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The effect of nest site on the nesting success of the Coot *Fulica atra*

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The nesting success of Coots (*Fulica atra*) breeding at lakes and small inland water bodies in the Mazurian Lakeland, Poland, was estimated in 2008 and 2009. Mean nesting success, indicated by hatching, was 75%; it was highest at lakes in the vicinity of built-up areas (86%), moderate at small inland water bodies (69%) and lowest at lakes far from human settlements (44%). Nesting success improved with decreasing distance to open water. Our results suggest that small inland water bodies and built-up areas along lake banks may serve as Coot refuges, acting as safeguards against predation, especially by the American Mink.

1. Introduction

Population trends of the Coot (*Fulica atra*) in recent decades in Europe are difficult to generalize because of many regional differences in this respect (Musil & Fuchs 1994, Kauppinen & Väänänen 1999, Houdková 2003, Rönkä *et al.* 2005, Stanevičius & Švažas 2005). Coot populations clearly declined in the end of the 20th century in most of central Europe (Rose 1996, Burfield & van Bomel 2004). Similarly, Coot numbers decreased significantly in the 1990s in several western and northern regions of Poland (Tomiałojć & Stawarczyk 2003, Cempulik & Betleja 2007, Ręk 2009), and the Polish Coot population has also been declining very recently (Neubauer *et al.* 2011). By the mid-1980s, the Mazurian lakes in NE Poland harbored thriving populations of many waterfowl species, including the Coot, which was one of the most numerous breeding species (Lewandowski 1964, Borowiec & Jakubczyk 1975, Bukaciński & Jabłoński 1992). However, during the 1990s the Coot population of the Mazurian Lakeland has markedly declined (Brzeziński *et al.* 2012). The decline was expressed not only by much lower densities of breeding pairs, but also by their disappearance from most Mazurian lakes.

The reasons for these population changes at the Mazurian Lakeland may be tentatively related to several environmental factors. One of these is the increased eutrophication of lakes, which negatively affects the submerged macrophyte biomass and Zebra Mussel (*Dreissena polymorpha*) densities (Ozimek & Kowalczewski 1984, Stańczykowska & Stoczkowski 1997). Submerged Charophytes are an important component of the diet of the Coot (Perrow *et al.* 1997), and the Zebra Mussel became the staple food of Coots in many water habitats after its invasion in Europe (Borowiec 1975, Stoczkowski & Stańczykowska 1995). Shrinking food resources cannot be excluded as being one reason for the Coot population decline.

Another possible reason for the Coot decline is the expansion and predation of the introduced American Mink (*Neovison vison*; Brzeziński & Marzec 2003). Some authors have not found conclusive evidence for waterfowl populations being limited by Mink predation (Arnold & Fritzell 1987, Halliwell & Macdonald 1996, Bartoszewicz & Zalewski 2003), but others have (Viksne *et al.* 1996, Craik 1997, Ferreras & Macdonald 1999, Nordström *et al.* 2003). Birds are exposed to Mink predation mostly during the breeding season (Gerell 1967), and some groups, such as Rallidae, seem to be particularly vulnerable (Day & Linn 1972, Chanin 1981, Ferreras & Macdonald 1999). Overall, alien predators, such as the American Mink, can be more successful in reducing numbers of their prey populations than indigenous predators (Salo *et al.* 2007).

The aim of the present study was to analyse nest losses of Coots in relation to nest location. Nest sites were described according to the size of the water body (lakes and small inland water bodies) and the presence or absence of built-up areas. Other environmental parameters were collected for the nest sites to explore their role in determining nest losses (see Material and methods). Nest-site selection might be a response to predation pressure largely by the American Mink (Brzeziński *et al.* 2012), but the real measure of Coot adaptation to predation is breeding success. For this reason follow-ups of nests were carried out.

