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Current state and perspectives of the protection of Northern Lapwing in the agricultural landscape

Dissertation

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Summary

The agricultural landscape, which today occupies approximately half of the area of Europe, has changed dramatically in the last 80 years. Gradually, the area used for agriculture decreased, mainly at the expense of built-up areas, and agricultural production intensified at the same time, which can be demonstrated in particular by the massive use of industrial fertilizers and pesticides, changes in the composition of cultivated crops or the onset of increasingly powerful mechanization. At the same time, almost 9 % of EU agriculture area was irrigated, significant share of grasslands was ploughed up or abandoned, size of the fields has increased while the surrounding greenery was destroyed. Changes in agricultural practice and the transformation of the landscape had a negative impact on the abundance of a number of previously common bird species and the overall species diversity. In my thesis I have focused on the Northern Lapwing, representative of Waders, to find out more applicable data about current habitat requirements of this species, to identify what threats it faces and to verify the possibilities of its more effective protection.

Although historically several bird species were able to adapt to the conditions of the new cultural steppe, the increase in the intensity of farming since the 1950s was so significant that we are witnessing the rapid population decrease of once common species. The numbers of Grey Partridges, an iconic farmland bird species, have declined by more than 90 % in Europe since 1980, and most of the previously common species of the agricultural landscape, such as the Skylark, Red-backed Shrike, Yellowhammer or Turtle Dove, have a long-term negative trends. One of the most endangered groups are the Waders. Since 1982, the populations of five wader species - Northern Lapwing, Black-tailed Godwit, Common Redshank, Eurasian Curlew and Common Snipe - whose dominant nesting habitat in the first half of the 20th century were wet grasslands, are gradually decreasing in the Czech Republic. In the introduction, I will present their current state, the general factors responsible for their long-term decline and the basic principles of their protection (**Chapter 1**).

According to research, the main reason for decline of lapwing population is primarily low breeding productivity. Lapwings nest once a year, but some females can have several replacement clutches. In condition of the Czech Republic, approximately 35 – 60 % of the first clutches hatch successfully, in other cases the nests are unsuccessful due to predation, mechanical destruction, abandonment or other reasons. Our research proved, that first clutches are on average 3–7 % larger than the replacement ones. The chicks that hatch from them are larger and have a higher chance of fledging than those from replacement clutches (**Chapter 2**). It is precisely for these reasons that it makes the most sense to focus the main conservation efforts on the first clutches.

Aside predation, the biggest threat for survival of lapwings' nests represents spring agricultural work. Today up to 80% of nests are placed in arable fields, where lapwings prefer ploughed fields and spring crops over winters sown crops. Roughly a third of 1,125 nests monitored in the Czech Republic in last 35 years were in ploughed fields, where most of the clutches are destroyed by agricultural machinery. To eliminate this threat, direct protection of nests can be used. It consists of finding the nest, its visible marking and then ensuring protection by contacting the concerned farmer. There are only few studies monitoring the potential effect of nest marking on predation or the risk of clutch desertion. For this reason, I have decided to experimentally verify risks associated with direct protection of nests to prove, that marking of them did not increase the probability of its predation (**Chapter 3**).

In addition to nests destroyed by agricultural machinery, the predation is another significant threat. In Czech Republic the number of depredated nests varied from 20 to 50 %. There are several species of nests predators including foxes, weasels or corvids. Predators' abilities to locate lapwing's nests vary. An experimental research we have carried out has verified that corvids are able to fix the exact position of an incubating lapwing and subsequently inspect the site (**Chapter 4**). Especially the nest placed closer than 100 m from the nearest perches have a higher risk of predation. If breeding sites are to be systematically protected, it is necessary to preserve their open character.

The systematic protection of the whole entire breeding habitats is another option how to support lapwings. The basis for comprehensive protection is to have solid data on current nesting sites, especially the number of nesting pairs, the regularity of breeding occurrence or the detail characteristics of nesting sites. Therefore, in 2008, I initiated the systematic public mapping of lapwings' breeding sites. The results confirmed, among other things, that lapwings tend to occupy suitable nesting sites regularly. Most often, these were waterlogged locations, which are more attractive for lapwings due to higher food availability compare to dry fields. The outcomes of the mapping helped to define the conditions for future agro-environment measures (AEM), which farmers can enter from 2015 (**Chapter 5**).

For the future of the lapwing, it is desirable to enhance the interest of farmers in its protection, especially their willingness to join AEM. Individual consultancy, direct cooperation in the field or other various forms of education, could be used for this. Passionate farmers with an interest in nature will also be more accepting or even actively implementing revitalization measures on their land, including the recreation of wetlands (**Chapter 6**).

General introduction

Farmland birds in crisis

The agricultural landscape represented 54 % of the area of the Czech Republic in 2020 (Ministry of Agriculture 2022), at the EU level share of land for agricultural production was 38 % of the total land area in 2016 (Eurostat 2020). Its current shape is the result of several thousand years of human economic activity and natural processes. A number of factors, such as the morphology of the terrain, hydrogeological and climatic conditions or historical development, contributed to its present form (Mazoyer & Roudart 2006). Through his agricultural activities, man has thus created a new environment for a whole range of bird species originating from different types of natural biotopes. These include steppe birds, such as the Skylark, Great Bustard or Grey Partridge, originally forest species, e.g. the Hoopoe, some species of warblers and finches or wetland species represented by various types of waders, herons or storks (Van der Weijden et al. 2010).

Until the beginning of the 20th century, manual harvesting prevailed (Janick 2013), which allowed safe escape for birds and other animals. Moreover, thanks to the varied ownership structure (Rychlík 2014), its course was not uniform, and thus enough suitable biotopes were always preserved for the development of insects or for the nesting of birds. As a result, farmland has created optimal conditions for wide range of bird species, that can be demonstrated on one of the most typical farmland species, the Grey Partridge. Its numbers in the Czech Republic had peaked at more than 2 million birds between 1933 and 1937 in contrast to 31 thousand of birds in 2018 (Šálek & Zámečník 2020). Unfortunately, our knowledge of population size of most of species is rather limited. Usually we have only regional data indicating, that breeding densities of some birds were significantly higher compared to the recent situation (Šťastný et al. 2006).

In case of waders, historical data indicate increase of the numbers from 19. century till first half of 20. century (Klůz 1957, Šťastný et al. 2006, Fiala 2008). However, in case of lapwing, the disposal of meadows and changes in its quality were probably the main cause of the local disappearance of lapwings in some places in the Czech Republic already in the first half of the 20th century (Klůz 1957).

Intensification of farming as a major threat to farmland birds

While in the past farmland birds benefited from the development of agriculture, the onset of intensive agricultural practices and inappropriate interventions in the landscape, that took place in the second half and especially in the last quarter of 20th century, seriously threatened their existence (Krebs et al. 1999, Donald et al. 2001, Donald et al. 2006). Agricultural intensification involves maximizing primary production for human consumption and includes the increase of the inputs of agricultural resources such as fertilisers, pesticides, more productive varieties of crops, technologies or knowledge to enhance the level of yield per unit of farmland (Krebs et al. 1999, Donald et al. 2001, Donald et al. 2006). At the same time, the interventions in the landscape took place in Eastern Europe as part of the so-called collectivization of agriculture (Rychlík 2014). Between the years 1948–1989, 270,000 ha of meadows and pastures, 145,000 ha of borders (i.e. 800,000 km), 120,000 km of dirt roads were ploughed and 3,000 ha of woods, groves, draws and 30,000 km of linear greenery were removed (Vašků 2011).

An important positive changes of trends of bird species with intermediate association to farmland were monitored after the collapse of the communist system in 1989, when some significant changes of the farmland management took place (Reif et al. 2008a). Among all, due to low economic profit of the whole sector use of pesticides significantly dropped, significant number of usually small family farms started to run their business or some former agriculture land was left aside due to unclear ownership. Nevertheless, trends of most farmland bird specialists including lapwing have remained negative (Reif et al. 2008a, Reif at al 2008b). Further decline of farmland birds has taken place after the Czech Republic joined the European Union in 2004, where subsidies from Common agriculture policy has driven further intensification (Reif & Vermouzek 2019).

The most significant factor responsible for dramatic decline of waders has been the drying and ploughing of wet meadows, that were an important source of food (**Chapter 1**, Ausden et al. 2001, Erber et al. 2002, McKeever 2003, Fiala 2008, Plum & Filser 2005, Eglington et al. 2010). In the years 1960 – 1980 alone, the decline of meadows in favour of arable land in the Czech Republic amounted to a full 20 % (Rychnovská et al. 1985). Along with conversion of grassland to arable also irrigation of those in many cases waterlogged sites took place. The fundamental negative impact of these interventions on waders is recorded in detail within long-term monitoring, that was carried out near town Náměšť nad Oslavou in central part of Czech Republic from 1958 till 2006 (Fiala 2008). At present, 1,084,800 ha of piped drainage is officially registered in the Czech Republic, which represents roughly a quarter of drained agricultural land (Kulhavý et al. 2007, Vašků 2011), plus approx. 450,000 ha not registered (Vašků 2011).

Along with waders, drainage has had a negative impact on the development of the abundance of several other bird species that are now endangered, e.g. Black Grouse, Corncrake or Meadow Pipit (Šťastný et al. 2006, Šťastný et al. 2021). Environmental and biodiversity problems arising from irrigation will be even further driven by climate change, which is predicted to result in a decrease of recharging of spring surface water and aquifer due to lower rainfall (Nicholls et al. 1999, Thompson et al. 2009, Stephens et al. 2016).

At the same time, the composition of crops was changing. Since the 1960s, the share of wheat and barley has been increasing at the expense of other cereals (ČSÚ 2023). As wheat is grown almost exclusively as a winter crop, and also in the case of barley, winter varieties make up less than half of the production, the areas of cereal stubble and spring cereals are gradually decreasing. It has reduced food offer for several seed-eating bird as stubbles was recognize as important feeding habitat from autumn to spring (Donald & Morris 2005, Gillings et al. 2005, Winspear & Davies 2005, Eggers et al. 2011). Spring cereals also represent a suitable nesting environment not just for waders as lapwing or Ring Plover, but also for other bird species such as Skylark or Wheatear (**Chapter 1**, Wilson et al. 1997, Chamberlain & Crick 1999, Berg et al. 2002, Henderson et al. 2009, Eggers et al. 2011). Although cca 15 % of lapwings nest in the winter crops, mainly wheat, soon after hatching of chicks they move to surrounding sites usually with lower and sparse vegetation (Devereux et al. 2004, own unpublished data).

The intensification of agriculture is also evidenced by the increasing productivity of agricultural production. While increased use of fertilizers was supporting yields of crop (Chloupek et al. 2004), it had negative impact on earthworm biomass and surface invertebrates, an important component of lapwing diet (Ausden et al. 2001, Erber et al. 2002, McKeever 2003, Plum & Filser 2005, Eglington et al. 2010). New crop varieties and more efficient use of water resources also contribute to higher yields. The result is faster growing, taller and denser crops. This reduces the supply of suitable food and offer of nesting habitats for lapwings and other bird species as the Skylark or Yellow Wagtail, which prefer lower, more open and more varied habitats (**Chapter 1**, Wilson et al. 2005, Winspear & Davies 2005). The same trend caused by high use of fertilizer, digestate from biogas plants and reseeding with grass dominant mixtures is happening in grasslands (**Chapter 1**, Britschgi et al. 2006, Manning et al. 2015, Manu et al. 2022).

During farming operations in the field, fast agricultural technology with a wide scope threatens nests, as well as young and, rarely, even adults of ground-nesting bird species including several species of waders, Corncrake, Skylark, Corn Bunting, Whinchat, Grey Partridge, or Montagu's Harrier (**Chapter 1**, Green et al. 1997, Tyler et al. 1998, Steen et al. 2012). Although, for example, Black-tailed godwit is able to warn young ones against agricultural machinery (Belfin 2021), direct killing of waders' chick during spring works or meadows harvest occasionally happens (Schekkerman et al. 2009, own unpublished data).

Abandonment of farming or targeted afforestation of agricultural land is also a threat to waders (**Chapter 1**). In both cases, this usually applies to the least nutritious areas, and unfortunately this also often includes waterlogged habitats that are attractive for waders to nest. Areas overgrown in this way are attractive for some bird species of agricultural landscape, such as Yellowhammer, Corn Bunting or Red-backed Shrike, but species that require an open character of the environment quickly leave them (**Chapter 1**, Verhulst 2004, Brambilla et al. 2007, Mikulić et al. 2014).

Low breeding success of lapwing – a problem to solve

Nesting of lapwing

Despite Northern Lapwing remains the most common wader in the Czech Republic, its population have declined by more than 80 % since 1982 till 2022 (Czech Society for Ornithology 2023). The main reason for decline of lapwing population is primarily low breeding success (Peach et al 1994). Lapwing nest survival rates exceeding 50 % per year are likely to be sustainable and result in the minimal productivity range required for population stability if annual chick survival rates (from hatching to fledging) are around 25 % in the Central and Western Europe (MacDonald & Bolton 2008a). Only few sites in Europe have achieved this level of nest survival however (MacDonald & Bolton 2008a, Pilacka et al. 2022).

Lapwings are a migratory species in the territory of the Czech Republic, with wintering grounds in Western and South-western Europe and North Africa. The first birds are flying back from their wintering grounds already in February, and the migration peaks in March (Šťastný et al. 2006). Older lapwings return to the breeding grounds before yearlings, with adult males arriving earliest of all (Parish 1996).

Under normal conditions, lapwings start laying from the third decade of March with a peak in the first decade of April, while the timing of nesting can be influenced by the climatic conditions of the given year. The nesting activity then gradually decreases until the first decade of June, when, in the conditions of the Czech Republic, lapwings start incubating the last clutches (Kubelka & Šálek 2013). Some important costs of early breeding include low invertebrate activity owing to low soil temperature, risk of snow (Nordström 1975, Beintema and Visser 1989) or even frozen period of few days, that can be life threatening to adults (own unpublished data). Such costs may be better accepted by females in good physical condition (**Chapter 2**, Andersson & Gustafsson 1995, Parish 1996). This gives them advantages that include the ability to choose from several males and territories and the prospect of early hatching, allowing them to invest energy in larger eggs (**Chapter 2**, Grønstøl 1997).

Laying date and clutch size depend on body condition (Drent & Daan 1980), which again may be determined by age, breeding experience and physiological condition. First breeding attempts occurred at one-year-old for most females, but at two-years-old for most males (Parish 1996). Males make multiple shallow nest scrapes, one of which the female chooses to lay eggs in after filling it with a thin nest lining. Female lays typically four eggs within ~5 days. Incubation is initiated once the final egg is laid and lasts for ~26 days egg laying and incubation period ~31 days in total (Galbraith

1988). Lapwings nest once a year, but some females can have up to four replacement clutches (Cramp & Simmons 1983, Parish et al. 1997).

Seasonal timing has the biggest effect on egg size in lapwings, with first clutches at the beginning of the breeding season containing on average 5.6 % larger eggs in comparison with late and probable replacement clutches. This finding is in line with studies of other waders (**Chapter 2**, Redmond 1986, Hegyi 1996, Hegyi & Sasvari 1998, Sandercock et al. 1999). Chicks that hatch from them are larger and in better condition than chicks that hatch later (Sheldon 2002, Larsen et al. 2003). Previous research has also proved that more experienced females can increase the survival rate of chicks with their care (Blomqvist et al. 1997).

Early chicks hatch in an environment that is more attractive for them - the spring crops as maize, barley, beets or sunflowers are still low and easy to move (Devereux et al. 2004) and, moreover, usually some drying wet features are still present in the landscape where chicks have access to soil invertebrates and other water-bound insects (Sheldon 2002, Eglington et al. 2010). Compared to chickens born later, they only have a disadvantage in the greater need for thermoregulation, because the weather in April can be significantly colder than a month later.

A significant number of females are nesting polygamous. The nesting of two or more females in the territory of one male has been repeatedly demonstrated in various European populations, in the range of 20-54 % of the females in the population (Berg 1993, Byrkjedal et al. 1997, Parish & Coulson 1998, Liker & Székely 1999, Grønstøl 2003, Zöllner 2003, Šálek 2005). While the onset of incubation of monogamous females and primary females (the first to nest in a polygamous clutch) was synchronized, secondary females (second to last) were demonstrably delayed by an average of 4 days behind primary females (Šálek 2005). These results indicate that later-nesting females, which are biased toward secondary females, have smaller egg volumes (Grønstøl 1997). Also, different egg size in first clutches were confirmed for yearling females, that laid eggs around 5 % smaller than adults (Parish 1996).

Main reasons for nest failure

As evidenced by some studies, the main reason for the failure of the recovery of the populations of the lapwing and other waders is predation of nests and chicks before fledging (Bolton et al. 2007, MacDonald & Bolton 2008a, Teunissen et al. 2008, Schekkerman et al. 2009, Bellebaum & Bock 2009). In Czech Republic 20 to 50 % of nests were depredated (**Chapter 1**). Among three main methods of identifying predators responsible for nest predation and quantifying their relative contributions to lapwing nest failure belong the examination of nest remains, the recording of the timing of predation events, and the use of nest cameras (Green 2004; MacDonald & Bolton 2008a). While nest predation by mammals occurs mainly at night and is often the result of systematic terrain mapping by a given species, avian nest predators are mainly active during the day. In general, nests are predated mainly by mammal's predators, especially fox (Seymour et al. 2003, Bolton et al. 2007, Teunissen et al. 2008). Other mammalian predators include European Badger and other mustelids or Hedgehog, as bird predators were recorded mainly corvids, Marsh Harrier, storks and herons (Teunissen et al. 2008, Schekkerman et al. 2009, Bellebaum & Bock 2009).

Aside predation, the biggest threat for survival of lapwings' nests represents spring agricultural work. Roughly a third of 1,125 nests monitored in the Czech Republic between 1988 and 2018 were in ploughed fields, where most of the clutches are destroyed by agricultural machinery. Totally 46 % of the first clutches hatched successfully and 9 % were destroyed by agricultural machinery (**Chapter 1**). It is important to mentioned that without direct nest protection damage could be much higher; e.g. in South Bohemia, 37 % of 52 nests would be damaged instead of the observed 14 % in 2011, and 55 % of 57 nests instead of only 2 % in 2012 (Kubelka 2015). If all the nests destroyed by machinery would be saved, nest survival rate would get close to 50 % level considered to be sustainable.

How to help lapwings to increase breeding success?

Elimination of nests destruction by agricultural machinery

Direct protection activities are mainly focused on the first clutches in arable fields, thus saving the clutches that have the best starting conditions for further growth. According to some results, nesting success on arable land after exclusion of possible destruction by farming machinery can be higher than 75 % (Sheldon et al. 2007, Hoodless & MacDonald 2014), however, our unpublished data indicate, that foxes in particular are able to focus on specific nesting sites of lapwings in ploughed fields and gradually prey on practically all nests, including replacement clutches. In early clutches, especially in spring with unusual weather conditions, increased predation may also be related to lower food supply for predators (Kubelka et al. 2018). Nevertheless, the share of nests destroyed by agricultural machinery is naturally the highest in arable land, as the total loss of nests along with depredated ones is practically absolute. Lapwings have a certain chance of successful nesting only on very waterlogged parts of the fields, which farmers must avoid during spring work.

Replacement clutches accounted for roughly 54 % over all monitored periods (**Chapter 1**). As lapwings prefer to nests in open habitats with low vegetation usually up to 15 cm (Cramp & Simmons 1983), for alternative nesting they usually use fields with spring crops, especially corn, less often spring cereals, sunflowers, beets and other open location especially with some presence of water. At first glance, it might look that the risk of destruction of nests by agricultural machinery in these cultures is already minimal, but in some cases, lapwings might be still in danger. This is most visible in farms operating in the organic farming system, where mechanical weeding is main tool to eliminate weeding. According to research in the Netherlands in 2005 and 2006, 62 and 65 % of failed nest on organic farms were due to farming activities while on conventional farm farming activities it was only 38 and 50 % (Kragten & Snoo 2007). In addition, chemical treatment is increasingly being replaced by mechanical weeding even among conventional farmers. This applies, for example, to maize (Kumar et al. 2020) which is clearly the most commonly used by lapwings for replacement clutches. When we were monitoring nest success in maize, virtually no nest was destroyed by machinery (own observation). Current trends of mechanical weeding indicate that the nesting success of replacement clutches in these biotopes will be significantly lower in the future (Heisel et al. 2002; Carballido et al. 2013).

Direct protection is quite demanding in time and human resources. Although one person can trace the nests himself, in the case of a nesting sites with two or more breeding birds it is inefficient and more appropriate is cooperation of at least two or more people (Kubelka et al. 2012). In the conditions of the Czech Republic, this is still more of a marginal form of lapwing protection, with approximately 40 - 100 nests protected this way per year (**Chapter 3**), but the interest of public for this activity is gradually increasing and the number of people dedicated to direct protection grows every year (Zámečník 2020a). Therefore, it is essential that they use the correct procedures when marking nests.

The nests are usually marked by bamboo poles or sticks highlighted with a reflective red or orange spray at the top placed at least 5 m from the nest in both directions on the row (**Chapter 3**). In previous studies, where the poles were significantly closer (2–3 m in Switzerland, and 3–5 m in the Netherlands), cases of nest desertion were relatively numerous (Schifferli et al. 2006, Kragten et al. 2008). Especially at the beginning of incubation, lapwings are more susceptible to disturbance and may leave the nest if sticks appear near the nest at that time (Schifferli et al. 2009). This is confirmed by our experience, when the farmer found the nests in the field himself during spring work and marked them with thick branches up to 1 m high stuck at a distance less than 1 m from the nest. A total of 2 of the 7 nests marked this way were abandoned and in one case lapwing apparently actively attacked the pole and knocked it to the ground (unpublished own observation).

Our research proved that the presence of bamboo poles has not increase the risk of predation (**Chapter 3**). Still it would be desirable to repeat the research in the case of a more massive use of the direct protection model. The ability of predators, e.g. Corvids, to learn is generally well known (Koenen et al. 1996, Murthy et al. 2003, Nieder et al. 2020) and if direct protection is to be truly effective, it is necessary to further verify its benefits.

Predation in respect to breeding site

As lapwings nest in the open landscape, incubating birds are usually highly visible and also have a perfect overview of potential predators themselves (Götmark et al. 1995). This open habitat may be selected to increase predator detection, with close proximity to tall landscape features or those that may harbour predators (e.g. trees, hedgerows, buildings, woodland) reducing the likelihood of site occupancy by breeding pairs (**Chapter 4**, Milsom et al. 2000, MacDonald & Bolton 2008b, Bertholdt et al. 2016). Lapwing also show a preference for feeding in short grass more than other wader species (Green 1986, Ausden et al. 2003).

In case of danger, they leave the nest relatively quickly and rely on cryptic coloured clutches (Lloyd et al. 2000). At the same time lapwings actively defend their nesting territories against avian predators (**Chapter 4**, Elliot 1985, Walters 1990, Kis et al. 2000), similar to some other waders (Larsen et al. 1996, Hegyi & Sasvári 1997). Lapwings may also try to lure some predators away by feigning injury (Walters 1990, Santos 2020).

Lapwings diversified mobbing response within the breeding season and depending on predator species. Raven, Hooded Crow and harriers evoked the strongest response, while Common Buzzard, White Stork, Black-headed Gull and Rook were less frequently attacked (Królikowska 2016). Lapwings increased their mobbing response against Raven, Common Buzzard, White Stork and Rook throughout the breeding season, while defence against Hooded Crow, harriers and Black-headed Gull did not exhibit clear temporal patterns (Królikowska 2016).

Nevertheless, lapwings usually leave the nest immediately at the approach of a predator penetrating into the territory (Šálek & Cepáková 2006), probably behaving so in order to prevent disclosing the nest's position (Walters 1982, Koivula & Rönkä 1998), so it is easier for the predators to visit the nests during the absence of parents in the territories. Experiment have proved, that corvids can fix the position of a sitting bird from perches, and if they manage to break into the territory, they can locate and prey on the temporarily abandoned nest (**Chapter 4**). The critical distance of the perch from the nest in our research was 100 m - nests that were closer were predated significantly more than nests further away (**Chapter 4**). Also other research proved that with the growing distance from the perch the risk of predation decreases (Berg et al. 1992, Šálek & Šmilauer 2002, MacDonald & Bolton 2008b, Laidlaw et al. 2015).

In Western Europe several approaches to eliminate predation has taken place, however, these methods are time-consuming, expensive and often controversial, with the potential for unforeseen increases in other predator or competitor species (Bodey et al. 2009). Instead, special attention should be paid to breeding sites of lapwings e.g. in land planning to avoid establishment of bio corridors, tree planting or afforestation close to breeding grounds. Also, in revitalization projects, e.g. creation of small wetlands, promote the importance of their placement in open country away from trees and other perches, creation of shallow banks to eliminate the risk of chicks drowning (Schekkerman et al. 2009) and avoid planting of trees to maximise benefits for waders.

Agri-environment climate measure (AECM) for the protection of Northern Lapwing

The decline in the abundance of the lapwing has resulted in a whole range of conservation activities of a diverse nature. In addition to the protection of nests in various ways (**Chapter 3**, Kragten & Snoo 2007, Schifferli et al. 2006, Schifferli et al. 2009, Malpas et al. 2013, Plard et al. 2020), a number of models are based on territorial protection of lapwings breeding grounds including the improvements of their quality (**Chapter 1**, **Chapter 5**, Sheldon et al. 2007, Smart et al. 2013, Hoodless & MacDonald 2014, Schmidt et al. 2017). A basic condition for well-targeted protection is a more detailed knowledge of the current living requirements of lapwings, their distribution, structure and character of nesting areas and nesting success. Therefore, in 2008, a nationwide monitoring of the nesting occurrence of Lapwing was launched, which aimed to gather the initial information needed to set the conditions for possible territorial protection (**Chapter 5**).

Monitoring has shown that around 80 % lapwings nest on arable land today. The largest colonies of lapwings were formed in ploughed fields. For breeding sites with known history, half of them lapwings occupied each year and around one third regularly. The presence of wetlands and meadows on the nesting site increased the number of nests, and the presence of wetlands also increased hatching success (**Chapter 5**). The results confirmed that, based on monitoring, it is possible to design areas where there is a high probability of regular occurrence of lapwings. It was also confirmed that waterlogged arable land is currently the most attractive environment for lapwings.

On the basis of these findings, the conditions of an agri-environment climate measure were proposed (**Chapter 5**, Zámečník 2014), which we subsequently succeeded to get implemented to as new measure of Common Agricultural Policy from 2015 (**Chapter 6**, Ministry of Agriculture 2015).

The conditions of the measures were based on the established data on nesting preferences. Farmers is required to leave the area as ploughed field until June 15, then during the next month, sow the area with certified mixture of crops for pollinators or wild game. This mixture has to plough from November 15 till the end of December to create a suitable nesting environment for the lapwings after returning from their wintering grounds. No chemicals are allowed to be used (**Chapter 6**, Ministry of Agriculture 2015).

The support of lapwings, skylarks and other land-nesting species by creating uncropped cultivated areas on arable land was on option within so-called Entry Level Stewardship program, English equivalent to our AECM. Unlike in case of Czech Republic placement of the measure was not directly linked to the historical occurrence of lapwings, despite lapwings were breeding on 40 % of 212 plots (Chamberlain et al. 2009) or 33 % of 36 plots (MacDonald et al. 2012). Similar approach aimed at protection of lapwings nesting on arable land was tested in Germany in 2010-2015. In contrast to England, it was possible to enter here only with fields where lapwings historically nested. Confirmed breeding of lapwing was on 43 % of 61 plots (Schmidt et al. 2017).

In order to select the most suitable areas for inclusion in the AECM, solid data on the nesting occurrence of lapwings was necessary to obtain. That is why a special "Lapwing database" was launched in 2012, which, in addition to usual requirements, also requested for additional information as regularity of breeding occurrence, presence of wet features, size of the breeding size or vegetation height. These additional data helped to make a decision whether the given area is suitable for inclusion in AECM (Zámečník 2023). From 2012 till 2014, a total of 2,987 records were collected as a baseline for selection of 260 breeding sites suitable for AECM. Over the years, it was possible to add new areas, so in 2019 total number of eligible sites reached 433 breeding sites. The number of farmers who joined the measure gradually increased from 2015 till 2019, when 77 sites of total area of 455 ha has been included in the measure (Ministry of Agriculture, unpublished data).

Verification of AECM effectiveness took place in 2016, 2018 and 2020 and was funded by the Ministry of Agriculture (Zámečník 2020b). A pairwise comparison of areas was chosen, where one area was included in the AECM and the other was registered as a breeding ground, and at the same time other parameters were taken into account so that the compared areas were as similar as possible (comparable area, similar proportion of neighbouring cultures, presence of bare area on both monitored areas). On both areas, 3 control visits were carried out during the season, the first at the beginning of breeding season, the second at the time of chick hatching and the last one at the time of chicks' fledging and hatching of chicks from replacement clutches. Also possible occurrence of other wader species was monitored (Zámečník 2020b).

In 2020, when the number of observed sites was highest (totally 22 pairs), displaying behaviour of lapwings was recorded on 64 % of 22 breeding sites involved in AECM compared to 27 % of the control sites, however, no statistically significant difference was found in favour of the areas in commitment. The results indicate that well-selected areas are attractive for nesting lapwings. The fact that no statistically significant difference was found between AECM and control is largely due to the strict entry criteria. Compared to the assumptions, there was a surprising significant decrease in the number of birds during further control visits (Zámečník 2020b).

In 2022, a comprehensive revision of the layer of nesting sites, which are proposed in the AECM, took place. All 433 areas were visited at least once during breeding season, and based on results of monitoring, the personal data of the mappers and records in the ornithological database, revision of the sites proposed as AECM was done. Meanwhile, we evaluated all lapwing records in the ornithological database from last 5 years and, in cooperation with volunteers, new additional nesting sites were added. In total, the total number of nesting sites suitable for AECM increased to more than 700 (Zámečník 2022).

Outline of the thesis

The aim of the work was to expand the current awareness of the causes of the long-term decline in the abundance of the Northern Lapwing, and to try, on the basis of these updated data, to propose possible methods of practical protection that have the potential to support not only this species, but also other representatives of waders and bird species of open agricultural landscapes in general.

- The initial aim of the work was to summaries a knowledge search supported by our data on the current state of the population of formerly meadow wader species, including lapwing, to identify on basic level the current threats and to introduce the basic approaches to their protection (**Chapter 1**).
- As the main factor responsible for the population decline of these species is low breeding success, therefore specific attention was paid to the identification of nesting parameters that may be important for increasing overall success (**Chapter 2**).
- In addition to natural predation, a significant proportion of nests are destroyed unnecessarily by agricultural machinery, which is further driven by higher acceptance of arable land as breeding ground, especially ploughed fields. Therefore, our goal was to verify whether nest marking does not increase their predation or the risk of their abandonment (**Chapter 3**).
- Although we did not actively engage in predation, we tried to verify with an experiment what abilities predators have when detecting nests and what parameters the nesting site should optimally have in order to eliminate at least part of the predation events caused by corvids (**Chapter 4**).
- By systematically collecting data on the current population of lapwings and other characteristics of their nesting environment, we obtained data that we used for the design of the overall protection of nesting sites through the agri-environment climate measure Protection of the Northern Lapwing (**Chapter 5**). We were trying to further develop this protection model and, above all, to motivate farmers to get involved in it on the largest possible area (**Chapter 6**).

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Chapter 1

Threats and conservation of meadow-breeding shorebirds in the Czech Republic and Slovakia

Vojtěch Kubelka, Václav Zámečník, Katarina Slabeyová, Vlasta Škorpíková & Miroslav Šálek

This article covers the most recent population estimates, trends, threats and protection measures for five meadow-breeding shorebirds in the Czech Republic (CZ) and Slovakia (SK): Northern Lapwing *Vanellus vanellus*, Black-tailed Godwit *Limosa limosa limosa*, Common Redshank *Tringa totanus totanus*, Eurasian Curlew *Numenius arquata arquata* and Common Snipe *Gallinago gallinago gallinago*. All species have undergone strong long-term declines in CZ and SK, however, at least in recent years, trends appear to have improved for Common Redshank and Northern Lapwing in CZ. Common threats to grassland breeding shorebirds in both countries and major factors driving observed declines have been: (1) drainage of grasslands, (2) conversion of grasslands to arable land and high fertilizer input in meadows leading to overgrowth and thick, poorly penetrable habitat, (3) drilling of meadows during the Lapwing incubation period and (4) grazing abandonment at fishpond margins. The majority of failed clutches have been depredated or damaged by agricultural machinery. Current population estimates in breeding pairs are: Northern Lapwing (CZ: 5,000–7,000; SK: 2,000–4,000), Black-tailed Godwit (CZ: 5–10; SK: 0), Common Redshank (CZ: 25–40; SK: 20–50), Eurasian Curlew (CZ: 0–1; SK: 0) and Common Snipe (CZ: 500–800; SK: 30–100). Conservation in small-scale nature reserves has been effective, as has direct nest protection. Large-scale effective conservation on grasslands is generally lacking, however a newly launched agri-environmental scheme for Northern Lapwing on arable land seems to be a promising conservation measure, also promoting other wildlife in the agricultural landscape.

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This series summarizes current knowledge of status, trends, threats, and conservation measures for meadow-breeding waders across Europe. The articles arose from the workshop ***'Threats and protection of meadow birds in Europe'****, held on 29 September 2014 at the IWSG annual conference in Haapsalu, Estonia. Guest Editor: Hermann Hötker.*

Threats and conservation of meadow-breeding shorebirds in the Czech Republic and Slovakia

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Kubelka, V., V. Zámečník, K. Slabeyová, V. Škorpíková & M. Šálek. 2018. Threats and conservation of meadow-breeding shorebirds in the Czech Republic and Slovakia. *Wader Study* 125(3): 164–174.

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Keywords

agri-environmental scheme

agricultural intensification

direct nest protection

Gallinago gallinago

Limosa limosa

nest predation

Numenius arquata

Tringa totanus

Vanellus vanellus

waders

INTRODUCTION

Development and intensity of agriculture

The Czech and Slovak agricultural landscapes went through a quite complicated development with several important changes in intensity and use of agricultural land during the 20th century (e.g. Andreska 1990, Pykal & Janda 1994, Šálek 2000, Albrecht 2015). Because the Czech Republic (CZ) and Slovakia (SK) underwent the 'velvet divorce' from the former Czechoslovakia as recently as 1993, changes in agriculture were very similar in both countries. Here, we present a brief history of CZ, based on Albrecht's (2015) thorough summary with input from other resources.

