

# Long term Trends in Introduced Eurasian Magpie (*Pica pica*) Abundance: Agricultural Land Expansion Effects on Jeju Island

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**Abstract:** Island agro-ecosystems are highly vulnerable to ecological disturbances caused by introduced vertebrates. The Eurasian magpie (*Pica pica*), intentionally introduced to Jeju Island in 1989, has since established and expanded across urban and agricultural landscapes. Long-term monitoring from 2006 to 2021 recorded an increase in the island's magpie population from 9,500 to 35,094 individuals, showing a steady upward trend with only a brief period of stabilization. Annual line transect and point count surveys were analyzed together with agricultural census data on cultivated land area at the municipal scale. In Jeju city, magpie population size showed a positive but statistically non-significant relationship with cultivated land area ( $R^2 = 0.18$ ,  $P = 0.105$ ), whereas in Seogwipo city, a significant positive association was observed ( $R^2 = 0.31$ ,  $P = 0.025$ ). Residual analysis revealed that deviations from model predictions differed between the two municipalities, with higher-than-expected values occurring primarily in horticultural farmland areas. These findings demonstrate regional variation in population response to cultivated land expansion and provide quantitative evidence of long-term population growth of magpies on Jeju Island

**Keywords:** Agricultural landscape, Alien species, Jeju Island, Magpie, Population trend

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## Introduction

Island agro-ecosystems are highly vulnerable to invasive vertebrates. Such species can severely impact ecosystem structure and agricultural productivity by preying on native fauna, competing for habitat, and damaging crops [1-3]. Because island food webs are often simplified and lack major predators, the deliberate introduction of even a single alien species can lead to rapid population growth and long-term human-wildlife conflict [4].

The Eurasian magpie (*Pica pica*) belongs to the family Corvidae, widely distributed throughout the Palearctic region, including the Middle East, Europe, Korea, and China [5,6]. In Korea, it inhabits most of the peninsula except for few small islets [7,8]. Magpies exhibit high ecological adaptability, occupying a wide range of habitats from urban parks and farmlands to forests [9], and flexibly adjust to environmental change by exploiting human food wastes or feeding on agricul-

tural crops.

Unlike the Korean Peninsula, Jeju Island historically lacked resident magpie populations, as confirmed by local bird checklists compiled before the 1980s [7,8]. In 1989, 48 magpies were intentionally introduced from the mainland to commemorate the 20th anniversary of Asiana Airlines, marking the first confirmed establishment of the species on the island [10]. Although wildlife translocations by private entities were not subject to the strict environmental regulations that exist today, the release occurred prior to the enforcement of Korea's Wildlife Protection and Management Act (1991), which later established formal restrictions on the introduction of non-native species. Initially, breeding was limited due to territorial overlap with competitors such as the large-billed crow (*Corvus macrorhynchos*) [11]. However, the species gradually adapted to the island's geographical and ecological conditions, expanding into urban parks, citrus orchards, and vegetable fields [8,12]. In this process, magpies have preyed on small mammals, birds, amphibians, and reptiles, and have caused agricultural damage to fruit and grain crops [11,12], leading farmers in some areas to bear ongoing pest control costs.

The spread of alien species reduces native biodiversity and disrupt ecosystems, with reports from other regions of magpies attacking native birds and mammals or destroying nests [13-16]. Long-term population monitoring of alien species is therefore essential for evaluating ecosystem health and detecting changes driven by habitat modification, climate, disease, or other factors [17-21]. For alien species in particular, such monitoring enables early detection of range expansion or invasion risk, facilitating rapid responses in both agricultural and ecological management [22-24].

