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Improving the accuracy of estimates of nesting population size by detailed censuses of active nests of the Great Reed Warbler

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Abstract: We present a method for estimating nesting population size in a passerine bird based on counts of active nests, which can provide more accurate estimates on true population size than other methods. We surveyed 5 different reed habitat types in a region of Serbia in 2009–2011 to estimate the population size of the Great Reed Warbler. The estimation was based on the counts of active nests and was limited to the first clutches laid by females. We recorded a total of 442 nesting females. To estimate the population size for the studied region, the nesting densities were multiplied by the total area of the reedbed and the mean proportion of reed cover in each reedbed. This method may be used in areas/countries where there are no regular censuses and in bird species with strong habitat affiliations. In contrast to other methods, our estimation excludes uncertainty due to the presence of floater males and double counting of singing males, but considers polygyny, overall improving the accuracy of the estimate of the nesting population size. The disadvantages are that the method is time-consuming and demands considerable effort and reliable data on habitat area and quality.

Key words: Population size estimation, survey census, reed habitat type, nest density, *Acrocephalus arundinaceus*

1. Introduction

Reliable information on the distribution and population trends of animals is fundamental for the conservation and management of species and their habitats (Hagemeijer and Blair, 1997; Donald et al., 2007). Such information requires exhaustive censuses or accurate estimates of population size. In most western European countries, the systematic monitoring of bird species has been conducted for several decades (Cramp, 1998), whereas in eastern and southeastern Europe the systematic monitoring of bird populations has been rarely performed and often relies on speculation (e.g., Puzović et al., 2003). Frequently used census techniques for population estimation include point counts, line transects (Järvinen and Väisänen, 1975; Järvinen et al., 1991; Gregory et al., 2004), or, for special cases, territory mapping, spot mapping, the counting of birds at/or near aggregations, and nest searching (Bibby et al., 2000). Rarely, scaled measurements have been used, based on the relative frequency of species (e.g., 1 for 0%–20%, 5 for 80%–100%) in the case of data collected in transect sampling in various habitats (Matvejev, 1976). In countries where censuses are not performed or are performed irregularly, different field census techniques may be required for accurate estimates on bird population sizes.

The aims of the present study were (1) to present an improved method for estimating the nesting population size based on active nests found in reedbeds, (2) to quantify the density of nests in different reed habitat types, and (3) to estimate the size of the nesting population of the Great Reed Warbler (*Acrocephalus arundinaceus*) in the area of Sombor (northwestern Serbia). In the absence of data from regular species monitoring, we intensively searched for active nests and determined nesting densities in major reed habitat types in a well-surveyed region, and then used data on the extent of reed habitat types in the region to obtain a reliable, accurate estimate of the nesting population size of Great Reed Warbler for the region.

For our study, we selected the Great Reed Warbler, a reed specialist inhabiting patchy reedbeds (*Phragmites australis*) rich in edges adjacent to the water (Leisler, 1981; Graveland, 1998). Typical habitats include reedbeds along the banks of rivers and canals, heterogeneous reedbeds on mining ponds, fishponds, and marshes (e.g., Fischer, 1994; Fedorov, 2000; Mérő et al., 2014, 2016; Mérő and Žuljević, 2014). The overall population of the Great Reed Warbler in Europe has been estimated between 1,500,000 and 2,900,000 pairs, and has been relatively stable, with a slight decline since 1981 (BirdLife International, 2015).

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However, long-term studies from the 1980s and 1990s indicated that the Great Reed Warbler has declined considerably in Central Europe (Kloubec, 1995; Cramp, 1998; Graveland, 1998; Trnka, 1999). Europe covers some 25%–49% of the global range, and the population in Asia can only be approximately estimated as 9,180,000–34,800,000; improvement of the estimates is clearly needed (BirdLife International, 2015). Accurate and precise estimates of population sizes must be based on exhaustive documentation, because the reliability of estimates needs to be demonstrated to understand what information is required to improve them (Brouwer et al., 2003). As far as we are aware, a population estimate based on such principles, methods, and detailed knowledge has not yet been carried out in Serbia for any passerines, probably due to the lack of a systematic bird monitoring program.

