



**BREEDING BIOLOGY AND CONSERVATION
MANAGEMENT OF A GROUND-NESTING
SHOREBIRD, THE COLLARED PRATINCOLE
(*GLAREOLA PRATINCOLA*)**

Thesis for the Degree of Doctor of Philosophy (PhD)

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Debrecen, 2025

Hereby I declare that I prepared this thesis within the Doctoral Council for Natural Sciences and Engineering, Doctoral School of Juhász-Nagy Pál, University of Debrecen in order to obtain a PhD Degree in Natural Sciences at Debrecen University.

The results published in the thesis are not reported in any other PhD theses.

Debrecen, 2025

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Hereby I confirm that Ádám Kiss candidate conducted his/her studies with my supervision within the Evolution and Biodiversity Doctoral Program of the Doctoral School of Juhász-Nagy Pál between 2019 and 2023. The independent studies and research work of the candidate significantly contributed to the results published in the thesis.

I also declare that the results published in the thesis are not reported in any other theses.

I support the acceptance of the thesis.

Debrecen, 2025.

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Prof. Dr. Tamás Székely

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OF A GROUND-NESTING SHOREBIRD, THE COLLARED
PRATINCOLE (*GLAREOLA PRATINCOLA*)**

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*“A székicsérek hol itt, hol ott próbálkoznak, s nem “képesek”
megérteni, hogy a terület már nem az övük...”*

Endes Mihály [1989, Nagykunsági barangolások]

PART I

My PhD dissertation focuses on the breeding ecology and behaviour of a ground-nesting shorebird, the Collared Pratincole *Glareola pratincola*. Formerly, this species was a common breeder in the Great Hungarian Plain; however, their numbers dwindled over the past six decades. The objective of my dissertation is to investigate the breeding ecology, behaviour and reproductive success of this species, and using these approaches, develop new management ideas to improve management strategies for this characteristic species of alkaline grasslands called “puszta”.

In Part I, I present the background of my Ph.D. dissertation, followed by the main objectives, results, discussions and conclusions. Finally, I summarise the main insights generated by my research and provide recommendations for conservation management.

1. Introduction

1.1. Conservation of grassland birds

Grasslands cover 40 % of the surface of the Earth, which are among the most extensive ecosystems on all continents, except in Antarctica (Parente et al., 2024). Their key role in stabilizing climatic and environmental conditions are unquestionable (Bengtsson et al., 2019). Grasslands also harbour a large number of species and their populations that are adapted to a specialist life-style (Petermann & Buzhdygan, 2021). Grassland organisms are also among the most vulnerable ones, e.g. Asian grassland birds are the second most threatened avian group after forest species (Birdlife International, 2003). A sad example is the Slender-billed Curlew *Numenius tenuirostris*, which experienced a catastrophic population loss and extinction in our modern times that warns conservationists that further species extinctions are expected (Buchanan et al., 2024).

In the Palearctic the transformation and disappearance of permanent grassland habitats has drastically altered the ecological landscape (Török & Dengler, 2018). Several factors threaten permanent grasslands, but the most significant ones are their conversion into arable land, abandonment of land-use management, more intensive grassland treatment, drainage of water, excessive heat and drought (Schils et al., 2022; Douglas et al., 2023). Parallel with these changes, the loss of important wetland habitats has reached alarming proportions in recent decades (Gutzwiller & Flather, 2011; Fluet-Chouinard et al., 2023). In comparison to these two vulnerable habitat types, the expansion of intensively managed agricultural areas has grown dramatically (Stoate et al., 2009).

Many bird species within the group known as 'farmland birds' have adapted to human-induced changes at various levels (Traba & Morales, 2019). However, the increasing intensity and environmental impact of agriculture pose new and ongoing challenges for these species, leading to population declines and, in some cases, local extinctions (Donald et al., 2001). Unfortunately, some of the characteristic grassland bird species of Eurasia decreased dramatically, for example Little Bustard

Tetrax tetrax, Northern Lapwing *Vanellus vanellus* (Morales & Bretagonelle, 2022; van den Berg, 2024).

Shorebirds are globally distributed birds and they are considered as model organisms for migratory behaviour, feeding ecology and breeding systems (Goss-Custard, 1979; Piersma, 2007; Székely, 2019). Due to their diverse breeding habitats, they are also excellent model systems to monitor environmental changes especially in those habitats where they are typically found, for example wetlands, grasslands and meadows (Székely et al., 2024). Since many shorebirds are forced – either out of necessity or due to changes in their habitat selection strategy – to nest in farmlands, thereby exposing themselves to the effects of agriculture, studying them in these altered habitats allows us to translate research findings into conservation measures (Garvey et al., 2013).

The species I focus on in this dissertation – the Collared Pratincole *Glareola pratincola* – is an excellent conservation model species, as its endangered status poses a challenge in several European countries (Lokhman et al., 2020). In my dissertation, I investigate nest-site selection, nest success and survival as well as breeding behaviour of Collared Pratincole breeding primarily in agricultural environments. Using recently developed field protocols to investigate breeding ecology and behaviour, I derive conservation management recommendations for this species. My ultimate objective is to highlight the significance of species-focused research for conservation and management of grasslands, wetlands and agri-environments.

1.2. Dissertation objectives

The overarching aim of the current dissertation is to investigate the effects of environmental factors influencing breeding strategies of Collared Pratincoles, focusing on their nest success, nest-site characteristics, and social interactions with other co-nesting species. Based on the results, I provide recommendations to contribute to the conservation efforts.

The dissertation includes four studies with the following objectives:

Objective 1. To investigate nesting ecology and nest success in various agricultural habitat types, and to evaluate the effects of conservation activities on nest survival.

Objective 2. To investigate environmental predictors of nest-site selection of pratincoles, and estimate the population trend using long-term data.

Objective 3. To overview the occurrences of pratincoles in their former natural habitats from the past 25 years, and characterize the details observations from 2022 and 2024 when the species reappeared as a grassland breeder.

Objective 4. To investigate colony formation in pratincoles, particularly in the context of mixed-species colonies that include Northern Lapwing, Black-tailed Godwit *Limosa limosa* and Common Redshank *Tringa totanus*.

2. Methodology

2.1. Study species

The Collared Pratincole is a medium-sized insectivorous shorebird which feeds in the air as well as on the ground (Cramp & Simmons, 1983). The subspecies *Glareola pratincola pratincola* breeds throughout Europe up to the western part of Russia, the Middle East, and the southern regions of Africa (Cramp & Simmons, 1983). As long distance migrants, pratincoles winter in Africa; the arrival of individuals in the breeding grounds is usually recorded in late April and depart for their autumn migration in August. Both the global and European status of the species is Least Concern by IUCN Red List (2025), although a number of populations are declining (BirdLife International, 2016). The populations are dispersed and isolated from each other within the European subcontinent, found in the Mediterranean region and the northern and eastern coastline parts of the Black Sea (Lokhman et al., 2020). Major populations are located in Spain, Greece and along the northwestern, and western coastlines of the Black Sea. Larger populations in Europe are generally stable, or even locally increasing, while smaller, isolated

populations are frequently at the risk of decline (Lokhman et al., 2020). Western populations are well-monitored and documented (for example in Spain and France) by researchers and conservationists, whereas the current status of eastern populations (e.g. Romanian or Ukrainian) is less known. Its population trends fluctuate over the years, making it very difficult to estimate the exact population size for entire Europe (Lokhman et al, 2020), which is estimated at about 7,800-14,900 pairs. The global population is estimated to be around 160,000-600,000 individuals (Lokhman et al, 2020). The Collared Pratincole is listed in Annex I of the European Union Birds Directive (2009/147/EC), which includes species requiring special conservation measures due to their sensitivity (EUR-LEX, 2025).

The Collared Pratincole is a ground-nesting shorebird; nest sites are frequently located in pastures covered by short vegetation and open areas mixed with shallow wetlands, which are the main foraging sites of the species (Cramp & Simmons, 1983). Shifts in habitat selection and the increased occupation of farmlands were recorded in several countries across Europe, suggesting that it may be a common behavioural response to a changing landscape, which may contribute to the recent declining trends observed in Europe (Lokhman et al., 2020).

Villanueva (1993) documented the species in southern Spain mainly on cattle-grazed pastures with similar degrees of grazing pressure. In the Great Hungarian Plain, Collared Pratincoles preferred alkali vegetation, dominated by *Artemisio - Festucetum pseudovinae* and *Camphorosmetum annuae* plant communities. Pratincoles bred close to shallow wetlands, sodic marshlands and soda pans (Szabó, 1965).

The majority of agricultural nesting habitats consist of croplands and fallow lands that either lack vegetation or have only minimal vegetation cover. The cultivated crops in these areas include spring-sown crop varieties (see in Figure 1).



Figure 1. Collared Pratincole family in corn field
(Photo credit: Ákos Monoki)

In Spain, pratincoles primarily breed in fields of cotton, sunflower, sorghum, chickpea, sometimes rice (Villanueva, 1993).

Fallows play a crucial role in the lives of farmland birds (Tarjuelo et al., 2020) and even Collared Pratincoles. These fields are left uncultivated for the main part of the year, devoid of or sparsely covered with vegetation (Eurostat, 2025). In the Nagykovács region, these fallow lands are usually rice fields that are left unplanted for the season. These sites are managed by disc-ploughing, where the processes are completed only late in the season (around late May to early June - after the sowing and crop maintenance). During the past seven years, the Hortobágy National Park (HNP) has collaborated with local agrotechnological companies and farmers to develop undisturbed fallow lands – considered as potential nesting sites for shorebirds – in an effort to attract pratincoles for breeding and reduce the number of pairs at risk in intensively managed areas. Since then, pratincoles and other shorebirds have been nesting in these areas every year in varying numbers.

2.1.1. Collared Pratincoles in Hungary

Pannonic salt steppes and salt marshes are considered as important habitats of the Great Hungarian Plain and have always been considered unique habitats (Fekete et al., 1997). Within the geographical borders of Europe, Hortobágy is the largest contiguous alkali grassland habitat that still exists within the vast Eurasian steppe zone (Végvári & Barta, 2016). However, due to human impacts, numerous unfavourable processes have acted in the area over the past century, to which the characteristic alkali steppe species have responded in different ways, but generally negatively, i.e., with population loss (Török et al., 2012). Collared Pratincole is a member of this group. In Hungary, the species was known as a typical breeding character species of alkali grasslands which were intensively grazed with cattle, sheep, horse or water buffalo. The largest number of breeding pairs was estimated to half thousand pairs at the beginning of the 20th century, which collapsed by the 1990s (Kovács & Kapocsi, 2004). The species was a locally common breeder in the Great Hungarian Plain, with major populations found in the Hortobágy, Kiskunság, Kardoskút and vicinity of Szeged (Sterbetz, 1974). Substantial changes in land-use management of the Great Hungarian Plain took place during the late 1940's, resulting in the first signs of decline in the Hungarian population. Subsequently, pratincoles disappeared as breeders, first from Szegedi-Fertő (1940–1950), then from the Kiskunság (1960–1980), and finally from the Hortobágy (1980–1990). Last colonies in puszta areas were detected in Kunmadarasi-puszta and Kecskeri-puszta areas during the mid-1990s (Kovács & Kapocsi, 2004).

Based on personal communications with Csaba Aradi and Gábor Kovács, historical colony of Hortobágy sites were visited, recorded with GPS device and supplemented with local ecological and habitat management data in 2017; Out of the 54 locations, 30 were grazed by cattle, 13 by both cattle and sheep, and 8 by sheep only (collected by Ádám Kiss). Nesting behaviour doesn't differ substantially from other plover or lapwing species; pratincoles scrap small clutch holes and line with small amounts of dry grass, plant residuals, or droppings (Haraszthy et al., 2019). In Hortobágy, László Szabó Vilmos (1965), Csaba Aradi

(1979) and Gábor Kovács documented a particular nesting behaviour, when pratincole laid eggs on top of dry cow manure.

Through long-term detrimental changes, the species suffered from a dramatic loss of almost the complete breeding population in Hungary. During the Soviet era (since the 1950s), large-scale landscape modifications transformed the puszta, including the construction of canal systems, drainage projects, and its conversion into rice fields or other land uses incompatible with and degrading the natural environment. Moreover, the quality and extent of high-salinity, sparsely vegetated shallow wetlands began to decline, as the number of grazing livestock managing these habitats also decreased rapidly. Since the 1950's, the afforestation programs in the Great Hungarian Plain introduced tree cover in areas where forests had not naturally existed before, providing nesting opportunities for new predators, especially crows (Ecsedi et al., 2020).

From the 1980s onwards, researchers studying the species observed a new phenomenon: Collared Pratincoles began nesting increasingly often in croplands (Széll, 1993), but the first breeding appearance in agricultural lands was documented significantly earlier in 1902 in Kiskunság (Cerva, 1928). Breeding colonies appeared in the municipal boundary of Karcag, Túrkeve, Kisújszállás in Jász-Nagykun-Szolnok County, Ecsegfalva, Szarvas, Csabacsúd, Gyomaendrőd in Békés County, and Bugyi, Kiskunlacháza, Apaj in Bács-Kiskun County (Széll, 1993). The presence of active paddy field systems had a significant effect on nest-site selection. Breeding population size in Hungary was estimated to 40-90 pairs between the mid-1990's, 30-90 pairs between 2002-2007 and 30-52 between 2013-2018 (Kiss, 2021). However, prior to 2012, population size estimation was based on approximations rather than precise knowledge of the number of breeding pairs in specific colonies. Since 2012 the monitoring scheme has changed in the Nagyknuság; we started to estimate population size by the number of located nests and families. Between 2012 and 2024, we have experienced a continuous increase in the local population, which showed the growing number of recorded nests and/or families (Figure 2).

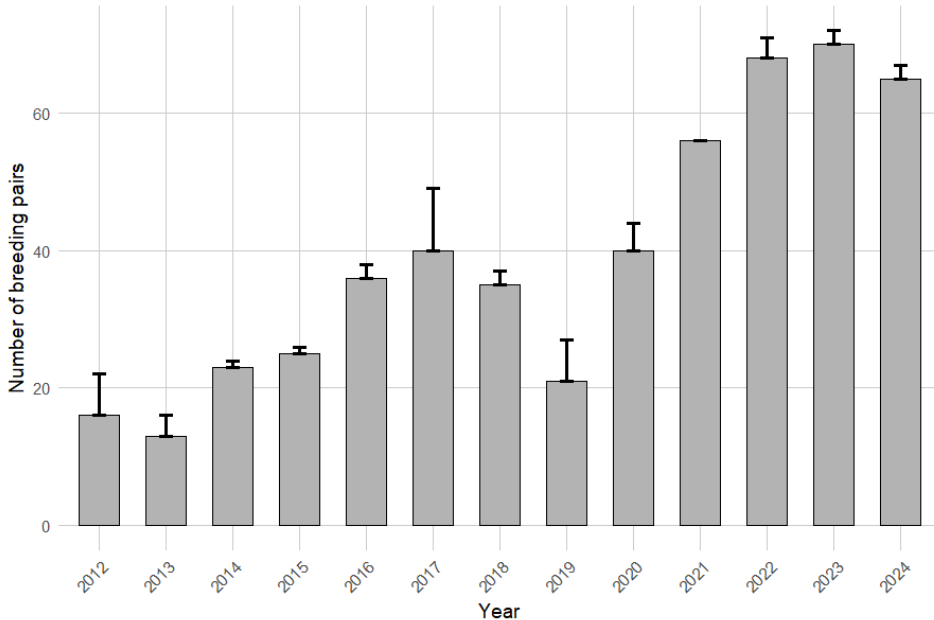


Figure 2. Number of breeding pratincole pairs in the Nagykunság area between 2012 and 2024

In Hortobágy, the conservation management of active colonies was not a difficult practice in the puszta habitats. The proper management of the puszta and wetland habitats with an adequate grazing livestock population was fundamentally regulated by the memorandum and founding document prepared in the founding year of 1973. During the pratincoles' breeding period, the HNP staff consulted with local farmers to ensure that grazing livestock avoided the nest sites during the incubation period (G. Kovács, pers. comm). However, organizing the protection and rescue of pratincole colonies in croplands was more complicated, at least in the 1980s and 1990s. The involved national park directorates (Hortobágy, Körös-Maros, Kiskunság, Duna-Ipoly) occasionally experienced conflicts among conservationists and farmers when breeding pairs nested in the area (Kapocsi, 1997). The most significant conflicts arose from the difficulty of detecting bird nests, which necessitated the designation of protective zones spanning sometimes up to several hectares, within which agricultural activities were not permitted. This primarily posed a problem in maize and sunflower fields. There was another remarkable factor that made

conservation efforts more difficult and complicated: pratincoles appeared in agricultural fields outside areas protected by nature conservation laws, such as national parks and Natura 2000 areas.

This is a problem that still exists today – breeding sites in Nagykunság have no legal protection at all, and the same situation applies to the other breeding sites. Local solution was developed by Antal Széll (Kiss et al., 2018), who tried to work with small buffer zones around each nest. These oval-shaped spots covered a maximum of 100 square meters (Figure 3).

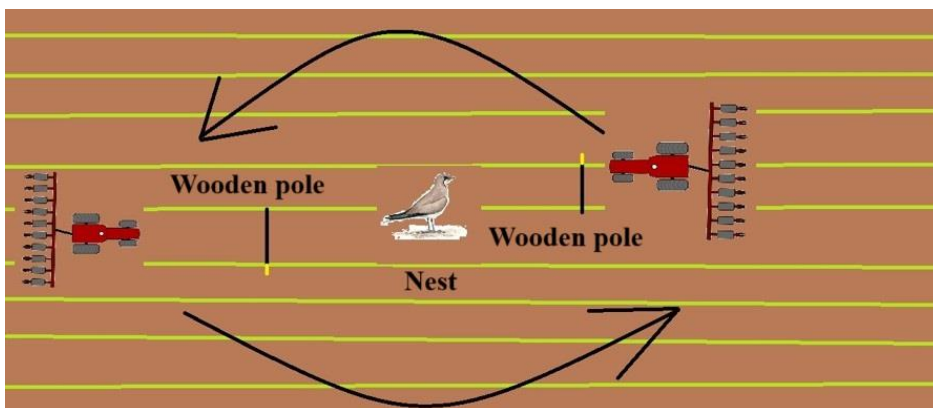


Figure 3. Marking buffer zone around a pratincole nest. The distance between wooden poles is 24 m, and between the crop rows is 4 m.

When agricultural works began, conservationists together with farmers designated the location of buffer zones, the areas which the farmers avoided during agricultural fieldwork (see Figure 3). The nearby operation of agricultural machinery apparently did not disturb the incubating shorebirds (Kiss et al., 2018).

2.2. Breeding biology field protocol

I have been investigating Collared Pratincoles in the Nagykunság area since 2008.

The study area covers approximately 15,000 hectares (Figure 4).

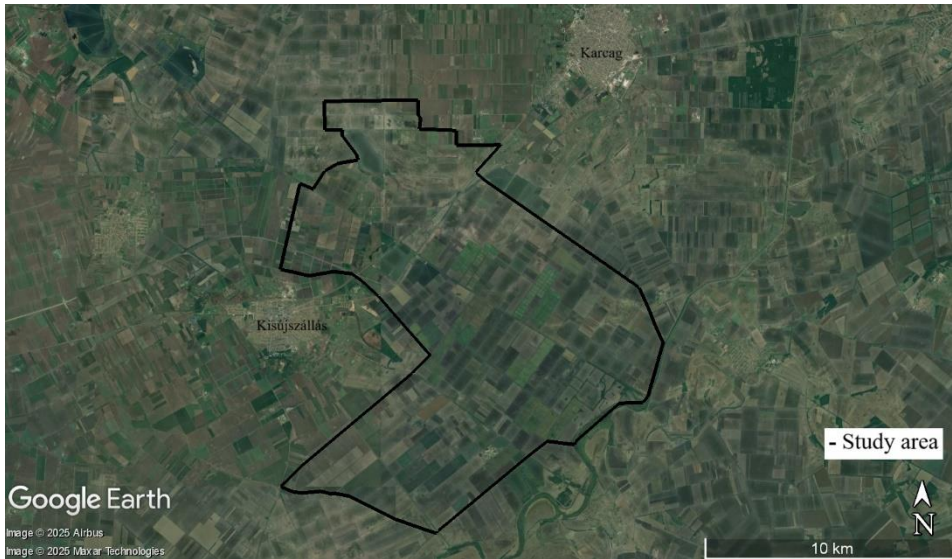


Figure 4. Map of the study area

During surveys (average every second day from end of April to beginning of August), we approached the nests by car in the fields for two important reasons: (i) cars and other machines do not disturb the birds, allowing us to approach incubating birds without disturbance, as the car functions as a mobile hide; (ii) using cars helps avoid drawing the attention of predators to the nest's location. Nests were disturbed for only a few minutes when nest measurements and site coordinates were recorded followed by the methodology proposed by Székely et al. (2008). The coordinates of the nests were summarized using Arcmap GIS software and these projections formed the basis for subsequent spatial analyses.

To collect spatial and nest data of Collared Pratincoles and other co-nesting shorebird species, we searched nests regularly in the Nagyunság, and occasionally in the Kiskunság. During nest search activities, we surveyed the potential nesting sites every other day on average. When we found a new nest, we recorded spatial and timing data, clutch size and other environmental variables per each nest, such type of habitat, vegetation cover, and characteristics of the ground surface. Agricultural habitat types were classified into three categories: croplands, spring-cover crops, and fallow lands, based on their agrotechnological

differences. Finally, we collected data on potential environmental variables that could potentially predict nest-site selection or nest survival such as the presence of permanent and seasonal water bodies, crop types unsuitable for nesting shorebirds, ditches, canals, farm buildings, forests and other tree plantations and improved them as polygon layers using ArcMap software.

Nest fate was one of the most important variables we measured ultimately providing valuable information about our conservation efforts. Accordingly, in all cases, we identified the final fate of each nest based on visual patterns observed at the site or from trail camera records. Nest fates were classified as hatched (when at least one chick hatched) or failed, with failed nests further categorized as predated, deserted, flooded by heavy rainfall, destroyed by agricultural machinery, or unknown (Kiss et al. 2024). We defined successful hatching by the presence of eggshell fragments or chick droppings in the nest cup, predation by predator tracks or signs of mammals or birds nearby, desertion by a cold egg and absence of the pair, and abandonment after rainfall by the egg being stuck in mud.

In order to determine nest fate and record incubation behaviour, we used different camera types near the nests. Cameras were placed close to each nest followed by Székely and Kubelka (2019)'s fieldwork protocol. Smaller camera types, as Wyze and GoPro cameras were set closer to the nests than trail cameras. When approaching each nest, we were careful not to draw the mesopredators' attention to the nests when setting or collecting the camera. Trail cameras were recording for about one week, Wyze cameras worked for 2 days, and GoPro cameras collected videos for only 2 hours.

2.3. Conservation protocol

The Collared Pratincole is a strictly protected species, threatened directly with extinction, moreover it is one of the rarest breeding shorebird species in Hungary. The species is included in the Hungarian Red List. Accordingly, strict rules apply to the protection and research of the species the legal background of which is detailed in Act No. LIII. of 1996 on Nature Conservation in Hungary (Nemzeti Jogszabálytár, 2025). The conservation tasks of strictly protected species is organized by the Hungarian national park directorates, as nature conservation management

units. Thus, park ranger services of the particular directorates are involved in organizing the protection of endangered species. In the case of the Collared Pratincole, this task is assigned to Hortobágy National Park Directorate.

3. Results

3.1. Study 1. Kiss, Á, Végvári, Zs, Kubelka, V., Monoki, Á, Kapocsi, I., Gőri, Sz. & T, Székely. (2024). Breeding in an agricultural landscape: conservation actions increase nest survival in a ground-nesting bird. *Oryx*, 58(2), 240-249.

3.1.1. Background

Shorebirds regularly nest under challenging conditions; nest success is influenced by various biotic and abiotic factors, and their nest survival rates are generally low (Colwell, 2010). Nest failure is caused by negative changes in wetland conditions, various direct and indirect effects of agricultural land use, nest predation, direct weather effects, and nest desertion (Kubelka et al., 2018).

Similarly, numerous factors negatively influence the nesting success of Collared Pratincoles. The main threats are predation, desertion, trampling, and flooding caused by heavy rainfall, which frequently affect colonies breeding in both natural and agricultural fields; however, there are distinct differences between the threats experienced in these two habitats. Trampling of eggs and chicks by grazing animals is a common phenomenon in grassland colonies (Villanueva, 1993). In intensively used cropland habitats, the trampling effect of agricultural machinery, nest destruction due to cultivation, and the direct or secondary effects of applied chemicals are significant threats (Villanueva, 1993). The physical transformation of the agricultural environment has led to an increasing presence of generalist mesopredators. The growing extent of secondary planted forests and the higher number of abandoned ditches favour bird and mammalian predators — particularly Carrion Crows *Corvus corone cornix* and Red Foxes *Vulpes vulpes* — facilitating access to the nest sites (Haraszthy, 2019).

Various studies published over the past decades show that the nesting success of populations breeding in natural habitats is significantly high compared to those in agricultural areas (Villanueva, 1993; Kovács & Kapocsi, 2004; Kayser, 2008). This is not surprising, but it suggests that a large number of nests may be destroyed year after year in populations that are less studied or recorded by researchers or conservationists.

The pressure exerted by mammalian and avian predators has a significant impact on the nest success of shorebirds, and the effect of this negative factor increases globally from year to year (Kubelka et al., 2018). However, with targeted interventions, this impact can be substantially mitigated as part of local and regional conservation projects (Fletcher et al., 2010).

The conservation status of Collared Pratincoles was critical around the turn of the millennium, with a serious threat of imminent local extinction. To prevent extinction, the HNP staff made an intensive effort to locate and protect as many nests as possible. Regular nest checks were increased, and consultations with local farmers also became more frequent to enhance nest protection. Additionally, through our professional consultations with game managers, the number of legally hutable nest predators was reduced by the hunters in the vicinity of nesting sites. The most significant conservation intervention was the creation of a specific agricultural habitat in 2017, through a collaboration between local farmers and HNP. The aim was to attract breeding pairs to undisturbed fallow areas specifically established for this purpose.

3.1.2. Objectives

In this study, we investigated the nest success and nest survival of Collared Pratincoles affected by their nest-site characteristics in agricultural fields. We investigated nest success values among different ecological variables, such as crop type, distance from nearest wetland and field boundary, colony density, and effects of timing as year and timing of breeding. We compared nest survival across years and agricultural habitats. We also aimed to determine whether various protection actions, such as focal nest protection or, habitat management of agricultural breeding sites and predator control, influenced nest success, and survival.

Our hypothesis was that conservation actions help increase the nest success of Collared Pratincoles.

3.1.3. Methods

HNP has been organizing conservation efforts for pratincoles, supplemented by data collection during the breeding season. Between 2012 and 2021, we found 315 nests, and we observed hatching at 212 nests. Breeding sites with nest locations and water bodies were included in spatial maps for further analyses. We designated around 100 m² buffer zones around the nest in all cases when the focal nest was located in intensively used agricultural lands. In addition to nest success, we calculated daily and total nest survival rates using Mayfield's (1975) methods and analysed them by comparing different years and habitat types. We evaluated the effectiveness of direct nest protection efforts by examining the number of successful nests as a function of protection type. Finally, we were able to obtain official data from hunters on the number of bird and mammal nest predator species killed annually, and we compared these data with daily and total nest survival rates.

3.1.4. Results

The first key result of the study was the description of the hatching period of the Collared Pratincole at our study site, which was found between mid-May and early August, with a peak in mid-June. The timing of hatching differed between habitats: pratincoles in row crops and spring-cover crops started earlier, followed by pairs in fallow lands. Majority of nests were found in row crops, and the mean clutch size was significantly larger compared with nest in other two habitat types. Nevertheless, both the nest success and the number of hatched chicks were influenced by habitat type: pairs in fallow lands and spring-cover crops had higher success rates than pairs in croplands. Earlier nests were more successful during the nesting period, and pairs nesting in colonies with higher densities were also more effective. Both daily and total nest survival rates showed an increasing trend over the years, but there were no statistically significant differences between groups in different habitats. Although nest survival was exceptionally low in 2012, followed by consistently higher values in subsequent years, we consider this year relevant for interpretation, given the uniform methodology applied and

the generally low breeding success observed in earlier years despite more limited data. Pratincole nests were most often destroyed by egg and/or chick predation. During the study years, direct nest protection was one of our most important conservation actions; we had to designate a buffer zone for almost every second nest. Conservation activities were effective, as 64% of all protected nests fledged successfully. Although the hunting of common nest predators is an important practice in our conservation efforts, we did not find a significant relationship between the number of eliminated predators and nest survival between 2017 and 2021.

3.2. Study 2. Kiss, Á., Monoki, Á. & Végvári, Zs. (2017). Nest-site selection and population trend of Collared Pratincoles (*Glareola pratincola*) breeding in agricultural habitats of the Nagykovácsok region (Hungary). *Ornis Hungarica*, 25(1), 25-38.

3.2.1. Background

The shift of Collared Pratincole colonies from alkali puszta to croplands accelerated in the 1980s, presenting a new challenge for conservationists: finding and rescuing a colony in intensively used arable land. Colonies were established in higher numbers in the Nagykovácsok, Kiskovácsok regions and in Békés County, in the area of Szarvas and Csabacsúd, which served as important population centers for the species at the time. Between the end of the 1980s and 2016 colonies were found in the vicinity of paddy fields, mainly in corn and sunflower fields, but the characteristics of nest-site selection were not investigated in detail.

3.2.2. Objectives

In this study, we aimed to identify the environmental factors affecting the nest-site selection of pratincoles in Nagykovácsok. We investigated how nest-site choice was influenced by the spatial location of alkali soil spots within croplands, the area of the nearest wetland, and the types and proportions of crops in the Nagykovácsok landscape. We collected data on agricultural habitat types used by pratincoles and analysed their frequency distribution. We hypothesized that direct nest-site selection was influenced by the spatial position of the closest wetlands and the type of agricultural habitats available for nesting.

Finally, we estimated the size of the local population during the study years and analysed the population trend.

3.2.3. Methods

We calculated the number of pairs, the number of successfully breeding pairs, and the ratio of successful pairs in each colony for 258 nests, between 2008 and 2016. Nest coordinates were collected and analysed as geospatial layers using ArcMap 10.0 software. To address nest-site selection, we determined three response variables: number of breeding pairs, number of successfully nested pairs, and proportion of successfully nested pairs in each colony. Our predictors were crop type, distance and size to the closest shallow wetland, and distance to the nearest alkali soil patch. Agricultural habitats were classified into four groups. We estimated colony size and compared it across various agricultural crop types, as root or row crops, spring cereals, early summer crops and fallows. We assumed that nest-site choice and success could be significantly affected by these environmental factors.

3.2.4. Results

We found one significant relationship between the all of response variables and predictors: the number of breeding pairs correlated positively with the size of the nearest wetland. Most nest were found in croplands followed by fallow lands. The average number of pairs per colony was substantially lower compared to colonies previously found in former alkali habitats in Hortobágy. We found a substantial increase in the estimated total population size in Nagykunság during the study period.

3.3. Study 3. Kiss, Á., Takács, Á., & Pigniczki, C. (2024). The recolonization of the Collared Pratincole (*Glareola pratincola*) in its natural steppe habitats in Hungary—an overview of the species' grassland activities between 1995 and 2024. *Ornis Hungarica*, 32(2), 298-308.

