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First data on breeding success of Croatian inland colonies of Common Tern *Sterna hirundo*

Prvi podatki o gnezditvenem uspehu celinske populacije navadne čigre *Sterna hirundo* na Hrvaškem

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Abstract

In 2018 and 2019, the breeding success of two Common Tern colonies on artificial lakes near the River Sava in Zagreb, Croatia, was studied. The colonies were visited weekly from May to July and we collected data on phenology, number of breeding pairs, clutch size as well as egg and chick survival. We also conducted a comparison between early and late breeders. Hatching and fledging success was within previously observed ranges, apart from a low hatching success on Siromaja in 2019. The smaller colony on Siromaja had a higher productivity in both years than the colony on Rakitje, although in 2018 an avian pox virus killed much of the late chicks on Rakitje. Early breeders seem to have had higher hatching success and average clutch size. Furthermore, a greater proportion of them managed to hatch all their eggs compared to late breeders, but the differences were not statistically significant. Our study provided baseline data for future monitoring of phenology and breeding success with regard to the management of breeding colonies.

1. Introduction

The Common Tern *Sterna hirundo* breeds, often colonially, throughout the Holarctic and winters along seacoasts of South America, Africa, Australia, as well as southern and south-eastern Asia. It inhabits different coastal habitats, but also breeds in freshwater habitats, where it readily accepts artificial sites (Becker & Ludwigs 2004). The Common Tern is a relatively long-lived species, with the oldest ringed bird reported to be 33 years old (Fransson *et al.* 2010). They generally lay 1–3 eggs which they incubate 20–21 days if undisturbed, or 27–28 days in areas with disturbance (Nisbet & Cohen 1975). Chicks wander from the nest after 3 days and fledge 22–28 days after hatching (Nisbet & Drury 1972). In the case of early nest failure, Common Terns usually have replacement clutches (Nisbet & Cohen 1975), often at the same colony (González-Solís *et al.* 1999, Becker & Zhang 2011).

Common Terns breed along the Sava and Drava Rivers in continental Croatia, and on islets in the Adriatic Sea (Kralj *et al.* 2013). Their breeding population of 400–700 estimated breeding pairs (Kralj *et al.* 2013) is classified as near threatened (Tutiš *et al.* 2013). The Common Tern is a target breeding species for 13 Natura 2000 sites in Croatia (Narodne Novine 2019). Breeding population census efforts are, however, reduced to occasional nest counts for inland colonies (Mikuska *et al.* 2017, Kralj *et al.* in print) and rare adult or nest counts along the coast (Lucić *et al.* 2012). Some studies did mention reasons for unsuccessful breeding (Fenyosi 2005), but no investigations of hatching success, fledging success or productivity have thus far been conducted in Croatia. Breeding success monitoring and other demographic indicators in addition to population size can give valuable information for timely problem diagnosis and conservation actions (Szostek & Becker 2012).

We set out to establish breeding success monitoring of our largest inland colonies. The aims of this study were to test breeding success monitoring methodology and to provide first data on Common Tern breeding success and phenology in Croatia.

2. Methods

2.1. Study location

During the 2018 and 2019 breeding seasons, we surveyed breeding success on two Common Tern colonies near Zagreb, Croatia. One was a floating platform set up in mid-May 2018 in Siromaja gravel pit (45°45'23.9"N, 16°11'05.0"E), while the other is an artificial island located in Rakitje gravel pit (45°47'49.8"N, 15°50'24.9"E). Both lakes are located c. 500 m from the Sava River. Common Terns usually arrive to these sites during April and depart through August and September (Kralj *et al.* 2013). We also regularly check other potential breeding sites in the area and count breeding pairs if present (Kralj *et al.* in print).

2.2. Field work

Colonies were either visited or observed weekly from mid-April in order to determine the start of incubation. In case we missed observing this milestone, we estimated it by using the egg-immersion method as described by Hays & LeCroy (1971). After confirming the start of incubation, we did not disturb the colony for two weeks due to high risk of nest desertion (Koffijberg *et al.* 2011). During the third week, we visited the colony and counted the number of nests and eggs per nest. Where following hatching success, we marked as many nests as possible. In 2018 we used bamboo garden markers numbered with a permanent marker to mark the nests, as recommended by Koffijberg *et al.* (2011), while in 2019 we used acrylic paint and permanent markers on pebbles. The reasons for this change are described in results under Monitoring methodology. In 2018 we only marked nests on the platform at Siromaja, whereas in 2019 we marked nests on both colonies. On Siromaja we attempted to mark all observed nests, while on the larger colony at Rakitje we marked a representative proportion following guidelines by Koffijberg *et al.* (2011). We recorded the number of eggs and/or chicks in each nest and their status (observed state, incubation stage), as well as counted all apparently active nests (Walsh *et al.* 1995, Mikuska *et al.* 2007), including non-marked nests on Rakitje. We revisited the colonies each subsequent week and repeated the process, marking any new nest observed on the Siromaja colony. We ringed any chicks observed to be at least two weeks old (Nisbet & Drury 1972) with metal and coloured plastic rings. We also noted the number of dead chicks, documenting those that had been ringed earlier. We stopped visiting a colony when all chicks had fledged.