2. Materials and methods

2.1. Study area

The study area was the municipality of Sombor, which covers an area of 1178 km^2 at an elevation of 89 m a.s.l. in the northwestern part of the northern Serbian province of Vojvodina. Sombor is a lowland area with a semidry continental climate, where the mean annual precipitation varies between 400 and 900 mm. The mean annual temperature is 10.7 °C; July is the warmest month, with a mean monthly temperature of 21.1 °C, while January is the coldest, with a mean monthly temperature of 0.8 °C (Tomić, 1996). Reed habitats of the Sombor municipality were categorized into the following reed habitat types.

Large canals – These water bodies are part of the Danube–Tisza–Danube hydro-system of canals, and also include a few other wide canals (Table 1). Their total length is 114 km, with an average width of 25 m. A narrow reedbed is found on both sides, often interspersed with

Table 1. Sizes of the studied reed habitats and reedbeds, and their vegetation cover.

Reed habitat type	Study sites	Area of surveyed reed habitat (ha)	Average width of reedbed (m)[b]	Area of surveyed reedbed (ha)[a]	Vegetation cover of reedbeds (%)		
					Reed	Cattail	Other
Large canal	VBC 1	2.0	4.5	0.4	80	15	5
	VBC 2	8.8	4.5	1.8	35	5	60
	VBC 3	1.6	3.5	0.3	30	15	55
	VBC 4	1.6	3.5	0.3	60	25	15
	DTD 1	1.5	4.5	0.4	65	15	20
	DTD 2	2.1	5.5	0.5	10	5	85
	Bajski canal	1.2	2.5	0.2	65	0	35
Small canal	Kígyós 1	1.0	2.5	0.2	90	0	10
	Kígyós 2	0.8	3.5	0.3	85	0	15
	Kígyós 3	1.0	3.5	0.3	80	10	10
	Mostonga	1.2	3.0	0.3	34	5	61
	Čonić	0.4	1.0	0.1	60	5	35
	Jaroš	0.4	1.0	0.1	15	30	55
	Gradina	0.4	5.0	0.4	65	15	20
	Stara Mostonga	0.7	7.0	0.7	80	5	15
Mining pond	Bager	1.3	N/A	1.2	90	9	1
	Pista	0.7	N/A	0.7	60	30	10
	Gakovo	1.4	N/A	0.9	85	10	5
Marsh	Jezero Stanišić	3.0	N/A	2.0	95	4	1
	Medura	8.4	N/A	4.4	90	0	10
Fishpond	Kolut 1	6.0	N/A	0.2	55	44	1
	Kolut 2	4.0	N/A	0.2	100	0	0
	Kolut 3	6.0	N/A	0.2	70	30	0

[a] water surface excluded; [b] given only for canals.

other herbaceous plants, such as cattail and/or sedge, and occasionally with weed shrubs. The water is supplied from the River Danube through a sluice system. Rarely, the reed is burned at the end of the winter (February and/or March).

Small canals – These water bodies mainly consist of narrow irrigation and drainage canals (Table 1). Their total length is 821 km. Small canals have been classified into 4 categories based on their size/discharge by the water authority in Vojvodina (Mérő et al., 2016). In the present study, we considered only the first-order (larger) canals, because nesting data for the Great Reed Warbler for the other 3 small canal categories are lacking, and we therefore excluded these from the present population size estimation. The total length of first-order small canals is 205 km. The reed stands are located on one or both banks, often displaying a patchy structure. The reedbeds were mown annually, during the inflorescence time in August and September.

Mining ponds – The majority of the mining ponds were established between the 1900s and 1960s, through the excavation of clay or sand for brickyards or construction. The mining ponds are predominantly small habitats, varying in size from less than 1 to a few ha. The reedbeds are patchy or fragmented, due to the irregular water depth and nonreed herbaceous vegetation (e.g., cattail). The water levels depend on the precipitation falling mostly in the autumn and winter, and on the evapotranspiration of the reeds in the summer, when water level often decreases rapidly. At times, the water level undergoes high interseasonal fluctuation; e.g., in 2010, the water level increased by ~1 m within 2 weeks (at the beginning of June).

