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DIFFERENCES IN NEST SITE SELECTION IN WHITE-WINGED TERN *CHLIDONIAS LEUCOPTERUS* AND BLACK TERN *CHLIDONIAS NIGER* IN EAST-CENTRAL POLAND

Abstract. In this paper, we compared microhabitat preferences of two species of terns: Black Tern *Chlidonias niger* (a non-expansive species) and White-winged Tern *Chlidonias leucopterus* (an expansive species, new to the region since 1997) on oxbow lakes in eastern Poland. The Black Tern clearly preferred places situated closer to the wall of helophytes and with a larger proportion of such vegetation than at the random sites. While White-winged Tern preferred places situated far from the wall of helophytes and with with deeper water. Probably, White-winged Tern prefers places in the center of the patch of vegetation, because most often there is a lower level of predation pressure. This strategy is unreliable due to the weather, which is responsible for the majority of losses in clutches.

Key words: biotic factors, expansion, habitat preference, vegetation, Poland.

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Artur Goławski, Sylwia Goławska. Różnice w preferencji miejsc gniazdowania u rybitwy białoskrzydłej *Chlidonias leucopterus* i rybitwy czarnej *Chlidonias niger* w środkowo-wschodniej Polsce.
Abstrakt. Porównano preferencje siedliskowe dwu gatunków rybitw: rybitwy czarnej *Chlidonias niger* (gatunek gniazdujący od wielu lat) i rybitwy białoskrzydłej *Chlidonias leucopterus* (gatunek będący w ekspansji od 1997) na starorzeczach w środkowo-wschodniej Polsce. Rybitwa czarna wyraźnie preferowała miejsca na gniazdo położone bliżej helofitów rosnących na skraju starorzecza oraz z większą proporcją takich roślin wokół gniazda w porównaniu z miejscami wybranymi przypadkowo. Natomiast rybitwa białoskrzydła preferowała miejsca gniazdowania zlokalizowane dalej od helofitów i z większą głębokością wody niż miejsca przypadkowe. Prawdopodobnie rybitwa białoskrzydła preferuje gniazdowanie w centrum płata roślinności, gdyż powinno być najbezpieczniej ze względu na presję drapieżników. Ta strategia nie sprawdza się jednak na starorzeczach w tej części Polski ze względu na główną przyczynę strat w lęgach, którą są silne wiatry.

As an aspect of nest site selection is assumed to have adaptive value, so nests are built on sites that provide optimum conditions for reproduction (Wiens 1992). Many species of waders breed colonially; the selection of colony and nest sites thus reflect trade-offs between predation risk, flooding risk and proximity to foraging sites (Borboroglu & Yorio 2004, Kim & Monaghan 2005). It is also well-known that the habitat preferences of an expanding species may play a major part in the expansion process when it occupies a favourable habitat enabling high levels of reproduction and the establishment of new populations (Veech *et al.* 2011, Ledwoń *et al.* 2014).

The White-winged Tern *Chlidonias leucopterus* is a species inhabiting river valleys in eastern Poland; this region is its westernmost regular breeding site in Europe (Gochfeld *et al.* 2016). The last 20 years have witnessed a westward expansion of White-winged Tern in Europe (Gruneberg & Boschert 2009, Ławicki *et al.* 2011). The number of pairs has risen markedly in eastern Poland, where the species has been breeding regularly since 1997. At that time, just 30 pairs were reported from there, but in some recent years the number of pairs has been in excess of 1,000 (Goławski *et al.* 2016). The typical nesting habitat of White-winged Tern is assumed to be naturally waterlogged grassland (Kapocsy 1979, Cramp 1985), but in dry seasons in eastern Poland this species has been found on oxbow lakes – permanent water bodies with vegetation offering potential nesting sites for terns, mainly Water Soldier *Stratiotes aloides* (Goławski *et al.* 2015). Another autochthonous species, nesting all over this region, is the Black Tern *Chlidonias niger*, with a breeding population of between 480 and 650 pairs (Goławski *et al.* 2016). White-winged Tern and Black Tern are roughly the same size, with a body weight of ca. 70 g. Both species normally lay three eggs of very similar dimensions (35x25 mm), and both build nests of roughly the same size, i.e. ca. 15 cm in diameter, which have to be constructed on a firm base (Cramp 1985).

