblages

The roles of non-seasonal human activities further underline the importance of everyday practices in shaping bird communities in severe cold region residential areas. First, human feeding and resident's vegetable gardens were found to significantly promote bird abundance. Feeding sites and resident's gardens provide reliable, spatially concentrated food resources throughout much of the year, which is particularly valuable in severe cold regions where natural food sources are limited for extended periods.

At the same time, human feeding and bird-keeping behaviors were negatively associated with bird diversity, suggesting that they may contribute to community simplification. Regular feeding tends to favor a small set of dominant, aggressive species—such as sparrows and pigeons—that can monopolize food and exclude subordinate species. Cage-bird keeping may further suppress wild birds through competition for space, trapping of wild individuals and frequent human presence and noise near buildings. The finding that residential areas with many kept birds had fewer Azure-winged Magpies and other territorial species illustrates how culturally embedded practices can reshape local bird assemblages in severe cold region cities.

The positive correlation between the number of refuse sites (garbage points) and Bird Abundance/Diversity suggests that a moderate distribution (less than highly concentrated) of refuse-related resources is more successful in supporting a wider variety of bird species than localized (single point) feeding opportunities. Refuse sites may serve as widely spaced sources of food, cover and perching locations, and they frequently occur where vegetational edges, constructed environments and open space converge. However, improper management of refuse can result in a concentration of rats at these locations and increase the transmission of animal-to-human diseases. As such, the need exists to develop and manage these sites in such a way as to create a balance between their ecological value and their sanitary requirements.

4.3. Implications for spatial planning, urban design and climate-sensitive residential renewal

A series of strategies for developing and maintaining residential areas in severe cold regions, organized by season and activity, are presented here based on the empirical findings of this research, for potential implementation across each season. Winter - Seasonal Bird Feeding. Winter bird feeding has moderate benefits for local birds (Jokimaki, J. et al. 2012). The location, timing and hygiene of bird-feeding sites must be standardized, and food types offered must be diversified among a wide variety of birds; the use of supplemental water sources and nest boxes may reduce the strong seasonal bottlenecks imposed by cold temperatures during the winter months (Plummer, K.E. et al. 2019; Schaper, L. et al. 2021). Spring — residential garden cultivation. The cultivation intensity and spatial arrangement of residential vegetable gardens shift with the arrival of spring, and the noise and human activity associated with these gardens can affect the success of breeding and nesting. Controls should therefore be introduced to reduce human

activity and noise during critical breeding and nesting periods within a designated buffer area (Remacha, C. et al. 2016). Summer — vegetation maintenance. Summer offers opportunities to reduce the frequency of pruning and trimming of greenery, retain patches of natural-growing vegetation, and establish a diverse selection of plant species, so as to provide consistent coverage and foraging opportunities for local wildlife.

Autumn — vegetable drying. The common practice of drying autumn vegetables should be standardized across residential areas by establishing designated drying areas located away from key foraging and nesting resources for birds, together with storage methods that minimize disturbance to birds.

Translating these findings into spatial planning and urban design requires moving beyond season-by-season behavioral guidance and addressing the residential area as a designed ecological unit. At the residential-area scale, our results suggest that biodiversity-friendly layouts in severe cold regions should formally allocate space for the seasonal practices that the climate makes inevitable. Master plans and detailed control plans for new residential areas, and renewal plans for existing ones, should designate dedicated outdoor storage and autumn vegetable-drying zones at the periphery of courtyards or along sun-exposed building edges, spatially separated from the foraging and perching habitats identified in this study (vegetated edges, large shrubs, mature trees adjacent to the Songhua River and large green spaces). Treating these residents' activities as planned land uses, rather than informal occupation, allows the disturbance footprint to be bounded by design rather than diffused across the entire residential area.

At the urban-design and site-design scale, three concrete levers emerge from the correlation results. First, garbage-point siting standards should follow a distributed rather than centralized model: our results indicate that a higher number of moderately spaced refuse points, rather than a few large concentrations, supports both abundance and diversity, so design codes should specify minimum point density and maximum spacing rather than only a per-capita waste capacity. Second, vegetation design guidelines for severe cold region residential areas should require multi-strata planting (canopy, understory shrubs, ground cover) and explicit retention of unpruned vegetation patches as foraging refugia, with management standards that constrain the timing and intensity of summer pruning during breeding periods (Remacha, C. et al. 2016). Third, the renewal cycle itself becomes a design variable: because freeze–thaw damage drives recurring wall, balcony and pavement retrofits every one to two years, renewal works should be coordinated within each residential area into a single short construction window outside the autumn migration and spring breeding peaks, so that the cumulative chronic disturbance documented in our results is consolidated into a discrete, plannable event. Together, these measures reframe seasonal residents' activities and climate-driven renewal not as ecological nuisances to be managed afterwards, but as design parameters integrated into the spatial planning of residential areas in severe cold region cities.

5. Conclusion

This study analyses the relationships between human activity indicators and bird biodiversity at the local level. This analysis has identified several strong relationships (patterns) between the activities that shape the local Climate in each region and the number of birds present in that region, as well as patterns of bird diversity. However, there is no concrete evidence that one affects the other because the relationship between causal factors cannot yet be determined; and also, while many of these indicators may not be the reason a region has many types of birds, some may serve as proxy indicators of larger issues that are affecting larger scales of socioeconomic and/or environmental conditions. Therefore, it is likely that predictors for different types of animals (e.g., insect populations, small mammal populations) may respond in different ways to the factors associated with these activities and climate. One approach researchers

might pursue would be to combine longitudinal studies (that track an animal over time), with studies that examine birds in areas undergoing residential redevelopment, and multi-taxa studies, to better understand which exact types of factors are causing Bird Abundance and Diversity levels to vary among these types of activities.

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