Marshes – The marshes are generally characterized by open or closed reed stands formed during long, continuous succession. They were established through the regulation of the sluggish and strongly meandering rivers Mostonga and Kígyós in the lowland of northwestern Vojvodina. Most of the cut-off meanders (oxbows) have been drained and used as productive croplands. Oxbows remained only in the lowest-lying areas and became marshes with time. Marshes now cover 238 ha. Since the Danube–Tisza–Danube Canal was established, the water level of the marshes has generally decreased; the water is supplied through precipitation during the autumn and winter, while it disappears in early summer, i.e. in June or July, mainly because of intensive evapotranspiration.

Fishponds – Only the Kolut fishpond (approximately 200 ha) was included in this study, as the reed vegetation is adequate for the nesting of the Great Reed Warbler. The remaining 9 smaller and newer fishponds were excluded because their reed stands were mown or removed at least twice a year. The total area of the reedbed on the Kolut fishpond is 20 ha.

2.2. Data sampling and statistical analysis

Generally, nests were surveyed at 18 sites from early June to mid-August between 2009 and 2011. In the case of VBC1, Kígyós 1, Čonić, Bager, and Pista, nesting started earlier and surveys started in mid-May (Table 1). In all 3 years, the nest survey was conducted with the same intensity and effort at each study site, and we made every effort to find all nests. After nests were found, measured, and mapped at a study site, they were regularly checked once every 5 or 6 days.

The entire reedbeds on both sides of the selected sections of the large and small canals were surveyed for nests. We selected sections of canals where the reed cover of the banks varied from almost none to pure reed stands. We included poor reed stands (little reed cover) in order to avoid overestimating the nesting population by focusing only on good sites with abnormally high numbers. At the large canals, we used a canoe to find nests in reedbeds along the coastline. On average, we completed a 1-km-long section (e.g., VBC 1, VBC 3) in c. 3 h. The visibility of nests depended on reed density, light conditions, and nest height (these conditions were also relevant in other reed habitat types); however, nests here were easily detected. At the small canals, we walked the habitat in waders if the water depth was 80 cm or less; in other cases, we used a canoe. The time needed for the survey was similar to that needed at large canals. The visibility among reeds was good and finding nests was straightforward, especially in reedbeds where only fresh reed grew. In the case a nest failed before subsequent checks, we attempted to find the replacement clutch in the nearest surrounding area within approximately 10 m. At mining ponds, we searched nests using waders and surveyed the entire reed extent. At Pista, the nest survey took c. 2 h, while at Bager and Gakovo, c. 4 h. In marshes, we used waders, and in fishponds we used a boat to survey selected parts of the reedbeds. For marshes and the fishpond, the survey of one part took c. 6 h. In these 3 reed habitat types, replacement clutches were found within a 5-m radius of the initial brood. To save time, we marked all of the nests found by fixing a piece of insulation tape onto a strong reed stalk nearby to facilitate the repeated finding of the nest. Finally, we estimated the proportion of reed cover (%) by using ArcGIS 10.0 for Windows and Google Earth 6.1. In the case of linear habitats, the width of the reedbeds was measured near the nests.

The definition of '1 breeding pair' in this study corresponds to 1 breeding female Great Reed Warbler, i.e. a female possessing a nest with eggs or young ('active nest'). Only first clutches were included in estimating the population size, and replacement clutches were excluded to avoid double counting. By focusing on females with active nests in estimating the nesting population size, we excluded potential biases arising from the presence of nonbreeding females, floater males, and renesting attempts, but accounted for polygyny. For each study site, we calculated the density of nests as the number of nests divided by the available reedbed area (Table 2). Although nest densities of the Great Reed Warbler have been presented in an earlier work (Mérő et al., 2015), that study provided nest densities only for a subset (5 of 23) of the sites surveyed in this study and not for reed habitat types, which are the main focus here. We used one-way ANOVAs to test differences in the number of replacement clutches among the 3 study years, and to test differences in nesting density among the 5 reed habitat types and among the 3 study years. We used Tukey's HSD post-hoc test to compare mean densities of reed habitat types.

