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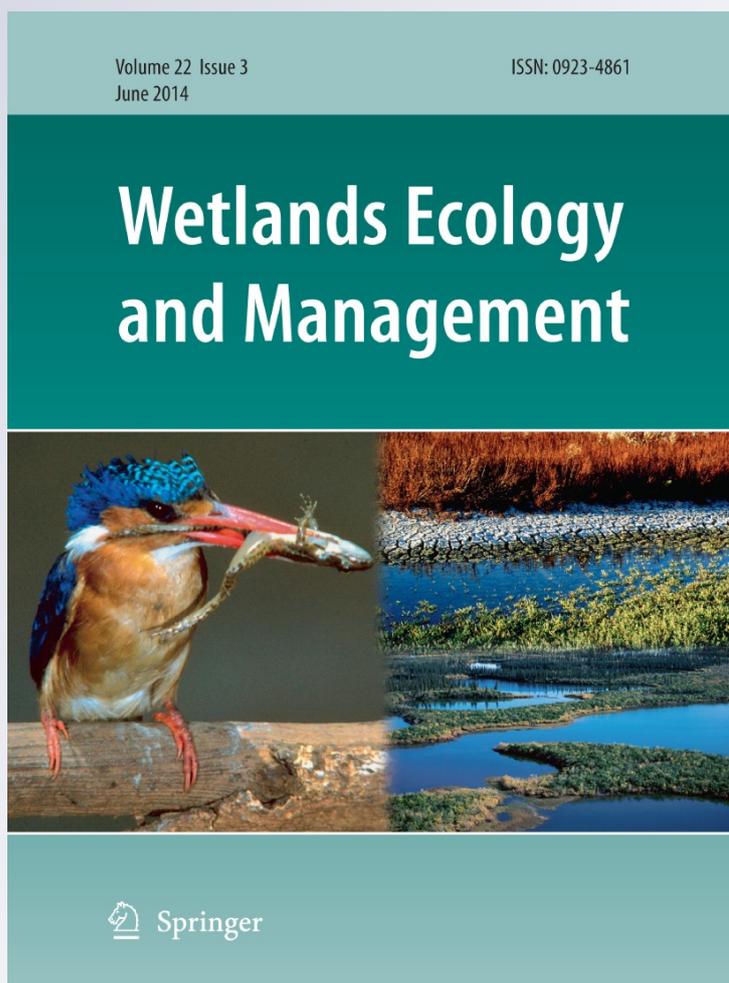
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Management of reedbeds: mosaic reed cutting does not affect prey abundance and nest predation rate of reed passerine birds

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Abstract Reed passerine birds are strict habitat specialists inhabiting reedbed habitats. In Europe, many of these species are threatened due to loss and degradation of natural reedbeds. Another important factor that can negatively affect the abundance of reed passerines is commercial reed harvesting. Previous studies have shown negative impacts of large-scale winter reed cutting on passerine breeding assemblages and arthropod communities. The effect of reed cutting on a small scale, however, has not been studied experimentally to date. The aim of this study was to investigate whether and how small-scale, mosaic reed cutting influences prey abundance and nest predation rate of reed passerines. In June, after the reed had reached maturity, we conducted nest predation experiments with artificial nests and arthropod sampling using pan traps in cut reed patches, adjacent uncut reed patches and unmanaged reedbed. We found no differences in the risk of egg predation between three

types of reedbeds. In contrast, the abundance of arthropods in cut and adjacent uncut reed patches was significantly higher than that in unmanaged reedbed. We assume this was caused by habitat heterogeneity, small size of cut patches and their rapid recolonization by arthropods from adjacent uncut patches. Our results suggest that in contrast to large-scale reed cutting, small-scale, mosaic reed cutting has no negative effect on nest survival and food abundance of reed passerine birds. However, given that we performed all experiments in June, i.e., when the reed was mature, our findings cannot be generalized to whole breeding period of all reed passerine birds. Therefore, temporal variation in nest predation rate and arthropod abundance in managed and unmanaged reedbeds during the entire breeding season should be examined in future studies.

