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Research Article

The effects of weather and reed management on nesting parameters of the Great Reed Warbler, *Acrocephalus arundinaceus* (Aves: Sylviidae)

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Abstract

Nesting parameters such as clutch size, hatching rate or nesting success have been extensively studied in birds in relation to biotic and abiotic factors. In this study we aimed to investigate the effects of air temperature, amount of precipitation, reed burning, and water depth (independent variables) on nest density, clutch size, hatching rate, and nesting success (dependent variables) of the Great Reed Warbler during a nine-year period. We found that neither the clutch size nor the hatching rate was influenced by any of the predictor variables. Nest density was positively influenced by the water depth, while the nesting success was negatively related to the amount of precipitation. Reed burning had no effect on any of the nesting parameters. Similarly, to our results, short-term studies reported a positive relationship between nest density and water depth, and a negative relationship between the nesting success and amount of precipitation, indicating that these two environmental variables generally influence the two nesting parameters. However, the impact of various reed management practices, such as harvesting or removal, on the nesting variables of the Great Reed Warbler needs further clarification.

Key words: reed burn, water depth, air temperature, precipitation, Mayfield nesting success, Serbia.

Introduction

The effects of weather variables such as precipitation, air temperature and wind on nesting variables (e.g. clutch initiation date, clutch size, number of fledglings) in passerines have been the subject of many studies (e.g. Fischer 1994, Nowakowski 2000, Skagen & Yackel Adams 2012, Honza *et al*. 2012, Fantle-Lepczyk *et al*. 2016). These weather variables may considerably influence nesting success of birds. Precipitation followed by strong wind and low temperatures influences clutch survival often negatively, i.e. through more costly incubation and brooding, food deficiency (Cucco *et al*. 1992, Fischer 1994, Cox *et al*. 2013). However, such climatic impacts have not only effects in a local population of a species; the weather influences nesting success of birds along latitudinal and longitudinal geographical gradients (e.g. Cooper *et al*. 2005, Mérő *et al*. 2015a). Beside weather circumstances, ecological disturbances can change ecosystem and community structure, and influence resources, substrate availability and/or the physical environment (White & Pickett 1985). Management of vegetation as a man-induced disturbance may also influence nesting and reproduction success in passerines (Sutter & Ritchison 2005, Murray & Best 2014). Beside that, nesting success is influenced by climatic factors; the nesting density of *Acrocephalus* warbler was found to depend on environmental factors such as habitat structure, habitat fragmentation and/or flooding (Paracuellos 2006, Benassi *et al*. 2009, Mortelliti *et al*. 2012, Sozio *et al*. 2013).

The breeding ecology of the Great Reed Warbler, (*Acrocephalus arundinaceus*) Linnaeus, 1758, has been extensively studied in several European populations, e.g. in Poland (Dyrcz 1981), in Sweden (Hasselquist 1998), in the Czech Republic (Petro *et al*. 1998), and in Serbia (Mérő *et al*. 2014). The nesting success in the Great Reed Warbler can depend on reed (*Phragmites australis*) (Cav.) Steud. 1841, structure characteristics, such as reed height, reed density and nest distance from reed edge (Graveland 1998, Hansson *et al*. 2000, Báldi & Batáry 2005). Previous studies reported that reed density influenced nest predation frequency, i.e. less concealed nests were more often depredated than nest hidden in dense reed (Batáry & Báldi 2005). Furthermore, brood parasitism by the Common Cuckoo (*Cuculus canorus*) Linnaeus, 1758, can result in considerably lower nesting success in the Great Reed Warbler in reed habitats that have more potential vantage points (Moskát & Honza 2000). Low nesting success in the Great Reed Warbler may appear when there is no adequate prey availability (Graveland 1996), or/and because of adverse weather, such as rainy and windy weather followed by low temperatures (Beier 1981, Fischer 1994).

Few Great Reed Warbler long-term studies analysed and discussed annual variations in polygyny (Bensch 1995), demographic variations and lifetime reproductive success (Hasselquist 1995), the effect of male arrival on their fitness (Hasselquist 1998), and how brood parasitism influences return rate in both sexes (Koleček *et al*. 2015). However, we still know little about how weather circumstances and vegetation management affect breeding performance (e.g. hatching rate, nesting success), during a long-term period in different populations within the distribution range of the species. The aim of our study was to explore the effects of weather variables (mean air temperature and amount of precipitation during the nesting period), reed burning, and water depth on nest density, clutch size, hatching rate, and nesting success of the Great Reed Warbler for a nine-year period in north-western Serbia.