2.3. Data analysis

The highest number of observed active nests during a single visit was taken as the number of breeding pairs on that colony for the respective season (Walsh *et al.* 1995). The maximum number of eggs per nest was noted as clutch size for that nest for the season, while the number of eggs present in a nest on the last visit before hatching was taken as an estimate of number of hatched chicks. We omitted a nest from the calculations if for any reason we could not estimate the fate of its clutch (e.g. loss or mixing of markings, documented brood size inconsistency, etc.). Hatching success was thus calculated as the estimated number of hatched chicks in monitored nests divided by the total number of monitored eggs. Since it turned out to be impossible to monitor all nests on either colony, we estimated the total number of hatched chicks on a colony with the formula:

Total number of hatched chicks =
breeding pairs × average clutch size ×
monitored nests hatching success

Number of fledged chicks was calculated as all ringed chicks plus any small chicks present during the last visit, subtracted by the number of dead chicks observed with the current year's rings. Dividing the number of fledged chicks with the total estimated number of hatched chicks, we calculated fledging success. Colony productivity was calculated as the number of fledged chicks divided by the estimated number of breeding pairs.

For the colony on Siromaja in 2019 we also compared "early breeders" and "late breeders". "Early breeders" were estimated to be nests first observed before "peak incubation", i.e. the date of the highest observed number of active nests–being 26 May (Walsh *et al.* 1995). "Late breeders" were nests first observed on or after that date, thereby including most of the current year's renesting attempts. This analysis was not performed for either colony in 2018 or for Rakitje in 2019 because the relatively late starting dates for those colonies blurred any distinction between first and subsequent breeding attempts. Yate's corrected Chi square test was used to test differences in breeding success.

3. Results

In 2018, we observed Common Terns regularly on or near their breeding sites from late April. They started incubating on the platform on Siromaja lake in late May, while incubation on the island on Rakitje lake started in mid-June (Table 1). Young fledged through July on Siromaja and from mid-July to late August on Rakitje. In 2019, we regularly observed Common Terns on or near breeding sites from mid-April. On both Siromaja and Rakitje, incubation started in early May. Young fledged

Table 1: Common Tern breeding success across two years on Siromaja and Rakitje, two colonies near Zagreb. Hatching success – estimated number of hatched chicks in monitored nests divided by total number of monitored eggs. Fledging success – number of fledged chicks divided by total estimated number of hatched chicks. Productivity – number of successfully fledged chicks per breeding pair.

Tabela 1: Gnezditveni uspeh navadne čigre v dveh letih na kolonijah Siromaja in Rakitje. Uspeh izvalitve – ocenjeno število izvaljenih mladičev, deljeno s številom gnezd (le gnezda, ki so bila spremljana redno). Uspeh speljave – število speljanih mladičev, deljeno z oceno izvaljenih mladičev. Produktivnost – število speljanih mladičev na gnezdeči par.

	Siromaja		Rakitje	
	2018	2019	2018	2019
start of incubation začetek valjenja	23 May	02 May	mid-June	08 May
last chick ringed obročkan zadnji mladič	26 July	16 July	23 August	05 August
breeding pairs gnezdečih parov	30	39	106	134
monitored nests število nadzorovanih gnezd	23	43	-	43
hatching success uspeh izvalitve	85.29%	69.16%	-	79.41%
mean clutch size povprečna velikost legla	2.77	2.43	-	2.37
% pairs with clutch of 1 % parov z enim jajcem	8.57%	10.00%	-	6.98%
% pairs with clutch of 2 % parov z dvema jajcema	5.71%	36.67%	-	51.16%
% pairs with clutch of 3 % parov s tremi jajci	85.71%	53.33%	-	39.53%
% pairs with clutch of 4 % parov s štirimi jajci	0%	0%	-	2.33%
fledging success uspeh speljave	45.45%	52.17%	-	41.60%
productivity (fledglings/bp) produktivnost (speljanih/gp)	1.0	0.92	0.57	0.78

from early June to mid-July on Siromaja, and from late June to early August on Rakitje.