2. Material and methods

2.1. Study area

The study was conducted at the Mazurian Lakeland, located within the Baltic glaciation in north-eastern Poland. The entire region covers an area of about 13,180 km^2 and contains 742 lakes larger than 0.1 km^2 (Jańczak 1999). Most of the lakes are eutrophic, and the littoral zone is usually overgrown with Reed *Phragmites australis* and Lesser Bulrush *Typha angustifolia*. The study was carried out in the breeding season (April–June) of 2008–2009. Data were collected at the following lakes: Probarskie (53°49’N, 21°23’E), Inulec (53°48’N, 21°29’E), Czos (53°52’N, 21°18’E), Piecki (53°45’N, 21°20’E), one bay of the Lake Orzysz (53°50’N, 22°04’E) and at 17 unnamed small inland water bodies distributed at 53°50’– 53°52’ N and 21°36’–21°43’ E. These were usually located in small (up to 5 ha) and shallow (up to 2 m) natural hollows surrounded by arable fields, meadows or fallows. Dominant vegetation at the inland water bodies were Reed, Lesser Bulrush and Sedges *Carex* spp.

2.2. Data collection

Nest losses were estimated after detecting and following 107 nests (5 lakes and 7 small inland water bodies including 46 nests in 2008; 4 lakes and 6 small inland water bodies including 61 nests in 2009). Nests were searched by walking through the littoral zone or canoeing along the edge of open water and emergent vegetation. After locating a nest, the location was plotted on 1:10,000 maps. The distance of the nest to the nearest human settlement (with an accuracy of 100 m), distance to the nearest bank and distance to open water (both with an accuracy of 1 m), and water depth at the nest site (with an accuracy of 0.05 m) were measured. Nests were visited at 7-day intervals, with a minimum of four visits to each nest, carried out until the beginning of June. This allowed a determination of brood fate, while reducing the disturbance to birds and the risk of predation. Eggs were counted but not individually marked. The fate of each nest was recorded on successive visits. The brood was considered lost if all eggs were missing or damaged, or if the nest was abandoned or destroyed. A brood was considered successful if at least one juvenile had been observed or if there were traces of hatching. All cases of re-nesting were treated as new nests.

2.3. Statistical analyses

A generalized linear mixed model with binomial error distribution and logit link function was applied to assess the effect of nest placement on nesting success. Four explanatory variables were used: (1) distance from a nest to open water (used as a covariate; Dist.open), (2) distance from a nest to

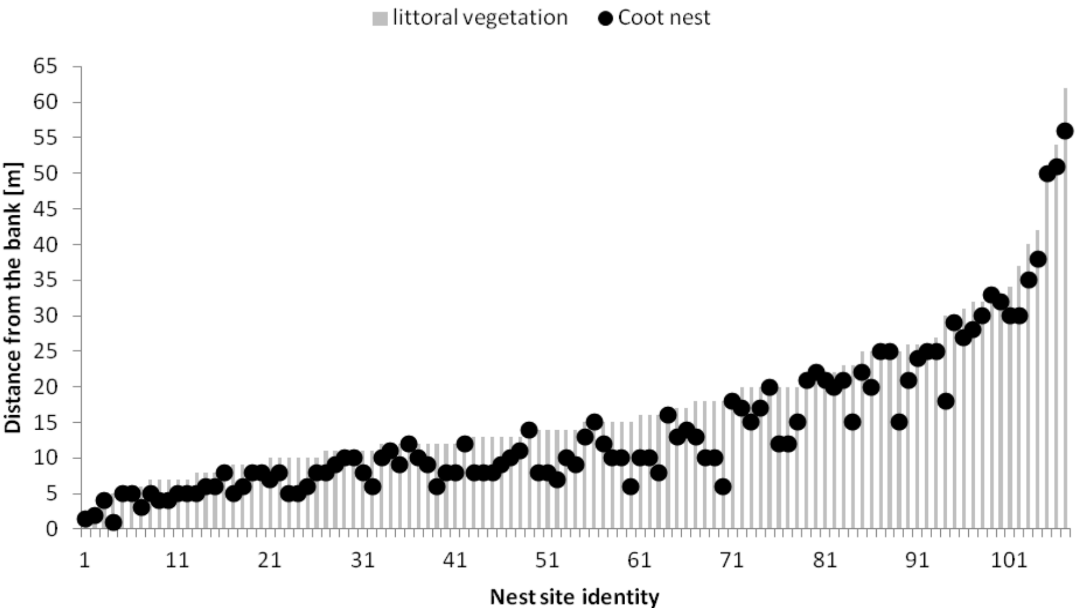

Fig. 1. Distribution of Coot nests in the littoral vegetation zone at the lakes and small inland water bodies.