The area of agricultural land was persistently declining (by about 20%) during 1927–2008. Until the 1980s, both arable land and grassland were declining; since then, arable land continued to decline, whereas grassland has been steadily increasing. The area of forest land increased by about 10% since the Second World War (Albrecht 2015). South Moravia represents a unique biogeographical region in CZ: it is warmer, drier, and generally flatter than the rest of the country. It also features highly fertile soil, and thus the region has long been a centre of agriculture. In South Moravia, there are 363,000 ha of cultivated agricultural land, of which 90% is arable land. The transformation of arable land to permanent grasslands recently (comprising an area of 19,000 ha) has occurred mainly in less fertile areas of the region, organic farming (4,900 ha in 2007) has developed mainly in less productive parts, and a total of 708 ha of agricultural land lay fallow (Vaishar *et al.* 2011).

Numbers of farm animals changed significantly during the focal period, which had an significant influence on the intensity and nature of agricultural land use (Albrecht 2015). Numbers of cattle were significantly decreasing until 1960, then increased nearly to the numbers present in *ca.* 1927, and then again rapidly dropped to less than half of the initial abundance. The conditions of cattle breeding also changed significantly. Scattered small stable breeding prevailed up to 1950. Cattle could graze only on marginal lands that were difficult to use for other purposes, and meadows were only mowed and all cut grass was dried on site. Concentrated large-scale breeding with minimal use of grazing was established during the later period of collectivization, with silage production at drained and graded meadows. After 1990 most cattle were bred freely in pasturelands, including partially during the winter. Numbers of horses decreased by about 93% during the focal period, whereas numbers of sheep fluctuated significantly (Albrecht 2015). Similarly to other European countries (Hötker 1991), shorebirds in CZ, mainly during 1950–1990, were negatively affected by conversion of wet grasslands into arable land, higher fertilizer input, excessive use of pesticides, increased intensity of fishpond agriculture, and direct nest destruction during farming operations (Šálek 2000). Conventional use of agricultural land is still very intense, with high levels of direct nest destruction (Kubelka *et al.* 2012a).

METHODS

This article summarizes the most updated population estimates, trends, threats and protection measures for five meadow-breeding shorebirds in CZ and SK: Northern Lapwing *Vanellus vanellus*, Black-tailed Godwit *Limosa limosa limosa*, Common Redshank *Tringa totanus totanus*, Eurasian Curlew *Numenius arquata arquata* and Common Snipe *Gallinago gallinago gallinago*. Presented information is based on a review of published articles, grey literature and unpublished datasets concerning both countries. Other European 'grasslands shorebirds' do not currently breed in the region, therefore they are not included here.

SPECIES AND BREEDING HABITAT

All five species inhabit various environments including grasslands in CZ and SK. For four species, the legal conservation status is the same in both countries: Northern Lapwing = Vulnerable (VU), Black-tailed Godwit = Critically Endangered (CR), Eurasian Curlew = CR, and Common Snipe = Endangered (EN). Common Redshank is listed as CR in CZ, but as EN in SK (Danko 2002, Plesník *et al.* 2003, Hudec & Šťastný 2005).

Northern Lapwing, Black-tailed Godwit and Common Redshank, formerly more or less strictly meadow shorebirds, are nowadays more commonly using arable land in CZ and SK for breeding (Šálek 2000, Danko 2002, Šťastný *et al.* 2006). The increase in intensification was followed by a decline in breeding shorebird populations (Martiško 1994, Šťastný *et al.* 2006) and a higher proportion of Northern Lapwings (Šálek 1990, 1994, Fiala 2002, Schröpfer 2002, Šťastný *et al.* 2006) and later also Black-tailed Godwits (Kubelka & Kadava 2014, Kubelka *et al.* 2016) started to use arable land, especially its wetter parts (field wetlands), as breeding habitat – i.e. habitat where nests are situated (we have less precise information about the movement of families, but in many cases they stay in the same habitat during the chick rearing period). Due to political changes, there was a decrease in agricultural intensity around 1990, but without noticeable positive effects on breeding farmland shorebird trends (Reif *et al.* 2008).

Arable land is the predominant habitat for Northern Lapwing, hosting more than 75% of the breeding population in CZ on ploughed fields, winter wheat and spring crops, whereas meadows and pastures host a smaller proportion of the breeding population (Kubelka *et al.* 2012a), with preference for ploughed fields in South Bohemia (Šálek 1990, 1994, Kubelka 2015). The last breeding Black-tailed Godwits in the whole region, in a South Bohemian fishpond area near České Budějovice, are now equally using arable land and meadows or pastures (Kubelka & Kadava 2014), and sometimes also bottoms of fishponds (Kubelka & Pykal 2012). However, the predominant breeding habitat for both Black-tailed Godwit and Common Redshank was wet meadow until the end of 20[th] century (Šálek 1987, Martiško 1994, Bureš 1998, Kubelka *et al.* 2016). Generally, all shorebirds use wetlands in the fields and meadows for breeding more often during wetter years and slowly overgrowing bottoms of fishponds during drier years (Čamlík *et al.* 2010, Kubelka & Pykal 2012, own unpubl. data).

Breeding Common Redshanks were closely monitored only in the fishpond area near České Budějovice and the breeding habitat was recorded for 76 confirmed or presumed breeding pairs during 2005–2016. Altogether, fishpond bottoms or sludge lagoons were most commonly used (46%, 35 pairs), then arable land with marshlands (30%, 23 pairs) and least often meadows or pastures (24%, 18 pairs). The shift towards the arable land is notable even during this period. Only 11% of 38 pairs used arable fields during 2005–2010, however 50% of 38 pairs of Redshanks used arable land for breeding during 2011–2016 (V. Kubelka unpubl. data).

Eurasian Curlew is still a proper grassland breeder with nests only exceptionally found in arable land (Hudec &

Šťastný 2005, Gahura 2010). The last regular breeding area was restricted to artificial grassland of Václav Havel airport in Prague (Šena 2013, Žďárek *et al.* 2015). All other traditional meadow breeding grounds have been abandoned, particularly due to habitat deterioration and human disturbance (Gahura 2010). The Common Snipe differs from previous species and is not restricted to the lowland wet meadows, but can also inhabit middle and higher altitudes where it prefers even smaller wetlands and peat bogs in forested landscape, with tolerance of nearby trees and shrubs (Šálek 2000, Šťastný *et al.* 2006).

NUMBERS, TRENDS AND DISTRIBUTION

Northern Lapwing is the most common shorebird species with the widest distribution in both countries: 5,000–

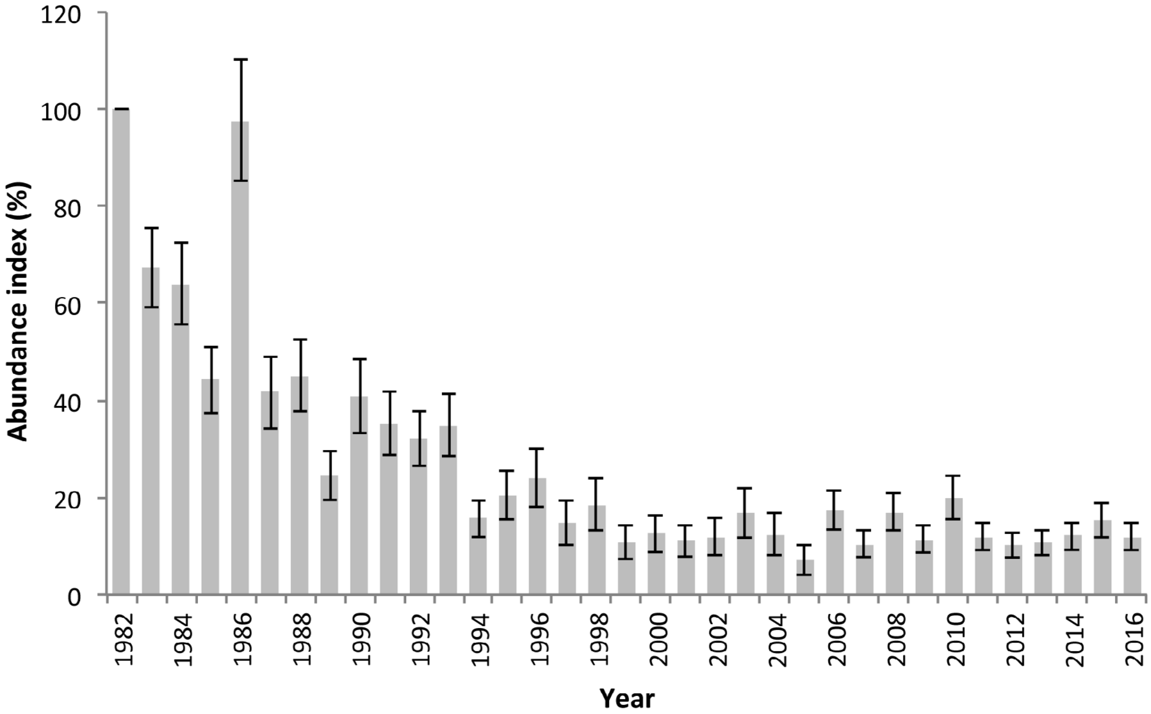

Fig. 1. Trend of the abundance of Northern Lapwing *Vanellus vanellus* with 95% confidence intervals, based on the JPSP – the common bird monitoring scheme in the Czech Republic (ČSO 2017) since 1982 (100%).

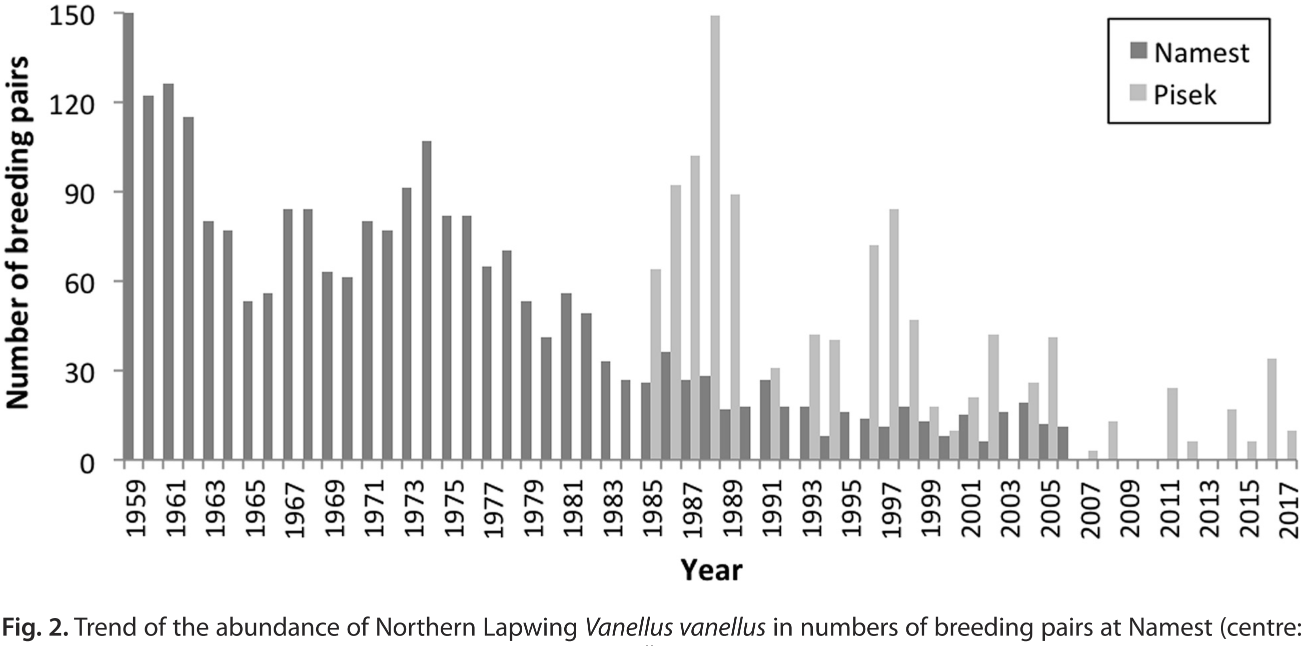

Fig. 2. Trend of the abundance of Northern Lapwing *Vanellus vanellus* in numbers of breeding pairs at Namest (centre: 49.2°N, 16.2°E) in Vysocina district (Fiala 2002) and Pisek (M. Šálek unpubl. data) in South Bohemia (centre: 49.2°N, 14.1°E), both in the Czech Republic. Covered regions differ in size. Empty years in Pisek region indicate no monitoring in that year.

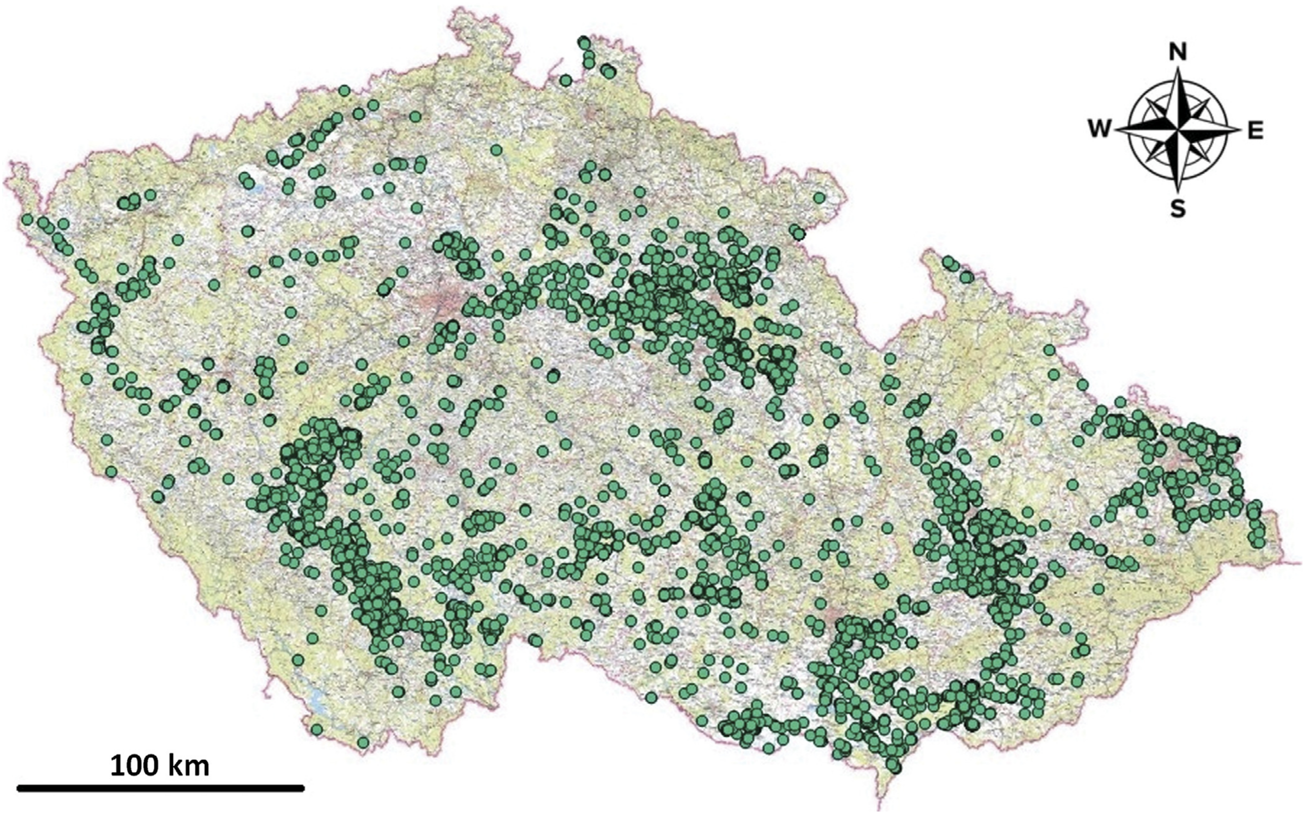

Fig. 3. Distribution of Northern Lapwing *Vanellus vanellus* breeding grounds in the Czech Republic based on volunteer monitoring during 2012–2018. *N* = 4,972 visits of particular breeding grounds, many of them repeatedly (ČSO, own unpubl. data).

7,000 breeding pairs in CZ and 2,000–4,000 in SK. Three detailed atlas-mapping work periods in CZ (1973–1977, 1985–1989, and 2001–2003; Šťastný *et al.* 2006), based on the help of hundreds of volunteers, provide a good estimate for the population trend in the whole country: approximately 20,000–40,000 pairs during 1985–1989 and only 7,000–10,000 pairs during 2001–2003 (Šťastný *et al.* 2006). According to the recent detailed monitoring of Lapwing breeding grounds in CZ during 2012–2016, we estimate the current population at approximately 5,000–7,000 breeding pairs (Žďárek *et al.* 2015). There is only one older estimate from national atlas mapping in SK: 2,500–5,000 breeding pairs up to the year 2002 (Danko *et al.* 2002); the current estimate is 2,000–4,000 breeding pairs.

The long-term trend (*ca.* 1970–2014) is a strong decline in both countries (Figs. 1 & 2; Danko *et al.* 2002, Šťastný *et al.* 2006, Žídková *et al.* 2007, Kubelka *et al.* 2012a, own unpubl. data). Where known, medium- and short-term trends also show strong declines (Table 1), but in CZ the short-term trend (*ca.* 2004–2014) is a moderate decline (own unpubl. data, ČSO 2017). Northern Lapwing is spread all over both countries apart from the high mountains, in various habitats of the agricultural landscape (Fig. 3; Danko 2002, Šťastný *et al.* 2006, Kubelka *et al.* 2012a). There are several estimates of Lapwing nest survival in CZ (Table 2), but no thorough estimate of chick survival.

Black-tailed Godwit is a rare breeder in CZ with only 5–10 breeding pairs left (Kubelka & Kadava 2014), and the species is now gone from SK. Godwits have inhabited mainly grasslands (meadows and pastures) in lowlands of both countries, but half of the population in CZ breeds nowadays on arable land (Kubelka & Kadava 2014, Kubelka *et al.* 2016). Long-, medium- and short-term trends are all strong declines for CZ (Fig. 4, Table 1); previous population estimates in CZ were 250–500 breeding pairs for 1973–1977, then only 30–60 pairs for 1985–1989 and 10–20 pairs for 2001–2003 (Hudec & Šťastný 2005, Šťastný *et al.* 2006). There were 5–40 breeding pairs of godwits in SK before 2002 (Danko *et al.* 2002).

Common Redshank is more or less equally abundant in CZ (25–40 breeding pairs) and SK (20–50). Redshanks inhabit mainly lowland partly-flooded pond-bottoms and also meadows and pastures in CZ, and marshlands in arable land in CZ and SK. Long-term trends are a strong decline in CZ and a decline in SK. Medium-term trends are strong declines in CZ, whereas the short-term trend in CZ is probably stable (Table 1; Šálek 1996, Kubelka & Pykal 2012, Bureš 2015). Previous population estimates based on atlas mapping in CZ are 80–150 breeding pairs for 1973–1977, 40–60 pairs for 1985–1989 and 25–40 pairs for 2001–2003 (Hudec & Šťastný 2005, Šťastný *et al.* 2006) and numbers seem to be the same since then (Kubelka & Pykal 2012, Žďárek *et al.* 2015). There were 35–70 breeding pairs of Common Redshank in SK before

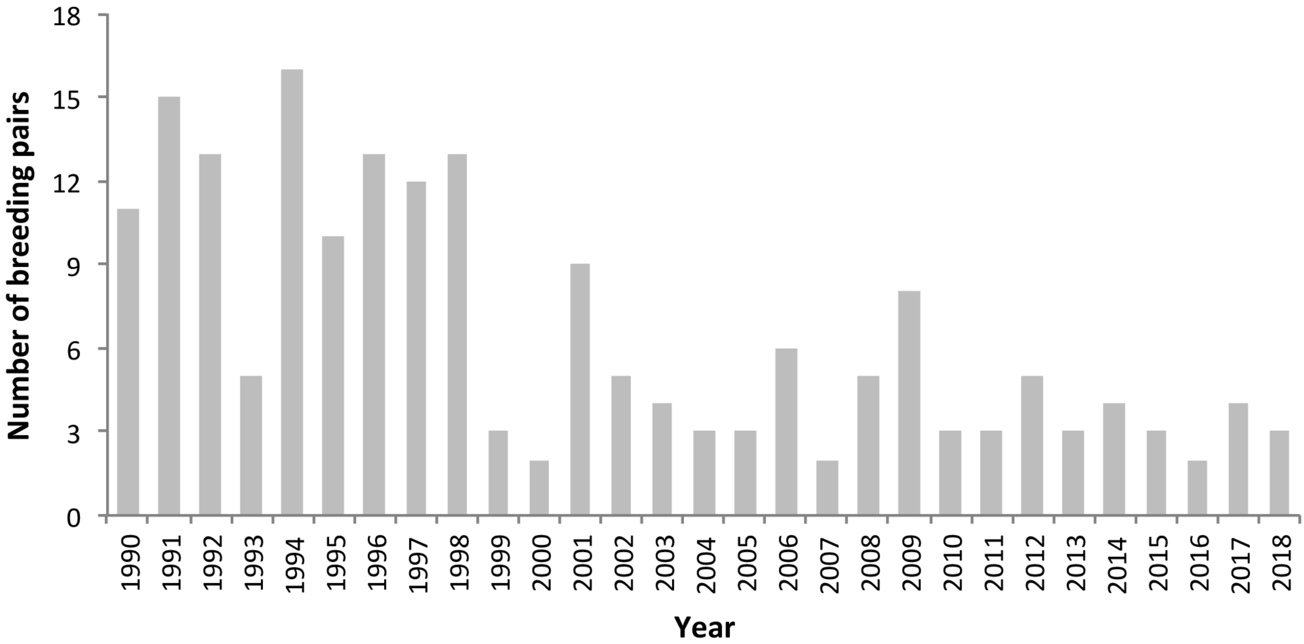

Fig. 4. Trend of the abundance of Black-tailed Godwit *Limosa limosa* in IBA Českobudějovické rybníky (centre: 49.0°N, 14.3°E) in South Bohemia, Czech Republic during 1990–2016. These include confirmed and presumed breeding pairs only. Adopted from Bureš 2012, Kubelka & Kadava 2014, Kubelka *et al.* 2016 and V. Kubelka unpubl. data.

2002 (Danko *et al.* 2002) and the decline may not be so pronounced at some localities (Fig. 5). No demographic parameters are available for this species.

Eurasian Curlew is a very rare breeder in CZ (0–1 pairs). The species is now gone from SK. Curlews mainly inhabit grasslands (meadow and pastures) in lower elevations. Long-, medium- and short-term trends are strong declines in CZ (Fig. 6), as is the long-term trend in SK (Table 1). Previous estimates for CZ were 25–50 breeding pairs for 1973–1977, 5–15 pairs for 1985–1989 and 1–3 pairs for 2001–2003 (Hudec & Šťastný 2005, Šťastný *et al.* 2006). Recently, pairs are occasionally seen in suitable breeding habitat, but breeding was not confirmed for several years (ČSO & ČZU 2018). There were 3–30 breeding pairs of Eurasian Curlew in SK before 2002 (Danko *et al.* 2002). Apparent nest survival from the vanishing South Moravian population of this species during 1974–2001 was as follows: out of 50 nests, mainly meadow clutches, 23 (46%) hatched at least one chick, 22 (44%) were depredated, one (2%) damaged by agricultural machinery and four (8%) abandoned. Chick survival was very low. From 140–150 breeding pairs in the area over the years, fledged juveniles were detected

Table 1. Current population estimates and trends of five shorebird species in the Czech Republic (CZ) and Slovakia (SK) See text for details.

Species	State	Population estimate (breeding pairs)	Long-term trend *ca.* 1970–2014	Medium-term trend *ca.* 1970–1990	Medium-term trend *ca.* 1990–2014	Short-term trend *ca.* 2004–2014
Northern Lapwing *Vanellus vanellus*	CZ	5,000–7,000	strong decline	strong decline	strong decline	moderate decline
	SK	2,000–4,000	strong decline	?	?	?
Black-tailed Godwit *Limosa limosa*	CZ	5–10	strong decline	strong decline	strong decline	strong decline
	SK	0	strong decline	?	?	?
Common Redshank *Tringa totanus*	CZ	25–40	strong decline	strong decline	strong decline	stable
	SK	20–50	decline	?	?	?
Eurasian Curlew *Numenius arquata*	CZ	0–1	strong decline	strong decline	strong decline	strong decline
	SK	0	strong decline	?	?	?
Common Snipe *Gallinago gallinago*	CZ	500–800	strong decline	strong decline	strong decline	?
	SK	30–100	strong decline	?	?	?

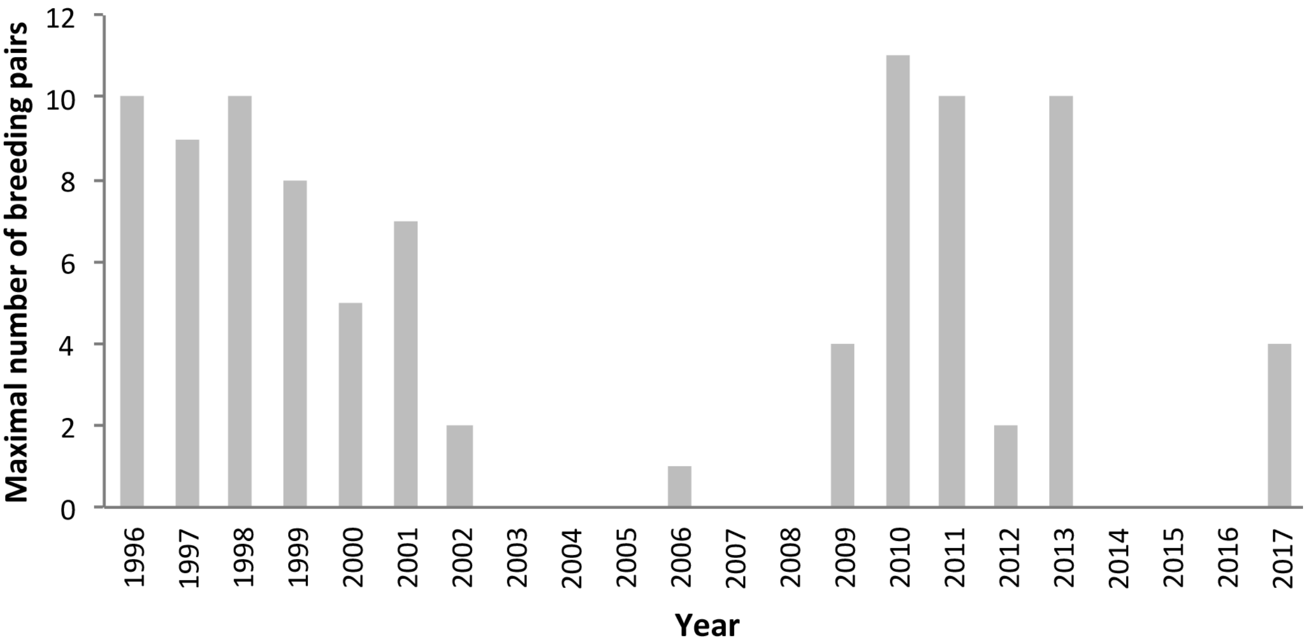

Fig. 5. Trend of the abundance of Common Redshank *Tringa totanus* in IBA Poiplie in Central South Slovakia during 1996–2017. Maximum number of possibly breeding pairs is presented (Mojžiš *et al.* 2011, M. Mojžiš, D. Kerestúr, R. Václav pers. comm.). Empty years indicate no monitoring in that year.

only in 15 cases. Most chicks were killed by mowing machinery and the rest by predators (Gahura 2010).

Common Snipe breeds regularly in both countries: 500–800 breeding pairs in CZ and 30–100 in SK. Common Snipes inhabit lowland grasslands (meadows and pastures) as well as peat-bogs in more forested landscapes at higher elevations. Long-term trends are a strong decline in CZ (Fig. 7) and SK; medium- and short-term trends are also a strong decline in CZ (Table 1). Previous estimates for CZ were 1,200–2,400 pairs for 1985–1989 and 500–800 pairs for 2001–2003 (Hudec & Šťastný 2005, Šťastný *et al.* 2006). There exist no more updated estimates in CZ and it is difficult to judge whether the negative trend continues because some areas seem to be similarly occupied by Common Snipes in recent decades (Fig. 8). There were 100–250 breeding pairs of Common Snipe in SK before 2002 (Danko *et al.* 2002). No demographic parameters are available for this species.

THREATS AND CONSERVATION

Northern Lapwing

Common threats to grassland-breeding Lapwings in both countries and major factors driving these trends are: drainage of grasslands; conversion of grasslands to arable land; high fertilizer input in meadows leading to overgrowth and thick, poorly penetrable habitat; drilling of meadows during the Lapwing incubation period; and grazing abandonment at fishpond margins (Šálek 1994, 2000, Danko 2002, Šťastný *et al.* 2006, Kubelka 2015). Fishpond cultivation intensification in CZ also plays a role (Šálek 2000, Albrecht 2015).

Apart from indirect effects of agricultural intensification, there are key threats of nest and chick predation and direct damage by agricultural machinery. Predation is the most common cause of failure of Lapwing clutches in South Bohemia (Table 2; Šálek 1992, Šálek & Šmilauer 2002, Kubelka & Šálek 2013, Kubelka 2015), West Bohemia (Schröpfer 2002) and East Bohemia (Table 2). Larger breeding colonies in meadows experienced a lower nest predation rate (Šálek & Šmilauer 2002). Daily nest predation rate has increased over 25 years in the fishpond area near České Budějovice (Fig. 9). Nest cameras have recorded three mammal predators as most important: Red Fox *Vulpes vulpes*, Stone Marten *Martes foina* and Eurasian Badger *Meles meles* (Kubelka 2015, Sládeček *et al.* unpubl. data). However, avian predators probably also play a role (Šálek & Cepáková 2006, Šálek & Zámečník 2014) and Klabník (1984) noted the Carrion Crow *Corvus corone* as the only recorded predator of Lapwing clutches in North Bohemia. Three avian predators were determined as chick predators in CZ: Marsh Harrier *Circus aeruginosus*, Common Kestrel *Falco tinnunculus* and Long-eared Owl *Asio otus* (Kubelka 2015, Zámečník *et al.* unpubl. data).

Direct nest destruction by agricultural machinery is a common and widespread cause of Lapwing clutch failure (Table 2). When a ploughed field is cultivated, the egg loss can reach 100% (own unpubl. data). It could be the same for meadows which are often drilled or rolled during the Lapwing incubation period (Šálek 1992, 1994). Damage by agricultural machinery could be much higher without direct nest protection; e.g. in South Bohemia, 37% of 52 nests would be damaged instead of the observed 14% in 2011, and 55% of 57 nests instead of only 2% in

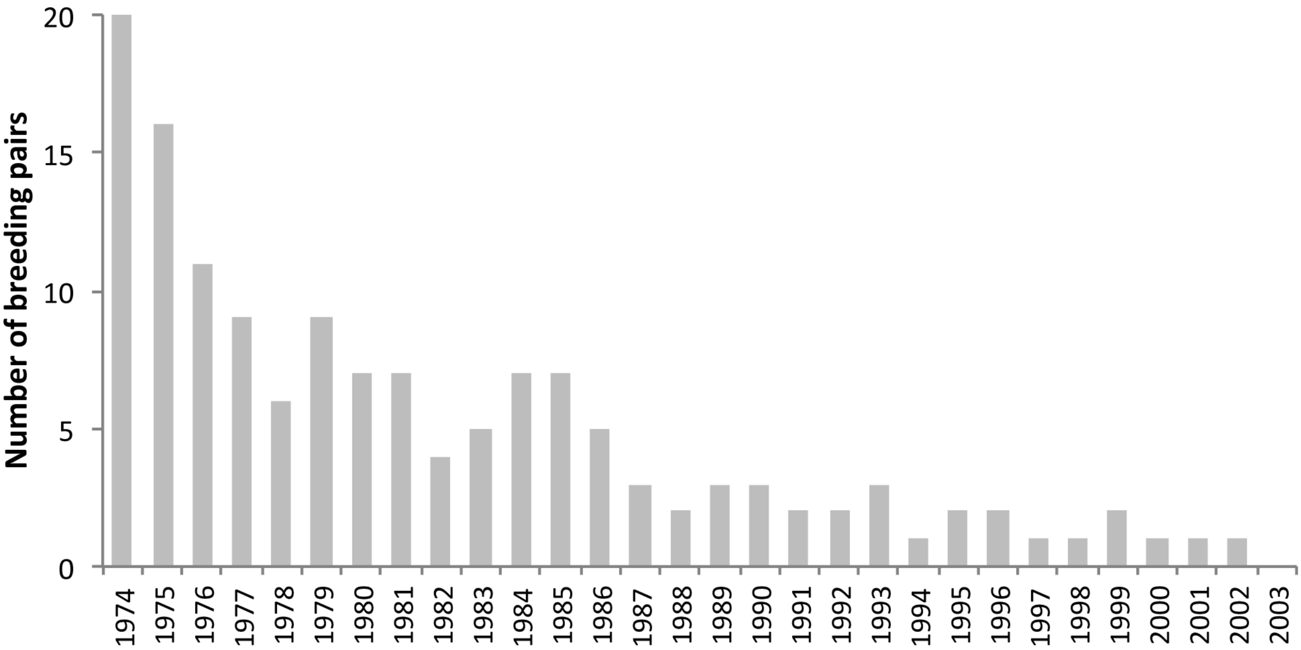

Fig. 6. Trend of the abundance of Eurasian Curlew *Numenius arquata* in South Moravia (centre: 48.9°N, 17.3°E), Czech Republic during 1974–2010. These include confirmed and presumed breeding pairs only. There was one non-breeding pair in 2003 and no breeding Curlews were recorded afterwards (Gahura 2010).

2012 (Kubelka 2015). Therefore, we can assume that in a conventional agricultural landscape in CZ without any conservation measures, at least one third of all clutches (especially from first breeding attempts) is damaged by agricultural machinery every year.

Nest trampling by cattle is only a minor problem at a few localities where cattle are released to the pasture in the middle of the Lapwing incubation period (own unpubl. data). Another detected threat (based on the chick ringing data) is hunting pressure at wintering sites, which has been found to be negatively associated with Lapwing population trends in different parts of CZ (Žídková *et al.* 2007).