To estimate the nesting population size of the Great Reed Warbler in Sombor, we used data on mean nest density, reedbed areas, and the proportion of reed cover. First, we calculated the mean nest density for each reedbed for each of the 3 years (Table 2). Using these results, we estimated the mean nest density for each of the 5 reed habitat types. For linear reed habitat types (large and small canals), we calculated reedbed area as the product of the mean width (from field data) and the length (from the Sombor water management company) of the reedbed for the Sombor municipality. For the other 3 reed habitat types, we used a hand-held GPS receiver to estimate the sizes of the studied reedbeds. The proportion of reed cover of the reedbeds was estimated on the basis of the field work data; for each reed habitat type, we calculated the mean proportion of reed cover. Finally, the total area of the reedbeds for each reed habitat type, the mean proportion of reed cover of each reed habitat type, and the mean nesting densities of each reed habitat type were used to estimate the number of nesting pairs for each reed habitat type for each study year. ArcGIS 10.0 for Windows was used for area calculations, and statistical analyses were performed with SPSS 17.0.

3. Results

During the 3 years, we recorded a total of 595 nests, corresponding to 442 nesting Great Reed Warbler pairs: in 2009, 129 nesting pairs in 20 sites; in 2010, 158 pairs in 23 sites; and in 2011, 155 nesting pairs in 17 sites (Table 2). The number of replacement clutches was highest in 2010

Table 2. Number of nests and nest density of the Great Reed Warbler in the studied reedbeds.

Study area	Number of first clutches (replacement clutches)			Nest density in reedbeds (ha^{-1})		
	2009	2010	2011	2009	2010	2011
VBC 1	10 (0)	9 (2)	10 (1)	22.5	25.0	25.0
VBC 2	N/A	14 (4)	15 (3)	N/A	7. 8	8.3
VBC 3	7 (1)	8 (8)	8 (4)	23.3	26.7	26.7
VBK 4	10 (0)	8 (1)	8 (1)	33.3	26.7	26.7
DTD 1	13 (1)	7 (0)	N/A	32.5	17.5	N/A
DTD 2	0 (0)	0 (0)	0 (0)	0.0	0.0	0.0
Bajski canal	0 (0)	1 (1)	0 (0)	0.0	5.0	0.0
Kígyós 1	5 (0)	10 (11)	12 (3)	25.0	50.0	60.0
Kígyós 2	13 (1)	11 (4)	9 (6)	43.3	36.7	30.0
Kígyós 3	12 (0)	16 (10)	15 (4)	40.0	53.3	50.0
Mostonga	8 (0)	7 (3)	14 (3)	26.7	23.3	46.7
Čonić	9 (0)	4 (1)	8 (2)	90.0	40.0	80.0
Jaroš	2 (3)	2 (1)	2 (1)	20.0	20.0	20.0
Gradina	N/A	7 (2)	8 (1)	N/A	17.5	20.0
Stara Mostonga	N/A	6 (4)	3 (3)	N/A	8.6	4.3
Bager	10 (1)	16 (23)	19 (1)	8.3	13.3	15.8
Pista	5 (0)	5 (1)	6 (0)	7.1	7.1	8.6
Gakovo	16 (2)	19 (20)	16 (0)	17.8	21.1	17.8
Jezero Stanišić	5 (1)	2 (0)	N/A	2.5	1.0	N/A
Medura	1 (0)	4 (1)	N/A	0.2	0.9	N/A
Kolut 1	2 (2)	2 (0)	N/A	10.0	10.0	N/A
Kolut 2	0 (0)	4 (1)	N/A	0.0	20.0	N/A
Kolut 3	2 (1)	0 (0)	N/A	10.0	0.0	N/A
Total	127 (15)	158 (101)	155 (39)			