the bank of a water body (covariate; Dist.bank), (3) water depth adjacent to a nest (covariate; Depth), (4) type of water body and proximity to buildings, combined (three categories: lake far from built-up areas (Type=0), lake nearby built-up areas (Type=1), inland water body far from built-up areas (Type=2), used as a fixed categorical factor). The three covariates were not correlated (*R* <0.1 in all cases). Moreover, study year and identity of a water body were used as random factors in a nested design, with identity being nested within year. The GLMMs were conducted in R (R Development Core Team 2011). Model selection was based on the information-theoretic approach. We used all possible GLMMs and assessed the extent of their support by the data on the basis of Akaike's Information Criterion (AIC). Each candidate model included intercept and random components. Due to the relative similarity of AIC for several models, model averaging was applied and averaged parameter estimates presented.

3. Results

All nests were located in the littoral zone which was between 2 and 62 m wide (Fig. 1). Coots constructed their nests in the Reeds (72%), Lesser Bulrush (17%) and other vegetation (11%). Mean distance between nest and open water was 3.4 m (± 2.7 SD, *n* = 107; range 0–12) and mean distance to the nearest bank was 14.2 m (± 10.6 SD, *n* = 107; range 1–56). Water depth at nest sites during egg-laying varied between 20 and 135 cm, with a mean depth of 71.0 cm (± 20.9 SD, *n* = 107).

Among all recorded nesting attempts, 75% were successful (at least one hatchling). This value denoted 44% for nests located on lakes far from buildings, 86% for nests located at lakes nearby built-up areas, and 69% for nests placed at inland water bodies.

In the set of candidate models, the univariate GLMMs were weakly supported by the data. All of them were better than the intercept-only model (Table 1). Among all candidate models, three appeared to be the most informative and were thus considered best (ΔAICc<2; models 1, 2 and 3). Cumulative weight (ϖAICc) of these three models exceeded 0.7.

According to the averaged parameter estimates, the chance for success was 138 times higher for nests located at lakes adjacent to built-up areas, and 23 times higher for nests at inland water bodies than for nests at lakes far from built-up areas (treated as a reference category; Table 2). The differences between Type=1 and Type=2 nests was

Table 1. Set of competing generalized linear mixed models explaining the nesting success in the Coot. For each model the following characteristics are listed: parameters of the intercept and all covariates included in a given model, information on including the fixed factor (Type), number of variables (df), Akaike's information criterion (AICc), differences in AICc between a given model and best model (ΔAICc) and Akaike's weight (ϖAICc) indicating probability that given model is the best one.

Nr.	Intercept	Dist.bank	Dist.open	Depth	Type	df	AICc	ΔAICc	ϖAICc
1	6.86	–	–0.21	–3.41	+	7	101.0	0.00	0.337
2	4.31	–	–0.21	–	+	6	101.6	0.65	0.243
3	5.62	–	–	–3.07	+	6	102.8	1.88	0.131
4	6.86	0.01	–0.21	–3.49	+	8	103.3	2.33	0.105
5	4.40	–0.01	–0.21	–	+	7	103.9	2.89	0.079
6	5.61	0.02	–	–3.25	+	7	105.0	4.06	0.044
7	3.23	0.00	–	–	+	6	105.5	4.58	0.034
8	2.38	–	–0.19	–	–	4	108.3	7.36	0.008
9	3.77	–	–0.19	–1.98	–	5	108.9	7.94	0.006
10	2.87	–0.063	–0.19	–	–	5	109.7	8.75	0.004
11	4.14	–0.03	–0.19	–1.86	–	6	110.5	9.54	0.003
12	2.99	–	–	–	+	5	110.9	9.95	0.002
13	2.51	–	–	–1.57	–	4	112.5	11.59	0.001
14	1.79	–0.03	–	–	–	4	113.2	12.28	0.001
15	2.79	–0.02	–	–1.49	–	5	114.3	13.37	0.000
16	1.32	–	–	–	–	3	119.9	18.89	0.000

Table 2. Averaged parameter estimates of the set of generalized linear mixed models explaining nest success of the Coot. In parameter averaging models listed in table 1 with DAICc < 5 were used.