Material and Methods

The study was conducted at the Bager mining pond (N 45.7880˚, E 19.0983˚) in the suburban area of Sombor, north-western Serbia. Sombor is a lowland area (average elevation 89 m), with a semi-dry continental climate, with mean annual precipitation of 590 mm, ranging between 400 and 900 mm. The mean annual temperature is 10.7˚C, with mean warmest monthly temperature in July of 21.1˚C, and mean coldest monthly temperature in January of 0.8˚C (Tomić 1996). The surface of the pond is approximately 1.3 ha, and during the entire study period, the pond was mainly covered by reed (Table 1). The Bager Pond was established in the 1960s where clay was excavated for the local brickyard. Water level in the pond depends on precipitation in autumn, winter and early spring and in wet years in early summer when a large amount of precipitation falls (e.g. in 2010, Table 1). Furthermore, the variation of the level of groundwater can also influence the water level in the pond. In four years (2009, 2010, 2012 and 2014) at the end of winter (February or March), the reed extent of the pond was partially burnt (27-85%) by the locals (Table 1). This enabled us to study the effects of burning, i.e. reed management, on the nesting parameters of the Great Reed Warbler.

The fieldwork was conducted from mid-May to end of July in a nine-year period from 2008 to 2016. We surveyed systematically the entire extent of the pond for Great Reed Warbler nests. The nests were checked regularly at six-day intervals in 2008 and 2016, and five-day intervals from 2009 to 2015. At every second event, we surveyed systematically the entire pond again in case to find newly constructed nests. During nest checks, we recorded the following data: number of eggs, number of nestlings, number of lost eggs, number of non-hatched eggs, number of lost nestlings and number of fledglings and water depth measured under nests. In cases when remains of eggs were found or previously recorded eggs vanished, or nestlings disappeared, we concluded that the nest was predated. In all other cases, we recorded nest fate as abandoned. Furthermore, we calculated the mean air temperature and total amount of precipitation for the entire nesting season (May, June, and July) for each year. We took the data on mean monthly air temperature and maximum amount of precipitation per month from the Republic Hydro-meteorological Service of Serbia. In this study nest, density is defined as the total number of nests found per a hectare, i.e. the ratio of the total number of nests per a year and the surface of the pond (1.3 ha). The nest density is not equivalent to the density of nesting pairs (e.g. number of nesting females). Mapping of singing males was not performed in this study.

Table 1. Main characteristics and dominant vegetation of Bager Pond for the period 2008-2016.

Year	Proportion of open water (%)	Mean water depth near nests (cm ± SD), (n = sample size)	Vegetation cover (%)		Proportion of managed area (%)
			Phragmites australis	*Typha angustifolia*	
2008	10	59.4 ± 29.24 (62)	85	5	0
2009	8	6.8 ± 17.23 (66)	89	3	85
2010	7	108.2 ± 37.20 (150)	92	1	50
2011	8	77.5 ± 26.91 (115)	91	1	0
2012	4	8.7 ± 10.26 (43)	95	1	27
2013	3	70.0 ± 16.01 (56)	97	0	0
2014	0	70.9 ± 11.30 (89)	100	0	85
2015	0	80.3 ± 21.92 (101)	100	0	0
2016	0	45.6 ± 19.09 (65)	99	1	0

Similarly, to Jelínek *et al*. (2014), for each year, we calculated the proportion of active nests by dividing the number active nests with the total number of nests. With one-sample t-test we compared the proportions of active nests between the years. In case there was significant difference in the proportions of active nests between the years, we applied simple linear regression to estimate the relationships between the proportion of active nests, and air temperature and amount of precipitation. This approach was necessary in order to ascertain whether weather variables influence nest desertion or not.