3.3.1. Background

Habitat rehabilitation or habitat engineering is an important project for conserving endangered species, but before starting, it always requires careful planning. (Hunt et al., 2018). Conservation-based restoration of important habitats can achieve sudden results, to which

birds respond with positive population trends (Góri et al., 2006; Boros et al., 2024). In the past decades, habitat restoration projects have played an important role in restoring natural grassland and wetland habitats of the Great Hungarian Plain. The conservation management of these habitats should primarily be carried out through grazing by with various traditional species as Hungarian Grey Cattle and/or water buffalo, as well as racka or merino sheep, goats, donkeys, and horses. Through this management, rare species – even those that have previously disappeared – can be provided with a habitat again. One such species is the Collared Pratincole, whose return to the grasslands of Hungary has been eagerly awaited by many conservation experts.

3.3.2. Objectives

Our main goals were: (1) to describe the 2022, and the subsequent recolonisation by pratincoles in Kiskunság, Alsó-Szúnyog-pusztá; (2) to summarize the observations of pratincoles in their former habitats during the breeding seasons between 2013 and 2024; and (3) to collect suspected and confirmed breeding data in Hungary between 1995 and 2021.

3.3.3. Methods

Firstly, we detailed our field observations that we collected on nesting behaviour in grassland habitats. Behavioural details were collected using the methodology outlined by Székely et al. (2008) and Székely & Kubelka (2019).

Secondly, we collected observations from former breeding sites dating from 2013 to 2024 using the databases of conservationists and citizen ornithologists. We summarized all data collected between 1 April and 30 June, the main breeding season for the species in Hungary. Sites summarized by István Sterbetz (1974) were considered former breeding sites, and we focused on these habitats.

3.3.4. Results

(1) As a key result, we observed pairs displaying courtship behaviour in Apaj, as part of the Alsó-Szúnyog-pusztá habitat restoration area, followed by observations of incubation and chick-rearing behaviour. In 2022, pratincoles (1-3 pairs) appeared and bred in the most sodic part of this area, this, approximately one and half hectares area was grazed

with livestock in high level. This habitat was also favoured by other rare or scarce breeding shorebirds, such as the Northern Lapwing *Vanellus vanellus*, Black-tailed Godwit *Limosa limosa*, Kentish Plover *Charadrius alexandrinus*, Common Redshank *Tringa totanus*, Pied Avocet *Recurvirostra avosetta*, and Black-winged Stilt *Himantopus himantopus*, forming unique mixed breeding colony. Suspected breeding activity of the species was also recorded in 2023, and breeding was confirmed in 2024 in the same location.

(2) After disappearance, the species became an uncommon visitor in its traditional habitats; only 21 observations were recorded during the breeding season, mainly from the Hortobágy, but observations have been increasing for the past few years.

(3) Except for a few cases, the species has not bred in alkali steppe habitats since 1995, when it disappeared from the Hortobágy, the species' last known grassland habitat. Only three confirmed breeding events were documented between 1995 and 2021, and these nests were located in Alsó-Szúnyog-puszta, Apaj and Kelemen-szék soda pan, Fülöpszállás.

3.4. Study 4. Kiss Á., Végvári Zs., Monoki Á., Kapocsi, I. & Székely T. (2025) Mixed-species nesting in an agricultural landscape: Collared Pratincoles are attracted to Northern Lapwings (submitted MS to Ibis in revision 1)

3.4.1. Background

Colonial nesting is a common strategy among birds, especially waterbirds, (Lamarre et al., 2017). Presence of nesting species with comparable ecological needs can affect similar species in nest-site choice (Cunningham et al., 2016). Colonial nesting that involves multiple species is a widespread phenomenon, offering breeding opportunities and conferring various advantages to the species involved. Communication and interactions between species can be beneficial at both the individual and colony levels. Defence strategies may vary between species, which can amplify the overall impression of defence activities in the presence of predators (Colwell, 2010).

Collared Pratincole is a classic example in the group of colonial shorebirds; the species breed in various size colonies, usually consisting

2-50 pairs (Lokhman et al., 2020). Their social interactions between pairs are complex, pratincoles visit foraging sites in small groups together and cooperate to defend themselves against predators (Galván et al., 2017).

Collared Pratincoles also prefer to participate in mixed colonies with various shorebird species, such as lapwing and plover species, Kentish Plover, European Stone-curlew *Burhinus oedicephalus*, Black-tailed Godwit, Common Redshank, Pied Avocet, Black-winged Stilt (Villanueva, 1993). Based on Csaba Aradi's investigations (1979) in Hortobágy, these species formed a complex mixed-species unit, in which species with different behavioural patterns collectively formed a complex social network.

3.4.2. Objectives

During our conservation work, we observed a potential ecological relationship between Northern Lapwings and Collared Pratincoles, which we aimed to investigate further. In this study, we examined the factors influencing nest-site selection and the formation of mixed colonies in Collared Pratincoles, particularly focusing on the ecological role of Northern Lapwings.

3.4.3. Methods

Between 2013 and 2024, we assessed egg-laying dates for nests whenever it was possible. We categorised and analysed Collared Pratincoles' solitary, single-species, and mixed-species nesting units.

When surveying mixed colonies, we focused on all shorebird species with equal effort. In addition to the nests of Lapwings and Pratincoles, we also collected nesting data for Black-tailed Godwits and Common Redshanks, albeit in smaller numbers. The date of egg-laying was known for some nests, either recorded directly at laying, estimated using the egg-floating method (Székely et al., 2008), or back-calculated from the hatching date expressed as Julian days, assuming an incubation period of 18 days for Collared Pratincole and 26 days for Northern Lapwing (Myhrvold et al., 2015) Using these data, we investigated the differences between egg laying-date of first eggs and relative egg laying date of pratincoles and lapwings in colonies. We also incorporated egg laying Julian dates (188 nests for Pratincoles, 122 nests for Lapwings) into a colony structure analyses. We examined the spatial distribution of

nests within each colony using spatial analysis. The colony structure was analyzed using two datasets: (i) one including all nests, and (ii) another including only pratincole nests that were established after the first lapwing nests. We then calculated the average Euclidean distance between each Collared Pratincole nest and all Northern Lapwing nests. For comparison, we generated 1,000 random points within the field polygon, measured their mean Euclidean distance from the Collared Pratincole nests, and tested whether the distances to actual nests differed significantly from those to random points. Finally, to investigate potential associations between the area size of colony and colony size, we compared individual areas and colony sizes by considering social units (single- and mixed-species) and the number of known Collared Pratincole nests within each colony.

3.4.4. Results

Our first result was the difference in the timing of egg-laying between lapwings and pratincoles: lapwings started earlier, both in separate nesting sites and in mixed colonies formed together with the pratincoles. The most common habitat type for mixed colonies was row crops, followed by fallow land and spring cover crops. Mixed colonies on fallow land developed significantly later than those on the other two habitat types. Collared Pratincoles frequently formed mixed colonies together with Northern Lapwings, and in some cases also with other shorebird species. Another important result was that the nests of the Collared Pratincole and the Northern Lapwing were significantly closer to each other than computed for random points. Based on our further refined analysis, the pratincole nests were significantly closer to the lapwing nests than to random points, with the lapwings starting their incubation period earlier. Colony area size correlated with the number of pratincole nests in both single-species and mixed-species colony social units. Additionally, mixed-colony sizes increased significantly faster, considering the nests of all shorebird species within a given colony, compared to single-species colony sizes.

During our investigation activities the Collared Pratincole proved to be an umbrella species in our conservation projects; by restoring important habitats or even creating new breeding sites focused on our

target species, we indirectly help other species that choose similar breeding habitats (Roberge & Angelstam, 2004; Morales & Traba, 2016; LIFE Public Database, 2025). Moreover, when we organize the direct nest protection of pratincoles, we indirectly focus on the protection of other species as well. It means our nest-searching and rescuing practice also focuses on the local populations of Northern Lapwing, Black-tailed Godwit, and Common Redshank at a similar level.

4. Discussion

Pratincoles have declined significantly in different parts of Europe, and thanks to concentrated efforts by conservationists and land owners, the declining trend has been reversed (Arnassant et al., 2019; Zafarana et al., 2019; Sponza & Salvador, 2023). Using field protocols for individual-based ecological and behavioural studies, we quantified the impact of conservation measures on reproductive success and analysed key components of pratincoles' reproductive behaviour (see above). We also investigated nest site selection, and initiated a study on quantifying the costs and benefits of their colonial behaviour. Using the individual-based focus, our work has demonstrated the success of conservation measures and uncovered previously unstudied aspects of pratincole ecology, life history and behaviour. Thus the scientific approach that has been invented for understanding breeding systems, sex roles and population demography of shorebirds (Székely et al., 2024), proved to be an excellent tool to underpin practical conservation.

4.1. Nest site selection and nest success

Inland habitats in Hungary have undergone dramatic transformations over the past decades, leading to the loss of characteristic species that were key members of their ecological niche. Collared Pratincoles have shifted their habitat in an unusual way: they moved from natural grasslands to cultivated agricultural fields. One thing is common between steppe and agricultural habitats: the limited ground vegetation and the presence of bare soil surfaces (Studies 1, 2, 3). We found that among the agricultural habitats, birds predominantly selected row crops, as maize and sunflower cultivation are dominant in this area (Studies 1, 2,

4). However, nesting in these habitats carries significant risks due to intensive land use. Without conservation interventions, Collared Pratincoles would unfortunately suffer significant nest losses. However, through direct nest protection, we have achieved remarkable success (Study 1).

The average nest success rate in agricultural fields was lower (Study 1) than reported in studies conducted in natural habitats in Spain (Villeneuve, 1993), though this pattern did not hold across other studies (Kayser et al., 2008, Hanane et al., 2010). Although the mean number of hatched chicks per nest differed from other populations (Hanane et al., 2010), it was likely sufficient to support the growth of the local population (Study 1).

Our goal of establishing fallow lands for pratincoles was successful in 2017 and it motivated us to continue developing the agricultural habitat management and collaborating with local farmers. Our primary goal of attracting some pairs was successful, and in addition, we learned that breeding success was also significantly higher compared to intensively cultivated row crops (Study 1).

The appearance of an open, shallow wetland with limited vegetation cover played a crucial role in nest site selection (Studies 2, 3), which was actually a determining factor in all of the Collared Pratincole's natural and artificial habitats within its distribution (Lokhman et al., 2020). Although we did not find a relationship between nest success and the distance to the nearest flooded paddy fields at the level of individual pairs, the presence of water is certainly not negligible at the population level (Studies 1, 2). Further studies are needed to investigate the significance of proximity to wetlands and other habitat characteristics in future.

4.2. Strategies of colony formation in a colonial nesting bird

The Collared Pratincoles typically nest in loose colonies and in our study area they often form mixed-species colonies with other shorebirds, terns, or even passerine species (Szabó, 1965; Villanueva, 1993). We found that the presence of co-nesting species have an impact on the target species in all habitat types tested (Study 3, Study 4). The presence of the lapwings, which is the most common breeding shorebird species in

Hungary, had a peculiar role on the nest site selection of the pratincoles. Since lapwings often start nesting before the pratincoles arrive back from their wintering areas, it is likely that pratincoles seek out the proximity of lapwings rather than the other way around (Study 4). In some cases, however, the pratincoles attracted lapwings and other shorebird species, as observed by Aradi (1979) at traditional breeding sites in the Hortobágy.

Whilst solitary nesting did occur (Studies 2, 4), mixed species nesting was the most common that included Black-tailed Godwit, Northern Lapwing, Common Redshank in our study site whereas elsewhere in Hungary Kentish Plover, Pied Avocet, and Black-winged Stilt have also been reported (Studies 2, 3, 4). A conclusion from this work is then that the design and management of agricultural and natural habitats should not only consider the target species but also the needs of co-nesting species.

4.3. Novel habitat management

Sensitive species react rapidly to negative changes in their habitats, potentially leading to drastic population loss or extinction (Ewers & Didham, 2006). The return of the Collared Pratincoles has highlighted an alternative process, namely the shift in habitat selection and use. Acceptable conservation management for the species has been implemented here, but it is also possible that individuals from the growing population, strengthened by direct nest protection interventions and agricultural habitat developments, may also be spreading to new sites (Studies 1, 2, 3). Therefore, it is important that these habitat restorations continue in the future. Ecsedi et al. (2020) documented 750 shallow wetlands, which should be restored through intensive grazing by cattle and buffalo, ensuring that approximately one-third of them retain more than 50% of their open water coverage. However, the creation of such habitats requires the proper retention and potential supplementation of water through inundations. Over the past five years, regional precipitation data explain dramatic wetland losses, making water retention perhaps the most crucial factor in the Great Hungarian Plain region. Maintaining shallow wetland habitats – whether a saline marsh, a soda pan, or a rice field functioning as a secondary wetland – is essential for the Collared

Pratincole, and its last significant population in the Carpathian Basin resides in the part of the Nagykunság, where inundations occur every spring over 1400-1800 hectares. Therefore, without rice fields, the population would likely disappear within the next few years. The fallowing of rice fields is a well-established agricultural practice, into which we have successfully incorporated the creation of shorebird-focused habitats (Studies 1, 4). Similarly, Villeneuve (1993) suggested that the fallow lands in Doñana National Park would be suitable for the species, but this can only be achieved through collaboration with farmers.

5. Recommendations for conservation management

Based on the above results and previous conservation recommendations (Kiss et al., 2018; Kiss & Zalai, 2020), supplemented with the conservation outcomes of our studies, I propose the following recommendations:

5.1. Effective nest protection management

(i) Consultation with landowners and the designation of buffer zones: Organizing nest-rescuing activities requires thoughtful communication with land owners and different stakeholders. 'No two people are alike'; there are significant differences in the ecological sensitivities between one farmer and another. Therefore, every occasion involving agricultural land use should be discussed as precisely as possible, down to the day and hour. We aimed to mark buffer zones with wooden poles only during land-working activities, to reduce the likelihood of attracting the attention of crow species. The wooden poles were always thin, with a maximum diameter of 2 centimetres, to prevent crows or harriers from perching on top (Figure 5).



Figure 5. Pratincole nest marked with a wooden pole (see in the background)

(ii) Row cultivation: During cultivation activities, the tractor operator must approach the buffer zone slower than the prescribed working speed and ensure that the buffer zone is avoided on both sides. It is essential to maintain a distance of at least three rows of root crops (more than one and a half meters) from the nest to prevent soil clods from being thrown up during hoeing and potentially striking the nest. Parents with freshly hatched chicks must also be approached slowly, as young chicks (less than one week old) are unable to run away from the machinery. Instead of leading them to a safer location, parents often hide their chicks under themselves.

(iii) Pesticides and insecticides: It is necessary to avoid direct spraying of pesticides within the buffer zone. Machinery approaching the buffer zone should avoid it, as previously suggested, by separating the spraying boom over the zone to prevent direct pesticide discharge. This method has been technically feasible even with older types of spraying equipment. The hatched chicks are often led by their parents within the farmland or to weedy patches along its edges, particularly where common reed *Phragmites australis* and/or scentless mayweed *Tripleurospermum inodorum* are present. These plants provide adequate cover for the chicks, protecting them from unfavourable weather conditions and effectively

hiding them from predators. These habitat patches should also be kept free of chemicals.

(iv) Ploughing: It is important to avoid soil rotating techniques at nesting sites, as these activities easily attract storks, herons, gulls and crows. As a result, it is necessary to ensure that these activities are carried out only after the chicks have fledged in these areas. It is also important to maintain this restriction at gathering sites.

If the restriction leads to any issues, we designate a protective zone of at least 50x50 meters per nest in practice.

(v) Irrigation: Since the proportion of irrigated areas is also increasing in Hungary, this risk factor must be addressed separately. Water supplement of cropland using an irrigation reel system always causes nest destruction due to the powerful force of the sprayed water jet, therefore this method should not be used on nesting sites during the incubation period. The use of linear irrigation systems also carries significant risks, but here the force of the water jet is weaker, resembling a summer rain effect. Based on our experience, it causes less disturbance, yet it may bother the brooding bird or induce it to desert the nest.

(vi) Impacts of extreme weather: The climate of the Carpathian Basin is constantly changing and is becoming increasingly dry, with hotter summers (Bartholy et al., 2007). As a result, more extreme weather conditions affect the Great Hungarian Plain, having an intensified impact on living organisms. After extreme rainfall, eggs often become covered in mud. Such weather effects were particularly common in our study area between 2000 and 2010, but heavy rains became less frequent after 2010. Eggs heavily covered by mud were washed with lukewarm clean water, giving the embryos a better chance for proper development.

On hot summer days, chicks tend to hide under vegetation or soil clumps for shade. During this period, the parents are also less active. Individuals continuing incubation tend to engage in shading behaviour during the hot midday hours. In the case of active colonies, it is important to coordinate with land users to ensure that work is carried out early in the morning or late in the afternoon whenever necessary, thereby avoiding the risk of trampling or disturbing the chicks.

(vii) Game management and pest control: The most effective approach is to employ a dedicated specialist within conservation projects whose specific task is the planned annual control of legally huntable predator species known to prey on nests (Lóránt & Fejes, 2024). Where this is not possible, but a game manager is responsible for the area, sharing relevant information can be highly beneficial. Each year, we systematically collect data on the nests of corvids and the dens of carnivorous predators, along with their geo-coordinates, and provide this information to hunters. Game managers in Hungary are legally entitled to eliminate predators using various rifles and selective traps, such as ladder traps, Larsen traps, and swan-neck traps, which are commonly used in our region.

5.2. Preparing breeding sites for a habitat specialist

(i) Choosing the perfect sites at the perfect time for shorebird conservation:

Annual reviews of agricultural nesting site planning were essential due to the crop rotation system, especially in the case of rice fields that were left fallow in the years following cultivation. This was also beneficial for conservationists as it allowed planning based on this regulation. The conversion of dry rice fields into fallow land took place every year, but agricultural practice was usually carried out later, in late May or June, when the breeding season of the Collared Pratincoles was coming to an end. Consequently, these areas played a less significant role in the nesting of shorebirds during this period.

Since the beginning of our efforts in 2017, we have aimed to include areas in habitat development programs where nesting data are already available. Since 2017, we have been working with landowners to establish fallow areas of between 30 and 100 hectares per year, with varying sizes, in the Nagyrét region, which is the main nesting hotspot in the Nagykovácsok and where the highest activity of Collared Pratincoles is observed.

Another remarkable aspect of site selection is ensuring a flooded rice field near the areas prepared for the birds. We have always taken this into account and, in most cases, we were able to select locations with

farmers where the shorebird habitat was surrounded by flooded fields in almost every direction, applying an island model.

Timing of tillage operations is also crucial. We scheduled the soil preparation work for the period after the average arrival of Collared Pratincoles in Hungary. The fallow lands were prepared between 25 April and 5 May. Since we have observed that Northern Lapwings play a key role in the nest-site selection of Collared Pratincoles, it would be worthwhile to focus on multi-phase habitat restoration in the future. It means creating fallow lands for the early-breeding lapwings as well (potentially as early as late March), followed by a later phase in mid-April to attract Northern Lapwings, Black-tailed Godwits and Common Redshanks, and an even later phase to accommodate late-breeding shorebirds and arriving Collared Pratincoles.

(ii) Preparation: The technique used for site preparation consists of two rounds of disc harrowing in spring. First, a heavy disc harrow is used for stubble cultivation, followed by a second pass for soil turning. A few days pass between the two operations. Based on recent years' practice, however, the second round of disc harrowing is followed by a finishing treatment using a Crosskill roller. This helps break up soil clumps more effectively, creating a smoother surface (see Figure 6). We have observed that this habitat form is more attractive to Collared Pratincoles than fallows ploughed twice with a heavy disc harrow. After the last intervention, the soil surface remained sufficiently cloddy, allowing the chicks to hide behind the clods from predators and find shade during the midday hours. Since farming practices and species conservation can be easily coordinated, it would be beneficial to establish a species-specific, locally targeted Agri-Environmental Management Programme in the future, which would open up new perspectives for the protection of the species.



Figure 6. Fallow land in a final state suitable for attracting pratincoles
(Photo credit: Ádám Kiss)

(iii) Predator-free nesting areas: One of the most essential aspects of the cooperation is to ensure that the prepared areas remain undisturbed by agricultural land use until the end of the fledging season, regardless of which shorebird species are nesting in the area. These sites function as conservation shelter zones during incubation.

Our future plans include establishing a permanent electric fence system immediately after completing the disc-ploughing operations, which will hopefully completely exclude mammalian predators from the nesting zones.

5.3. Recommendations for grassland and wetland management

We have observed the recolonization of Collared Pratincoles in the Kiskunság, where a well-planned and extensive management process has created suitable breeding conditions in Alsó-Szúnyog-puszta. The key was continuous water replenishment through periodic flooding and habitat management involving carefully selected indigenous livestock

species (Boros et al., 2024). These restoration works are also taking place in the Hortobágy, so hopefully, conditions will improve there in the coming years. However, the most significant issue is the lack of precipitation, which makes the retention of steppe waters and the planning of flood events increasingly important. The Nagykunság and southern Hortobágy habitats are located just 20 kilometres apart in a straight line, a negligible distance in terms of potential "re-attraction" efforts. The HNP defines the grazing unit and the types of livestock required for grazing in each specific steppe area within its lease agreements. This ensures the appropriate grazing of shorebird habitats. The number and spatial extent of habitat restorations is continuously increasing, leading to the re-establishment of a 'healed' alkali steppe habitat and wetland areas as an important habitat complex. This continuous habitat restoration effort is expected to lead to the recolonization of Collared Pratincoles in the Hortobágy region.

Finally, it is important to point out that secondary forest and tree plantations in both the agricultural landscape and near natural nesting sites often facilitate the settlement of bird predators, particularly crow species and birds of prey such as the Eurasian Hobby *Falco subbuteo* and the Common Kestrel *Falco tinnunculus*. Therefore, the management plans of these areas should include limitations for tree cover. Similarly, for the same reason, conservation managers should avoid installing nest boxes for Saker Falcons *Falco cherrug* and Peregrine Falcons *Falco peregrinus* close to breeding shorebirds, as this could pose a serious threat to both adults and juveniles.

6. Conclusions and future studies

My research and conservation work produced several novel findings:

- Due to the intensive conservation efforts, nest survival of Collared Pratincoles increased over the years which presumably led to an increased number of breeders (Study 1).
- Due to direct nest protection actions in collaboration with farmers, the nest survival in row crops – that is in principle detrimental for pratincole nesting – was high and comparable to other crop types (Study 1).

- Our agricultural habitat restoration program functioned in favour of the conservation of pratincoles: on an individual level, the nest success of pratincoles breeding in fallow lands and extensively used spring cover crops were significantly higher than those in row crops (Study 1).
- Extensive shallow wetlands, such as paddy fields, play a crucial role in nest-site selection and are associated with the colony size of pratincoles (Study 2).
- As a result of habitat restoration in the Kiskunság region, pratincoles started to nest in their natural habitat after an 18-year gap (Study 3).
- Pratincoles typically nest in loose colonies, and they are attracted to nesting sites close to Northern Lapwings (Study 4).
- Mixed colonies are established with the appearance of Lapwings first, followed by pratincoles during the breeding season (Study 4).

To continue the success of the pratincole conservation and management project, I propose four main lines of research.

First, it is important to gain a more thorough understanding of the nest site selection process. Nest-site selection may vary between shorebird species and can be influenced by various environmental factors, such as the effects caused by different crop types and those shaped by different agricultural management techniques. These analyses could serve as a basis for conservation management recommendations in the future.

Second, detailed analyses are needed about the costs and benefits of mixed-colony nesting. Breeding behaviour and defensive strategies vary among shorebird species, which can influence the benefits of nesting in mixed colonies. Also, the costs may differ since efforts in nest defence activities can vary between the different species. As a result, the advantages of colony membership may differ in terms of survival of their nests, chicks or adults. I believe that behavioural observations and survival data can provide important insights into the costs and benefits of breeding in mixed-species colonies.

Third, whilst nest success is an important measure of a conservation policy, the ultimate estimates of individual success are survival and lifetime reproductive success, which influence population demographic processes. I started to ring chicks and adults during my PhD, although further ringing and resighting are needed to gather robust data

for demographic analyses. Nevertheless, the resightings of colour-ringed adults and chicks near the study area make it likely that detailed demographic analyses will be possible with continued ringing effort.

Fourth, to understand nest site selection, colony formation and ultimately, the reproductive success and survival of pratincoles, detailed movement data are needed. The tracking technology already exists to follow the movements of adults, and in the near future, I plan to use these techniques.

Taken together, the combination of detailed individual-based research with strong conservation actions on the ground provided a synergetic effect that will further advance the conservation of this charismatic species. This work attests that the collaboration between conservationists, land owners and behavioural ecologists can provide significant advances that have not only implications for science but also for practical conservation.

7. Összefoglaló (Summary in Hungarian)

Az állandó gyepterületek átalakítása és eltűnése drasztikusan átstrukturálta Európa élőhelyszerkezetét az utóbbi évtizedekben (Schils és mtársai, 2022). A legjelentősebb veszélyeztető tényezőként a szántóföldi művelésbe vonás, legeltetés és kaszálás felhagyása, intenzív gyepművelés, felszíni vizek elvezetése, illetve a klimatikus változások okozta kiszáradás okozta és okozza folyamatosan a legtöbb ökológiai és természetvédelmi problémát (Schils és mtársai, 2022). Párhuzamosan ezzel, a vizes élőhelyek területi aránya is rendkívül sokat csökkent az elmúlt évtizedekben (Gutzwiller & Flather, 2011). Ezen élőhelyek kárára a szántóföldek aránya drasztikusan megnőtt (Stoate és mtársai, 2009). Ezen változásokra a nyílt területek madárfajai eltérően reagáltak, egyes fajok tudtak a változásokhoz alkalmazkodni, mások állományai lecsökkentek vagy akár teljesen el is tűntek (Traba & Morales, 2019). Azonban a tájátalakítás intenzifikációja következtében világszerte jelentős populációvesztéseket dokumentáltak, sőt egyes fajok lokális vagy régiószintű kipusztulása sem volt ritka esemény (Donald és mtársai, 2001).

Doktori értekezésemben a szántóföldi környezetben fészkelő székicsér élőhelyválasztásának befolyásoló tényezőit, költési sikerének hátterét, a természetes szikes pusztai élőhelyekre való visszatérését és más partimadár fajokkal alkotott szaporodóközösség kialakulásának jellemzőit vizsgáltam.

A korábbi szikes pusztai karakterfaj drasztikus populációcsökkenésen ment keresztül az 1900-as években, melynek következtében 1995-ben kipusztult magyarországi természetes szikes pusztai élőhelyeiről és kevés kivételtől eltekintve fészkelőként csak 2022-ben jelent meg újra. Az 1980-as és 1990-es években azonban természetvédők a faj élőhely-váltását figyelték meg; a székicsér szántóföldi élőhelyeken kezdett egyre gyakrabban fészkelni (Széll, 1993). A szántóföldi élőhelyek választásának feltárása mellett azonban új feladat hárult az állami és civil természetvédelemre; a faj védelmét természetvédelmi oltalommal nem rendelkező, intenzíven kezelt szántóföldeken, jellemzően napraforgó- és kukoricakultúrákban kellett biztosítani, ahol fokozottabban ki voltak téve a mezőgazdasági földhasználatból eredő direkt- és indirekt zavarásnak, az intenzív csapadékok okozta fészekpusztulásoknak és a fokozott fészekpredációnak (Kovács & Kapocsi, 2004).

Doktori témám a székicsérek szántóföldi védelmének szervezése mellett végzett két évtizedet felölelő kutatások és eredményeik közlése. Vizsgálataim elsősorban a szántóföldi fészkelőhely-választást befolyásoló környezeti tényezők megértését, a fészkelési sikerre és fészektúlélésre hatást gyakorló változók feltárását és hatások “erejének” mérlegelését, a székicsér élőhelyválasztását irányító szociális ingerek, azaz más partimadár-fajokkal történő vegyes kolóniaalkotás hátterének vizsgálatát és a természetes élőhelyein mutatott előfordulását célozták meg. Doktori értekezésemben ezeknek a vizsgálatoknak az eredményeit foglaltam össze és a megszerzett információk alapján természetvédelmi kezelési javaslatokat tettem élőhely- és fajvédelmi részletekben.

7.1. 1. Vizsgálat. Kiss Ádám, Végvári Zsolt, Kubelka Vojtech, Monoki Ákos, Kapocsi István, Góri Szilvia & Székely Tamás. (2024). Breeding in an agricultural landscape: conservation actions increase nest survival in a ground-nesting bird. (Fészkelés mezőgazdasági tájban: a természetvédelmi intézkedések növelik a talajon fészkelő madarak fészeksikerét). *Oryx*, 58(2), 240-249.

A szántóföldi környezetben megmaradt székicsérpopulációk mérete nagyon lecsökkent az ezredforduló után, komoly esélye volt, hogy a faj kipusztul az országból. A nagykunsági fészkelőhelyeket felügyelő Hortobágyi Nemzeti Park Igazgatóság komoly lépéseket kezdett el tenni a faj eltűnésének megakadályozása érdekében. A fészkek megkeresése, védelmének szervezése, a megmaradt párok átlagosan kétnaponta végzett ellenőrzése, illetve a fészkelés végeztével az aktuális fészeksors megállapítása egymást követő fontos lépések voltak. 2012 és 2021 között a védelem szervezése mellett adatokat gyűjtöttünk az eltérő mezőgazdasági élőhelytípusokban talált fészkelésekről, azoknak a fészkelési sikereiről. Vizsgálatunkban azt céloztuk meg, hogy az egyes ökológiai változók, így a mezőgazdasági élőhely típusa, a legközelebbi vizes élőhelyektől, illetve a fészkelőhely táblaszegélyétől való távolság, vagy a telepsűrűség, illetve időbeli hatások, mint év a fészkelés időzítése befolyásolja-e a székicsérek költési sikerét. Ezt követően összevetettük az eltérő mezőgazdasági élőhelyeken fészkelő székicsértelepek napi és teljes fészektúlélési rátáit, illetve az évenkénti változásait. Ezek mellett ellenőriztük, hogy milyen hatással volt a direkt fészekvédelem és a területen végzett dűvadkontroll a fészkelési sikerre, illetve napi és teljes túlélési rátákra. Vizsgálataink során megállapítottuk, hogy a kapáskultúrákban és a tavaszi vetésidejű kultúrákban fészkelő párok korábban kezdték a fészkelést, mint az ugarokon fészkelő párok. Ennek agrotechnológiai okai vannak, hiszen a tavasszal vetett kultúrák hamarabb vannak kialakítva, mint az ugaroltatott területek. 2017-től kezdve a Hortobágyi Nemzeti Park és Nagykun 2000 Mg. Kft. együttműködésének köszönhetően már május elején kialakításra kerültek úgynevezett „székicsérbarát” ugarterületek. A fészkelési siker elemzése során megállapítottuk, hogy azok a székicsérek, amelyek extenzíven kezelt tavaszi vetésidejű kultúrákban, vagy művelésből ideiglenesen kivett

ugarokon fészkeltek, sikeresebbek voltak és több fiókát tudtak kikeltetni, mint azok a párok, amelyek intenzíven használt kapáskultúrákon voltak. A fészkelési sikert a fészkelés időzítése és a telepsűrűség is befolyásolta; azon párok, amelyek korábban kezdtek, illetve sűrűbb kolóniákban szaporodtak, sikeresebbek voltak. A napi és teljes túlélési ráta folyamatosan nőtt a vizsgálati időszak során, de nem találtunk különbséget a túlélési ráták és élőhelyek között, mellyel kapcsolatban az a hipotézisünk, hogy kapáskultúrákban fészkelő párok esetében a túlélési ráta hasonló szintre emelkedett a direkt fészekvédelem gyakorlata miatt, mint a másik két élőhelytípusban tapasztalt túlélési ráták. A szántóföldi élőhelyfejlesztési akciónk mellett a direkt fészekvédelem is működött, hiszen a védőzónával jelölt fészkek többsége sikeresen keltetett fiókákat. A célzott dűvadgyérítés által elejtett állatok terítékméretei és a fészkelési siker között azonban nem találtunk statisztikai összefüggést, ettől függetlenül a célzott dűvadkontrollt folytatni kell a jövőben.