Source	exp(B)	95%CI	z	*P*
Intercept	2.10	0.03; 176.16	0.33	0.7426
Dist.bank	1.00	0.89; 1.13	0.04	0.9678
Dist.open	0.81	0.66; 0.99	2.04	0.0418
Depth	0.04	0.00; 1.68	1.70	0.0899
Type=2	138.23	5.44; 3510.39	2.99	0.0028
Type=1	22.61	0.80; 642.69	1.83	0.0679
Type=0	1.00			

not significant ($P = 0.188$, not shown in Table 2). The effect of distance to open water negatively affected nest survival. The effect of water depth only slightly increased the model parsimony expressed as AICc (by 0.65; comparison of models 1 and 2) so its importance appeared questionable.

4. Discussion

Nest-site selection is one of the most crucial decisions made by birds, as it influences their breeding success. In the Coot, the selection is determined by several habitat characteristics, such as density and height of halophyte vegetation, distance from open water, and water depth (Stanevičius 2002). A properly-chosen nest site enables easy access to the nest, resistance to the impact of waves, and concealment against predators. In reality, the choice must balance between several environmental factors, but the majority of nests concentrate within narrow ranges of gradients of different environmental parameters (Stanevičius 2002). The present results showed that the Coot can occupy a wide spectrum of nest sites. Decreasing water depth and distance to open water had a slight positive impact on breeding success. Moreover, nesting in the vicinity of built-up-areas and far from large lakes, at small inland water bodies, increased the breeding success significantly.

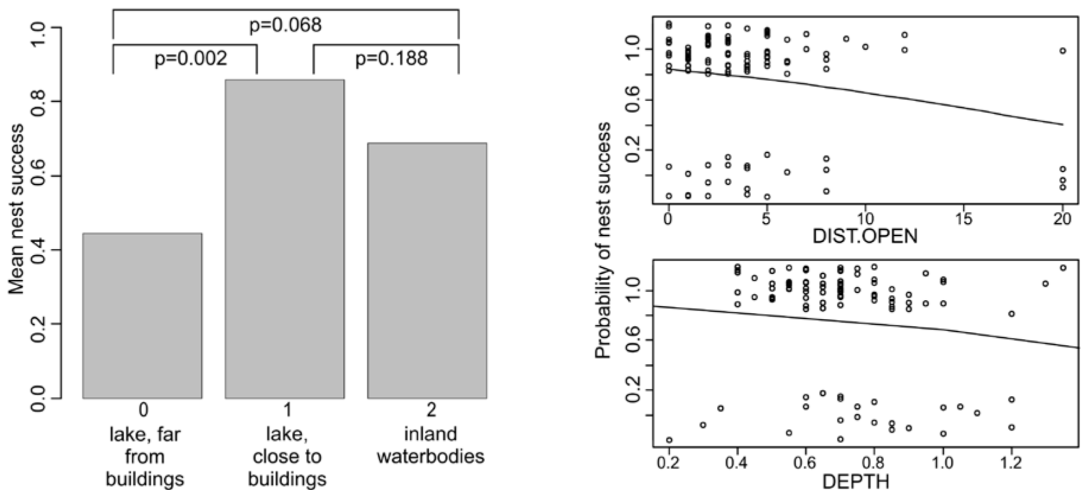

Fig. 2. Effects of type of water body (left panel) and distance to open water and water depth (two right panels) on the nest success in the Coot.

Besides nesting at lakes, Coots also inhabited small, isolated water bodies in the agricultural landscape of the Mazurian Lakeland. The selection of small water bodies by Coots is unexpected, as nesting in such places has several disadvantages. The water level of inland water bodies is highly unstable, while the area for foraging is relatively small and scattered in an unsuitable matrix (agriculture landscape). On the other hand, Coot nests at small inland water bodies were at a greater distance from the shoreline than nests located at lakes, thus potentially being more difficult to reach by terrestrial carnivores. Small inland water bodies may also act as refuges for Coots against predation: birds apparently attempt to avoid Mink predation by moving to more isolated islands at the Finnish Baltic coast (Nordström & Korpimäki 2004). Mink rarely move far from the lakes, usually occupying linear home ranges along the banks (Gerell 1970, Melero *et al.* 2008, Brzeziński *et al.* 2010) and they visit small inland water bodies used by waterfowl as breeding sites sporadically.

