Preliminary Spatial Assessment of the Relationship Between Artificial Releases and the Current Distribution of the Grey Partridge (*Perdix perdix* L.) in Hungary

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Abstract
The Grey Partridge (*Perdix perdix* L.) has suffered a long-term decline across Europe, with population reinforcement through captive-bred releases becoming a widespread management tool. In Hungary, the ecological role and spatial consequences of such practices remain insufficiently documented. This study presents a preliminary spatial assessment of the relationship between artificial release sites and the present distribution of *P. perdix*. Locations of past and recent releases were georeferenced and compared with verified occurrence records from the Magyar Madártani és Természetvédelmi Egyesület (MME – Hungarian Ornithological and Nature Conservation Society). Spatial overlay and basic density analyses in QGIS revealed a notable geographic overlap between release areas and recent observations. A moderate positive correlation between the two datasets suggests that artificial releases may considerably shape the current pattern of free-ranging populations. These findings, while preliminary, highlight the need for more detailed temporal and ecological analyses to clarify the contribution of reintroduced individuals to the persistence of wild populations. The results provide a foundation for future quantitative studies and management evaluation in Hungarian agricultural landscapes.

Keywords: *Perdix perdix*, reintroduction, GIS, wildlife management, Hungary, spatial analysis

1. Introduction

The Grey Partridge (*Perdix perdix* Linnaeus, 1758) once represented one of the most characteristic and abundant farmland bird species across Europe, with several million breeding pairs during the early twentieth century. However, during the second half of the century, populations collapsed almost everywhere due to the intensification of agriculture, the widespread use of pesticides, and the disappearance of linear habitats that once provided suitable nesting and chick-rearing habitats [1,2]. Across Western and Central Europe, including France, Poland, and the United Kingdom, long-term monitoring has shown steep declines of more than 80% since the 1970s [3–5].

The main causes of this decline are well understood: loss of nesting cover due to field consolidation and removal of hedgerows; reduction of arthropod prey through pesticide use; and increasing uniformity of crop structure, which leaves partridges and other ground-nesting birds exposed to predators [2, 6].

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As a result, the Grey Partridge has become a key indicator species of farmland biodiversity, reflecting the overall deterioration of the agricultural environment [1,3].

In Hungary, the Grey Partridge was once widespread throughout the Great Plain and Transdanubia. Earlier records suggested populations exceeding half a million pairs during the mid-twentieth century [7]. However, as populations began to collapse from the 1970s onward, in parallel with rapid agricultural mechanisation and a loss of grasslands and field margins. The species' ecology, reproductive parameters, and release success were studied in detail under the "Harka Project," which demonstrated that even intensive restocking could not halt the long-term decline when suitable habitats were lacking [10].

Despite large-scale releases by hunting associations, national monitoring indicates that populations have not recovered. The Hungarian Ornithological and Nature Conservation Society (MME) operates two complementary long-term monitoring programmes: the *Mapping of Breeding Birds (MAP)*, which records breeding distribution using 10×10 km UTM grid squares, and the *Monitoring of Common Breeding Birds (MMM)*, which provides relative abundance indices based on standardised surveys [8,9]. These datasets are directly comparable with the Országos Vadgazdálkodási Adattár (OVA- National Game Management Database), which reports the number and spatial distribution of annual releases and harvests of Grey Partridge since the late 1990s [10].

The integration of OVA and MME data offers a unique opportunity to evaluate how the spatial footprint of releases (1997–2010) corresponds to subsequent breeding occurrences recorded between 2010 and 2025. This temporal arrangement allows assessment of possible post-release persistence, dispersal, and recolonisation patterns. By combining digitised historical release maps with UTM-based breeding records, it becomes possible to quantify spatial overlap and similarity using geospatial metrics such as the Jaccard index [11], while the long-term MMM trend indices (1999–2024) provide context for national population trajectories.

Accordingly, the present pilot study aims to:

-Digitise and georeference historical partridge release areas from OVA records for 1997, 2000, 2003, 2006, 2008, and 2010.

-Overlay these layers with MME UTM grid data (2010–2025) to detect spatial coincidence.

-Quantify overlap using both absolute and proportional metrics, including the Jaccard similarity index.

-Compare spatial findings with temporal population trends from MME (1999–2024) to assess whether restocking efforts have mitigated the national decline.

This integrative geospatial and statistical approach forms a reproducible baseline for future research on post-release survival, landscape connectivity, and adaptive management of small-game species in intensively farmed regions.