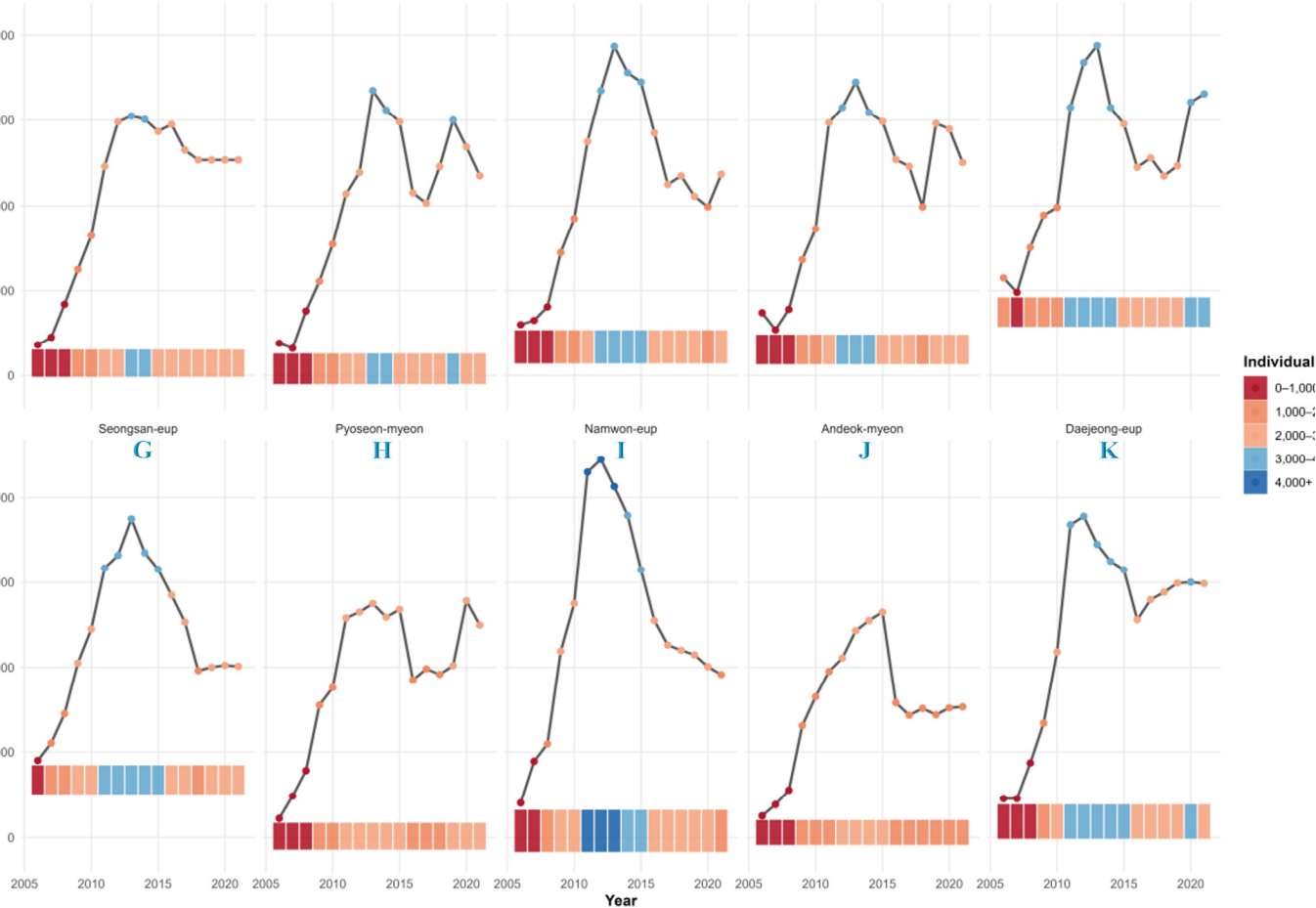
Over the past two decades, Jeju Island has undergone marked agricultural intensification, with forest and scrub converted to citrus-dominated orchards and open vegetable plots, according to the *Statistical Yearbook of Jeju Province* (Jeju Special Self-Governing Province, 2023). These habitat changes may increase food availability, nesting substrates, or both, thereby supporting higher magpie densities [8,12]. From an agricultural perspective, the magpie is now recognized as a pest species due to its tendency to peck fruit, feed on germinating seeds, and damage plastic mulches and irrigation lines in citrus and vegetable farms. Consequently, understanding how land-use changes influence magpie populations is essential for devising management strategies that minimize crop losses while maintaining ecological balance.