In this paper, we attempt to compare microhabitat preferences in two species of terns on oxbow lakes in eastern Poland. One of the species (Black Tern) has been breeding in eastern Poland for a very long time, whereas the other one White-winged Tern turned up only recently and is still in the process of expansion.

Study Area

The study area lies in the valley of the River Bug near the villages of Morzyczyn and Prostyn in east-central Poland (52.6667° N, 21.9002° E). This area is the westernmost regular breeding site of White-winged Tern in Europe; it is also a well-known permanent breeding site of Black Tern (Ławicki *et al.* 2011). The Bug is one of the largest rivers in Poland protected within the Natura 2000 network, with abundant breeding sites like oxbow lakes (Goławski *et al.* 2015). Some 60% of these oxbows are covered in Water Soldier, while their margins are surrounded by 5-15 m wide beds of rushes *Juncus* sp., Sweet Flag *Acorus calamus* and bulrushes *Typha* sp., these last growing in water as deep as 80-90 cm. Only around 30% of the oxbows are open water, usually their middle parts. They are from 27 to 33 ha in area, with a maximum width of 70 m and a maximum depth of 1.8 m (Goławski *et al.* 2017).

Methods

The fieldwork for this study was carried out in the three seasons in 2009-2010 and 2016. During this time, 5 colonies of Black Tern and White-winged Tern were monitored. Both species breed in colonies situated in the same patch of Water Soldier. During this study, 58 White-winged Tern clutches and 44 Black Tern clutches were monitored. Nest inspections began around 15-20 May, that is, when the clutches were initiated, and continued until early July, when the last hatchlings appeared. Every year the first inspection involved searching for nests in all or part (in colonies with more than 30 breeding pairs; two colonies) of the breeding colony. In the biggest colonies, the nests found in a 5 m wide belt of Water Soldier were monitored. Such a belt was selected at random, but always in such a way that it began in the middle of a patch of Water Soldier and ended at the edge of that patch, which coincided with the bank of the oxbow lake. For this purpose, an inflatable dinghy was used to gain access to the nests on the oxbows.

During the first or second inspection of the colony, habitat parameters were measured where nests had been built and also in other randomly selected places. These parameters were chosen on the basis of papers dealing with habitat selection in *Chlidonias* terns (Mazzocchi *et al.* 1997, Maxson *et al.* 2007). They were as follows: 1) water depth, 2) distance of the measured place from the compact wall of helophyte vegetation, 3) degree of coverage (%) of floating vegetation within a radius of 2 m of the measured place (mainly Water Soldier), 4) degree of coverage (%) of helophytes (mainly sweet flag and rushes) within a radius of 2 m of the measured place, 5) the height of the vegetation surrounding a nest or random place at a distance of 20 cm from these places (mean of four measurements made in the principal compass directions). These parameters were measured for all nests found in accordance with the above scheme. The random measurement transects were situated at the edge of the terns' breeding colony. The measurements in random places (n = 76) were performed on the same day as the nest site measurements in the following manner: a measurement transect was marked out from the boundary between helophytes and floating plants, i.e. the zone close to the bank of the oxbow (the tern nests closest to the oxbow bank were also in this zone). This is where the first measurement was made, and the place was selected random. Subsequent measurements were made every 2 m towards the centre of the oxbow until this was reached or until the end of the Water Soldier patch.

A general linear mixed model (GLMM) with logit-link function and binomial error variance was applied to all the statistical analyses in this work. To reduce any effects of multicollinearity, pairs of habitat variables were tested for correlation using Spearman's rank correlation test (Sokal & Rohlf 1995). If two variables were highly correlated ($r_s > 0.60$, Mertler & Vannatta 2002), only one data set was selected (one factor was removed – the percentage of floating macrophyte species 2 m around the nest). Akaike's Information Criterion (AIC, Akaike 1973) corrected for small samples (AICc) was used to select the most appropriate models, i.e. the best fit to the data set. Models were ranked in relation to each other using ΔAIC_c values, where $\Delta_i = AIC_{c(i)} - AIC_{c(min)}$. We considered models with $\Delta AIC_c < 2$ as equally good and consequently as having the highest Akaike weight (ω_i) (Burnham and Anderson 2002). In both GLMM analysis the following parameters describing the randomly measured places were treated as independent factors: 1) water depth, 2) distance of measured place from the compact wall of vegetation, 3) degree of coverage (%) of helophytes within a 2 m radius, 4) the height of the vegetation surrounding a nest. IDs (numbers from 1 to 5) were assigned to colonies in accordance with the order in which they were inspected; they were random factors in all the GLMM analyses. The both analyses concerned the differences between the parameters describing nest sites and random places, separately for each tern species and they concerned analysis from the general model containing the four variables mentioned above. The dependent variables in these analyses were the random places/nest sites constituted a 0-1. Only results with a probability of $\alpha \leq 0.05$ were assumed to be statistically significant. All statistics were performed in SPSS version 21.0. for Windows (SPSS Inc. 2012).