Large-scale effective protection for Lapwings on grasslands is generally lacking, but protection in small-scale nature reserves can work well. Conservation measures in CZ consist of efficient small-scale measures (nature reserves

Table 2. Apparent nest survival and failure estimates for Northern Lapwing *Vanellus vanellus* from three localities in the different part of Bohemia. Other failures mean overgrowing in Plzeňsko, flooding and unknown nest failure in Českobudějovicko.

Area	Years	*n* nests	Apparent survival and failure of clutches (% from all nests)					Source
			Hatched	Depredated	Machinery	Other	Abandoned	
Českobudějovicko (South Bohemia, CZ) (GPS 49.1°N, 14.3°E)	1988–1991	267	60.4%	21.7%	13.9%	0.0%	3.0%	Šálek 1992
Českobudějovicko (South Bohemia, CZ) (GPS 49.1°N, 14.3°E)	2011–2015	545	38.2%	47.9%	5.7%	2.0%	6.2%	own unpubl. data
Plzeňsko (West Bohemia, CZ) (GPS 49.6°N, 13.2°E)	1992–2001	35	34.3%	42.9%	14.3%	8.7%	0.0%	Schröpfer 2002
Královéhradecko (East Bohemia, CZ) (GPS 50.2°N, 15.6°E)	2012–2014	119	53.5%	31.0%	11.6%	0.0%	3.9%	own unpubl. data

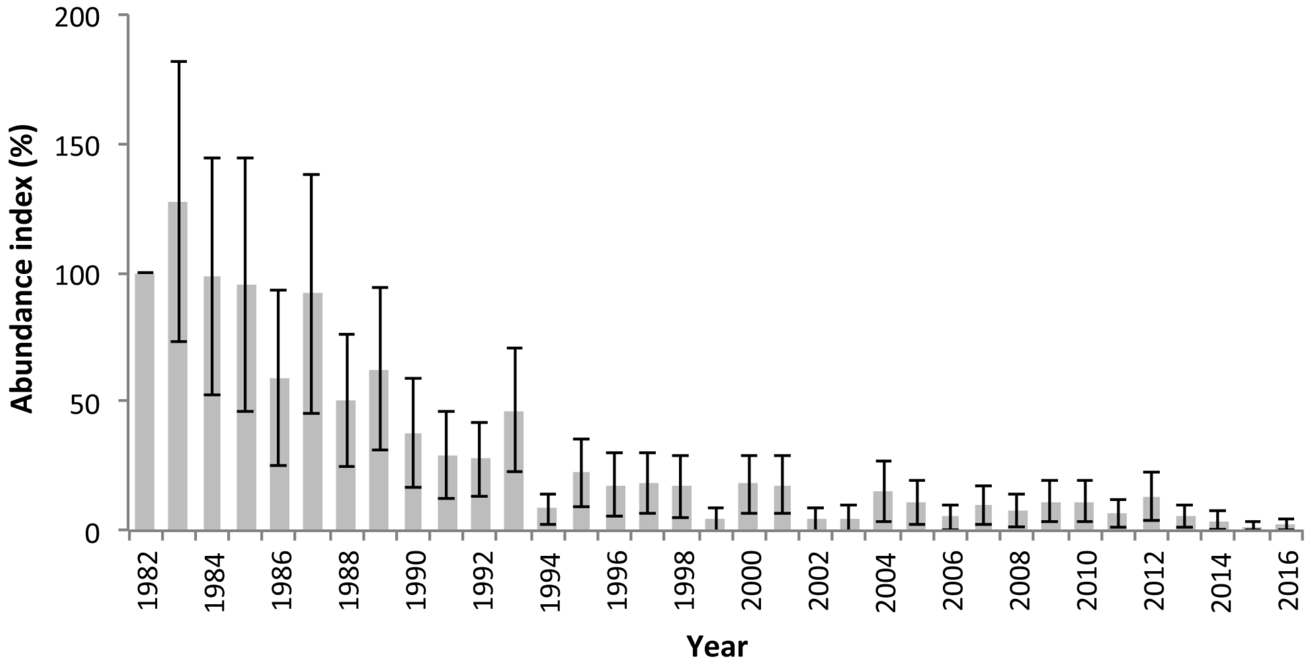

Fig. 7. Trend of the abundance of Common Snipe *Gallinago gallinago* with 95% confidence intervals, based on the JPSP – the common bird monitoring scheme in the Czech Republic (ČSO 2017) since 1982 (100%).

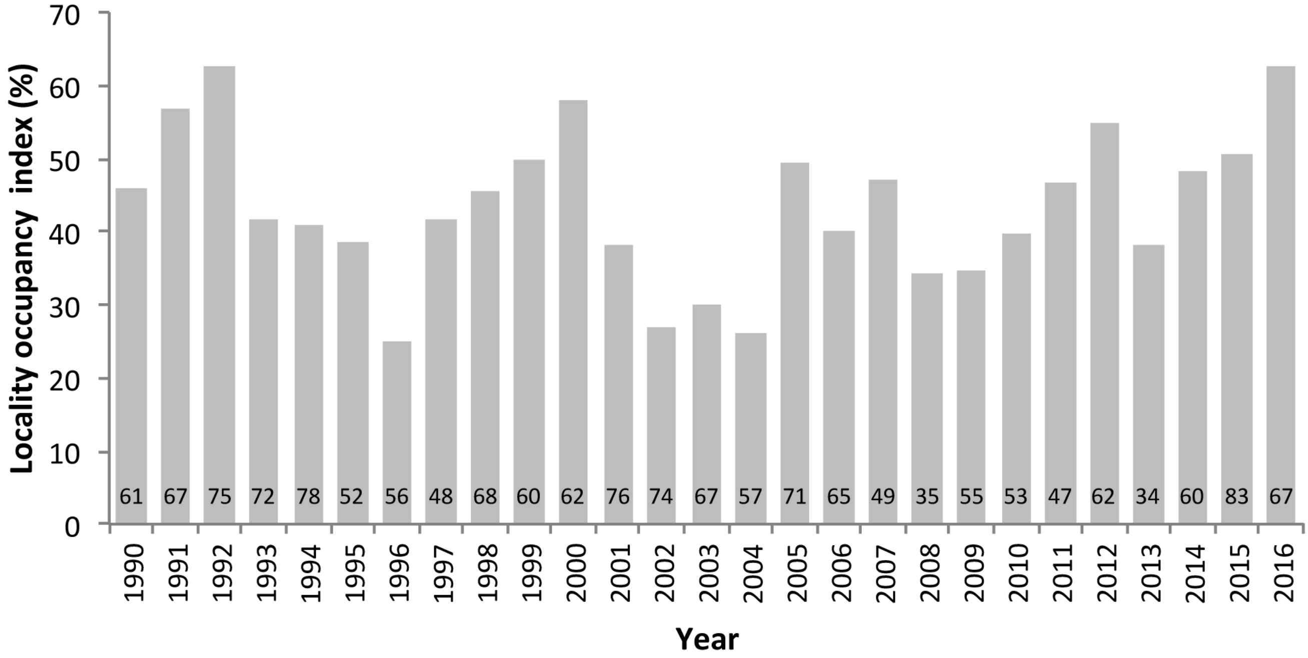

Fig. 8. Locality occupancy by at least one Common Snipe *Gallinago gallinago* in Vysočina district (centre: 49.5°N, 15.6°E), Czech Republic during 1990–2016. Number of monitored localities each year is given in each bar (V. Kodet unpubl. data).

with a high water table) and direct nest protection against agricultural machinery (Kubelka *et al.* 2012b). This protection consists of two thin 2 m-long conspicuous bamboo poles with the top end highlighted with reflective spray, placed along the line of cultivation 10–12 m apart, with a nest in the middle. The measure works very well, as it is adequately obvious for farmers, but the marking does not increase nest predation (Zámečník *et al.* 2018). An agri-environmental scheme for Lapwings on arable land, consisting of the ploughed field left without any intervention through the breeding period (Zámečník 2014), seems to be promising after four years in practice, but exact evaluations have not been done yet.

Black-tailed Godwit

The main factors driving the declines are the same as for Lapwing (Šálek 1987, Bureš 2012). Effective large-scale protection measures are generally lacking. Direct nest

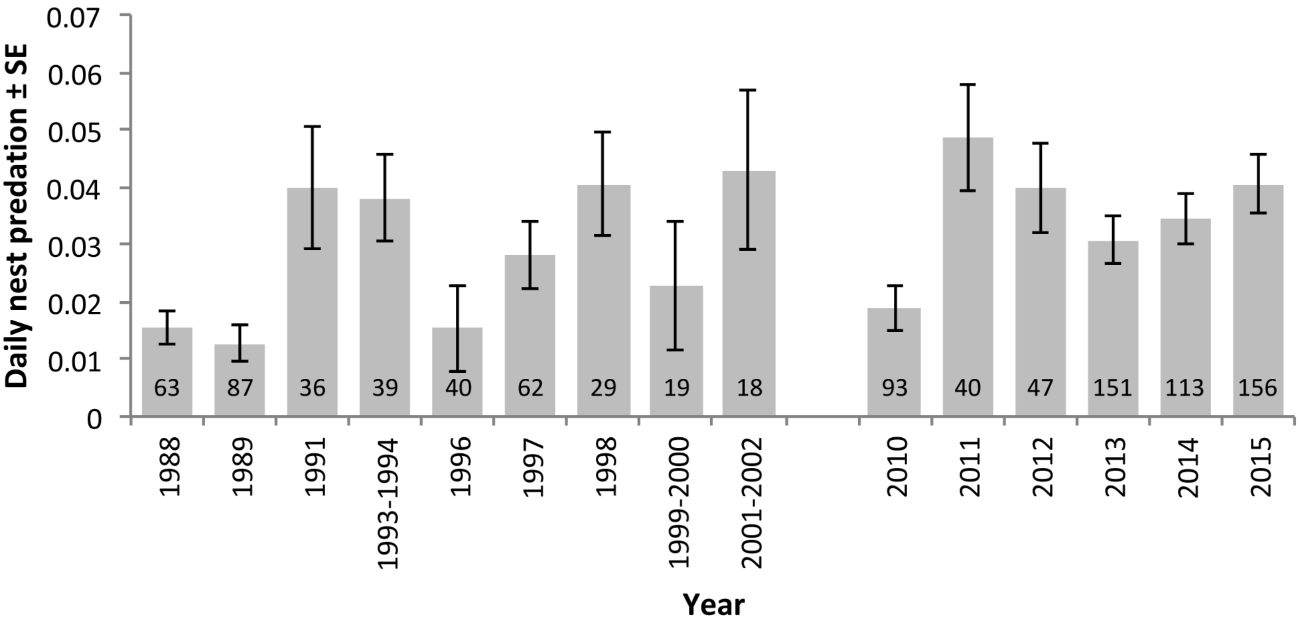

Fig. 9. Daily predation rates (± standard error) of Northern Lapwing *Vanellus vanellus* nests near České Budějovice (centre: 49.1°N, 14.2°E) in South Bohemia, Czech Republic (Šálek & Šmilauer 2002, V. Kubelka *et al.* unpubl. data, M. Šálek *et al.* unpubl. data, V. Štorek pers. comm.). Daily nest predation computation follows Mayfield's (1961, 1975) approach with SE computation according to Johnson (1979). Sample sizes (number of nests involved) are given in each bar.

protection works well at the last breeding grounds of this species in South Bohemia (Zámečník *et al.* 2018). Negotiation with fish farmers to maintain a low water level in a fishpond, after Black-tailed Godwits or Common Redshanks initiate breeding on the fishpond bottom, has been proven as an effective conservation measure (Kubelka & Pykal 2012).

Common Redshank

The main factors driving the declines are the same as for Lapwing (Šálek 1987, 1996, 2000). Effective large-scale protection measures are generally lacking. Protection in CZ and SK consists of nature reserves, and direct nest-site protection is applied effectively for part of the population in South Bohemia, CZ (Zámečník *et al.* 2018).

Eurasian Curlew

The main factors driving the declines are the same as for Lapwing; another factor in CZ is the higher human disturbance at former breeding grounds (Gahura 2010). Effective large-scale protection measures are generally lacking. There are no protection measures in CZ; the last regular breeding site was the airport and the airport regime, paradoxically without human disturbance, is probably the best protection.

Common Snipe

The conversion of meadows to arable land, drainage of wetlands, high fertilizer input, and drainage of meadows are assumed to be the main threats in CZ and SK (Šálek 2000, Danko *et al.* 2002, Hudec & Šťastný 2005). An agri-environmental scheme implemented on meadows in CZ during 2004–2013, consisting of a postponed cutting regime only (Scharf *et al.* 2007), has not been properly evaluated, but it was probably ineffective as shorebirds avoided these sites (V. Kodet pers. comm., own unpubl. data). Therefore, application of this scheme was terminated in 2014. Protection in nature reserves with a higher water table works well in some parts of CZ and SK, as does quite sophisticated restoration of former peat bogs (Lysák & Kodet 2016), where Common Snipe can work nicely as a flagship and umbrella species (Kodet 2017).

FUTURE PERSPECTIVES

Meadow shorebirds are still generally declining in CZ and SK. However, at least in recent years, improvement of these trends is apparent for a few species. In addition to direct nest protection for various shorebird species, which is effective and has not increased nest predation rates (Zámečník *et al.* 2018), revitalisation of peat bogs is beneficial for Common Snipe (Lysák & Kodet 2016) and can serve as an inspiration for future revitalisation projects. Another conservation measure successfully promoting meadow shorebirds consists of leaving fishponds at a low water level through the whole breeding season. This prescription works very well, however, negotiation with fish farmers is difficult and rarely successful (Sychra *et al.* 2008).

A very promising conservation tool for meadow shorebirds seems to be the new agri-environmental scheme launched for Northern Lapwing on arable land in CZ in 2015. This prescription consists of non-managed ploughed fields during the whole breeding season, preferably at traditional and waterlogged breeding grounds (Zámečník 2014), which is very similar to the German scheme (Schmidt *et al.* 2017). The recent comparison of agri-environmental scheme plots with control sites (Lapwing breeding grounds were also suggested for the prescription, but not implemented by the farmer) suggests that the scheme not only promotes a higher abundance of Northern Lapwing but also attracts Lapwing families with chicks hatched elsewhere, as well as Common Redshank and Black-tailed Godwit, which are very rare in CZ. Other farmland birds such as Eurasian Skylark *Alauda arvensis* and Western Yellow Wagtail *Motacilla flava*, as well as daylight-active butterflies and bumblebees, also benefit from the scheme (V. Kubelka unpubl. data). Northern Lapwing works nicely as the 'umbrella species' in this case; however, thorough evaluation of overall breeding productivity is still needed, with quantification of key mortality factors for nests and chicks (e.g. predation, agricultural machinery, starvation) on the plots under the agri-environmental scheme regime and on control plots.

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Chapter 2

Seasonality predicts egg size better than nesting habitat in a precocial shorebird

Vojtěch Kubelka, Martin Sládeček, Václav Zámečník, Eva Vozabulová & Miroslav Šálek

Egg size represents a fundamental predictor of chick mass and body condition. Chicks from bigger eggs have significantly increased survival, especially in precocial species, where chicks must forage for themselves and cope with environmental threats, such as bad weather or predators. Therefore, our understanding of the factors influencing egg size is crucial both from the perspective of their breeding ecology as well as of their conservation. However, studies simultaneously addressing multiple factors and quantifying their influence on egg size in large samples are rare. Here, we test the effect of seasonality, clutch size and nesting habitat on egg size, measured as volume, in a ground-nesting shorebird, the Northern Lapwing *Vanellus vanellus*, using a sample of 4384 eggs from 1125 clutches in South Bohemia, Czech Republic, during the period between 1988 and 2018. We report a significant decline in egg size over the breeding season, on average bigger eggs in larger clutches with a significant difference between 2-egg and 4-egg clutches, and no direct effect of nesting habitat. From our review of the same predictors across 15 Northern Lapwing populations throughout Europe it is apparent that replacement or late clutches have on average 3–7% smaller eggs than first or early clutches. Nesting habitat only rarely affects egg size and there are no significant differences in egg size between 3-egg and 4-egg clutches. Earlier studies showed that chicks hatching from bigger eggs early in the breeding season performed better, and that there was higher food abundance available for chicks at that time. This fact, together with the documented seasonal decline in egg size, sends an important message to conservationists and policymakers that early breeding attempts may play a pivotal role in safeguarding shorebird breeding productivity.

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Seasonality predicts egg size better than nesting habitat in a precocial shorebird

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Egg size represents a fundamental predictor of chick mass and body condition. Chicks from bigger eggs have significantly increased survival, especially in precocial species, where chicks must forage for themselves and cope with environmental threats, such as bad weather or predators. Therefore, our understanding of the factors influencing egg size is crucial both from the perspective of their breeding ecology as well as of their conservation. However, studies simultaneously addressing multiple factors and quantifying their influence on egg size in large samples are rare. Here, we test the effect of seasonality, clutch size and nesting habitat on egg size, measured as volume, in a ground-nesting shorebird, the Northern Lapwing *Vanellus vanellus*, using a sample of 4384 eggs from 1125 clutches in South Bohemia, Czech Republic, during the period between 1988 and 2018. We report a significant decline in egg size over the breeding season, on average bigger eggs in larger clutches with a significant difference between 2-egg and 4-egg clutches, and no direct effect of nesting habitat. From our review of the same predictors across 15 Northern Lapwing populations throughout Europe it is apparent that replacement or late clutches have on average 3–7% smaller eggs than first or early clutches. Nesting habitat only rarely affects egg size and there are no significant differences in egg size between 3-egg and 4-egg clutches. Earlier studies showed that chicks hatching from bigger eggs early in the breeding season performed better, and that there was higher food abundance available for chicks at that time. This fact, together with the documented seasonal decline in egg size, sends an important message to conservationists and policymakers that early breeding attempts may play a pivotal role in safeguarding shorebird breeding productivity.

Key words: clutch size, chick survival, egg size, nesting habitat, Northern Lapwing, precocial offspring, predation, seasonal timing, *Vanellus vanellus*, wader

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Egg size in birds is not only a measure of parental investment, but also represents an important predictor of chick growth and survival (Williams 1994, Christians 2002, Krist 2011). In general, egg size is more important for precocial birds, where chicks must forage for themselves soon after hatching and are more exposed to harsh climatic conditions or predators in comparison with altricial nestlings (Starck & Ricklefs 1998). Precocial birds enhance survival of their chicks by investing more in eggs, which are, on average, proportionally more energy-rich and larger than eggs of altricial birds (Carey *et al.* 1980, Sotherland & Rahn 1987, Starck & Ricklefs 1998, Deeming 2007, Stoddard *et al.* 2017). Shorebirds belong to the bird clades with the proportionally largest eggs (Rahn *et al.* 1975).

The positive relationship between egg size and chick size, measured usually as, respectively, volume and mass, has been found in many bird species (Martin 1987, Christians 2002, Krist 2011) including shorebirds (Byrkjedal & Kålås 1985, Galbraith 1988a, Grant 1991, Thompson & Hale 1991, Hegyi 1996, Blomqvist *et al.* 1997, Hegyi & Sasvari 1998, Dittmann & Hötker 2001, Sheldon 2002, Larsen *et al.* 2003). Bigger chicks are in better body condition, are capable of longer-lasting self-thermoregulation, are more effective at searching for prey and can escape from predators easier. This advantage of hatching from a bigger egg can positively influence chick survival until fledging (Davis 1975, Galbraith 1988a, Bolton 1991, Grant 1991, Sheldon 2002, Eglington *et al.* 2010, Krist 2011).

Variability in egg size is higher among clutches than within a clutch (Nol *et al.* 1984, Redmond 1986, Thompson & Hale 1991, Blomqvist & Johansson 1995, Dittmann & Hötker 2001, Parish *et al.* 2001). Egg size thus seems to be a consistent maternal trait, because eggs in a female's consecutive clutches are more similar in size than the eggs of different females, and intrinsic factors of particular females, such as protein storage or ovary size, probably play an important role (Christians 2002). Nevertheless, older, more experienced and heavier females lay bigger eggs than younger and lighter individuals of the same species (Nol *et al.* 1984, Thompson & Hale 1991, Parish *et al.* 2001, Christians 2002). Despite the generally assumed pivotal role of female intrinsic characteristics (Christians 2002), environmental factors, e.g. food availability during the egg formation period, can influence egg size (Lank *et al.* 1985, Perrins 1996, Nol *et al.* 1997). As food availability can differ among nesting habitat types (e.g. Galbraith 1988b, Blomqvist & Johansson 1995), habitat quality may influence not only the food availability for chicks (Devereux *et al.* 2004, Kentie *et al.* 2013), but also the egg size via the food supply for females prior to the egg-laying period. Furthermore, eggs in replacement or seasonally later clutches tend to be smaller than in the first ones (Byrkjedal & Kålås 1985, Redmond 1986, Galbraith 1988a, Šálek 1995, Hegyi 1996, Grønstøl 1997, Hegyi & Sasvari 1998, Sandercock *et al.* 1999, Sharpe 2006), possibly suggesting combined effects of intrinsic as well as several environmental factors. Therefore, a possible seasonal change in egg size could have important consequences for chick survival.

From interspecific comparison it is apparent that many bird species trade-off the number of eggs in the clutch against egg size (Blackburn 1991, Figuerola & Green 2006, Martin *et al.* 2006). However, this pattern has not been found in shorebirds (Olsen *et al.* 1994), which usually have clutches of four eggs (Lack 1947, Arnold 1999), although there is some inter and intraspecific variability in the number of eggs in complete clutches (del Hoyo *et al.* 2018). Studies on the trade-off between egg size and clutch size at the intraspecific level are less common (e.g. Rohwer 1988, Hořák *et al.* 2008, Pellerin *et al.* 2016, Song *et al.* 2016).

The Northern Lapwing *Vanellus vanellus*, a precocial shorebird, breeds in agricultural landscapes using diverse nesting habitats with variable availability of different foraging opportunities (Cramp & Simmons 1983, Shrubb 2007). This species probably aggregates energetic reserves for egg production particularly after

Northern Lapwing *Vanellus vanellus* chicks facing a difficult future while hatching late in the breeding season from smaller eggs in a maize field, which is often hot and dry with scarce food supply (photo V. Kubelka, 26 May 2012, Češňovice, South Bohemia, Czech Republic).

arrival to its breeding grounds, as suggested by indirect evidence (Galbraith 1989, Blomqvist & Johansson 1995, Shrubb 2007), lays a varying number of eggs in the clutch (Cramp & Simmons 1983, Shrubb 2007) despite a predominant clutch size of four eggs (Klomp 1970), and thus represents a suitable model species for investigating environmental or physiological factors affecting egg size (Galbraith 1988a).

Our aim is to assess and quantify the role of factors influencing egg size in Northern Lapwings and discuss the implications for conservation practices. We are using a long-term data set to ask the following questions. (1) Do seasonal timing (seasonality), nesting habitat and/or clutch size influence egg size? (2) Is chick size after hatching predicted by egg size in our study area? In addition, by reviewing the existing literature, we investigate (3) variation in the effect size of seasonality, nesting habitat and clutch size across Northern Lapwing populations, and discuss possible consequences for chick performance.

METHODS

Study area and field measurements

We searched for Northern Lapwing (Lapwing from hereon) nests near České Budějovice, Czech Republic, during 17 breeding seasons: 1988–1989, 1991, 1993–1994, 1996–1997, 2008–2009, 2011–2018. The study area (centre: 49.0°N, 14.4°E) consists of approximately 60 km^2 of agricultural landscape with prevailing arable land at an altitude of 380–420 m (for more details see Šálek & Šmilauer 2002, Zámečník *et al.* 2018). Lapwings breed in the whole area in small aggregations (rarely more than 25 pairs) or less commonly as individual pairs. We searched for nests using binoculars and telescopes, or by direct nest searching in denser breeding colonies during the breeding season. The peak of the start of incubation was usually during the first two weeks in April with the overall median on 7 April, the earliest clutch incubation started on 19 March in 2017 and the latest on 15 June in 2013.

We recorded nest locations and assigned nesting habitat into one of six categories (Table 1). We determined the first day of incubation for each nest using the flotation method (van Paassen *et al.* 1984) or using the observed egg-laying dates of first or sequential eggs. The incubation start represents a day when the third egg was laid (Shrubb 2007). For two egg clutches the laying date of the second egg was used. We took egg measurements (length, width) to the nearest 0.05 mm using vernier calipers. Due to possible egg size differences with the laying sequence within clutches (Lislevand *et al.* 2005), only complete clutches were included. Nests where not all eggs were measured and also two-egg or three-egg clutches found at a later incubation stage were excluded to eliminate a possible effect of partial predation on clutch size and mean within-clutch egg size in a clutch. The final dataset contained 1125 clutches with all eggs measured, specified known nesting habitat and defined first day of incubation. During 2013–2014 we also weighed chicks in or close to the nest at the day of hatching, using electronic scales with an accuracy of 0.01 g. The fate of chicks was not determined in this study. Additionally, we collected data following the same procedures in East Bohemia (50.18°N, 15.61°E; more detail on study site in Zámečník *et al.* 2018), at c. 200 km from the South Bohemian study site. These data were used only in the comparison among European populations.

Data processing

From the egg measurements, we estimated egg volume according to Galbraith's (1988) formula: $V = 0.457 \times L \times W^2$, where V is egg volume in mm^3, L is length of the egg in mm and W is width of the egg in mm. We converted the values to cm^3 and calculated the mean egg volume for each clutch as the targeted response variable. Similarly, we computed mean body mass of freshly hatched chicks from each clutch. We coded the

Table 1. Description of nesting habitat categories in South Bohemia, Czech Republic, and relative proportion (%) of these habitats among 1125 clutches.

Habitat category	Description	Number (%)
Ploughed field	Ploughed fields, stubble fields with partial ploughing	32
Meadow	Meadows and pastures	13
Winter crops	Winter wheat, oil-seed-rape fields	15
Spring crops	Harrowed fields, spring crops, maize fields, spring beans	33
Clover	Clovers and temporary grass planting on arable land	1
Other	Fallow lands, dry fishpond bottoms, other marshlands, potatoes	6

first day of incubation for each clutch as the number of days since the start of the calendar year, but without taking into account leap years, for easier comparability of data; thus 91 always equals 1 April and 152 equals 1 June, etc. Because a warmer winter or wetter spring can accelerate the start of the Lapwing breeding season (Both *et al.* 2005, Musters *et al.* 2010) and the timing of the breeding season was unique every year in our study population, we also computed standardized first days of incubation expressed as a number of days prior to or after the median first day of incubation for each year separately. There was no temporal trend in egg size variation for the 1125 clutches over the 17 breeding seasons of 1988–2018 (General Linear Model: slope = –0.009, $F_{1,1123} = 1.12$, $P = 0.282$), which is important when addressing the questions in this study.

Literature review and effect size assessment

We searched for relevant publications using the keywords 'Northern Lapwing' or '*Vanellus vanellus*' in the electronic databases Web of Science, Searchable Ornithological Research Archive and Google Scholar, or via reference works (Cramp & Simmons 1983, Shrubb 2007, del Hoyo *et al.* 2018) and references in relevant publications. We found 13 publications which held information on egg size and at least one predictor that is also used in this study, in combination with our two data sets, this accounts to 15 Lapwing populations in our review study.

For better comparison among populations, we expressed the effect size of each predictor as a relative percentage difference between mean values of the tested categories and the overall mean egg size in a particular dataset. The reasons for this standardization was a possible geographical variation in egg size, as seen in shorebirds (Väisänen 1977) and in Lapwings particularly (Chylarecki *et al.* 1997), and the fact that some studies used different egg volume computations or used egg mass instead of egg volume. Seasonality was reported in two ways: (1) comparison between first and replacement clutches as assessed in individually marked birds; (2) comparison between early and late clutches using the regression line of egg size against incubation start days over the two-month breeding season. In the cases where the breeding season was a little bit longer (Sheldon 2002, this study), the effect size was adjusted for a two months period only. Note that in two studies (Sheldon 2002, Sharpe 2006), the date was not standardized according to the yearly median of the first day of incubation, and therefore the seasonal change in egg size could be less apparent in these cases.

When reporting the influence of nesting habitat on egg size, only Galbraith (1988a) had a proportionally balanced distribution of first and replacement clutches between two tested prevalent habitat categories, and Murton & Westwood (1974) had similar sample sizes between habitats for different months during the breeding season. Other studies did not account for the possible different proportions of first and replacement clutches between two tested habitats and one study (Cherkaoui & Hanane 2011) even acknowledges the possible impact of this disbalance on egg size. No study accounted for a possible influence of a change in clutch size over the breeding season (Shrubb 2007). It is therefore necessary to interpret the significance of reported values and the comparison of effect sizes of clutch size and nesting habitat among studies with caution.

We incorporated data in the comparative analyses only if more than ten clutches were available per category, otherwise, we assigned them as NA: no data available. In the case of Klabník (1984), we calculated egg volumes from the mean egg measurements according to the given formula (Galbraith 1988a) and then calculated egg size differences for particular categories from egg volumes. For the estimates of predictor effect sizes, in four studies (Murton & Westwood 1974, Galbraith 1988a, Baines 1990, Blomqvist & Johansson 1995) we calculated mean egg volumes for each category from the given subset values (e.g. per year or habitat) using a weighted mean according to sample size (number of clutches) in each subset. We used these values for the predictor effect size estimates by calculating the percentage difference between the mean values of tested categories and the overall mean egg size in the particular dataset of the given Lapwing population. Overall values of predictor effect sizes were calculated as the mean weighted by sample size (number of clutches) across all studies that reported the relationship and its quantification.

Statistical analyses

All statistical analyses were performed with R v. 3.3.3 (R Core Team 2017). We performed general linear models (GLM) using the 'lm' function or general linear mixed-effects models (GLMM) fitted with the 'lmer' function from the 'lme4' package (Bates & Maechler 2012). Apart from models with one dependent variable only, we performed two models to assess simultaneously the effect of seasonality, habitat and clutch size on egg size. The first model included all three possible two-way interactions between variables but because none of them were significant, the model presented here included only fixed effects of the three dependent variables with year as a random intercept. Models were estimating the effect of particular variables while controlling for all other variables in the model (Table 3). Individual categories of nest habitat and clutch size were compared using post-hoc multiple comparisons of means (Tukey contrasts) in the 'multcomp' package (Hothorn *et al.* 2017). Model assumptions, such as normality and homoscedasticity of residuals, were checked visually from diagnostic plots (Crawley 2013). To visualize uncertainty in our model estimates in plots, we added the 95% credible intervals based on the joint posterior distribution of 5000 simulated values based on model outputs as generated by the 'sim' function in R (Gelman *et al.* 2016). Data and R codes for this study are available at Open Science Framework (https://osf.io/zxbhs/).

RESULTS

Effect of seasonality, clutch size and nesting habitat on egg size in South Bohemia

The mean egg volume in the clutch varied from 19 to 28 cm^3 (mean: 23.40 cm^3 ± 1.38 SD, median: 23.44 cm^3) and declined significantly over the breeding season, using the first day of incubation for individual clutches (Figure 1, Table 2). Also clutch size was significantly related to mean egg size (Table 2). Mean egg volume in 2-eggs clutches was 4.1% smaller than in 4-eggs clutches (Tukey contrasts: $z = 2.77$, $P = 0.021$); other clutch sizes did not differ significantly, although egg size tended to increase with clutch size (Figure 2). There was no effect of nesting habitat after controlling for seasonality and clutch size (Table 2). Nesting habitat was significant only on its own (GLMM: $F_{5,794} = 11.67$, $P < 0.001$), with on average smaller eggs in spring

Table 2. Effect of seasonality, clutch size and nesting habitat on mean egg size in the clutch. Linear mixed effect models with the random intercept effect of year, all variables were controlled for the effect of remaining ones (type III analysis controlling for the effect of all remaining predictors, $n = 1125$ clutches). Two-way interactions and single terms are included in the first model. Seasonality is expressed as standardized first day of incubation, see Methods for more details.

Model	Predictor	*F*	*df*	*P*
First	Seasonality	2.57	1,1101	0.110
	Clutch size	5.27	3,1100	0.001
	Habitat	1.77	5,1076	0.012
	Seasonality×Clutch size	1.85	2,1096	0.160
	Seasonality×Habitat	1.32	5,1073	0.250
	Habitat×Clutch size	1.30	7,1098	0.250
Second	Seasonality	68.79	1,7640	<0.001
	Clutch size	3.25	3,1112	0.020
	Habitat	1.27	5,7990	0.270

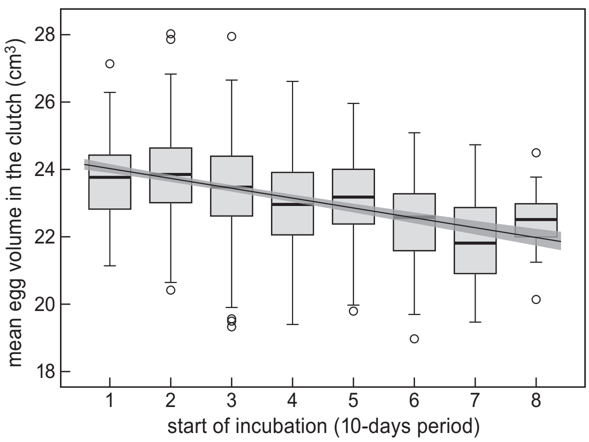

Figure 1. Mean egg volume in clutches in relation to standardized first day of incubation ($n = 1125$ clutches in 17 breeding seasons during 1988–2018 in South Bohemia, Czech Republic). Line with shaded area indicates model prediction with 95% credible intervals based on the joint posterior distribution of 5000 simulated values based on model outputs (Table 2) and generated by the 'sim' function in R (Gelman *et al.* 2016). Boxplots represent two 10-day periods before and six 10-day periods after the median of the first incubation day each year. Medians are denoted by thick lines, 25% and 75% quartiles by boxes, whiskers denote minimum and maximum values (when these do not expand beyond the ± 1.5 times inter-quartile range), or 1.5 inter-quartile range with outliers denoted with open circles.

