Nest site location and breeding success of Common kingfisher (*Alcedo atthis*) in the Danube river system

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Abstract

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Common kingfisher, *Alcedo atthis* is a fish-eating species that preferentially breeds alongside natural watercourses or smaller water bodies. During the seasons 2012, 2014 and 2015, we monitored the density of kingfisher population, nest site location and its breeding success in the Danube river system from Bratislava to Gabčíkovo (Slovakia). Population density was estimated on 23–27 pairs/55 km of the length of river branches. Average distance between nesting holes occupied by different breeding pairs was 816 m ± 421 SD. Kingfishers used river banks and wind throws to dig a burrow. The nest site location, but not nest parameters, was affected by the maximal height of the suitable area of the wall. As wind throws had larger suitable area, the location of nests in wind throws differed from the location in riverbanks. Breeding attempts were successful in 86% cases. The reason of unsuccessful breeding was mainly predation. Almost 72% of pairs bred two times per season, 17.9% of pairs three times and 10.7% of pairs four times per season. The most successful were the second and the third breeding attempts. Breeding pairs produced on average 6.43 young per successful breeding and 14.95 young per season. In total, 58% of pairs alternated breeding attempts. The rest of pairs overlapped attempts using different holes. Average distance between the holes concurrently used by a pair was 113.73 m (min = 0.3 m; max = 372 m). Neither this parameter nor the date of the first egg-lying in previous attempt affected the duration of the overlapping.

Keywords

breeding success, burrow-nesting birds, nest site location, population density

Introduction

Kingfisher uses for breeding uncovered banks. They are created either naturally (e.g., meandering of the river, falling of the tree) or by anthropogenic activity (e.g., mining or dam construction causing subsequent erosion of the banks) (Morgan and Glue, 1977; Cramp, 1990; Hudec and Šťastný, 2005; Čech, 2007). In general, the soil composition is very important for the nest site selection of the burrowing birds (Heneberg, 2004, 2009, 2013). Banks along the streams must be soft enough to be excavated but secure enough to avoid the collapse of the bank (Heneberg, 2013). Nest site position within a bank "wall" is usually a compromise between the predation risk and the risk of flood (Straka and Grim, 2007; Čech, 2007, 2013). Except for the nest location, the other way how to avoid flooding is to create a tunnel inclining slightly upward to prevent water from running down to the nest chamber (Hudec and Šťastný, 2005). Birds select nest sites very cautiously, because they use

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the same nest hole for consecutive clutches. Many pairs use two or three nesting holes for successive breeding attempts within a season and between years (Cramp, 1990; Čech, 2009).

Kingfishers live solitarily outside the breeding season. During the breeding season part of the population is socially monogamous, but polygamic/polyandric pairs have been observed in up to 35% cases (Cramp, 1990; del Hoyo et al., 2001; Čech, 2009). Changing of the territory or a mate during the season is not uncommon. Birds are successful in 54–80% of breeding attempts (Cramp 1990; del Hoyo et al., 2001). In general, nests of burrowing birds, kingfishers included, suffer mainly from predation (Sieber, 1980; Cramp, 1990; Heneberg, 2005). Pairs have two or three breedings in a season (Fry et al., 1999; Kucharski, 2001; Hudec and Šťastný, 2005), rarely four attempts have been documented (Cramp, 1990; Novotny, 1994; Čech, 2006, 2010). The breeding attempts of one pair may alter or overlap. When a pair overlaps two breeding attempts, male broods and feeds hatchlings while female lays and incubates another clutch in a different burrow (Cramp, 1990). There is no information about factors, which can cause the altering/overlapping strategy or the length of altering/overlapping.