Results

Four models best predicted habitat preferences in the Black Tern (Table 1). This species clearly preferred places situated closer to the wall of helophytes and with a larger proportion of such vegetation than at the random sites. The difference in water depth between these two categories was close to being significant. Only plant height the did not differ distinctly between these two categories (Tables 2, 3). In the case of White-winged Tern, on the other hand, two such models were found (Table 1), and two parameters differed significantly between the nesting sites and random places (Tables 2, 3): the water was shallower in the random places, and the distance to the wall of helophytes was greater at the nesting sites. Neither the proportion of helophytes nor their height differed significantly between the random places and the nesting sites (Tables 2, 3).

Discussion

Black Tern chose breeding sites with a larger proportion of helophytes and closer to the wall of these plants, i.e. closer to the edge of the oxbow compared to the reference sites. In contrast, White-winged Tern preferred to place their nests farther away from the helophytes and on water deeper than at other available sites. Direct comparison of the nest sites of the two tern species also showed Black Tern to be nesting closer to the wall of helophytes and on shallower water (Goławski &

Mróz 2018). White-winged Tern thus built its nests more towards the centre of the patches of vegetation (mainly Water Soldier) than Black Tern, which in turn more often chose the edge of such patches, on the borderline with the helophytes. No detailed studies of microhabitat preferences in White-winged Tern are known to have been carried out, except for the publication of Goławski & Mróz (2018). Such preferences have been described for Black Tern, in particular detail for its populations inhabiting North America and western Europe (Hickey & Malecki 1997, Mazzocchi, *et al.* 1997, Van der Winden *et al.* 2004, Maxson 2007), and the habitat preferences were similar to those described in eastern Poland.

Table 1. Best models describing the habitat preferences in two tern species. The number of parameters in a model (*K*), the Akaike Information Criterion score (AIC_c), the difference between the given model and the most parsimonious model (ΔAIC_c), and the Akaike weight (ω_i) are listed; zone – nest/random places distance to "helophyte zone", helophytes % – % of helophytes 2 m around the nest/random places, water – water depth under the nest/random places, plant height – height of plant 20 cm around the nest/random places

Tab. 1. Modele najlepiej opisujące preferencje siedliskowe dwóch gatunków rybitw. Liczba parametrów w modelu (*K*), kryterium Akaike'a skorygowane (AIC_c), różnica między danym i najlepszym modelem (ΔAIC_c), relatywna waga danego modelu w zestawie wszystkich modeli (ω_i); zone – odległość gniazda/miejsca przypadkowego od heleofitów, helophytes % – % pokrycia helofitami w promieniu 2 m od gniazda/miejsca przypadkowego, water – głębokość wody po gniazdem/miejscem przypadkowym, plant height – wysokość roślin w odległości 20 cm od gniazda/miejsca przypadkowego. (1) – Preferencje siedliskowe rybitwy czarnej *Chlidonias niger*, (2) – Preferencje siedliskowe rybitwy białoskrzydłej *Chlidonias leucopterus*

Model	***K***	**AIC_c**	**ΔAIC_c**	ω_i
Habitat preference of Black Tern *Chlidonias niger* (1)				
Zone	2	368.203	0	0.278
Zone + helophytes %	3	368.464	0.262	0.244
Zone + water	3	370.089	1.887	0.108
Zone + plant height	3	370.127	1.925	0.106
Habitat preference of White-winged Tern *Chlidonias leucopterus* **(2)**				
Zone + plant height + water	4	260.454	0	0.623
Zone + plant height + helophytes % + water	5	262.450	1.996	0.230