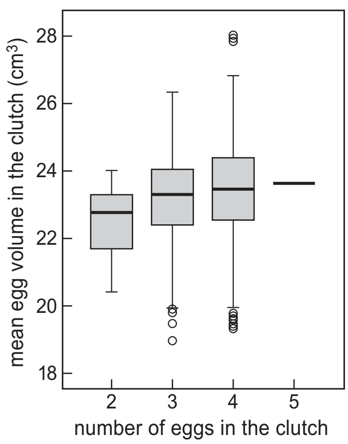

Figure 2. Mean egg volume in the clutch in relation to the clutch size. See Figure 1 for an explanation of the box plots. Overall $n = 1125$ clutches, 4 eggs = 987 clutches, 3 eggs = 121 clutches, 2 eggs = 16 clutches, 5 eggs = 1 clutch) during 1998–2018 in South Bohemia, Czech Republic.

crops later in the season (Table 3), than in ploughed fields, meadows and winter crops (Tukey contrasts: all P-values < 0.001). In the comparison of three main habitats with similar mean first day of incubation, i.e. ploughed field, meadow and winter crop (Table 3), the habitat category did not influence the mean egg volume in the clutch (GLMM: $F_{2,281} = 1.65$, $P = 0.190$, $n = 676$ clutches).

Table 3. Mean egg volumes and mean clutch incubation start date in six nesting habitats ($n = 1125$ clutches) in South Bohemia during 1988–2018. For more detailed habitat descriptions see Table 1.

Habitat	Mean egg volume (cm^3)	SE	Mean incubation start	SE (days)	*n*
Ploughed field	23.71	0.07	6 April	0.59	362
Meadow	23.56	0.11	2 April	0.55	147
Winter crops	23.49	0.10	4 April	0.59	167
Spring crops	22.97	0.07	27 April	0.94	367
Clover	23.85	0.30	8 April	3.75	15
Other	23.43	0.18	11 April	1.88	67

Egg size and chick size in South Bohemia

The mean chick mass in a clutch right after hatching was significantly related to the mean egg volume in the clutch (GLM: slope = 0.701, $F_{1,44} = 99.32$, Adjusted $R^2 = 0.69$, $P < 0.001$) with heavier chicks hatching from bigger eggs (Figure 3).

Comparison among European populations

There was a significant effect of seasonality (first clutches vs. replacements, or regression of egg size over the two-month breeding season) on egg size in 7 out of the 11 reviewed studies (Table 4). All 10 studies that reported relationships were negative: generally, clutches laid later in the season consisted of smaller eggs than clutches from the first part of the breeding season. On average there was a 5.6% decline (range 0.1–11.8%, $n = 10$ studies, 2389 clutches) of egg size in the course of the breeding season. When the two approaches assessing seasonality were treated separately, the average decline for known first and replacement clutches was 2.9% (0.1–11.8%, $n = 5$ studies, 612 clutches), and the regression over the two-month breeding season showed a mean decline of 6.5% (5.9–7.3%, $n = 5$ studies, 1777 clutches).

Table 4. Review of seasonality, nesting habitat and clutch size effect on egg size in different Northern Lapwing populations. NA = no data available, *ns* = no significant relationship. NA/*ns* = reporting non-significant relationship but without exact data for the effect size estimate. Two main habitat categories are compared in each study. Only 3-eggs and 4-eggs clutches are compared. Relationships are expressed in percentage of the difference between mean values of tested categories from the overall mean egg size in the particular dataset (see Methods for details) and are directional for seasonality and clutch size but not for nesting habitat. Significant relationships (given by test presented in each study) are highlighted in **bold**.

Source	Location	Study period	Number of clutches (eggs)	Seasonality[a] (% change)	Habitat	Clutch size 3–4
this study, Šálek 1995	S Bohemia (CZ)	1988–2018	1125 (4384)	**(–6.8%)**	0.4% (*ns*)	+1.1% (*ns*)
our unpubl. data	E Bohemia (CZ)	2013–2018	119 (467)	**(–6.1%)**	1.3% (*ns*)	+0.3% (*ns*)
Baines 1990	N England (GB)	1986–1987	386	NA	0.2% (*ns*)	NA
Bellebaum & Dittberner 2001	NE Germany	2000	69 (252)	(–3.5%)	NA	NA
Blomqvist & Johansson 1995	SW Sweeden	1987–1990	216 (787)	–0.1%	**2.9%**	NA
Cherkaouki & Hanane 2011	N Morocco	2003–2010	69 (255)	NA	**3.1%**	NA
Galbraith 1988a	S Scotland (GB)	1984–1986	220 (790)[b]	**–2.3%**	**2.9%**	+1.0% (*ns*)
Grønstøl 1997	W Norway	1991–1994	72 (288)[b]	**–11.8%**	NA	NA
Hart *et al.* 2002	SE England (GB)	1997	61 (226)	NA/*ns*	NA/*ns*	+0.9% (*ns*)
Hegyi 1996	C Hungary	1988–1995	34[b]	**–3.8%**	NA	NA
Klabník 1984	N Bohemia (CZ)	1975–1981	83 (318)	NA	NA	–0.8% (*ns*)
Murton & Westwood 1974	E England (GB)	1971–1973	55 (205)	NA	**6.0%**	NA
Parish *et al.* 2001	NE England (GB)	1992–1995	702	**–4.0%**	NA	NA
Sharpe 2006	N Wales (GB)	2003–2004	274	**(–7.3%)**	NA/*ns*	NA/*ns*
Sheldon 2002	C England (GB)	1999–2000	190	**(–5.2%)**	NA/*ns*	NA/*ns*

[a]first vs. replacement clutches, or the regression line through the whole season (in parentheses)
[b]marked/individually recognized females – Seasonality means first vs. replacement clutches of the same females

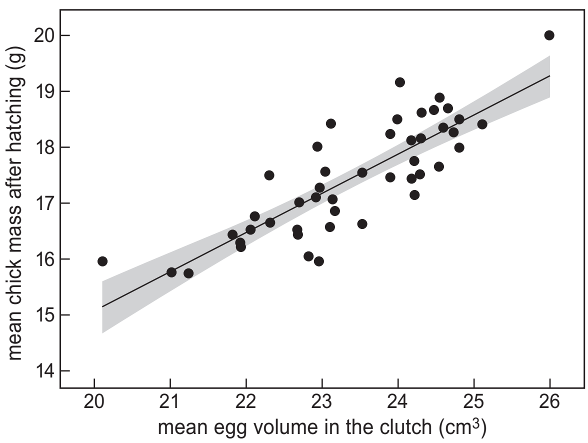

Figure 3. Relationship between mean chick mass at the day of hatching and mean egg volume. Line with shaded area indicates model prediction with 95% credible intervals based on the joint posterior distribution of 5000 simulated values based on model outputs (Table 2; see caption Figure 1). As we were not aware of the hatching order of chicks, the mean chick body mass from all chicks in the clutch and the mean egg volume of all eggs in the clutch were used, each dot in the figure represents one family/clutch (n = 46 clutches comprising 161 chicks during 2013–2014) in South Bohemia, Czech Republic.

The influence of nesting habitat, measured as the difference between the two most prevalent habitat categories, was significant in four out of ten cases. On three occasions, eggs were bigger in arable land than in coastal pastures, rough grazed pastureland or heathland. In one case, eggs were bigger in wet meadows than in saline grasslands. In all four cases, the study sites were dominated by a uniform habitat type. The effect size was between 0.2–6.0% (n = 7 studies, 2190 clutches; Table 4), but note different habitat categories. There were no significant differences in egg size between clutches of three or four eggs in any of the seven studies. The effect size was on average 0.9% (–0.8–1.1%, n = 5 studies, 1608 clutches) of the mean egg size (Table 4).

DISCUSSION

We have investigated the relative importance of three factors – seasonality, nest habitat and clutch size – potentially influencing egg size in Northern Lapwings in Europe. By using a long-term dataset from South Bohemia and reviewing literature we estimated, for the first time, effect sizes across multiple populations. We targeted our research on egg size with several possible response variables (seasonality given by egg-laying date, nesting habitat, clutch size or habitat), but directly studied other parameters of reproductive investment, such as clutch size (Shrubb 2007) and egg-laying date (e.g. Both *et al.* 2005, Brandsma *et al.* 2017).

Seasonality

Seasonal timing has the biggest effect on egg size in Lapwings, with first clutches at the beginning of the breeding season containing on average 5.6% larger eggs in comparison with late and probable replacement clutches. This finding is in line with studies of other shorebirds (Byrkjedal & Kålås 1985, Redmond 1986, Hegyi 1996, Hegyi & Sasvari 1998, Sandercock *et al.* 1999).

We identify three main, but not mutually exclusive, factors that can be responsible for this phenomenon: (1) depleted energy reserves during laying of a replacement clutch (Hegyi & Sasvari 1998), (2) younger females producing smaller eggs and laying generally later in the season (Christians 2002), and (3) lower food availability for females laying later in the breeding season. There are several indications that the females' food supply influences egg size and that energetically rich earthworms play an important role (Baines 1990, Grønstøl 1997). For example, in South Sweden, Lapwings arrived at their breeding grounds at the same time, but females at the sites with more earthworms started laying earlier (Högstedt 1974). The more time spent before egg-laying on arable land with better availability of earthworms, the bigger eggs produced (Blomqvist & Johansson 1995). Earthworms become less available later in the season as they retreat deeper into the soil, particularly during dry weather conditions (Baines 1990, Beintema *et al.* 1991), or, they may be less easily found in compacted soil under growing crops. Warmer winters and wetter springs can accelerate the start of the Lapwing breeding season (Both *et al.* 2005, Musters *et al.* 2010), however, more rain early in the spring could also mean more easily available prey for females (Ausden *et al.* 2001), which could be used to gather more energy and produce larger eggs than during dry conditions.

Habitat

The effect of habitat on egg size was only significant in four out of ten studies. All these four studies share a feature of landscape uniformity and polarization. This 'landscape polarization' (Wilson *et al.* 2001, Siriwardena *et al.* 2012), defined as the presence of different but uniform habitats at various parts of the study area, probably limits feeding possibilities of an individual

Lapwing, because there are less or no other different habitats around the nest site. In three studies, eggs were found to be always bigger in arable land than in coastal pastures (Blomqvist & Johansson 1995), rough grazed pastureland (Galbraith 1988a) or heathland (Murton & Westwood 1974), which is in accordance with better earthworm availability in arable land (Blomqvist & Johansson 1995). Two studies (Blomqvist & Johansson 1995, Cherkaoui & Hanane 2011) reported smaller eggs in the habitat with higher proportions of replacement clutches, and only two studies (Murton & Westwood 1974, Galbraith 1988a) could be partially controlled for seasonality (see Methods). Therefore, the overall effect of habitat on egg size must be interpreted with caution; it can be over-estimated and be more driven by seasonality, similarly to the findings in South Bohemia.

On the other hand, no egg size differences among habitats were found in studies without 'landscape polarization' within the study area, i.e. consisting of grassland only (Baines 1990, Hart *et al.* 2002) or arable land only (Sharpe 2006, East Bohemia in this study), probably only with subtle qualitative differences between prevailing nesting habitat categories. Furthermore, the effect of habitat on egg size in Lapwing was also not visible in a mosaic agriculture landscape consisting of a heterogeneous mixture of arable fields with different crop types, meadows, pastures and fish ponds (South Bohemia, this study, Sheldon 2002), where females can easily feed nearby in different habitats, which is a common behaviour in Lapwings (Baines 1990, Berg 1993, Blomqvist & Johansson 1995), thereby removing any effect of nesting habitat on egg size. Although egg sizes differed among some habitats within arable land in South Bohemia (this study), this was in fact caused by seasonality (here the incubation start date), and not by habitat. The smaller eggs in replacement clutches later in the season in spring cereals, after mechanical damage of first clutches during agricultural activities such as harrowing of ploughed fields, is the most probable explanation of this pattern. This finding implies that future studies should address all possible relevant predictors simultaneously in one model to be able to distinguish their relative importance.

Clutch size

There were no significant differences in egg size between the 3- and 4-egg clutches based on the literature review. However, there was a slight tendency to bigger eggs in larger clutches, with eggs of 4-egg clutches being on average 0.9% larger than 3-egg clutches. The significantly smaller eggs in 2-egg clutches in South Bohemia fits this pattern. Similarly, also Galbraith (1988a) found smaller egg volumes in 2-egg clutches in comparison with larger clutches. However, apart from the South Bohemian study locations, none of the other studies accounted for the possible change in clutch size over the season (Shrubb 2007), therefore it is important to treat the comparison among studies with caution. Nevertheless, any difference in egg size between 3-egg and 4-egg clutches is small, probably with only minor biological relevance.

The data gathered here suggest that Lapwings that produce smaller clutches do not have more energy to increase egg size, following the trade-off principle. On the contrary, the egg size is generally smaller in these smaller clutches, especially in South Bohemia (Šálek 1995, this study), demonstrating that Northern Lapwings do not trade-off clutch size against egg size among individuals. But this may of course be different within individuals. This finding corresponds to interspecific comparisons among shorebirds (Olsen *et al.* 1994) and intraspecific studies in some waterfowl species (Rohwer 1988, Hořák *et al.* 2008).

Chick survival and conservation implications

The well-studied advantage of heavier shorebird chicks hatched from bigger eggs (Byrkjedal & Kålås 1985, Galbraith 1988a, Grant 1991, Thompson & Hale 1991, Hegyi 1996, Blomqvist *et al.* 1997, Hegyi & Sasvari 1998, Dittmann & Hötker 2001, Sheldon 2002, Larsen *et al.* 2003) was confirmed also for Northern Lapwings breeding in South Bohemia. Besides the quality of parents (Blomqvist *et al.* 1997), any initial advantage of a larger size can have significant effects on body condition, growth and survival (Galbraith 1988a, Sheldon 2002). In Scotland, chicks hatched from eggs bigger than 23 cm^3 were twice as likely to survive until fledging as chicks from smaller eggs (Galbraith 1988a). A similar advantage for higher chick survival was apparent also in Sweden (Blomqvist *et al.* 1997). Our finding of on average 5.6% larger eggs and subsequently bigger chicks at the beginning of the breeding season compared to the end of the season, will probably provide an important advantage to early hatching Lapwing chicks. In addition, availability of food and water for chicks is also known to often deteriorate at the end of the breeding season (Matter 1982, Galbraith 1988c, Beintema *et al.* 1991). Chicks can try to compensate for decreased food availability by increasing foraging activity; however, this means a higher exposure to potential predators (Evans 2004) and likely an increase in the chick predation rate (Mason *et al.*

2018). Maintaining high food availability for adults and chicks could be stimulated by a high-water table during the breeding season (e.g. Eglington *et al.* 2010), and could be an important conservation measure for shorebirds breeding in agricultural grasslands.

The Northern Lapwing has undergone a significant decline throughout Europe (BirdLife International 2004, Delany *et al.* 2009) and despite extensive efforts to change this trend (e.g. Tucker *et al.* 1994, Wilson *et al.* 2009), the species is still declining (BirdLife International 2015). The majority of Lapwing populations, either on grassland or in regions with predominantly arable fields, are not able to produce a sufficient number of fledglings to compensate for year-round adult mortality (Peach *et al.* 1994, French *et al.* 2000, Sheldon 2002, Sharpe 2006, Roodbergen *et al.* 2012) and chick survival may play a pivotal role (Roodbergen *et al.* 2012).

In light of the current results it is obvious that conservation measures for Lapwings should involve support for the first breeding attempts by preventing clutch losses due to destruction by agricultural activities, in particular during the early breeding season. This can be achieved via nest protection (Kragten *et al.* 2008, Zámečník *et al.* 2018), or on a larger scale, with the use of effective agri-environmental schemes (Eglington *et al.* 2010, Smart *et al.* 2014, Schmidt *et al.* 2017). However, nest predation seems to be in general the most common case of shorebird nest failure (MacDonald & Bolton 2008) and an increase in nest predation rates has been recorded throughout Europe (Roodbergen *et al.* 2012, Kubelka *et al.* 2018). Therefore, the use of predator exclusion by nest exclosures (Isaksson *et al.* 2007), habitat management (Laidlaw *et al.* 2017) or predator control (Bolton *et al.* 2007) might be also essential for the multifaceted support of Lapwing breeding success at sites with high predation pressure.

Taken together, the literature review and our own field data show that in Lapwings bigger eggs, together with food being more readily available for chicks at the beginning of the breeding season, is a double advantage for chicks hatching from the first breeding attempt. Protection of first clutches together with safeguarding or restoring food availability via a higher water table should be an important target in conservation measures for shorebirds breeding in the agricultural landscape.

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SAMENVATTING

De grootte van een ei voorspelt in hoge mate het gewicht en de lichaamsconditie van het kuiken dat uiteindelijk uit het ei kruipt. Grote eieren bieden een aanzienlijk betere overlevingskans voor de nakomelingen dan kleine, vooral bij nestvlieders (waarvan de kuikens na het uitkomen zelf moeten foerageren, bestand moeten zijn tegen soms barre weersomstandigheden en op hen loerende roofdieren). Daarom is het belangrijk om te begrijpen welke factoren de grootte van eieren beïnvloeden, zowel vanuit een broedecologisch perspectief alsook vanuit vogelbeschermingsoogpunt. Het komt echter niet veel voor dat in een studie meerdere factoren tegelijkertijd worden gemeten om zo hun invloed op de grootte van eieren te kwantificeren. In dit onderzoek testten we het effect van de tijd in het seizoen, de legselgrootte en de nesthabitat op het volume van eieren bij de Kievit *Vanellus vanellus* in Zuid-Bohemen (Tsjechië). Tussen 1988 en 2018 werden in totaal 4384 eieren (1125 legsels) gemeten. Het volume van de eieren nam gedurende het broedseizoen significant af. Gemiddeld waren de eieren in grote legsels groter dan in kleine legsels (verschil tussen tweelegsels en vierlegsels significant). We vonden geen direct effect van de nesthabitat op het volume van de eieren. Uit ons overzicht van dezelfde variabelen in 15 kievitenpopulaties in Europa die eerder waren onderzocht, blijkt dat vervangende of late legsels gemiddeld 3–7% kleinere eieren hebben dan eerste of vroege legsels. De nesthabitat beïnvloedde in deze studies de grootte van de eieren niet of nauwelijks. En er waren geen significante verschillen in de grootte van de eieren tussen legsels met drie en vier eieren. Vroegere studies hebben laten zien dat kuikens uit grote eieren vroeg in het broedseizoen het beter doen dan kleine eieren later in het seizoen en dat de voedselbeschikbaarheid vroeg in het seizoen beter is. Dit gegeven, samen met de gedocumenteerde seizoenafname van de grootte van de eieren, is ook belangrijk voor natuurbeschermers en beleidsmakers. Vroege broedpogingen kunnen een cruciale rol spelen bij het verbeteren van het broedsucces van steltlopers.

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Chapter 3

Visible marking of wader nests to avoid damage by farmers does not increase nest predation

Václav Zámečník, Vojtěch Kubelka & Miroslav Šálek

Only a few studies have assessed the predation risk on artificially marked nests, or have examined ways of marking nests to avoid destruction by machinery. Until now, however, neither type of study has directly addressed this apparent trade-off experimentally. The impact of marking the nests of Northern Lapwing *Vanellus vanellus* with thin 2 m-long conspicuous bamboo poles with the top end highlighted with reflective red or orange spray has been tested for three years in two breeding areas of waders in the Czech Republic. A total of 52 pairs of nests on agricultural land, with each pair consisting of one marked nest and one unmarked reference counterpart nest, were monitored for 2004 nest-days until hatching, agricultural operations or failure. The results proved that marking itself does not result in increased nest predation. The nests found in the early incubation stage were under higher threat of depredation, irrespective of the presence of marking. Our results show that it is possible to find a finely-tuned trade-off in nest marking of ground-nesting birds between risk of damage by agricultural machinery and risk of increased nest predation. Our positive experience with Northern Lapwing, and episodically with three other wader species in the Czech Republic, suggests that this direct nest protection could be used effectively for a wider variety of ground-nesting birds.

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Visible marking of wader nests to avoid damage by farmers does not increase nest predation

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Summary

Only a few studies have assessed the predation risk on artificially marked nests, or have examined ways of marking nests to avoid destruction by machinery. Until now, however, neither type of study has directly addressed this apparent trade-off experimentally. The impact of marking the nests of Northern Lapwing *Vanellus vanellus* with thin 2 m-long conspicuous bamboo poles with the top end highlighted with reflective red or orange spray has been tested for three years in two breeding areas of waders in the Czech Republic. A total of 52 pairs of nests on agricultural land, with each pair consisting of one marked nest and one unmarked reference counterpart nest, were monitored for 2004 nest-days until hatching, agricultural operations or failure. The results proved that marking itself does not result in increased nest predation. The nests found in the early incubation stage were under higher threat of depredation, irrespective of the presence of marking. Our results show that it is possible to find a finely-tuned trade-off in nest marking of ground-nesting birds between risk of damage by agricultural machinery and risk of increased nest predation. Our positive experience with Northern Lapwing, and episodically with three other wader species in the Czech Republic, suggests that this direct nest protection could be used effectively for a wider variety of ground-nesting birds.

Introduction

In most European countries the numbers of farmland birds have declined over recent decades (Chamberlain *et al.* 2000, Donald *et al.* 2001, 2006, Chamberlain and Vickery 2002, Butler *et al.* 2010, PECBMS 2013). There is an increasing evidence that one of the main problems for ground-nesting birds is low breeding success due to intensive agriculture and predation (e.g. MacDonald and Bolton 2008, Roodbergen *et al.* 2012). Several approaches to the elimination of nest destruction and depredation have been developed in many European countries, including various forms of direct nest protection (Guldemond *et al.* 1993, Isaksson *et al.* 2007, Kragten *et al.* 2008, Grüebler *et al.* 2012, Kentie *et al.* 2015, Santangeli *et al.* 2015, Sutherland *et al.* 2015). On meadows and arable land, the most widely-used technique is conspicuous marking to make the nest site visible to farmers operating machinery, e.g. with bamboo poles (Kragten *et al.* 2008, Schifferli *et al.* 2006, 2009). Farmers usually drive round the nest and leave a small part of the land undisturbed. The area of undisturbed land varies from several square metres in the case of waders and songbirds (Kentie *et al.* 2015, Schifferli *et al.* 2006; Grüebler *et al.* 2012) up to dozens of square metres in the case of Montagu's Harrier *Circus pygargus* (Kunstmüller and Kodet 2008). Direct protection is primarily applied to avoid nest destruction by farm machinery, but the use of relatively short poles just 1 m in height and inconspicuously coloured may not be sufficiently visible to farmers, and may therefore not be very effective in nest protection (Kragten *et al.* 2008). At the same time, marking itself has been considered to increase the risk of nest depredation (Kragten *et al.* 2008). However, the assumption about the risk of depredation of directly protected wader nests has never been properly verified experimentally.

The objective of our study was to investigate the use of long poles that are more visible to farmers and therefore more effective for direct protection of nests. It provides new findings from the Czech Republic, where the local population of Northern Lapwing *Vanellus vanellus* dropped by around 90% between 1982 and 2015 (Czech Society for Ornithology 2015). Most of this population breeds on arable land, where it is strongly dependent on farmland practices. As in other European countries, the main factors responsible for this decline are intensification of farming which includes irrigation, conversion of grasslands to arable, the development of agricultural machinery, increased use of pesticides and fertilisers (Fiala 2002, Šťastný *et al.* 2006, Kubelka *et al.* 2012a, Zámečník 2013), and predation of nests and chicks (Šálek 2000). On grasslands, the most high-risk operations are spring rolling and harrowing (Šálek 2000, Kubelka *et al.* 2012b); on arable land, the nests are often destroyed during cultivation of ploughed and fallow fields and when spring crops are sown (Kubelka *et al.* 2012a). Since 2009, direct protection of Lapwing nests has been one of the cross-compliance requirements. All farmers in the Czech Republic receiving direct payments are obliged to avoid destruction of nests when they have been officially informed about their position (Ministry of Agriculture of the Czech Republic 2015). This tool is still implemented only occasionally, but on traditional breeding sites it can be a crucial way of eliminating the destruction of clutches by farming activities. However, before this option can be promoted more widely among volunteers it is necessary to gather enough evidence that it is an effective measure and constitutes best practice. For this reason, the main objective of our study was to test experimentally whether marking the nests with two thin bamboo poles which would be visible enough to operating farmers affects the risk of predation on active Northern Lapwing nests. Our study aimed to provide evidence on whether nest marking of this type can be considered a safe conservation tool as regards the nest predation risk to ground-nesting birds in an agricultural landscape.

Methods

Data collection

Field work was carried out between 2010 and 2013 in two regions of the Czech Republic, one in South Bohemia (49.12N, 14.31E) and one in East Bohemia (50.18N, 15.61E), with a total area of about 500 km^2. In both regions, the dominant habitat is agricultural land, mainly a mosaic of arable (winter wheat, ploughed fields, spring cereal, oilseed rape, maize) interspersed with meadows, pastures (only in south Bohemia), linear non-cropped habitats along ditches and roads and, especially in south Bohemia, fishponds. The main potential nest predator species (red fox *Vulpes vulpes*, beech marten *Martes foina*, pine marten *M. martes*, stoat *Mustela erminea*, weasel *M. nivalis*, European hedgehog *Erinaceus europaeus*, Marsh Harrier *Circus aeruginosus* and Carrion Crow *Corvus corone*) are identical for these two areas (own observations and data from cameras placed at the nests).

Northern Lapwing breeding sites were determined on the basis of the conspicuous display and courtship behaviour of birds (e.g. Cramp and Simmons 1983) from the second half of March until the end of May. Nests were located either visually with the use of binoculars and spotting scopes, or by direct inspection of densely populated fields by a skirmish line with 5–8 (max. 12) observers (Kubelka *et al.* 2012b). The positions of the nests that were found were stored in a GPS tracker. All nests were marked with a thin willow twig 50 cm long fixed 15 m from the nest, exactly as in Šálek and Šmilauer (2002). This inconspicuous marking was found not to affect nest survival (Galbraith 1988). The incubation stage was assessed using a flotation test (van Paassen *et al.* 1984). When more than one nest was found in the same type of habitat and with a similar incubation stage and position within the field, pairs of nests were established and one (randomly selected) of the nests was provided with bamboo poles. Paired nests were chosen to be approximately 50–200 m away from each other. The bamboo poles were 2 m in length, 2–3.5 cm thick at the base, and 1 cm thick at the top. The top end was highlighted with a reflective red or orange spray.

Marking wader nests and predation

The sprayed part of the bamboo was 15–20 cm in length. The bamboo poles were fixed along the line of cultivation 10–12 m apart, with a nest in the middle.

Our experiment was designed exclusively to test nest predation risk, i.e. nest pairs were situated in fields where no immediate farming activity was expected. Nevertheless, farmers were informed about the position of poles and if we were informed about an unexpected farming operation that could cause nest destruction, the experiment ended just before this operation (as control nests were also protected by bamboo poles). Both paired nests were repeatedly visited on the same day at irregular intervals, with a median of seven days (minimum two days and maximum 18 days), until the final fate of any of them was determined. Nests were recorded as successful when at least one egg hatched. Eggs were assumed to have hatched successfully when chicks or small remnants of eggshell were present in the nest (Green *et al.* 1987). Nests were assumed to have failed when no eggs hatched. If a nest was found empty, without eggshell remnants, or with large pieces of eggshell nearby, the nest was recorded as depredated. If there were signs of recent farming operations, and remnants of the nest were found, the nest was recorded as failed due to farming activities (three nests in two pairs, one nest even with bamboo poles). In our dataset, the losses were due only to predation and agricultural machinery; there was no desertion or other reason for failure. Once one of the nests was depredated or destroyed, the experiment on that pair was terminated. The date of predation was then calculated as the midpoint of the period between the last visit when eggs were present and the final visit. For the three nests (two pairs) destroyed by farm machinery, the experiment was terminated by the date of the last positive visit.

Data analysis

We used a paired t-test to test whether both marked and unmarked nests were equally distributed in respect to distance from the habitat edge. In order to assess whether the nests provided with poles also attracted predators toward the nest counterparts without poles, we compared the proportion of simultaneous predation events on both nests within nest pairs and proportion of predation events on just any one of the two nests within a pair. If the former prevails, we can assume significant attraction of poles for predators to both nests in a pair. The nest predation rate was calculated according to Mayfield (1975) as the proportion of the number of depredated nests and the sum of nest-day exposures. Hatching success reflected the daily survival rate powered by the mean incubation period of Northern Lapwing (27 days; Cramp and Simmons 1983).

A mixed-effect model (GLMM) with the chi-square testing procedure (likelihood ratio test, LRT) was applied to assess the fixed effects of poles, incubation stage, habitat, distances from the habitat edge and the interactions of the poles with all remaining predictors on the nest predation risk (response variable) expressed binomially (surviving = 1, predation = 0). Non-predation means a still active nest with eggs, or a hatched nest. The nest-specific incubation stage on the day when the experiment began might add to the explanation of nest depredation, so we included it in the model. As the locality might pseudo-replicate the predation risk of the same predators, we assigned nest pairs and breeding grounds as random effects. First we tested the effects of interactions, and after they had been removed we checked the contributions of the fixed effects (Crawley 2007). We adopted $\alpha = 0.05$ for the rejection of a hypothesis. We also checked the relationship between incubation stage on the day when the poles were installed and the day in the season (corrected by median date of incubation start in analysed nests within particular years). All statistical procedures were performed by 'lme4' package in R, version 3.1.2 (R Core Development Team 2014).

Results

A total of 104 nests in 52 pairs of nests in 15 localities, accounting for 2004 nest-days of exposure and 57 depredated nests were included in the analysis (Table 1). The distance from the nearest habitat edge of nests provided with poles [140 m ± (SE) 12.3 m] did not differ significantly from

Table 1. Dataset of nest pairs collected for various habitats in two areas in Bohemia.

Bohemia	ploughed field	maize	spring cereal	other
South	26	11	6	3
East	6	0	0	0

the control nests without poles [131 m ± (SE) 13.7 m] (paired t-test, t_{51} = 1.4, P = 0.18). The incubation stage on the day of the beginning of the experiment was identical for the nests provided with poles [nine days ± (SE) 0.8 days] and for the nests without poles [nine days ± (SE) 0.8 days] (paired t-test, t_{51} = 0.2, P = 0.82). Incubation stage was not correlated with day in the season (Spearman's rank correlation coefficient r_s = -0.16, P = 0.10).

The total daily nest predation rate was 2.8% ± (SE) 0.37%. The daily predation rate was 2.8% ± (SE) 0.54% in the marked nests (n = 52) and 2.8% ± (SE) 0.51% in the unmarked nests (n = 52), i.e. the hatching success was 47.0% for the marked nests and 44.8% for the unmarked nests. The mixed-effect model did not detect an effect of poles on the predation risk of the experimental nests (Table 2). The incubation stage was the only significant fixed effect; it showed that fresh nests were more prone to predation risk than nests closer to hatching date. As shown in Figure 1, nests found in the halfway incubation stage (14 days) still had about a 60% chance of survival while the nests found earlier had markedly reduced survival. We did not detect significant effects of habitat, distance from field edge or any interaction on nest survival, with the exception of the interaction poles × stage. This suggested that there were different effects of incubation stage in nests provided with poles and in nests without poles. A *post-hoc* analysis indicates that the nests without poles were more prone to depredation in the early stages of incubation (GLMM; estimate = 0.04 ± (SE) 0.011, χ^2 = 12.2, P < 0.001) than the nests provided with poles (GLMM; χ^2 = 1.9, P = 0.17). The proportion of simultaneously depredated nest pairs (40.4%) was not significantly higher than the number of predation events on one (28.8%) of the two paired nests (test of proportions, χ^2_1 = 1.1, P = 0.30). We suggest that the poles did not affect simultaneous attraction to both nests within experimental pairs.

Discussion

Although marking of ground-nesting birds' nests for nest protection is generally used in many European countries, only a few studies have evaluated the effectiveness of this marking (Sutherland *et al.* 2015). Our experience indicates that, when applied in an optimal way, direct nest protection could be a suitable method for avoiding nest destruction during farming operations without raising the risk of nest depredation or desertion.

Probably the largest investigation was carried out in 2005 and 2006 in the Netherlands; this analysis included 1,644 protected nests against 229 nests without any protection (Kragten *et al.* 2008). The authors recorded a higher rate of predation of the marked nests in one study area

Table 2. Results of a mixed-effect model explaining the effects of the factors on the predation risk for the experimental Northern Lapwing nests. Ordered according to decreasing χ^2 values. A positive estimate means increasing survival.

Predictor	estimate	SE	χ^2	df	P
stage	0.04	0.007	20.867	1, 8	< 0.001
poles:stage	−0.02	0.012	3.841	1, 10	0.050
habitat	0.19	0.132	2.045	1, 8	0.153
poles	0.01	0.062	0.022	1, 8	0.882
poles:edge	−0.09	0.200	0.234	1, 10	0.628
edge	0.01	0.156	0.009	1, 8	0.925
poles:habitat	0.06	0.128	0.265	1, 10	0.607

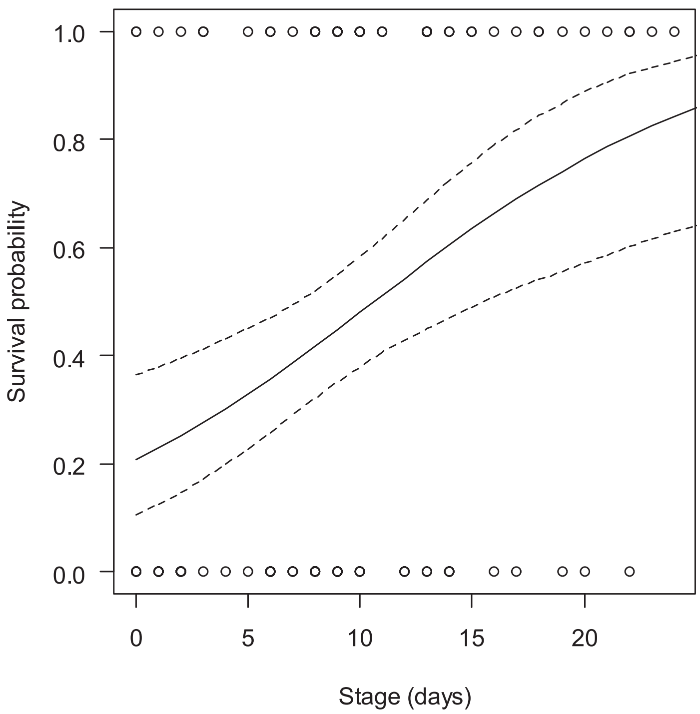

Figure 1. Probability (+95% CI) of nest survival (n = 104 nests) according to nest stage at the date of pole installation. All nests (provided with poles and without poles) are included.

during one season. They admit that the conspicuous markings may enhance nest predation in some circumstances. In addition, 6% of protected nests were destroyed due to farming operations. According to Götmark (1992), marking itself reduces nest destruction due to farming operations, but might attract predators through investigator disturbance. To avoid this potential bias, an experimental design based on pairing of nests, with only one of them marked and the other as a reference nest, was applied in our study. This design helped us to eliminate the effects of habitat, locality and to control the incubation stage at the date when the experiment started. However, our study has not revealed any impact of marking of nests on nest predation.