Nesting success for each year was estimated with the Mayfield method where data of egg-days and nestling-days were used (Mayfield 1975). In this study, we define the nesting success as the probability that an egg produces a fledgling. The multiplication of the egg and nestling survival rate for the entire incubation and nestling period and the hatching rate resulted in the final nesting success rate, and was then converted to percentages (Mérő *et al*. 2015b). In this study, the hatching rate is defined as the probability that an egg present at hatching time produces a hatchling (Mayfield 1975). Then we applied multiple linear regression by using the backward elimination method to check which factor as a predictor variable (the air temperature, the amount of precipitation, the reed burn, i.e. proportion of burnt reed area, and the water depth) affected the nest density, the clutch size, hatching rate and the nesting success (as dependent variables). Dependent variables displayed normal distribution (Shapiro-Wilk test, $p = 0.229 - 0.874$). The full model containing all four predictor variables was first tested by the enter function (see SPSS). In the next step, the backward elimination function eliminated step-by-step those predictor variables, which did not significantly contribute to the explained variance. In our case, this method excluded the predictor variable, which had the least effect on nest density, clutch size, hatching rate, and nesting success. The final model contains the predictor variable/s that has the strongest effect on the studied nesting parameters. We built a multiple linear regression model for every dependent variable separately. Statistical analyses were implemented in the SPSS 17.0 statistical software (SPSS Inc., Chicago USA).

Results

We found 161 Great Reed Warbler nests at the Bager Pond during 2008-2016, with lowest number of nests ($n = 9$) found in 2012 and highest number of nests ($n = 39$) found in 2010. The mean clutch size varied from 3.8 ± 1.36 (SD, in 2016) to 4.5 ± 1.23 (SD, in 2013), while the hatching rate varied from 0.80 in 2014, to 0.97 in 2011 (Table 2). Mayfield breeding success for the entire study period averaged 48.9%, and ranged from 17.6% in 2010, to 68.6% in 2011 (Table 2). The proportion of active nests differed significantly between years (range: 70-100%, one-sample t-test, $t_8 = 22.41$, $p < 0.0001$), however we found no evidence that this difference was due to the weather variables, i.e. weather variables did not influence the nest desertion (air temperature, $F_1 = 0.83$, $p = 0.394$; amount of precipitation, $F_1 = 0.30$, $p = 0.600$).

Table 2. Nesting parameters of the Great Reed Warbler at the Bager Pond for the period 2008-2016.

Year	Number of nests	Nest density (ha^{-1})	Mean clutch size (SD)	Hatching rate	Mean number of fledglings (SD)	Mayfield nesting success (%)
2008	17	13.1	3.9 ± 1.27	0.85	2.2 ± 1.72	47.8
2009	11	8.5	4.0 ± 1.48	0.91	2.5 ± 1.75	67.0
2010	39	30.0	4.2 ± 0.76	0.95	0.5 ± 1.40	17.6
2011	20	15.4	4.3 ± 1.13	0.97	2.9 ± 1.83	68.6
2012	9	6.9	4.1 ± 1.13	0.85	1.7 ± 1.98	48.9
2013	13	10.0	4.5 ± 1.23	0.89	2.9 ± 1.80	67.1
2014	14	10.8	4.4 ± 0.85	0.80	2.1 ± 1.94	49.5
2015	23	17.7	4.1 ± 0.64	0.90	1.9 ± 2.01	46.7
2016	15	11.5	3.8 ± 1.36	0.81	1.2 ± 1.72	34.7

The nest density was non-significantly influenced by the predictor variables in the full model (backward elimination multiple linear regression with explained variance, $F_4 = 5.91$, $p = 0.057$, $R^2 = 0.86$). The final minimum adequate model contained only water depth, which influenced positively (coefficient estimate, 0.17 ± 0.047 SE) the nest density ($F_1 = 12.86$, $p = 0.009$, $R^2 = 0.65$; Figure 1). In case of the clutch size we found neither the full model ($F_4 = 1.18$, $p = 0.439$, $R^2 = 0.54$), nor the final model ($F_1 = 1.31$, $p = 0.290$, $R^2 = 0.16$), explained the variation of clutch size. Similarly, the hatching rate was also not influenced by any of the predictor variables in the full ($F_4 = 0.24$, $p = 0.903$, $R^2 = 0.19$), and final reduced model ($F_1 = 0.96$, $p = 0.360$, $R^2 = 0.12$). The nesting success of the Great Reed Warbler was non-significantly influenced by the predictor variables in the full model ($F_4 = 3.04$, $p = 0.153$, $R^2 = 0.75$). In the final model, we found that the increase of the amount of precipitation influenced negatively (-0.11 ± 0.041 SE) the nesting success ($F_1 = 7.04$, $p = 0.033$, $R^2 = 0.50$; Figure 2).