7.2. 2. Vizsgálat. Kiss Ádám, Monoki Ákos, & Végvári Zsolt. (2017). Nest-site selection and population trend of Collared Pratincoles (*Glareola pratincola*) breeding in agricultural habitats of the Nagykovácsok region (Hungary) (A mezőgazdasági élőhelyeken költő székicsérek (*Glareola pratincola*) fészkelőhely-választása és trendje a Nagykovácsok régióban (Magyarország)). *Ornis Hungarica*, 25(1), 25-38.

A székicsérek az 1980-as évektől kezdve rendszeresen különböző mezőgazdasági kultúrákban kezdtek el fészkelni, amelyekben egy hasonlóság volt; minden esetben kopár, vegetációmentes, vagy kultúravegetációval gyéren borított szántóföldi élőhelyek voltak. Ebben a tanulmányban 2008 és 2016 között vizsgáltuk a székicsérek fészkelhely-választási szokásait, melynek során a kolóniaméreteket, a sikeresen költő párok számát és arányát a kolónián belül vetettük össze az élőhelytípusokkal, a legközelebbi vizes élőhely távolságával és méretével, és a legközelebbi szikes élőhelyfolt távolságával. A vizsgálati időszak alatt gyűjtött adatok alapján összevetettük a kolóniaméreteket az egyes élőhelytípusok között. Végezetül a populációs trendet becsültük meg 2008 és 2016 között. A válaszváltozók és a prediktorok statisztikai vizsgálatánál csupán egy szignifikáns összefüggést találtunk; a

költőpárok száma pozitívan korrelált a legközelebbi vizes élőhely méretével. A fészkek többségét kapáskultúrákban találtuk, ezt követték mennyiségben az ugarok. Az átlagos párszám kolóniánként jelentősen alacsonyabb volt, mint a korábban a Hortobágy egykori szikes élőhelyein megfigyelt kolóniaméreték átlagai. A vizsgálati időszak során a Nagykunságban a becsült teljes populációméret szignifikáns növekedését figyeltük meg.

7.3. 3. Vizsgálat. Kiss Ádám, Takács Ádám, & Pigniczki Csaba (2024). The recolonization of the Collared Pratincole (*Glareola pratincola*) in its natural steppe habitats in Hungary—an overview of the species' grassland activities between 1995 and 2024. (A székicsér (*Glareola pratincola*) visszatelepése természetes pusztai élőhelyére Magyarországon – gyepterületi előfordulásainak áttekintése 1995 és 2024 között) *Ornis Hungarica*, 32(2), 298-308.

Az élőhelyek természetvédelmi szempontú fejlesztése kiemelten fontos a veszélyeztetett fajok védelme szempontjából, mely mindig pontos tervezést igényel (Hunt és mtársai, 2018). A magyarországi szikes puszták, rétek és mocsarak kezelése szempontjából a legfontosabb azok felszíni vizeinek megőrzése, a vízpótlás fenntartása akár mesterséges módon és a területek legeltetése gondosan megválasztott és megfelelő egyedszámú legelő állatállomány biztosításával. Ha a feltételek teljesülnek és az élőhelyek ökológiailag javulnak, akkor a karakter növény- és állatfajok visszatelepüléssel reagálnak (Göri és mtársai, 2006; Boros és mtársai, 2024). Terepi megfigyeléseink bizonyították, hogy 2022-ben a székicsérek (1-3 pár) hosszú idő után újra megtelepedtek és fészkeltek a felső-kiskunsági Apaj térségében az Alsó-Szúnyog élőhely-rekonstrukción. 2023-ban is jelen voltak párok a területen, de biztos fészkelést 2024-ben lehetett újra dokumentálni. A szürkemarha és a házi bivaly legeltetésével optimális kondíciók alakultak ki a területen, ahol a székicsérek többek között széki lilékkal és más ritka partimadár-fajokkal, így nagy godákkal, bíbicekkel, piroslábú cankókkal, illetve gulipánokkal és gólyatöcsökkel alkottak egy fészkelő-közösséget egy körülbelül másfél hektáros kopár vakszikfoltos területrészen, amely sekély vizes élőhelyekkel volt szinte minden oldalról körülvéve.

Tradicionalis fészkelőhelyein mutatott gyakoribb megjelenései a fészkelési időszakban azonban újabb reménnyel tölti el a természetvédőket, hiszen különösen az elmúlt években, kiváltképp a Hortobágyon nagyobb számban voltak megfigyelései a fajnak.

A székicsérek 1995-öt követően állandó fészkelőként eltűntek magyarországi gyepterületi élőhelyikről, és ezt követően 2022-ig csupán hét alkalmi fészkelési eseményről van információnk, melye közül három igazolt kiskunsági és négy feltételezett hortobágyi adatunk van.

7.4. 4. Vizsgálat. Kiss Ádám, Végvári Zsolt, Monoki Ákos, Kapocsi István & Székely Tamás (2025). Mixed-species nesting in an agricultural landscape: Collared Pratincoles are attracted to Northern Lapwings Partimadár-közösség az agrártájban: a székicsérek költőhely-választását befolyásolják a bíbicek jelenléte) (a kézirat ‘major revision’ alatt az Ibis folyóiratban)

A koloniális fészkelés gyakori stratégia a madarak, különösen a vízimadarak körében, amelynek a célja a szaporodási siker rátájának növelése egyed és kolónia szinten (Lamarre és mtársai, 2017). A hasonló ökológiai igényű fajok fészkelési jelenlétükkel befolyásolhatják egymás fészkelőhely-választását (Cunningham és mtársai, 2016). A védelmi intézkedéseink során lehetséges ökológiai kapcsolatot figyeltünk meg a székicsér és a bíbic között, amelyet részletesebben szerettünk volna megvizsgálni. Ebben a tanulmányban megvizsgáltuk a fészkelőhely-választást befolyásoló tényezőket és a vegyes kolóniák térbeli elrendeződését és időbeli kialakulását. Elemeztük és kategorizáltuk a székicsér magányos, egyfajos és vegyes fajú fészkelési egységeit. Első eredményünk a székicsérek és bíbicek tojásrakási időpontjainak eltérése volt; az bíbicek jellemzően korábban, a székicsérek később kezdték a költést. A vegyes kolóniák leggyakoribb élőhelyét a kapáskultúrák biztosították, ezt követték az ugarok és a tavaszi vetésidejű kultúrák. Az ugarokon kialakult vegyes kolóniák szignifikánsan később alakultak ki, mint a másik két élőhelytípuson. A vegyes kolónia gyakori fajközösség volt a térségben. Egy másik fontos eredményünk, hogy a székicsérek és bíbicek, illetve a fészkelést korábban már megkezdő bíbicek fészkei szignifikánsan közelebb helyezkedtek el egymáshoz, mint a

véletlenszerűen generált pontokhoz. A kolóniaterület mérete korrelált a székicsérek fészkeinek számával a csak székicsér és a vegyes fajösszetételű kolóniák esetében is. Ezen felül a vegyes kolóniák mérete szignifikánsan meredekebben növekedett – figyelembe véve az adott kolóniában található összes partimadár faj fészkeit – mint az egyfajos kolóniák mérete. Kutatásunk természetvédelmi szempontból is egy fontos eredményre világított rá; a székicsér ernyőfaj a térségben, de mivel a vegyes kolóniák kialakulása gyakori jelenség, a faj hosszú távú megőrzése érdekében a társfészkelő fajok és különösen a bíbic élőhelyválasztását is jobban meg kell értenünk, illetve a jövőben koncentrálnunk kell a bíbicek védelmét célzó mezőgazdasági élőhely-fejlesztésekre is.

7.5. Élőhely-és fajvédelmi intézkedések és javaslatok

A disszertáció részeit képező publikációk és további két természetvédelmi közlemény (Kiss és mtársai. 2018; Kiss & Zalai, 2020) alapján összeállítottam egy kezelési javaslatcsomagot is, amely ajánlásokat tartalmaz a székicsérek szántóföldi és gyepterületi védelme és a védelem fejlesztése szempontjából. Szántóföldi védelem feladatainak jellemzése során kitértem a gazdálkodókkal folytatott kommunikáció fontosságára, a védőzónák kijelölésére és védelmi funkcióik részletezésére az egyes talajápolási és növényvédelmi munkák tekintetében, valamint a hivatásos vadászati szervekkel történő együttműködésre célorientált dúvadgyérítés formájában. Kezelési javaslatcsomag formájában szintűgy a dolgozat részét képezi a szántóföldi élőhelyek kiválasztási folyamatának, a talaj tárcsázásos+rögtörő hengerezéses kezeléssel végzett megfelelő előkészítésének és fenntartásának, valamint a szikes szárazpusztai és vizes élőhelyek kezelési lehetőségeinek leírása.

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9. References

- Aradi, C. (1979). Telepesen fészkelő madarak etológiai vizsgálata. MTA *Biológiai Osztály Közleményei*, 22, 239–256.
- Arnassant, S., Gauthier-Clerc, M., Kayser, Y., Vincent-Martin, N., & Wasse, G. (2019). La Glaréole á Collier en Camargue. https://tourduvalat.org/wp-content/uploads/2019/08/SciencesGestion_La_Glar%C3%A9ole_%C3%A0_collier_en_Camargue_Fr.pdf
- Bartholy, J., R. Pongrácz, & Gelybó, G. (2007). Regional climate change expected in Hungary for 2071–2100. *Applied ecology and environmental research*, 5(1), 1-17. https://doi.org/10.15666/aeer/0501_001017
- Bengtsson, J., Bullock, J. M., Egoh, B., Everson, C., Everson, T., O'Connor, T., O'Farrell, P. J., Smith, H. G., & Lindborg, R. (2019). Grasslands—More important for ecosystem services than you might think. *Ecosphere*, 10(2), e02582. <https://doi.org/10.1002/ecs2.2582>
- BirdLife International. (2016). *Glareola pratincola*. In The IUCN Red List of Threatened Species. IUCN. <https://www.iucnredlist.org/species/22694127/120026910>
- Birdlife International (2003). Saving Asia's Threatened Birds: A Guide for Government and Civil Society. Cambridge: Birdlife International.
- Boros, E., Szomor, D., & Mile O. (2024). In Élőhely-rekonstrukciók lehetőségei és tapasztalatai Magyarország síkvidéki területein (Ed Kelemen, A.), pp. 62–63.
- Buchanan, G. M., Chapple, B., Berryman, A. J., Crockford, N., Jansen, J. J. F. J., & Bond, A. L. (2024). Global extinction of Slender-billed Curlew (*Numenius tenuirostris*). *Ibis*, 167(2), 357–370. <https://doi.org/10.1111/ibi.13368>
- Cerva F. (1928). A székicsér (*Glareola pratincola* L.) tojásból való felnevelése. *Aquila*, 34–35, 184–194.
- Colwell, M.A. (2010). Shorebird Ecology, Conservation, and Management. University of California Press, Berkeley, USA.

- Cramp, S. & Simmons, K.E.L. (1983). *The Birds of the Western Palearctic*, volume 3. Oxford University Press, Oxford, UK.
- Cunningham, J. A., Kesler, D. C., & Lanctot, R. B. (2016). Habitat and social factors influence nest-site selection in Arctic-breeding shorebirds. *The Auk: Ornithological Advances* 133: 364–377. <https://doi.org/10.1642/AUK-15-196.1>
- Donald, P. F., Green, R. E., & Heath, M. F. (2001). Agricultural intensification and the collapse of Europe's farmland bird populations. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 268(1462), 25–29. <https://doi.org/10.1098/rspb.2000.1325>
- Douglas, D. J. T., Waldinger, J., Buckmire, Z., Gibb, K., Medina, J. P., Sutcliffe, L., Beckmann, C., Collar, N. J., Jansen, R., Kamp, J., Little, I., Sheldon, R., Yanosky, A., & Koper, N. (2023). A global review identifies agriculture as the main threat to declining grassland birds. *Ibis*, 165(4), 1107–1128. <https://doi.org/10.1111/ibi.13223>
- Ecsedi, Z., Zalai, T., & Oláh, J. (2020). Ecology and management of grazing soda marshes in the Hortobágy. Monograph. Balmazújváros: Hortobágy Természetvédelmi Egyesület
- EUR-LEX (2025). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0147>
- Eurostat (2025). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Fallow_land
- Ewers, R. M., & Didham, R. K. (2006). Confounding factors in the detection of species responses to habitat fragmentation. *Biological reviews*, 81(1), 117–142.
- Fekete, G., Molnár, Z., & Horváth, F. (1997). A magyarországi élőhelyek leírása, határozója és a Nemzeti Élőhely-osztályozási Rendszer. A Nemzeti Biodiverzitás-monitorozó Rendszer Kézikönyvei II. Természettudományi Múzeum, Budapest, 298.

- Fletcher, K., Aebischer, N. J., Baines, D., Foster, R., & Hoodless, A. N. (2010). Changes in breeding success and abundance of ground-nesting moorland birds in relation to the experimental deployment of legal predator control. *Journal of Applied Ecology*, *47*(2), 263–272. <https://doi.org/10.1111/j.1365-2664.2010.01793.x>
- Fluet-Chouinard, E., Stocker, B. D., Zhang, Z., Malhotra, A., Melton, J. R., Poulter, B., Kaplan, J. O., Goldewijk, K. K., Siebert, S., & Minayeva, T. (2023). Extensive global wetland loss over the past three centuries. *Nature*, *614*(7947), 281–286. <https://doi.org/10.1038/s41586-022-05572-6>
- Galván, I. (2017). Activity patterns of collared pratincoles *Glareola pratincola* in a breeding colony. *Animal Biodiversity and Conservation*, *40*(2), 147–152.
- Garvey, M. E., Nol, E., Howerter, D. W., & Armstrong, L. M. (2013). A spatial analysis of factors affecting nesting success of shorebirds in the Canadian prairies. *The Condor*, *115*(1), 58–66. <https://doi.org/10.1525/cond.2012.110146>
- Goss-Custard, J. D. (1979). Effect of habitat loss on the numbers of overwintering shorebirds. *Studies in Avian Biology*, *2*(1), 67–178.
- Góri, S., Lakatos, G., Szilágyi, E., Andrikovics, S., & Aradi, C. (2006). Recolonization of waterbirds after wetland rehabilitation (Hortobágy National Park, Hungary). In *Limnology and Aquatic Birds: Abstracts and Selected Papers from the Fourth Conference of Societas Internationalis Limnologiae (SIL) Aquatic Birds Working Group* (p. 180).
- Gutzwiller, K. J., & Flather, C. H. (2011). Wetland features and landscape context predict the risk of wetland habitat loss. *Ecological Applications*, *21*(3), 968–982. <https://doi.org/10.1890/10-0202.1>
- Hanane, S., Boukhriss, J., & Selmi, S. (2010). Breeding ecology of Collared Pratincoles *Glareola pratincola* in two coastal habitats in northwest Morocco. *Bird Study*, *57*(2), 236–243. <https://doi.org/10.1080/00063651003610569>

- Haraszthy, L. 2019. Székicsér (*Glareola pratincola*) [Collared Pratincole]. – In: Haraszthy, L. Magyarország fészkelő madarainak költésbiológiája 1., pp. 531–539. – Pro Vértes Nonprofit Zrt., Csákvár
- Hunt, K. L., Fraser, J. D., Friedrich, M. J., Karpanty, S. M., & Catlin, D. H. (2018). Demographic response of Piping Plovers suggests that engineered habitat restoration is no match for natural riverine processes. *The Condor: Ornithological Applications*, 120(1), 149–165. <https://doi.org/10.1650/CONDOR-17-93.1>
- IUCN Red List (2025). The IUCN Red List of Threatened Species. <https://www.iucnredlist.org/en>
- Kapocsi, I. (1997). A székicsér és a feketeszárnyú székicsér 1996-os megfigyelési adatai Karcag környékén. *A Puszta*, 14, 211–213.
- Kayser, Y., Gauthier-Clerc, M., Bechet, A., Poulin, B., Massez, G., Cherain, Y., Paoli, J., Sadoul, N., Vialet, E., & Paulus, G. (2008). Compte rendu ornithologique camarguais pour les années 2001-2006. *Revue d'écologie*, 63(4), 299–349.
- Kiss, Á., Molnár, A., Monoki, Á., Kapocsi, I., Kovács, G., Aradi, Cs., Széll A., Csíder i., Lóránt M., C Óze P. (2018). A szántóföldi környezetben fészkelő székicsér *Glareola pratincola* természetvédelmi helyzete és megőrzésének lehetőségei Magyarországon, különös tekintettel a nagykunsági fészkelő-állományra. *Aquila*, 125, 49–72.
- Kiss, Á., & Zalai, T. (2020). Observations and recommendations on the habitat improvement for Collared Pratincole (*Glareola pratincola*) in agro-environment in the Nagykovács, Hungary. *Virgo*, 2, 21–34
- Kiss, Á. 2021. Székicsér (*Glareola pratincola*). In Magyarország madáratlasza (ed. Szép, T., Csörgő, T., Halmos, G., Lovászi, P., Nagy, K., & Schmidt, A.), pp. 265–266. Agrárminisztérium, Magyar Madártani és Természetvédelmi Egyesület, Budapest.
- Kovács, G. & Kapocsi, I. (2004). Székicsér *Glareola pratincola*. In A Hortobágy madárvilága (ed. Ecsedi, Z.), pp. 272–276. Winter Fair, Balmazújváros-Szeged, Hungary.

- Kubelka, V., Šálek, M., Tomkovich, P., Végvári, Z., Freckleton, R. P., & Székely, T. (2018). Global pattern of nest predation is disrupted by climate change in shorebirds. *Science*, *362*(6415), 680–683. <https://doi.org/10.1126/science.aat8695>
- Lamarre, J., Legagneux, P., Gauthier, G., Reed, E. T., & Bêty, J. (2017). Predator-mediated negative effects of overabundant snow geese on arctic-nesting shorebirds. *Ecosphere*, *8*(5), e01788. <https://doi.org/10.1002/ecs2.1788>
- LIFE 3.0—LIFE Project Public Database. 2025. <https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE11-NAT-BG-000362/urgent-measures-to-restore-and-secure-long-term-preservation-of-the-atanasovsko-lake-coastal-lagoon>
- Lokhman, Y.V., Fedosov, V. N., & Mikhail, V.K. (2020). Collared pratincole *Glareola pratincola*. In European Breeding Bird Atlas 2: Distribution, Abundance and Change (eds. Keller, V., Herrando, S., Vorišek, P., Franch, M., Kipson, M., Foppen, R.P.B. et al.), p. 284. Lynx Edicions/European Bird Census Council (EBCC), Barcelona, Spain
- Lóránt, M. & Fejes, É. (2024). Guideline on Predator Control Strategies for the Conservation of the Great Bustard (*Otis tarda*). Technical Report, CMS Secretariat, 1–21.
- Mayfield, H. F. (1975). Suggestions for calculating nest success. *The Wilson Bulletin*, *87*(4), 456–466.
- Morales, M. B., & Traba, J. (2016). Prioritising research in steppe bird conservation: A literature survey. *Ardeola*, *63*(1), 137–150.
- Morales, M.B., & Bretagonelle, V. (2022). An update on the conservation status of the Little Bustard *Tetrax tetrax*: global and local population estimates, trends, and threats. *Bird Conservation International*, *32*(3), 337–359. <https://doi:10.1017/S0959270921000423>

- Myhrvold, N.P., Baldrige, E., Chan, B., Sivam, D., Freeman, D.L. & Ernest, S.M. (2015). An amniote life-history database to perform comparative analyses with birds, mammals, and reptiles. *Ecological Archives*, 96, 3109–3109. <https://doi.org/10.1890/15-0846R.1>
- Nemzeti Jogszabálytár–1996. Évi LXXXV. törvény (2025). <https://njt.hu/jogszabaly/1996-85-00-00>
- Parente, L., Sloat, L., Mesquita, V., Consoli, D., Stanimirova, R., Hengl, T., Bonannella, C., Teles, N., Wheeler, I., & Hunter, M. (2024). Annual 30-m maps of global grassland class and extent (2000–2022) based on spatiotemporal Machine Learning. *Scientific Data*, 11(1), 1–22. <https://doi.org/10.1038/s41597-024-04139-6>
- Petermann, J. S., & Buzhdygan, O. Y. (2021). Grassland biodiversity. *Current Biology*, 31(19), R1195–R1201.
- Piersma, T. (2007). Using the power of comparison to explain habitat use and migration strategies of shorebirds worldwide. *Journal of Ornithology*, 148(1), 45–59., <https://doi.org/10.1007/s10336-007-0240-3>
- Roberge, J.-M., & Angelstam, P. E. R. (2004). Usefulness of the umbrella species concept as a conservation tool. *Conservation Biology*, 18(1), 76–85. <https://doi.org/10.1111/j.1523-1739.2004.00450.x>
- Schils, R. L. M., Bufe, C., Rhymer, C. M., Francksen, R. M., Klaus, V. H., Abdalla, M., Milizzo, F., Lellei-Kovács, E., Berge, H., Bertora, C., Chodkiewicz, A., Dămățircă, C., Feigenwinter, I., Fernández-Rebollo, P., Ghiasi S., Hejduk, S., Hiron, M., Janicka, M., Pellaton, R., Smith, K. E., & Price, J. P. N. (2022). Permanent grasslands in Europe: Land use change and intensification decrease their multifunctionality. *Agriculture, Ecosystems & Environment*, 330, 107891. <https://doi.org/10.1016/j.agee.2022.107891>
- Sponza, S., & Salvador, P. (2023). A new successful breeding site of Collared Pratincole *Glareola pratincola* along the northern Adriatic coastline. *Rivista Italiana Di Ornitologia*, 93(1), 17–22. <https://doi.org/10.4081/rio.2023.648>

- Sterbetz, I. (1974). Die Brachschnalbe *Glareola pratincola*. Die neue Brehm-Bücherei, A. Ziemsen Verlag, Wittenberg, Lutherstadt, p. 111.
- Stoate, C., Baldi, A., Beja, P., Boatman, N. D., Herzon, I., Van Doorn, A., de Snoo, G.R., Rakosy, L., & Ramwell, C. (2009). Ecological impacts of early 21st century agricultural change in Europe—a review. *Journal of Environmental Management*, *91*(1), 22–46. <https://doi.org/10.1016/j.jenvman.2009.07.005>
- Szabó, L. V. (1965). Fészkelő madártársulások vizsgálata a kunmadarasi szikeseken. *Állattani Közlemények*, *52*: 111–134.
- Székely, T. (2019). Why study plovers? The significance of non-model organisms in avian ecology, behaviour and evolution. *Journal of Ornithology*, *160*(3), 923–933. <https://doi.org/10.1007/s10336-019-01669-4>
- Székely, T., Kosztolányi, A. & Küpper, C. (2008). Practical guide for investigating breeding ecology of Kentish Plover *Charadrius alexandrinus*. University of Bath, UK
- Székely, T. & Kubelka, V. (2019). Protocol for collecting behavioural data for ÉLVONAL shorebird project https://elvonalsorebirds.wordpress.com/wp-content/uploads/2019/02/szekely-kubelka-2019_elvon-al-behavioural-protocol_v2-1.pdf
- Székely, T., Carmona-Isunza, M. C., Engel, N., Halimubieke, N., Jones, W., Kubelka, V., Rice, R., Tanner, C. E., Tóth, Z., Valdebenito, J. O., Wanders, K., & McDonald, G. C. (2024). The causes and implications of sex role diversity in shorebird breeding systems. *Ibis*, *166*(2), 357–385. <https://doi.org/10.1111/ibi.13277>
- Székely, A. (1993). A székicsér (*Glareola pratincola*) fészkelőhelyválasztása agrár élőhelyeken. *Partimadár*, *1*, 8–15.
- Tarjuelo, R., Margalida, A., & Mougeot, F. (2020). Changing the fallow paradigm: A win–win strategy for the post-2020 Common Agricultural Policy to halt farmland bird declines. *Journal of Applied Ecology*, *57*(3), 642–649. <https://doi.org/10.1111/1365-2664.13570>

- Török, P., Kapocsi, I., & Deák, B. (2012). Conservation and management of alkali grassland biodiversity in Central-Europe. In *Grasslands: Types, biodiversity and impacts* (Ed. Zhang W.J.), pp. 109–118., New York: Nova Science Publishers Inc.
- Török, P., & Dengler, J. (2018). Palaeartic grasslands in transition: Overarching patterns and future prospects. *Grasslands of the world: Diversity, management and conservation* (Ed. Zhang W.J.), pp. 15–26., New York: Nova Science Publishers Inc.
- Traba, J., & Morales, M. B. (2019). The decline of farmland birds in Spain is strongly associated to the loss of fallowland. *Scientific reports*, 9(1), 9473. <https://doi.org/10.1038/s41598-019-45854-0>
- van den Berg, R. (2024). The breeding ecology of the northern lapwing (*Vanellus vanellus*) in France: Investigating the decline of a widely-distributed wader [PhD Thesis, Université de Strasbourg]. <https://theses.hal.science/tel-04690418/>
- Végvári, Z., & Barta, Z. (2016). Multivariate climatic effects and declining avian populations in an alkaline grassland complex. *Climate Research*, 68(1), 39–48. <https://doi.org/10.3354/cr01372>
- Villanueva, B. C. (1993). Influences of Agricultural Land-Use and Habitat Modification on the Breeding Biology and Conservation of Collared Pratincoles *Glareola pratincola* in SW Spain. University of Glasgow (United Kingdom).
- Zafarana, M., Pitrella, C., Pepi, D., & Pietro, M. (2019). Talking to the farmers about the conservation of the Collared Pratincole *Glareola pratincola*. <https://doi.org/10.13140/RG.2.2.24307.07201>

PART II

10. List of Publications

Study 1. Kiss, Á., Végvári, Z., Kubelka, V., Monoki, Á., Kapocsi, I., Góri, S., & Székely, T. (2024). Breeding in an agricultural landscape: conservation actions increase nest survival in a ground-nesting bird. *Oryx*, 58(2), 240-249. <https://doi.org/10.1017/S0030605323000911>

Study 2. Kiss, Á., Monoki, Á., & Végvári, Zs. (2017). Nest-site selection and population trend of Collared Pratincoles (*Glareola pratincola*) breeding in agricultural habitats of the Nagykunság region (Hungary). *Ornis Hungarica*, 25(1), 25-38. <https://doi.org/10.1515/orhu-2017-0002>

Study 3. Kiss, Á., Takács, Á., & Pigniczki, C. (2024). The recolonization of the Collared Pratincole (*Glareola pratincola*) in its natural steppe habitats in Hungary—an overview of the species' grassland activities between 1995 and 2024. *Ornis Hungarica*, 32(2), 298-308. <https://doi.org/10.2478/orhu-2024-0037>

Study 4. Kiss, Á., Végvári, Zs., Monoki, Á., Kapocsi, I., & Székely, T. (2025). Mixed-species nesting in an agricultural landscape: Collared Pratincoles are attracted to Northern Lapwings (manuscript submitted to *Ibis*)

11. The author's contribution the specific studies

	Chapter 1	Chapter 2	Chapter 3	Chapter 4
Original idea	•	•	•	•
Study design and data collection	•	•	•	•
Data analysis	•	•	•	•
Manuscript writing	•	•	•	•

12. Appendices

Breeding in an agricultural landscape: conservation actions increase nest survival in a ground-nesting bird

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ISTVÁN KAPOCSI², SZILVIA GÓRI² and TAMÁS SZÉKELY^{1,6}

Abstract Agricultural intensification has affected wildlife across Europe, triggering steep declines and regional extinctions of farmland birds. Effective conservation activities are essential for the preservation of biodiversity in an agricultural landscape, but current efforts have not succeeded in halting these declines. Here we investigate a ground-nesting shorebird, the collared pratincole *Glareola pratincola*, which has shifted its habitat use in Central Europe over the last 20 years from alkaline grasslands to intensively managed agricultural fields. We show that nesting success was different between three agricultural habitat types, with the highest nesting success in fallow lands and the lowest in row crops. Nesting success was also associated with the timing of breeding and breeding density, as nests produced early in the breeding season and those in high-breeding-density areas hatched more successfully than those produced later in the season and at low density. We implemented direct conservation measures including marking nests and negotiating with farmers to avoid cultivating the field between nest markers, controlling nest predators and, most recently, creating suitable nesting sites and foraging areas for pratincoles. As a result of these conservation actions, nest survival increased from 11.2% to 83.5% and the size of the breeding population increased from 13 to 56 pairs during 2012–2021. Thus, we show that agricultural landscapes can continue to provide suitable habitats, and targeted conservation actions have the potential to reverse the declines of farmland species.

Keywords Agricultural land use, conservation action, farmland birds, *Glareola pratincola*, nest survival, predator control, shorebirds, waders

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Introduction

Natural habitats are disappearing or degrading at global scales and at an unprecedented rate as a result of the combined effects of current climatic processes and changes in land use during the Anthropocene (Fahrig, 1997; Balmer & Erhardt, 2000; Davidson, 2014; Hu et al., 2017). One of the main driving factors is the expansion of intensive forms of agricultural land use, which has led to the reduction and sometimes even complete disappearance of various native habitats across Europe (O'Connor & Shrubbs, 1986; Potter, 1997). These declines are especially severe amongst grassland breeding animals that are considered to be sensitive to environmental changes, as evidenced by recent steep declines of steppe species (Fuller, 2000; Massa & La Mantia, 2010; Ward et al., 2010; Guerrero et al., 2012). As a consequence of the loss of grassland habitats, birds that traditionally bred in open natural habitats now increasingly breed on arable land and in agricultural areas (Galbraith, 1987; Böhning-Gaese & Bauer, 1996; Brady & Flather, 1998).

However, agricultural landscapes can lead to mal-assessment in habitat choice as they appear suitable to prospective breeders but the conditions they offer often result in inferior reproductive success (Székely, 1992), and thus they may be ecological traps (Schlaepfer et al., 2002; Robertson & Hutto, 2006; Pärt et al., 2007; Gilroy et al., 2011; Hollander et al., 2017). Additionally, the intensification of agricultural practices can affect the nesting success of ground-breeding birds in numerous ways, including direct loss of nests, chicks and/or adults through mowing, cultivation by agricultural machinery, use of pesticides, irrigation and/or drainage (Berg et al., 1992; Wilson et al., 2005; Kentie et al., 2013). There are numerous examples of the negative affects of agriculture on ground-breeding birds, including local extinctions of flagship species such as the great bustard *Otis tarda* and grey partridge *Perdix perdix* (Donald et al., 2001; Arroyo et al., 2002; De Leo et al., 2004; Alonso & Palacín, 2010; Potts, 2012; Gooch et al., 2015). These pressures on farmland birds have intensified as a result of global climate change, which has amplified predation rates in human-modified habitats. Specifically, environmental changes have boosted the populations of mesopredators, which have further reduced the nest or offspring survival rates of ground-breeding birds (Roodbergen et al., 2012; Kentie et al., 2015; Kubelka et al., 2018; Brzeziński et al., 2020). To mitigate

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these negative effects, targeted conservation actions are needed (Arroyo et al., 2002; Schekkerman et al., 2008; Zámečník et al., 2018).