In our study, we focused on following topics: 1) Does maximal height of the suitable uncovered "wall" affect a location of a nest within a bank? As predation risk and possibility of flood mainly affect breeding, we can expect that in larger suitable areas birds will dig burrows in positions – far from the top to reduce possibility of predation and far from the bottom to reduce possibility of flooding; 2) Are the first breeding attempts more successful than the later ones? As in many bird species is the first clutch larger than the second one, depending on parents condition and available food resources, we expect the higher success of the first attempts; 3) Does distance between simultaneously used holes affect a length of overlapping between breeding attempts? As the flight between long distance holes takes time and energy needed for parental care, we can expect that a longer distance between the holes will cause shorter time of overlapping; 4) Does the date of laying the first egg in previous attempts affect a length of altering/overlapping between breeding attempts? A later date of the first egg laying can press the breeders to shorten the time of altering and elongate the time of overlapping between breeding attempts and hereby shorten the time of breeding period to finish it in time.

Material and methods

Data collection

Altogether we documented 74 breeding attempts of 35 pairs of kingfishers. Field work was carried out from April to September in the seasons 2012, 2014 and 2015 in the Danube river system from Bratislava to Gabčíkovo (Fig. 1). This area is a part of Protected Landscape Area Dunajské luhy in the south-western Slovakia. At the beginning of the breeding season we searched for new nesting holes and observed the gradual occupation of the old ones. When we had found an occupied burrow, consecutively we took measurements of its basic parameters - the width and the height of the entrance opening, tunnel depth, distance of the hole to the bank top and to the bottom, maximal height of the suitable area of the bank or wind throw. To each nesting hole we assigned GPS coordinates which were consecutively transmitted to Google Earth software to measure distances among individual nesting holes used by different breeding pairs. Breeding density was calculated as the number of breeding pairs estimated to the sum of the length of controlled river branches. We checked the burrows using a special inspection camera. When we had found fresh eggs or incubating female inside the hole, we started to control a breeding attempt in periodical intervals of seven days. If we found uncompleted clutch, we were able to estimate the date of laying the first egg, taking that laying interval in kingfisher females is one day (Cramp, 1990). In cases when we found full clutch, we estimated the date of laying the first egg according to the hatching date, as it is known that the incubation period usually takes 21 days (Cramp, 1990). In several cases, when we missed the hatching, we estimated the date of laying the first egg from the hatchling's appearance (Čech, 2009). Several days after the young hatched, we captured parents, determined their sex and age and ringed them. Fledglings were ringed in the age of minimum 15 days. We consider a nest to be successful, when fledglings reached age up to 20 days. In this age they are fully plumaged and able to leave the nest (Čech, 2009). We continued to control the nest holes after the chicks ringing, because of the possibility of another breeding attempt. Parents of successful nests stayed near to the nest hole and continued in consecutive breeding process either in the same hole, or in another hole, close to the first one. For unsuccessful attempts we consider the nests destroyed by flood, wall slide and predation. In cases of predation we found excavated nesting chambers and destroyed burrows. We finished the field work in September when the last fledglings left the nests.

Statistical analyses

Measurements of nest holes and their location were collected during the season 2012, 2014 and 2015. Breeding data used in analyses were collected in the seasons 2014 and 2015. To differentiate between riverbanks and wind throws in the hole's measurements and nest's location we used the Canonical Correspondent Analysis (CCA). From twelve variables used in the analysis, six

Fig. 1. Map of study area. Danube river system between Bratislava and Gabčíkovo.

variables participated on 100 % variability (Table 1). Two variables which have been considered to have biologically significant relationship, were consecutively analysed using ANOVA test. The correlation between the height of a suitable "wall" size and nest location was tested by Pearson's correlation test. Breeding success (number of fledglings) was estimated only for successful nests. Single breeding attempt´s success was compared by Kruskal-Wallis test. The effects of the first egg laying date of the previous attempt and the distance between simultaneously used holes on the length of alternating/overlapping were tested by univariate linear regressions. All analyses have been done in SPSS Statistics software ver. 16 (SPSS Inc, 2007) and STATISTICA 8 (Statsoft Inc, 2013).

Table 1. Canonical loadings (i.e. correlations) for the wind throw/riverbank nest holes of the Kingfisher. Traits with correlations that are greater than or equal to an absolute value of 0.4 are considered to have biologically significant relationships (in boldface; McGarigal et al., 2000).

