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COMPARISON OF SPRING AND SUMMER CLUTCHES OF GREAT CRESTED GREBES (*PODICEPS CRISTATUS*)

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The intensively farmed fishponds of the Třeboň Basin in South Bohemia, Czech Republic, host a substantial number of Great Crested Grebe (*Podiceps cristatus*) pairs that nest later than the expected spring season. This may be associated with fishpond farming. Our work found no substantial difference between spring and summer egg characteristics and no differences between the number of eggs in spring and summer clutches. The high number of eggs in spring nests was significantly related to both decreasing distances between nests and decreasing number of nests on the fishpond. The increase of the number of eggs in summer nests was significantly related to the distance to the edge of littoral vegetation.

Key words: egg, Great Crested Grebe, Podiceps cristatus, nest, fishpond, habitat, clutch.

INTRODUCTION

Some bird species have adapted well to continuous and repeated human activities in cities and agricultural landscapes, but the response to human disturbance is difficult to predict (Price 2008). The response of water birds to human disturbance is crucial in the Czech Republic, where almost all water bodies suitable for their nesting are artificial. Of those human-made water-bodies in the Czech landscape, intensively farmed fishponds are frequent, and the Great Crested Grebe *Podiceps cristatus* (Linnaeus, 1758) is relatively well adapted to their conditions (Rajchard *et al.* 2013). One of its adaptions is the ability to limit the number of offspring depending on how favourable conditions remain throughout the processes of laying, incubation and chick raising. This happens mainly through two mechanisms: variable clutch size and asynchronous hatching (Vlug 2005). Changes in reproductive behaviour are also linked with changes in the nesting environment (Marxmeier & Duettmann 2002, Zaynagutdinova & Mikhailov 2019).

Egg-laying occurs from the beginning of April through the end of August (Konter 2005), but mainly between the end of April and the start of June (Šťastný *et al.* 2006). The Great Crested Grebe nests initiated in spring on fishponds are often destroyed by ducks, which are released by farmers during the grebes' main breeding season. Water level and in turn, shoreline locational changes may also affect the nesting success rate (Sychra 2012). Though few aspects of Great Crested Grebe biology have been studied in a fishpond setting, the causes and consequences of a protracted breeding period have been examined in detail. Interestingly, when a pair loses eggs or young, substitute clutches are laid (Cramp 1985, Konter 2007). Average clutch size is known to vary significantly, also dependent upon the specific characteristics of the nest location (Zaynagutdinova & Mikhailov 2019).

Bukacinska *et al.* (1993) observed the effects of the season when egg laying took place and proximity to a colony on nesting parameters for Great Crested Grebes on Luknajno Lake in northeast Poland. They found that eggs appeared earlier in the Grebe nests located in colonies and that those same nests were situated in sparser vegetation than the nests outside the colony. Additionally, the colonial grebe clutches were larger than the clutches of their non-colonial counterparts (Bukacinska *et al.* 1993). Colonial nests showed an increased average clutch size and total clutch size, while the non-colonial grebe nest values decreased for those same metrics. In addition, nests that were located closer to water and outside of littoral vegetation had a higher egg length. Konter (2005) suggested that the extent of aggregation is dictated by the quality of the site and the ability of the grebes to reduce their aggressiveness towards one another. Location of the nest is a crucial factor of protecting the nest from native and non-native predators (Brzezinski *et al.* 2018, Walesiak *et al.* 2019).

The Great Crested Grebe nesting on fishponds has created a unique situation to examine. Nesting and egg-laying occur over a very long period on these artificial and food-rich water bodies that comprise a large portion of their present habitat. While differences in egg characteristics, as well as clutch sizes among nests of Great Crested Grebes are known, little is known about the effect of when the eggs are laid on egg and clutch characteristics, which was found to be different for other bird species (e.g. Blomberg *et al.* 2017 for greater sage-grouse, *Centrocercus urophasianus* (Bonaparte, 1827)). We aim to test for potential differences in Great Crested Grebe eggs and clutches laid between spring and summer on artificial water bodies.

MATERIAL AND METHODS

Data collection

Data about Great Crested Grebe clutches were collected during several visits to two fishponds of Naděje fishpond system (fishponds Víra – 49.1068189N, 14.7461175E, Skutek – 49.1090664N, 14.7540567E) in the northern part of Třeboň Basin, South Bohemia, in the Czech Republic in 2007, 2008 and 2009. Only clutches with three, four, five and six eggs were included in the evaluation as they were presumed complete if they no longer contained completely white eggs freshly laid. If less than three eggs were observed, an incomplete clutch was assumed. There is still a possibility that clutches with three to six eggs were incomplete as all nests were not observed continuously, but visited in 21-days intervals. If more than six eggs were found in a nest, it was assumed that more than one female contributed to its content. Nests observed in May and June were considered "spring" nests and nests found in July and August were considered "summer" nests. The sampling yielded a total of 325 eggs, of which 261 eggs (2007: 145, 2008: 48, 2009: 68) were from 62 spring nests, and 64 eggs (2007: 28, 2008: 9, 2009: 27) were from 19 summer nests. The eggs found in the same nest are treated as one clutch hereafter.