Here we report the results of a 10-year conservation effort focused on the collared pratincole *Glareola pratincola*, which is affected by habitat alterations and has undergone population declines across many parts of Europe (Yuri et al., 2020). The collared pratincole is a ground-nesting shorebird that used to breed in loose colonies on alkaline grasslands close to wetlands in Central Europe (Cramp & Simmons, 1983), and a large inland breeding population existed in Hungary until the mid 1900s (Aradi, 1979; Kiss et al., 2018). Collared pratincoles feed on flying insects including dragonflies, flies and beetles of various sizes. They scrape their nests into livestock hoofprints or into the bare ground (Beretzky, 1954; Cramp & Simmons, 1983). The collared pratincole is categorized as Least Concern on the IUCN Red List but the global population is declining (BirdLife International, 2021). It has been difficult to assess population changes because of the high dispersal propensity and semi-nomadic strategy of the species, leading to large fluctuations in breeding densities (Yuri et al., 2020). Collared pratincoles are now breeding on agricultural land in Europe (Calvo & Alberto, 1990; Calvo, 1994; Calvo & Furness, 1995; Lebedeva, 1998; Kiss et al., 2017; Yuri et al., 2020), and most breeding attempts now occur on arable

farmland even in some of the coastal breeding populations (Vincent-Martin, 2007; Nardelli et al., 2008; Kiss et al., 2017). During the past decade, the Hungarian population has fluctuated between 22 and 65 pairs, at two major breeding sites (the Nagykunság and Kiskunság regions). These sites are the last remaining regular breeding locations of collared pratincoles in the Carpathian Basin (Kiss et al., 2018).

We have four objectives: firstly, to quantify nesting success of the collared pratincole and investigate the ecological variables that could predict nesting success, including habitat type, timing of breeding, proximity to open water and breeding density; secondly, to compare nest survival rates between different agricultural habitats; thirdly, to investigate the effects of conservation measures on nest survival; and finally, to investigate potential associations between predator control and nest survival.

Study area

We carried out data collection and conservation activities in the Nagykunság region in eastern Hungary (Fig. 1). The climate is eastern continental, characterized by dry and warm periods during the breeding season interspersed with short, heavy rainfall of 20–100 mm/h (Hungarian Meteorological Service, 2021). We focused on the southern part of Nagykunság, where the landscape is dominated by

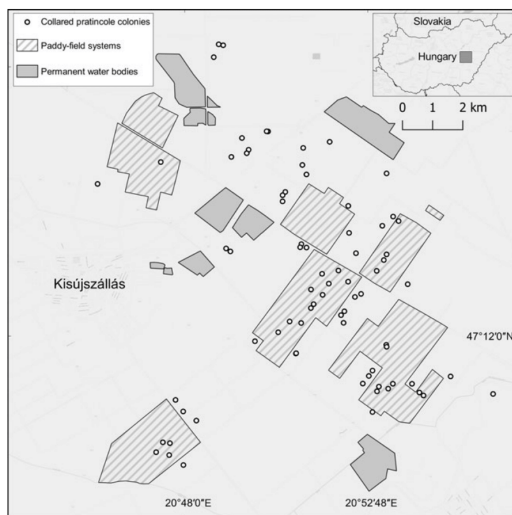


FIG. 1. The c. 12,500-ha study area in eastern Hungary.

cultivated lands, primarily rice fields (Fig. 1). Because of the requirements of rice cultivation, each year > 1,500 ha of farmland is flooded, providing important habitats for breeding and migrating shorebirds (Kiss et al., 2017). In Nagykunság, the estimated number of collared pratincoles fluctuated between 13 and 56 breeding pairs during 2012–2021 (mean $32.4 \pm SE 5.3$; data from the database of the Hortobágy National Park Directorate).

Methods

Data collection

Starting in 2012, we collected data on breeding sites, including nest-site location, nesting success and behaviour. We recorded the data using a handheld digital assistant and then transferred the data to *ArcMap 10.1* (Esri, Redlands, USA). We also collected observations in croplands used by collared pratincoles and in shallow wetlands. Using nest points and various agricultural variables we created a map of nest points and shapefiles of arable lands and shallow water bodies.

We prepared maps of nest locations and polygons of croplands and water bodies for further analyses using *ArcMap*. We carried out monitoring activities of birds on potential nesting sites, location and revisiting of nests using binoculars and spotting scopes. We always approached nests to a distance of 8–10 m using four-wheel drive cars (even within agricultural fields) to limit any possible disturbance to incubating birds. In addition to the locations of nests, we identified the agriculture habitat types used for nesting (Plate 1, Supplementary Table 1). We identified these using Calvo's (1994) methodology based on the planting patterns of crops: we classified fields with crops planted in rows at least 60 cm apart as row crops, areas where crops were sown without leaving any row gaps as spring cover crops and areas that were left unsown after tilling as fallow. After locating the nests, we recorded the clutch size, nest cover and location coordinates for each nest and then placed a small stick c. 1 m from the nest to mark the nest location in the field. After locating a new nest, we consulted the owner or manager of the land. To prevent nest destruction by farming activities, we marked a buffer zone around the nests using 1.5 m-tall wooden poles. However, to avoid attracting the attention of potential nest predators, we only placed the nest markers during periods of active agricultural work (Zámečník et al., 2018). The sizes of these oval-shaped nest protection zones were 100 m², which is sufficient to ensure adequate protection from agricultural machinery (Plate 2).

During the incubation period, we checked all of the nests remotely using a spotting scope every other day. The incubation period was 18 days (based on Myhrvold et al., 2015), and our field observations supplemented with use of the egg-floating methodology; see details in Székely et al.,

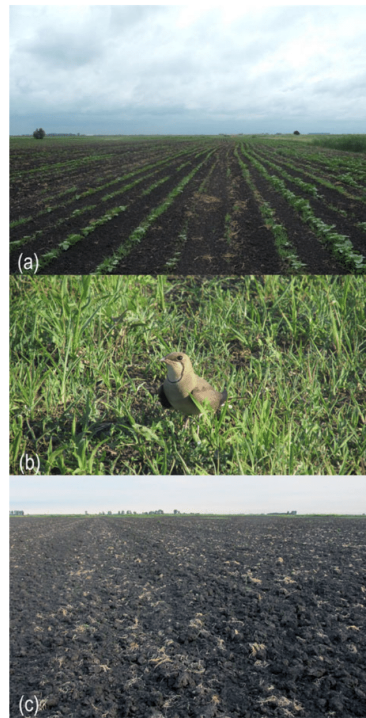


PLATE 1 Main breeding habitats of collared pratincoles *Glareola pratincola* in Hungary: (a) row crop, (b) spring cover crop, (c) fallow land.

2006), and after the last nest visit, we classified each nest as hatched, predated, abandoned, unknown, flooded or destroyed by agricultural machinery. To identify the fate of each nest, we used the methods of Green et al. (1987) to identify potential nest predators in addition to our field observations (Kiss et al., 2018). We established successful hatching if there were small eggshell fragments or small chick droppings in the nest cup, predation if we found predator tracks or signs of predation by mammals or birds near the nest, desertion if the pair was not nearby and the egg was cold and abandonment because of rainfall if the egg was stuck in mud. We determined a nest successful if at least one chick hatched.



PLATE 2 Protection zone around collared pratincole nest, marked temporarily by 1.5 m-tall wooden poles. This photograph was taken using a telephoto lens that distorts the actual distance between the two wooden poles.

The survival and productivity of ground-nesting birds are influenced by predation (Martin, 1993; Roodbergen et al., 2012; Kubelka et al., 2018). To investigate relationships between pratincole breeding success and number of nest predators removed from the study area, we collected data from hunters. Potential huntable nest predators include mammals (red fox *Vulpes vulpes*, golden jackal *Canis aureus*, European badger *Meles meles*) and birds (Eurasian magpie *Pica pica*, hooded crow *Corvus cornix*). We requested hunting bag data from professional hunters for the period 2017–2021 and we aggregated the number of individuals killed for each year. Hunting bag data relate to the regional hunting district (c. 26,000 ha), which covers c. 65% of collared pratincole nest sites (National Game Management Database, 2022).

Estimating daily and total nest survival

To investigate the effects of year and agricultural habitat on nesting success, we estimated daily and total nest survival rates using calculations provided by Mayfield (1975). We applied this method to estimate the chances of a clutch surviving daily and for the full nesting period (egg laying + incubation period) by defining the daily nest survival rate as the number of failed nests divided by the sum of exposure days (Johnson, 1979). We calculated total nest survival using Mayfield's formula: $(\text{daily nest survival})^{\text{nesting period in days}}$, where the total nesting period is egg laying period + incubation (20 days in total). We defined exposure time as the number of days from finding a nest to the confirmed (or expected) last day of the breeding attempt. The incubation period started when the complete clutch had been laid. For those nests that hatched (i.e. at least one chick hatched), we calculated the exposure time from the day of nest finding to the confirmed (or predicted, using the egg floating methodology; Székely

et al., 2006) date of hatching (Mayfield, 1975; Kubelka et al., 2018). For predated nests, we calculated exposure from the day of nest finding until the midpoint between the last positive and the first negative visit to the nest. For all other outcomes (i.e. unknown, abandoned, flooded, destroyed by agricultural machinery), we defined exposure time from the day of nest finding until the last positive nest visit, following standard protocols (Kubelka et al., 2018). We focused trail cameras on 116 nests to identify species of nest predators and the date of hatching.

Statistical analyses

We performed the statistical analyses in R 3.3.3 (R Core Team, 2021). To identify relationships amongst individual-level reproduction success metrics (i.e. nests hatched or failed and the number of hatched chicks), we used generalized linear models (GLMs) with factors of year, habitat type, Julian day of egg laying, distance from the closest field boundary, distance from the closest water body and colony density. The latter factor represented the mean distance from the focal nest to the three closest nests within the same breeding colony. As nesting success was a binary response variable (hatched or failed), we used a logistic regression GLM with the *logit* link error function. Field boundaries and water bodies were available in shape files. We computed the mean distance from the three neighbouring nests using the *mindist* spatial neighbourhood function available in the *spatstat* package in R. For the start of incubation, we used the Julian day of clutch completion at a given nest. We used ANOVA, implemented using the *lm* function, to analyse the associations between (1) clutch size and habitat type, (2) timing of hatching and habitat type, and (3) daily nest survival (aggregated for years and habitats).

Results

Timing of breeding and breeding success

During 2012–2021, we found 315 nests, for 212 of which we also determined the hatching date of the first chick. Egg laying started in late April and terminated in mid July (c. 2.5 months duration), with most nests (60%) laid during 25 May–15 June. The first eggs hatched on 16 May, which implies that the clutch was completed on 29 April. The latest hatch date was recorded on 3 August. The mean hatching date was 15 June \pm SE 1 day ($n = 212$ nests; Table 1, Supplementary Fig. 1).

Collared pratincoles bred in three agricultural habitats: most nests were in row crops (48%), followed by fallow lands (29%) and spring cover crops (23%, $n = 315$ nests; Table 1). The timing of breeding was different between

TABLE 1 Timing of breeding, clutch size and nesting success of collared pratincoles *Glareola pratincola* in agricultural habitats in Hungary (mean \pm SE; Fig. 1). We found 315 nests over our study period, but as we were only able to establish hatching times for 212 of these nests, we show hatching times separately.

	Row crop	Spring cover crop	Fallow land	Overall
Timing of hatching (Julian day)	158.5 \pm 0.9	164.6 \pm 2.3	175.8 \pm 1.9	165.6 \pm 1.0
Timing of hatching (calendar day)	9 June	15 June	26 June	15 June
Number of nests with known hatching times	94	50	68	212
Clutch size	2.66 \pm 0.05	2.58 \pm 0.08	2.49 \pm 0.08	2.59 \pm 0.04
Number of hatched chicks per nest	1.54 \pm 0.10	1.50 \pm 0.14	1.72 \pm 0.12	1.58 \pm 0.07
Total number of nests	152	72	91	315

habitat types: nests in row crops or spring cover crops hatched earlier than in fallow lands (one-way ANOVA, $b > 6.311$, $F_{2,210} = 39.02$, $P_{\min} = 0.009$; Supplementary Fig. 1). Similarly, clutch size was related to habitat type: the largest clutch sizes were in row crops (one-way ANOVA, $b < -0.0491$, $F_{2,268} = 2.601$, $P_{\min} = 0.0254$; Table 1). A total of 75% ($n = 68$) of nests on fallow lands hatched at least one chick, whereas the corresponding figures were 69% ($n = 50$) on spring cover crops and 62% ($n = 94$) in row crops (Table 1). The overall nesting success was 67% ($n = 315$ nests). Nesting success was related to the type of habitat: nests in spring cover crops or fallow lands were more successful and produced more hatchlings than nests in row crops. In addition, nesting success was also associated with both time in the season and breeding density, as early nests and those in areas with higher breeding densities produced more chicks (Table 2).

Daily nest survival increased significantly over the study period (linear regression, $b = 0.0064$, $n = 8$, $P = 0.0189$; Fig. 2). Total nest survival increased from 11.2 to 83.5% (Supplementary Table 2). However, using two-way ANOVAs we found no association between habitat type and daily nest survival (two-way ANOVA, $b = -0.046$, $SE = 0.036$, $P = 0.21$) or total nest survival (two-way ANOVA, $b = -0.103$,

$SE = 0.144$, $P = 0.48$), using year as the unit of analysis. The highest level of total nest survival was recorded in fallow lands (Supplementary Table 2).

Causes of nest failure

Most nest failures ($n = 102$) were caused by predation (58%), followed by nest abandonment (23%) and flooding by heavy rainfall (17%), with 1% having an unknown fate. As a result of the nest-marking scheme, agricultural machinery destroyed only a few nests (1%; Supplementary Table 3). In total, 83% ($n = 49$) of all nest predation and 89% ($n = 17$) of all flooded nests were found in row crops and spring cover crops, respectively. The most common predators of eggs and chicks were red foxes, European badgers, hooded crows, western marsh harriers *Circus aeruginosus* and Caspian gulls *Larus cachinnans*.

Conservation action

During the study period, we directly protected 159 nests (c. 50% of the total) with a protection zone. The number of protected nests fluctuated across years and habitats, although the largest proportion (92%) of protected nests

TABLE 2 Nesting success and the number of hatched chicks of collared pratincoles in Hungary and their relationships to agro-technology, time, space and other ecological variables. Logistic and linear regression analyses were used to explore the relationship between these variables, as appropriate. Significant relationships are indicated in bold.

Variable	Nesting success				Number of hatched chicks			
	Estimate	SE	z	P	Estimate	SE	t	P
Intercept	-463.12	124.42	-3.72	< 0.01	-292.04	63.84	-4.58	< 0.01
Agricultural habitat								
Spring cover crops	1.03	0.40	2.56	0.01	0.42	0.20	2.11	0.04
Fallow lands	1.35	0.45	3.03	0.01	0.72	0.22	3.32	0.01
Ecology & timing								
Year	0.23	0.06	3.74	< 0.01	0.15	0.03	4.62	< 0.01
Egg-laying date	-0.01	0.01	-1.36	0.18	-0.01	0.01	-2.29	0.02
Field boundary	0.01	0.01	0.95	0.34	0.01	0.01	1.01	0.32
Distance from water body	< 0.01	< 0.01	0.40	0.69	< 0.01	< 0.01	1.56	0.12
Social behaviour								
Breeding density	< 0.01	< 0.01	-1.39	0.16	< 0.01	< 0.01	-2.47	0.01

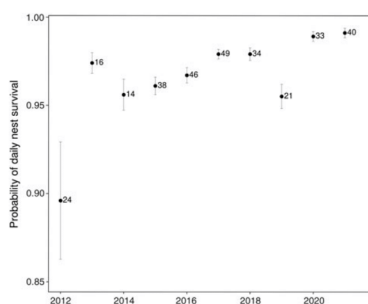


FIG. 2 Daily nest survival (mean \pm SE) in relation to the study year ($r^2 = 0.55$, $n = 10$ years). The number of nests per year is indicated.

was in row crops (Table 3). Nest protection was successful, as 64% of protected nests produced at least one chick ($n = 101$; Table 3). The number of nests we rescued via direct protection measures was 150 (Table 3).

Hunters culled a mean of 454 mammals and 655 birds annually in the hunting district that overlapped with our study site (i.e. 1.7 mammals and 2.5 birds per 100 ha; Table 4). Daily nest survival was not predicted by the number of culled avian (linear regression, $b = 0.0001$, $n = 5$, $P = 0.655$) or mammalian predators (linear regression, $b = 0.0005$, $n = 5$, $P = 0.503$).

Discussion

Here we show that the nesting success of a ground-nesting bird is predicted by the agricultural habitat type of its nest

TABLE 4 Number of predators culled during 2017–2022 in the c. 26,000-ha hunting district that overlaps with the collared pratincole nest sites.

Year	Mammals	Birds	Total
2017	280	263	543
2018	488	312	800
2019	415	699	1,114
2020	504	1,046	1,550
2021	582	953	1,535
Total number of culled predators	2,269	3,273	5,542

as well as breeding density and timing of breeding. We increased daily nest survival of pratincoles over the study period through conservation measures, so that the majority of nests now hatch successfully.

Collared pratincoles that breed on fallow lands and in spring cover crops had significantly higher nesting success than those nesting in row crops. Nesting success for other shorebirds is also influenced by the timing and intensity of agricultural operations. For example, nest losses of northern lapwings *Vanellus vanellus* depend on the timing of spring tillage during the nesting period (independently of crop type; Sheldon et al., 2007). We observed that predation pressure was lower in extensively used habitats compared with intensively treated areas. Similar patterns have been documented in black-tailed godwits *Limosa limosa* (Kentie et al., 2015) and other ground-nesting species (Berg et al., 1992). It is probable that the rise of modern intensive agriculture has favoured generalist predators (Pescador & Peris, 2001). In addition, rainfall was more likely to flood nests in fields of row crops, as the heavy agricultural machines used for these crops compact the soil and thus water drains more slowly in

TABLE 3 Nest protection activities for collared pratincoles in Hungary in relation to year and habitat type ($n = 315$ nests). Nests rescued refers to nests that would have been destroyed by agricultural machinery without direct protection.

Year	Number of nests	Number of nests protected (%)	Number of nests rescued (%)	Number of protected nests hatched (%)	Number of unprotected nests hatched (%)
2012	24	14 (58)	14 (58)	0	3 (30)
2013	16	9 (56)	9 (56)	5 (56)	5 (71)
2014	14	3 (21)	3 (21)	0	8 (73)
2015	38	31 (82)	31 (82)	17 (55)	7 (100)
2016	46	24 (52)	20 (43)	18 (75)	12 (55)
2017	49	12 (24)	12 (24)	8 (67)	29 (78)
2018	34	17 (50)	17 (50)	12 (71)	14 (82)
2019	21	13 (62)	13 (62)	7 (54)	3 (38)
2020	33	9 (27)	8 (24)	9 (100)	20 (83)
2021	40	27 (68)	23 (58)	25 (93)	10 (77)
Habitat					
Row crops	152	146 (96)	140 (92)	92 (63)	2 (33)
Spring cover crops	72	8 (11)	5 (7)	6 (75)	44 (69)
Fallow lands	91	5 (5)	5 (5)	3 (60)	65 (76)
Total	315	159 (50)	150 (48)	101 (64)	111 (71)

these habitats. The frequency of heavy rains appears to have declined during the study period, which could also have contributed to the higher nest survival we observed over these years.

Collared pratincoles breed in colonies of various sizes, and thus we expected inter-nest distance to be an important predictor of nesting success. A similar pattern was observed by Berg (1992), who found that predation risk was negatively correlated with the number of neighbours within a breeding colony of northern lapwings. Nest predation was also negatively correlated with nest density in other wader species (Macdonald & Bolton, 2008). In another colonial shorebird, the pied avocet *Recurvirostra avosetta*, nesting success was highest at intermediate densities (Hötter, 2000), suggesting that density might have a non-linear effect on breeding success in certain cases.

Several shorebird species are declining in their native breeding habitats across Europe, having been forced to choose riskier breeding sites as their preferred habitats are converted into agriculture (Berg, 1992; Schifferli et al., 2006; Kentie et al., 2015). For the collared pratincole and similar species such as the Eurasian curlew *Numenius arquata*, nesting success tends to be higher in their natural habitats than in agricultural ones (Berg, 1992; Calvo, 1994; Vincent-Martin, 2007). In our study area, pratincoles only occupied agricultural habitats, which allowed us to compare the impacts of various types of human-made habitats on nesting success. However, we have no data on nest survival in the native grasslands of this species because these are now rare. In other studies that did include grasslands, higher nesting success was reported in these natural habitats (Calvo, 1994; El Malki et al., 2013).

Most fields in our study site were managed in different phases during the breeding season; therefore, the peak hatching dates occurred at different times. Nesting strategies were highly dependent on the local agricultural schedule because row crops and spring cover crops were sown first, followed by the ploughing of fallow lands. In row crops and spring cover crops, vegetation grows particularly uniformly and rapidly, reducing the time period during which the pratincoles can nest successfully. By contrast, vegetation on fallow lands grows heterogeneously in mosaic patches, creating more suitable nesting conditions. The highest number of nests was in row crops, which was the most common type of agricultural breeding habitat available for collared pratincoles and other shorebirds at our site.

The clutch size of pratincoles is similar in Hungary, Spain (Bertolero & Martínez Vilalta, 1999) and France (Vincent-Martin, 2007) and higher than that in Ukraine and Morocco (Pozhidaeva & Molodan, 1992; El Malki et al., 2013). However, the number of successfully hatched chicks was lower than in Ukraine (Pozhidaeva & Molodan, 1992) and in Algeria (Bensaci et al., 2014).

Conservation actions

Nesting success was different between the three major breeding habitats, with the results suggesting that the most productive habitats were spring crops and fallow fields. This difference persisted even though conservation measures focused on row crops, which increased the nesting success for this habitat. Separating the impact of conservation actions from that of the nesting habitats themselves would be difficult, as the majority of nest protection measures focused only on row crops. The finding that neither daily nest survival nor total nest survival was different between habitats might seem counterintuitive, although the analyses that we carried out at year level (rather than at the individual nest level as in the other analyses) would have lower statistical power. Nevertheless, we only had accurate data until the chicks hatched, so we can only draw conclusions regarding the effects of the habitats from the incubation period. Direct nest protection interventions increased nest survival similarly to other studies, such as the wood turtle *Glyptemys insculpta* conservation project that found nesting success can be increased by designing appropriate interventions (Bougie et al., 2020). In the absence of direct nest protection, breeding success was probably low in critical habitats, similar to that described by Calvo (1994), who found that as a result of changing agricultural practices, nesting success also improved. Nesting success and the daily survival rate of nests have increased significantly over the past decade probably because of conservation actions.

Although the number of culled predators did not predict nest survival, we believe this is because of the relatively crude nature of the data (i.e. hunting bag data) and small number of sample years. Predator control is likely to be important for the long-term survival of ground-nesting birds (Neuman et al., 2004; Bolton et al., 2007). We are currently designing a project to investigate the effects of predator control on the nesting success of pratincoles. In addition, there are various other natural and human-induced factors that could influence the nest survival of ground-nesting birds, and we need more precise data on the effects of culling on the density of the most common nest predators.

Compared with unmarked nests, we did not find increased predation rates in nests marked with poles, similar to that observed by Zámečník et al. (2018), perhaps because the poles were left near nests for only short time periods. Local farmers were supportive of this nest protection, and so none of the known nests were at serious risk during agricultural work. However, the collared pratincole conservation project should be further improved through the establishment of fields and fallow lands that are free from agricultural disturbance. As a result of the current agricultural scheme, agricultural land in Hungary and elsewhere in Europe tends to be used intensively, so arable fields are typically producing crops for most of the year (Tarjuelo et al., 2020).

Hortobágy National Park is involved in a species-focused recovery programme that includes improving alkaline grasslands to attract pratincoles, although the habitat restoration seems to have been unsuccessful so far (Kovács & Kapocsi, 2004). Based on the results presented here, we believe that joint actions by conservationists and farmers are key (Kiss et al., 2018). Maintaining good relationships between farmers and conservationists is essential to achieving success in conservation projects (Logsdon et al., 2015; Homberger et al., 2017). Direct nest protection activities had to be implemented mostly in row crops because these types of agricultural land (especially sunflower and corn fields) are cultivated intensively during the breeding season. By contrast, in spring cover crops and fallow lands (with a few exceptions), we observed no disturbance by agricultural machinery after ploughing or sowing.

On a global scale, human activity can negatively influence the behaviour, productivity and nest survival of ground-nesting birds in various habitats, especially on farmland (Fahrig, 1997; Donald et al., 2001; Colwell, 2010; Ward et al., 2010). We have set ourselves the goal of habitat development at the local level, as a result of which 50–100 ha of fallow lands are created every year to facilitate the settlement of shorebirds on the Nagykunság rice systems. These empty fields are created through disc ploughing from the middle to the end of April, and after the treatment there is no human disturbance during the breeding season. These areas are small in relation to the size of the total habitat, but this seems to be a promising project as increasing numbers of birds have nested and gathered in these fallow areas in recent years. Improvements could be supported through the development of targeted agricultural programmes, which would set management standards specifically for the arable lands used by the species and financially support the conservation efforts of farmers.

Our results suggest that direct conservation activities can achieve desired outcomes even in intensively farmed agricultural habitats. Without such interventions, a large proportion of farmland bird nests could be destroyed by agricultural machinery. We believe that the Eurasian populations of collared pratincoles are threatened considerably by anthropogenic pressures: for instance, even in their native breeding habitats the pratincoles are subject to adverse effects from climate change, pollution and an unnaturally high density of mesopredators. In addition to effective direct nest protection, it will be important to increase the proportion of safe fallow lands in the future as a specific agri-environmental protection measure, so that as many farmland birds as possible have the opportunity to choose this undisturbed agricultural habitat for breeding. As collared pratincoles nest in several places in artificial habitats across Europe, mainly close to wetlands such as rice fields, breeding habitats should be protected

or restored more widely to maintain biodiversity in agricultural landscapes.

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Conflict of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards.

Data availability The dataset is available in the Dryad data repository at doi.org/10.5061/dryad.mgqnk9959.

References

- ALONSO LÓPEZ, J.C. & PALACÍN, C. (2010) The world status and population trends of the great bustard (*Otis tarda*). *Chinese Birds*, 1, 141–147.
- ARADI, C. (1979) Telepesen fészkelő madarak etológiai vizsgálata. *MTA Biológiai Osztály Közleményei*, 22, 239–256.
- ARROYO, B., GARCÍA, J.T. & BRETAGNOLLE, V. (2002) Conservation of the Montagu's harrier (*Circus pygargus*) in agricultural areas. *Animal Conservation*, 5, 283–290.
- BALMER, O. & ERHARDT, A. (2000) Consequences of succession on extensively grazed grasslands for central European butterfly communities: rethinking conservation practices. *Conservation Biology*, 14, 746–757.
- BENSACI, E., BOUTERA, N., CHERIEF, A., SAHEB, M., MOALI, A. & HOUHAMDI, M. (2014) Breeding ecology studies of collared pratincoles *Glareola pratincola* in the Central Hauts Plateaux of Algeria. *Wader Study Group Bulletin*, 121, 43–48.
- BERETZK, P. (1954) Über das Vorkommen der Brachschwalbe, *Glareola pratincola* (L.) in Ungarn und einigen Nachbarländern. *Larus*, 6, 192–205.
- BERG, Á. (1992) Factors affecting nest-site choice and reproductive success of curlews *Numenius arquata* on farmland. *Ibis*, 134, 44–51.
- BERG, Á., LINDBERG, T. & KALLEBRINK, K.G. (1992) Hatching success of lapwings on farmland: differences between habitats and colonies of different sizes. *Journal of Animal Ecology*, 61, 469–476.
- BERTOLERO, A. & MARINEZ VILALTA, A. (1999) La perdiu de mar *Glareola pratincola* al delta de l'Ebre: seguiment de la població i biologia reproductora. *Bulletin Parc Natural Delta de l'Ebre*, 10, 14–19.
- BIRDLIFE INTERNATIONAL (2021) *Glareola pratincola*. In *The IUCN Red List of Threatened Species* 2017. dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T22694127.A166268593.en.