On Jeju Island, wildlife-induced crop damage has been reported in several hundred farms annually, and birds such as pheasants, magpies and crows account for a substantial proportion of compensation claims, highlighting the growing scale of bird-related agricultural conflicts on the island [25,26].

In this study, monitoring data on magpie abundance with annual statistics on cultivated land area to address two research questions: (i) How has the abundance of introduced magpies changed over time on Jeju Island? (ii) Does farmland expansion explain the observed population trends, and are responses consistent between the urbanized Jeju city and the peri-urban Seogwipo city? Our findings provide a scientific basis for designing policies that reconcile alien species management with agricultural productivity and biodiversity conservation.

## Results and Discussion

From 16 years of monitoring, the Jeju island magpie population increased from 9,500 individuals in 2006 to 35,094 individuals in 2021 (Table S1), showing a steady upward trend except for a brief plateau in the middle years [27,28]. This pattern is consistent with earlier reports that, following the 1989 introduction, magpies rapidly established across lowland areas and adapted to a variety of habitats including orchards, croplands, and urban parks [11,12,29,30]. Sustained long-term monitoring is critical to detect such gradual population changes, as demonstrated in other avian studies in island systems [17,19,31]. Beyond this island-wide increase, annual trajectories varied among administrative regions, with several divisions showing sharp increases around 2010–2014 followed by either stabilization or partial decline, whereas others maintained relatively high levels thereafter (Fig. 1).



**Fig. 1. Annual changes in magpie (*Pica pica*) abundance from 2006 to 2021 across administrative regions of Jeju Island.** Points represent annual counts, and lines indicate temporal trends. Panels A–E correspond to administrative divisions within Jeju City, and panels G–K correspond to divisions within Seogwipo City.

These divergent regional patterns may partly reflect differences in local management intensity, including pest-control trapping and culling efforts, which have been periodically implemented to mitigate crop damage and perceived nuisance from magpies. Such variation highlights the potential influence of human intervention on population dynamics, suggesting that management pressure should be considered when interpreting long-term trends.

Regression analyses of annual magpie population size against cultivated land area at the municipal scale showed a significant positive relationship in Seogwipo city ( $R^2=0.31$ ,  $P=0.025$ ), whereas no significant relationship was found in Jeju city ( $R^2=0.18$ ,  $P=0.105$ ) (Table 1). Although these coefficients of determination are relatively low, they reflect large annual fluctuations in magpie abundance and the disproportionate leverage of two years with <10,000 ha of arable land. These years exerted strong influence on the regression line, thereby lowering the overall explanatory power. Nevertheless, the figures are informative, illustrating the

**Table 1. Results of linear regression and Pearson correlation between magpie abundance and arable land area (2006–2021).**