All data acquisition procedures were in line with animal welfare and legislation; only non-invasive methods were used that did not harm the species or its environment. Egg length and width, as well as nest distances to the next nearest nest and the edge of the littoral vegetation, were measured during the birds' absence from the nest. Eggs were measured using callipers with a 0.5 mm precision.

Data processing

An index comparing the proportion of width and length of eggs was created (index WL). The volume in cm^3 of all eggs was calculated following Narushin's (Narushin 2005) formula as employed by Nedomova and Buchar (2013).

Descriptive statistics (minimal value, maximal value, mean, standard deviation, first quartile, median, third quartile) for all egg characteristics (width, length, WL index, volume) were calculated. The differences between the spring and summer eggs in minimal value, maximal value, mean, standard deviation, first quartile, median, third quartile were tested using two-factor hierarchical ANOVA (first factor is time – spring or summer eggs, second factor is the clutch the egg belonged to). Then a chi-square test was used to determine if a difference between spring and summer nests in the number of eggs in the clutches was present.

In the next step, the relationship of number of eggs in clutch (clutch size) separately for spring and summer nests to the measured characteristics of the location of each nest (i.e. the number of nests on a fishpond, distance of the nest to the edge of vegetation, and nearest nest distance) were all examined. Multiple linear regression (Nusair & Hua 2010) with forward selection of independent variables was used to find statistically important predictors of clutch size. Stepwise regression is a model-building technique that finds subsets of predictor variables that most adequately predict responses on a dependent variable by regression. Forward selection starts with null model, and an entry statistic is computed for each effect eligible for entry in the model – in the first step the most significant variable (if there is any) is added to the model, other variables are added in further steps until there are variables that meet the criteria to enter the model, then stepping is terminated (TIBCO Software Inc. 2020). The linear regression model was then assessed based on the partial regression and residual graphs, and with an F-test (Robinson 1998).

RESULTS

Egg characteristics

Basic descriptive characteristics for the width, length, WL index, and volume of spring and summer eggs are shown in Table 1. Despite a greater variability in spring eggs, no statistically significant differences between spring and summer eggs were found for width ($F(1, 246) = 0.064$, $p = 0.8$), WL index ($F(1, 246) = 2.377$, $p = 0.124$), and volume ($F(1, 246) = 2.155$, $p = 0.143$). A weak statistical difference was found for length ($F(1, 246) = 5.033$, $p = 0.0258$), but the difference is only 0.6 mm in means (Table 1). Thus, further analyses of the potential differences in location of nests (calculated in next sections) are not influenced by volumetric differences in eggs laid by females in spring and summer nests. The size of clutches (= number of eggs in the clutches) does not differ between spring and summer nests (chi-square = 5.2, d.f. = 3, $p = 0.158$).

Spring nests

The potential dependence of clutch size on the location of nests for spring nests was tested by multiple linear regression with the forward selection of independent variables (number of nests on fishpond, distance to the next nearest nest, and the distance to the edge of littoral vegetation). Two of those three measured variables were found to be statistically important by the stepwise regression model – the distance to the nearest neighbouring nest, and the total

Table 1. Descriptive characteristics of eggs.

	length (mm)		width (mm)		index WL		volume (cm^3)	
	spring	summer	spring	summer	spring	summer	spring	summer
min. value	47.00	49.50	32.00	33.50	0.58	0.59	20.97	32.44
max. value	59.00	60.00	40.50	37.50	0.79	0.74	48.07	43.17
mean	53.93	54.49	35.95	35.93	0.67	0.66	37.70	38.10
standard deviation	2.31	2.37	1.34	0.98	0.04	0.03	3.45	2.82
first quartile	52.50	53.00	35.00	35.38	0.64	0.64	35.23	35.58
median	54.00	54.50	36.00	36.00	0.67	0.65	37.85	38.74
third quartile	55.50	56.13	37.00	36.63	0.69	0.68	39.94	40.24

Table 2. Results of linear regression for clutch sizes (= number of eggs in clutch is dependent variable).

	Sums of squares	DF	Mean squares	F	p
A. Spring nests					
Regression	19.070	2	9.534	12.276	< 0.001
Residual	45.843	59	0.777		
Total	64.919				
B. Summer nests					
Regression	7.057	1	7.057	14.1	< 0.01
Residual	10.627	17	11.289		
Total	17.684				

number of nests on the fishpond (Table 2). These two independent variables explained 27 % of variability of clutch size (adjusted $R^2 = 0.269$, standard error of estimate = 0.881). Based on regression coefficients we found that the number of eggs is lower in nests that are further one from another (as spring nest clutch size was negatively related to distance to the nearest neighbouring nest). The number of eggs is lower in the nest that is located on fishpond with a higher number of nests as spring nest clutch size was negatively related to the increasing number of nests on the respective fishpond (Table 3).

Summer nests

The multiple linear regression with the forward selection of the same independent variables as for spring nests was also performed for summer nest clutch size. Summer nests were only significantly affected by one independent

Table 3. Regression model for estimate of the number of eggs in the clutch (= clutch size).