Trait	Axis 1
Maximal height of the wall	**0.67**
Maximal width of the wall	-0.08
Tunnel depth	-0.21
Height of the wall in nest location	**0.57**
Width of the wall in nest location	0.11
Water level	0.19
Eigenvalue	1.50
Cumulative % of total variance explained	1.00

Results

Density of studied population was estimated on 23–27 breeding pairs/55 km length of river branches. Distance between the breeding holes of different pairs measured during the first breeding attempt was 816 m ± 421 SD (n = 34, min = 24 m, max = 1,700 m). One nest wall was occupied by a single breeding pair. We have never observed two different pairs occupying the same nest wall.

Nesting sites and holes

Kingfishers preferentially used nest holes made in riverbanks or in wind throws. The average parameters of used holes are presented in the Table 2. Traits considered to have biologically significant relationship, differentiating nest location between riverbanks and wind throws, are the maximal height of the wall and the height of the wall in the nest location (CCA, Table 1). The wind throws were higher than river banks, the maximal height of the wall was significantly higher in wind throws ($F_{1,47} = 30.139$, $P < 0.001$), as well as the height of the wall in the nest location was significantly higher in wind throw ($F_{1,50} = 27.817$, $P < 0.001$; Fig. 2). Moreover, we found differences in the location of the nesting hole as the distance of the hole to the bank top was larger in wind throws ($F_{1,51} = 14.761$, $P < 0.001$) as well as the distance of the hole to the bottom ($F_{1,51} = 17.714$, $p < 0.001$; Fig. 3). According to the results from CCA these traits were not considered as significant variables differentiating holes in riverbanks and wind throws. Probably, it was caused by the large overlapping of these parameters between riverbanks and wind throws. Consecutively, we found significant positive correlation between the maximal height of the wall and the distance of the hole to the bank top (r = 0.63, $P < 0.001$, n = 49, Fig. 4a) as well as the distance of the hole to the bottom (r = 0.74, $P < 0.001$, n = 52, Fig. 4b). These results show effect of suitable wall size on the nest hole location. Individual parameters of a nest hole were not affected by a suitable wall size.

Table 2. Nest hole's parameters of the Kingfishers in riverbanks and wind throws

		All nests			Windthrow			Riverbank	
	n	Mean	Min	Max	SD	Mean	SD	Mean	SD
Height of the entrance opening	51	7.6	5.3	13.0	1.39	7.7	1.44	7.5	1.31
Width of the entrance opening	51	6.2	4.5	12.0	1.36	6.1	1.38	6.4	1.35
Tunnel depth	44	55.0	24.5	85.0	12.08	52.3	11.97	58.5	11.60
Distance of the hole to the bank top	53	69.6	20.0	270.0	43.25	85.4	45.86	43.6	20.70
Distance of the hole to the bottom	53	141.0	52.0	313.0	53.40	161.9	49.44	106.5	40.94
Distance between hole and left edge	53	116.6	16.0	427.0	81.47	134.6	93.38	86.9	44.59
Distance between hole and right edge	53	125.4	22.0	487.0	98.07	121.2	97.72	132.5	100.76
Height of the wall in nest location	52	192.7	75.0	410.0	79.37	228.3	75.10	130.7	37.97
Width of the wall in nest location	53	241.5	68.0	567.0	129.68	254.9	134.54	219.4	121.28
Maximal height of the wall	49	206.0	75.0	422.0	87.65	251.0	83.30	140.7	39.98
Maximal width of the wall	48	300.8	90.0	600.0	128.08	292.3	119.66	313.6	142.38
Water level	53	24.9	0.0	120.0	26.05	28.5	27.91	19.0	22.04