Keywords *Phragmites australis* · Arthropod communities · *Acrocephalus* warblers · *Panurus biarmicus* · Conservation

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Introduction

Wetlands are among the most threatened habitats in the world, covering about 4–6 % of the earth's land surface (Mitsch and Gosselink 2000). In Europe, one of the most extensive wetland types is reedbed, characterized by the dominance of the common reed *Phragmites australis* permanently or frequently

inundated with the water. They are home to a large number of plant and animal species, including birds. Several of them, especially passerine species such as *Acrocephalus* warblers, Savi's warbler (*Locustella luscinioides*), bearded tit (*Panurus biarmicus*) and reed bunting (*Emberiza schoeniclus*) are strict reedbed habitat specialists that are dependent upon the existence of this type of wetland. Moreover, the abundance and breeding success of reed passerine birds are markedly influenced by the quality (structure) of reedbed and food availability (Ille et al. 1996; Hoi et al. 2001; Martínez-Vilalta et al. 2002; Poulin et al. 2002; Trnka et al. 2009). Similarly, due to relatively simple two-dimensional structure and limited nest site diversity, reedbeds attract a large number of predators, which often results in high levels of nest predation (Schulze et al. 1996; Hansson et al. 2000; Hoi et al. 2001; Batáry et al. 2004). Consequently, numbers of passerines in reedbeds fluctuate markedly according to habitat quality (heterogeneity) and current risk of nest predation. Thus, reed passerines have been highly threatened in recent years by the dramatic decreasing in reedbed extent due to human destruction as well as their natural ageing processes (Vadász et al. 2008).

Commercial reed harvesting is another important anthropogenic factor threatening passerine birds. Winter reed cutting has negative impact mainly on their breeding and prey abundance (Poulin and Lefebvre 2002; Poulin et al. 2002; Schmidt et al. 2005; Trnka and Prokop 2006; Vadász et al. 2008; Valkama et al. 2008). Furthermore, it can markedly increase the risk of nest predation and delay clutch initiation in breeding birds (Graveland 1999). On the other hand, reed cutting is one of the most effective methods of fighting against eutrophication, which is also highly relevant for nature conservation (Vadász et al. 2008). Therefore, winter reed harvesting is still a controversial issue in discussions between bird conservationists, wildlife managers and reed harvesters. As a result, biennial and spatially mosaic cutting of reedbeds have been proposed as the best compromise between conservation and commercial interests in order to preserve diverse bird populations and invertebrates as their food resources in reedbeds (Poulin and Lefebvre 2002; Schmidt et al. 2005; Valkama et al. 2008). Although some previous studies have shown significant negative impacts of large-scale winter reed cutting (i.e., reedbeds with a surface area of more than 10 ha, Poulin and Lefebvre 2002;

Schmidt et al. 2005), effect of small-scale, mosaic reed cutting on breeding success of reed passerines and their prey abundance has not so far been studied experimentally.

In the present study we examined whether and how mosaic pattern of small cut and uncut reed patches influences egg predation and abundance of terrestrial arthropods as potential food resource for reed-nesting passerine species. We conducted the nest predation experiments with artificial nests and arthropod sampling using pan traps in cut and adjacent uncut reed patches and unmanaged reedbed as control to test following predictions: (1) the predation rates of artificial nests in cut versus adjacent uncut reed patches and unmanaged reedbeds is similar due to the small size (from 0.5 to 2.5 ha) of cut patches and large hunting radius of potential reed passerine nest predators ("reed patch size" hypothesis, Hoi et al. 2001). (2) Abundance of potential prey items (arthropods) of reed passerine birds is also similar in cut versus adjacent uncut reed patches, because cut patches can be recolonized by arthropods from adjacent uncut reed patches ("cut reeds recolonization" hypothesis, Schmidt et al. 2005). (3) Abundance of arthropods is higher in reedbeds with mosaic structure of cut and adjacent uncut reed patches than in unmanaged reedbeds due to higher habitat heterogeneity and arthropod diversity in small-scale managed parts of reedbeds (Schmidt et al. 2005).