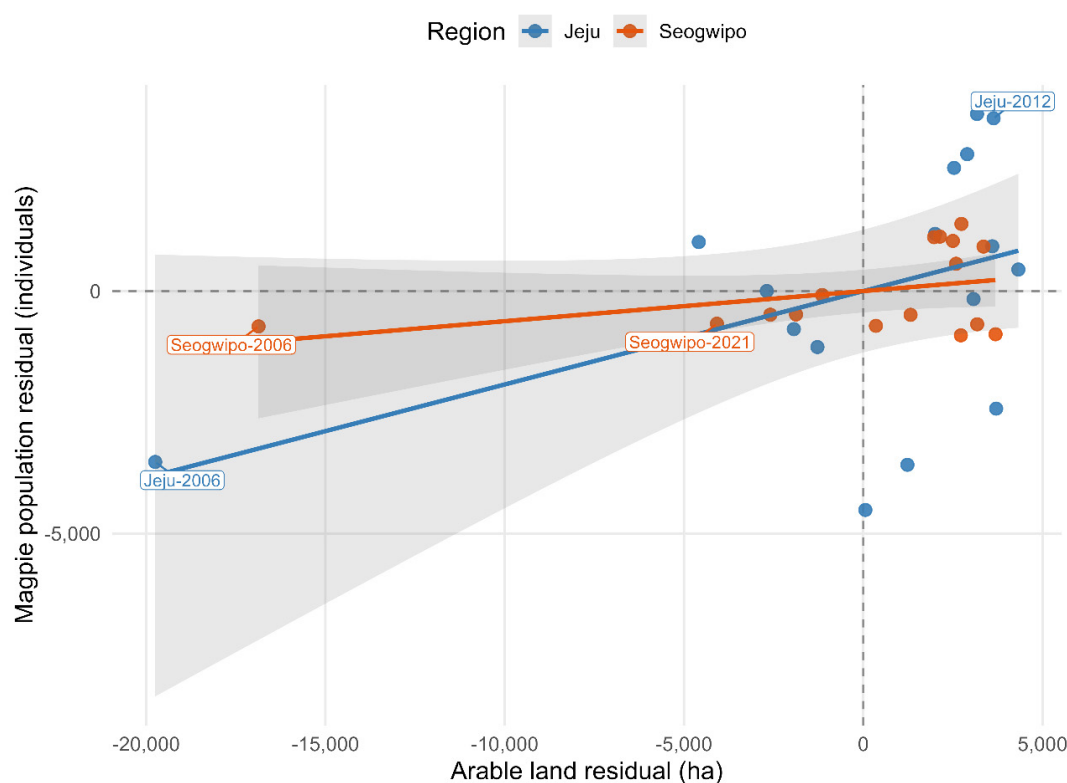
| Region        | N (years) | $R^2$ | P-value | Pearson r |
|---------------|-----------|-------|---------|-----------|
| Jeju city     | 16        | 0.18  | 0.105   | 0.42      |
| Seogwipo city |           | 0.31  | 0.025*  | 0.56*     |

1) Linear regression models were fitted as  $y = a + bx$ , where  $y$  is annual magpie abundance and  $x$  is total arable-land area (ha).  
2)  $R^2$  indicates the proportion of variance explained, P-values test the significance of the slope ( $b$ ), and Pearson  $r$  measures the strength of correlation (–1 to 1).  
3) Significance levels: \* < 0.05, \*\* < 0.01, \*\*\* < 0.001.

relative difference between the two regions, with Seogwipo showing a stronger association. The positive pattern in Seogwipo-si accords with studies indicating that agricultural mosaics, particularly orchard–cropland complexes, provide stable high-energy food sources and nesting substrates for birds [32–34]. Magpies, along with other species such as the azure-winged magpie (*Cyanopica cyanus*) and brown-eared bulbul (*Hypsipetes amaurotis*), are known to feed on various fruit crops, including pears and citrus [32,35]. Case studies from Korean pear orchards quantified percent-level fruit losses to birds, including magpies, and evaluated the effects of different protection measures [32,36]. These findings support the hypothesis that Seogwipo city orchard-dominated farmland increases seasonal food availability and nesting opportunities, thereby sustaining higher magpie densities [32–34,37].

By contrast, residual analyses revealed distinct spatial patterns between the two municipalities (Fig. 2). In Seogwipo city, positive residuals tended to appear in areas dominated by orchard and vegetable farmland, suggesting that magpie numbers were higher than predicted based on farmland area alone. This pattern may reflect the influence of intensive horticultural activity, which provides consistent food resources and nesting substrates. Such localized aggregations likely correspond to intensive horticultural districts that provide consistent food resources and nesting substrates. In Jeju city, however, residuals were more diffusely distributed, reflecting the influence of urban structure and the fragmented nature of surrounding farmland. These results suggest that additional urban variables such as impervious surface cover, road density, and land-use heterogeneity may modulate magpie distribution [8,38,39]. Consequently, more comprehensive models incorporating urbanization indices, habitat fragmentation metrics, and management intensity will be required to better explain the observed residual variation [38,40,41].