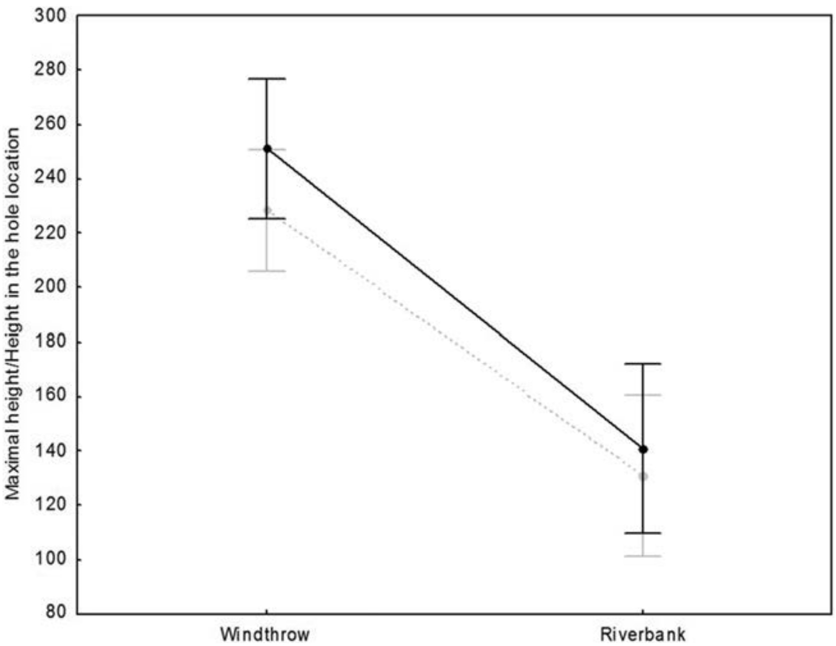

Fig. 2. Differences in maximal height of the suitable wall and the height of the wall in the nest location (cm) between banks and wind throws. Dots denote means, vertical bars denote 95% confidence intervals. Black line shows maximal height of the wall, dashed line shows height of the wall in the nest location.

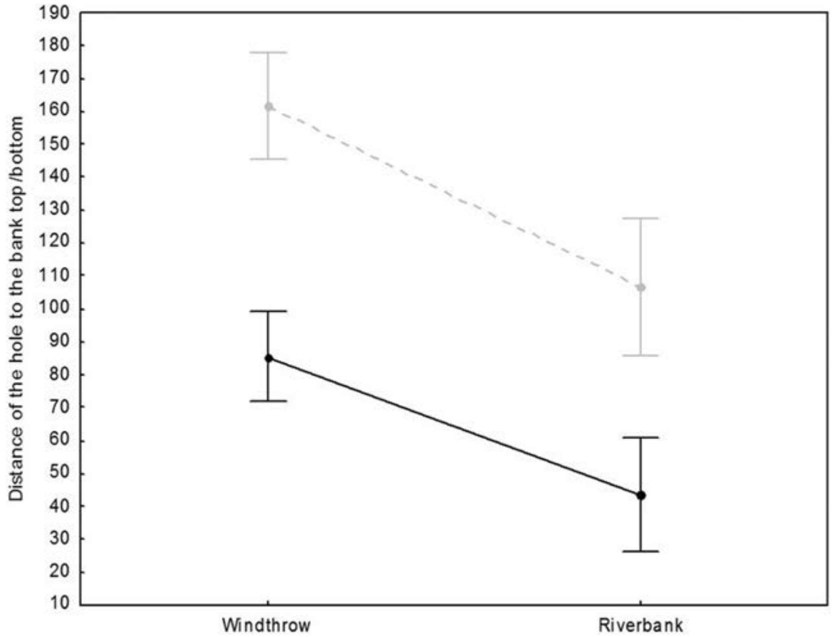

Fig. 3. Differences in nest hole location in riverbanks and wind throws. Dots denote means, vertical bars denote 95% confidence intervals. Black line shows distance of the hole to the bank top, dashed line shows distance of the hole to the bottom.