(one-way ANOVA, F_3 = 4.42, P = 0.016), which differed significantly from that in 2009 (Tukey's HSD post-hoc test, q = 4.13, P = 0.013). We also found that nest density differed significantly among the 5 reed habitat types (F_5 = 9.27, P < 0.0001). Nest density was significantly higher on small canals than in any other reed habitat type, which did not differ from each other significantly (Table 3). The nest densities did not differ between the study years (F_3 = 0.69, P = 0.506). Second nesting attempts were not observed.

From the numbers of nesting pairs detected in 2009–2011 (Table 4), we estimated the nesting population size in the Sombor municipality as between 2200 and 2800 pairs. The average of the 3 years was 2423 nesting pairs (Table 4), corresponding to a mean density of 2.1 pairs/km^2. Two-thirds (66.6%) of the nesting pairs (n = 1606 nesting pairs for the entire study period) bred on small canals (Table 4). The average numbers of nesting pairs in the other 4 reed habitat types were much lower: 374 on large canals, 221 on mining ponds, 166 in marshes, and 167 on fishponds.

4. Discussion

We aimed to improve the accuracy and reliability of estimates of the population size of Great Reed Warblers in the Sombor municipality by applying a proper and exhaustive census of active nests in which the proportion of replacement clutches was considered to avoid double counting. As our results indicate, the numbers of replacement clutches varies strongly from nesting season to nesting season. Environmental factors such as weather conditions, predation pressure, and Cuckoo (*Cuculus canorus*) parasitism rate appear to exert the greatest influence on the number of replacement clutches (Claassen et al., 2014). In the 2010 nesting season, for example, the amount of precipitation was significantly higher than in 2009 or 2011, which resulted in widespread clutch failure due to flooding; this may have led to the birds raising a higher number of replacement clutches (Mérő et al., 2014). A precise knowledge of the number of replacement clutches is thus a highly important element in the presented method of population estimation.

Nest density was highest on small canals and lower in other reed habitat types (Table 4). This may be because other reed habitat types have large extents of homogeneous reedbeds, which are used less frequently by Great Reed Warblers. In linear habitat types such as large and small canals, the narrow reedbeds along the banks provide the most reedbed edges adjacent to water, which are preferred for nesting by Great Reed Warblers, which typically nest within the first few meters of the reedbed edges. The high nest density in linear reed habitat types demonstrates the strong edge preference of this species (Báldi, 1999; Báldi and Kisbenedek, 1999, 2000). The nest density on mining ponds, where the reed structure is patchy, was intermediate compared to those in marshes and fishponds (low density), and those in linear reed habitat types (high density).

The census technique presented in this study has several advantages over the common line transect or point count methods, or other methods based on counting singing males. A census based on occupied nests, i.e. the number of females, excludes the uncertainties related to the presence of nonbreeding floater males and avoids double counting, but considers polygyny, and will thus provide a more accurate estimate of the nesting population size (Table 5). Such sources of uncertainty cannot be systematically

Table 3. Results of Tukey's HSD post-hoc tests for nest densities between the various reed habitat types (significant differences are highlighted in bold).

Compared pairs	q statistic	P value
Large canals vs. Small canals	**5.94**	**0.001****
Large canals vs. Mining ponds	0.73	0.899
Large canals vs. Marshes	2.49	0.407
Large canals vs. Fish ponds	1.54	0.785
Small canals vs. Mining ponds	**5.45**	**0.002****
Small canals vs. Marshes	**5.94**	**0.001****
Small canals vs. Fish ponds	**5.61**	**0.001****
Mining ponds vs. Marshes	1.79	0.691
Mining ponds vs. Fish ponds	0.81	0.899
Marshes vs. Fish ponds	1.00	0.899

Level of significance: **P < 0.01.

Table 4. The nesting density of the Great Reed Warbler in the 5 reed habitat types, and the estimated nesting population size for Sombor municipality.