2. Materials and methods

Data sources

Two independent datasets were used for spatial and temporal analysis: (1) historical *Grey Partridge (Perdix perdix)* release areas from the National Game Management Database (OVA), and (2) *10×10 km UTM* breeding-distribution and trend data from the *Mapping of Breeding Birds (MAP)* and *Monitoring of Common Breeding Birds (MMM)* programmes of the Hungarian Ornithological and Nature Conservation Society (MME).

The OVA maps contained digitised polygons of confirmed release sites for six discrete years—1997, 2000, 2003, 2006, 2008 and 2010—representing actual release events rather than cumulative intervals [14].

Each paper map was scanned and georeferenced in QGIS 3.34 (Prizren) using the coordinate reference system *EPSG 32634* (WGS 84 / UTM zone 34N). Minor geometric errors were corrected, and all polygons were converted to single-part features to ensure topological consistency.

The MME dataset, covering 2010–2025, followed the *European Bird Atlas 2 (EBBA2)* 10×10 km grid framework.

Attribute fields (*MAPmin*, *MMMmin*, *tort50*) were interpreted according to the official documentation [15].

For this study, only non-zero UTM squares (cells with confirmed breeding or observation records within Hungary) were retained.

Spatial processing and overlay

After standardising coordinate systems, polygons representing releases in different years were

merged using the *Dissolve* tool to remove internal boundaries and then combined through *Union (multi-layer)* to create a single composite layer of all historical release areas.
To eliminate overlap redundancies, the *Unary Union* algorithm was applied, resulting in a unified geometry of total release extent.
This composite layer was intersected (*Intersection* tool) with the filtered MME UTM layer to identify areas where release polygons overlapped with breeding-survey cells.
Area was calculated in hectares using the *Field Calculator* expression:
$area / 10000
The results provided both total release area and the portion coinciding with MME UTM cells.

Calculation of spatial similarity
Spatial coincidence was quantified by the **Jaccard Index (J)** [16, 17]:

$$J(A,B) = |A \cap B| / |A \cup B|$$

Where:
A = total release area (OVA),
B = total surveyed breeding area (MME),
and A ∩ B = their intersection.
Additionally, an **Overlap Ratio** (percentage form) was derived as Overlap Ratio = (|A ∩ B| / |A|) × 100
For each study period (1997–2000, 2003–2006, and 2008–2010), the absolute (ha) and proportional (%) spatial overlap between release areas and UTM breeding squares was calculated using the Jaccard index.
An overall index was then derived for the full 1997–2010 period to assess the cumulative spatial relationship between former release sites and later breeding occurrences.
The resulting Jaccard values reflect the degree of spatial coincidence, where higher values indicate stronger spatial overlap between historical release areas and subsequent breeding distributions.

Population-trend comparison
MME MMM trend data (1999–2024) provided annual population indices relative to 1999 = 1.0, with mean annual change, standard error (SE) and 95 % confidence intervals [13].
Parallelly, OVA supplied yearly release and harvest statistics for the same interval [14].
The datasets were joined in Microsoft Excel 2021, generating dual-axis time-series charts in which the primary axis depicted release and harvest intensity (individuals) and the secondary axis showed relative population index values.
This combination enabled examination of whether increased restocking corresponded with detectable population improvements.

Software and workflow
All spatial operations were executed in QGIS 3.34, using default geoprocessing parameters. Tabular calculations and graphics were prepared in Microsoft Excel 2021 following SPASB layout requirements.

3. Results and discussion

Spatial overlap between release and breeding sites (1997–2010)
Spatial analyses revealed a limited coincidence between the historical grey partridge (*Perdix perdix*) release areas (OVA data, 1997–2010) and the national UTM-based breeding survey data (MME, 2010–2024).
Spatial intersections occurred in scattered regions across the country, primarily in Central and Southeastern Hungary, but large parts of the historical release areas remained outside the confirmed breeding distribution.
A gradual decrease in overlap was observed across consecutive release periods (1997–2000, 2003–2006, and 2008–2010), indicating that fewer released individuals or populations were later detected as breeding in the same UTM squares (Figure 1).

For each period, both the absolute (ha) and proportional (%) overlap were computed, and an overall index was derived for the 1997–2010 period.
The total release area was approximately 998,000 ha, of which about 410,000 ha intersected UTM breeding squares.
The overall Jaccard index (J = 0.1679; 16.79%) indicates a low to moderate spatial coincidence between historical release areas and later breeding distributions (Table 1.).