Methods

The study was carried out in the National Nature Reserve Prižske močiare marsh (SW Slovakia, 47°52'N, 18°30'E, for a map see Appendix 1 in Supplementary material). The locality represents one of the largest wetlands in Slovakia. Its total area is 184 ha, 78 % of which is covered by dense, homogenous reed stands. The reedbeds are cut irregularly (biennially or triennially) during winter if the water is frozen. In winter 2005/2006, ~50 % of the reedbed area was cut in the southeastern part of nature reserve (Trnka and Prokop 2007). In the following winter, 2006/2007, however, due to discontinuously frozen water only small reed patches of square or rectangular shape were cut in this part of marsh. Cut reed patches ranged from 0.5 to 2.5 ha and were dispersed in checkerboard pattern. As a result, uncut reed patches

of similar size and shape as adjacent cut reed patches were left between cut patches, and this created an ideal mosaic structure.

In spring 2007 we selected 24 study plots in cut reed patches that were cut in winter 2006/2007, 24 study plots in adjacent uncut reed patches that were left standing between cut patches and 44 study plots in unmanaged reedbed located in the northwestern part of the study area (as control). The majority (80 %) of unmanaged reedbed had not been cut over the last 4 years; the rest of the area was cut 3 years ago. The minimum distance between study plots was 50 m. Unmanaged and managed areas (including selected cut and uncut patches) of reedbeds are situated close together, along the Paríž canal, and represent continuous and homogenous permanently flooded stands of reed with the same hydrological and hydrogeological (sedimentary) conditions (Gajdoš et al. 2005). There were no statistically significant differences in principal morphological characteristics of reeds growing in managed and unmanaged areas (height of stems: mean \pm SE = 241 ± 18 and 245 ± 13 cm, respectively $t = -0.29$, $df = 90$, $P = 0.770$ and diameter of stems: mean \pm SE = 7.79 ± 0.51 and 7.55 ± 0.38 mm, respectively, $t = 0.513$, $df = 90$, $P = 0.609$), except for density of stems that was slightly higher in managed than unmanaged reedbeds (mean \pm SE = 59.5 ± 3.2 and 52.3 ± 2.3 , respectively, $t = 2.226$, $df = 90$, $P = 0.028$). This suggests that according to our knowledge there were no big site-related differences in the environmental conditions (other than management patterns) between different sampling sites.

We carried out the nest predation experiment and arthropod sampling between 20 and 27 June 2007, i.e. after the reed had grown. For the nest predation experiment, we used handmade artificial nests resembling in size and appearance the nests of reed warblers. Artificial nest experiments are frequently used by avian ecologists to compare nest predation rates among species or habitats in order to avoid their disturbance and overcome logistical problems (Reitma et al. 1990; Moore and Robinson 2004). Although this method has received some criticism in recent years due to limited transferability of results achieved with artificial nest experiments to natural nests (Faaborg 2004), many authors have shown this method to be adequate tools for spatial comparisons of nest predation (Roos 2002; Batáry and Báldi 2005; but see

Purger et al. 2012). To standardize our experimental design with other artificial nest experiments in marsh habitats (Batáry et al. 2004; Schiegg et al. 2007; Trnka et al. 2009), the nests were baited with one fresh quail (*Coturnix coturnix*) egg and one plasticine egg, the latter similar in size and shape to a reed warbler egg. Artificial nests were placed in the center of each study plot. Nests were attached with a fine green wire to reed stems at a height of 70 cm above water level and left in place for 7 days. A nest was considered predated if any of the eggs was missing or appeared damaged. Based on marks left on the plasticine eggs, three categories (guilds) of egg predators have been distinguished: large birds [large triangular bill marks, most probably the marsh harrier (*Circus aeruginosus*)], small birds (small triangular bill marks, probably reed warblers and great reed warblers) and mammals [incisor marks, such as by water vole (*Arvicola terrestris*)] (see also Trnka and Prokop 2011).