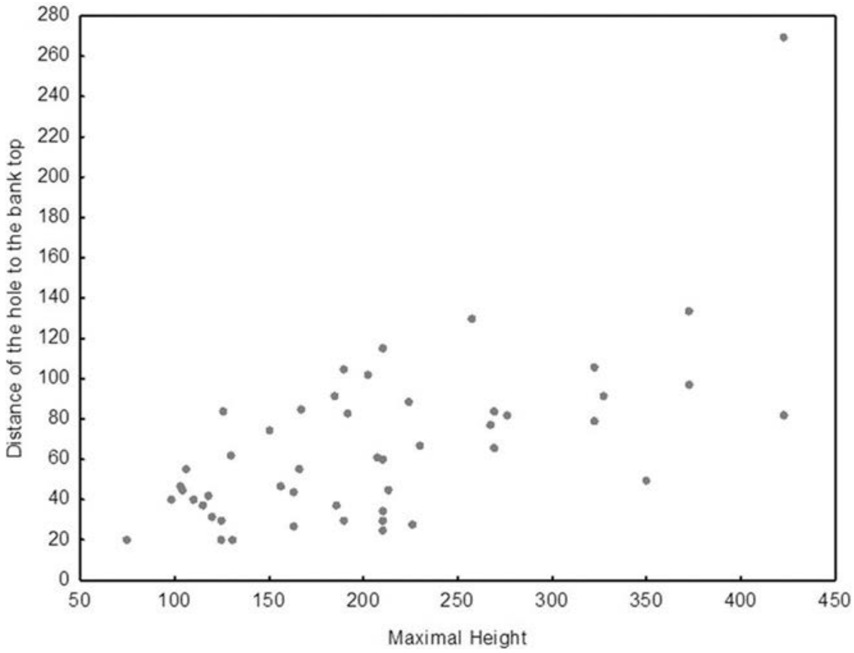

Fig. 4a. Positive correlation between maximal height of the wall and distance of the hole to the bank top.

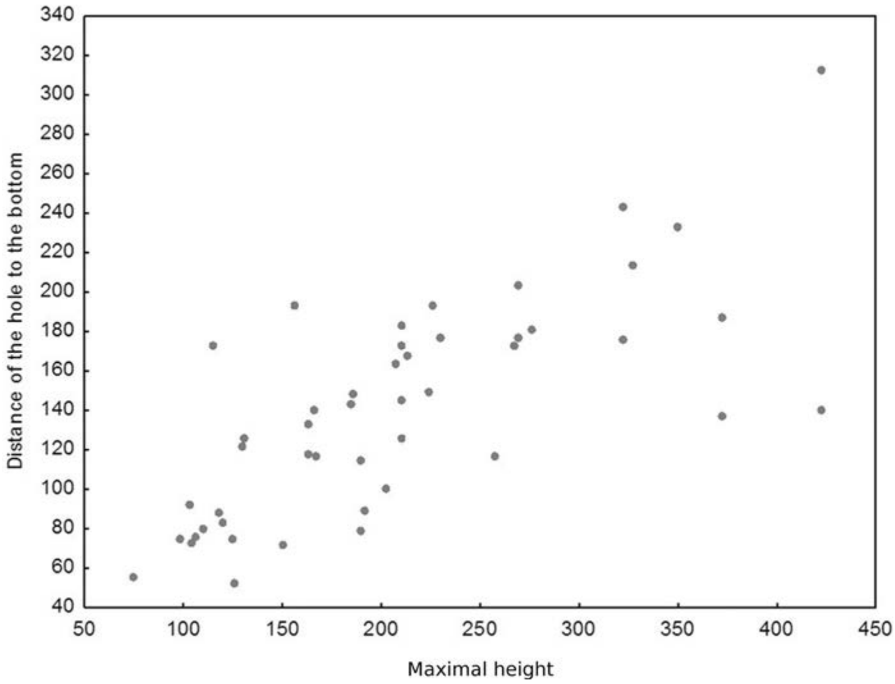

Fig. 4b. Positive correlation between maximal height of the wall and distance of the hole to the bottom.