- BOHNING-GAESE, K. & BAUER, H.G. (1996) Changes in species abundance, distribution, and diversity in a central European bird community. *Conservation Biology*, 10, 175–187.
- BOLTON, M., TYLER, G., SMITH, K.E.N. & BAMFORD, R.O.Y. (2007) The impact of predator control on lapwing *Vanellus vanellus* breeding success on wet grassland nature reserves. *Journal of Applied Ecology*, 44, 534–544.
- BOUGIE, T.A., BYER, N.W., LAPIN, C.N., PEERY, M.Z., WOODFORD, J.E. & PAULI, J.N. (2020) Wood turtle *Glyptemys insculpta* nest protection reduces depredation and increases success, but annual variation influences its effectiveness. *Canadian Journal of Zoology*, 98, 715–724.
- BRADY, S.J. & FLATHER, C.H. (1998) Agricultural land use patterns and grassland nesting birds. *Game and Wildlife*, 15, 775–784.
- BRZEZINSKI, M., ŻMIHORSKI, M., NIEOCZYM, M., WILNIEWCZYC, P. & ZALEWSKI, A. (2020) The expansion wave of an invasive predator leaves declining wader bird populations behind. *Diversity and Distributions*, 26, 138–150.
- CALVO, B. (1994) Effects of agricultural land-use on the breeding of collared pratincole *Glareola pratincola* in south-west Spain. *Biological Conservation*, 70, 77–83.
- CALVO, B. & ALBERTO, L.J. (1990) Nest-site selection of the collared pratincole *Glareola pratincola* in the province of Sevilla, Spain. *Bulletin of the International Wader Study Group*, 58, 13–15.
- CALVO, B. & FUERNES, R.W. (1995) Colony and nest-site selection by collared pratincoles (*Glareola pratincola*) in southwest Spain. *Colonial Waterbirds*, 18, 1–10.
- COLWELL, M.A. (2010) *Shorebird Ecology, Conservation, and Management*. University of California Press, Berkeley, USA.
- CRAMP, S. & SIMMONS, K.E.L. (1983) *The Birds of the Western Palearctic*, volume 3. Oxford University Press, Oxford, UK.
- DAVIDSON, N.C. (2014) How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research*, 65, 934–941.
- DE LEO, G.A., FOCARDI, S., GATTO, M. & CATTADORI, I.M. (2004) The decline of the grey partridge in Europe: comparing demographics in traditional and modern agricultural landscapes. *Ecological Modelling*, 177, 333–335.
- DONALD, P.F., GREEN, R.E. & HEATH, M.F. (2001) Agricultural intensification and the collapse of Europe's farmland bird populations. *Proceedings of the Royal Society of London*, 268, 25–29.
- EL MALKI, S., HANANE, S., JOULAMI, L. & EL HAMOUMI, R. (2013) Nesting performance of the black-winged stilt *Himantopus himantopus* and collared pratincole *Glareola pratincola* on a Moroccan coastal wetland: a comparison between natural and artificial habitats. *Wader Study Group Bulletin*, 120, 47–52.
- FAHRIG, L. (1997) Relative effects of habitat loss and fragmentation on population extinction. *The Journal of Wildlife Management*, 61, 603–610.
- FULLER, R.J. (2000) Relation between recent changes in lowland British agriculture and farmland bird populations: an overview. *Ecology and Conservation of Lowland Farmland Birds*, 1950, 5–16.
- GALBRAITH, H. (1987) Threats to breeding waders: the impact of changing agricultural land-use on the breeding ecology of lapwings. *Wader Study Group Bulletin*, 7, 102–104.
- GILROY, J.J., ANDERSON, G.Q.A., VICKERY, J.A., GRICE, P.V. & SUTHERLAND, W.J. (2011) Identifying mismatches between habitat selection and habitat quality in a ground-nesting farmland bird. *Animal Conservation*, 14, 620–629.
- GOOCH, S., ASHBROOK, K., TAYLOR, A. & SZEKELY, T. (2015) Using dietary analysis and habitat selection to inform conservation management of reintroduced great bustards *Otis tarda* in an agricultural landscape. *Bird Study*, 62, 289–302.
- GREEN, R.E., HAWELL, J. & JOHNSON, T.H. (1987) Identification of predators of wader eggs from egg remains. *Bird Study*, 34, 87–91.
- GUERRERO, I., MORALES, M.B., OSATE, J.J., GEIGER, F., BERENDESE, F., DE SNOO, G. & TSCHARNTKE, T. (2012) Response of ground-nesting farmland birds to agricultural intensification across Europe: landscape and field level management factors. *Biological Conservation*, 152, 74–80.
- HOLLANDER, F.A., TITEUX, N., HOLVECK, M.J. & VAN DYCK, H. (2017) Timing of breeding in an ecologically trapped bird. *The American Naturalist*, 189, 515–525.
- HOMBERGER, B., DUPLAIN, J., JENNY, M. & JENNI, L. (2017) Agri-environmental schemes and active nest protection can increase hatching success of a reintroduced farmland bird species. *Landscape and Urban Planning*, 161, 44–51.
- HÖTKER, H. (2000) Intraspecific variation in size and density of avocet colonies: effects of nest-distances on hatching and breeding success. *Journal of Avian Biology*, 31, 387–398.
- HU, S., NIU, Z., CHEN, Y., LI, L. & ZHANG, H. (2017) Global wetlands: potential distribution, wetland loss, and status. *Science of the Total Environment*, 586, 319–327.
- HUNGARIAN METEOROLOGICAL SERVICE (2021) *Hungarian Meteorological Service homepage*. met.hu [accessed 10 July 2022].
- JOHNSON, D.H. (1979) Estimating nest-success: the Mayfield method and an alternative. *The Auk*, 96, 651–661.
- KENTIE, R., BOTH, C., HOOIJMEIJER, J.C. & PIERSMA, T. (2015) Management of modern agricultural landscapes increases nest predation rates in black-tailed godwits *Limosa limosa*. *Ibis*, 157, 614–625.
- KENTIE, R., HOOIJMEIJER, J.C., TRIMBOS, K.B., GROEN, N.M. & PIERSMA, T. (2013) Intensified agricultural use of grasslands reduces growth and survival of precocial shorebird chicks. *Journal of Applied Ecology*, 50, 243–251.
- KISS, Á., MOLNÁR, A., MONOKI, Á., KAPOCSI, I., KOVÁCS, G., ARADI, C. et al. (2018) A szántóföldi környezetben fészkelő székicsér *Glareola pratincola* természetvédelmi helyzete és megőrzésének lehetőségei Magyarországon. különös tekintettel a nagykunsági fészkelő-állományra. *Aquila*, 125, 49–72.
- KISS, Á., MONOKI, Á. & VÉGVÁRI, Z. (2017) Nest-site selection and population trend of collared pratincoles *Glareola pratincola* in agricultural habitats of the Nagykunság region (Hungary). *Ornis Hungarica*, 25, 37–49.
- KOVÁCS, G. & KAPOCSI, I. (2004) Székicsér *Glareola pratincola*. In *A Hortobágy madárvilága* (ed. Z. Ecsedi), pp. 272–276. Winter Fair, Balmazújváros-Szeged, Hungary.
- KUBELKA, V., ŠÁLEK, M., TOMKOVICH, P., VÉGVÁRI, Z., FRECKLETON, R.P. & SZEKELY, T. (2018) Global pattern of nest predation is disrupted by climate change in shorebirds. *Science*, 362, 680–683.
- LEBEDEVA, E.A. (1998) Waders in agricultural habitats of European Russia. Migration and international conservation of waders: research and conservation on north Asian, African and European flyways. *International Wader Studies*, 10, 315–324.
- LOGSDON, R.A., KALCIC, M.M., TRYBULA, E.M., CHAUBEY, I. & FRANKENBERGER, J.R. (2015) Ecosystem services and Indiana agriculture: farmers' and conservationists' perceptions. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 11, 264–282.
- MACDONALD, M.A. & BOLTON, M. (2008) Predation on wader nests in Europe. *Ibis*, 150, 54–73.
- MARTIN, T.E. (1993) Nest predation and nest sites. *BioScience*, 43, 523–532.
- MASSA, B. & LA MANTIA, T. (2010) The decline of ground-nesting birds in the agrarian landscape of Italy. *Revue d'Ecologie, Terre et Vie*, 65, 73–90.

- MAYFIELD, H.F. (1975) Suggestions for calculating nest success. *The Wilson Bulletin*, 87, 456–466.
- MYHRVOLD, N.P., BALDRIDGE, E., CHAN, B., SIVAM, D., FREEMAN, D.L. & ERNEST, S.M. (2015) An amniote life-history database to perform comparative analyses with birds, mammals, and reptiles. *Ecological Archives*, 96, 3109–3109.
- NARDELLI, R., ANDREOTTI, A., BIANCHI, E., BRAMBILLA, M., BRECCIAROLI, B. & CELADA, C. (2008) *Rapporto sull'applicazione della Direttiva 147/2009/CE in Italia: dimensione, distribuzione e trend delle popolazioni di uccelli*. Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), Rome, Italy.
- NATIONAL GAME MANAGEMENT DATABASE (2022) *The National Game Management Database 2022*. ova.info.hu [accessed 21 November 2021].
- NEUMAN, K.K., PAGE, G.W., STENZEL, L.E., WARRINER, J.C. & WARRINER, J.S. (2004) Effect of mammalian predator management on snowy plover breeding success. *Waterbirds*, 27, 257–263.
- O'CONNOR, R.J. & SHRUBB, M. (1986) *Farming and Birds*. Cambridge University Press, Cambridge, UK.
- PART, T., ARLT, D. & VILLARD, M.A. (2007) Empirical evidence for ecological traps: a two-step model focusing on individual decisions. *Journal of Ornithology*, 148, 327–332.
- PESCADOR, M. & PERIS, S. (2001) Effects of land use on nest predation: an experimental study in Spanish croplands. *Folia Zoologica*, 50, 127–136.
- POTTER, C. (1997) Europe's changing farmed landscapes. In *Farming and Birds in Europe: The Common Agricultural Policy and Its Implications for Bird Conservation* (eds D.J. Pain & M.W. Pienkowski), pp. 25–42. Academic Press, San Diego, USA.
- POTTS, G.R. (2012) *Partridges*. Harper Collins, London, UK.
- POZHIDAEVA, S. & MOLODAN, G.N. (1992) Productivity of the collared pratincole *Glareola pratincola* on the northern coast of the Azov Sea. *Wader Study Group Bulletin*, 65, 23.
- R CORE TEAM (2021) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. r-project.org [accessed 6 November 2023].
- ROBERTSON, B.A. & HUTTO, R.L. (2006) A framework for understanding ecological traps and an evaluation of existing evidence. *Ecology*, 87, 1075–1085.
- ROODBERGEN, M., VAN DER WERF, B. & HÖTKER, H. (2012) Revealing the contributions of reproduction and survival to the Europe-wide decline in meadow birds: review and meta-analysis. *Journal of Ornithology*, 153, 53–74.
- SCHIEKERMANN, H., TEUNISSEN, W. & OOSTERVELD, E. (2008) The effect of 'mosaic management' on the demography of black-tailed godwit *Limosa limosa* on farmland. *Journal of Applied Ecology*, 45, 1067–1075.
- SCHIFFERLI, L., SPAAR, R. & KOLLER, A. (2006) Fence and plough for lapwings: nest protection to improve nest and chick survival in Swiss farmland. *Osnabrücker Naturwissenschaftliche Mitteilungen*, 32, 123–129.
- SCHLAEPPER, M.A., RUNGE, M.C. & SHERMAN, P.W. (2002) Ecological and evolutionary traps. *Trends in Ecology & Evolution*, 17, 474–480.
- SHELDON, R.D., CHANEY, K. & TYLER, G.A. (2007) Factors affecting nest survival of northern lapwings *Vanellus vanellus* in arable farmland: an agri-environment scheme prescription can enhance nest survival. *Bird Study*, 54, 168–175.
- SZEKELY, T. (1992) Reproduction of Kentish plover *Charadrius alexandrinus* in grasslands and fish-ponds: the habitat mal-assessment hypothesis. *Aquila*, 99, 59–68.
- SZEKELY, T., KOSZTOLANYI, A. & KÖPPER, C. (2006) Practical guide for investigating breeding ecology of Kentish plover *Charadrius alexandrinus*. Unpublished report. University of Bath, Bath, UK.
- TARIUELO, R., MARGALIDA, A. & MOUGEOT, F. (2020) Changing the fallow paradigm: a win-win strategy for the post-2020 common agricultural policy to halt farmland bird declines. *Journal of Applied Ecology*, 57, 642–649.
- VINCENT-MARTIN, N. (2007) *Statut de conservation de la Glaréole à collier Glareola pratincola en Camargue: identification des facteurs limitant la reproduction*. PhD thesis. Ecole Pratique des Hautes Etudes, Paris, France.
- WARD, M.P., SEMEL, B. & HEKKERT, J.R. (2010) Identifying the ecological causes of long-term declines of wetland-dependent birds in an urbanizing landscape. *Biodiversity and Conservation*, 19, 3287–3300.
- WILSON, J.D., WHITTINGHAM, M.J. & BRADBURY, R.B. (2005) The management of crop structure: a general approach to reversing the impacts of agricultural intensification on birds? *Ibis*, 147, 453–463.
- YURI, V., LOKHMAN, V., FEDOSOV, N. & MIKHAIL, V.K. (2020) Collared pratincole *Glareola pratincola*. In *European Breeding Bird Atlas 2: Distribution, Abundance and Change* (eds V. Keller, S. Herrando, P. Vorišek, M. Franchi, M. Kipson, R.P.B. Foppen et al.), p. 284. Lynx Edicions/European Bird Census Council (EBCC), Barcelona, Spain.
- ZAMEČNÍK, V., KUBELKA, V. & ŠALEK, M. (2018) Visible marking of wader nests to avoid damage by farmers does not increase nest predation. *Bird Conservation International*, 28, 293–301.

Supplementary table 1. Agricultural habitat types of Collared Pratincole *Glareola pratincola* in Hungary.

Habitat	Characteristics of preparation and treatment	Examples
Row crops	Planted in wide rows, intensive land use with pesticides and row cultivation	corn, sorghum, sunflower
Spring cover crops	Planted in narrow rows, less intense land use by chemicalization	Alexandra-clover, alfalfa, barley, millet, oat, phacelia
Fallow lands	Created by disc ploughing, there aren't any disturbance by agricultural machineries	dry paddies, rested areas

<i>Mean daily nest survival rate</i>	Year		Row crops
	2021	2020	
0.94	26	9	No. Nests
	24	9	No. of hatched nests
	356	136	Exposure (days)
	0.99	1	Daily nest survival
0.93	76.9	100	Total nest survival rate (%)
	4	16	No. nests
	3	15	No. of hatched nests
	32.5	185.5	Exposure (days)
0.97	0.97	0.99	Daily nest survival
	23.4	77.7	Total nest survival rate (%)
	10	8	No. nests
	8	5	No. of hatched nests
0.97	168.5	50	Exposure (days)
	0.99	0.94	Daily nest survival
	57.4	5.6	Total nest survival rate (%)
			Fallow lands

Supplementary table 3. Nest fates, exposure days, daily and total nest survival rate probabilities of Collared Pratincoles.

Year	Hatched (%)	Predated (%)	Abandoned (%)	Flooded (%)	Unknown (%)	Agricultural activities (%)	Exposure (days)	Daily nest survival rate	Total nest survival rate (%)
2012	13	71	0	17	0	0	202.5	0.9	11.2
2013	68	12	14	6	0	0	189	0.97	52.5
2014	57	14	7	22	0	0	136	0.96	40.6
2015	63	26	11	0	0	0	363.5	0.96	45.5
2016	66	9	4	17	2	2	478	0.97	50.6
2017	76	16	8	0	0	0	615	0.98	67.4
2018	76	21	3	0	0	0	387	0.98	65.9
2019	48	24	19	9	0	0	246	0.96	40.1
2020	88	3	9	0	0	0	371.5	0.99	80.5
2021	88	7	5	0	0	0	557	0.99	83.5

Nest-site selection and population trend of Collared Pratincoles (*Glareola pratincola*) breeding in agricultural habitats of the Nagykunság region (Hungary)

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Abstract The Collared Pratincole (*Glareola pratincola*), which was once a typical breeding species of the sodic grasslands of the Great Plain, has become threatened with extinction from Hungary. It disappeared from the traditional grassland breeding sites before the 2000 and is currently breeding only in three sites in agricultural environments in Hungary. The objectives of our research were to find links between the use of shallow wetlands and the breeding behaviour of the species and to identify the characteristics of its breeding on ploughed fields. Data were collected between 2008 and 2016 as part of preparations for the conservation of the largest population which is found in the Nagykunság. We found a positive correlation between colony size and the area of the nearby wetland. We calculated the proportion of habitat-types used for nesting, and found that cultivated fields and fallow lands were the most important. Additionally, we also found that colony sizes were substantially smaller during the research period than those found earlier in the traditional grassland habitats. Finally, we found a positive trend in the size of the population during the research period.

Keywords: R, ARCGIS, agricultural breeding habitat, crop type, Collared Pratincole conservation management, nest site selection

Összefoglalás Az egykor az Alföld szíkes pusztáin költő székicsér mára kipusztulással közvetlenül fenyegetett madárfaj lett hazánkban. A tradicionálisnak számító pusztai élőhelyeiről az ezredforduló előtt teljesen eltűnt, és évtizedek óta kizárólag csak mezőgazdasági környezetben költ. Jelenleg három területen fészkel az országban. A 2008 és 2016 közötti időszakban vettünk fel adatokat a legnagyobb méretű nagykunsági populáció védelmének szervezése során. Kutatásunk célja az volt, hogy kapcsolatot keressünk a sekélyvizes élőhelyek és a székicsérek költési szokásai között, valamint megállapítsuk a szántóföldi fészkelések jellemzőit. A kolóniát alkotó párok száma és a közeli vizes élőhely mérete között pozitív korrelációt találtunk. Meghatároztuk a székicsérek által költésre leggyakrabban használt élőhelytípusok arányát, melyekben a kapáskultúrák és az ugaroltatott területek voltak a legjellemzőbbek. A költőtelepek méreteit is rögzítettük, mely során azt állapítottuk meg, hogy a vizsgálati időszakban tapasztalt telep méretek lényegesen kisebbek a tradicionális élőhelyekre jellemzőknél. Meghatároztuk a mintavételi időszakot érintő állományváltozás pozitív irányú trendjét.

Kulcsszavak: R, ARCGIS, mezőgazdasági fészkelőhelyek, szántóföldi kultúra-típus, székicsér fajvédelem, fészkelőhely-választás

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Introduction

The Collared Pratincole is distributed in the Indo-African biogeographical region and is divided into three known subspecies. The world population is estimated to 160.000–600.0000 individuals (Wetlands International 2015), while the European population includes 7.800–14.900 pairs (Birdlife International 2015). The nominate race *G. p. pratincola* breeds in Europe and Asia (Tucker *et al.* 1994). Although the world population is not endangered, the species shows a declining trend in its entire distribution area (Wetlands International 2015). The European population has a highly fluctuating trend (Birdlife International 2015).

The range of the nominate race in the Western Palearctic extends from the Iberian Peninsula across the Carpathian Basin to the Caspian region, and its breeding habitat includes saline steppes, steppes and semideserts (Hayman *et al.* 1991). Nesting in agricultural landscapes has been detected in a number of European countries in the 1980s and the 1990s (Calvo & Alberto 1990, Kayser 2015).

In Spain, population decline due to habitat loss has been identified during the early 1990s. In the Sevilla region, 62% of the breeding pairs were found in fallow and arable lands. The majority of the colonies in agricultural areas were located in sunflower and cotton fields and occasionally in sorghum and chickpea cultivations (Calvo & Alberto 1990). However, breeding success was substantially lower as compared to in fields than in grasslands close to seminatural marshlands (Calvo 1994).

Studies conducted on the nest site selection of waders breeding in agricultural landscapes in Western Russia found that the Collared Pratincole breeding in agricultural areas is one of the most vulnerable waders (Lebedeva 1998).

In France, the majority of the population is located in the Camargue region. As the number of pairs fluctuated between 37–127 in the period of 2004–2014, this population is considered as threatened. Nests in agricultural areas were mostly found in maize and sorghum plantations (Kayser 2015). In Montenegro, 70–80 pairs of Collared Pratincoles breed in dry salinas close to Ulcinj (Saveljic 2002).

The populations of Collared Pratincole experienced a dramatic decline in the last ten years and is one of the waders that are close to local extinction in Hungary. Other species that experienced similar declines due to gradual habitat loss and fragmentation, disappearance of wetlands and collapse of grazing livestock include the Kentish Plover (*Charadrius alexandrinus*) and the Stone Curlew (*Burhinus oedinenus*) (Rakonczai *et al.* 1989).

In the 19th century, the species was still considered as a widely distributed bird in the entire Great Hungarian Plain, and there were also colonies in Transdanubia (Chernel 1899). In contrast, in the 20th century, colonies were known only in areas between the rivers Danube and Tisza, in Hortobágy, Nagyunság and in Békés County. In Hortobágy, where the most significant populations bred in the early 1990, the total population amounted to 500 pairs (Kovács & Kapocsi 2005). For example, in August 1942, 150 individuals were observed in the vicinity of Hajdúböszörmény, which might have consisted of birds from the Hortobágy population during their pre-migratory aggregation. The Hortobágy population amounted to 180–200 pairs during the 1960s and 150–160 pairs during the 1970s (Kovács & Kapocsi 2005).

Within Hortobágy the largest colonies were found near Kunmadaras in the 1960s and 1980s, predominantly close to Csíkos and Mérgecs Marshes, in Bogárczó, close to Döghalom and Gyúró-kút areas (Szabó 1980). Further, pratincoles regularly bred in Nagyvíván, Nyírő-lapos, Nyári-járás, Mátá, Angyalháza, Zám and Szelencés areas. Traditional colonies survived in declining numbers during the early 1980s (Kovács & Kapocsi 2005).

Colonies in the eastern Hortobágy (Nyári-járás, Angyalháza, Szelencés areas) were lost until 1985, and a few breeding sites remained in the southern areas (Kovács 1993). From 1980 onwards, the Hortobágy population totalled up to 100 pairs in the best years but experienced its final declining stage which included less than 50 pairs in later years (Kovács 1993). In the 1990s, pratincoles ceased to breed in the Kunmadaras area, with only occasional breeding activities (Kovács & Kapocsi 2005). Nest sites were known in the Kecskeri area 20 kilometres from Kunmadaras area during the 1980s and 1990s (Endes 1991).

Similarly to the processes observed in Hortobágy, pratincoles also suffered a drastic population decline in the Kiskunság region. In the 1970s, colonies of up to 30–40 pairs regularly formed in Kelemen-szék and Kis-rét marshes. In the 1980s, colonies of Apaj and Űrbő significantly decreased and then disappeared from salt pans of Upper Kiskunság (Bankovics *et al.* 2015). In later years, only occasional breeding activities were observed in the region. In 1992, a nest with a single egg was observed in an overgrazed grassland plot in Harta-Akasz-tó area (Berdó 1992). At the turn of the century, a brood with two young was found in Kelemen-szék marsh (Pigniczki 2000).

Similarly to the Hortobágy and Kiskunság populations, those of Békés County also have dramatically declined, and only pairs breeding in agricultural landscapes survived (Széll 1996). In the 1930s, a flock showing nest protection behaviour was spotted in the alkali steppe of Csudaballa, located in between Túrkeve and Gyomendrőd (Tarján 1934). Breeding pratincoles were known in the Kóré-zug area in Dévaványai-Ecegi steppes in the early 1990s (Széll 1996). In 1993, a colony of 2–3 pairs was observed in a dry pond of the Fertő Fishponds of Szentés (Bod 1993).

The characteristic breeding habitat of the Collared Pratincole included steppes interspersed with temporarily flooded wetlands (Széll 2014). In Hortobágy, pratincoles nested in areas with sporadic vegetation intensively grazed by cattle, in the vicinity of grazed and open-water salt pans as well as wet grasslands. Nest-sites were chosen in dry Puccinellietum wetlands grazed by cattle and also in barren plots of *Camphorosmetum*, *Spergularia*, *Pholurus* and *Plantago tenuiflora* vegetation (Szabó 1980).

Eggs were often laid on dry cattle dung or in cattle footprints, often in nest cups lined with plant material. Occasionally, Collared Pratincoles bred in barren edges of excavations, plained rice-field dykes, abandoned livestock roosts, boundaries of salt pans as well as in areas surrounding duck farms covered by dry manure layers (Szabó 1980). At the turn of the century, a pair of pratincoles successfully bred in a mudflat during emergency floods in 1999 and 2000 (Kovács & Kapocsi 2005).

In the 1980s, the number of surviving colonies in native grasslands started to decline heavily and completely disappeared during the early 1990. This population collapse was probably due to the gradual decline of livestock grazing and the disappearance of wetlands as a result of the establishment of irrigation canal networks (Kovács & Kapocsi 2005). In

parallel to the intensive decline of livestock grazing, especially that of cattle, populations declined and disappeared in alkali grasslands (Sterbetz 1974). Following declining population trends, colonies were found increasingly often in intensively cultivated arable and fallow lands. Since 1994, Collared Pratincoles have bred only in these types of habitats (Oláh & Széll 1994).

However, colonies breeding in arable lands were first detected a lot earlier: in 1902, a colony of five pairs were found in a carrot field in the Great Hungarian Plain and in 1906, a colony of a few pairs were observed in a feed-corn field. In 1919, birds showing nest protection behaviour were found in a fallow land. Later, a colony consisting of a minimum of three pairs were found, and the eggs from the nest were collected (Cerva 1926).

Breeding activities in agricultural areas were reported close to Zádor-lapos, Asszonyszállás, Kunlapos from 1980 onwards, from 1985 onwards in the vicinity of Mezőtúr, in Csabacsúd in 1987 and in Szarvas and Ecségfalva in 1988 (Széll 1993). In 1994, two colonies were found in maize fields in Kiskunlacháza (Selmeczi-Kovács 1994), and 82 pairs bred in three agricultural regions of the Great Hungarian Plain (Oláh & Széll 1994). In 1996, two early-phase colonies were discovered in a sunflower field in Kunlapos area near Karcag (Kapocsi 2002).

Agricultural habitats are now considered as vital for the nesting of Collared Pratincoles. A special focus is given to flooded and fallow rice fields as well as sunflower and maize plantations (Csider 2008). In the past 20–25 years Collared Pratincoles almost exclusively bred in the vicinity of rice fields in eastern Hungary, with a few occasional exceptions. In 1994, breeding pairs were located in flooded rice plantations in neighbourhoods of Csabacsúd, Karcag, Kisújszállás, Mezőtúr and Szarvas (Oláh & Széll 1994). Studies carried out on nest site conditions and distance to the nearest water body concluded that the height of rice amounts to 3–4 cm during the initial phase of breeding, thus forming adequately sparse vegetation. Nests were 0.1–2 kilometres away from water bodies (Széll 1993). Collared Pratincoles breeding in root crops regularly hunt in the close neighbourhood of the colony, occasionally in nearby cereal fields (Kiss 2011).

The aim of this study was to present data on the status of the largest, Nagykunság population of Collared Pratincoles and to identify environmental factors related to the nest site selection of Collared Pratincoles. We specifically considered four factors: (1) physical characteristics of nearby wetlands (2), type of arable field (3), characteristics of alkali soil plots, and (4) proportion of crop types in the landscape. Additionally, we aimed to estimate colony size and proportion in agricultural areas. Finally, we provide an estimation of the short-term population trend of Collared Pratincoles in the Nagykunság region.

Materials and Methods

Our study area comprised all known pratincole habitats in the administrative districts of Karcag, Kisújszállás and Ecségfalva, which extend to a total of 33,144 hectares (*Figure 1*). Within this region, we identified the following habitat types (in order of decreasing proportion in the landscape): arable lands, rice fields, marshes and extensively managed grasslands.

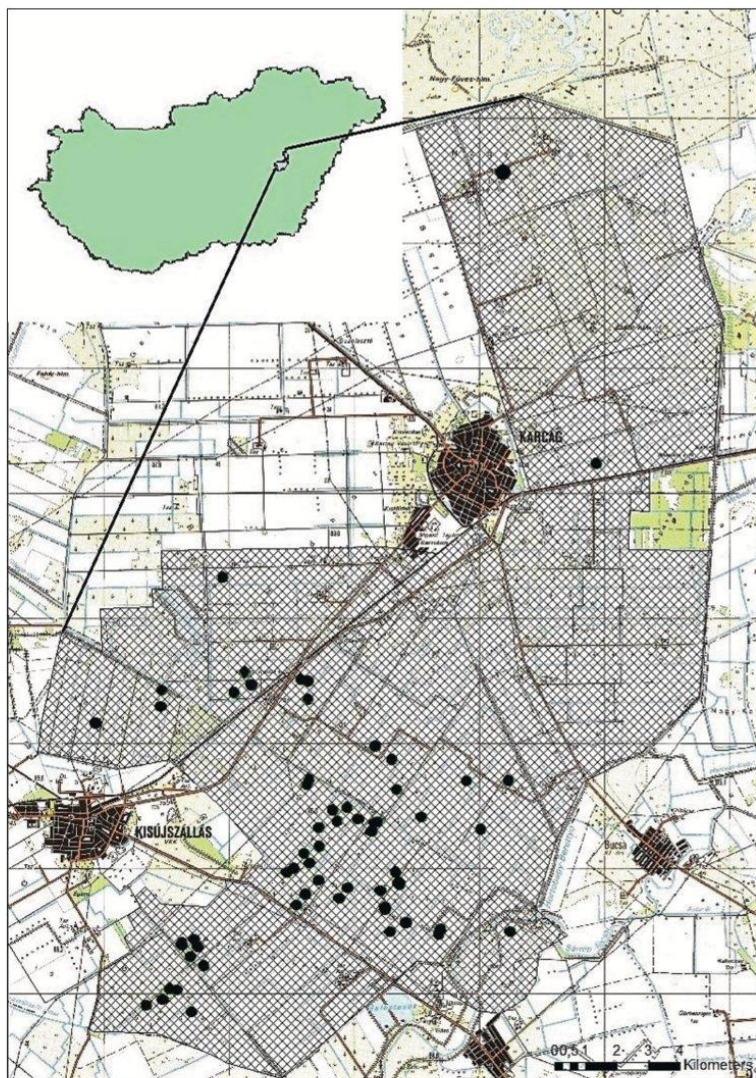


Figure 1. Location of the study area and colonies monitored between 2008 and 2016
1. ábra A vizsgálati terület átnézeti képe 2008–2016 között a költőállományok pontjaival

Breeding activities were also regularly recorded in the following areas near Karcag in the 1990s and early 2000s: Kunlapos, Bengecseg, Apavára, Botonás (Kapocsi 2002). In these areas we found only occasional breeding activities in the study period, which we less frequently but regularly monitored. Focal searches of Collared Pratincoles were conducted in rice fields, arable lands and in their 2 km surrounding. Focal areas were surveyed several times a week.

Surveys of potential nest sites where pratincoles were prospecting in agricultural areas were already started during the spring migration period. Nest sites were determined based on the behaviour of birds that showed exploratory flights and colony establishment activities (Kovács & Kapocsi 2005). Searches for incubating birds were initially conducted in the boundary zone of the field hosting the colony, and were later extended to areas within the particular field to precisely locate nests.

Because incubating birds generally tolerate agricultural machines around the colony, nests with eggs could be easily located from 4WD cars. When we visited nests, breeding pairs were only disturbed during the short interval of recording GPS coordinates, nest parameters (site, egg numbers) and taking photos. We considered a location to be a nest site if it was occupied by a nest at least once.

When we found nests with young, we recorded pointing coordinates in the EOV coordinate system. All nest locations and history were recorded in a control log, which contained information on date, site ID and coordinates of locations, nest status, number of eggs/young, number of successfully hatched young as well as the cause of breed failure if applicable. Using the coordinates of located nests, we generated a point layer of nests and colonies using ARCMAP 10.1 software for spatial analysis.

To analyse nest site choice, we employed three response variables: (1) number of pairs, (2) number of successfully breeding pairs, and (3) proportion of successfully breeding pairs for each colony. We used crop type, the distance and size of the nearest shallow wetland, and the distance of the nearest alkali soil patch as predictors. We applied linear mixed models, entering year as random term, using the „lme4” package in the R statistical programming environment (R Development Core Team 2016). Additionally, we tested whether the distance of nearest neighbours within colonies was related to habitat type, by applying Kruskal-Wallis-test.

During nest search we also determined colony size. We considered a breeding pair to be colonial if the disturbance experienced by the nesting pair has evoked nest protecting behaviour in pratincoles in neighbouring areas. Additionally, we collected colony sizes found since 2008 and compared their frequencies in various crop types. Finally, each breeding season, we estimated the total size of the breeding population of the region by considering the numbers of both first and replacement clutches.

Habitats

During the study period, we identified and estimated the size and location of natural as well as artificially flooded wetlands. Agricultural habitats used by pratincoles were classified into four categories, based on soil preparation, timing of crop sowing and technology.

Root crops

This class includes crops sown between mid-April to early May. Soil settlement following basic cultivation is carried out in the spring before seedbed preparation with disc, harrow, roller and other machinery. Following seedbed preparation, bare soil surface of small grain size is formed which is sufficiently compressed in seed depth and only covered by straw. This type is characterised by large row distances, ranging between 70 and 76 cm (Csajbók 2012). This habitat class is represented by sunflower, maize and sorghum in the region.

Spring cereals

This type is represented by oat sown in March and April, which starts to grow only late as a result of soil and precipitation conditions, generally during the spring arrival of pratincoles. In lower-lying areas with longer water cover, this crop does not germinate, leaving barren alkali spots behind.

Early summer crops

This class includes crops sown late, in May or June. In the Nagykunság region, this type is represented by alfalfa, Alexandria clover and millet. Early summer crops play an important role as green fertilizers of fallow white rice fields. These crops are sown into small-grain settled seedbank, similar to cereal sowing (Csajbók 2012). This habitat class is occupied by pratincoles during barren, early developmental stages, prior to germination.

Fallow land

These fields are abandoned for cultivation for a year, managed by heavy discs once or twice a year between early- and mid-May. Fallow lands are mostly represented by fallow white rice fields in the region. Cultivation technology of white rice requires crop alternation (Sárvári 2011). Owing to discing, the soil will be smaller-grained.

Results

Nest site selection

During the study period (2008–2016), we found 258 breeding events in colonies or solitary pairs (*Figure 2*). The proportions of breeding events in various habitat types are summarised in *Table 1*.