Timing of conservation action

Nests at earlier stages of incubation are under higher risk of predation as these include a group of poorly placed nests prone to be easily discovered by predators (Ricklefs 1969, Martin and Roper 1988, Eggers *et al.* 2005). An explanation that fresh Lapwing clutches were defended less intensively and thus were more exposed to predation risk is not supported by previous investigation (Kis *et al.* 2000). If these early clutches are marked for a longer time before field cultivation, subsequent losses due to predation will make this measure inefficient due to the unreasonable demands that it makes on farmers as these either unnecessarily drive around depredated nest or have to stop the tractor to check the nest. If it is depredated, drivers have to take away the bamboo poles before continuing their work.

A further risk connected with marking of early clutches is nest desertion. In Switzerland, half of the Lapwing nests marked with bamboo poles while eggs were being laid were deserted, probably due to sensitivity of females to disturbance of this kind in the early stages of nesting (Schifferli *et al.* 2009). This was probably aggravated by the relatively close placement of the poles, only 2–3 m from the nest. Also Kragten *et al.* (2008) recorded greater desertion of marked nests than of unmarked nests. As the nests in their study were marked immediately after they were found, clutches in the early stages of incubation were very likely also included. In our study, nest marking did not result in any nest desertion, as bamboo poles were placed only when the clutches were complete. This indicates that clutches that are just being laid should be marked with poles only if field operations are imminent. If this is not possible, it is questionable whether the nests should be protected at all, having in mind the uncertain benefits of this measure in this particular case. Our finding that nests without poles were more prone to depredation in the early incubation stages than nests provided with poles we interpret as a type I error.

Optimal use of bamboo poles

In our experiment, poles were placed at least 5 m from the nest and there was no evidence of nest desertion. In previous studies, the poles were significantly closer (2–3 m in Switzerland, and 3–5 m in the Netherlands) and, as mentioned above, cases of nest desertion were relatively numerous. From the farmer's point of view, it makes practically no economic or technical difference whether the poles are placed 3 m or 5 m from the nest. Therefore to eliminate possible disturbance to the birds, poles should be placed at least 5 m from the nest.

In addition, it seems that taller poles that are sprayed with a bright colour at the top end are more effective than shorter poles with a natural colour. Altogether with this project, from 2010 until 2016 we used direct protection for more than 400 nests and all cases of nest destruction (up to 4% of protected nests) were due to a communication failure (own unpubl. data). It is therefore crucial to stay in close contact with farmers. They need to be informed without delay, and must be given precise information about the number of nests, the way in which they are marked and the dates of hatching. It is also useful to provide a map with the positions of the nests. It seems that the use of a bright reflective colour at the top of poles acts optimally for informed farmers, even if they are working at night (own unpubl. data), and that the bright reflective colour does not attract potential nest predators.

Direct protection has also been used with success for protecting a small number of nests of rarer waders breeding in the Czech agricultural landscape in the South Bohemian region (own unpubl. data) – several tens of nests of Little Ringed Plover *Charadrius dubius*, three nests of Black-tailed Godwit *Limosa limosa*, and one nest of Redshank *Tringa totanus*. These species easily accept marking of their nests with bamboo poles, and direct nest protection was highly successful.

Disadvantages of direct protection

Although our results did not show an increased rate of predation due to conspicuous nest marking to inform farmers, there is still a question of the learning abilities of some predators. It has already been confirmed that some predators are able to remember the position of an incubating individual, and they visit the breeding site when the parents are away (Šálek and Zámečník 2014). Corvids, in particular, are known to develop their predation tactics and to learn. Once these birds connect poles with possible prey, marking could lead to increased predation. Another risk arises with the possible attractiveness of the small plots around the nest that are created as a result of the tractor driver's efforts to avoid destroying a nest. This effect has already been proved for Montagu's Harrier (Koks and Visser 2000, Santangeli *et al.* 2015). To provide evidence of this, however, further specifically designed experiment is required.

In addition, it is not known how predators would respond to a high concentration of poles installed near to the nests in large breeding colonies concentrated around one hotspot (e.g. a piece of waterlogged land inside an arable field). We suggest that it would be more effective and technically more feasible in this case to protect the whole nesting colony from the risk of damage by farmers, rather than marking and avoiding each nest individually. In the long term, the best option is to adopt targeted agri-environment measures that would create an optimal breeding habitat and would prohibit any agricultural activity during the breeding season. However, a measure of this type should preferably be applied at regular breeding sites of local importance, and only if allowed by legislation and accepted by farmers.

Conclusion

Our results show that it is possible to find a finely tuned trade-off in marking the nests of ground-nesting birds between the risk of damage by agriculture machinery and the risk of increased nest predation. Two thin bamboo poles with the nest located between them are sufficiently visible for the farmer but, at the same time, they do not attract potential predators. Our positive experience with Northern Lapwing and episodically with three other wader species in a mosaic of arable plots and meadows in the Czech Republic suggests that this type of direct nest protection could be used effectively for a wider variety of ground-nesting birds. However, it is necessary to carry out further research on the responses of individual species to this kind of disturbance in association with depredation risk in larger colonies. Although direct nest protection can be used as a suitable protection tool, it is time-demanding and should be applied only when other conservation measures fail. Especially for regular breeding sites, it cannot effectively substitute a targeted large-scale conservation measure, e.g. an agri-environmental scheme.

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Chapter 4

Delayed nest predation: a possible tactic toward nests of open-nesting birds

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Predators use various tactics to find and depredate bird nests. This study examines a possible tactic of visually orientated predators termed "delayed nest-visit". This consists in remembering the positions of incubating parents and subsequent easy depredation of eggs when the parents are away from their nests. Conditions for use of this tactic were experimentally simulated by installing artificial nests with quail eggs and plastic dummies of northern lapwings (*Vanellus vanellus*) at 11 actual breeding grounds with various habitat conditions in southern and eastern Bohemia, Czech Republic. Habitat, presence of the dummy, and their interaction significantly affected nest survival. While 17.2 % of the nests baited with the dummy were depredated, this occurred in only 6.9 % of the nests without the dummy. This depredation rate was affected by the visibility of the dummies in particular habitats. The results suggest that predators may remember the nest position to delay their first visit to a previously located bird nest from a remote place and may use this tactic to easily capture the clutches. The use of this tactic showed that at least some predator species are able to apply much more sophisticated approaches in search of birds' nests than previously assumed.

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Delayed nest predation: a possible tactic toward nests of open-nesting birds

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Abstract. Predators use various tactics to find and depredate bird nests. This study examines a possible tactic of visually orientated predators termed "delayed nest-visit". This consists in remembering the positions of incubating parents and subsequent easy depredation of eggs when the parents are away from their nests. Conditions for use of this tactic were experimentally simulated by installing artificial nests with quail eggs and plastic dummies of northern lapwings (*Vanellus vanellus*) at 11 actual breeding grounds with various habitat conditions in southern and eastern Bohemia, Czech Republic. Habitat, presence of the dummy, and their interaction significantly affected nest survival. While 17.2 % of the nests baited with the dummy were depredated, this occurred in only 6.9 % of the nests without the dummy. This depredation rate was affected by the visibility of the dummies in particular habitats. The results suggest that predators may remember the nest position to delay their first visit to a previously located bird nest from a remote place and may use this tactic to easily capture the clutches. The use of this tactic showed that at least some predator species are able to apply much more sophisticated approaches in search of birds' nests than previously assumed.

Key words: artificial nests, ground-nesting birds, egg predation, nest crypsis, search image tactic, *Vanellus vanellus*

Introduction

Predation of bird nests specifically contributes to avian mortality (Ricklefs 1969, Nilsson 1984), and therefore, an understanding of mechanisms responsible for nest predation, including search image tactics, is a key topic of behavioural ecology and evolutionary biology in birds (Martin 1995, Lima 2009). Bird eggs may be a valuable food item the acquisition of which motivates predators to locate nests and deplete entire clutches (Salathé 1987, Careau et al. 2008). Predators' finding of bird nests has often been considered incidental, such that when predators are searching for food across suitable habitats they occasionally come upon nests (Vickery et al. 1992, Vigallon & Marzluff 2005). Sometimes, however, nests can be depredated after they have been purposely detected and visited. This is especially the case of nests concentrated in large colonies where the predators deliberately return based on their previous experience (Andersson & Waldeck 2006, Varela et al. 2007) and/or return to the nests if all eggs cannot be carried off at once (Salathé 1987, Olsen & Schmidt 2004).

For their part, breeding birds apply various defence tactics against nest predators (Montgomerie & Weatherhead 1988). If parents actively defend the nests, if they fastidiously incubate the clutches (Montgomerie & Weatherhead 1988, Opermanis 2004), or if finding the nest is difficult or time consuming (e.g. because of vegetation cover or low nest density), predators can address the trade-offs between costs (risk of injury or time expenditure) and benefits (obtaining food) arising from the active search of a nest (Wiklund & Andersson 1994, Thyen & Exo 2005, Cresswell 2011). In such cases, predators may develop more effective nest search tactics to increase their gains relative to costs. One such tactic used by visually orientated bird predators in open habitats may include to overview fields from elevated vantage points such as trees or pylons (Olsen & Schmidt 2004, MacDonald & Bolton 2008, pers. obs.). This tactic could be particularly efficient if the predator is able to find and remember locations of incubating parents and consciously postpone the egg depredation until such time as the parents are away from the nest. To the best of the authors' knowledge, however, this potential "delayed nest-visit" tactic has never been observed directly or experimentally tested in the field. It has been established that at least corvids (Corvidae) have rapid learning and cognitive abilities (Emery 2006). They are able to develop various foraging tactics (Eggers et al. 2005), including to form visually based search images from elevated points (Olsen & Schmidt 2004, Fernández-Juricic et al. 2010). In addition, corvids are known to possess a memory for caching locations of long duration (Brodin 2005). It was therefore presumed that remembering nest positions from remote perches followed by a delayed intervention whenever the parents were away from the nest might be one of their regular search image tactics.

The northern lapwing (*Vanellus vanellus*) is a useful prey model for testing whether at least some predators use the delayed nest-visit tactic. This ground-nesting shorebird breeds in open landscapes across the Palearctic (Cramp & Simmons 1990). Non-hidden parents incubate their clutches in sparse vegetation (Cramp & Simmons 1990), which enables early detection of approaching predators (Götmark et al. 1995). Moreover, the cryptic colouration of their eggs might play a role in camouflaging the nests (Lloyd et al. 2000). Consistent with an assertion that motion at the nest may serve as an impulse for nest detection by a predator (Skutch 1949), it is easier to search out lapwing nests by means of the incubating parents and from a distance than by immediate scanning (walking through or flying over) large field areas in search of cryptic clutches. However, lapwing parents actively defend their nesting territories against avian predators (Elliot 1985, Kis et al. 2000, Seymour et al. 2003), similar to some other shorebirds (Larsen et al. 1996, Hegyi & Sasvári 1997), so it is easier for the predators to visit the nests during the absence of parents in the territories. In addition, northern lapwings usually leave the nest immediately at the approach of a predator penetrating into the territory (Šálek & Cepáková 2006), probably behaving so in order to prevent disclosing the nest's position (Walters 1982, Koivula & Rönkä 1998). A predator's success in searching out a nest once it has walked into the proximity of the nest is therefore limited by nest crypsis. If, however, the predator knows the exact nest position from previous perching, it can easily find and depredate the eggs. Indeed, crows (*Corvus corone*), which often use perching at field edges, are considered to be common predators of northern lapwing eggs along with foxes (*Vulpes vulpes*) in many areas (e.g. Kis et al. 2000, Seymour et al. 2003, Olsen & Schmidt 2004, MacDonald & Bolton 2008, pers. obs.), even though direct observations of depredation events are scarce (Olsen & Schmidt 2004) and the dominant predators of lapwing nests remain unknown.

This study experimentally tested the use of this possible predatory tactic by examining nest predation risk on artificial nests with quail eggs and plastic adult northern lapwing dummies installed in crow nesting territories at northern lapwing breeding grounds. The idea is based on that if predations will occur with a delay after removing the dummy, there must be that at least some predators are able to remember the remote position of previously occurring subject in the field and potentially use this tactic in nest searching. Its existence would prove that predators are able to apply much more sophisticated approaches when searching out bird nests than was previously assumed.

Material and Methods

The study was conducted in southern and eastern Bohemia, Czech Republic, in areas with breeding northern lapwings and crows (Šťastný et al. 2006, Kubelka et al. 2012). The experiment was conducted from April to May 2012 using artificial nests simulating small, open-nesting shorebird nests. Nests were formed as shallow open pits lined with a small amount of dry plant material from the surrounding area, then baited with four quail eggs with their tip ends facing to the centre of the nest. The nests were installed in the early morning (05.00-08.00 h) as nest pairs (trials), where the two nests (30 m apart) within each trial did not differ in any measured parameter (installation time, habitat, vegetation height, and distance to a perch for avian predators and to the field edge). A commercially produced plastic dummy of the northern lapwing in real size and colour was attached to one randomly selected nest within each trial to imitate incubating bird. After ca. 12 h of exposure, the dummy was removed and two eggs were exchanged between the nests within each pair in order to provide the same handling time and olfactory characteristics. If any nest was found to be destroyed during this inspection, the trial was excluded from further analysis. Successfully surviving nest pairs were subsequently exposed for 48 h. The fates of nests (predation or survival) were determined and surrounding vegetation height was estimated. Nest pairs destroyed by machinery were excluded from the analysis. We avoided using cameras and other tools allowing detection of individual predators as any other objects at the nests except the dummy may strongly influence the results and their interpretation.

This experiment was designed to maximize the probability of locating nests from perches by visual bird predators, particularly crows. The trials were therefore situated in areas of nesting crows and close to northern lapwing nesting territories where predators may have experience with their nests. The trials were not, however, within the protective zone which may be created by northern lapwings and were at least 200 m from the nearest active lapwing nest (Elliot 1985). The nests were located up to 100 m from elevated points (perches), as a previous study in that area had confirmed a higher predation risk to northern lapwing nests from this distance (Štorek 2011). A perch was defined as any fixed object (e.g. a tree or pylon) in the field or at its edge enabling a predator's lookout from a height of at least 5 m. The choice of habitats for nest placement was limited to those habitats usually occupied by nesting lapwings in the study areas (Kubelka et al. 2012), including (a) crop fields with denser and/or taller dark growth where dummies are hidden from visual predators; (b) ploughed fields and maize with mosaic of bare ground and sparse vegetation cover, where dummies can easily blend in with the substrate; and (c) managed meadows with uniform short-grass cover where dummies are easily found. Trials were deployed in sets of 8-9 nest pairs around a given breeding area with a distance of at least 300 m between two neighbouring trials.

Specifically of interest was whether predation would occur more often at nests after removal of the dummy than at control nests (not previously provided with the dummies). Software R 2.12.0 (R Development Core Team 2010) was used for computations of a generalized linear mixed-effect model (GLMM, 'lmer' in R package 'lme4') with log link function and binomial error distribution to test the effects of dummy's presence, habitat, vegetation height, distance to a perch, and the first-order interaction of the dummy's presence with perch distance, vegetation height and habitat on predation risk (depredated or not). The GLMM framework was applied to account for the proximity of nests within trials and breeding grounds by including the trial identity and breeding ground as random effects. The null hypothesis was rejected at $P < 0.05$.

Results

A total of 96 nest pairs were installed at 6 breeding areas in southern Bohemia and 5 breeding areas in eastern Bohemia. With the exception of 3 areas in southern Bohemia provided with 8 trials each, 9 trials were installed at each of the remaining 8 areas. Seven nests in 7 pairs were depredated before removal of the dummy and 2 other pairs were destroyed by machinery. Therefore, 9 nest pairs distorting the original experimental design were excluded and 87 pairs were included into the analysis. In this final sample, crop fields constituted the most represented habitat (52 trials), followed by meadows (20). Samples from ploughed fields (6) and maize (9) were pooled for further analysis, as the dummies in these habitats were regarded as similarly camouflaged.

The GLMM analysis revealed that habitat, presence of the dummy, and their interaction significantly influenced nest predation risk (Table 1). Whereas in meadows only those nests provided with the dummy were depredated (23.8 % of all such trials), 40 % of such nests, compared with only 20 % of control nests, were lost due to predation in ploughed fields and maize. Low predation risk (6.8 % of all nests) was recorded in crop fields regardless of dummy presence (Fig. 1).

In sum, 15 nests previously exposed with the dummy were depredated (17.2 %) compared to six control nests (6.9 %). At seven (the majority) of 11 breeding areas, the nests previously exposed with the dummy were more depredated than control nests (consistent with the prediction), at two breeding areas these predation rates were identical, at one breeding area the result was opposed to the prediction and at one

Table 1. Results of the mixed-effect model explaining the effects of factors on predation risk to experimental nests. The order of levels included into the model among the categorical variables was as follows: "habitat" – crop fields (reference value), ploughed fields and maize, meadows; and "dummy" absent (reference value) or present.

Predictor	Estimate	Std. error	χ^2	df	P
habitat	−0.213	0.1269	9.67	2, 7	0.008
	0.058	0.0835			
habitat × dummy	−0.237	0.1481	6.58	2, 11	0.037
	−0.218	0.0961			
dummy	0.169	0.1776	6.41	1, 8	0.011
height	−0.032	0.0452	1.53	1, 8	0.216
perch × dummy	−0.031	0.0284	1.23	1, 12	0.266
height × dummy	−0.036	0.0526	0.49	1, 12	0.486
perch	0.022	0.0240	0.13	1, 8	0.715

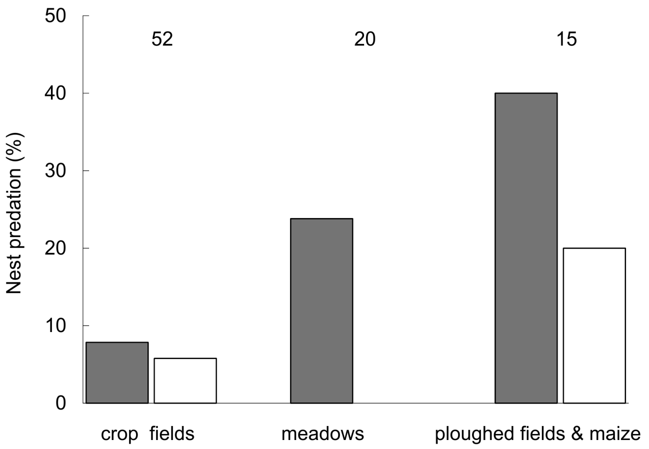

Fig. 1. Proportions of nest predation on dummy (grey bars) and control (white bars) nests in 87 experimental pairs. The numbers indicate sample sizes.

area the depredation did not occur at all. Vegetation height, distance to perch, and their interactions with a dummy's presence did not contribute significantly to the predation rate in this model.

Discussion

Significantly (2.5×) higher depredation rate of nests previously provided with dummies compared with control nests confirms that, in at least on some places (7 of 11 breeding grounds, i.e. 63.6 % of the sites included in this study), the predators registered the dummies as subjects of increased interest and subsequently inspected the corresponding positions preferably. Although the absolute differences between predation rates on dummy-provided nests and the control nests did not seem very great, it must be taken into account that nest exposure lasted only a few hours, which was certainly not enough time for relevant inspection of complete home feeding ranges by many predators present at the study sites. In addition, some of the nests of both types were apparently depredated incidentally (Vickery et al. 1992). On the other hand, a scent at the nests that might influence nest attractiveness for predators using olfactory cues (Rangen et al. 2000) did not contribute to this difference because manipulation and time spent by an observer at all nests were the same. In addition, the dummies were exposed on the nests only during daylight, so their presence was convenient for predators with daily activity, i.e. primarily birds.

Predation on lapwing nests strongly varies among habitats (Berg et al. 1992, Sheldon et al. 2007) including the study area (Šálek & Šmilauer 2002) and, according to the results of this study, one reason for this variation may be different visibility of incubating parents. Good visibility of the dummies in meadows can lead to stronger predation on the dummy-provided nests in contrast with the control nests, all of which survived. Higher nest predation in ploughed fields and maize compared with other habitats may demonstrate this habitat's increased attractiveness for predators searching for food while walking (i.e. incidentally), despite the fact that dummy-provided nests were also disadvantaged more than control nests in this habitat. The suitability of ploughed fields and maize for predators might be based on the fact that these fields abound in bare ground and thus supply various forms of surface-dwelling invertebrates (e.g. carabid beetles) attractive for generalist predators that can then focus on visual searches of such easy prey while walking (Bradbury & Kirby 2006). In contrast, a low predation rate in crop fields regardless of the presence of a dummy could be due to good concealment of both dummies and nests in dense vegetation, which is rather avoided by predators due to the lower general availability of prey there (Tagmann-Ioset et al. 2012). That effects of perch distance and vegetation height on nest predation risk were non-significant in this study may not be surprising, because all nests were purposely located within a distance of 100 m from elevated points. There are two main reasons for this. First, the predation risk in the study area is known to be significantly higher within this range compared to greater distances (Štorek 2011). Second, up to this distance, nests are viewed from above at a relatively sharp angle such that the height of vegetation may play a minor role compared to habitat substrate.

Incubating parents use a variety of tactics to protect their nests from predators (Conway & Martin 2000, Coates & Delehanty 2008), one of which is to passively remain on the nest, as this may immediately discourage approaching avian predators, and defend the nest against direct attack (Montgomerie & Weatherhead 1988, Opermanis 2004). This is known in species such as ducks, which have cryptic plumage but uniformly coloured eggs that are much more easily found from above (Albrecht & Klvaňa 2004, Andersson & Waldeck 2006). This tactic is obviously not the case for the northern lapwing, however, even though its incubation effort represents in average more than 80 % of the daytime and the nests remain unattended for only a very short time during the day (Grønstøl 2003, pers. obs.). Because lapwings leave the nests at the time of a predator's approach (Šálek & Cepáková 2006), a predator such as crow that has surpassed the protective umbrella formed by aggressive lapwing adults attacking intruders in nesting territories and has reached the proximity of the nest by walking, is therefore no longer hindered by incubating parents (pers. obs.). The success of its search is therefore limited in particular by crypsis of the nest. However, if the predator knows the nest's exact position as a result of previous perching, it can easily and quickly find and depredate these cryptic eggs, doing so in a manner which would not be detected by a casual observer. The common use of this tactic could then easily explain why successful depredation of clutches at the time of fighting between incubating parents and predators is rarely observed (if at all), even though predation rates on northern lapwings nests are generally high (MacDonald & Bolton 2008), including in the study area (Šálek & Šmilauer 2002).

Only seven experimental nests in this study (3.7 % of nests) were depredated before removal of the dummy, which suggests that a few predators ignored its presence in the nest. Unfortunately, there are no other data useful for clarification of these incidents as no cameras were added to the nests. It may at least be excluded that these depredations were due to nocturnal mammalian predators such as foxes or hedgehogs (*Erinaceus* spp.); because the dummies were exposed exclusively during daylight, avian predators were probably responsible for these attacks. The generalization of real proportions of depredation events must be treated with a caution. First, to increase chance that the object will be found from distance, we designed the experiment using proximity of elevated points. Second, large areas were included to detect whether general pattern exists throughout sites, habitats and regions regardless other non-controlled variables potentially influencing predation patterns. Third, the plastic dummies may attract more or less the predators than living lapwings (e.g. because of difference in plumage reflectance). In spite of these uncertainties, however, this should not call into question the principle of the specific predation tactic's consisting of delayed reaction to a remote stimulus that disappeared after a certain time. After all, predators preferentially visited those places with a previous subject of interest over the neighbouring, control, places where this subject had never been present. We therefore conclude that, while depending upon habitat, at least some predators can remember the nest positions during perching from observing incubating parents and delay the first visit there until after the parents leave the nest. The tactic proves that predators are able to apply a much more sophisticated approach in searching out birds' nests than was previously assumed. For example, it would explain how the predators avoid conflicts with the incubating lapwings at the nests and why these events are not commonly observed in spite of a generally high loss of northern lapwing nests due to predation. Although the predators in this study were not specifically determined, the study was designed in order to maximize the effect of visually orientated bird predators, particularly crows. However, much remains to confirm that corvids or even other predators are responsible for this predation tactics on birds' nests and whether they respond similarly to dummies as real parents. Also, there is a need for more detailed studies to assess the rate of actual application of this tactic in various prey species.

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Chapter 5

Survey of breeding Northern Lapwings (*Vanellus vanellus*) in the Czech Republic in 2008: results and effectiveness of volunteer work

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The paper analyses and summarizes the results of a national survey of the Northern Lapwing (*Vanellus vanellus*) in the Czech Republic conducted during the breeding season 2008. Thirty seven observers collected the data within 300 field visits on 151 breeding grounds particularly in southern and eastern Bohemia. A detailed questionnaire was readily filled in by the observers but most of them did not perform all four visits required for each site's survey during the season, as the work effort declined in the period of the third and fourth visits. We suggest simplifying of the questionnaire as well as reduction of the number of visits in future surveys. Arable land (particularly ploughed fields, winter wheat and spring cereal) dominated as nesting habitat of Northern Lapwings at 78% of localities while meadows and pastures were occupied less frequently. Breeding grounds were usually inhabited by one to four pairs while larger colonies, present mostly in ploughed fields, occurred rarely. Presence of marsh patches and/or meadows on the breeding grounds was positively correlated with lapwing abundance. In addition, the results indicate higher hatching success in ploughed fields and at sites with a presence of marsh patches. Agricultural activities were evaluated as the main threatening factor for breeding Northern Lapwings. Regularly occupied breeding grounds were considered as particularly important for lapwing population; these sites are easily detectable early in the breeding season which enables introduction of suitable long-term conservation actions, for example the discussed agri-environmental schemes for Northern Lapwings on arable land.

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Survey of breeding Northern Lapwings (Vanellus vanellus) *in the Czech Republic in 2008: results and effectiveness of volunteer work*

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Studie shrnuje a hodnotí výsledky celostátního monitoringu čejky chocholaté (*Vanellus vanellus*) v České republice v hnízdní sezóně 2008. Do monitoringu se zapojilo 37 ornitologů, kteří provedli celkem 300 kontrol na 151 hnízdištích zejména v jižních a východních Čechách. Navržený podrobný formulář byl ochotně a uspokojivě vyplňován, větší potíže pozorovatelům činilo dodržet požadované čtyři kontroly každé lokality a jejich terénní úsilí později v sezóně klesalo. Formu dotazníku při dalším podobném monitoringu hnízdišť bude vhodné zjednodušit a počet kontrol omezit na dvě. Dominantním hnízdním biotopem čejek byla ze 78 % orná půda (zejména oraniště, ozimé obiloviny a jařiny), louky a pastviny byly zastoupeny méně. Hnízdní lokalita byla nejčastěji obsazena 1–4 páry čejek, větší kolonie, obvykle v oraništích, vznikaly vzácněji. Výsledky indikují vyšší úspěšnost líhnutí v oraništích. Přítomnost mokřiny a louky na hnízdišti zvyšovala hnízdní početnost, přítomnost mokřiny také úspěšnost líhnutí. Zemědělská činnost byla respondenty hodnocena jako hlavní ohrožující faktor. Významnými hnízdišti jsou většinou pravidelně obsazované lokality a lze je dobře identifikovat již začátkem hnízdní sezóny, což usnadňuje zavedení vhodných dlouhodobých ochranářských opatření, například diskutované agroenvironmentální opatření pro čejku chocholatou na orné půdě.

The paper analyses and summarizes the results of a national survey of the Northern Lapwing (Vanellus vanellus) *in the Czech Republic conducted during the breeding season 2008. Thirty seven observers collected the data within 300 field visits on 151 breeding grounds particularly in southern and eastern Bohemia. A detailed questionnaire was readily filled in by the observers but most of them did not perform all four visits required for each site's survey during the season, as the work effort declined in the period of the third and fourth visits. We suggest simplifying of the questionnaire as well as reduction of the number of visits in future surveys. Arable land (particularly ploughed fields, winter wheat and spring cereal) dominated as nesting habitat of Northern Lapwings at 78% of localities while meadows and pastures were occupied less frequently. Breeding grounds were usually inhabited by one to four pairs while larger colonies, present mostly in ploughed fields, occurred rarely. Presence of marsh patches and/or meadows on the breeding grounds was positively correlated with lapwing abundance. In addition, the results indicate higher hatching success in ploughed fields and at sites with a presence of marsh patches. Agricultural activities were evaluated as the main threatening factor for breeding*

Northern Lapwings. Regularly occupied breeding grounds were considered as particularly important for lapwing population; these sites are easily detectable early in the breeding season which enables introduction of suitable long-term conservation actions, for example the discussed agri-environmental schemes for Northern Lapwings on arable land.

Keywords: agri-environmental scheme, effectiveness of volunteer work, monitoring, Northern Lapwing, species protection, *Vanellus vanellus*

ÚVOD

Čejka chocholatá (*Vanellus vanellus*) je nejběžnější hnízdící bahňák v České republice, nicméně v posledních desetiletích dochází k trvalému poklesu její početnosti. Ještě v letech 1984–1988 se velikost hnízdní populace pohybovala na úrovni 20 000–40 000 párů, během mapování 2001–2003 to však už bylo pouze 7000–10 000 párů (Šťastný et al. 2006). Pokles početnosti mezi roky 1982–2010 až o 80 % dokumentují také výsledky Jednotného programu sčítání ptáků (Česká společnost ornitologická 2011, Reif et al. 2008). Výrazný úbytek čejek potvrzuje i analýza kroužkovacích údajů o nevzletných mláďatech z 10 regionů ČR v letech 1976–2004 (Žídková et al. 2007). Shodně nepříznivý trend byl zaznamenán také ve většině zemí Evropy, zejména ve starých členských státech Evropské unie (BirdLife International 2004). Po vstupu nových zemí převážně ze střední a východní Evropy do EU v roce 2004 lze předpokládat, že díky dotacím ze Společné zemědělské politiky (dále jen SZP) dojde i přes existenci různých podpůrných opatření k další intenzifikaci zemědělství. Ta představuje významný ohrožující faktor pro hnízdící bahňáky a může se tak prohloubit pokles jejich početnosti v Evropě (Delany et al. 2009).

Výsledky četných výzkumů probíhajících na různých místech Evropy potvrzují, že na čejky negativně působí několik významných a vzájemně provázaných faktorů. Kromě intenzifikace zemědělské výroby na orné půdě je jednou z hlavních příčin ztráta či znehodnocení tradičních hnízdních stanovišť v mokřadech včetně vlhkých luk (Hötker 1991, Wilson et al. 2004, Eglington et al. 2008). V ČR přispělo odvodňování a rozorávání nivních travních porostů ve druhé polovině 20. století k tomu, že čejky začaly ve větší míře hnízdit na orné půdě, podobě jako tomu bylo již v 1. polovině 20. století v některých západoevropských zemích (Šťastný et al. 2006). V rybniční oblasti u Náměště nad Oslavou došlo k tomuto přesunu v sedmdesátých letech (Fiala 2002), na Písecku byl tento trend ve větší míře zaznamenán až po roce 1987 (Šálek 1990). Významné ohrožení pro čejky představují zemědělské práce v hnízdní době (např. Galbraith 1988a, Heath et al. 2000, Wilson et al. 2001, O'Brien et al. 2002, Kragten & de Snoo 2007) a predace (např. Berg et al. 1992, MacDonald & Bolton 2008, Teunissen et al. 2008). V západní Evropě byl prokázán nárůst predace čejčích hnízd z 18 % před rokem 1980 na 56 % mezi lety 1996–2006. Potvrzen byl rovněž významný pokles v přežívání čejčích nevzletných mláďat (Roodbergen et al. 2012). Čejku v ČR ovlivnilo také omezení pastevního hospodářství v okolí rybníků, zvýšení intenzity rybářského hospodaření spolu s intenzivnějším hnojením luk (shrnuto v Šálek 2000a). Všechny zmíněné vlivy vedou k tomu, že hnízdní úspěšnost čejek je nízká a zdaleka nestačí na autoreprodukci mnoha evropských populací (Peach et al. 1994, Roodbergen et al. 2012).

Podpořit hnízdní populace bahňáků

(např. Ottvall & Smith 2006, Verhulst et al. 2007) nebo konkrétně čejku chocholatou (Sheldon et al. 2004) v některých zemích Evropy by měla speciální agroenvironmentální opatření (dále jen AEO), jejichž cílem je zachovat vhodná hnízdiště v dobrém stavu. Například ve Velké Británii vznikly v rámci AEO plochy vytvořené jarní podmítkou obilného strniště, které byly zachovány ve formě úhoru během hnízdního období (Sheldon et al. 2007). Podle výsledků monitoringu, který z velké části prováděli dobrovolníci, se úspěšnost líhnutí snůšek čejek na těchto pozemcích pohybovala okolo 85 % a byla jednoznačně vyšší než na kontrolních plochách. Nicméně podle Chamberlaina et al. (2009) se čejky v hnízdní době vyskytovaly pouze na 40 % z 212 nabízených ploch, přičemž hnízdění bylo předpokládané na 25 % a prokázané pouze u 11 % ploch. Příčinou mohl být fakt, že tyto plochy byly střídány v rámci farem podle osevního postupu a v některých případech byly založeny na nevhodných stanovištích, např. v blízkosti lesa. Ve většině případů se opatření na ochranu čejky chocholaté soustředí na travní porosty. Jejich hlavním cílem je posunout termíny seče na pozdější dobu, a tím předejít hnízdním ztrátám způsobeným zemědělskými pracemi (např. Kleijn et al. 2001). Jak ale ukazuje dlouholetý monitoring, na plochách se závazkem AEO nedochází k očekávanému zvyšování hnízdní hustoty v porovnání s kontrolními plochami (Berendse et al. 2004, Breeuwer et al. 2009). Jako vhodné doplňující opatření je proto navrhována úprava vodního režimu, zejména částečné zavodnění těchto ploch během hnízdění (Eglington et al. 2008, Belleaum & Bock 2009).