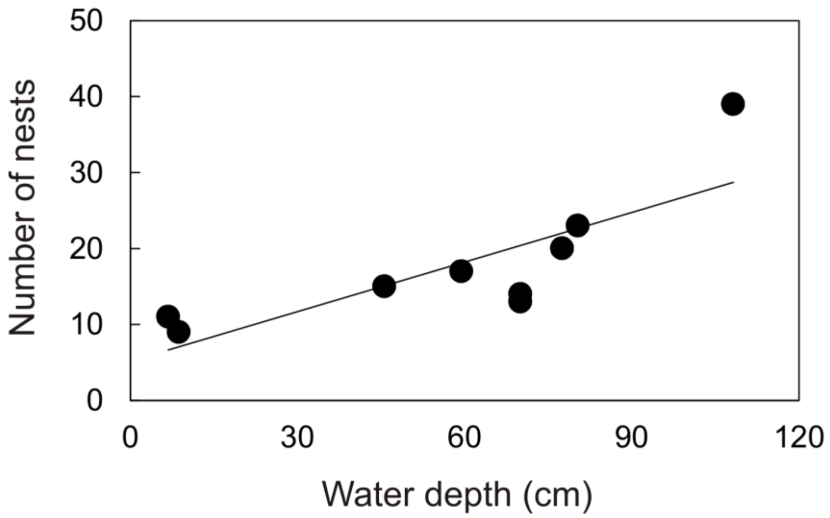

Figure 1. The relationship between mean water depth and nest density of the Great Reed Warbler at the Bager Pond for the period 2008-2016.

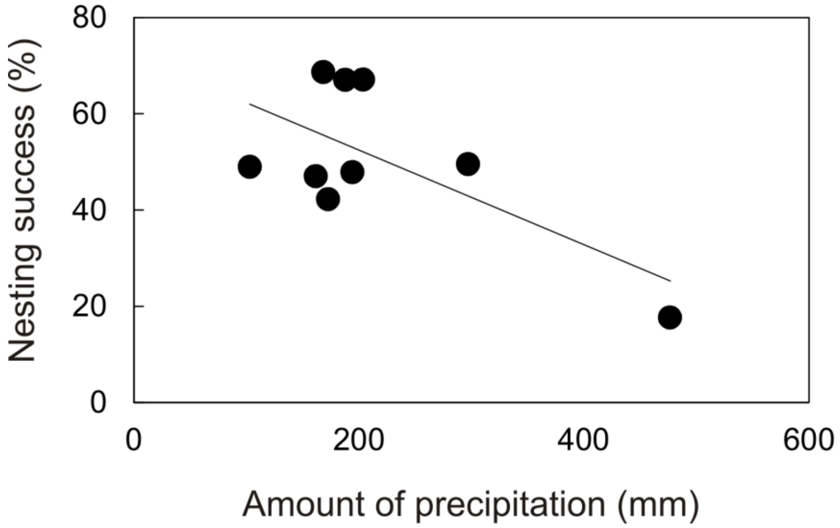

Figure 2. The relationship between the amount of precipitation and nesting success of the Great Reed Warbler at the Bager Pond for the period 2008-2016.

Discussion

Our results suggest that clutch size and hatching rate of the Great Reed Warbler was not influenced by air temperature, amount of precipitation, water depth, and reed burning. This finding is supported by the fact that in the extremely wet 2010, and in the extremely dry 2009 and 2012, these two nesting parameters displayed no remarkable differences (Table 2). Nevertheless, we found that nest density and nesting success were influenced by water depth and the amount of precipitation, respectively. This was because of the nesting seasons with larger (2014 and 2016) and extreme (2010) amount of precipitation (Table 1). The nest density was highest in the wet 2010 and lowest in the dry 2009 and 2012, while the nesting success was extremely low in the wet 2010 (Table 2). Finally, an interesting finding is that not only that reed burning had no impact on all four nesting variables, but it also was firstly removed from all four full models.