A temporal comparison among the three periods revealed a slight decline in overlap percentages, suggesting a reduction in post-release establishment success over time.

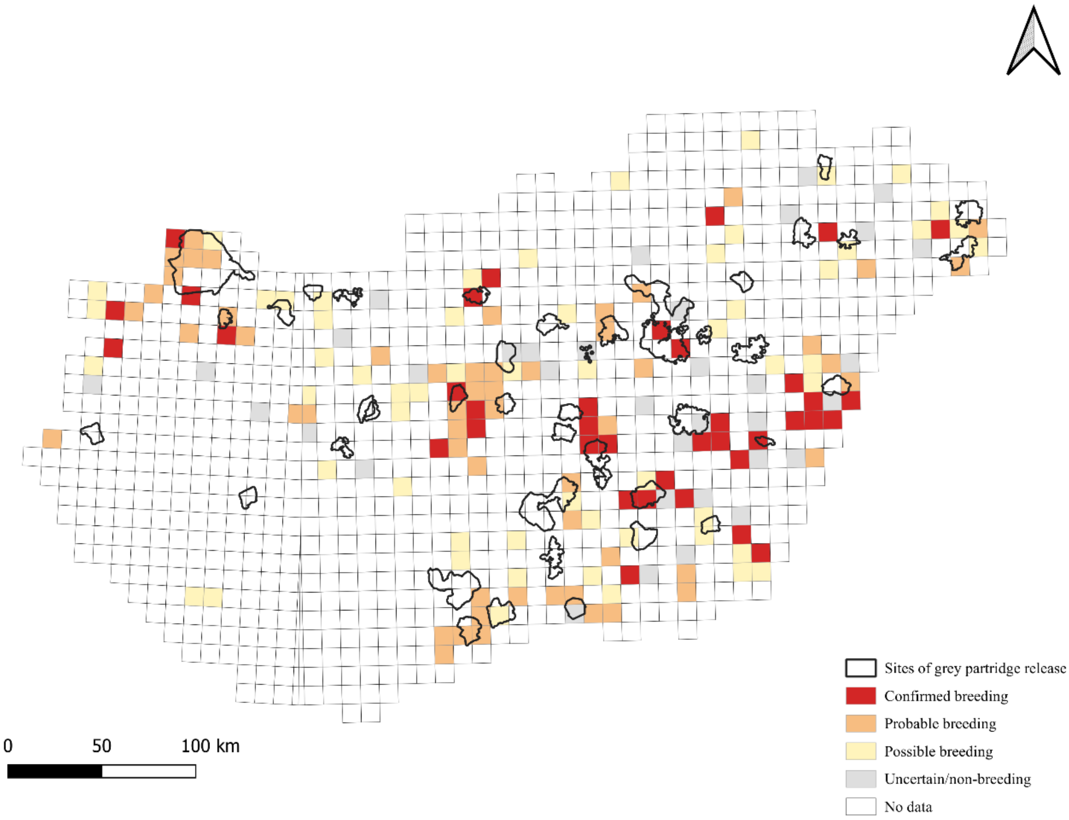

Figure 1. Sites of grey partridge (*Perdix perdix*) releases between 1997–2010 and UTM-based breeding squares (MME 2010–2024). Colours indicate breeding probability categories according to the MME monitoring system (Source: OVA and MME)

Table 1. Quantitative spatial overlap between release areas (OVA) and breeding areas (MME UTM squares) by study period (1997–2010). (Source: OVA and MME)

Period	Released area (ha)	Overlap area (ha)	UTM area (ha)	Jaccard index	Jaccard index (%)
1997–2000	370 890.65	144 274.68	1 850 899.70	0.0694	6.94 %
2003–2006	389 075.95	161 161.16	1 850 899.70	0.0775	7.75 %
2008–2010	238 110.76	104 070.01	1 850 899.70	0.0524	5.24 %
1997–2010 (total)	**998 077.36**	**409 505.85**	**1 850 899.70**	**0.1679**	**16.79 %**

Population trend analysis (MMM data 1999–2024)

Population trend data from the Hungarian Common Bird Monitoring Program (MME MMM) showed a **slow but steady decline** in the national grey partridge population since 1999, despite repeated releases during the 1990s and 2000s (Figure 2).

The population index fluctuated around 0.6–0.8 relative to the 1999 baseline, showing only short-term local recoveries but no sustained increase.

This declining trend, combined with the limited overlap between release and breeding areas, suggests that restocking efforts failed to compensate for the ongoing loss of suitable habitat and population fragmentation.