Breeding biology

Breeding success of kingfishers in the Danube branches reached 86% (n = 64). The reason of unsuccessful breeding was mainly predation (five cases of documented nest losses), bank slide (one case), disintegration of a wind throw (one case), flooding the nest hole (one case), and abandonment of the clutch (one case). In one case the reason was unknown. Majority of breeding pairs (23 pairs) bred two times per season. Three breeding attempts were recorded in seven pairs. Three pairs were observed to breed four times. Breeding success of individual breeding attempts was different (Kruskal-Wallis Test χ^2 = 11.407, P = 0.010). The largest number of fledglings was produced in the second and the third attempts, while the least successful was the fourth one (Fig. 5). Breeding success of one pair was on average 6.43 ± 0.88 SD young per nest (breeding attempts: n = 64, min = 3, max = 8) and altogether 14.95 ± 4.85 SD young per season (breeding pairs: n = 19, min = 6, max = 26).

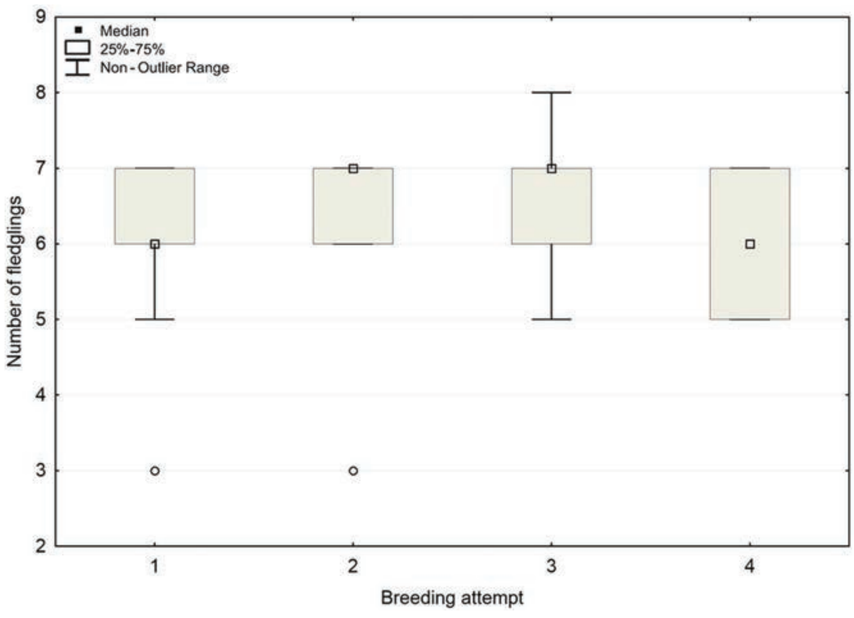

Fig. 5. Number of fledglings produced in different breeding attempts.

Kingfishers used two different breeding strategies: 58% of pairs altered and 42% overlapped the consecutive breeding attempts. The former started another breeding after finishing the previous one, with a pause between breeding attempts of 11.85 days ± 5.91 SD (n = 13, min = 5, max = 22). In the latter, the male fed the young in one hole, while female concurrently /laid/ or incubated another clutch in a different hole. The length of overlapping was 12.56 days ± 5.56 SD (n = 32, min = 5, max = 23). Birds used two different holes simultaneously when overlapping. Seven pairs used nest holes being far from the previous nest, at a different nest wall (min = 31 m, max = 372 m). Five pairs used nest holes within the same nest wall (min = 0.3 m, max = 43 m). Distance between the simultaneously used holes was not correlated with the length of overlapping (linear regression: $r^2 = 0.173$, $F = 1.671$, $P = 0.232$, $n = 9$). The date of laying the first egg in the previous attempt also did not affect neither the length of the pause when the birds were altering (linear regression: $r^2 = 0.00$, $F = 0.02$, $P = 0.965$, $n = 12$) nor the length of overlapping (linear regression: $r^2 = 0.168$, $F = 3.0376$, $P = 0.102$, $n = 16$).