Local ecological studies add further context. Park et al. [12] documented breeding density and seasonal diet of magpies on Jeju, reporting broad lowland nest distributions and a diverse diet including both animal prey and plant matter. Oh et al. [11]



**Fig. 2.** Residual plots showing the relationship between magpie (*Pica pica*) abundance and cultivated land area in Jeju (blue) and Seogwipo (orange).

Each point represents an annual data value. Solid lines indicate fitted trend lines for each city, and shaded areas denote 95% confidence intervals. The horizontal dashed line ( $y = 0$ ) represents the reference line where observed and predicted values coincide. Text labels (e.g., Jeju-2012, Seogwipo-2021) mark representative years showing the largest residuals or endpoints in each city's time series.

reported early breeding biology and range expansion patterns shortly after introduction. Combined with orchard-feeding records [32,33], these studies collectively support the interpretation that Seogwipo's orchard–cropland matrix provides stable foraging and nesting resources. In contrast, Jeju city higher proportion of urbanized land likely limits nesting site availability and access to food resources [8,38,40].

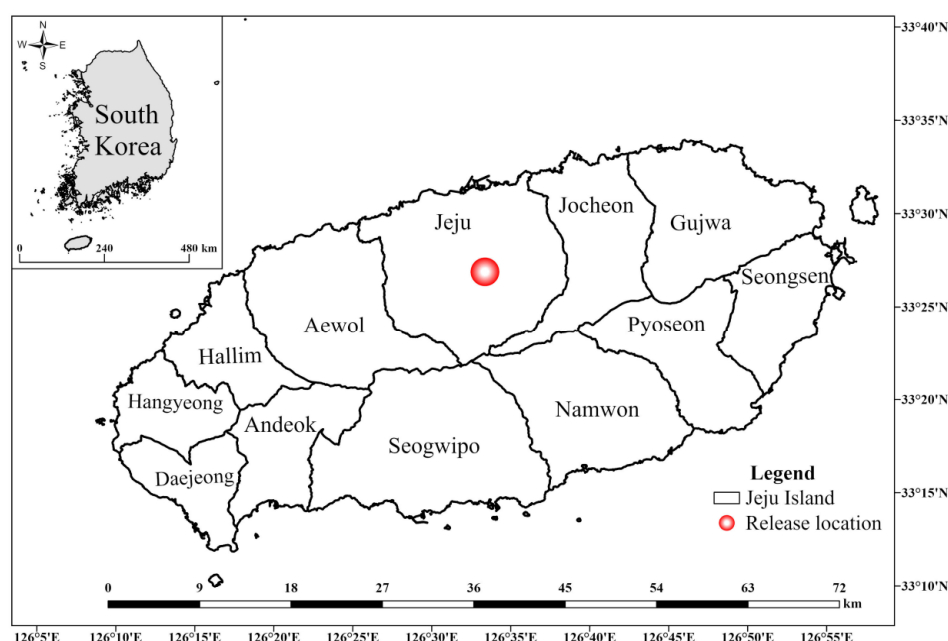
From an agricultural management perspective, the observed positive relationship between cultivated land and magpie population size particularly in Seogwipo city underscores the species' dependence on agricultural habitats. Korean orchard studies have shown that single measures such as fruit bagging rarely eliminate bird damage [33,36]. Integrated approaches, including partial block netting of high-value areas, rotating deterrents to prevent habituation, and, where permitted, targeted trapping (e.g., ladder-entrance traps), have proven effective in reducing crop losses [34,36,42]. Because labor and material costs increase with coverage area and duration, protection efforts should prioritize block margins adjacent to hedgerows, irrigation canals, and village edges, where bird activity is often concentrated [32,34,36].