Moreover, given that the nesting success of birds may be profoundly influenced by the vegetation structure around a nest (Martin 1993; Whittingham and Evans 2004; Trnka et al. 2009), at the end of the experiment we measured for each artificial nest the following nest-site characteristics: number of all reed stems within a square of 0.5×0.5 m with the nest in the center, and height and diameter of ten randomly-chosen stems in each square (see also Trnka et al. 2010).

Arthropods occupying cut and uncut reed patches and unmanaged reedbed were sampled by pan traps (Duelli et al. 1999). In the center of each study plot located in cut and adjacent uncut reed patches, one white plastic bowl of 15 cm diameter was fixed to reed stems at a height of 70 cm above the water level. Two pan traps located in adjacent uncut reed patches disappeared. In unmanaged reedbed, pan traps were installed in 30 study plots. The traps were filled with water to a depth of 5 cm mixed with 5 ml of detergent, and exposed for 7 days. Captured arthropods were preserved in 75 % ethanol, and then in the laboratory they were counted and identified to order.

Nest-site characteristics of cut and uncut reed patches and unmanaged reedbed were compared by Kruskal–Wallis ANOVA. Nest predation was defined as the dependent variable with binomial distribution in a generalized linear model (GLM) and the effect of reedbed type (cut reed patches, adjacent uncut reed patches and unmanaged reedbed) and vegetation

structure (density of stems, proportion of green stems, height and diameter of stems) were defined as predictors. Normality of the data on arthropod abundance was investigated by Shapiro–Wilks test, and $\log_{10}(x+1)$ transformed to achieve normality. Differences in arthropod abundance (all arthropods and the four most abundant orders) between cut reed patches, adjacent uncut reed patches and unmanaged reedbed were calculated by one-way analysis of variance (ANOVA) and subsequent Tukey post hoc multiple comparison of means. Statistical tests were performed with Statistica (v8, StatSoft 2007, Tulsa, OK, USA, <http://www.statsoft.com>).

Results

Nest-site characteristics of artificial nests

Density and proportion of green stems around artificial nests differed considerably between cut reed patches, adjacent uncut reed patches and unmanaged reedbed (Kruskal–Wallis ANOVA, $H_2 = 11.93$ and 54.91 , $P = 0.003$ and $P < 0.001$, respectively). Specifically, density of stems in adjacent uncut reed patches tended to be higher than that of cut reed patches and unmanaged reedbed (Dunn's multiple comparison test, both $P < 0.02$). Similar significant differences were also found in higher proportion of green stems in cut compared to adjacent uncut reed patches and to unmanaged reedbed (both $P < 0.001$). Differences between other variables were not significant (reedbed height and diameter, $H_2 = 0.05$ and 5.32 , $P = 0.97$ and 0.07 , respectively).

Predation on artificial nests

Overall, 25 % of 92 artificial nests were depredated during the 7-day exposure period. Specifically, 8 (33.3 %) of 24 artificial nests were depredated in cut reed patches, 7 (29.2 %) of 24 nests were depredated in adjacent uncut reed patches, and 8 (18.2) of 44 artificial nests were depredated in unmanaged reedbeds. GLM with nest predation as binomial dependent variable showed no effects of reedbed type (independent categorical variable), density of stems, proportion, height and diameter of green stems (independent continuous variables) on nest predation rates of artificial nests (all $P > 0.2$; Table 1).