Numerous bird species breed within human settlements or in their vicinity, and human activity, if not directed against birds, may increase the probability of brood survival. One of the explanations for nesting in the vicinity of built-up areas is undoubtedly predator avoidance, which may be more frightened by the presence of humans than their potential prey. Thus, Coots may select the vicinity of built-up areas for nesting, most probably as a predator avoidance strategy. In accordance with this presumption, Coots nesting at lakes close to human settlements had significantly lower nest losses than birds nesting far from built-up areas. Similar observations have been reported for Coots nesting in Warsaw, Poland: breeding success was lower in peripheral areas than in the city center (Bock & Jędraszko-Dąbrowska 2011).

The present study reports lower predation rate than some previous studies, which may have resulted from breeding Coot moving from shoreline reed beds (potentially high nest-predation rate) to inland lakes (lower nest-predation rate). We recorded about 25% of Coot nests lost, which is lower than those recorded at the Mazurian Lakeland in the early 1980s, when Mink were absent in the region (about 40%; Jędraszko-Dąbrowska & Dębińska 1993). Similarly, Ręk (2009) reported that nest losses of Coot were higher in the period before Mink invasion (over 50%) than after colonization (about 30%) in south-western Poland. This decline in nest losses after the arrival of the Mink may sound paradoxical, but may be explained by the fact that Coots nested at sites relatively safe from Mink predation, such as islands, which compensates nest losses observed at narrow reed belts along the pond shores (Ręk 2009).

Predation risk must be considered by birds when selecting a nest site (Martin 1993, Schmidt & Whelan 1998, Trnka *et al.* 2011). Birds tend to minimize their nest losses by avoiding detection of their nests by predators and, if a predator succeeds in finding the nest, by active defense or distraction displays. In the Coot, predation is a major cause of nest failure (Blūms 1973, Koshelev 1984, Ręk 2009) and the rate of nest losses can vary considerably from one location to another (Havlín 1970). Coot broods are often depredated by predators, particularly the Marsh Harrier *Circus aeruginosus* and Hooded Crow *Corvus corone cornix* (Blūms 1973, Koshelev 1984, Zduniak 2006). However, predation by native carnivores has always caused nest losses in the Coot, and only a rapid increase of their populations could have explained the recently-increased mortality and rapid decline of the Mazurian Lakeland Coot population (cf. Brzeziński *et al.* 2012). In recent decades, no such increase has been observed for native bird predators except for an increase in the Hooded Crow in urban habitats (Tomiałojć & Stawarczyk 2003, Neubauer *et al.* 2011).

Efficient alien predators have caused avian population declines and even extinctions world-wide (Blackburn *et al.* 2005, Hilton & Cuthbert 2010). At the Mazurian Lakeland, such a new threat is undoubtedly the American Mink. The expansion of Mink started in Poland at the end of the 1970s (Ruprecht *et al.* 1983, Brzeziński & Marzec 2003), and the first documented records of feral Mink presence in the study area are from 1984 (Żurowski & Kammler 1987). In the second half of the 1980s, the Mink population increased rapidly (Brzeziński & Marzec 2003), and the results of trapping conducted along the banks of lakes revealed high Mink densities (Brzeziński *et al.* 2012). The naivety of Coots, when confronted with such a predator, is a good candidate reason for population decline, which could not be quickly compensated by behavioural changes in the selection of nesting sites. Results of the present study imply that after time, built-up areas located at lake banks and small inland water bodies begin to serve as Coot refuges where predator pressure and nest losses are relatively low. The recovery of Coot populations to former levels in areas invaded by the Mink depends on the abundance of such safe nest sites.

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Pesimäpaikan vaikutus nokikanan pesimämenestykseen

Työssä selvitettiin nokikanan (*Fulica atra*) pesimämenestystä järvillä ja pienvesistöissä Mazurian järvialueella Puolassa vuosina 2008–09. Keskimääräinen kuoriutumisprosentti oli 75, ollen korkeimmillaan rakennettujen alueiden lähijärvillä (86 %), kohtalainen pienissä sisämaavesistöissä (69 %) ja alimmillaan kaukana asutuksesta olevilla järvillä (44 %). Pesimämenestys koheni siirryttäessä lähemmäs avovettä. Tulokset viittaavat siihen, että sisämaan pienvesistöt sekä jokivarsien asutusalueet voivat ovat suotuisia nokikanalle, kenties saalistuspaineen vuoksi. Eritoten minkki voi olla merkittävä tässä mielessä.

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