Out of the three models, the only significant relationship was a positive relationship between the number of pairs and the size of nearest wetland: larger water bodies predicted colony size defined as the number of nesting pairs ($b=0.006$, $t=2.328$). None of the predictors in the two other models had significant effects on any of the response variables ($p>0.323$ for all cases) (*Figure 3*).

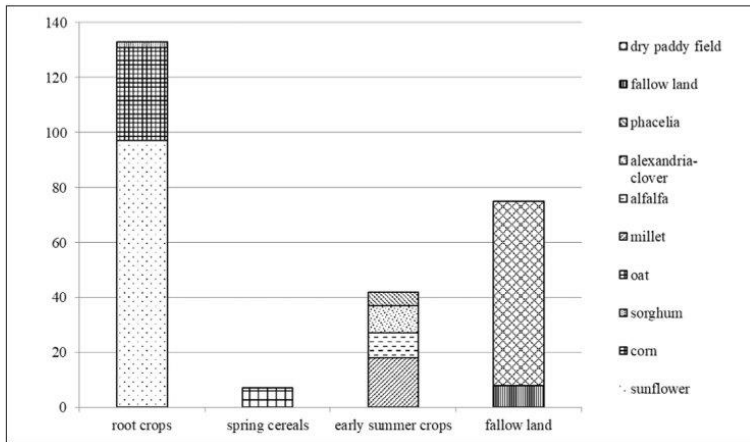


Figure 2. The number of nests in different in agricultural crops during the study period
2. ábra Az agrár-élőhelyek foglalási aránya a mintavételi időszakban

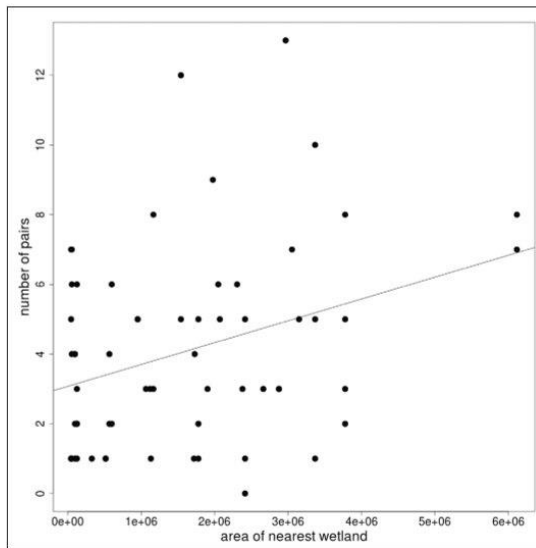


Figure 3. The number of breeding pairs as a function of the area of the nearest wetland (in m²)
3. ábra Telepalkotó párok számának növekedése a legközelebb lévő sekélyvizes élőhely méretével arányosan

Table 1. Colony sizes and frequency of their occurrences in various crop types
1. táblázat Székicsér-kolóniák méretei, illetve előfordulásuk arányai a különböző élőhelytípusokban

Size of colony (number of pairs)	Number of occurrence	Occurrence in cultivated lands (%)	Occurrence in spring seeding lands (%)	Occurrence in summer seeding lands (%)	Occurrence in fallow lands (%)
13	1	100	0	0	0
12	1	100	0	0	0
11	0	0	0	0	0
10	1	0	0	0	100
9	1	0	0	0	100
8	3	66.6	0	33.3	0
7	4	75	0	0	25
6	5	40	20	20	20
5	10	40	0	0	60
4	5	20	20	40	20
3	10	60	0	20	20
2	8	50	0	25	25
Solitary pairs	13	54	0	23	23

The mean distance to nearest neighbours calculated for each colony did not differ between habitat types (Kruskal-Wallis $\chi^2=5.290$, $df=9$, $p=0.8084$).

Out of the four habitat types, occupancy rates were the largest for root crops (52%) and fallow lands (29%). While 16% of nests were found in fields of crops sown during early summer, this number amounted only to 3% in spring sown crops (Figure 2).

Characteristics of colonial breeding

Mean colony size was 4.94 pairs/colony ($n=49$ colonies). More than half (67%) of colonies consisted of 2–5 pairs. The largest colonies, consisting of 7–13 pairs were established mostly in root crops (64%), fallow lands (28%) and rarely in early summer crops (8%) (Table 1).

We found colonies consisting of more than 11 pairs only in two occasions. In 2015, a colony of 13 pairs were found in KISRÉT of KISÚJSZÁLLÁS, while a colony of 12 pairs was established in GYALPÁR in the same region. The proportion of colonies consisting of 10 or more pairs was thus substantially smaller (6.1%) than the proportion of smaller colonies (93.9%).

Solitary breeders made up 21% of all nesting records. More than half of the solitary nesting pairs were located in root crops.

Trend of the Nagykunság population between 2008–2016

The minimum population size was found in 2008 with only 15 breeding pairs in the region. In contrast, the maximum population size was in 2016 with 36–37 pairs. During the study period, both the number of pairs and number of clutches increased. Total population size increased significantly in the region between 2008–2016 (Figure 4) (linear regression, $b=2.00$, $df=7$, $p=0.002$) although the increase was smaller before the peak year of 2016.

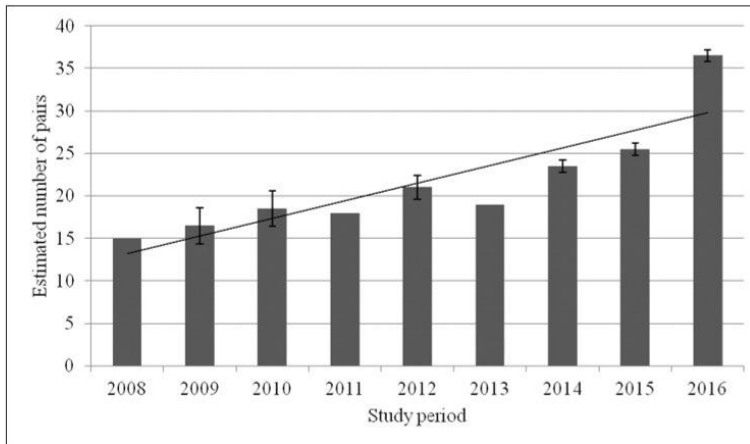


Figure 4. Population trend of Collared Pratincoles in the Nagykunság region during the study period
4. ábra A nagykunsági székicsérpopuláció változásának trendje a vizsgálati időszakban

Discussion

During the early 1990s, the remaining pratincole populations suffered a further dramatic decline. Moreover, traditional breeding in native steppes gradually disappeared, which might be explained by a number of mutually non-exclusive hypotheses. First, the decline of cattle grazing resulted in the decrease of areas covered by barren alkaline wetlands. Additionally, the marsh vegetation of soda pans and wet grasslands became continuous, and insect communities characteristic to open habitats and shallow and water bodies declined and disappeared. Furthermore, the establishment of dykes and ditches led to the draining of temporary steppe wetlands, sinking of the groundwater table, inducing steppe soil formation (Kovács & Kapocsi 2005).

Behaviours related to nest site selection, colony establishment and breeding have also substantially changed in pratincoles nesting in agricultural landscapes, compared to those breeding in native grasslands. As a result of our analyses, we found a significant relationship between colony size and size of the nearest water body: larger water bodies predicted larger colonies. During the late 1990s, colonies of Eastern Hungary survived only in areas harbouring active rice fields (Oláh & Széll 1994).

A former hypothesis proposed that food availability in rice fields attracts pratincoles, that in turn form colonies close to rice fields (Széll 1993). We assume that the presence of flying insect fauna connected to temporarily flooded shallow wetlands influenced annual nest site selection in pratincoles. Accordingly, we have repeatedly observed that late or supplementary broods as well as aggregation sites were found in the vicinity of intensively emerging *Sympetrum fonscolombei* dragonflies. Similarly to our findings, the presence of nearby

wetlands also predicted colony sites in Spain, where colony sites were determined by the location of suitable arable lands in the neighbourhood of wetlands. Both in natural and agricultural habitats, the majority of colonies were found within a 100 metre range of wetlands (Calvo & Furness 1995). Therefore the availability of wetlands (including marshes and reedbeds) is vital for pratincole conservation (Calvo 1995).

Our observations match previous findings on the crop type preference of pratincoles nesting in agricultural habitats. In a previous study, pratincoles preferred sunflower, oil pumpkin, silage maize and spring barley fields, fallow and uncultivated land as well as abandoned rice fields (Kovács 1992). Root crops with sparse vegetation available in the vicinity of rice fields were concluded to provide the most suitable nest sites. Prior to our study period, a high proportion of breeding events in Hungary was in sunflower and maize fields (Széll 1993). Although we found clutches in 11 crops of four major crop types, our findings agreed with these general patterns because the proportion of root crops, especially that of sunflower, was significantly higher than that of other crops. The number of clutches found in maize fields was smaller than those found in sunflower plantations, which is explained by larger total cover of the latter plant as it is less responsive to soil conditions. In arable lands of 10–100 hectares located in the vicinity of rice fields, sunflower fields are cultivated each year, attracting prospecting pratincoles by sparsely vegetated soil surfaces. Sunflower was also the most important crop in agricultural areas to Spain, where most of the breeding population was found in sunflower and cotton fields in the south-eastern part of the country. Interestingly, pratincoles regularly establish colonies close to breeding Lapwings, *Vanellus vanellus* (Calvo & Furness 1995).

Fallow lands are represented by fallow rice fields in the region, as uncultivated arable lands are rather rare. During spring arrival of pratincoles, these habitats are covered by rice stubble, not attracting prospecting birds. From mid-May onwards, fields are cultivated by heavy disks, creating barren and rugged soil patches, suitable for nesting. Accordingly, fallow rice fields primarily attract late or failed pairs. More than one fourth of clutches were found in this habitat type. During the 1990s and early 2000s, it was not known that pratincoles may breed in dry rice fields. From 2005 onwards, the role of this habitat type has been increasingly important, as these provide nesting opportunities for late and failed breeders (Csíder 2008, Kiss 2011). In our study, we confirmed the preference for root crops, which seems to be unchanged during the past decade. Similar to root crops, fallow lands were also preferred for breeding, with a special respect to fallow rice fields.

Breeding events in spring cereals were recorded rarely. This habitat type was selected by smaller colonies only when open soil patches covered by sporadic vegetation were available, or spring oat fields have not yet germinated prior to spring arrival of pratincoles. Nest in alfalfa or phacelia fields sown in April or May were found only in a few cases. To provide green fertilizers in fallow white rice fields, Alexandria clover and millet are regularly sown in part of the fields in May or early June. Fast-growing crops with high nutrient content are rotated into the soil as green fertilizer, or harvested in August. In drought conditions, these plants develop rather slowly; thus, these fields provide suitable nest sites in barren or sparsely vegetated stages for pratincoles. Therefore a considerable proportion of pratincole nest was found in this crop type.

Based on previous experiences in Hortobágy habitats, pratincole colonies are established through coordinated exploratory movements, and ensure fast alarming and protection of the nest from approaching predators or intruders (Aradi 1979). Our data show that colonies of 10–30 pairs, that were formerly a general colony size, are no longer typical. Indeed, larger and more closed colonies are established in natural habitats. According to previous studies of pratincole behaviour, colony structure dissolves or completely disappears in agricultural habitats (Kovács & Kapocsi 2005).

The studied Nagykurság population of pratincoles has been the largest nesting population because the occasionally established colonies in the Kiskurság region and the Szarvas-Gyomaendrőd-Mezőtúr area have been significantly smaller than in the Nagykurság region for many years. The study population therefore is of national importance. Although the size of this nesting population increased slowly since the minimum of 2008, the number of breeding pairs increased considerably in 2016, resulting in a significant population increase during the study period. However, it is not clear whether this increase is driven by natural population increase, movements between colonies in Hungary or immigration from outside the Carpathian Basin.

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References

- Aradi, Cs. 1979. Telepesen fészkelő madarak etológiai vizsgálata [Behavioral assessment of colonially breeding bird-species]. – MTA Biológiai Osztály Közleményei 22: 239–256. (in Hungarian)
- Bankovics, A., Boros, E., Lóránt, M., Ludnai, T., Németh, Á. & Pigniczki, Cs. 2015. Madártani megfigyelések és tudományos kutatások [Ornithological observations and researches]. – In: Iványosi, Sz. A. (szerk.) A Kiskursági Nemzeti Park Igazgatóság negyven éve. – Kiskursági Nemzeti Park Igazgatóság (in Hungarian)
- Berdó, J. 1992. Székicsér (*Glareola pratincola*) fészkelése Harta-Akasztó pusztán [Breeding of Collared Pratincole (*Glareola pratincola*) in Harta-Akasztó pusztá]. – Partimadár 2: 8. (in Hungarian)
- Birdlife International 2015. – www.birdlife.org (in Hungarian)
- Bod, P. 1993. Székicsér (*Glareola pratincola*) eredményes költése Szentes Fertő halastón [Successful breeding of Collared Pratincole *Glareola pratincola* in Fertő-fishponds, Szentes]. – Partimadár 1: 15–16. (in Hungarian)
- Calvo, B. 1994. Effects of agricultural land use on the breeding of Collared Pratincole *Glareola pratincola* in south-west Spain. – Biological Conservation 70(1): 77–83. DOI: 10.1016/0006-3207(94)90301-8
- Calvo, B. 1996. Feeding habitats of breeding Collared Pratincoles *Glareola pratincola* in Southern Spain. – Colonial Waterbirds 19 (special publication 1): 75–77. DOI: 10.2307/1521948
- Calvo, B. & Alberto, L.J. 1990. Nest-site selection of the Collared Pratincole *Glareola pratincola* in the province of Sevilla, Spain. – Bulletin of the International Wader Study Group 58: 13–15.
- Calvo, B. & Furness, R. W. 1995. Colony and nest-site selection by Collared Pratincoles (*Glareola pratincola*) in Southwest Spain. – Colonial Waterbirds 18(1): 1–10. DOI: 10.2307/1521393

- Calvo, B. & Vázquez, M. 1995. Field technique suggestion for the study the Collared Pratincoles *Glareola pratincola*. – Bulletin of the International Wader Study Group 78: 33–35.
- Chernel, I. 1899. Magyarország madarai, különös tekintettel a gazdasági jelentőségökre [Birds of Hungary, particularly their economic significance]. – Magyar Ornithologiai Központ, Budapest, pp. 142–146. (in Hungarian)
- Csajbók, J. 2012. Szántóföldi növények termesztése és növényvédelme [Cultivation and pest control of agricultural plants]. – University of Debrecen
<http://www.agr.unideb.hu/ebook/szantofoldinovenyek/index.html> (in Hungarian)
- Csáder, I. 2008. A székicsér (*Glareola pratincola*) állománya és védelmi helyzete Magyarországon, különös tekintettel a Kistűszállás-Nagyréti populációra [Population trend and conservation of Collared Pratincoles (*Glareola pratincola*) in Hungary, especially the population of Nagyréti, Kistűszállás's region]. – MSc Thesis, University of Debrecen, <https://dea.lib.unideb.hu/dea/handle/2437/96681> (in Hungarian)
- Endes, M. 1991. Székicsér (*Glareola pratincola*) telepes fészkelése Karcag mellett [Collared Pratincole (*Glareola pratincola*) colonies in region of Karcag]. – Calandrella 5: 87. (in Hungarian)
- Hayman, P., Marchant, J. & Prater, T. 1991. Shorebirds: An Identification Guide to the Waders of the World. – A & C Black
- Kapocsi, I. 2002. Időjárási tényezők hatása a szántóföldi növénykultúrában költő székicsér populációra [The effects of weather conditions the Collared Pratincoles (*Glareola pratincola*) breeding population]. – A Pusztá 17: 10–14. (in Hungarian)
- Kayser, Y. 2015. Suivi de la reproduction de la Glaréole à collier *Glareola pratincola* en Camargue et ses environs et actions de conservation pour l'année 2015 [Nature-conservation actions and monitoring activities of breeding Collared Pratincoles (*Glareola pratincola*) in Camargue's region at 2015]. – <http://www.pole-lagunes.org/sites/default/files/Rapport%20glareoles%202015.pdf> (in French)
- Kiss, Á. 2011. A székicsér (*Glareola pratincola*) élőhelyválasztása a nagyikunsági agrárkörnyezetben [Habitat-selection of Collared Pratincoles (*Glareola pratincola*) in the Nagyikunság region, Hungary]. – MSc Thesis, University of Debrecen (in Hungarian)
- Kovács, G. 1992. Mesterséges szikes tavak és szikes kopárók létesítésének módszerei és tapasztalatai a Hortobágyi Nemzeti Parkban [Methods and experiences of making artificial wetlands in the Hortobágy National Park]. – Aquila 99: 155–161. (in Hungarian with English Summary)
- Kovács, G. 1993. A székicsér (*Glareola pratincola*) hortobágyi állományának alakulása [Population trends of Collared Pratincoles (*Glareola pratincola*) in the Hortobágy National Park]. – Partimadár 1: 16–18. (in Hungarian)
- Kovács, G. & Kapocsi, I. 2005. Székicsér (*Glareola pratincola*) [Collared Pratincole (*Glareola pratincola*)]. – In: Ecsedi, Z. (szerk.) A Hortobágy madárvilága [Birds of Hortobágy]. – Mezőgazda Kiadó, Budapest, pp. 272–276 (in Hungarian)
- Lebedeva, E. A. 1998. Waders in agricultural habitats of European Russia. – International Wader Studies 10: 315–324.
- Oláh, J., ifj. & Széll, A. 1994. A székicsér (*Glareola pratincola*) fészkelése és védelmi helyzete Magyarországon 1994-ben [Population trends and breeding of Collared Pratincoles (*Glareola pratincola*) in Hungary at 1994]. – Partimadár 3: 19–21. (in Hungarian)
- Pigniczki, Cs. 2000. A székicsér (*Glareola pratincola*) visszatelepítése a Kiskunság szikes tavaira [Resettlement of the Collared Pratincoles (*Glareola pratincola*) to soil lakes of Kiskunság]. – Tűzok 5: 24–25. (in Hungarian)
- R Development Core Team 2016. R: a language and environment for statistical computing R Foundation for Statistical Computing, Vienna, <http://www.R-project.org>
- Rakonczai, Z. 1989. Vörös Könyv – A Magyarországon kipusztult és veszélyeztetett növény- és állatfajok [The Red Book of the Hungarian Flora and Fauna]. – Akadémia Kiadó, Budapest, p. 128. (in Hungarian)
- Saveljic, D. 2002. Changes population size of some shorebirds breeding at Ulcinj. – Acrocephalus 23: 39–41.
- Sárvári, M. 2011. A rizs termesztése [Cultivation of rice]. – http://www.tankonyvtar.hu/hu/tartalom/tamop425/0010_1A_Book_adaptalt_02_egyeb_gabonanoventek_termesztese/ch16s04.html (in Hungarian)
- Selmeczi-Kovács, Á. 1994. Székicsér (*Glareola pratincola*) fészkelése Kiskunlacházán [Breeding Collared Pratincoles (*Glareola pratincola*) in Kiskunlacháza]. – Partimadár 4: 8–9. (in Hungarian)
- Sterbetz, I. 1974. Die Brachschnalbe *Glareola pratincola* [Collared Pratincole *Glareola pratincola*]. – Die neue Brehm-Bücherei, Ziemsens Verlag, Wittenberg, Lutherstadt (in German)
- Szabó, L. V. 1980. A Hortobágy madárvilága [Birds of Hortobágy]. – Manuscript 1980.

- Szell, A. 1993. A székicsér (*Glareola pratincola*) fészkelőhely-választása agrár-élőhelyeken [Nest-site selection by Collared Pratincoles (*Glareola pratincola*) in agricultural environment]. – Partimadár 1: 8–15. (in Hungarian)
- Szell, A. 1996. Fokozottan védett állat és védett növényfajok szaporodó közösségeinek előfordulása a Dévaványai Tájvédelmi Körzet térségében [The proliferating occurrence of protected animal and plant species in the region of Dévaványai Tájvédelmi Körzet]. – <http://www.nimfea.hu/kiadvanyaink/pusztaszella%20-%20vedett%20dvanya%20-%2096.pdf> (in Hungarian)
- Szell, A. 2014. Székicsér (*Glareola pratincola*) [Collared Pratincole (*Glareola pratincola*)]. – In: Haraszthy, L. (szerk.) Natura 2000 fajok és élőhelyek Magyarországon [Natura 2000 species and habitats in Hungary]. – Pro Vértes Közalapítvány, Csákvár, pp. 597–600. (in Hungarian)
- Tarján, T. 1934. Székicsér [Collared Pratincole]. – Aquila 38–41: 358. (in Hungarian)
- Wetlands International 2015. www.wetlands.org



The recolonization of the Collared Pratincole (*Glareola pratincola*) in its natural steppe habitats in Hungary – an overview of the species’ grassland activities between 1995 and 2024

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Abstract The Collared Pratincole (*Glareola pratincola*) is an endangered shorebird in Hungary, which disappeared as a character breeding species from its sodic grassland habitats during the mid-1990s. Therefore, it was a positive experience to witness the return of this species to its natural habitats, which we observed and documented in 2022 and 2024, and suggested in 2023. During the 2022 observation, one of the three pairs nesting in the Alsó-Szúnyog-pusztá reached the chick-rearing stage. We have summarised twenty-one observations of the species in its natural habitat during the breeding season between 2013 and 2024. Based on our data, Collared Pratincole has been confirmed to breed three times in Hungary in its natural habitats, with five additional instances of assumed breeding between 1995 and 2021. In 2022, the species bred in sodic grassland (*Camphorosmetum annuae*) grazed with livestock. Pratincoles nested in colonies mixed with Kentish Plovers (*Charadrius alexandrinus*) and other shorebirds, such as Northern Lapwings (*Vanellus vanellus*), Black-tailed Godwits (*Limosa limosa*), and Common Redshanks (*Tringa totanus*).

Keywords: shorebird, sodic grassland, grazing management, nesting behaviour

Összefoglalás A székicsér (*Glareola pratincola*) egy kritikusan veszélyeztetett partimadár-faj Magyarországon amely, mint sziki fészkelő karakterfaj eltűnt természetes élőhelyeiről az 1990-es évek közepén. Ebben a tanulmányban a faj szikes pusztai élőhelyeire történő visszatérését dokumentáltuk, hiszen az eredeti szikes pusztai környezetben hosszú idő eltelte után 2022-ben jelent meg és fészkelte sikeresen Magyarországon. Feltehetően 2023-ban is fészkelte a faj gyepeken, de 2024-ben a gyepi költését újra sikerült bizonyítani. A 2022-es megfigyelés során az Alsó-Szúnyog pusztán fészkelő maximum három párból legalább egy pár eljutott a fiókanevelési időszakig. Adataink alapján 2013 és 2024 között huszonegyszer észlelték a székicsért kóborlóként a költési időszakban gyepeken, továbbá három bizonyított és öt feltételezett költése ismert 1995 és 2021 között. Az Apaj határában fekvő Alsó-Szúnyog-pusztán bizonyított fészkelése magyar szürke szarvasmarhákkal illetve bivalyokkal legeltetett vakszikes területen (*Camphorosmetum annuae*) történt, ahol többek között széki lilékkel (*Charadrius alexandrinus*), bibicékkel (*Vanellus vanellus*), nagy godákkal (*Limosa limosa*) és piroslábú cankökkel (*Tringa totanus*) vegyes kolóniában költöttek.

Kulcsszavak: partimadár, szikes pusztá, legeltetési élőhelykezelés, fészkelési viselkedés

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Introduction

The Collared Pratincole (*Glareola pratincola*) is an insectivorous shorebird species that typically breeds in open, flat sodic areas interspersed with shallow wetlands and low vegetation in its surroundings (Cramp & Simmons 1983). The global population is presumed to be stable (BirdLife International 2021); however, European populations have shown a declining trend in recent decades (Lokhman *et al.* 2020). Within Europe, its populations are isolated and population declines were observed in both western and eastern regions (Lokhman *et al.* 2020). Threat factors include the degradation and loss of traditional steppe areas and wetland habitats. Due to these effects, the species has appeared to breed in alternative habitats, such as agricultural areas, similarly to many other shorebirds – a phenomenon increasingly observed over the past decades (Calvo 1994, Lokhman *et al.* 2020).

In Hungary, the Collared Pratincole is a critically endangered breeding shorebird, with a fluctuating population trend, though due to direct nest protection efforts, the number of breeding pairs increased significantly from 30–31 pairs to 78–86 pairs during the past twelve years (Kiss 2021, Kiss *et al.* 2024). Currently, two breeding populations are known within the Carpathian Basin, which are located in the cultivated fields near the sodic steppes of the Kiskunság region, and the agricultural habitats close to the rice fields in the Nagykunság, in the middle of the Great Hungarian Plain (Kiss *et al.* 2024). Pairs nesting in intensively cultivated farmlands are particularly vulnerable to direct and indirect impacts of agricultural practices, such as disturbance, trampling, ploughing, adverse weather conditions, and increased nest predation (Kiss *et al.* 2018). In the early 20th century, the previously stable population began to decline significantly following the changes that occurred after the Second World War, including the rapid decrease of grazing livestock. Traditionally, the Collared Pratincole was a characteristic and unique nesting species in sodic grasslands grazed by cattles and sheeps, typically near soda pans, marshes, and fishponds, which served as its typical feeding, and roosting places (Sterbetz 1974). The last stable breeding populations of the Collared Pratincole disappeared from the Southern Hortobágy in the mid-1990s (Kovács & Kapocsi 2004). In addition to disappearing from their traditional nesting sites, nesting pairs began to appear sporadically in various arable lands with sparse vegetation, typically in fallow fields. This phenomenon was documented by several ornithologists working in Hungary in the 1970s, 1980s, 1990s, and 2000s. Such nesting records were also known from Békési-sík, Hortobágy, Nagykunság, and Kiskunság (Haraszthy 2019). One of the last confirmed nesting events with parenting chicks in a natural habitat was recorded in 2000 (Pigniczki 2000).

The aim of the study is 1) to describe the recolonization of the species to its natural sodic habitat based on observations in the last three years; 2) to summarise the sightings at former breeding sites during the breeding seasons of Collared Pratincole between 2013 and 2024; and 3) to aggregate probable, suspected, and confirmed breeding data from grassland between 1995 and 2021.

Material and Methods

Collared Pratincole observation data in the former nesting sites were collected between 2013 and 2024 in Hungary, and these traditional breeding sites were documented by Sterbetz (1974) between the early 1900s and early 1970s. Further data were collected from the databases of Hortobágy National Park Directorate and Hortobágy Environmental Association, supplemented by additional records from the database of www.birding.hu and Gábor Kovács personal observations (Kovács 2017). Observations were filtered to the regional nesting period of Pratincoles, specifically between 1 April and 30 June, and include records on wandering individuals as well as typical breeding behaviours such as courtship activities, nest building, and incubation, if there are no other observations on breeding success.

Nesting events were confirmed via the observation of typical behavioural traits associated with the current breeding stage using binoculars and spotting scopes from a hotspot point (Kiss *et al.* 2018), supplemented by field methods developed by Székely *et al.* (2006) for documenting behavioural cues.

Results

Observations in the traditional nesting sites between 2013 and 2024

Based on available data, we collated twenty-one observations of Collared Pratincoles from grasslands during the nesting seasons in four counties (*Table 1, Figure 1*). Among these observations, courtship activities were noted in three instances, although these did not continue with nesting at the observed locations.

Suspected and confirmed breeding attempts between 1995 and 2021

Between 1995 and 2021, eight breeding events were previously recorded (*Table 2, Figure 2*). These data typically reflect the recolonization of nesting at traditional sites between the 1970s and 1990s. The data from Kiskunság can be considered verified nesting, as the nests were found and/or young chicks were observed with the parents. In the cases from Hortobágy, nests were not found after 1992, however, the observation in 2001 was documented as a colony. In other cases, based on the ageing condition of the juveniles, they could have come from nearby nesting sites in Nagykunság.

Observations in 2022

- May 18, 2022: Four Collared Pratincoles displayed intense courtship behaviour at the Alsó-Szúnyog-puszta flooding area. The site appeared highly suitable for potential resettlement, prompting its monitoring initiation (Á. Takács).
- Between May 20 and June 1, 2022: Fluctuating numbers of three to six individuals were observed in the area, showing varying levels of nesting activities (Cs. Pigniczki; Á. Takács).