Lake Rakitje had a colony of an estimated 106 breeding pairs in 2018. Most of the island was flooded until mid-June, so terns started nesting there when parts of the island started resurfacing. We estimate that 61 chicks fledged successfully. On the last day of ringing we observed 21 dead chicks and 3 dead adults on the colony.

The colony on lake Rakitje had an estimated 134 breeding pairs in 2019. Based on 43 monitored nests, 81 out of 102 monitored eggs hatched. From this we extrapolated an estimated 293 eggs that successfully hatched on the whole colony that year. Of the 43 monitored breeding pairs, one had a clutch of four eggs, 17 had clutches of three, 22 were clutches of two and 3 had clutches of one egg. 30 of the pairs (69.8%) managed to hatch all their eggs. The colony successfully fledged 105 chicks.

On the platform at Siromaja lake we estimated 30 breeding pairs of Common Terns in 2018. Based on 23 successfully monitored nests, 58 out of 68 monitored eggs hatched successfully. We estimate that 8 more unmonitored eggs hatched. Of the 23 monitored breeding pairs, 15 (65.22%) managed to hatch all their laid eggs. During the season we observed 30 clutches of 3 eggs, two clutches of 2 eggs and three clutches with only one egg. The total number of fledged chicks at the colony was 30.

In 2019 we estimated 39 pairs of Common Terns to be breeding on the Siromaja colony. Based on 43 monitored nests (some obviously being re-nesting attempts), 74 out of 109 monitored eggs hatched. We estimate an additional 32 eggs to have hatched. Of the 43 monitored breeding pairs, 22 (51.63%) managed to hatch all their laid eggs, 19 of them being early breeders and 3 late. Considering early versus late breeder performance (Table 2), the difference in hatching success was not significant ($\chi^2 = 0.77$, df = 1, $P = 0.380$) and neither was the proportion of pairs with all hatched eggs ($\chi^2 = 1.36$, df = 1, $P = 0.244$). Considering all nests observed on the colony, they had an average clutch size of 2.43 eggs, with 32 clutches of 3 eggs, 22 clutches of 2 eggs and six with only one egg. Among those, early breeders had 23, 8 and 3 clutches of 3, 2 and 1 eggs respectively, while late breeders had 9, 14 and

Table 2: Comparison of early versus late breeder breeding success on a breeding platform near Zagreb in 2019. "Early breeders" were estimated to be nests first observed before the date when we counted the greatest number of active nests on the colony (26 May), while "late breeders" were nests first observed on or after that date. Difference significance is given as p-value of Yate's corrected Chi square test.

Tabela 2: Primerjava gnezditvenega uspeha med zgodnjimi in poznimi gnezdilci na gnezdilnem splavu pri Zagrebu v letu 2019. Pri zgodnjih gnezdilcih so bila gnezda najdena pred datumom, ko je bilo na gnezdišču največ gnezd (26. maj), pri poznih so bila gnezda najdena prvič na ta dan ali kasneje. Značilnost razlike je prikazana s Hi-kvadrat testom in Yeatsovim popravkom.

Siromaja 2019	early breeders zgodnji gnezdilci	late breeders pozni gnezdilci	difference significance značilnost razlike
hatching success uspeh izvalitve	72.78%	53.85%	p = 0.38
nests with 100% hatched eggs gnezda s 100% izvaljenimi jajci	63.33%	23.08%	p = 0.24
mean clutch size povprečna velikost legla	2.59	2.23	
% pairs with clutch of 1 % parov z enim jajcem	8.82%	11.54%	
% pairs with clutch of 2 % parov z dvema jajcema	23.53%	53.85%	p = 0.23
% pairs with clutch of 3 % parov s tremi jajci	67.65%	34.62%	

3 clutches of 3, 2 and 1 eggs respectively. The difference was not significant ($\chi^2 = 6.81$, df = 5, $P = 0.23$). The total number of fledged chicks at the colony was 36.

Monitoring methodology

Regarding nest marking, in 2018 terns used some of the bamboo garden markers as nest material. This disabled identification of nests, the markers of which had been taken, as well as of nests containing multiple markers. Additionally, towards the end of the breeding season, some markings faded away and became impossible to read. For these reasons we were unable to follow 7 out of 34 (20.59%) marked nests until the end of the study. In 2019, when using pebbles with acrylic paint, we only lost track of 2 out of 42 (4.76%) marked nests.