Table 2. Mean and SE of variables at nesting sites of Black Tern and White-winged Tern, and in random places

Tab. 2. Średnia (mean) i błąd standardowy (SE) dla zmiennych opisujących położenia gniazda/miejsca przypadkowego. Opis jak w tabeli 1 (+ Floating macrophytes 2 m around the nest – % pokrycia roślinami pływającymi 2 m wokół gniazda/miejsca przypadkowego). (1) – Zmienna, (2) – Rybitwa czarna *Chlidonias niger*, (3) – Rybitwa białoskrzydła *Chlidonias leucopterus*, (4) – Miejsce przypadkowe

Variable (1)	**Black Tern *Chlidonias niger* *N* = 44 (2)**		**White-winged Tern *Chlidonias leucopterus* *N* = 58 (3)**		**Random places *N* = 76 (4)**	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**
Water depth (cm)	101.5	3.5	118.9	2.3	112.3	2.5
Helophyte vegetation 2 m around the nest/random place (%)	4.0	0.6	1.4	0.8	1.3	0.6
Floating macrophytes 2 m around the nest/random place (%)	46.9	2.8	45.7	1.7	41.7	2.1
Height of plants 20 cm around the nest/random place (cm)	9.6	0.5	8.5	0.5	8.8	0.4
Nest/random place distance to “helophyte zone” (m)	4.3	0.6	11.9	1.2	9.8	0.9

Why does White-winged Tern choose sites for nesting far from the oxbow edge? Two reasons for this behaviour need to be considered. First of all, White-winged Tern prefers places in the center of the patch of vegetation. Nesting in the center of such a habitat should result in higher breeding success, e.g. because predation pressure (Yorio and Quintana 1997, Minias *et al.* 2013). But predation on tern’s clutches is absolutely minimal in this region, and the prime cause of brood losses is bad weather (Goławski *et al.* 2017, Goławski & Mróz 2018). The Black Tern nesting closer to the edge of the oxbow lake is not so much exposed to the loss of clutches because of the weather, especially a strong wind and achieves a higher of hatching success (Goławski *et al.* 2017). The second possibility, far less probable in our opinion, is competition with Black Tern for the best nesting sites. Since Black Tern arrives back in eastern Poland much earlier than White-winged Tern, it chooses the best sites for building nests adjacent to the wall of helophytes, which guarantees the nests greater security. White-winged Tern is thus forced to nest farther away from the helophyte wall, which is why it suffers greater clutch losses. These greater losses are exacerbated by thunderstorms, which become more frequent and fiercer as the terns' breeding season progresses (Goławski *et al.* 2017).

Table 3. Factors affecting habitat preferences in Black Tern *Chlidonias niger* and White-winged Tern *Chlidonias leucopterus*; analysis from the general model. Statistically significant relationships are shown in bold. The random effect (colony ID) is not statistically significant in all cases.

Tab. 3. Preferencje siedliskowe u rybitwy czarnej i rybitwy białoskrzydłej; średnia dla modeli po selekcji zmiennych. Wyniki istotne statystycznie zaznaczono pogrubioną czcionką. Czynnik przypadkowy (ID kolonii) nie jest istotny dla obu analiz. Opis czynników jak w tabeli 1. (1) – Predyktor, (2) – Preferencje siedliskowe rybitwy czarnej, (3) – Preferencje siedliskowe rybitwy białoskrzydłej, (4) – Ocena, (5) – Błąd standardowy, (6) – Wartość prawdopodobieństwa

Effect (1)	**Estimate (4)**	**SE (5)**	**P (6)**
Habitat preference of Black Tern *Chlidonias niger* **(2)**			
Water depth	0.083	0.045	0.070
Helophyte vegetation 2 m around the nest	-0.076	0.029	**0.010**
Height of plants 20 cm around the nest	-0.001	0.006	0.927
Distance from nest to "helophyte zone"	0.174	0.041	**<0.001**
Habitat preference of White-winged Tern *Chlidonias leucopterus* **(3)**			
Water depth	-0.046	0.011	**<0.001**
Helophyte vegetation 2 m around the nest	0.015	0.053	0.779
Height of plants 20 cm around the nest	-0.076	0.047	0.104
Distance from nest to "helophyte zone"	-0.072	0.031	**0.022**

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