The recent estimates indicate that the species remains at a critically low density across most regions of Hungary, consistent with broader European patterns of farmland bird decline [1,2,3,5,6].

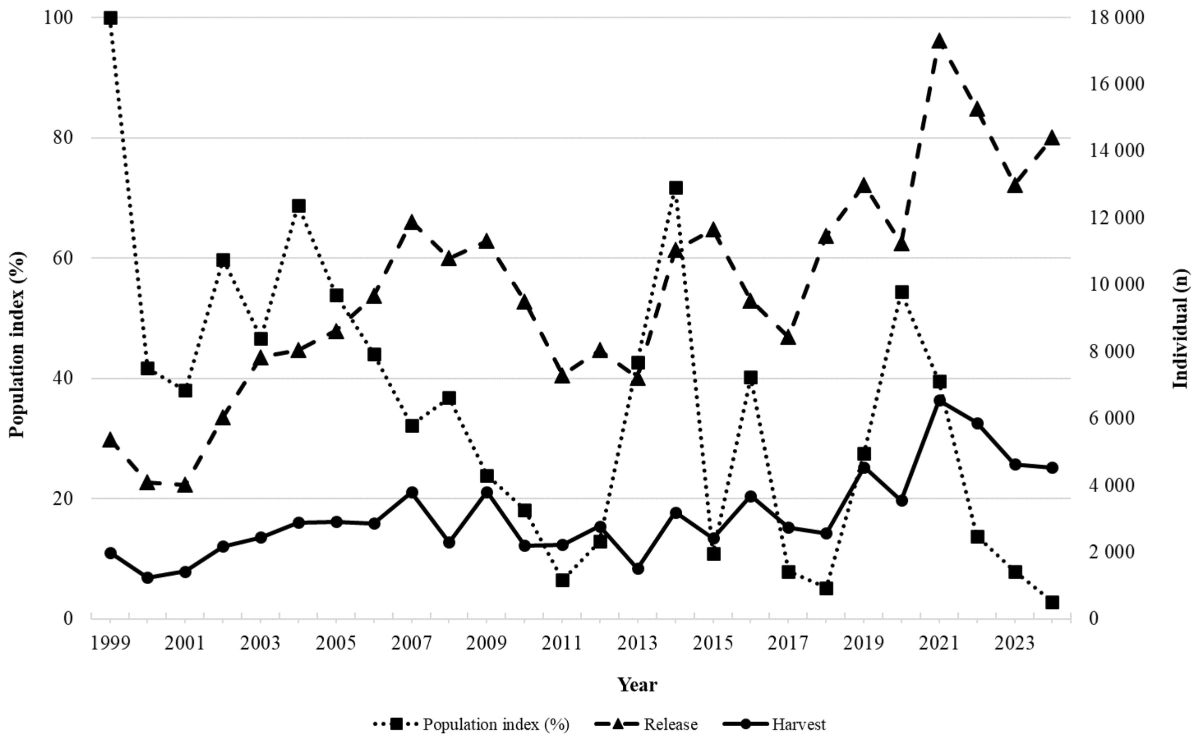

Figure 2. Long-term population trend of the grey partridge (*Perdix perdix*) in Hungary between 1999 and 2024, based on MME monitoring data. The national population index shows a slight but continuous decline despite historical release efforts. (Source: MME and OVA)

4. Conclusions

The spatial comparison between historical grey partridge (*Perdix perdix*) release areas and the national UTM-based breeding survey data revealed a low to moderate level of overlap. Despite extensive restocking activities between 1997 and 2010, the overall Jaccard index (J = 0.1679; 16.79 %) indicates that only a limited portion of the formerly released areas later coincided with confirmed breeding squares. Temporal comparison across the three studied release periods (1997–2000, 2003–2006, and 2008–2010) showed a gradual decrease in spatial overlap, suggesting that the establishment success of released individuals diminished over time.

Moreover, national population trend data (1999–2024) from the MME long-term monitoring program indicate a slow but steady population decline, even in the presence of restocking efforts [9]. This implies that the releases have not compensated for the overall negative population trajectory. The observed pattern may reflect the combined effects of habitat loss, agricultural intensification, and potentially low post-release survival or site fidelity of ground-nesting birds. [1, 2, 6, 10].

Overall, these findings highlight the limited long-term effectiveness of grey partridge restocking programs in Hungary and emphasise the necessity of integrating habitat management, predator control, and adaptive monitoring into future conservation and game management strategies. [7, 9, 12].

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