In conclusion, our analysis demonstrates that magpie populations on Jeju Island have grown substantially over the past 16 years, with a significant association between farmland area and population size in Seogwipo city. These results suggest that horticultural landscapes play a key role in sustaining magpie populations, highlighting the need for site-specific management strategies that balance agricultural productivity with biodiversity conservation.

## Materials and Methods

### Study area

Jeju Island ( $33^{\circ}10'–33^{\circ}34'N$ ,  $126^{\circ}10'–127^{\circ}E$ ) is located in the southwest of the Korean Peninsula (Fig. 3). It consists of 55 uninhabited islands, including eight inhabited ones, and has a total area of 1,845.88 km<sup>2</sup> [43]. Jeju Island was designated as a UNESCO Biosphere Reserve in 2002 and listed as a World Natural Heritage Site in 2007. The Gotjawal Forest, where tropical northern and southern limit plants coexist, is also designated as a Global Geopark [44]. In addition, volcanic cones (Oreum)



**Fig. 3. Geographic map of Jeju island in South Korea.**

**The red circle denotes the site of first release of 48 magpie individuals in 1989.**

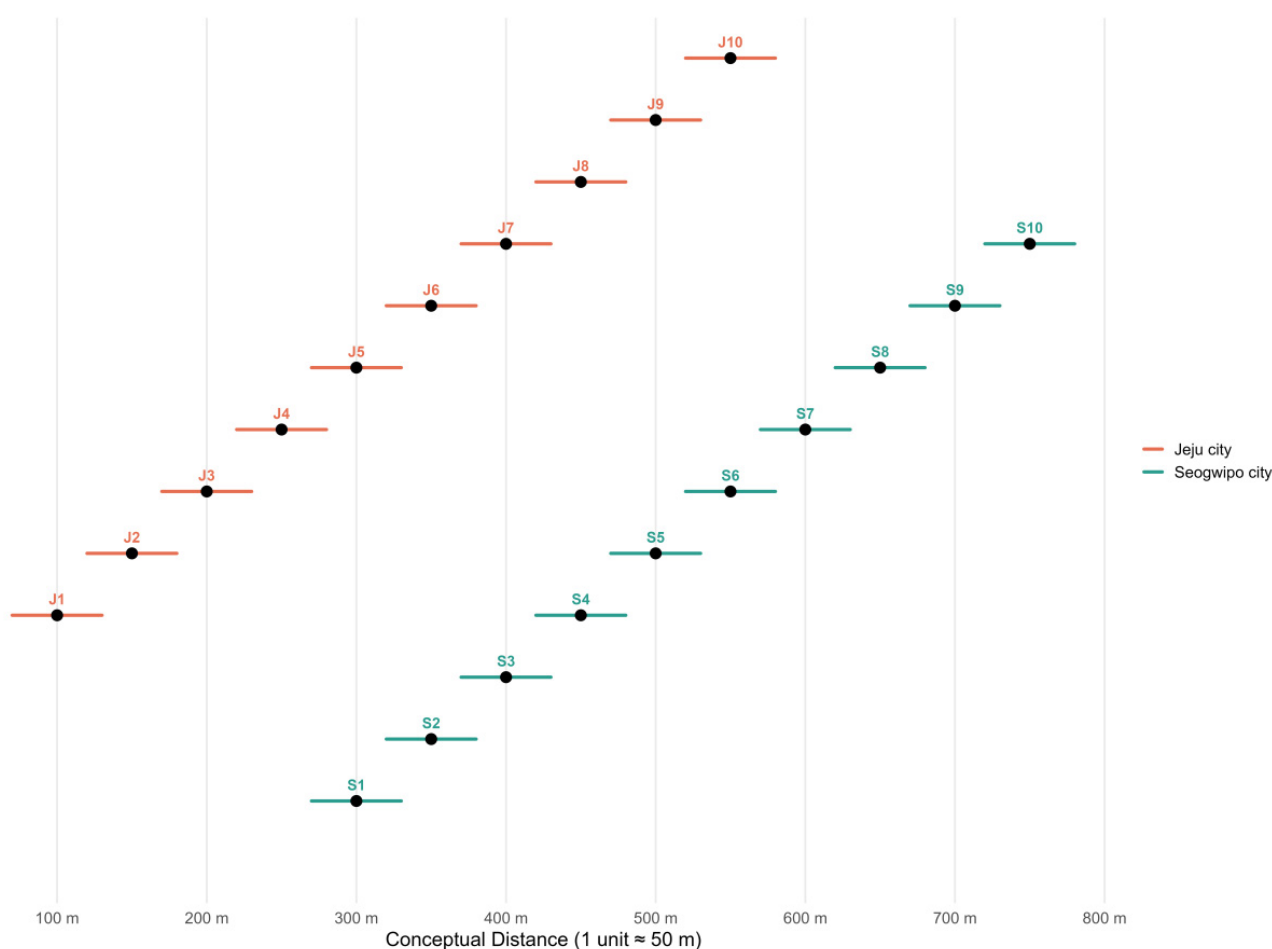
and wetlands serve as key ecological corridors for birds between coastal lowlands and Hallasan National Park in central Jeju [45]. Threatened species such as *Pitta nympha* (Vulnerable), *Ciconia boyciana* (Endangered), and *Haematopus ostralegus* (Near Threatened) migrate to Jeju for breeding or overwintering [46]. A total of 586 bird species have been recorded in Korea, about 70% of which occur on Jeju, making it a major component of the Korean Peninsula's ecological network [7,47].