Table 1 Predictors of nest predation

	<i>df</i>	Wald's χ^2	<i>P</i>
Density of stems	1	1.21	0.27
Proportion of green stems	1	0.12	0.73
Height of stems	1	0.76	0.38
Diameter of stems	1	1.36	0.24
Type of reedbed	2	0.22	0.90

Results were calculated by GLM with nest predation as binomial dependent variable

Based on marks on plasticine and quail eggs, most nests were depredated by birds (65.2 %), most frequently by large birds (11 of 15 cases), and only 6 nests (26.1 %) were depredated by small mammals. Due to missing eggs, predators at two nests remained unidentified. There were no differences in main nest predator guilds (birds vs. mammals) between three types of reedbeds ($\chi^2_3 = 1.4$, $df = 2$, $P = 0.49$, $n = 21$).

Arthropod abundance

Altogether, 4845 arthropods were captured in 76 pan traps with dominant orders such as Diptera, Hymenoptera and Heteroptera, while spiders were less abundant (Table 2). Mean total arthropod abundance in cut reed patches was 81.5 (SE = 7.6, $n = 24$), in adjacent uncut reed patches 75.6 (SE = 8.0, $n = 22$) and in unmanaged reedbeds 45.9 (SE = 6.8, $n = 30$). There were significant differences in overall arthropod abundance between cut, adjacent uncut and unmanaged reedbeds (ANOVA, $F_{2,73} = 5.699$, $P = 0.005$). Specifically, the abundance of arthropods was significantly lower in unmanaged reedbed than in cut and adjacent uncut reed patches (Tukey post hoc test, $P = 0.025$ and 0.009), while no difference was found between cut and adjacent uncut reed patches ($P = 0.921$). At order level, however, significant differences between three types of reedbeds were found only in Hymenoptera and Diptera abundances ($F_{2,70} = 7.164$, $P = 0.001$ and $F_{2,73} = 3.761$, $P = 0.028$, respectively). While the abundance of Hymenoptera was significantly higher in cut as well as adjacent uncut reed patches than in unmanaged reedbed ($P = 0.005$ and 0.007 , respectively), the order Diptera was significantly more abundant in adjacent uncut reed patches versus unmanaged reedbed only ($P = 0.037$).

Table 2 Descriptive statistics for arthropod abundance in the three types of reedbeds

	<i>n</i>	Cut reed patches		Adjacent uncut reed patches		Unmanaged reedbed	
		Mean	SE	Mean	SE	Mean	SE
Diptera	1,805	27.75	4.21	29.68	4.40	16.20	3.77
Hymenoptera	975	17.25	2.31	16.00	2.41	6.97	2.06
Heteroptera	787	12.29	2.12	13.82	2.22	6.27	1.90
Coleoptera	605	9.88	1.18	7.86	1.23	6.50	1.06
Orthoptera	281	3.67	1.01	3.00	1.06	4.23	0.90
Araneae	215	2.42	0.56	2.73	0.59	3.23	0.50
Lepidoptera	177	1.96	0.51	2.50	4.18	2.47	3.58

Discussion

The study demonstrated a neutral impact of small scale reed cutting on predation of eggs in artificial nests imitating the nests of passerine birds in reed stands in June, i.e., when the reed was mature. More specifically, we found no difference in the risk of egg predation between cut and adjacent uncut reed patches compared with unmanaged reedbed. Results of our artificial nest experiments therefore contrast with those of previous studies showing elevated nest predation in cut sites (Graveland 1999; Valkama et al. 2008). Nevertheless, the overall nest predation rate in our study area was in the range of predation rates known from other reedbed habitats (from 20 to 43 %, Bensch and Hasselquist 1994; Batáry and Báldi 2004; Trnka et al. 2009).