Reed habitat type (area ha)	Mean density of nesting pairs S. D. (ha^{-1})			Estimated number of nesting pairs		
	2009	2010	2011	2009	2010	2011
Large canals (47)	19.0 ± 15.3	15.2 ± 10.9	14.4 ± 13.1	438	350	333
Small canals (68)	40.8 ± 25.7	31.2 ± 16.2	38.9 ± 24.8	1775	1355	1689
Mining ponds (23)	11.1 ± 5.8	13.9 ± 7.0	14.1 ± 4.8	189	236	239
Marshes (238)	1.4 ± 1.6	0.9 ± 0.1	N/A	195	136	N/A
Fish ponds (200)	6.7 ± 5.8	10.0 ± 10.0	N/A	133	200	N/A
Total				2730	2277	2262

Table 5. Comparison of the advantages and disadvantages of estimation methods based on active nests and based on line transect or point count methods.

	Active nests	Line transect or point counts
Advantages	avoidance of double counting	less effort and time needed
	consideration of polygyny	extent (area) of habitat types is less important
	excludes uncertainty related to floaters	easier to maintain over long time periods
	more accurate estimate of nesting population	more suitable for several species
Disadvantages	time-consuming	possibility of double counting
	regular checking of nests required	inability to detect polygyny
	requires good data on extent (area) of habitat types	accidental detection of floaters
	less feasible for longer-term monitoring	provides no proof of nesting
	suitable for one or a few species	less accurate estimate of nesting population

excluded with the line transect or point count method, as nesting cannot be proved for certain. For instance, an observed singing male does not mean that the individual is holding or nesting in a territory; there should at least be observations of birds carrying nest material or food during the nestling stage. However, the line transect and point count methods have the advantage that less time and effort are needed, while a census based on nest numbers is much more laborious. Furthermore, the regular checking of nests is needed to detect potential renesting if the individuals are not marked. The frequency of nest checks depends on the species involved. In the case of the Great Reed Warbler, we found it most fruitful to check nests every 5th or 6th day, because the construction of a replacement nest takes an average of 6–8 days (personal observation). Nests detected near the first brood within 10 days may thus be regarded as replacement nests. New nests detected later than 10 days may originate from a different female.

The accurate estimation of the size of bird populations is important for their conservation. Population estimates based on unfounded techniques or overspeculation may result in a species not being classified with the appropriate conservation status. Examples may be seen from large variations in population size estimates relating to the Great Reed Warbler for 2 different periods (data taken from Cramp, 1998 and BirdLife International, 2015).

Most of the variation in the estimates probably arises from country-level uncertainty in the number of breeding pairs. For example, the estimates for Hungary (30,000–50,000 pairs in 1979–1993 and 70,000–110,000 pairs in 1998–2002) would point to the Hungarian population more than doubling in a period of a few years, while the estimates for Ukraine would indicate a close to 10-fold increase (30,000–35,000 pairs in 1990 to 275,000–380,000 pairs in 1990–2000). However, we would suggest that there was actually no such large increase in population size, but that the differences appeared because of the use of less accurate techniques for population size estimates. In fact, the trend in the overall nesting population of the Great Reed Warbler has showed a slight decline over 40 years (BirdLife International, 2015). Studies such as ours may help improve the accuracy of country-level estimates of population sizes. Studies that estimate population size on the basis of habitat requirements and availability may be especially important in countries where bird monitoring based on systematic sampling is not well advanced.

In conclusion, a census method based on active nests may provide more accurate estimates of the nesting density and population size of birds (particularly passerines) than other commonly used census techniques. Census techniques based on the counting of singing males can result in less accurate estimates of population size, leading to incorrect conservation implications. Although the census method presented in our study is time-consuming, it may be suggested when systematic monitoring is not performed and when bird species with strong habitat affiliations (such as reed passerines) are the focus. This study fills a gap in our knowledge on the nesting density and population size in a previously little-studied part of the range of the Great Reed Warbler.

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