Také v ČR existuje od roku 2004 speciální AEO zacílené na podporu bahňáků hnízdících v travních porostech (Scharf et al. 2007), jeho přínos však nebyl dosud vyhodnocen v odborném tisku. Jelikož většina čejek v ČR v současné době hnízdí na orné půdě (Šťastný et al. 2006), je žádoucí jejich ochranu zaměřit i na tyto kultury. Účinný způsob ochrany však vyžaduje jasnější představu nejen o aktuální početnosti čejek v různých regionech ČR, obsazovaných biotopech, ohrožujících faktorech nebo hnízdní úspěšnosti, ale také o vhodném způsobu monitoringu účinnosti realizovaných opatření, aby mohla být vhodně modifikována, pokud se ukáží jako neefektivní. Naše doposud provedené lokální studie o hnízdění čejek (Klabník 1984, Šálek 1990, Šálek 1994, Fiala 2002, Schröpfer 2002, Kunstmüller 2006) jsou příliš zatíženy místními podmínkami (např. různá biotopová nabídka nebo preference, početnost hnízdních seskupení a rozptýlení populace, rizika ohrožení zemědělstvím, predací aj.), takže nemusí spolehlivě odrážet stav na nadregionální úrovni.

Po vyhlášení čejky chocholaté ptákem roku 1995 (Formánek et al. 1995, Šálek 1995) a vyhodnocení výsledků této akce, která poukázala na zásadní význam orné půdy pro naše hnízdící čejky (Šálek 1996), Česká společnost ornitologická (dále jen ČSO) iniciovala v roce 2008 nový celostátní monitoring čejky chocholaté s několika cíli: (1) získat informace o aktuálním hnízdním výskytu čejek v ČR; (2) zjistit bližší informace o hnízdištích včetně charakteru vegetačního krytu, přítomnosti podmáčených ploch a travních porostů nebo hnojišť; (3) odhadnout úspěšnost líhnutí a definovat ohrožující faktory na hnízdištích; (4) posoudit možnosti využití dobrovolníků při monitoringu, jejich přístup ke sběru dat a využívání zpracovaného formuláře; (5) vyhodnotit význam monitoringu pro účely přípravy vhodných managementových opatření na podporu hnízdících čejek.

MATERIÁL A METODIKA

Sběr dat

Sběr dat byl rozdělen do čtyř období: I. Výběr hnízdišť čejkami (15.–31. 3.), II. Období líhnutí mláďat (21. 4.–10. 5.), III. Období vodění mláďat (1.–15. 6.) a IV. Pohnízdní shromaždiště (11.–31. 7.). Rozmezí jednotlivých období byla volena natolik široce, aby si každý pozorovatel našel čas na kontrolu svých dobrovolně vybraných lokalit. Minimálně 20denní rozestup mezi následujícími kontrolami snížil riziko provedení dvou kontrol na jedné lokalitě krátce po sobě v témže aspektu reprodukční sezóny. Pokud sčitatel navštívil lokalitu vícekrát během jednoho období, pro následné analýzy byla vybrána kontrola s nejvyšším počtem zjištěných čejek. Pro malý počet hlášení získaných ve IV. období, které navíc nemá přímou vazbu na hnízdní lokality, nebyla data z tohoto období zahrnuta do dalšího hodnocení.

V každém období mapovatelé uvedli název sledované lokality a její polohu (GPS souřadnice centra výskytu), mapovací kvadrát, nejbližší obec a kraj, upřesnili rozlohu a popis hnízdiště včetně poměru zemědělských kultur. U každé kontroly zaznamenávali datum, čas, počasí během pozorování a počet zjištěných čejek. Vítaným doplňkem byl výčet hlavních ohrožujících faktorů a historický výskyt čejek na lokalitě (dle jim dostupných informací). Cíleně byli respondenti dotazováni na přítomnost mokřin, luk, hnojišť na hnízdní lokalitě, neboť tyto prvky mohou výrazně zvýšit nabídku potravy pro čejky a hrát roli při výběru hnízdiště či ovlivnit hnízdní úspěšnost (např. Šálek 2000a, Sheldon 2002, Ausden et al. 2003, Kunstmüller 2006, Eglington et al. 2008, vlastní nepubl. údaje). Velikost lokality, kterou každý pozorovatel s ohledem na místní okolnosti mohl volit zcela subjektivně, nebyla u řady hlášení vůbec specifikována. Z těchto důvodů nebyl tento údaj nakonec zahrnut do dalších analýz, ačkoliv může jít o významnou proměnnou při interpretaci výsledků. Při mapování nebyla dohledávána hnízda, proto bylo jako hnízdiště mapovateli označeno širší území (jeden, či více sousedících biotopů), které čejky na dané lokalitě využívaly jak k toku, tak ke sběru potravy nebo odpočinku. Na takto pozorovatelem definované lokalitě byla zaznamenávána přítomnost jednotlivých prvků (viz výše). Čas strávený kontrolou lokality nebyl bohužel v řadě záznamů uveden, a tudíž nebyl dále analyzován. Rozdíly v kvalitě pozorovatelů by navíc mohly setřít důležitost času jako ukazatele úsilí mapovatelů. Za mokřinu je v této práci považována plocha s dočasně stojící vodou. Jde zejména o každoročně přítomné jarní kaluže v mírných terénních depresích nad špatně propustným podložím v zemědělských kulturách na rozdíl od mokřadu, jímž je obvykle trvale zamokřený a jen zřídka kosený travní porost s hojným výskytem ostřicových stoliček, charakteristický např. pro výtopy rybníků. Úhorem, pokud byl pozorovatelem uveden, je nazýváno spontánně zarůstající pole ponechané ladem po dobu alespoň jednoho roku a další ruderální plochy (zpravidla s vyšším, ale řidším a různorodým porostem).

Provedení monitoringu bylo doporučováno v plném rozsahu (čtyři termínované kontroly od poloviny března do konce července), avšak bylo možno uskutečnit pouze některé ze čtyř kontrol. Dodržování konkrétních termínů terénní práce při monitoringu čejek a důslednost při vyplňování rozsáhlého dotazníku jsou spolehlivými ukazateli úspěšnosti případného budoucího monitoringu účinnosti AEO pro čejku na orné půdě. Jedná se o přijatelná kritéria pro posouzení vhodnosti tohoto přístupu k získávání podkladových dat pro ochranářské účely.

Pro co nejlepší pokrytí celé ČR a co nejreprezentativnější vzorek lokalit byli vybráni regionální koordinátoři, kteří měli co nejvíce propagovat monitoring ve svém regionu a zajišťovat komunikaci s jednotlivými mapovateli. Regionů bylo 8: střední Čechy (Středočeský kraj, Praha), jižní Čechy (Jihočeský kraj), západní Čechy (Plzeňský kraj, Karlovarský kraj), severní Čechy (Ústecký kraj, Liberecký kraj), východní Čechy (Královéhradecký kraj, Pardubický kraj), Vysočina (kraj Vysočina), jižní Morava (Jihomoravský kraj, Zlínský kraj) a severní Morava (Olomoucký kraj, Moravskoslezský kraj). Tyto regiony byly i nadále používány při analýzách výsledků. Čejka je relativně vzácným druhem, proto byly zpracovány veškeré dostatečně podrobné a využitelné informace z jednotlivých lokalit, přestože lokality mohly být soustředěny vlivem zvýšené aktivity pozorovatelů do několika málo regionů. Pro málo zastoupené regiony mohou mít tedy výsledky omezenou vypovídací hodnotu.

Veškeré metodické pokyny mohli mapovatelé získat na webu ČSO na adrese http://www.josefovskelouky.cz/index.php?ID=1686, kde byl a stále je mimo jiné ke stažení podrobný formulář, různé nahrávky hlasu čejek a další užitečné informace.

Zpracování výsledků

Vliv více faktorů a současně i jejich vzájemných interakcí byl testován pomocí obecných a zobecněných lineárních modelů. Početnost čejek na hnízdištích měla po logaritmické transformaci normální rozdělení, takže vliv faktorů byl analyzován pomocí obecného lineárního modelu (LM). Binomicky vyjádřený výskyt mláďat nebo varujících rodičů (přítomnost nebo nepřítomnost) byl hodnocen pomocí zobecněného lineárního modelu s binomickou distribucí vysvětlované proměnné (GLM). Souhrnné výsledky těchto modelů jsou zařazeny formou příloh (Appendix 1 a 2) a jejich nejdůležitější interpretace jsou popsány slovně v kapitole Výsledky a dále diskutovány. Průměrné hodnoty uváděné ve výsled-

Appendix 1. Výsledky obecného lineárního modelu (LM) hodnotícího vlivy hlavních biotopových faktorů a jejich interakcí na početnost čejek na hnízdištích ve 2. období sčítání.
Appendix 1. *Results of a general linear model (LM) analysing effects of the main habitat attributes and their interactions on numbers of lapwings on breeding grounds in the second monitoring period.*

Faktor / *Factor*	df	χ^2	P
Louka, mokřina *Meadow, wetland*	2,108	35.6	0.030
Region *Region*	2,108	25.4	0.082
Region × Dominantní biotop *Region × Prevailing habitat*	8,88	62.0	0.083
Region × Louka, mokřina *Region × Meadow, wetland*	4,88	32.1	0.125
Dominantní biotop *Prevailing habitat*	5,108	29.8	0.318
Dominantní biotop × Louka, mokřina *Prevailing habitat × Meadow, wetland*	8,88	14.3	0.921

Appendix 2. Výsledky zobecněného lineárního modelu (GLM) hodnotícího vlivy hlavních biotopových faktorů a jejich interakcí na výskyt mláďat nebo varujících čejek ve 2. období sčítání.
Appendix 2. *Results of a generalized linear model (GLM) analysing effects of the main habitat attributes and their interactions on presence of chicks or warning adults in the second monitoring period.*

Faktor / *Factor*	df	χ^2	P
Region *Region*	2,86	26.87	< 0.0001
Region × Dominantní biotop *Region × Prevailing habitat*	8,72	15.58	0.049
Region × Louka, mokřina, hnojiště *Region × Meadow, wetland, dunghill*	4,72	9.30	0.054
Louka, mokřina, hnojiště *Meadow, wetland, dunghill*	2,86	4.49	0.106
Region × Početnost při 1. kontrole *Region × Numbers during the first visit*	2,72	2.81	0.246
Početnost při 1. kontrole *Numbers during the first visit*	1,86	0.91	0.341
Dominantní biotop *Prevailing habitat*	5,86	3.59	0.611

cích jsou doplněny o směrodatné odchylky (± SD). Statistické zpracování výsledků bylo provedeno v programu R (ver. 2.12.0; R Development Core Team 2010).

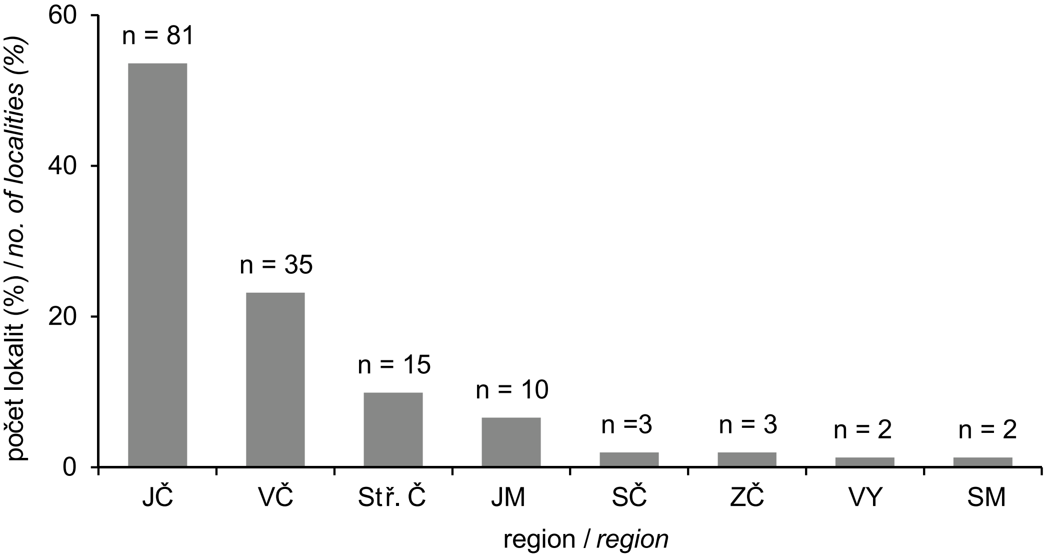
VÝSLEDKY

Úspěšnost dotazníkové akce

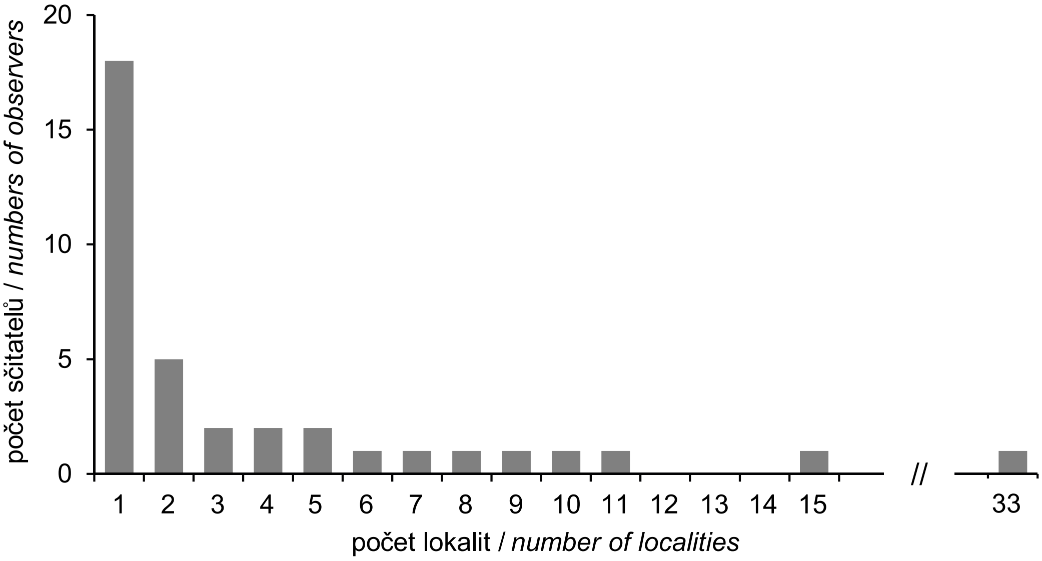
Na výzvu k monitoringu (Zámečník 2008), zveřejněnou také na internetových stránkách ČSO na adrese http://www.josefovskelouky.cz/index.php?ID=1686, odpovědělo a svá pozorování zaslalo 49 mapovatelů. Třicet z nich (61 %) poslalo data formou vyžadovaného formuláře, zbývajících 19 v jiné podobě. Využitelné byly údaje od 34 mapovatelů (69 %) ze 101 lokality, z toho 29 respondentů použilo formulář a dalších pět zpracovalo data jiným způsobem. Po přidání údajů tří autorů tohoto příspěvku vznikl soubor 151 sledovaných lokalit se 300 sčítanými obdobími v průběhu hnízdní sezóny od 37 mapovatelů reprezentujících osm regionů ČR. Tento souhrnný datový soubor byl využit při zpracování prezentovaných výsledků. Zastoupení jednotlivých regionů ČR však bylo nerovnoměrné. Více než polovina sledovaných lokalit se nacházela v jižních Čechách, další přibližně čtvrtina ve východních Čechách, takže více než dvě třetiny lokalit připadají na tyto dva regiony (obr. 1). Z žádného z ostatních šesti regionů nebyly zaslány údaje z více než 15 lokalit, proto byly při dílčích analýzách shrnuty do společné kategorie „ostatní regiony“.

Úsilí mapovatelů

Průměrný počet lokalit na jednoho mapovatele činil 4,1. Téměř polovina respondentů (49 %) však sčítala pouze jedinou lokalitu a jen čtyři pozorovatelé sčítali 10 nebo více lokalit (obr. 2), dva z nich byli autoři tohoto článku. Na 124 lokalitách (82 %) sčitatelé zaznamenávali přítomnost mláďat či varujících rodičů, na zbývajících 27 lokalitách (18 %) údaje o tomto nepřímém hodnocení



Obr. 1. Zastoupení sčítaných lokalit v jednotlivých regionech ČR (JČ = jižní Čechy, VČ = východní Čechy, Stř.Č = střední Čechy včetně Prahy, JM = jižní Morava, SČ = severní Čechy, ZČ = západní Čechy, VY = Vysočina, SM = severní Morava). U každého regionu je uveden počet lokalit. Jižní Čechy tvoří 53,6 % lokalit a východní Čechy 23,2 %.
Fig. 1. *Distribution of monitored localities in particular regions of the Czech Republic (JČ = southern Bohemia, VČ = eastern Bohemia, Stř.Č = central Bohemia including Prague, JM = southern Moravia, SČ = northern Bohemia, ZČ = western Bohemia, VY =Vysočina region, SM = northern Moravia). The numbers of localities are presented. Southern Bohemia and eastern Bohemia make up 53.6% and 23.2% of localities, respectively.*



Obr. 2. Úsilí jednotlivých mapovatelů (n = 37) vyjádřené počtem jimi sčítaných lokalit (n = 151).
Fig. 2. *Effort of individual observers (n = 37) expressed by the number of monitored localities (n = 151).*

hnízdní úspěšnosti chybí. Jednotlivé lokality byly sčítány v jedné až všech třech fázích hnízdního období, pouze 31 % lokalit přitom bylo sčítáno během celé hnízdní sezóny (tab. 1).

Na 86 lokalitách byly provedeny první dvě kontroly; z nich na 75 (87 %) byly přítomny čejky také během druhé návštěvy, zatímco na 11 již přítomny nebyly (13 %). Ze 75 lokalit s pozitivním výsledkem

Tab. 1. Navštěvovanost lokalit sčitateli v jednotlivých sčítacích obdobích. Zařazeny jsou údaje ze všech vyhodnocovaných lokalit. Celkem bylo provedeno 300 návštěv 151 lokalit.
Table 1. *The attendance of localities by observers in particular monitoring periods. Data from all localities are included. Altogether 300 visits of 151 localities were performed.*

	1. období *1st period*	2. období *2nd period*	3. období *3rd period*	počet lokalit *number of localities*	počet lokalit (%) *number of localities (%)*
	ANO/*YES*	ANO/*YES*	ANO/*YES*	47	31,1
	ANO/*YES*	ANO/*YES*	NE/*NO*	39	25,8
	ANO/*YES*	NE/*NO*	NE/*NO*	22	14,6
	NE/*NO*	ANO/*YES*	NE/*NO*	26	17,2
	NE/*NO*	ANO/*YES*	ANO/*YES*	10	6,6
	ANO/*YES*	NE/*NO*	ANO/*YES*	6	4,0
	NE/*NO*	NE/*NO*	ANO/*YES*	1	0,7
celkem ANO *total YES*	114	122	64	151	100

Tab. 2. Obsazenost lokalit čejkami v jednotlivých sčítacích obdobích. Zařazeny jsou údaje pouze z lokalit, kde byly provedeny kontroly ve všech třech hnízdních obdobích. Tři varianty obsazení lokalit v průběhu sezóny, NE-ANO-ANO, ANO-NE-ANO a NE-NE-ANO vůbec nenastaly, proto nejsou v tabulce uvedeny.
Table 2. *Occupancy of localities by lapwings in particular monitoring periods. Only localities with three visits during the whole breeding season are included. Three variant possibilities, NO-YES-YES, YES-NO-YES and NO-NO-YES, did not occur and are not mentioned in the table.*

	1. období *1. period*	2. období *2. period*	3. období *3. period*	počet lokalit *number of localities*	počet lokalit v % *number of localities (%)*
	ANO/*YES*	ANO/*YES*	ANO/*YES*	30	63,9
	ANO/*YES*	ANO/*YES*	NE/*NO*	12	25,5
	ANO/*YES*	NE/*NO*	NE/*NO*	4	8,5
	NE/*NO*	ANO/*YES*	NE/*NO*	1	2,1
celkem ANO *total YES*	46	43	30	47	100

(zjištěním čejek) při druhé kontrole bylo 43 (57 %) kontrolováno i při třetí kontrole. Z 11 lokalit s negativním výsledkem (tj. bez výskytu čejek) při druhé kontrole byly potřetí navštíveny jen čtyři lokality (36 %). To vše poukazuje na zřetelný (avšak statisticky neprůkazný) pokles motivace provést třetí požadovanou kontrolu lokality po předchozím neúspěchu, ovšem stejně tak na nedostatečnou motivaci provést vůbec tuto třetí kontrolu, byť čejky při druhé kontrole přítomny byly (jednostranný test proporcí, P = 0.096). Obecně byla třetí kontrola pro pozorovatele méně atraktivní a byla uskutečněna méně často. Motivace pro její provedení po úspěšné druhé kontrole průkazně poklesla v porovnání s provedením druhé kontroly po první úspěšné kontrole (ze 76 % na 57 %; test proporcí, n_1 = 113 a n_2 = 86 lokalit, P = 0,005).

Obsazení hnízdišť během sezóny

Jak se ukázalo, provádění třetí kontroly po druhé neúspěšné kontrole nebylo ani efektivní, protože kombinace přítomnosti čejek na lokalitě ANO-NE-ANO se nevyskytla (tab. 2). Obsazení hnízdišť v průběhu sezóny bylo hodnoceno pro 47 lokalit navštívených ve všech třech obdobích v průběhu hnízdní sezóny. Na 64 % lokalit se čejky vyskytovaly během všech tří kontrol, na 26 % lokalit pak chyběly při třetí kontrole.

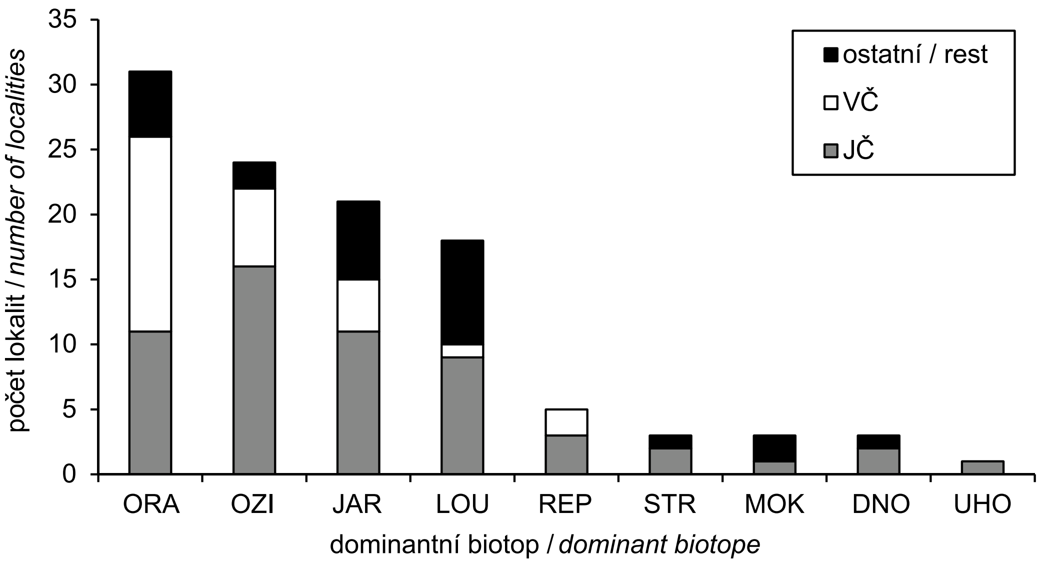
Hnízdní prostředí

Dominantním biotopem na hnízdištích čejek byla jednoznačně orná půda, a to ze 78 % (obr. 3). Mezi nejvíce obsazované kultury patřila v prvním sčítacím období oraniště (31 lokalit, 28 %), ozimé obiloviny (24 lokalit, 22 %), jařiny (21 lokalit, 19 %) a louky/pastviny (18 lokalit, 17 %) z celkového počtu 109 lokalit navštívených v tomto období. Oraniště převažovala ve východních Čechách, ozimy v jižních Čechách. V ostatních regionech převládaly louky a pastviny. Z celkového počtu sledovaných lokalit (n = 151) byla louka (jako dominantní biotop nebo méně zastoupený prvek na hnízdišti) přítomna na 37 % lokalit, mokřina (podmáčená plocha) na 65 % lokalit, hnojiště na 12 % lokalit.

Početnost na hnízdištích

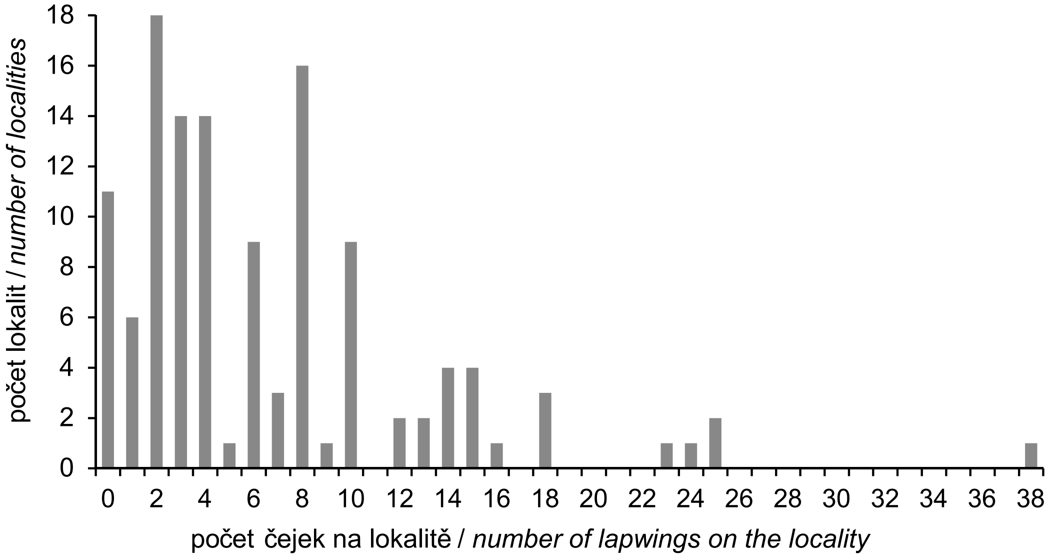
Nejčastější sestavou pozorovanou na hnízdištích byly 2 až 4 čejky, popř. také 8 čejek, což odpovídá 1–2 a 4 párům (obr. 4). Na lokalitách, kde byly sčítány čejky při první i druhé kontrole, byl vynesen vztah mezi početnostmi při těchto dvou kontrolách. Byly přitom vynechány lokality s počty více než 50 čejek pozorovaných při první kontrole považované za zjevně táhnoucí skupiny. Tento vztah byl průkazně pozitivní (Spearmanův korel. koef., $r_s = 0{,}61$, $P < 0{,}05$), i když počty čejek při druhé kontrole byly přibližně poloviční v porovnání s první kontrolou (obr. 5).

Nejvyšší průměrný počet čejek na lokalitu (9,6 ± 8,09) při druhém sčítání

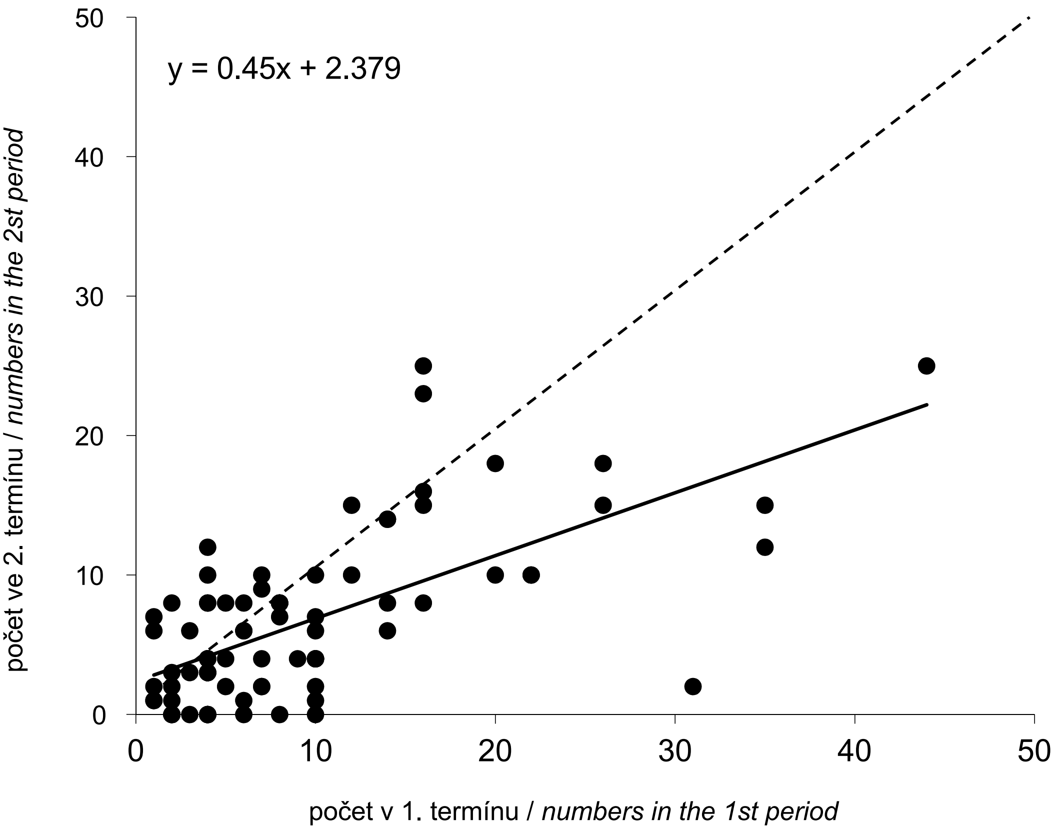


Obr. 3. Zastoupení dominantních biotopů na lokalitách a v jednotlivých regionech během prvního období sčítání (ORA = oraniště, OZI = ozim, JAR = jarní obilovina, LOU = louka/pastvina, REP = řepka, STR = strniště, MOK = mokřad, DNO = dno rybníka, UHO = úhor), n = 109. Šest méně sledovaných regionů (viz obr. 1) bylo shrnuto do kategorie „ostatní“. JČ = jižní Čechy, VČ = východní Čechy.

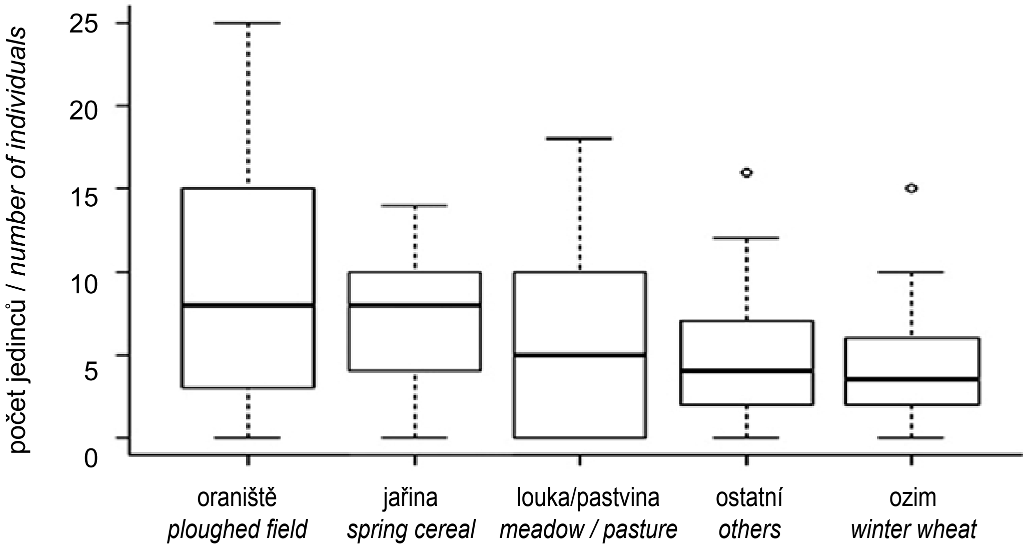
Fig 3. *Representation of dominant habitats on localities and in particular regions during the first monitoring period (ORA = ploughed field, OZI = winter wheat, JAR = spring cereal, LOU = meadow/pasture, REP = oil-seed rape, STR = stubble field, MOK = marshland, DNO = fishpond bottom, UHO = fallow land), total n = 109. Six less represented regions (see Fig. 1) were merged in the category „rest“. Regions: JČ = southern Bohemia, VČ = eastern Bohemia.*



Obr. 4. Histogram rozdělení počtu lokalit podle počtu pozorovaných čejek v termínu druhé kontroly (n = 123).
Fig. 4. *Histogram of distribution of lapwing numbers observed on the localities (n = 123) during the second monitoring period.*



Obr. 5. Korelace mezi početností čejek na hnízdištích při první a druhé kontrole (n = 82). Lokality s více než 50 čejkami při první kontrole jsou vynechány. Přerušovaná čára představuje situaci při nezměněném stavu (směrnice = 1).
Fig. 5. *Correlation between lapwing numbers on the localities during the first and second visits (n = 82). Localities with more than 50 lapwings during the first visit were omitted. Dashed line represents stable state (slope = 1).*



Obr. 6. Početnost čejek v biotopech dominantních na jednotlivých hnízdištích při druhém sčítání. Tučně jsou mediány, boxy vymezují 25% a 75% kvantily, úsečky přilehlé a kroužky odlehlé hodnoty [n = 83; oraniště = 27, jař = 17, louka/pastvina = 10, ozim = 16, ostatní (řepka, strniště, mokřad, dno rybníka a úhor) = 13].
Fig 6. *Lapwing numbers in dominant habitats on particular breeding grounds in the second monitoring period. Box-plots include medians, 25% and 75% quantiles, outliers (bars) and extreme values (circles) [n = 83; ploughed fields = 27, spring cereal = 17, meadow/pasture = 10, winter wheat = 16, others (rape oil-seed, stubble fields, marshland, fish-pond bottom and fallow) = 13].*

(líhnutí mláďat) byl zaznamenán v oraništích, případně v následných biotopech po zvláčení a osetí (šlo zejména o jařiny včetně kukuřice; obr. 6), čímž se tento biotop průkazně lišil od všech ostatních dominantních biotopů s průměrem 5,8 ± 4,69 čejek (Wilcoxonův dvouvýběrový t-test: W = 936, n = 83, p = 0,040). Všechny dominantní biotopy reprezentující méně než 10 lokalit (řepka, strniště, mokřad, dno rybníka a úhor) byly v této analýze shrnuty do kategorie „ostatní“.