Discussion

Nesting sites

Parameters of our kingfisher's holes are very similar to the parameters recorded from other populations mainly in the Czech Republic (Heneberg, 2004; Hudec and Šťastný, 2005; Straka and Grim, 2007). Our results showed that the maximal height of a suitable wall area affects the nest location, but not its parameters. Birds avoid being in vicinity to the bank top as well as to the bottom and try to dig holes in the middle of the wall. Birds nest higher from the water level to avoid flooding of the nest or predation by predators which scratch up tunnel through the entrance opening, as rat, weasel, marten or otter (Čech, 2007). On the other hand, nesting holes localised under the bank top could be dug out through nest chamber by predators such as Red fox (Cramp, 1990; Heneberg, 2005; Čech, 2007). We observed both cases, excavation from the entrance opening even from the top of the bank. Predation was the factor that affects the most nests losses. In spite of it, breeding attempts were successful in 86% of cases. It is known that lower predation risk enables birds to have larger clutch size and high breeding efficiency (Martin, 2004). In the case of kingfisher, high survival probability of chicks at the beginning of their life is reduced by the high death rate during the first winter (Morgan and Glue, 1977; del Hoyo et al., 2001).

Long breeding season (from March to September) allows for more breeding attempts of one pair. We documented up-to four breeding attempts of pair per season. Our results are consistent with the observations of the Czech population (Čech, 2009, 2010), but different from Polish, where there have never been recorded four breeding attempts of one pair. It was argued by shorter breeding season (Kucharski and Čech, 2009). Overall breeding success of our birds was established on average 6.43 young per nest and 14.95 young per season. When comparing with populations of kingfishers in other European countries where reproduction success was estimated from 5.19 to 5.63 young per nest (Morgan and Glue, 1977; Cramp, 1990; Hudec and Šťastný, 2005; Čech, 2009, 2010), we can state that Slovak kingfishers have a little higher reproduction success. We assume that a long breeding season could be caused by the rich choice of food in the Danube river system as it is known that food availability may limit breeding and affect clutch size (Lack, 1947; Ricklef, 2000). When kingfishers lay three or four clutches each containing of six or seven eggs, they can produce up to 26 young's per season (21% breeding pairs produced from 20 to 26 fledglings, own. obs.). It was documented that parents feed their chicks by fish of specific size (from 4 to 7 cm) (Campos et al., 2000; Isotti and Consiglio, 2002; Čech and Čech, 2007; Vilches et al., 2012) and every day deliver 62.6 ± 0.2 (SE) pieces of fish prey to a nest (Vilches et al., 2013). For both parents it is necessary to be in top condition to be able to hunt for such amount of fish. We assume that food availability determines the length of the breeding season and together with the parents' condition they are the key factors that determine the number of breeding attempts and consecutively overall breeding success. Such enormous effort of parents has its costs in the fact of worsening of the body condition and a lower probability of survival. It is well known that birds underlie trade-off between reproduction and survival (Stearns, 1992). Many breeding attempts and the production of many offspring shorten their lifetime as it was recorded in the Czech and British population (Morgan and Glue, 1977; Čech, 2009).

Kingfishers can breed three or four times in a given season due to a special strategy of overlapping two breeding attempts. Overlapping has been observed in other populations in different amount of cases (Cramp, 1990; Hudec and Šťastný, 2005; Kucharski and Čech, 2009). We recorded that 42% of breeding pairs used this strategy. Birds used two different holes for overlapped breeding. Long distance flight between two concurrently used holes could take time and energy that birds should use to parental care. On the basis of that assumption we expected that shorter distance enables longer overlapping period, but we did not confirm it. Other factor, such as the first egg laying date of the previous attempt, could influence the length of altering or overlapping. We expected that later date could press birds to elongate overlapping/shorten altering to manage the finishing the breeding process in time. In both cases we found no correlations, which can be explained by a low number of cases included in our analyses.

Conclusions

Finally, we can state that kingfishers from the Danube nest in riverbanks and wind throws. The maximum height of a suitable wall affects the nest location, however, not burrow parameters. Breeding success was observed in 86% of attempts. The main cause of unsuccessful breeding was predation. Pairs perform two, three or four breeding attempts, which they can alter or overlap. Many breeding attempts enable them to gain high breeding success.

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