## Monitoring of individuals

From 2006 to 2021, we conducted line transect and point count surveys across Jeju from June to August, after the magpie breeding season [48,49]. Twenty transects (1–2 km each) were established along roads or trails and surveyed twice by the same researcher (Fig. 4). Researcher walked slowly, stopping every 100 m to record magpies detected by observation and sound within a 25 m strip perpendicular to the transect [50]. Surveys in different areas were conducted simultaneously to avoid temporal bias [51].

## Data analysis

All statistical analyses were performed in R v4.2.2 (R Foundation for Statistical Computing, Vienna, Austria) [52]. Raw count data were imported with the readxl package, processed using dplyr and tidyr, and transformed into a year-by-city matrix of



**Fig. 4.** Schematic layout of survey transects in Jeju city (coral) and Seogwipo city (teal) with a 100-m detection radius.

Black dots mark the centers of each survey point; short colored horizontal bars show the (schematic) 100-m detection radius around each point. Labels J1–J10 and S1–S10 identify transects in Jeju city and Seogwipo city, respectively. The x-axis is shown in meters for conceptual spacing.

magpie abundance and cultivated area [53,54]. Annual cultivated area (ha) for each city was obtained from the Statistics Korea Agriculture, Forestry and Fisheries Census (accessed March 2025) and cross-checked with the Jeju Province Yearbook. For Jeju city and Seogwipo city, ordinary least squares regressions were fitted using the `lm` function, modeling annual abundance as a function of cultivated area [55]. Model assumptions were checked using residual-versus-fitted and scale-location plots, along with the Breusch–Pagan test from the `car` package [38,56,57].

**Data Availability:** All data are available in the main text or in the Supplementary Information.

**Author Contributions:** Y.-H.J. and H.-S.O. conceived and designed the research; Y.-H.J. and S.E.K. collected the data; Y.-H.J. and B.K. performed the analysis; Y.-H.J. wrote the first manuscript; H.-S.O. revised the manuscript; all authors approved the final version.

**Notes:** The authors declare no conflict of interest

#### Additional Information:

**Supplementary information** The online version contains supplementary material available at <https://doi.org/10.5338/KJEA.2025.44.37>

**Correspondence and requests for materials** should be addressed to Hong-Shik Oh.

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