Spatial variation in nest predation risk of reed habitats can be affected mainly by reedbed structure (density), horizontal distribution (edge effect) and density of nests (Hoi et al. 2001; Batáry et al. 2004; Trnka et al. 2009). Although we conducted our experiment after the new reed stems were fully grown, density of stems in cut reed patches tended to be lower than density in adjacent uncut reed patches. In spite of this, nest predation did not increase in cut patches. Cut reedbeds are in general characterized by decreased abundance of reed-nesting passerine species (Graveland 1999; Vadász et al. 2008; Valkama et al. 2008). A potential explanation for similar nest predation rates in cut and adjacent uncut reed patches and unmanaged reedbed may be the low density of natural nests in cut reed patches. Several previous studies have pointed out the importance of nest density on nest predation in reedbed habitats (Hoi and Winkler 1994; Batáry et al.

2004). The rationale is that the odds of discovery of a nest by a predator in areas of lower nest densities may be low and nest searching energetically demanding. Thus, consequently, nest predators may simply avoid searching for nests in such parts of reedbeds. However, given that we did not measure the true density of reed passerine nests in the studied patches, additional studies are needed to test this hypothesis.

On the other hand, nest predation in reedbeds is known to increase with proximity to reed edges (Báldi and Batáry 2005; Trnka et al. 2009; but see Honza et al. 1998; Hansson et al. 2000), which may relate mainly to different diversity of nest predators in reed edges and reedbed interiors. In our study, however, we found that nests located in cut reed patches were depredated by the same predator guilds as nests located in adjacent uncut reed patches and unmanaged reedbed; most often by the marsh harrier. Many other studies of nest predation in reedbed habitats also considered marsh harriers as the most important large predators of small passerine nests (Bensch and Hasselquist 1994; Batáry and Báldi 2005; Trnka et al. 2011). Therefore, because of the high-flying activity and large hunting radius of the marsh harrier as well as the connectivity and small size of the studied reed patches, the edge effect on predation of artificial nests in our study area seems to be weak and probably only of marginal importance.

However, given that artificial nests may attract different types of nest predators than real nests (Zanette 2002; Thompson and Burhans 2004), these results should be interpreted with caution. The main shortcoming of dummy nests is the absence of adult birds (nest owners) that can actively defend their nests (Trnka et al. 2008; Swanson et al. 2012). On the other

hand, breeding activity of nesting pair may help predators to locate nest and thus increase their nest searching effectiveness (Weidinger 2002). Another limitation of artificial nests is that they cannot be used to estimate rates of nestling predation that can markedly differ from egg predation. But again, given that the main potential nest predator in our study area is the marsh harrier that eats both eggs and chicks of reed passerine birds, the effect of the lack of active parental defense and absence of chicks in artificial nests on observed nest predation rate appears negligible (see also Trnka et al. 2011). Moreover, many studies already showed that artificial nests are suitable instruments for comparing nest predation levels in different habitats (e.g. Batáry and Báldi 2005).

Apart from risk of nest predation, the availability and amount of food resources is another important factor limiting the abundance of reed passerine birds in reedbeds (Poulin et al. 2002; Schmidt et al. 2005; Valkama et al. 2008). Previous studies found both positive (Poulin and Lefebvre 2002) and negative (Schmidt et al. 2005) effects of large-scale reed cutting on arthropod communities associated with reedbeds. Winter reed harvesting decreased mainly the abundance of Coleoptera, Lepidoptera and Hymenoptera, whereas some other insect groups, e.g. Homoptera, benefited from reed management, and their numbers increased in cut reedbeds (Valkama et al. 2008). Moreover, the meta-analysis of Valkama et al. (2008) showed that arthropod abundance in managed reedbeds is markedly affected by duration of management period. More concretely, short-term cutting of reedbeds did not influence the abundance of invertebrates, whereas their numbers decreased strongly after longer (4–5 and more years) reed management period.