4. Discussion

Arrival of Common Terns to the colonies around Zagreb in both years and the start of incubation in 2019 coincide with those observed along the Po River (Bogliani & Barbieri 1982), as well as in central Poland (Minias *et al.* 2015). They occurred about 10 days earlier than those observed in populations breeding along the North Sea (Becker & Zhang 2011, Dobson *et al.* 2017) and more than two weeks earlier than populations in south-eastern Massachusetts (Nisbet & Drury 1972) and the Danish Wadden Sea (Bregnballe *et al.* 2015). In 2018, birds started incubating between four and six weeks after they had started congregating near their breeding sites, while in 2019 incubation started two to three weeks after arrival. Time between arrival and laying for 2019 corresponds to that observed previously (Becker & Zhang 2011), but in 2018 the pre-laying period lasted longer. The most probable cause for this are extremely high spring water levels that occurred in 2018 in Croatia, flooding all potential breeding sites (Kralj *et al.* in print). Common Terns therefore did not have any suitable breeding sites in the area until we set up the floating platform at lake Siromaja in mid-May, while their traditional colony resurfaced only in mid-June.

All mean clutch sizes are within the range described by previous studies in England (Langham 1972, Bullock & Gomersall 1981), western Germany (Witt 1970), Denmark (Bregnballe *et al.* 2015) and Poland (Minias *et al.* 2015).

Hatching success on Siromaja in 2018 and Rakitje in 2019 was within the range described by previous studies in western Germany (77%, Witt 1970), southern Finland (80%, Lemmetyinen 1973) and northern Germany (73%, Becker *et al.* 1993). However, hatching success in the Siromaja colony in 2019 was smaller than that of a "highly contaminated" colony in northern Germany (68%, Becker *et al.* 1993), found in 1988 to have had a critical level of organochlorines which reduce hatchability (Fox 1976). Since there are many potential factors which can influence hatchability (Burger & Gochfeld 2003), we propose further monitoring of hatching success on the colony, as well as a toxicological survey of eggshells.

Considering early and late breeders on Siromaja in 2019, there was no statistically significant difference between early and late breeder clutch size and hatching success. Becker & Zhang (2011) did not find any differences in breeding success between early and late breeders either, while Bregnballe *et al.* (2015) found that early breeders had larger clutches. Continued monitoring of early and late breeder breeding success is required to elucidate whether there are any significant differences.

Fledging success and productivity were smaller than observed in older studies (Witt 1970, Langham 1972, Lemmetyinen 1973), but productivity was in line with other studies (Nisbet & Drury 1972, Hays 1978, JNCC 2016). Observed high mortality and consequential low fledging success on Rakitje in 2018 have later been connected to an avian pox virus infection diagnosed from dead birds (Savić *pers. comm.*). Minias *et al.* (2015) observed higher productivity in a large colony compared to smaller ones, although chicks from the larger colony were in poorer condition. They attributed the difference to opposing selective pressures – higher predation on smaller colonies versus higher parasitism/social stress on the larger ones. However, we observed an opposite situation regarding productivity. Lower apparent productivity on Rakitje (the larger colony) in comparison to Siromaja might be a result of habitat type differences. Chicks are protected from terrestrial and aquatic predators on the fenced floating platform on lake Siromaja. On the other hand, the island on lake Rakitje has dense patches of reeds, willow and poplar around its edges. While these patches provide chicks with cover from predators, they also enable them to hide from researchers, thus potentially lowering the surveyed number of fledglings on the colony. We recommend a study of fledgling condition on these colonies to further test the conclusions from Minias *et al.* (2015).

According to breeding success data, Siromaja and Rakitje seem like average Common Tern breeding colonies. They thus represent a valuable opportunity to monitor and research Common Tern population dynamics, ecology and ethology.

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5. Povzetek

V letih 2018 in 2019 smo raziskovali gnezditveni uspeh na dveh kolonijah navadne čigre v bližini Save pri Zagrebu. Kolonije smo obiskovali tedensko od maja do julija. Zbirali smo podatke o fenologiji, številu gnezdečih parov, velikosti legla in preživetju jajc ter mladičev. Primerjali smo podatke z zgodnjih in poznih gnezd. Uspešnost izvalitve in speljave sta bili v rangu prejšnjih opazovanj z izjemo nizkega uspeha speljave na Siromaji leta 2019. Manjša kolonija na Siromaji je imela v obeh letih višjo produkcijo mladičev kot kolonija na Rakitju. Leta 2018 je zaradi virusa na Rakitju poginilo veliko mladičev. Zgodnji gnezdilci so imeli večji uspeh izvalitve z večjim leglom, večji delež jih je izvalil vsa jajca v primerjavi s poznimi gnezdilci, a razlike statistično niso bile značilne. Naša raziskava je osnova za nadaljnje preučevanje fenologije in gnezditvenega uspeha predvsem pod vplivom naravovarstvenih ukrepov.

Keywords: phenology, clutch size, hatching success, fledging success, productivity

Ključne besede: fenologija, velikost legla, izvalitveni uspeh, uspeh speljave, produkcija

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