Dále jsme hodnotili, zda početnost čejek na hnízdišti ve 2. období (inkubace a líhnutí mláďat) byla ovlivněna: (a) biotopem (po sloučení biotopů kvůli početnímu vyrovnání velikosti vzorků na jařiny, oraniště, ozim+řepku a ostatní); (b) přítomností mokřiny (včetně dna vypuštěného rybníka) a luk; (c) zda se v těchto ohledech lišila mezi regiony (jižní Čechy, východní Čechy, ostatní). Analýza ukázala, že početnost čejek na hnízdištích byla statisticky významně ovlivněna přítomností mokřin a/nebo luk bez ohledu na dominantní biotop a region (Appendix 1). Nejpočetnější seskupení čejek se tedy tvořila na lokalitách, jejich součástí jsou podmáčené plochy či travní porosty.

Hnízdní úspěšnost

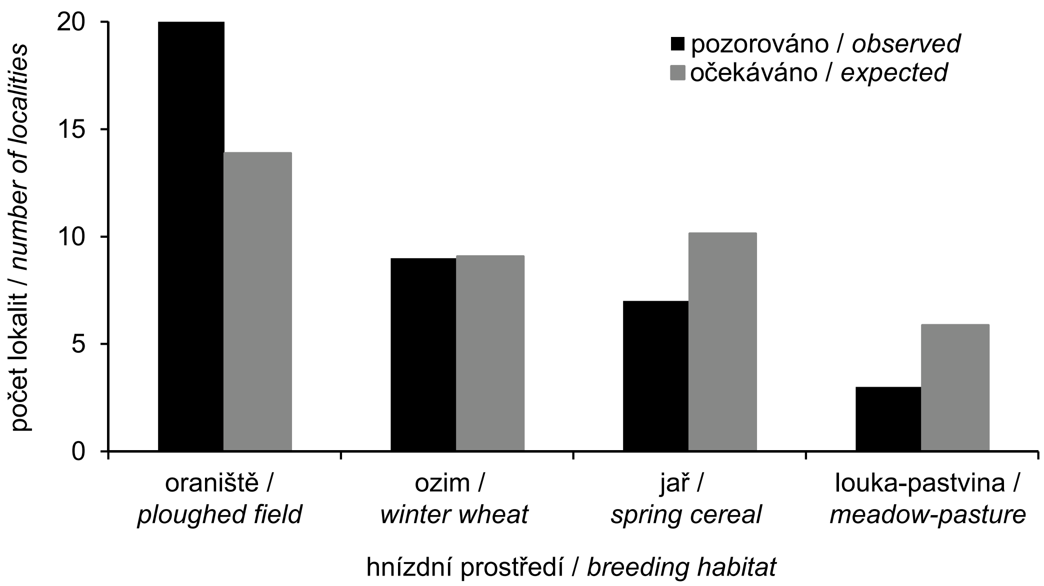
Z celkového počtu 124 lokalit, na kterých byla ve druhém či třetím sčítacím období zjišťována přítomnost kuřat („kuřetem“ je dále v textu myšleno vždy mládě čejky chocholaté od vylíhnutí po dosažení vzletnosti) nebo varujících rodičů indikujících úspěšně vylíhlé snůšky, byla na 63 (51 %) pozorována mláďata či varující dospělí ptáci, na 61 (49 %) nikoliv. Testovali jsme, zda je výskyt varujících rodičů nebo přímo pozorovaných mláďat spojen s přítomností luk, mokřin a hnojišť na lokalitě a zda je v tomto ohledu patrný rozdíl mezi regiony a převládajícími biotopy. Zjistili jsme vysoce průkazný rozdíl mezi regiony v podílu lokalit s varujícími čejkami bez ohledu na další atributy (Appendix 2). Nejvyšší podíl lokalit s varujícími čejkami v době vodění mláďat byl zaznamenán ve východních Čechách (93 %), nejnižší v jižních Čechách (27 %), ostatní regiony dosahovaly 69 %. V interakci s regionem se uplatnil i vliv dominantního biotopu, tj. dominantní biotop se uplatnil v tomto směru pouze v některých regionech. Nejvyšší úspěšnost líhnutí vykazovaly čejky v oraništích (na 77 % lokalit byli zaznamenáni varující dospělci nebo byla pozorována mláďata). Nižší byla naopak v loukách, pastvinách a jařinách (27 %). Tento trend však nebyl statisticky průkazný pro celý soubor dat (test homogenity, χ^2 = 5,1, df = 3, P = 0,164; obr. 7). Významným faktorem průkazně zvyšujícím podíl lokalit s výskytem varujících čejek nebo pozorovaných kuřat byla přítomnost samotné mokřiny (χ^2 = 10,12, df = 1, P = 0,001; obr. 8).

Historický status lokalit

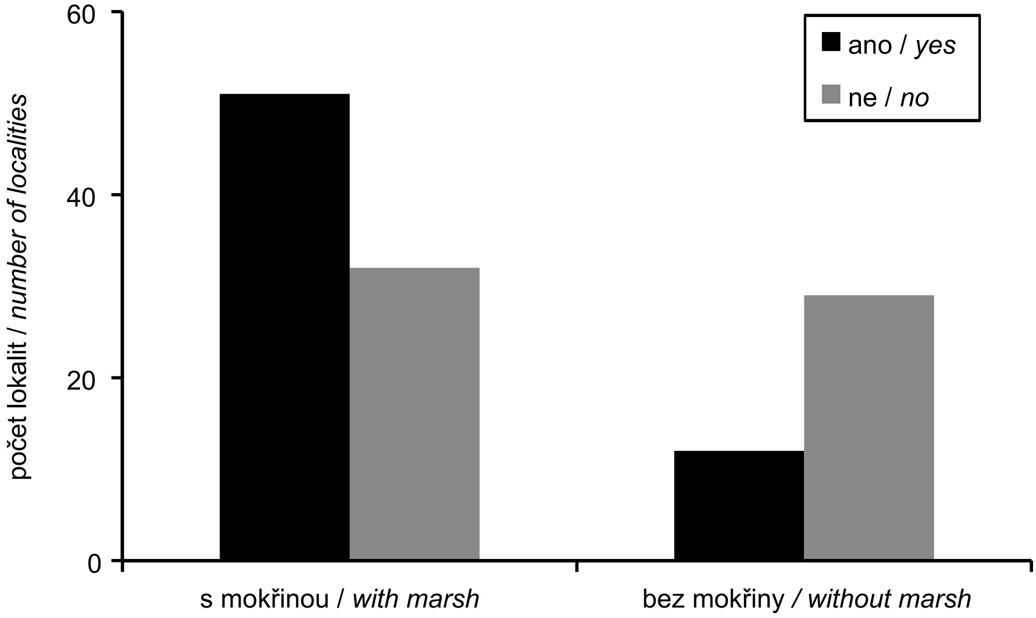
Z celkového počtu 151 lokalit nebyl u 83 z nich stanoven jejich historický status. Ze zbývajícího počtu 68 lokalit průkazně převažovaly lokality s každoročním hnízdním výskytem čejek (n = 33, 49 %), méně bylo lokalit s pravidelným výskytem (čejky na lokalitě hnízdily 3 až 4krát během 5 let; n = 24, 35 %) a nejméně bylo lokalit s občasným hnízdním výskytem (čejky na lokalitě hnízdily 1 až 2krát během 5 let), popř. šlo o úplně novou lokalitu (n = 11, 16 %) (test homogenity, χ^2 = 10,9, df = 2, P = 0,004). Přes mírný trend vyšší hnízdní úspěšnosti čejek na každoročně obsazovaných hnízdištích nebyl shledán statisticky významný rozdíl v zastoupení lokalit s přítomností kuřat (tj. s varujícími čejkami nebo pozorovanými mláďaty) v závislosti na historii lokality (χ^2 = 2,3, df = 2, P = 0,31).

Ohrožení lokalit

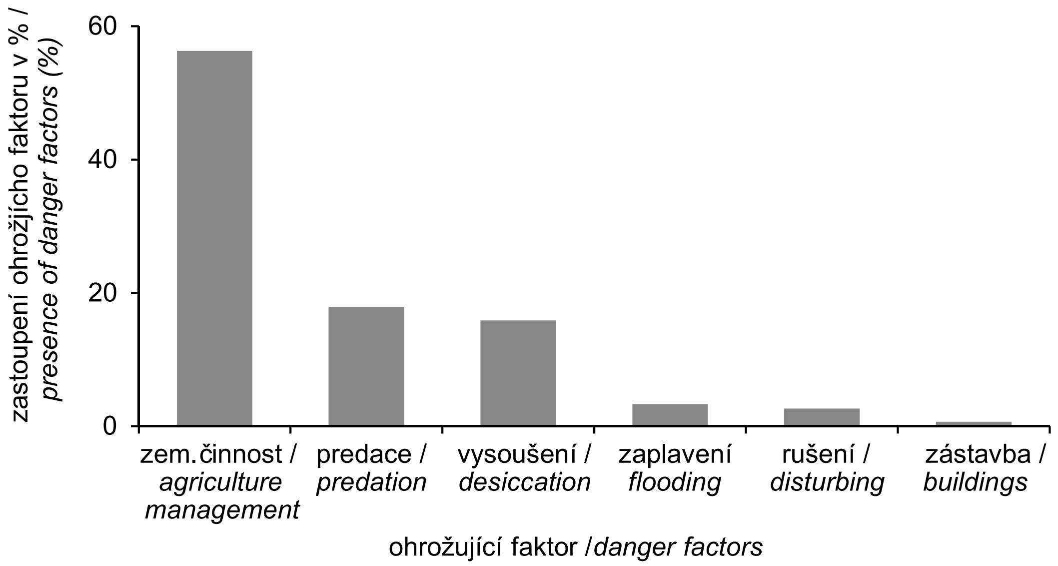
Sčitatelé na jednotlivých lokalitách uváděli významné ohrožující faktory pro dané hnízdiště. Jednoznačně nejvýznamnějším faktorem považovaným pozoro-



Obr. 7. Četnost varujících čejek / pozorovaných mláďat v nejvíce zastoupených hnízdních biotopech (n pro oraniště = 26, jař = 19, louka/pastvina = 11, ozim = 17).
Fig. 7*. Frequency of warning lapwings / observed chicks in the most represented breeding habitats (n for ploughed fields = 26, spring cereal = 19, meadow/pasture = 11, winter wheat = 17).*



Obr. 8. Přítomnost varujících čejek / pozorovaných mláďat na lokalitách s mokřinou (n = 83) a lokalitách bez mokřiny (n = 41).
Fig. 8. *Presence of alarm calling lapwings / observed chicks on localities with marsh (n = 83) and localities without marsh (n = 41).*



Obr. 9. Zastoupení hlavních ohrožujících faktorů pro každou lokalitu uvedených respondenty (vyjádřeno v % pro každý uváděný ohrožující faktor zvlášť, n = 151 lokalit pro každý ohrožující faktor, pozorovatelé mohli uvést více než jeden nebo žádný ohrožující faktor na jedné lokalitě).
Fig. 9. *Representation of particular threatening factors in particular localities (expressed as % for each factor separately, n = 151 localities for each factor, observers could indicate more than one or none factor per locality).*

vateli za ohrožující danou lokalitu byla zemědělská činnost (test homogenity: χ^2 = 58,8, df = 3, P < 0,001). Dalšími významnými ohrožujícími faktory byla predace a vysoušení lokalit (obr. 9).

DISKUSE

Výhody a slabiny monitoringu, úspěšnost dotazníkové akce a úsilí mapovatelů

Dotazník byl navržen v rozsáhlejší podobě pro zachycení co nejpodrobnějších a objektivně vyhodnotitelných údajů, což zvyšovalo nároky kladené na respondenty. Alternativou pro mapovatele bylo poskytnout jakákoliv data o pozorování čejek bez využití navrženého dotazníku. Většina respondentů odevzdala svá pozorování pomocí připraveného formuláře. Data zaslaná v této podobě byla snáze zpracovatelná a výrazně užitečnější pro hodnocení. Ve formuláři byly vždy vyplněny údaje o autorovi a umístění jeho lokality (na rozdíl od části zpráv došlých jinou formou) a respondenti poměrně ochotně vyplňovali i další požadované údaje. Pouze v několika případech nebyla hnízdní lokalita popsána dostatečně podrobně. Kolonka pro další poznámky často obsahovala informace upřesňující jiné části dotazníku nebo popisující neobvyklé situace. Pokud tedy pozorovatel lokalitu navštívil v daném sledovaném období, celkem bez problémů formulář vyplnil. V případě, kdy šlo o doplnění konkrétního údaje či měl pozorovatel na výběr z několika možností, vždy byly výsledky snáze hodnotitelné než když byla sčitateli ponechána volnost v obšírnějších popisech, jež mohly být respondenty pojaty vzájemně velmi odlišně. I tento přístup však měl svůj přínos v situacích, kdy bylo vhodnější přenést zodpovědnost za podobu výsledku a jeho interpretaci až na konečné zpracovatele (např. při hodnocení sporného ukazatele úspěšnosti líhnutí). Předložený formulář tedy považujeme za dobrý nástroj pro sběr dat od většího okruhu pozorovatelů, což dokazují i výsledky této studie, nicméně v rámci monitoringu AEO bude vhodné jeho podobu mírně upravit, vylepšit a zjednodušit v souladu s okruhy problémů diskutovanými níže.

Jako nejproblematičtější se ukázala obecná neochota realizovat kompletní monitoring (čtyři návštěvy) v průběhu celé sezóny. Poslední období monitoringu bylo proto nutno v konečné analýze zcela vynechat, protože o pohnízdních shromaždištích se sešlo jen velmi málo údajů. Motivaci sčitatelů později v sezóně by mohlo zvýšit např. interaktivní vyplňování dat elektronickou formou, kde by sčitatelé měli okamžitou zpětnou vazbu a např. věděli, „kdo v jejich okolí sčítá“ a „jak si vedou čejky v různých regionech ČR“. Rovněž průběžné vyhodnocování a zpřístupnění předběžných výsledků sčitatelům ještě během sezóny by mohlo zvýšit jejich motivaci k provedení dalších kontrol. Ukázalo se (viz níže), že není nezbytné vyžadovat ani tři kontroly během celé sezóny. Kromě toho, že i požadavek třetí kontroly mohl odradit některé pozorovatele pro svou časovou náročnost, z výsledků vyplývá, že třetí kontrola nepřináší informaci adekvátní vynaloženému úsilí. Klíčové údaje pro zhodnocení využívaných biotopů a faktorů ovlivňujících úspěšnost líhnutí poskytují totiž v uspokojivé formě první dvě kontroly. Argumentem pro vynechání třetí kontroly v budoucím monitoringu soustředěném na vytipování vhodných hnízdišť pro AEO na orné půdě (ačkoliv pro zaznamenání biotopů využívaných čejčími rodinkami v době vodění kuřat nebo při náhradním hnízdění by mohla být 3. kontrola užitečná) je také fakt, že kombinace ANO-NE-ANO (tj. přítomnosti čejek na lokalitě během 1., 2. a 3. kontroly) se v našem vzorku vůbec nevyskytla. Naopak velmi užitečnou položkou se stala přítomnost varujících rodičů jako alternativa přímého pozorování kuřat, kterou respondenti ochotně zaznamenávali a která umožnila analyzovat vliv různých biotopových atributů na úspěšnost líhnutí. Čejku vodící mláďata lze obvykle spolehlivě identifikovat právě podle charakteristického nápadného varování před nebezpečím při přiblížení pozorovatele či predátora k ukrytým mláďatům (Cramp 1983). Tato položka by proto měla být součástí i budoucího monitoringu.

Přestože výsledky některých hodnocení není možné považovat za reprezentativní a zcela spolehlivé pro jejich malé množství (zvláště z některých regionů), jsou díky možné místní specifičnosti cenným doplňkem naší obecné představy o velkoplošných trendech na území ČR a jsou proto i v této podobě užitečné. K opatrnosti při interpretaci výsledků nabádá také velká heterogenita pozorovatelů, mezi něž byli ve snaze vytěžit maximum ze všech získaných dat zařazeni např. i patrně zkušenější autoři této práce. Ti mohli věnovat sběru dat více úsilí a pokrýt tak více lokalit v některých regionech, konkrétně v jižních a východních Čechách. Nezdá se ale, že by tím byla zkreslena např. informace o ukazateli úspěšnosti líhnutí. Nejvyšší podíl lokalit s varujícími čejkami v době vodění mláďat byl totiž zaznamenán právě ve východních Čechách a naopak nejnižší v jižních Čechách, zatímco ostatní regiony (mimo operační prostor autorů) dosahovaly průměrných hodnot. Přesto však pro formulování široce použitelných AEO bude žádoucí uskutečnit důkladnější monitoring čejčích hnízdišť, zejména v regionech málo zmapovaných v roce 2008.

Forma dotazníku

Většina dotazníků došla v elektronické podobě, méně poté v papírové podobě pozemní poštou. Vyplňování elektronických dotazníků je v současné době uživatelsky přijatelnější a také atraktivnější; tak je tomu např. v Jednotném programu sčítání ptáků v ČR (http://jpsp.birds.cz). Zde pozorovatel vybírá z nabízených možností v rolovacích lištách a po odeslání jsou výsledky jednoduše přiřazeny k ostatním archivovaným záznamům, takže nedochází k žádnému dodatečnému vyřazování nekvalitně vyplněných dat a údaje jsou tak ihned připraveny pro vyhodnocení. To může být velmi důležité při naléhavé potřebě výběru vhodných lokalit pro AEO či pohotového vyhodnocení jejich účinnosti.

Hnízdní prostředí

Jednoznačná převaha výskytu čejek na orné půdě dokazuje urgentní potřebu ochrany čejky chocholaté v tomto prostředí bez ohledu na region. Naopak louky a pastviny nejsou v současné době klíčovými hnízdišti v takovém rozsahu jako tomu bylo dříve. Mohou však stále hrát důležitou roli v době vodění kuřat (viz např. Redfern 1982, Galbraith 1988a, Johansson & Blomqvist 1996). Zhodnocení tohoto jejich významu však vyžaduje detailnější zacílenou studii na čejčí kuřata. Z typu obsazeného biotopu vyplývá zejména důraz na oraniště (či následné jařiny) a ozimy, jež představují nejvýznamnější hnízdní prostředí čejek z hlediska absolutní početnosti hnízd v zemědělské krajině ČR. Cílem monitoringu nebylo zjišťovat preference čejek při výběru hnízdního prostředí. Data z lokálních prací shledávají nejpreferovanějším hnízdním biotopem čejek oraniště (Šálek 1994, vlastní nepubl. údaje), zatímco ozimy, ač hojně pro hnízdění vybírané, nejsou obvykle pro svůj celkově vysoký podíl v rámci obhospodařovaných ploch ve skutečnosti preferovány. V oraništích čejky formovaly nejpočetnější hnízdní uskupení, která mají také obecně vyšší šanci na úspěšné vyhnízdění díky efektivnější obraně čejek vůči predátorům (např. Elliot 1985, Šálek & Šmilauer 2002). Tento důvod a naopak citelné ztráty při souvislém vláčení a setí vzhledem k velkému počtu současně ovlivněných hnízd činí z oranišť klíčový biotop pro cílenou ochranu hnízdících čejek prostřednictvím AEO na orné půdě. Je ovšem nutno poznamenat, že rozdílné zastoupení dominantních biotopů zaznamenaných na hnízdištích v jednotlivých regionech může být dáno nejen preferencemi lokálních populací čejek, ale také rozdílným zastoupením samotných biotopů v regionu (např. v jižních Čechách může převažovat nabídka ozimů a ve východních Čechách naopak oranišť). Pro posouzení biotopových preferencí je nezbytné mít k dispozici celkovou nabídku biotopů v dané oblasti, stávající monitoring však se získáním tohoto údaje nepočítal.

Z poměrného zastoupení luk, mokřin a hnojišť (jako specificky registrovaných prvků prostředí přítomných na hnízdní lokalitě) vyplývá, že čejkám vyhovovaly lokality zejména s přítomností mokřiny, pokud možno také v kombinaci s loukami v blízkém okolí. Tato stanoviště jsou klíčová z hlediska nabídky vhodné potravy, kterou představují žížaly, rozmanitý hmyz a členovci, a to jak pro dospělé čejky, tak i kuřata (např. Beintema et al. 1991, Sheldon 2002, Hudec & Šťastný 2005). Pro vytipování vhodných hnízdišť čejek není důležitý pouze charakter samotného pozemku (např. oraniště), ale současně i podoba jeho okolí, tj. zda jsou přítomny louky a mokřiny nabízející kromě hnízdních příležitostí také potravní možnosti.

Početnost čejek na hnízdištích během sezóny, historický statut lokalit a hnízdní úspěšnost

Na hnízdištích převládaly malé skupiny čejek do čtyř párů. To sice do určité míry snižuje efektivitu potenciálních AEO na jednotlivých plochách, pro malý podíl velkých seskupení však není možné se při ochraně hnízdišť soustředit výhradně na ně. Navíc reálný počet jedinců na lokalitě bývá často vyšší než činí první odhad při monitoringu. Někteří ptáci mohou v okamžiku monitoringu sbírat potravu mimo hnízdiště a méně nápadné samice sedící na hnízdech nemusí být vůbec zaregistrovány (vlastní nepubl. údaje). Příznivým jevem je naopak velké množství pravidelných hnízdišť, jejichž lokalizace je předvídatelná a lze proto poměrně spolehlivě s předstihem navrhovat vhodné lokality pro AEO. Tím spíše, že na těchto pravidelných hnízdištích dosahovaly čejky i vyšší úspěšnosti líhnutí (byť neprůkazně, pravděpodobně kvůli malému vzorku lokalit). Alternativním (metodickým) vysvětlením pro nízký podíl hnízdišť vedených jako občasná však může být skutečnost, že se pozorovatelé cíleně (avšak nezáměrně) soustředili na lokality, kde čejky v předchozích letech pozorovali. V takovém případě získaný vzorek není náhodným výběrem ze všech existujících hnízdišť a výsledky získané jeho analýzou je nutno interpretovat jen s velkou opatrností.

Početnosti čejek na hnízdištích během první a druhé kontroly průkazně korelovaly (ač s přibližně polovičním úbytkem do druhé kontroly), což nasvědčuje setrvání mnoha čejek na svých hnízdištích i přes vysoké ztráty na snůškách (na cca 50 % hnízdišť nebyli při druhé kontrole zaznamenáni varující rodiče ani mláďata). Jako zcela minimální varianta monitoringu hnízdících čejek se tedy jeví druhá kontrola (období líhnutí kuřat), kdy lze velmi zhruba odhadnout i míru přežívání snůšek. Jde samozřejmě o velmi hrubé odhady, které však mohou být užitečné pro účely velkoplošného monitoringu AEO se zapojením široké veřejnosti.

Nejvyšší podíl varujících rodičů v oraništích (a následných jařinách, či kukuřici po oraništi) a naopak nízký v loukách, pastvinách a jařinách (existujících již jako jařiny v období výběru hnízdišť) je poněkud v rozporu s prokázanou preferencí pastvin jako biotopu vhodného pro výchovu čejčích kuřat ve Skotsku (Galbraith 1988a) i ve Švédsku (Johansson & Blomqvist 1996). Důvodů této odlišnosti může být několik. Buď čejčí rodinky v ČR louky a pastviny skutečně tolik nevyužívají (ale tuto možnost je potřeba pro neprůkaznost trendu a menší vzorek lokalit zvažovat s maximální opatrností) nebo se v ČR nenachází dostatek dostupných a vhodných pastvin (tak tomu bylo např. ve Walesu; Sharpe 2006), což naznačují výsledky zejména z východních Čech (obr. 3), či se prostě kuřata vylíhlá v oraništích pro následnou vysokou mortalitu vůbec nestačí na pastviny přesunout, podobně jako kuřata z orné půdy ve Skotsku (Galbraith 1988b). Možností je také podcenění luk a pastvin pozorovateli pro řídký výskyt hnízd na počátku hnízdní sezóny, takže tyto lokality nebyly následně dostatečně sledovány ani v období vodění mláďat.

Atraktivní hnízdní lokality čejek lze celkem spolehlivě identifikovat již koncem března (v období výběru hnízdišť) a již v té době je tedy nutno jim zajistit vhodnou ochranu. Naopak lokality zjištěné jako obsazené až ve druhém, případně třetím termínu monitoringu (2 % případů) zřejmě nemají pro hnízdní populaci čejek zásadní význam, ačkoliv je užitečné mít tyto lokality podchycené jako případná náhradní hnízdiště. Zjištění, že na většině lokalit čejky setrvávají od začátku hnízdního období až do doby vodění kuřat (rozdílné lokality pro vodění kuřat však mohly být v monitoringu podceněny, viz výše) či kladení náhradních snůšek, je příznivé pro zpracování cílených AEO, neboť se tím zvyšuje efektivita opatření na konkrétní lokalitě i přes průběžné ztráty způsobené např. predací. Podmínkou je samozřejmě odpovídající časové rozvržení AEO, které by mělo trvat od konce března (počátku prvních snůšek) až do vzletnosti mláďat z náhradních snůšek, tj. přibližně do poloviny června. Vedle fungujících krátkodobých ochranářských opatření formou přímé ochrany hnízd (Kubelka et al. 2012) je tedy potřeba zavést právě dlouhodobější AEO (podrobněji viz Zámečník et al. 2010), které bude v širším časovém i prostorovém měřítku systematicky zlepšovat hnízdní podmínky čejek chocholatých v zemědělské krajině s převahou orné půdy.

Významné regiony, ohrožující faktory čejčích hnízdišť

Vezmeme-li v úvahu pouze výsledky monitoringu z hlediska pokrytí ČR, byly by nejvýznamnějšími regiony (do kterých by se měla soustředit ochrana hnízdišť čejky chocholaté) jižní a východní Čechy. Nerovnoměrnost zastoupení lokalit v regionech v našem vzorku však může být dána nejen tím, že v jižních a východních Čechách se nachází opravdu nejvíce hnízdišť, ale také tím, že zde byl plánovaný monitoring jednotlivými koordinátory nejvíce propagován a posléze i realizován (do těchto regionů byly rovněž soustředěny terénní aktivity všech tří autorů tohoto příspěvku). Vyšší koncentrace čejčích hnízdišť v některých regionech může rovněž znamenat zvýšenou motivaci pozorovatele k provedení monitoringu a následně vyšší podíl údajů z daného regionu. Avšak důležitost jižních, východních a středních Čech zdůrazňuje již Šálek (2000b), kdy v letech 1995–1997 se 60 % čejčích hnízdišť v ČR nacházelo právě v těchto třech regionech.

V souvislosti s hnízděním čejek na orné půdě je jako nejzávažnější ohrožující faktor čejčích hnízdišť v ČR uváděna zemědělská činnost, a to na více než polovině lokalit. Nejvyšší hodnoty z hlavních dominantních biotopů dosáhlo pochopitelně oraniště, kde bylo zemědělství jako ohrožující faktor uvedeno na 82 % lokalit. Je však nutné odlišit negativní vliv přímé likvidace snůšek (např. Baines 1990, Berg et al. 1992) a mláďat (např. Schekkerman et al. 2009, Rickenbach et al. 2011) zemědělskou technikou při kultivaci pole od nepřímých vlivů intenzifikace zemědělství (viz úvod). Nepřímé vlivy intenzifikace zemědělství mohou být pozorovatelům při monitoringu čejek méně zřejmé, ale zpravidla hrají zásadní roli. Navíc lze náhlým snížením intenzifikace zemědělství dosáhnout výrazného zvýšení hnízdní produktivity čejky i dalších bahňáků zemědělské krajiny (Galbraith 1988a, Schekkermann 2008), což je potřeba zohlednit při plánování AEO. Na 17 % lokalit je uváděna jako významný negativní faktor predace, ta však bude ve skutečnosti hrát daleko významnější roli (srovnání např. Šálek 1992, MacDonald & Bolton 2008, Teunissen et al. 2008), protože je obtížné ji odhadnout jen na základě pozorování během krátkých návštěv lokalit bez detailního sledování hnízd. Na 15 % lokalit je uváděn ohrožující faktor vysoušení lokalit, což poukazuje na pokračující problém odvodňování i v současnosti. Další uváděné ohrožující faktory (zaplavení, rušení a zástavba) se uplatnily v podstatně menší míře.

Výše byly prezentovány pouze nejpodstatnější a nejpřesvědčivější výsledky monitoringu čejek v roce 2008, další sporné otázky si zaslouží upravený monitoring a podrobnější rozpracování. Výsledky stávajícího monitoringu mohou posloužit jako vhodný odrazový můstek pro další důkladný a reprezentativnější sběr dat v rámci celé ČR. K tomu bude zapotřebí provést podrobnější monitoring čejčích hnízdišť, zejména v regionech nedostatečně zmapovaných v roce 2008. Podrobnější monitoring by se mohl navíc zaměřit na získání přesnějších údajů o hnízdní úspěšnosti čejek, o výšce porostu na hnízdních lokalitách, o rozloze hnízdišť, o čase stráveném na lokalitě (terénním úsilí) se zohledněním předchozích zkušeností mapovatelů s výzkumem a sledováním čejek.

ZÁVĚR

Navržený dotazník přinesl užitečné informace o hnízdění čejek v ČR, které jsou dále využitelné při výběru vhodných hnízdišť pro připravované AEO a plánování dalšího podrobného monitoringu čejčích hnízdišť v ČR. Dotazník také ověřil možnosti využití dobrovolníků při vlastním monitoringu účinnosti těchto opatření. Míra jejich zapojení závisí na podobě dotazníku a časové náročnosti terénní práce. Efektivitu velkoplošného monitoringu může významně podpořit zejména zavedení atraktivnější elektronické verze dotazníku a snížení počtu požadovaných kontrol čejčích hnízdišť na dvě (začátek hnízdění a období líhnutí), v krajním případě na jedinou, a to v období líhnutí mláďat.

Z výsledků monitoringu čejek v roce 2008 zejména vyplývá, že: (1) za hlavní a dostatečně zmapované oblasti hnízdního výskytu čejek v ČR lze považovat východní a jižní Čechy; (2) klíčovým prostředím jsou oraniště nejen z hlediska početnosti, ale zřejmě i úspěšnosti hnízdění a efektivity připravovaného AEO; (3) za nejzávažnější ohrožující faktor hnízdišť čejek v ČR je považována zemědělská činnost; (4) důležitou součástí hnízdišť je přítomnost podmáčených ploch a luk; (5) velká hnízdní seskupení jsou vzácná a nenabízí dostatek prostoru soustředit se při ochraně hnízdišť výhradně na ně; (6) pravděpodobně převládají pravidelná hnízdiště s vyšší úspěšností líhnutí umožňující s předstihem navrhovat vhodné lokality pro účinná AEO; (7) vhodné hnízdní lokality čejek lze spolehlivě identifikovat již koncem března, od kdy je žádoucí zajistit vhodnou ochranu těchto ploch až do vzletnosti mláďat z náhradních snůšek, tj. přibližně do poloviny června. Při interpretaci některých výsledků této práce je potřeba mít na zřeteli, že monitoring čejek v roce 2008 měl určité metodické slabiny, kterých bude potřeba se v dalších navazujících akcích vyvarovat.

PODĚKOVÁNÍ

Náš velký dík patří řadě ornitologů, kteří se do monitoringu v roce 2008 zapojili a poskytli nám řadu cenných informací: J. Bartoníček, J. Bašta, J. Bureš, J. Cepák, G. Čamlík, T. Diviš, M. Dusík, M. Dušek, M. Fejfar, M. Hanzlíková, K. Harant, J. Havlíček, J. Horák, M. Horáková, M. Chaloupka, K. Chmel, A. Kaduch, R. Kalous, V. Kodet, V. Kovář, V. Koza, J. Mach, J. Malina, L. Malý, R. Muláček, V. Opluštil, M. Pakandl, L. Praus, J. Pražan, J. Sladký, J. Šinko, T. Telenský, P. Tousek a A. Vondrka. Dále bychom rádi poděkovali K. Řezáčové za významnou pomoc při zpracování primárních dat a dvěma anonymním recenzentům za cenné připomínky vedoucí k vylepšení původního rukopisu. Článek vznikl s podporou projektu CIGA ČZU v Praze č. 20124218 – Rizika hnízdních ztrát čejky chocholaté v zemědělské krajině a možnosti jejich zmírnění.

SUMMARY

Although the Northern Lapwing (Vanellus vanellus) *remains the most common breeding shorebird in the Czech Republic, it is an unceasingly declining species in the country; the population numbers dropped by about 80% during the last 35 years (Česká společnost ornitologická 2011).*

In 2008, a national survey focused on this species was announced with the aim to (1) update the list of breeding grounds in the country; (2) describe habitat characteristics of the nest sites including character of vegetation cover, presence of elements such as wetlands, marshlands, meadows and dunghills; (3) evaluate hatching success and specify factors threatening the breeding lapwings; (4) assess the involvement of volunteers in the project, their effort to collect and supply the data in a required form; (5) evaluate meaningfulness of such project for development of a suitable agri-environmental scheme (AES) for breeding lapwings on arable land.

Thirty seven observers collected field data during 300 visits on 151 breeding grounds (Table 1, Fig. 2) particularly in southern and eastern Bohemia (Fig. 1). The questionnaire was readily filled in by the majority of observers and the final data set provided results which were useful in several ways. In particular, many important breeding grounds of lapwings in the Czech Republic were identified. In spite of the documented applicability of volunteer work in the monitoring of AES effectiveness, we suggest some modifications of the monitoring scheme in the future. For example, three visits (out of four recommended in this project) per breeding ground were conducted on 47 sites only (Table 2). The effort of volunteers decreased from 76% of performed second visits after the suc-

cessful first one (i.e., if the lapwings were recorded) to 57% of performed third visits after the successful second one (Test of proportions, n_1 = 113 and n_2 = 86 breeding grounds, P = 0.005). Therefore, a reduction of the number of obligatory visits per site from four to two (one in the period of the establishment of nesting groups and one in the hatching period) would increase the amount of observers willing to be involved in this monitoring. Furthermore, we point out that the observers should have an immediate positive feedback which would increase their labour effort; a more interactive questionnaire easily available online is also recommended as it provides an opportunity for quick updates and electronic presentation of the results during the breeding season.