Table 1. Observations of Collared Pratincoles at former grassland breeding sites during the nesting period between 2013 and 2024

1. táblázat Adatok a székicsérek előfordulásairól az egykori gyepi költőhelyeken 2013 és 2024 között, a fészkelési időszakokban

Date	Location	Number of individuals	Breeding behaviour	Observers
29.04.2014 – 19.06.2014	Apaj Alsó-Szúnyog-pusztza	2	No	N. Kovács, Z. Cserna, Zs. Sempinger, Á. Kiss
28.06.2014 – 28.06.2014	Sándorfalva, Fertő (fishponds)	3	No	O. Kiss, Zs. Kiss, B. Csibrány
09.06.2015	Hortobágy, Hortobágy-fishponds	1	No	D. Balla
28.06.2015 – 30.06.2015	Hortobágy, Hortobágy-fishponds	2	No	T. Emri, M. Barna Zöld, J. Tar
14.05.2016	Nagyhegyes, Kis-Álomzug	1	No	A. Szilágyi
17.05.2016 – 20.05.2016	Balmazújváros, Magdolna-pusztza	1	No	J. Tar, Z. Ecsedi, D. Balla, J. Kecskés <i>et al.</i>
24.05.2016	Sándorfalva, Fertő (fishponds)	1	No	Á. Bede
22.04.2018	Nagyhegyes, Nagy-Álomzug	1	No	S. Konyhás
22.05.2018	Hortobágy, Hortobágy-fishponds	1	No	G. Kovács
16.05.2020	Hortobágy, Akadémiai-libanevelő	2	Yes, displaying male and female	J. Katona, A. Szilágyi, P. Gyüre, M. Nagy, J. Oláh
26.04.2021	Apaj, Alsó-Szúnyog-pusztza	2	No	Zs. Paráda
26.06.2021	Kardoskút, Fehér-tó	1	No	E. Kovács
11.05.2023	Kunmadaras, Kunmadarasi-pusztza	1	No	S. Borza, S. Ujfalusi
14.05.2023 – 24.05.2023	Hortobágy, Vincze-fenék	1	No	J. Tar, T. Zalai, T. Emri, M. Barna Zöld
01.05.2024	Hortobágy, Fényes-fishponds	1	No	M. Nagy, E. Tóth
02.05.2024	Akasztó, Miklapusztza	1	No	T. Bárdos, A. Liker, L. Kocsis
12.05.2024	Hortobágy, Hármaspusztza	1	No	M. Nagy, E. Tóth
12.05.2024 – 26.05.2024	Karcag, Kecseri-pusztza	6	Yes, displaying pairs (3)	Á. Kiss
27.05.2024	Pusztaszer, Vesszős-szék	1	No	Cs. Mészáros
27.05.2024	Mórahalom, Nagy-Széksós-tó	2	Yes, displaying pair	Cs. Mészáros, B. Tokody
17.06.2024	Kunmadaras, Kunmadarasi-pusztza	3	No	S. Borza

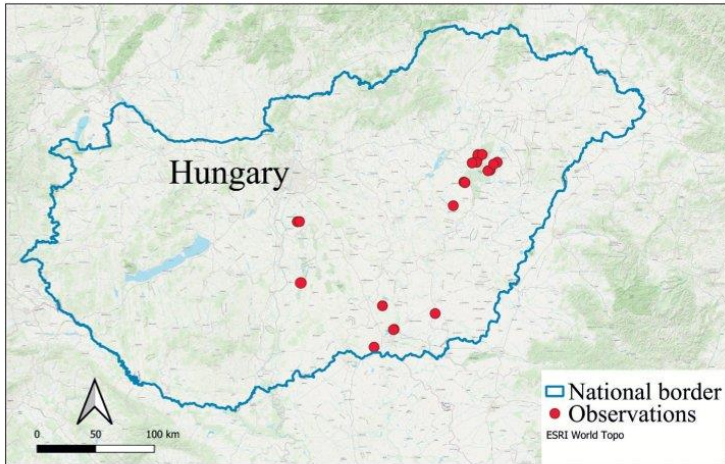


Figure 1. Data of Collared Pratincoles at traditional breeding sites during the nesting period between 2013 and 2024

1. ábra Költési időszakban mutatott székicsér-előfordulások az egykori költőhelyeken 2013 és 2024 között



Figure 2. Probable, suspected and confirmed breeding data of Collared Pratincole in grasslands, Hungary between 1995 and 2021

2. ábra Valószínű, feltételezett és bizonyított székicsér-fészkelések gyepeken, Magyarországon 1995 és 2021 között

Table 2. Assumed and verified nesting performances of Collared Pratincoles in grassland habitats in Hungary between 1995 and 2021

2. táblázat Feltételezett és igazolt gyepi székicsér fészkelések 1995 és 2021 között Magyarországon

Date	Location	Habitat (Plant community)	Confirmed nesting (no. of pairs)	Details	Observer
1997	Apaj, Alsó-Szúnyog-pusztá	Sodic grassland <i>Camphorosmetum annuae</i> , <i>Puccinellietum limosae</i>	Yes (10–12)	Found nests	A. Széll
09. 09. 1998	Kunmadaras, Ecsezug	Sodic grassland <i>Camphorosmetum annuae</i> , <i>Puccinellietum limosae</i>	No (1)	Two chicks (unknown age of chicks) with two parents, nest not found	G. Kovács
24. 06. 2000	Fülöpszállás, Kelemen-szék	Soda pan	Yes (1)	Two freshly hatched chicks with parents	Cs. Pigniczki (Pigniczki 2000)
2001	Kunmadaras, Csikos-hát	Sodic grassland <i>Camphorosmetum annuae</i>	No (4–5)	Alarming behaviour, no found nests	G. Kovács
2004	Apaj, Alsó-Szúnyog-pusztá	Sodic grassland, <i>Puccinellietum limosae</i>	Yes (8–10)	Nesting, nests with eggs were flooded by water after a heavy rain	Cs. Pigniczki, A. Széll
07.08. 2004	Kunmadaras, Forrás-fenék	Sodic grassland <i>Camphorosmetum annuae</i>	No (3)	Alarming behaviour, nest not found	G. Kovács
10. 08. 2005	Karcag, Ecsezug	Sodic grassland <i>Camphorosmetum annuae</i> , <i>Puccinellietum limosae</i>	No (1)	One chick (unknown age of chicks) with two parents, nest not found	G. Kovács
16. 07. 2013	Karcag, Ecsezug	Sodic grassland <i>Camphorosmetum annuae</i> , <i>Puccinellietum limosae</i>	No (3)	Adults with freshly fledged juveniles	G. Kovács, S. Borza

- June 1, 2022: In the late afternoon and early evening, three adult Collared Pratincoles were present. At 18:15, three individuals aggressively attacked a Northern Lapwing. Twenty minutes later, two individuals rested on the shore of the floodplain. At 19:15, one individual flew approximately 300 metres to a barren area, exhibited typical nesting behaviour, including checking and adjusting eggs, and assumed a brooding posture (Á. Kiss, P. Ócsai, Cs. Pigniczki, Á. Takács).
- June 18, 2022: No Collared Pratincole sightings were reported in the area (Cs. Pigniczki).
- June 28, 2022: Three individuals displayed typical nesting behaviour for the species, chasing away European Magpies (*Pica pica*). Later, they returned to roughly the same spots on the ground and remained vigilant (Á. Kiss, M. Lóránt, Á. Takács) (Figure 3).
- July 22, 2022: Two pairs were observed feeding; at one pair, Á. Takács spotted a nestling estimated to be no more than one week old.



Figure 3. A sentinel adult Collared Pratincole at Alsó-Szúnyog-pusztá in 2022 (Photo: Ádám Kiss)
3. ábra A fészkelőhelyen őrködő székicsér Alsó-Szúnyog-pusztán 2022-ben (Fotó: Kiss Ádám)

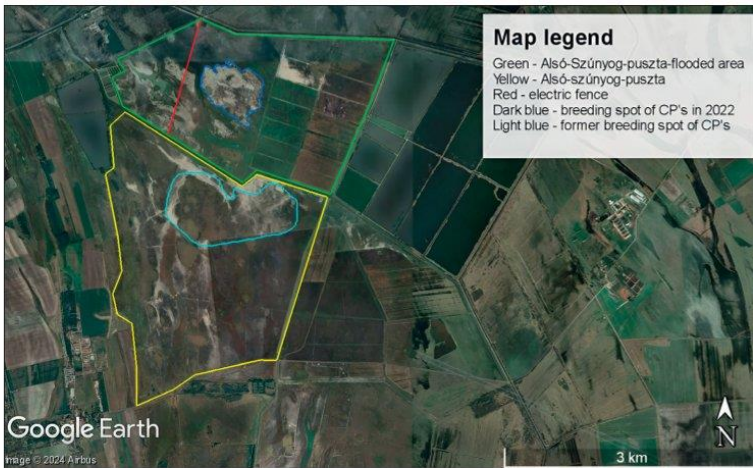


Figure 4. Distribution map of the breeding area of Apaj in 2022, important characteristics bordered by different coloured lines

4. ábra Az apaji fészkelőhely és jellemző szerkezeti elemei 2022-ben



Figure 5. Structure of the alkaline grassland as a breeding site of Collared Pratincoles in 2022 (Photo: Ádám Kiss)

5. ábra A székicsér gyepterületi fészkelőhelye 2022-ben (Fotó: Kiss Ádám)

Based on our observations, it is likely that between late May and early June in 2022, a minimum of one, and a maximum of three pairs of Collared Pratincoles began nesting under natural conditions on a grassland site. First clutches probably failed, however 1–2 pairs in the replacement clutches nested successfully.

This site covers approximately 329 hectares and has been managed through extensive grazing by local farmers under the professional supervision of the Kiskunság National Park Directorate. In 2022, the area was grazed by Hungarian grey cattle and water buffalo, enclosed by electric fencing (Figure 4). This high-level grazing management served as habitat maintenance. The area was flooded by freshwater during the winter. Within the flooding zone, the livestock created a highly mosaic habitat structure through grazing and trampling, benefiting shorebirds with varying habitat requirements.

The Collared Pratincoles and Kentish Plovers (*Charadrius alexandrinus*) selected a barren, approximately 1.6 ha area in the central part of the grassland that sparsely covered with halophile vegetation, and the surface of the ground was poached because of the trampling of the cattles (Figure 4). This white, sodic patch had a few larger areas with manure crust and scattered dung. This specific microhabitat was ideal for Pratincoles due to its unique structure and vegetation (Figure 5).

In Alsó-Szúnyog-puszta, the area's conservation status has been consistently excellent over the years, indicated by the presence of numerous valuable and rare shorebirds as important character species nesting alongside Collared Pratincoles. These include numerous

pairs of Northern Lapwing (*Vanellus vanellus*), 2–4 pairs of Kentish Plover, and a few pairs of Black-tailed Godwit (*Limosa limosa*), and Common Redshank (*Tringa totanus*), all confirmed as co-nesting shorebird species.

Visitors were closed out, thus direct and indirect human disturbance was eliminated. Trampling by grazing livestock in the flooded area likely destroyed some shorebird nests. Predation by mammalian and avian predators could have affected the nesting success of Collared Pratincoles and co-nesting shorebird species at the flooding site. We observed Red Foxes (*Vulpes vulpes*), Western Marsh Harriers (*Circus aeruginosus*), European Magpies, and Hooded Crows (*Corvus cornix*) in the area. Fox sightings occurred once, while Harriers were regularly present in small numbers (1–2 individuals). Hooded Crows occasionally flew alone above the area, however, did not establish a sustained presence due to the lack of suitable roosting sites. It is important to note that the medium-voltage power line in the area was removed in 2019, previously, the pylons and wires were both used as perching spots by predators, including Hooded Crows and other avian predators.

In 2022, intensive rainfall likely did not cause nest failures as no significant precipitation events happened that year. However, in 2023 and 2024, the area was affected by larger amount of precipitation during spring and summer.

Observations in 2023

- One adult was observed on 29th April (Á. Takács).
- Between May 6 and July 3, five additional observations were recorded from the area, typically involving 1–4 individuals, either on the ground or feeding above the site, reported by observers and uploaded to the www.birding.hu database.

Observations in 2024

- Two displaying adults were observed on the site on 2nd May (Á. Takács). Cs. Pigniczki likely found and recorded an alarming, plus an incubating pair on 25 May. These birds attacked flying predators, too. The two pairs moved to the former, traditional breeding site. A few days later, nesting could no longer be confirmed as the breeding bird was not present, the cause of nest failure remained unknown.
- On June 3, T. Sági observed a mating pair at Kelemen-szék near Fülöpszállás.
- On 5 June, Cs. Pigniczki also observed the same pair at Zab-halmi-szék, they arrived from the south, probably from Kelemen-szék and moved forward to the north while hunting above the area.

Discussion

Here, we presented the recolonization events of the Collared Pratincole in sodic grasslands habitats in Hungary in 2022–2024. Pratincoles are also nested in similar, low-vegetation and rarely covered nesting sites with huge bare areas on the ground, which

have historically characterized as the typical habitat of this species. This type of sodic grassland environment with this character plant community structure grazed mainly by cattle was similar to that was documented by Szabó (1980) in the Hortobágy. In southwest Spain, Collared Pratincoles chose breeding sites on dry mud spots close to marshlands, which were covered by cow pats in higher densities (Villanueva 1993). In 2022, Hungarian grey cattles often rested close to the breeding sites during the midday hours, leading to a higher density of cow pats.

The persistent emergence of Collared Pratincole nesting in natural habitats provides hope for conservation efforts, as the species' habitat selection likely involves a complex interplay of known and unknown factors. Indeed, it is a well-known fact in management processes that the grazing level of the area needs to be high. A similar habitat management practise was previously observed at the Kunmadarasi-pusztas area, in the Hortobágy by Gábor Kovács, moreover in Doñana National Park, Spain, where the breeding habitats around the salt lakes were grazed by a mixed flock of cattle and horses before the breeding season in 2018 (Á. Kiss *pers. obs.*). The high level of grazing in the habitat likely increased the local insect density, making potential prey more easily available in the area, however, we did not investigate this at this time. Hopefully, in the coming years, the species will reappear in previous traditional steppe and soda pan habitats, especially following successful nesting events by resident pairs during the preceding years. If management conditions remain favourable and the presence and density of co-nesting shorebird species show similar patterns, Collared Pratincoles could potentially become regular breeders in the natural habitats of the Kiskunság region.

In recent years, grazing management changes have also taken place in various parts of the Hortobágy region, suggesting that the species may also appear there before and during the breeding season, with individuals or pairs exploring the area. The species regularly visited the wetlands and "pusztas" of Southern Hortobágy during the nesting period and immediately after, which assumes that the ecological conditions for the species were favourable at that time. Though less frequent, spring and early summer sightings indicate that individuals potentially wandering through the region or those starting their breeding season later or after failed attempts may return to former nesting sites if suitable feeding conditions persist, possibly staying longer. Moreover, after the end of the breeding season, individuals from the current population in Nagykunság also reach their former steppe nesting sites. This was evidenced by a colour-ringed individual marked as a chick near to Nagyrét (Kisújszállás) in 2022, and observed as a juvenile by S. Borza close to Nagyvíván.

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References

- BirdLife International 2021. Species factsheet: *Glaresola pratincola*. The IUCN Red List of Threatened Species 2021: e.T22694127A166268593. – DOI: 10.2305/IUCN.UK.2021-3.RLTS.T22694127A166268593.en
- Calvo, B. 1994. Effects of agricultural land-use on the breeding of Collared Pratincole *Glaresola pratincola* in south-west Spain. – *Biological Conservation* 70(1): 77–83.
- Cramp, S. & Simmons, K. E. L. 1983. *The Birds of the Western Palearctic*, Vol. 3. – Oxford University Press, Oxford, UK, p. 480.
- Haraszthy, L. 2019. Székcicsér (*Glaresola pratincola*) [Collared Pratincole]. – In: Haraszthy, L. *Magyarország fészkelő madarainak költésbiológiája I.* [Breeding Biology of Birds in Hungary 1.]. – Pro Vértes Nonprofit Zrt. Csákvár, pp. 531–539. (in Hungarian)
- Kiss, Á., Monoki, A. & Végvári, Zs. 2017. Nest-site selection and population trend of Collared Pratincoles *Glaresola pratincola* in agricultural habitats of the Nagykunság region (Hungary). – *Ornis Hungarica* 25(1): 25–38. DOI: 10.1515/orhu-2017-0002
- Kiss, Á., Molnár, A., Monoki, Á., Kapocsi, I., Kovács, G., Aradi, Cs., Széll, A., Csíder, I., Lóránt, M. & Őze, P. 2018. A szántóföldi környezetben fészkelő székcicsér *Glaresola pratincola* természetvédelmi helyzete és megőrzésének lehetőségei Magyarországon, különös tekintettel a nagykunsági fészkelő-állományra [Breeding activities and conservation status of Collared Pratincole *Glaresola pratincola* breeding in agricultural habitats in the Nagykunság region, Hungary]. – *Aquila* 125: 49–72. (in Hungarian)
- Kiss, Á. 2021. Székcicsér (*Glaresola pratincola*) [Collared Pratincole]. – In: Szép, T., Csörgő, T., Halmos, G., Lovászi, P., Nagy, K. & Schmidt, A. (eds.) *Magyarország madáratlasza* [Bird Atlas of Hungary]. – Agrárminisztérium, Magyar Madártani és Természetvédelmi Egyesület, Budapest, pp. 265–266. (in Hungarian with English Summary)
- Kiss, Á., Végvári, Z., Kubelka, V., Monoki, Á., Kapocsi, I., Göri, S. & Székely, T. 2024. Breeding in an agricultural landscape: conservation actions increase nest survival in a ground-nesting bird. – *Oryx* 58(2): 240–249.
- Kovács, G. & Kapocsi, I. 2004. Székcicsér *Glaresola pratincola* [Collared Pratincole]. – In: Ecsedi, Z. (eds.) *A Hortobágy madárvilága* [Birds of Hortobágy]. – Winter Fair, Balmazújváros – Szeged, Hungary, pp. 272–276. (in Hungarian)
- Kovács, G. 2017. A Hortobágyon fészkelő székcicsérek áttelepedése gyepekről szántókra [Habitat changing of Collared Pratincoles in the Hortobágy region]. – Note (in Hungarian)
- Lokhman, Y. V., Fedosov, V. N. & Kalyakin, M. V. 2020. Collared Pratincole *Glaresola pratincola*. – In: Keller, V., Herrando, S., Vorišek, P., Franch, M., Kipson, M., Milanese, P., Martí, D., Anton, M., Klvaňová, A., Kalyakin, M. V., Bauer, H-G. & Foppen, R. P. B. (eds.) *European Breeding Bird Atlas 2: Distribution, Abundance and Change*. – Lynx Edicions, European Bird Census Council (EBCC), Barcelona, Spain, p. 284.
- Pigniczki, Cs. 2000. A székcicsér (*Glaresola pratincola*) visszatelapódása a Kiskunság szikes tavaira [Collared Pratincoles (*Glaresola pratincola*) returning to their former breeding site on the saline lakes of Kiskunság]. – *Tüzek* 5: 24–25. (in Hungarian)
- Sterbetz, I. 1974. Die Brachschwalbe: *Glaresola pratincola* [Collared Pratincole]. – *Neue Brehm-Bücherei*; mit 53 Abb. u. 24 Tab. Ziemsen (in German)
- Szabó, L. V. 1980. A Hortobágy Madárvilága [Birds of Hortobágy]. – Manuscript (in Hungarian)
- Székely, T., Kosztolányi, A. & Küpper, C. 2006. *Practical Guide for Investigating Breeding Ecology of Kentish Plover *Charadrius alexandrinus**. – University of Bath, UK
- Villanueva, B. C. 1993. Influences of Agricultural Land-Use and Habitat Modification on the Breeding Biology and Conservation of Collared Pratincoles *Glaresola pratincola* in SW Spain. – University of Glasgow, UK, pp. 56–59.
- <http://www.birding.hu>
- <http://map.mme.hu/page/programme>



Mixed-species nesting in an agricultural landscape: Collared Pratincoles are attracted to Northern Lapwings

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Author contributions

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Colonial breeding is a common reproductive strategy since coloniality often enhances reproductive success, and the benefits may be shared among co-nesting species. Here we investigate a ground nesting shorebird, the Collared Pratincole *Glareola pratincola*, which experienced a rapid population decline followed by a recent recovery in Hungary. Whilst traditionally the pratincoles nested on alkaline grasslands called “puszta”, in recent years they only bred on farmlands such as arable and sunflower fields. Using data from a 11year field study, here we report the nesting behaviour of pratincoles in relation to their social spacing: solitary nesting ($n = 7$), single-species colonies ($n = 30$) and mixed-species colonies ($n = 40$). The most common co-nesting species was Northern Lapwing *Vanellus vanellus* that nested in 57% of pratincole colonies. Three pieces of evidence suggest that pratincoles choose lapwings rather than *vice versa*. First, in mixed colonies lapwings bred earlier than the pratincoles. Second, the distance between pratincole and lapwing nests was significantly shorter than the distance between a pratincole nest and a randomly generated nest. Third, single-species pratincole colonies were frequently formed after no new lapwing nest was initiated. The area of the colony increased with nest numbers both in single-species and mixed-species colonies. We suggest that the primary beneficiaries of mixed colonies are the pratincoles, although lapwings may also benefit from increased vigilance and antipredator behaviour of pratincoles. An important implication of our study is that conservation actions that aimed at improving Collared Pratincole populations should also consider the habitat preferences of co-nesting species (such as Northern Lapwing) in order to achieve high breeding success of the conservation-targeted species.

Keywords: coloniality, anti-predator defence, nest-site selection, social behaviour, breeding behaviour

Choosing a suitable and safe breeding site is some of the most important life history decision, and these choices could influence reproductive success and breeding strategies (Jones, 2001; Loukola et al., 2012). Nest site selection can be influenced by many factors, including the biotic and abiotic environment as well as an individual's age, health status and sex (Paton, 1994; Latif et al., 2012). Nesting individuals may also cooperate with other species to increase their reproductive success (Burger, 1981; Włodarczyk, 2012; Tan et al., 2009). When breeding together with other species, the selection of breeding sites may be influenced by the presence of co-breeding species (Visscher, 2007; Johnson et al., 2011; Cunningham et al., 2016). Breeding associations among different species may occur when one (or several) co-breeding species benefit from the presence of other species (Arnold & Owens, 1999; Quinn & Ueta, 2008) or when suitable nest sites are limited and several species are forced to co-nest (Farine et al., 2014). Shared benefits may include nutrients required for offspring care and increased protection from predators (Ashbrook, 2008; Dean et al., 2015; Honda & Azuma, 2021). Concomitantly, mixed-species breeding has been reported from various waterbirds, raptors, seabirds, shorebirds and songbirds (Lamarre et al.; 2017, Gameiro et al., 2022).

The benefits of colonial breeding may depend on several ecological and behavioural factors. Higher breeding density may reduce the rate of predation for individual breeders in various waterbirds (Väänänen, 2000; Coulson, 2002; Hernández-Matías, et al., 2003, Minias, et al., 2020) or other bird groups (Arroyo et al., 2001; Picman et al., 2002; Serrano et al., 2005). The reduced predation rate may emerge from evicting predators, early warning of colony members of the approaching predators or diluting the risk of being depredated across many nesting individuals (Gameiro et al., 2022). Another important benefit of coloniality is enhanced food detectability, which can also have a significant impact on spatial arrangement of breeding sites (Burke & Montevecchi, 2009; Catlin et al., 2024).

Here we investigate the breeding strategies of a ground-nesting shorebird, the Collared Pratincole *Glareola pratincola*. Historically, pratincoles were characteristic breeders of alkaline grasslands, soda pans, and sodic lakes across Eurasia, including the Great Hungarian Plain (Sterbetz, 1974; Cramp & Simmons, 1983; Lokhman et al., 2020). After the 1940ies, the population size of Collared Pratincole decreased until the beginning of the 1990ies in Hungary, and it has been slowly recovering since 2012 (Kovács & Kapocsi, 2004; Kiss, 2021). Population recovery has coincided with an increasing use of agricultural habitats as breeding sites (e.g., arable land, sunflower and alfalfa fields, Kiss et al., 2018; 2024). Collared Pratincole may breed solitarily, in single-species colonies or in mixed-species colonies – in the latter case jointly with Northern Lapwing *Vanellus vanellus*, Eurasian Stone-curlew *Burhinus oediacnemus*, Common Redshank *Tringa totanus*, Black-tailed Godwit *Limosa limosa* or Kentish Plover *Anarchynchus alexandrinus* (Szabó, 1965; Aradi, 1979; Cramp & Simmons, 1983).

Here we have two main objectives. First, to summarise the frequencies of three different social spacing: solitary, single-species and mixed-species colonies of Collared Pratincoles, using data collected between 2013 and 2023 in Nagyikunság region, Eastern Hungary. Second, to investigate the nest site selection of pratincoles in relation to that of the most common co-breeder, the Northern Lapwing. Since lapwings show active predator deterrence (Elliot, 1985; Kis et al., 2000) and they typically start breeding earlier in the season than the pratincoles, we hypothesised that nesting colonies of lapwings attract pratincoles to breed nearby and thus pratincoles choose to nest close to lapwing nests.

Methods

Study area and fieldwork

We investigated pratincoles and associated species in the Nagyikunság region, Eastern Hungary (47°13'12.2"N, 20°53'13.5"E). Fieldwork focused on the southern part of this region that is largely agricultural fields, paddy fields, fishponds and patches of alkaline grasslands, approx. 13,000 hectares (Kiss et al., 2024). We carried out fieldwork between 2013 and 2023 starting in mid-April (when Northern Lapwing generally start to nest) and finishing in early August when

pratincole chicks have fledged and the families left the breeding sites. Using a 4WD vehicle, the observers (ÁK, ÁM) searched breeding sites and looked for nesting activities using standard protocols in shorebird field biology (Székely et al., 2008; Kubelka et al., 2018). Solitary nesting was defined as a breeding event when no other pratincole or other shorebird nest was within approximately 500 meters of the focal pratincole nest, whereas pratincole colonies were identified by having at least another pratincole nest within 500 meters. Based on Aradi (1979) and our field observations, when pratincoles in a colony exhibited alarm behaviour, we did not observe any individuals arriving from another colony located more than 500 meters away. When defining the colonies, we examined the distribution of nest-to-nest distance frequencies (see Supp Fig. 1), which supported our definition of colonies. The colonies were clearly distinguishable from each other by having large distances among them, usually more than one kilometre. To identify mixed colonies, we constructed a minimum convex polygon around the pratincole nests within each colony, and if there was/were nest(s) of other shorebird species inside the polygon, we defined it as a mixed colony.

For each pratincole and lapwing nest, we recorded the date of finding, location using EOV (sometimes referred as HD 1972) coordinates (Spatial Reference Development Team, 2024), clutch size and incubation float stage in the field; the latter was used to estimate the egg-laying date (Mabee et al., 2006; Sládeček et al., 2014). Each nest was visually checked from at least 100 m every other day. We also estimated the fate of each nest, classified as (1) hatched when at least one egg hatched, or (2) failed, which is further classified based on evidences in the nest scrape or around the nest (e.g., eggshell remains, footprints) as (i) deserted, (ii) flooded, (iii) destroyed by agricultural machinery, (iv) predated, or (v) unknown (Székely, 1992; Šálek & Smilauer, 2002; Mabee et al., 2006; Sládeček et al., 2014). The date of egg-laying was known for nests found during egg-laying, estimated using float stage (Székely et al., 2008) or back-calculated from the hatch date assuming 18 days and 26 days of incubation for Collared Pratincole and Northern Lapwing, respectively (Myhrvold et al., 2015). Nest predators were

identified by trail camera images, footprints around the nest or by visual observations during nest visits.

After each field season, we processed the nest coordinates in shapefile format using ArcMap 10.2 software (see Fig. 1). Field boundaries of each breeding site were recorded in polygon shape format. We identified three types of pratincole social spacing units: a) solitary nest, b) single-species colony, c) or mixed-species colony with Northern Lapwing.

Statistical methods

To investigate the relationships between egg laying dates of pratincoles and lapwings in a given area where the Julian day of egg laying of nests was the response variable, we considered the i) laying date of the first nest and ii) relative egg laying date which referred to the egg laying date of each nest relative to the mean egg laying date of a both species in a given colony divided by the standard deviation of egg laying dates of all nests in a colony. Next, we fitted separate Generalized Linear Models (GLMs) to both response variables using year, presence of co-nesting species (i.e., Northern Lapwing) and the type of agricultural habitats (croplands, spring-cover crops, fallow lands) as explanatory variables.

To understand the formation of the colony structure of the studied species, we carried out two sets of analyses to investigate spatial distribution of pratincole nests in mixed colonies. In the first set of analysis all nests were included, in the second set only nests which were laid after the first lapwing nest were included. For both sets we applied the following procedures: (i) we extracted the coordinates of Northern Lapwing and Collared Pratincole nests within polygons and allocated a colony ID to these nests; (ii) we used all nests irrespective of the timing of the egg laying dates and (iii) for each Collared Pratincole nest, we calculated the mean Euclidean distance to all Northern Lapwing nests within each polygon, (actual distances). (iv) In each polygon we randomly generated 1000 points and calculated the mean Euclidean distances of each Collared Pratincole nest to these random points; (randomdistances) were referred as random distances. Finally, we used linear regression to investigate if there is a statistical difference between

the actual and the random distances. In order to avoid edge effects, for each colony we defined the area for which the random points were generated by computing an inner rectangular polygon, equal widths to the field boundary polygon, obtained by downscaling it so that it crossed the nest with the minimum perpendicular distance to the field boundary polygon (Supplementary Fig. 2). For all nests within this borderline, we assumed no edge effect.

For the second set of data, we repeated the analyses using only nest data for which Collared Pratincole colonies were established later than the Northern Lapwing nests within the given area, to investigate if the timing of the egg-laying in Lapwings has an effect on the nest site selection of the pratincoles.

To analyse potential associations between the area of a colony, colony type (single-species or mixed-species) and the number of breeding pratincoles, we fitted a linear regression on the log-transformed colony area ($\log_{10}[\text{ha}]$) as a function of the full interaction term of the colony type and the log-transformed value of the number of nests, computed for i) pratincole nests only and ii) all shorebird nests.

We employed the following packages in the R statistical programming environment: readxl for reading Excel tables (Wickham & Bryan 2023); rgdal (Bivand et al., 2023) and rgeos (Bivand & Rundel, 2023) for geostatistical data processing and analyses as well as spatstat for generating random points within polygons, and for calculating distances between points (Baddeley et al., 2015).

Results

Nesting chronology and breeding habitats

We found 386 nests of Collared Pratincoles, 192 nests of Northern Lapwings, 30 nests of Black-tailed Godwits, and 10 nests of Common Redshanks between 2013 and 2023. The egg laying period was estimated for 295, 136, 13 and 6 nests of Collared Pratincoles, Northern Lapwings, Black-tailed Godwits and Common Redshanks, respectively. Egg-laying started between 26th March and 1st of April in lapwings and between 28th April and 4th May in pratincoles. The peak egg-laying was between 30th of April and 20th of May for lapwings (72%; $n = 98$ nests), whereas for pratincoles it was between 7th and 27th May (56.6%; $n = 167$ nest). Egg-

laying terminated between 4th and 10th of June in lapwings whereas between 9th and 15th July in pratincoles (Fig. 2).

The first mixed colonies were recorded on 5th May \pm 1.8 days (se) and the last ones finished on 14th June \pm 2 days, and the average duration of mixed colonies was 40 ± 1.8 days ($n = 40$ social nesting unit). In mixed colonies, the peak egg-laying dates of lapwings were between 30th April and 20th June (72.2%; $n = 88$ nests), and 7th and 27th of May (71.3%; $n = 129$ nests) for pratincoles (Fig. 2), and most mixed colonies (91.2%, $n = 34$) were in May (Table 1). In mixed colonies the lapwings started egg-laying significantly earlier than the pratincoles (Table 2). In mixed colonies the lapwings started egg-laying significantly earlier than the pratincoles, showing earlier relative egg laying dates for a given colony and suggesting that pratincoles chose to lay close to lapwings rather than *vice versa* (Table 2).

Mixed colonies were often in row crops (especially in sunflower and maize fields 73%; $n = 29$ social nesting units), fallow lands (18%; $n = 7$ nesting units), and spring-cover crops (mainly alfalfa and millet 9%; $n = 4$ nesting units). Mixed colonies in fallow lands were established later than mixed colonies in croplands or in spring-cover crops (Table 2). The frequency of nesting units differed among the three habitats; most mixed colonies were in row crops (Pearson's χ^2 test, $\chi^2 = 12.243$, $df = 4$, $P = 0.0156$, Table 3).

Nest spacing

We found 40 colonies of pratincoles mixed with lapwings, 30 colonies of single-species pratincole colonies and 7 solitary pratincole nests (Supplementary table 1). Mixed colonies were common, since 57% of colonies included at least one lapwing nest ($n = 70$; Supplementary table 1). In mixed colonies, 56% of all nests were pratincole nests ($n = 40$ nesting units; Supplementary table 1). The average number of pratincole and lapwing nests in mixed colonies was 5.6 ± 0.8 and 4.2 ± 0.6 , respectively ($n = 224$ and 168 nests for pratincoles and lapwings). The colony size (defined as the number of pratincole nests) was not associated with the number of lapwing nests in a given colony (linear regression, $b = 0.209$, $se = 0.214$, $t = 0.978$, $P = 0.334$).

When pooling pratincole and lapwing nest data, nests were significantly closer to each other than estimated by random distribution (logistic regression, $b = -124.63$, $se = 13.58$, $|t| = 9.177$, $P < 0.001$), and pratincoles laid their nests closer to lapwing nests which had already been laid before the pratincole nest than expected by random distribution (logistic regression, $b = -161.17$, $se = 19.37$, $|t| = 8.321$, $P < 0.001$).

Finally, we investigated spacing within colonies. The minimum distance between a lapwing and a pratincole nest was 8.94 m whereas the mean distance between lapwing and pratincole nest was 181.4 ± 4.88 m ($n = 224$ nest for Collared Pratincoles, 168 nest for Northern Lapwings). The area of mixed-species colonies was 4.1 ± 0.69 hectares ($n = 40$ nesting units) whereas single-species colonies was 1.8 ± 0.48 hectares ($n = 30$ nesting units). Larger colonies accommodated more nests than smaller colonies both in single-species and mixed-species colonies with a significant interaction term between colony type and nest numbers (Table 4, Fig. 3). The significant interaction terms indicates that in mixed colonies the area of the colony increased faster with the growing number of nests of all shorebirds (pratincoles, lapwings, godwits and redshanks) than in single-species colonies (Table 4).