The mean nesting success of the Great Reed Warbler for the nine-year study period was slightly higher (48.9%) than in the previous four-year study (43.1%) of Mérő *et al*. (2014) conducted on the Bager mining pond. The clutch size (ca. four eggs per nest) and number of fledglings (ca. two per nest) were similar as in the short-term study of Mérő *et al*. (2014). Furthermore, previous studies confirm similar clutch sizes, number of fledglings and nesting success (ranging from 23.1% to 59.7%) in the Great Reed Warbler in various reed habitats in Central Europe (Beier 1981, Dyrcz 1981, Petro *et al*. 1998, Mérő *et al*. 2015b).

Mérő *et al*. (2014) found that nesting success was similar in both burnt and non-burnt reed patches. Graveland (1999) reported that reed management by cutting and/or harvesting did not influence the nesting success in the Reed Warbler (*Acrocephalus scirpaceus*) Hermann, 1804, and in the Sedge Warbler (*Acrocephalus schoenobaenus*) Linnaeus, 1758. However, besides the previously reported results we suggest that the effects of various reed management practices on the nesting ecology of the Great Reed Warbler is still lacking, and therefore further studies are required.

The importance of water depth for the nesting of the Great Reed Warbler was previously reported as a factor that can characterize the quality of a reed habitat (Graveland 1998, Mérő *et al*. 2016). We confirm the results of previous studies that nest density was related to water depth (Mérő *et al*. 2014); however, Dyrcz (1981) and Mérő & Žuljević (2014) reported that nest density can also depend on reed structure. During the nest construction, Great Reed Warblers need water because they moisten nest material into the water (Kluyver 1955), and this may confirm the finding of this study that water is more important than management of reed cover, i.e. reed structure. Furthermore, nest predation was significantly lower in edges closer to grassland than at reed edges adjacent to water, suggesting that deeper water can be a limiting factor for some predators (Trnka *et al*. 2009). As concerns the clutch size, Bensch (1995) found no significant relationship between clutch size and air temperature in long term variation. However, similarly to this study the hatching failure (as described by Bensch 1995), was not influenced by the air temperature. In contrast with our results, the amount of precipitation influenced clutch size in other species, such as the Spotted Flycatcher (*Muscicapa striata*) Pallas, 1764; large amount of precipitation in May resulted in smaller clutches but larger in July. However, in June clutch sizes were not related to the amount of precipitation (O'Connor & Morgan 1982). In case of clutch size and hatching rate, it seems that besides of the studied environmental variables, other factors such as food supply (Rowe *et al*. 1994, Sockman *et al*. 2006), and/or fertility of eggs (Petro *et al*. 1998) may have larger effects on these breeding parameters.

In case of the negative effect of the amount of precipitation on nestlings, Fischer (1994) and Beier (1981) reported that cold and wet weather followed by low temperatures increase the risk of chick mortality. Petro *et al*. (1998) recorded nestling mortality in 4.3% of cases by predation, 10.4% by desertion, and 20.0% of cases as perished. The relatively high presence of perished nestlings suggests that chicks died because of rainy weather circumstances during the nestling period (Petro *et al*. 1998). Furthermore, large amount of precipitation may limit food resources and in extreme conditions, a rapid increase of the water level can flood complete nests (Mérő *et al*. 2014). The increased amount of precipitation negatively influenced nestling survival in other passerine and non-passerine species (Rodríguez & Bustamante 2003, Pérez *et al*. 2016). However, there are species, such as the Song Sparrow (*Melospiza melodia*) Wilson, 1810, whose nesting success increased with the amount of precipitation (Chase *et al*. 2005).

We conclude that beside occasional annual variations in the nesting success of the Great Reed Warbler (Table 2), nesting success varied similarly throughout the study period. The positive relationship between water depth and nest density, and the negative relationship between nesting success and amount of precipitation, confirmed results from previous short-term studies. It seems that these two variables have a general impact on the nest density and nesting success of the Great Reed Warbler. As concerns reed burning, in case of this long-term study we may conclude that it has no relevant effects on the nesting variables. However, the effects of other type of reed management, such as harvesting, and removal, on the nesting variables of the Great Reed Warbler should be investigated in future studies.

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