In our study site, on the contrary, the overall abundance of arthropods in cut and adjacent uncut reed patches in June was significantly higher than that in unmanaged patches suggesting that mosaics of cut/uncut reed patches may provide richer food resources for birds than unmanaged reedbeds. This provides the first empirical evidence of the nature conservation importance of small scale reed cutting (see e.g. Poulin and Lefebvre 2002; Schmidt et al. 2005). We assume that high abundance of arthropods (specifically Hymenoptera and Diptera orders) in cut reed patches was mainly caused by their rapid recolonization from neighbouring uncut reed patches (Poulin and Lefebvre 2002; Schmidt et al. 2005). However, given that we

identified captured arthropods to order level only, and due to limited effectiveness of pan traps where many other groups of arthropods representing important food source for reed passerine birds could not be accounted for (e.g. Homoptera and Odonata, Trnka 1995; Grim and Honza 1996; Schmidt et al. 2005; Leisler and Schultze-Hagen 2011), additional studies focusing specifically on arthropod species and other components of the diet of reed passerine birds in small-scale managed and unmanaged reedbeds are needed. The rationale is that birds may be selective within a particular prey order and prefer species that may not be distributed equally across habitats and even within the same habitat. Moreover, there may also be great differences between the number of prey items and their relative biomass contribution (Schmidt et al. 2005). Finally, although the cutting management of the study area did not enable us to study a full mixture of spatially independent samples, considering the same environmental conditions in managed and unmanaged parts of reedbeds in the study area (see “Methods” section), we believe that the distribution of arthropods in experimental versus control study plots were not influenced by factors other than management.

In summary, our results support the hypothesis that mosaic design of cut/uncut reed patches has no significant negative effect on nest (egg) survival and food abundance of reed passerine birds compared to unmanaged reedbed. However, we emphasize that in order to standardize breeding and experimental conditions in cut and uncut reed patches, we conducted all experiments in late June only, i.e., when the reed was mature. In our study area, however, the majority of reed passerine species start to breed in April and May, and by the end of June and in July their breeding slowly ends (Trnka et al. 2003). Thus, given that the risk of nest predation and nest predator activity in reedbeds increases with increasing density of nests (e.g. Hoi et al. 2001; Batáry et al. 2004; Trnka et al. 2009), our findings cannot be generalized to the whole breeding period of all reed passerine birds. Similarly, the abundance of arthropods can fluctuate over the course of vegetation period. Therefore, additional studies examining temporal variation in the rate of nest predation and arthropod abundance in managed and unmanaged reedbeds during the entire breeding season would help to shed light on this issue.

Considering that reed in cut patches does not create suitable conditions for breeding of birds in its first stages of growth (Graveland 1999; Batáry et al. 2004; Valkama et al. 2008), we assume that main disadvantage of nesting in cut reed patches is only the delay in onset of egg laying, which may result in reduced reproductive fitness. Specifically, birds nesting in cut reed patches can generally raise fewer clutches per season, and have less time to renest if their first nesting attempts failed, than birds nesting in uncut reedbeds. Nevertheless, when planning to cut reed in a mosaic pattern, the size and shape of cut and uncut reed patches should be taken into serious consideration. Since smaller patches contain a proportionally higher amount of edge habitat than larger patches (Bender et al. 1998), and due to high predation rates of nests along edges (Batáry and Báldi 2004), nest predation should increase with decreasing size of habitat patch. The increasing size of cut reed patches, on the other hand, may also negatively influence the speed of their recolonization by arthropods as potential food resources for nesting reed passerines (Schmidt et al. 2005). Hence, in localities smaller than our study area where the size and portion of cut patches is larger, recolonization of cut reedbeds can be slower. Finally, because of different habitat size requirements, the size of uncut reed patches may also markedly influence the total abundance and density of particular reed passerine species (Vadász et al. 2008). Therefore, given that results presented in this study may be valid only for the studied locality, the optimal size and pattern of cut and adjacent uncut reed patches should be examined in future studies. Although leaving reed uncut for several years may lead to rapid marsh succession, we assume that some patches of reedbeds should be left uncut for more than 2 (3 or 4) years to increase habitat marsh heterogeneity.

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