The results of this study show in particular that (1) the representativeness of the collected data largely varied among the regions (Fig. 1); (2) ploughed fields are probably the key habitat for breeding lapwings as well as for application of the most effective AES, given the highest numbers per breeding site in the hatching period (mean 9.6 ± 8.09[SD] in ploughed fields versus 5.8 ± 4.69[SD] in other habitats [Wilcoxon test, W = 936, n= 83, P = 0.04; Fig. 3 and 6]) as well as given the highest numbers of alarm calling birds indicating successful hatching there (Fig. 7); (3) agricultural activities were identified by the observers as the main factor that negatively influences breeding lapwings (Fig. 9); (4) wet patches and meadows are important components of breeding grounds (Appendix 1) and presence of wet patches supports hatching success (χ^2 = 10.12, df = 1, P = 0.001, Fig. 8); (5) large nest aggregations are rare (Fig. 4) and thus insufficient for sole protection of lapwing populations; (6) suitable breeding sites were reliably identified at the end of March and lapwings usually stayed there until late season (Spearman rank correl. coeff., rs = 0.61, P < 0.05, Fig. 5), suggesting a necessity to provide appropriate protection of breeding birds from March until mid June (i.e. fledging period of the young); (7) regularly occupied breeding grounds with relatively higher hatching success are probably a frequent alternative which provides an opportunity for effective application of AES on selected breeding grounds enough time before beginning of the breeding season, even though the rate of hatching success varied widely among regions (Appendix 2).

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Chapter 6

Protection of the Northern Lapwing - Use of agri-environment climate measures

Václav Zámečník

Leaflet introducing ways farmers, how to protect lapwings. Three main options are mentioned: 1) conserving existing and creating new wetlands in open agricultural landscapes is key for lapwings, 2) protection of nests from destruction by agricultural machinery is possible by marking them with two bamboo poles placed on a line 5 m from the nest and 3) a targeted agro-environment climate measure (AECM) for the most valuable breeding areas on arable land called Protection of the Northern Lapwing. Leaflet is introducing basic condition of AECM to the farmers and also environmental benefits for other species as Ring Plovers, Common Redshank, Black-tailed Godwits, Skylarks or Brown Hares. In the second half of the year, pollinators, seed-eating birds or various game species benefit from the measure.

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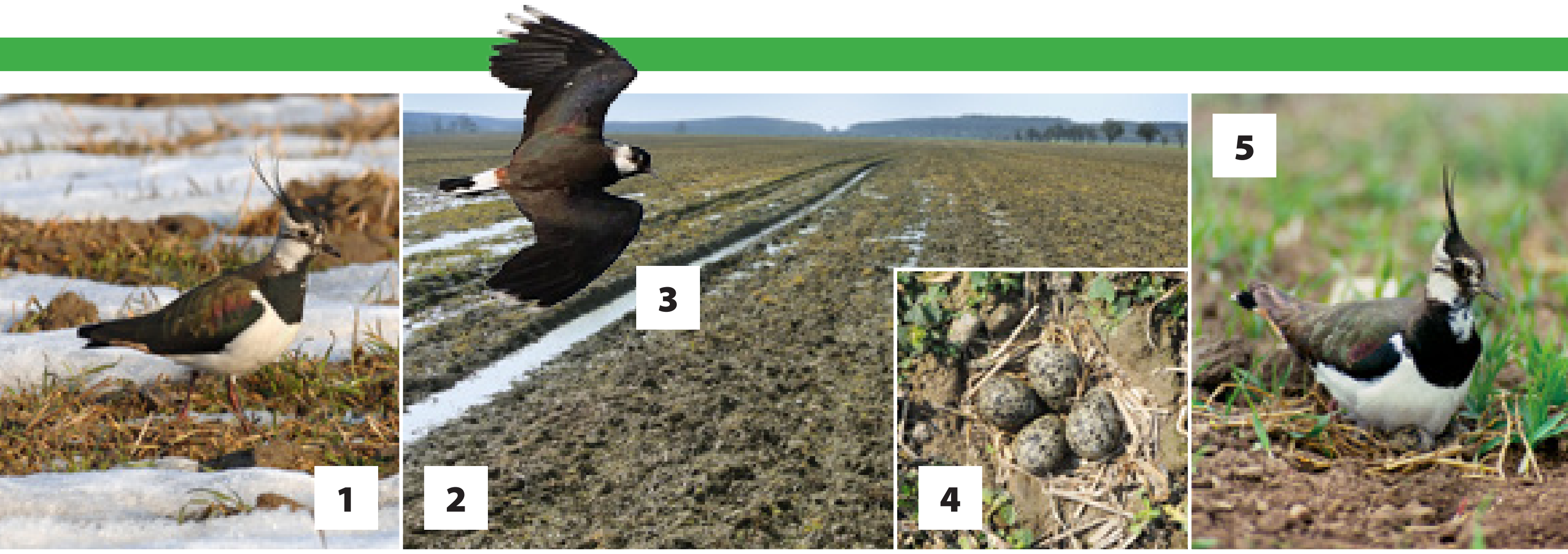
Available only in Czech.

Ochrana čejky chocholaté

Využití agroenvironmentálně-klimatického opatření

Čejka chocholatá *je elegantní pták velikosti hrdličky s nápadnou chocholkou na hlavě. Tento mizející ptačí druh můžete spatřit na zamokřených i sušších polích, na vlhkých loukách, v blízkosti vodních ploch a vodotečí nebo na dnech upuštěných rybníků.*

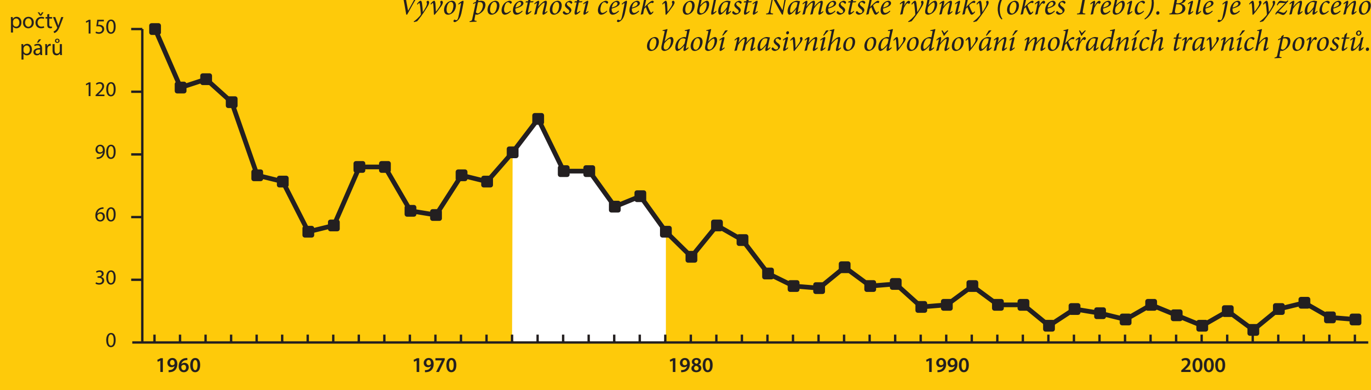


- **Přílet.** *První čejky je možné pozorovat už od února, kdy různě velká hejna protahují krajinou (1).*
- **Tok.** *Postupně obsazují hnízdiště (2), obvykle ve skupinách. Samci přitom předvádí nápadné svatební lety doprovázené pronikavým voláním (3).*
- **Snůšky.** *Do jednoho z hnízdního důlku, který samec hloubí na zemi, samice postupně snese nejčastěji 4 vajíčka (4), na kterých střídavě sedí oba rodiče (5). Pokud čejky o vajíčka přijdou, ať už kvůli zemědělským pracím nebo predaci, obvykle snesou náhradní snůšku, kterou tvoří často jen 3 vajíčka menších rozměrů.*

OHROŽENÍ ČEJKY CHOCHOLATÉ

Čejka chocholatá je jedním z nejvíce ubývajících ptačích druhů u nás. Jen od roku 1982 se její stavy snížily zhruba o 80 %. K poklesu početnosti čejek přitom v mnoha oblastech docházelo už před rokem 1982 v reakci na masivní **odvodňování mokřadních luk** a s tím spojený zánik tradičních hnízdních stanovišť (viz graf). Čejku ohrožuje také **ničení hnízd** při jarních zemědělských pracích na polích (např. jarní příprava půdy k osetí) nebo na loukách (např. vláčení), zvýšená **predace čejčích mláďat** a **nízká úspěšnost náhradních snůšek** kvůli pokročilé sezóně i četným predátorům, kteří v této době již jen s velkými obtížemi hledají potravu pro svá mláďata v biotopově silně ochuzené polní krajině.

Vývoj početnosti čejek v oblasti Náměšťské rybníky (okres Třebíč). Bíle je vyznačeno období masivního odvodňování mokřadních travních porostů.



VII VIII IX X XI XII

- **Mláďata.** *Zhruba po 27 dnech sezení se líhnou mláďata (6), která se krátce po oschnutí rozbíhají z hnízda. Samička mláďata podle potřeby zahřívá a vodí je za potravou (7), nejčastěji k mokřinám (8). Samec, pokud setrvá až do této doby, postává opodál a bedlivě rodinku střeží. Pokud se objeví nebezpečí, oba rodiče vzlétnou a varují (9). Přitom na potenciálního predátora útočí nebo se ho snaží odlákat od mláďat. Přibližně po 5 týdnech od vylíhnutí jsou mláďata vzletná.*
- **Pohnízdní období a odlet.** *Tohoroční mláďata vytváří s dospělými ptáky různě velké skupiny a společně se potulují po krajině (10). Zimují v jihozápadní Evropě.*

MOŽNOSTI OCHRANY

Pro čejky je klíčové **zachovat stávající a vytvářet nové mokřady** v otevřené zemědělské krajině. **Ochrana hnízd před zničením** zemědělskou technikou je možná pomocí jejich vyznačení dvěma bambusovými tyčemi umístěnými na řádku 5 m od hnízda (A). Pro nejcennější hnízdiště na orné půdě bylo připraveno zacílené **agroenvironmentálně-klimatické opatření** (AEKO) Ochrana čejky chocholaté, které v první polovině roku kromě čejek chrání také kulíky říční, skřivany polní nebo zajíce polní, výjimečně i naše nejvzácnější bahňáky vodouše rudonohé a břehouše černoocasé. V druhé polovině roku z opatření profitují opylovači, semenožraví ptáci nebo různé druhy zvěře (B).

Podopatření AEKO Ochrana čejky chocholaté

• **pětiletý závazek** mezi zemědělcem a státem • **každoroční vyplácení** dodatečných nákladů a ztrát zemědělci • roční výše podpory je **667 EUR/ha** (cca 18 000 Kč/ha) • podpora se vztahuje na plochu, která se musí vymezit jako **samostatný díl půdního bloku** • zemědělec pobírá i další platby **včetně SAPS a LFA** • pokud o podporu žádá ekolog, plocha dílu půdního bloku s hnízdištěm čejky již není podpořena dotací v rámci ekologického zemědělství • zemědělci musí plnit podmínky tzv. „cross compliance" a minimální požadavky na použití hnojiv a přípravků na ochranu rostlin

Podmínky podopatření

- od 1. 1. do 15. 6. – zabránění přejezdům zemědělské i jiné techniky (výjimka se vztahuje na 4 m pás od okraje dílu půdního bloku pro přejezdy techniky)
- od 16. 6. do 15. 7. – vysetí stanovené směsi (certifikované, uznané nebo kontrolované osivo, které není starší dvou let od posledního úředního odběru vzorku uvedeného na úředních návěskách; v případě setí směsi již namíchaného osiva je nutné směs použít nejpozději do dvou let od vydání míchacího protokolu) v jedné ze dvou variant:
  - složení stanovené směsi pro krmnou variantu:
10 kg prosa setého,
10 kg lesknice kanárské,
5 kg slunečnice roční na hektar
  - složení stanovené směsi pro opylovače:
6,25 kg svazenky vratičolisté,
5,00 kg hořčice bílé,
5,00 kg řepky jarní,
5,00 kg pohanky obecné,
3,75 kg komonice bílé na hektar
- od 15. 11. do 31. 12. – zapravení porostu do půdy, optimálně hlubokou orbou

Návrh hnízdišť zařazených do AEKO Ochrana čejky chocholaté naleznete v LPIS u položky tisk č. 3 (Agroenvironmentální údaje PRV 2015–2020 k datu). Pokud je hnízdiště čejky vymezeno, najdete ve sloupci „typ louky" slovo „ČEJKA". Informaci o vymezeném hnízdišti lze rovněž najít na konkrétním dílu půdního bloku na záložce „Podrobné" v části „AEO info – ENVIRO vymezení PRV 2015–2020". Vymezené hnízdiště lze graficky znázornit v mapě zapnutím žárovky v části „Dotace-Nové ENVIRO".

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Discussion

The Northern Lapwing belongs to a large family of bird species for which agricultural landscapes are the dominant environment. Historical sources indicate that with the development of agriculture, its number increased in the Czech Republic, but unfortunately this development reversed during the 20th century (Šťastný et al. 2006). The ploughing of waterlogged flowering grasslands and the drainage of the landscape seems to be essential (Chapter 1, Klůz 1957, Šálek 2000, Fiala 2008). Impact of these two connected interventions is probably best described from the area of ponds near town Náměšť nad Oslavou in central part of Czech Republic from 1958 until 2006. Before ploughing and irrigation the total number of nesting lapwings fluctuated from 53 to 126 pairs, while after the number of birds dropped to 6 - 30 pairs (Fiala 2008). When considering, how to promote more successful survival of lapwings in farmland, revitalization of once irrigation land and creation of new attractive wetland features should be one of the priorities.

Return of water to the landscape

Only five decades after last period of in most cases unreasonable irrigations (Vašků 2011) there general political agreement of the need to return water to the landscape and to enhance the overall ecological stability of the landscape, especially in response to ongoing climate change. The revitalization of the agricultural landscape including biodiversity is part of key European strategy called Green Deal (European Commission 2019) or Farm to Fork Strategy (European Commission 2020), on national level the same goals are part of the Strategic framework Czech Republic 2030 (Ministry of Environment 2023) and several other strategies. For the lapwing and waders this bring another opportunity to improve their living conditions. However, this process is slow and very expensive. While the creation of smaller wetlands, especially to support biodiversity, is relatively easy - the basic premise is the interest of the land owner - the revitalization of the river network is a long and expensive process with an uncertain end. In contrast to agricultural subsidies, these are individual projects that must always be solved directly at a specific location, taking into account local conditions. Since 2014 700 projects amounting CZK 5.1 billion (EUR 207 million) to restore natural water processes including natural flow regime within the landscape have been funded from the Operation Programme “Environment”, i.e. from the EU structural funds and hundreds of small projects have recently been supported from national subvention programmes/subsidiary schemes under the Ministry of the Environment of the Czech Republic (Landscape Management Programme, Landscape Natural Function Restoration Programme) (The Nature Conservation Agency of the Czech Republic 2023, unpublished data). Unfortunately, it is not possible to estimate the benefit of implemented projects for the lapwing and waders.

As a positive example of successful support of waders through water revitalisation can serve a bird park called "Josefovské louky", which has been built by the Czech Ornithological Society since 2008 on the floodplain meadows between the Stará and Nová Metuje rivers in eastern Bohemia (Czech Society for ornithology 2023a). The main goal of the park is to create ideal nesting areas for waders through the controlled irrigation of floodplain meadows, the construction of permanent water wetlands of various sizes, the elimination of invasion of woody plants, the subsequent natural grazing of a primitive breed of horses and backcrossed stilts, and the mechanical creation of areas with bare soil. In this way, it was possible to achieve repeated nesting of lapwings in the park (in 2022, 5 pairs successfully nested here) and, with additional measures, more demanding redshanks (Michálek 2022) and ring plovers. It is indisputable that creating of similar sites in the landscape would be beneficial for the lapwings, but only if these are placed in an open landscape without accompanying planting of trees (**Chapter 1**, **Chapter 4**, Štorek 2011, Šálek & Šmilauer 2002, MacDonald & Bolton 2008a).

Elimination of predation

The high level of predation of nests and lapwing chicks is being actively addressed in some countries, particularly in Western Europe, with various approaches. Most often, this involves passive protection of nests by enclosures or by fencing them (Isaksson et al. 2007, Rickenbach et al. 2011, Maplas et al. 2013, Verhoeven et al. 2022). In some cases, the method of targeted elimination of selected species of predators, most often foxes and corvids, was chosen (Bolton et al. 2007).
Predator exclusion has been found to be effective at improving avian hatching success (Smith et al. 2011). In natural habitats, where predation pressure is naturally low, the breeding success can be as high as 2.1 (in 2006) and 2.8 (in 2007) fledged young per single nest with four chicks (Pilacka et al. 2022). Also, the elimination of predators by using fencing contributed to higher fledging success - in England from 0.23 to 0.79 fledglings per pair (Malpas et al. 2013); in Switzerland chick survival increased from almost 0 % to 24 % (Rickenbach et al. 2011). However, this protection method is time-consuming and expensive and in case of population size estimated on level 6000 – 9000 pairs in 2014-2017 has no justification (Šťastný et al. 2021).

The results of an 8-year cross-over experiment examining the effect of red fox *Vulpes vulpes* and carrion crow *Corvus corone* control on breeding performance and population trends of lapwing showed no overall effect on the failure rate of 3139 lapwing nests (Bolton et al. 2007). Predator densities in the absence of control measures were highly variable among sites, and consequently the numbers of predators removed were similarly variable. Overall, predator control measures resulted in a 40% decline in adult fox numbers and a 56% reduction in territorial crows (Bolton et al. 2007). However, the effect of predator control varied significantly among sites, reflecting the variation in predator densities. Predator control measures were more likely to result in increased nest survival at sites where predator densities were high. Overall, predator control measures resulted in a 40% decline in adult fox numbers and a 56% reduction in territorial crows (Bolton et al. 2007).

In the Czech Republic, a similar protection model has not yet been systematically recommended, but as our data indicate, foxes in particular can purposefully search for fields with nesting lapwings on some nesting sites, and their potential shooting could contribute to an increase in nesting success (Oppel et al. 2011). However, the results so far indicate that the use of this method is often controversial, with the potential for unforeseen increases in other predator or competitor species (Bodey et al. 2009).

Direct nest protection

Lapwings reacted very quickly to negative changes in the landscape by changing their nesting preferences and gradually began to prefer arable land over grassland, especially ploughed fields (**Chapter 1, Chapter 5**). Without direct protection, practically all the first clutches of lapwings in this environment are unsuccessful (**Chapter 1, Chapter 3**), which may be unsustainable in the long term (**Chapter 2,** MacDonald & Bolton 2008b). Direct protection can in most cases prevent the destruction of nests during agricultural activities, but considering its marginal effect so far, a significant impact at the level of the entire population cannot be expected.

By far the largest number of protected nests was recorded in the Netherlands (Plard et al. 2020). The Dutch lapwing nest record scheme monitored 213 797 nests from 1995 to 2014 in different places across the Netherland (on average, 10 960 nests per year, from 38 nests in 1995 to 19 064 nests in 2006). The breeding success from monitored nests was used to estimate productivity (Plard et al. 2020). Most (99 %) monitored nests were marked with sticks to avoid destruction by agricultural activities and to ensure recovery of nests to monitor nest success. For each nest, the clutch size, the number of days the nest was monitored, the breeding success (successful: hatching of one egg at least/not successful) and the protection status (protected using sticks/not protected) were recorded (Plard et al. 2020).

If we assume that lapwings from the first clutches have the best chances to reach fledging (**Chapter 2**), such a high number of saved nests should display into overall nesting success. However, according to research in Netherland, direct protection contributed to the population growth rate by only 2 % (Plard et al. 2020). Nevertheless, it is not appropriate to resign from direct protection. Though the destruction of wader nests by agricultural activities has been demonstrated as a main driver of nest failure (Shrubb 2009), direct nest protection does not prevent from predation and do not improve habitat quality (**Chapter 3**, Plard et al. 2020). In this respect, it is not possible to compare the Czech Republic with the Netherlands, because they differ in the character of the landscape, agricultural practices or climatic conditions. Larger field units in the Czech Republic can be an advantage for lapwing chicks in some respects, as they could provide a safer environment (Šálek & Šmilauer 2002, MacDonald & Bolton 2008a).

In addition to CSO's efforts to promote direct protection among its members and the public (Zámečník 2015), another opportunity is to involve farmers themselves (Zámečník 2020a). Greater involvement of farmers in the protection of lapwing nests is one of the possibilities that can contribute to their effective protection. Some of farmers decided to systematically look for nests of lapwings from the tractor during spring work, mark them themselves and then bypass them when sowing the crop. Their example could inspire other farms and that is why we are planning to shoot a demonstration video in 2023 to introduce, how to optimally manage the direct protection from the farmer's point of view. If nests are searched by volunteers a varying amount of time before the agricultural work itself some risk of marked nests predation before the beginning of the agricultural work remains (**Chapter 3**), while farmers are always protecting active nests present in the field at a given moment. It cannot be assumed that farmers will start massively protecting lapwings in this way, but for now the number of farmers who protect the nests themselves is growing. At this moment, farmers in the Czech Republic are not financially rewarded for the protection of nests. For the future, some model rewarding farmers for actions beneficial for biodiversity as result-based agri-environment climate measure should be developed as it is being effectively used for protecting of other taxa, mainly plants (Burton & Schwarz 2013, Elmiger et al. 2023).

Agri-environment climate measure

From 2015, farmers can join AECM designed to protect lapwings breeding on arable land. Design of the scheme was based on data from volunteer monitoring (**Chapter 5**) and also experiences from UK within-fields fallow plots was used (Sheldon et al. 2005, Sheldon et al. 2007).

When designing this scheme, three assumptions were followed:

1) AECM will provide a suitable nesting environment that will be attractive for nesting

Ploughing of vegetation into the ground from second half of November was proposed to increase attractiveness of the site in the spring to create open habitat practically without vegetation (Cramp & Simmons 1983). The conditions of the measures completely eliminated the risks associated with the movement of agricultural machinery, but at the same time it was expected that they could also reduce the risk of nest predation. If plant remains were partially left on the field after the vegetation had been cultivated at the end of the year and new vegetation started to grow early in Spring, a visually more heterogeneous environment should would be created and cryptic coloured eggs would survive better. However, a more detailed evaluation of nest timing and predation in AECM sites has not yet taken place.

2) A food-attractive area will be created.

One of the conditions of the measure is the exclusion of chemical treatment, including fertilization, which should support the development of invertebrates and insects (**Chapter 1**, Britschgi et al. 2006). At the same time, until mid-June, the area is left to its own development, which leads to the development of a varied plant community of various types of field weeds (Hanusová in prep.) and related invertebrates, as well as to the partial regeneration of cultural crops, with which the area is sown from June 16 to July 15. Their proportion and predominant species composition vary significantly in different locations according to local conditions, and at the same time as wild plants increase the overall diversity on the nesting site (Hanusová in prep.). Especially attractive for bids are fields with temporary wetlands, that are hosting significantly more diverse and numerous communities of plants and animals than dry fields and, in addition to lapwings, they are used for breeding by other bird species, including wader species such as Redshank, Ring Plover or Common Snipe (Sychra et al. 2021).

3) A diverse and structured vegetation will create optimal cover for chicks to minimise predation

The last assumption was that the areas will gradually become overgrown and, due to different height and spatial diversity, suitable areas for the development of chickens will be created, which will increase, in addition to higher food opportunities, also optimal hiding options (McKeever 2003).

Data from monitoring of AECM effectiveness in 2020 indicate, that well-selected sites lapwings occupy (Zámečník 2020b). During first visit displaying or nesting activity of lapwing was recorded on 64 % of 22 AECM sites compared to 27 % of the control sites. However, no statistically significant difference was found in favour of sites in commitment. Compared to the assumptions, there was a surprisingly significant decrease in the number of birds during further control visits (figure 1) (Zámečník 2020b). There could be several explanations for this. The nesting success rate is low on both sites due to predation and for replacement clutches lapwings prefer spring crops. Only in one case lapwings were observed nesting in the AECM site during second control in case, when no bird was seen during first control (Zámečník 2020b). The second alternative is that some lapwings leave the area early with their chicks – in some AECM sites vegetation exceeds 20 cm already in April and despite it is not so dense as normal crops, lapwings may not feel safe enough there. Especially in some dry sites there could be also limited feeding options, despite no chemical treatment. Another explanation for moving from breeding site could be lapwing's fear of potentially high predation risk resulting from several families feeding close to each other in relatively small area. If suitable biotopes are near the AECM within 2 km distance, e.g. maize or open wetlands, lapwings may prefer to move there (own unpublished data).

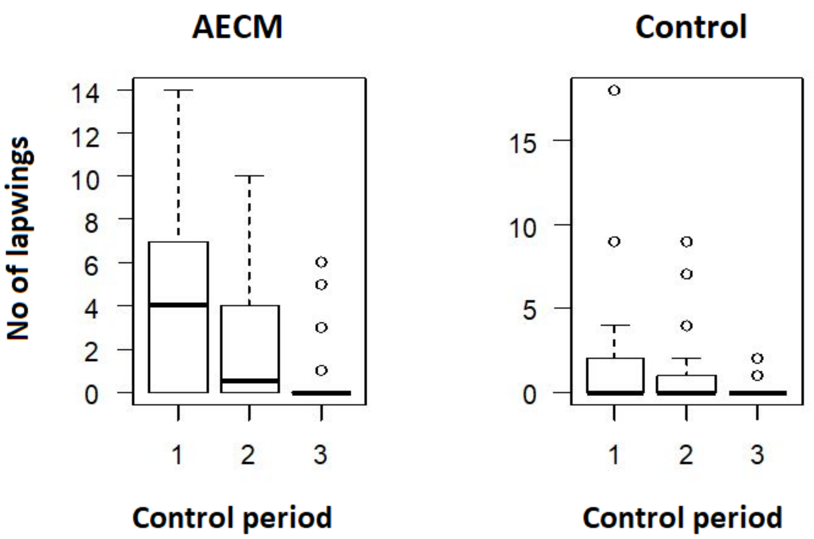

Figure 1: Seasonal trend in AECM and control is significantly declining.

Unfortunately nesting success has not been monitored as our intentions was not to minimise the disturbance of birds during breeding, just to prove possible presence of chicks by entering the site and monitoring bird behaviour. Information on nesting success differ significantly. In Germany were lapwing observed on 65 % of the 61 plots at the beginning of breeding season (Schmidt et al. 2017), very similar to 64 % of occupied sites in the Czech Republic (Zámečník 2020b). Breeding was confirmed at 26 out of 61 lapwing plots (43 %), whereas only 18 pairs bred on 9 control plots (15 %). Hatching success was significantly higher at lapwing plots on level of 37.5 % (24 of 64 pairs at 11 plots) while on untreated sites it was only 16.7 % (Schmidt et al. 2017). It indicates significantly higher predation pressure compared to England, where hatching success of lapwings on unsown within-field fallow plots was on opposite very high. Totally 85 % (Sheldon et al. 2007) and 77 % (Hoodless & MacDonald 2014a) of the clutches hatched successfully. In our previous research total nesting success over all study periods and sites was 46 %, in addition 9 % of nests were destroyed by agriculture machinery. These results indicate, that by eliminating this threat overall nesting success could be around 50 % (**Chapter 1, Chapter 3**). This level of nesting success has been confirmed by some other studies as well (Teunissen et al. 2008, Pilacka et al. 2022).

Similar to situation in the Czech Republic, many lapwings soon after hatching moved away from German experimental plots (Schmidt et al. 2017), so total chick survival could not be examined. These findings indicate, that more precise research of the nesting success of lapwing in AECM sites and further movements of the families with chicks including their survival needs should be done.

There were also some differences among management. While in Czech AECM and Germany experimental plots cultivation takes place in late Autumn, in England it was from February 1st till March 20th. Evidently both options were accepted by lapwings. Also size of the plots were different. In England the cultivated area had to be located on level, or slightly sloping ground; in fields larger than 5 ha with an open aspect and at least 100 m away from woods, in-field and hedgerow trees, overhead power-lines and public rights of way in order to minimise nest disturbance and predation. It could not be placed in fields bounded by tree lines or adjacent to woods, unless the field was larger than 10 ha. The cultivated area had to be at least 1 ha and no more than 2.5 ha in size and at least 100 m wide (Natural England 2013). In Germany plots were situated on fields or in their neighbourhood with evidenced lapwing breeding and the size of the areas ranged from 1 – 2.6 ha (Schmidt et al. 2017). Nevertheless, results from Germany indicates, that larger fields are better and consider 5 ha limit as optimal compromise for lapwings and farmers (Schmidt et al. 2017). In Czech Republic we preferred maximal size of AECM sites to be 10 ha in most cases, but on some over-logged fields with high number of breeding pairs we accepted even larger area.

Cooperation with farmers

As quality of the farmland and farming management are crucial in lapwing protection, there is no way forward without close engagement of nature conservationists and farmers. The practical implementation relay directly on farmers themselves who first have to decide to join the given measure. While in some cases the main motivation may be the guarantee of a certain income from a given area, for a large part of farmers key the barriers to entry may be the fear of an increase in the administrative burden, more frequent controls and the risk of a possible sanction for breaching the conditions, which can occur either through the error of the farmer himself, but in some cases also caused by a third party (Meierová & Chvátalová 2022).

In addition, farmers often do not receive more information about the measures from the state administration than an overview of the conditions and the financial rate, and this may not be enough for most of them. Therefore, it is necessary for nature conservation and farmers to find a common language and for farmers to better understand why the given measure was actually created, what were the reasons for setting the given conditions and, above all, what the implementation of the measure can help in the given site. There are several ways to convey this information to the farmer, each of them has its place and can often function independently or in conjunction (Meierová 2020).

Probably the easiest way is the creation of ideally visually attractive and comprehensibly grasped information material (prints, videos), which will present the given protection measures to farmers, including the necessary technical details (**Chapter 6**). Another possibility is the organization of educational seminars and lectures. The last option is individual counselling, where nature conservation representatives actively try to reach out to the concerned farmer and, during a personal meeting, discuss in detail all the technical, economic and environmental aspects of the given measure (Klöckner 2015).

Therefore, as part of the support for the extension of the measure, since its inception in 2015, I have actively approached farmers in the case of locations that had a high perspective from the point of view of long-term nest occurrence or the nature of the location in question (waterlogging, attractive surroundings, etc.). In 2017, with the support of the Ministry of Agriculture, I personally visited 98 farmers farming on the most promising areas according to the data from ornithological database. Also this intervention contributed to increase of total area of the measure from 196 in 2017 to 318 ha in 2018 (Ministry of Agriculture, unpublished data). The personal contact in this case is also an opportunity for mutual sharing of views on the agricultural landscape, presentation of the specifics of agricultural practice and the latest knowledge in the field of nature conservation, and opening up possibilities for synergy in more effective protection of birds and overall biodiversity and agricultural management (Meierová 2020).

Conclusion

The long-term decline of farmland birds demonstrates that unless changes are made to current agricultural practices, we may lose most of our previously common species in a short period of time. As an example can be used the Northern Lapwing, whose abundance in Czech Republic decreased by more than 80 % since 1982 till 2022 (Czech Society for Ornithology 2023b). The main cause is overall intensification, especially inappropriate interventions in the agriculture landscape as its drainage or conversion of former waterlogged flowering meadow to arable fields. If we want to reverse the current negative trend, revitalisation of agriculture land, especially the restoration of the drained areas, where field agricultural production is inefficient from an economic point of view, should be promoted at the political level and in the expert debate between the agricultural community and nature conservation. Also further research to find the most appropriate managements of farmland should be further carried out.

In our work, we focused mainly on the possibility of direct protection of nests, which eliminates unnecessary losses of the first clutches, in which lapwings invest the most energy. Lapwing chicks, that hatch from them, have the most favourable initial conditions for achieving fledging. So far, this protection model is only marginally applied. Although the contribution itself to the overall nesting success of lapwings is not essential according to some researches, it also has a significant educational impact. Therefore, it is desirable that this protection be used more massively and, ideally, that the farmers themselves adopt it to a greater extent.

Even from 2023, farmers will be able to enter a targeted AECM to support the successful nesting of lapwings. The first results of monitoring indicate that well selected areas are occupied by lapwings, but it is not yet clear how it contributes to the overall breeding success. Therefore, it is desirable to devote further research especially to this parameter.

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Author contributions

Chapter 1 - Threats and conservation of meadow-breeding shorebirds in the Czech Republic and Slovakia: V.K., V.Z. a M.Š collected the data; V.K. analysed data with input from V.Z. a M.Š.; V.K. conceived the paper with input from V.Z., K.S, V.Š., M.Š; V.K. analysed and visualized the data with input from V.Z., K.S, V.Š., M.Š; V.K. drafted the paper and wrote the final paper with input from V.Z., K.S., V.Š. a M.Š

Chapter 2 – Seasonality predicts egg size better than nesting habitat in a precocial shorebird: V.K., M.S., V.Z., E.V. a M.Š. collected the data; V.K. and M.S. analysed data with input from V.Z., E.V. a M.Š.; V.K. conceived the paper with input from M.S., V.Z., E.V. a M.Š.; V.K. and M.S. analysed and visualized the data with input from V.Z., E.V. a M.Š.; V.K. drafted the paper and wrote the final paper with input from M.S., V.Z., E.V. a M.Š.

Chapter 3 – Visible marking of wader nests to avoid damage by farmers does not increase nest predation: V.Z., V.K. a M.Š. collected the data; V.Z., V.K. a M.Š. analysed data; V.Z. conceived the paper with input from V.K. and M.Š; M.Š. analysed and visualized the data with input from V.Z.; V.Z. drafted the paper and with input from V.K. and M.Š.; V.Z. wrote the final paper with input from V.K. and M.Š.

Chapter 4 – Delayed nest predation: a possible tactic toward nests of open-nesting birds: M.Š. collected data; M.Š a V.Z. conceived the paper; M.Š. analysed and visualized the data; M.Š. drafted the paper and with input from V.Z.; M.Š. wrote the final paper with input from V.Z.

Chapter 5 - Survey of breeding Northern Lapwings (*Vanellus vanellus*) in the Czech Republic in 2008: results and effectiveness of volunteer work: V.K., V.Z. a M.Š. organized and participated in data collection; V.K., V.Z. a M.Š. conceived the paper; V.K. analysed and visualized the data with input from V.Z. a M.Š; V.K. drafted the paper and with input from V.Z., M.Š.; V.K., V.Z. and M.Š wrote final paper.

Chapter 6 - Protection of the Northern Lapwing - Use of agri-environmental-climatic measures: VZ conceived the paper; VZ wrote final text.

Declaration of originality

I declare that this thesis has not been submitted for the purpose of obtaining the same or any other academic degree earlier or at another institution. My involvement in the research presented in this thesis is specified in the statement of contributions and it is also expressed through the authorship order of the included publications and manuscript. All relevant literature sources used while writing chapters in this thesis have been properly cited.

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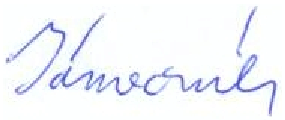

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