Discussion

Our study resulted in three main findings: (i) Unlike many ground-nesting shorebirds, Collared Pratincoles often breed in mixed colonies in Hungary, typically with Northern Lapwings, (ii) in mixed-species colonies the pratincole nests were laid later than lapwing nests suggesting that pratincoles were attracted to the vicinity of lapwings, and (iii) breeding lapwings seem to play a key role in planning conservation actions in the future. Below we discuss these findings.

Costs and benefits of mixed and single-species colonies

Why did lapwings attract pratincoles to nest nearby? We showed that pratincoles seeked out the proximity of lapwings, rather than vice versa. We view this as an outcome of two main processes. On the one hand, lapwings are territorial, so they prefer to keep a space around their nest free from additional species (Elliot, 1985; Kis et al., 2000), whereas pratincoles are colonial so they readily nest very close to each other and

to other species as well. On the other hand, both species may draw benefits from nesting in loose colonies. First, more eyes spot an approaching predator quicker than a few pairs of eyes. This has been showed for foraging shorebirds (Cresswell et al., 2003), and also seem applicable for colonial nesting (Burger, 1987, Colwell, 2010; Cunningham et al., 2016).

Second, larger crowds of birds can mob and evict potential predators more efficiently than a single pair or a small number of breeders (Minias et al., 2020). Mobbing can distract a predator's attack, which thus leads to improved nest survival.

Third, lapwings are more aggressive to intruders than pratincoles, whereas pratincoles have a sophisticated strategy of "broken wing" display with which they lure predators away. In uniform habitats such as steppes where many pratincoles nest, pratincoles can warn colony members within hundreds of metres whilst the predator is approaching. By producing a repertoire of broken wing displays, false brooding and weird choking (intense choking distress behaviour) displays, the predator can be easily led away from the real location of the nest. Observations on foxes and dogs show that ground nesting little terns can successfully lead mammalian predators away from the colony using broken-wing displays (Székely, T, Kovács, G. *pers. obs.*; De Framond et al., 2022).

Implications for conservation managements

Our result is important for conservation management since Collared Pratincole is an excellent umbrella species in Eurasian steppes and wetlands; accordingly, the species plays an important role in conservation at both local and regional levels, similarly for other shorebirds species in other study sites (Maslo et al., 2016; Morales & Traba, 2016; LIFE Public Database, 2025). Efforts to protect them provide benefits for other ground-nesting bird species with decreasing populations that choose similar habitats (Roberge & Ambelgstam, 2004). Here we show that presence of co-breeding bird species, like the Northern Lapwing, is crucial for nest site selection of Collared Pratincoles. Based on this we suggest when establishing conservation activities, including the creation of natural and artificial nesting sites by humans, it is important to ensure that these sites are attractive not only to the target

species but also to other important shorebird species. Habitat improvements should consider both spatial and temporal features of the habitat selection of all study species with special attention to mixed colony breeder species. Our results imply variation in the species-specific settlement patterns of mixed-species colonies across different agricultural habitats. Birds started mixed colonies later in fallow lands compared to the other two habitat types. This effect was likely due to applied agrotechnological methods as fallow lands were formed later in time (after completing sowing activities). This motivated us to create undisturbed fallow lands for the pratincoles earlier every year in collaboration with local farmers (details in Kiss et al., 2024). Thus, we propose that decision makers should apply a community-level approach for future conservation projects targeting shorebirds.

Ethical note

None.

Conflict of interest

The authors declare that they have no conflict of interest.

Data availability statement

The section of the database on Northern Lapwing that underpins our study's findings is accessible through the Reproductive Research Group and the Directorate of the Hortobágy National Park upon reasonable request. Data on GPS locations of Collared Pratincole nests cannot be shared due to its endangered status and to preserve the anonymity of nesting site locations.

References

- Aradi, Cs. (1979). Telepesen fészkelő madarak etológiai vizsgálata. MTA *Biológiai Osztály Közleményei* 22: 239–256.
- Arnold, K. E. & Owens, I. P. F. 1999. Cooperative breeding in birds: the role of ecology. *Behavioral Ecology* 10: 465–471.
- Arroyo, B., Mougeot, F., & Bretagnolle, V. (2001). Colonial breeding and nest defence in Montagu's harrier (*Circus pygargus*). *Behavioral Ecology and Sociobiology*, 50(2), 109–115.

<https://doi.org/10.1007/s002650100342>

- Ashbrook, K., Wanless, S., Harris, M. P., & C. Hamer, K. (2008). Hitting the buffers: Conspecific aggression undermines benefits of colonial breeding under adverse conditions. *Biology Letters*, 4(6), 630–633. <https://doi.org/10.1098/rsbl.2008.0417>
- Baddeley A, Rubak E, Turner R (2015). *Spatial Point Patterns: Methodology and Applications with R*. Chapman and Hall/CRC Press, London. ISBN 9781482210200, <https://www.routledge.com/Spatial-Point-Patterns-Methodology-and-Applications-with-R/Baddeley-Rubak-Turner/p/book/9781482210200>
- Bivand, R., Keitt, T., Rowlingson, B. (2023). `_rgdal`: Bindings for the 'Geospatial' Data Abstraction Library. R package version 1.6-7, <https://CRAN.R-project.org/package=rgdal>
- Bivand, R., Rundel, C. (2023). `_rgeos`: Interface to Geometry Engine - Open Source ('GEOS'). R package version 0.6-4, <https://CRAN.R-project.org/package=rgeos>
- Burger, J. (1981). A Model for the Evolution of Mixed-Species Colonies of Ciconiiformes. *The Quarterly Review of Biology*, 56(2), 143–167. <https://doi.org/10.1086/412176>
- Burger, J. (1987). Physical and social determinants of nest-site selection in Piping Plover in New Jersey. *The Condor* 89: 811—818.
- Burke, C. M., & Montevecchi, W. A. (2009). The foraging decisions of a central place foraging seabird in response to fluctuations in local prey conditions. *Journal of Zoology*, 278(4), 354–361. <https://doi.org/10.1111/j.1469-7998.2009.00584.x>
- Catlin, D. H., Gibson, D., Hunt, K. L., Weithman, C. E., Boettcher, R., Gwynn, R., Karpanty, S. M., Fraser, J. D., Ritter, S., & Maxwell, S. M. (2024). Movement patterns of foraging common terns (*Sterna hirundo*) breeding in an urban environment in coastal Virginia. *PLOS ONE*, 19: e0304769. <https://doi.org/10.1371/journal.pone.0304769>
- Cramp, S. & Simmons, K.E.L. (1983). *The Birds of the Western Palearctic*, volume 3. Oxford University Press, Oxford, UK.

- Cresswell, W., Quinn, J. L., Whittingham, M. J., & Butler, S. (2003). Good foragers can also be good at detecting predators. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 270: 1069–1076. <https://doi.org/10.1098/rspb.2003.2353>
- Colwell, M.A. (2010). *Shorebird Ecology, Conservation, and Management*. University of California Press, Berkeley, USA.
- Coulson, J. (2002). Colonial breeding in seabirds. *Biology of marine birds*, 87–113.
- Cunningham, J. A., Kesler, D. C., & Lanctot, R. B. (2016). Habitat and social factors influence nest-site selection in Arctic-breeding shorebirds. *The Auk: Ornithological Advances* 133: 364–377. <https://doi.org/10.1642/AUK-15-196.1>
- Dean, B., Kirk, H., Fayet, A., Shoji, A., Freeman, R., Leonard, K., Perrins C.M. & Guilford, T. (2015). Simultaneous multi-colony tracking of a pelagic seabird reveals cross-colony utilization of a shared foraging area. *Marine Ecology Progress Series* 538: 239–248. <https://doi.org/10.3354/meps11443>
- De Framond, L., Brumm, H., Thompson, W. I., Drabing, S. M., & Francis, C. D. (2022). The broken-wing display across birds and the conditions for its evolution. *Proceedings of the Royal Society B: Biological Sciences*, 289, 20220058. <https://doi.org/10.1098/rspb.2022.0058>
- Elliot, R. D. (1985). The exclusion of avian predators from aggregations of nesting lapwings *Vanellus vanellus*. *Animal Behaviour*, 33: 308–314. [https://doi.org/10.1016/S0003-3472\(85\)80144-5](https://doi.org/10.1016/S0003-3472(85)80144-5)
- Farine, D. R., Downing, C. P., & Downing, P. A. (2014). Mixed-species associations can arise without heterospecific attraction. *Behavioral Ecology* 25: 574–581. <https://doi.org/10.1093/beheco/aru023>
- Gameiro, J., Franco, A. M., Catry, T., Palmeirim, J. M., & Catry, I. (2022). Antipredator benefits of heterospecific colonial breeding for a predominantly solitary bird. *Animal Behaviour*, 189: 101–111. <https://doi.org/10.1016/j.anbehav.2022.05.005>

- Hernández-Matías, A., Jover, L., & Ruiz, X. (2003). Predation on common tern eggs in relation to sub-colony size, nest aggregation and breeding synchrony. *Waterbirds*, 26: 280–289.
[https://doi.org/10.1675/1524-4695\(2003\)026\[0280:POCTEI\]2.0.CO;2](https://doi.org/10.1675/1524-4695(2003)026[0280:POCTEI]2.0.CO;2)
- Honda, R., & Azuma, N. (2021). Asymmetric antipredator behaviour in a mixed-species colony of two non-mobbing bird species. *Ardea*, 109: 167–173. <https://doi.org/10.5253/arde.v109i3.a9>
- Johnson, M., and J. R. Walters (2011). Proximate and ultimate factors that promote aggregated breeding in the Western Sandpiper. *Zoological Research*, 32: 128–140. <https://doi.org/10.3724/sp.j.1141.2011.02128>
- Jones, J. (2001). Habitat selection studies in avian ecology: a critical review. *The auk*, 118: 557–562. <https://doi.org/10.1093/auk/118.2.557>
- Kis, J., Liker, A. Szekely, T. (2000). Nest defence by lapwings: observations on natural behaviour and an experiment. *Ardea*, 88: 155–163.
- Kiss, Á., Molnár, A., Monoki, Á., Kapocsi, I., Kovács, G., Aradi, C., Széll, A., Csíder, I., Lóránt M., & Óze, P. (2018). A szántóföldi környezetben fészkelő székicsér *Glareola pratincola* természetvédelmi helyzete és megőrzésének lehetőségei Magyarországon, különös tekintettel a nagykunsági fészkelő-állományra. *Aquila*, 125: 49–72.
- Kiss, Á., Végvári, Z., Kubelka, V., Monoki, Á., Kapocsi, I., Gőri, S., & Székely, T. (2024). Breeding in an agricultural landscape: conservation actions increase nest survival in a ground-nesting bird. *Oryx* 58: 240–249. <https://doi.org/10.1017/S0030605323000911>
- Kovács, G. & Kapocsi, I. (2004). Székicsér (*Glareola pratincola*). In A Hortobágy madárvilága (ed. Ecsedi, Z.) pp. 272–276. Winter Fair, Balmazújváros-Szeged, Hungary.
- Kubelka, V., Šálek, M., Tomkovich, P., Végvári, Z., Freckleton, R. P., & Székely, T. (2018). Global pattern of nest predation is disrupted by climate change in shorebirds. *Science*, 362: 680–683.
<https://doi.org/10.1126/science.aat8695>
- Lamarre, J. F., Legagneux, P., Gauthier, G., Reed, E. T., & Bêty, J.

- (2017). Predator-mediated negative effects of overabundant snow geese on arctic-nesting shorebirds. *Ecosphere*, 8: e01788. <https://doi.org/10.1002/ecs2.1788>
- Latif, Q. S., Heath, S. K., & Rotenberry, J. T. (2012). How avian nest site selection responds to predation risk: testing an ‘adaptive peak hypothesis’. *Journal of Animal Ecology*, 81: 127–138. <https://doi.org/10.1111/j.1365-2656.2011.01895.x>
- LIFE 3.0—LIFE Project Public Page. (2025). <https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE11-NAT-BG-000362/urgent-measures-to-restore-and-secure-long-term-preservation-of-the-atanasovsko-lake-coastal-lagoon>
- Loukola, O. J., Seppänen, J. T., & Forsman, J. T. (2012). Intraspecific social information use in the selection of nest site characteristics. *Animal Behaviour* 83: 629–633. <https://doi.org/10.1016/j.anbehav.2011.12.004>.
- Lokhman Y. V., Fedosov, V. N. & Mikhail, M.V. (2020). Collared pratincole (*Glareola pratincola*). In European Breeding Bird Atlas 2: Distribution, *Abundance and Change* (eds Keller, V., Herrando, S., Vorišek, P., Franch, M., Kipson, M., Foppen, R.P.B. et al.), p. 284. Lynx Edicions/European Bird Census Council (EBCC), Barcelona, Spain.
- Mabee T.J., Wildman A.M. & Johnson C.B. (2006). Using egg flotation and eggshell evidence to determine age and fate of Arctic shorebird nests. *Journal of Field Ornithology*. 77: 163–172. <https://doi.org/10.1111/j.1557-9263.2006.00037.x>
- Maslo, B., Leu, K., Faillace, C., Weston, M. A., Pover, T., & Schlacher, T. A. (2016). Selecting umbrella species for conservation: A test of habitat models and niche overlap for beach-nesting birds. *Biological Conservation*, 203: 233–242. <https://doi.org/10.1016/j.biocon.2016.09.012>
- Minias, P., Gach, K., Włodarczyk, R., Bartos, M., Drzewińska-Chańko, J., Rembowski, M., Jakubas, D. & Janiszewski, T. (2020). Colony size as a predictor of breeding behaviour in a common waterbird. *Plos one*,

- 15: e0241602. <https://doi.org/10.1371/journal.pone.0241602>
- Morales, M. B., & Traba, J. (2016). Prioritising research in steppe bird conservation: A literature survey. *Ardeola*, *63*: 137–150.
- Myhrvold, N.P., Baldridge, E., Chan, B., Sivam, D., Freeman, D.L. & Ernest, S.M. (2015). An amniote life-history database to perform comparative analyses with birds, mammals, and reptiles. *Ecological Archives*, *96*: 3109–3109. <https://doi.org/10.1890/15-0846R.1>
- Paton, P. W. (1994). The effect of edge on avian nest success: how strong is the evidence? *Conservation Biology*, *8*: 17–26. <https://doi.org/10.1046/j.1523-1739.1994.08010017.x>
- Picman, J., Pribil, S., & Isabelle, A. (2002). Antipredation value of colonial nesting in Yellow-headed Blackbirds. *The Auk*, *119*: 461–472. <https://doi.org/10.1093/auk/119.2.461>
- Quinn, J. L. & Ueta, M. (2008). Protective nesting associations in birds. *Ibis*, *150*: 146–167. <https://doi.org/10.1111/j.1474-919X.2008.00823.x>
- Roberge, J. M., & Angelstam, P. E. R. (2004). Usefulness of the umbrella species concept as a conservation tool. *Conservation biology*, *18*: 76–85. <https://doi.org/10.1111/j.1523-1739.2004.00450.x>
- Šálek M., & Smilauer, P. (2002). Predation on Northern Lapwing *Vanellus vanellus* nests: the effect of population density and spatial distribution of nests. *Ardea*, *90*: 51–60.
- Serrano, D., Oro, D., Ursua, E., & Tella, J. L. (2005). Colony size selection determines adult survival and dispersal preferences: Allee effects in a colonial bird. *The American Naturalist*, *166*: E22–E31. <https://doi.org/10.1086/431255>
- Sládeček, M., Kubelka, V., Mlíkovský, J., & Šálek, M. (2014). Coping with nest predation risk in a species-rich bird community inhabiting a Siberian wetland. *Folia zoologica*, *63*: 256–268. <https://doi.org/10.25225/fozo.v63.i4.a5.2014>
- Spatial reference Developmental Team (2024). <https://epsg.io/23700>
- Sterbetz, I. (1974). Die Brachschnalbe: *Glareola pratincta* (*Collared*

- Pratincole*). – Neue Brehm-Bücherei; mit 53 Abb. u. 24 Tab. Ziemsen
- Szabó, L. V. (1965). Fészkelő madártársulások vizsgálata a kunmadarasi szikeseken. *Állattani Közlemények*, 52: 111–134.
- Székely, T. (1992). Reproduction of Kentish plover (*Charadrius alexandrinus*) in grasslands and fish-ponds: the habitat mal-assessment hypothesis. *Aquila*, 99: 59–68.
- Székely, T., Kosztolányi, A. & Küpper, C. (2008). Practical guide for investigating breeding ecology of Kentish Plover *Charadrius alexandrinus*. – University of Bath, UK
- Tan, K., Yang, M., Radloff, S., Pirk, C. W., Crewe, R. M., Phiancharoen, M., Hepburn, R. & Oldroyd, B. P. (2009). Worker reproduction in mixed-species colonies of honey bees. *Behavioral Ecology*, 20: 1106–1110. <https://doi.org/10.1093/beheco/arp103>
- Väänänen, V. M. (2000). Predation risk associated with nesting in gull colonies by two *Aythya* species: observations and an experimental test. *Journal of Avian Biology*, 31: 31–35. <https://doi.org/10.1034/j.1600-048X.2000.310105.x>
- Wickham H, Bryan J (2023). `_readxl: Read Excel Files_`. R package version 1.4.3, <https://CRAN.R-project.org/package=readxl>
- Włodarczyk, T. (2012). Recognition of individuals from mixed colony by *Formica sanguinea* and *Formica polyctena* ants. *Journal of insect behavior* 25: 105–113. <https://doi.org/10.1007/s10905-011-9280-x>
- Visscher, P. K. (2007). Group decision making in nest-site selection among social insects. *Annual Review of Entomology*, 52: 255–275. <https://doi.org/10.1146/annurev.ento.51.110104.151025>

Table 1. Egg laying dates of Collared Pratincoles in relation to type of nesting units (i.e., solitary nesting, single-species colony, mixed-species colonies), and the number of pratincole nests (in brackets) in Nagykunság region, Hungary. Data are from 2013 – 2023 inclusive ($n = 71$ nesting units).

Nesting unit	16-30 April	1-15 May	16-31 May	1-15 June	16-30 June	1-15 July	16-31 July	Total
Solitary	0	0	0	0	2 (2)	2 (2)	0	4 (4)
Single-species	0	6 (33)	6 (37)	11 (62)	6 (20)	1 (3)	0	30 (155)
Mixed-species	1 (5)	22 (125)	12 (78)	2 (10)	0	0	0	37 (218)

Table 2. Egg laying date (a) and relative egg laying date (b) of Collared Pratincoles (response variables), and their relationships to presence of Northern Lapwings, year of study, and crop type. Generalized Linear models, and significant associations are in bold. ($n = 188$ and 122 for pratincoles and lapwings, respectively). Relative egg laying date is the normalised egg laying date for a given colony (see Methods).

(a) Egg laying date				
Variable	Estimate	se	t	<i>P</i>
Intercept	-281.539	847.911	-0.332	0.741
Northern Lapwing	-8.376	2.099	-3.989	<0.001
Year	0.206	0.419	0.489	0.626
Fallow lands	12.707	2.908	4.369	<0.001
Spring-cover crops	0.172	3.367	0.051	0.959
(b) Relative egg laying date				
Variable	Estimate	se	t	<i>P</i>
Intercept	44.54	46.752	0.953	0.344
Northern Lapwing	-1.106	0.110	-10.01	<0.001
Year	-0.022	0.023	-0.943	0.349
Fallow lands	-0.062	0.144	-0.431	0.668
Spring-cover crops	-0.322	0.179	-1.803	0.076

Table 3. Crop type in relation to a social nesting units of Collared Pratincoles ($n = 77$ nesting units)

	Solitary breeding	Single-species colony	Mixed-species colony
Cropland	2	11	29
Spring-cover crop	1	8	4
Fallow land	4	11	7

Table 4. Maximum area of pratincole colonies and their relationships to mixed-species or single-species colonies, number of pratincole nests (a), and all nest of shorebird species (b). Linear regression models were applied to investigate the relationship between the log-transformed values of these variables. Significant relationships are indicated in bold. ($n = 386$ nests of Collared Pratincoles, 192 nests of Northern Lapwings, 30 nests of Black-tailed Godwit, and 10 nests of Common Redshank).

(a)				
Variable	Estimate	se	t	<i>P</i>
Intercept	-0.064	0.149	-0.427	0.671
Nesting unit (Single-species)	-1.451	0.278	-5.217	< 0.001
Number of pratincole nests	0.68	0.209	3.255	< 0.001
Nesting unit (Single-species)	1.439	0.398	3.621	< 0.001
Number of pratincole nests				
(b)				
Variable	Estimate	se	t	<i>P</i>
Intercept	-1.047	0.907	-5.124	< 0.001
Nesting unit (Single-species)	-0.468	0.278	-1.681	0.098
Number of all shorebird species nests	1.487	0.207	7.200	< 0.001
Nesting unit (Single-species):	0.633	0.342	1.849	0.069
Number of all shorebird nests				

Figure 1. Examples of mixed-species colonies of Collared Pratincoles in Nagykurság, Hungary. Mixed-species colony in the same location in 2021 (a) and 2023 (b). Mixed-species colony in a different area in 2023 (c). The boundaries of colonies are illustrative only, since we used the maximum polygon to estimate the area of colonies.

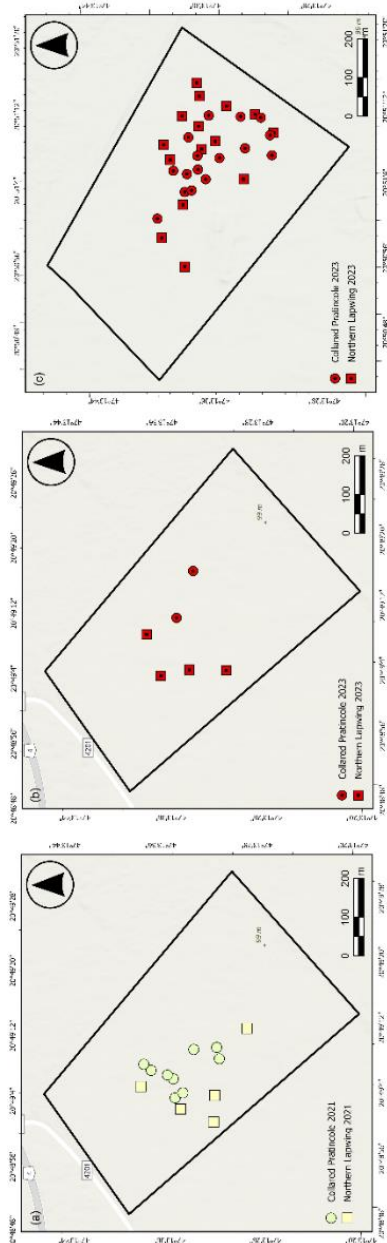
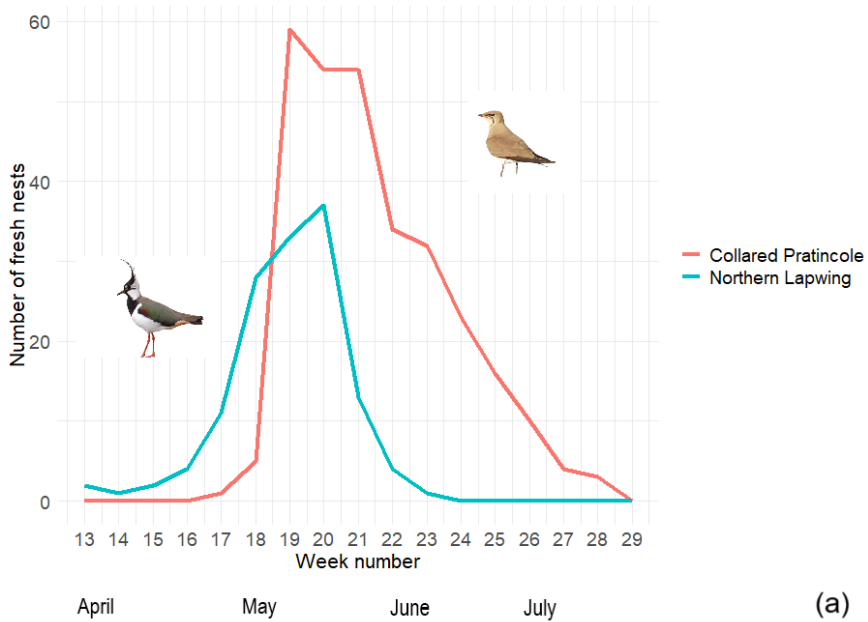
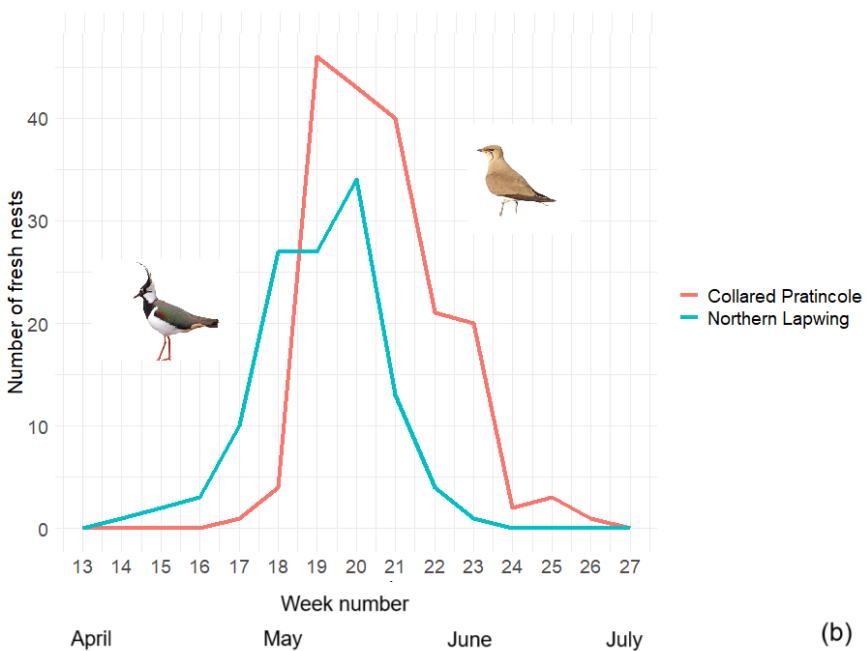


Figure 2. Egg laying dates of Northern Lapwings and Collared Pratincoles (a) all nests ($n = 295$ and 136 for pratincoles and lapwings, respectively), and (b) nests in mixed colonies only ($n = 188$ and 122 for pratincoles and lapwings, respectively).

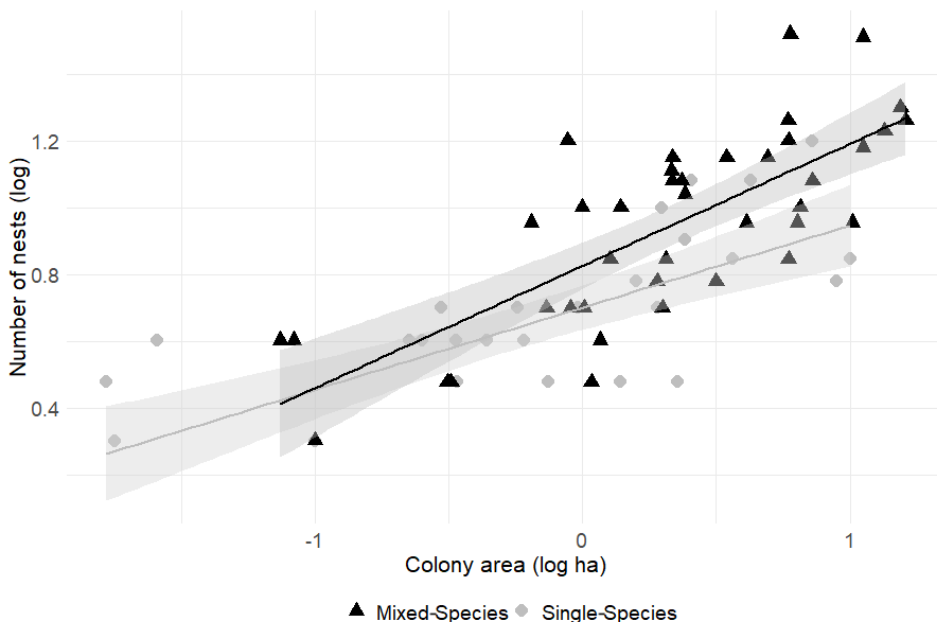


(a)



(b)

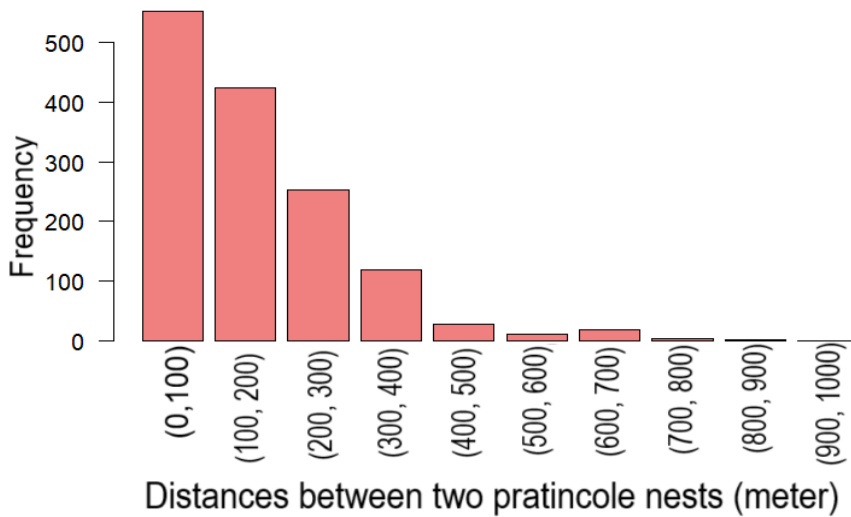
Figure 3. Number of nests of pratincoles nesting in single-species social spacing ($n = 30$ nesting units) and all shorebird nesting in mixed colonies ($n = 40$ nesting units) as a function of the area size of the colonies.



Supplementary Table 1. Distribution of nesting units of Collared Pratincoles in Nagykunság study site

Year	Number of single-species colony (Pairs)	Number of mixed-species colony (Pairs)	Number of solitary pair	Total number of colonies (pairs)	Proportion (%) of Collared Pratincole nests in a mixed colony	Average size of mixed colony (hectares)
2013	3(10)	1 (3)	1	4(13)	60	0.9
2014	3(11)	1(2)	0	4(13)	67	1.1
2015	4(26)	2(8)	0	6(34)	50	3.1
2016	5(29)	2(17)	0	7(46)	77	4.1
2017	1(5)	4(44)	0	5(49)	80	3.7
2018	4(27)	1(6)	0	5(33)	75	1
2019	5(17)	1(1)	1	6(18)	20	2
2020	1(3)	6(27)	1	7(30)	35	4.5
2021	0(0)	9(38)	1	9(38)	48	5.4
2022	2(7)	8(46)	3	10(53)	55	4
2023	2(20)	5(32)	0	7(52)	44	5.8

Supplementary Figure 1. Distributions of nest-to-nest distance frequencies of Collared Pratincole nests within colonies at 100-meter intervals (n=379 nests).



Supplementary Figure 2. The spatial structures of different colonies (a,b,c) were analyzed considering edge effects.