	Regression coefficient	Standard error of R.c.	t-test (d.f. = 59)	Significance
A. Spring nests				
Intercept	6.038	0.349	17.315	< .001
Number of nests on the pond	–0.039	0.009	–4.251	< .001
Distance from another nest	–0.105	0.044	–2.400	< .05
B. Summer nests			t-test (d.f. = 17)	
Intercept	3.492	0.293	11.934	< .001
Distance from the edge of littoral vegetation	0.125	0.037	3.360	< .01

variable – the distance of the nest from the edge of the littoral vegetation. The resulting model was also significant (Table 2). The number of eggs in summer nest clutches increased with the distance of the nest from the edge of the littoral vegetation (Table 3). This variable alone explained 36 % of variability of the summer clutch sizes (adjusted $R^2 = 0.364$, standard error of estimate = 0.791).

DISCUSSION

Egg characteristics and clutch size can be considered a specific marker of the health of adult birds, and indirectly as a marker of food availability (Rajchard *et al.* 2013). Our results show that spring clutch size increases with the density of nests (i. e. lower distance between nests), but decreases with the total number of nests on the fishpond. This dependence can be influenced by the concentration of nesting pairs in an area with sufficient food supplies, and also represent the nesting pairs in favourable conditions. In contrast, the decrease in clutch size concerning the number of nests on fishpond can be attributed to potential intraspecific competition that occurs on a pond with a higher number of breeding pairs and a relatively lower amount of easily reached food supplies as hypothesized e.g. by Arnold (1992). Our results are supported by the work of Šťastný *et al.* (2006), who reported nesting attempts between April and August and did not mention any differences in the quality of spring and summer clutches. Nesting in spring can be considered normal and expected since a larger part of the population takes part in it, and spring nesting commonly occurs in the natural habitats of Great Crested Grebe. Our study demonstrates a relatively great frequency of summer nesting in artificial habitats, i.e. fishponds (almost ¼ of all nests were summer nests – 23.46% of all nests), and importantly this later nesting may be a specific adaptation to the late filling of fishponds that occurs in May, or even as late as June. Grebes colonize fishponds in this period and find plenty of food, such as stocked carp fry or other fish. As birds in pairs were not ringed, we could not say if summer nests belong to the pairs that nested in spring or not. On the other hand, our observation for 15 years (between 1998 and 2013) revealed, that many pairs that do not initially nest in colonies, left their isolated nest on all neighbouring fishponds and moved quickly to the fishpond just stocked by fish where they make new nests in colony (unpublished observation) even from completely inappropriate material (Rajchard *et al.* 2013) such as stems of horned pondweed (*Zannichellia palustris* L.). It is worth noting that summer nesting can be a substitute for a failed first spring nest or could be a second brood of early nesters, too.

Our results show that the size of summer clutches increases with the distance of the nest from the edge of littoral vegetation. So, this means that summer clutches tend to produce larger clutches during the summer nesting period if located deeper within the littoral vegetation – usually reeds (Cheriet *et al.* 2015). Compared to spring nests, where "colonial" behaviour was detected as the main factor of clutch size, in summer nests the location concerning the edge of littoral vegetation was found to be most important (the distance from shoreline explains 36% of the variability of clutch size). Our result could be in line with the findings of Zaynagutdinova and Mikhailov (2019), who found that pairs nesting on open water started incubation earlier than pairs in reed stands. Later nesting was also found by Bukacinska *et al.* (1993) for non-colonial nesting pairs. However, it is necessary to point out that the determination of how to define colonial nesting compared to a more dispersed breeding pattern is very difficult. Besides, the composition of the littoral vegetation and the condition of the stands could contribute to the later nesting of Grebes in the monitored area as well (Rajchard *et al.* 2013). This outcome is in agreement with the findings of Marxmeier and Duettmann (2002) on the later start of Grebe nesting in declining littoral stands.

An interesting nesting phenomenon observed especially on intensively managed fishponds is the seasonal distribution of Great Crested Grebe clutches; we observed that they are distributed over a very long period (May-August). Either water level fluctuation may cause this during spring due to technological measures in carp breeding or, in some cases, by the late filling of fishponds. Under natural conditions, late clutches tend to be smaller in size than the early ones, as shown in Blomberg *et al.* (2017) in the case of greater sage-grouse. Konter (2008) also reported the decrease of clutch size with laying date. However, on intensively managed fishponds, in late spring and early summer, there is a significant improvement in the food supply; carp fry grows up to a size suitable as food for grebes, and at the same time many small invasive fish species *Pseudorasbora parva* (Temminck & Schlegel, 1846) will hatch as well. Favorable food conditions are expected to initiate nesting (possibly even repeated nesting). These same favorable food conditions both ensure the good physiological condition of the birds and balanced clutch size over a longer nesting period for grebes in such fishponds. Due to these specific conditions in fishponds, clutch initiation over a longer period without negative effects on clutch size can be expected.

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Our research complies with the current laws of the Czech Republic. All data acquisition procedures were in line with animal welfare and legislation; only non-invasive methods have been used that do not harm the species or its environment. There are no conflicts of interest as well as no competing interests.

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