Mammals under a colony of great cormorants: population structure and body condition of yellow-necked mice

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Abstract: Investigations into small mammals within the territory of a breeding colony of great cormorants (*Phalacrocorax carbo sinensis*), carried out in 2011–2014 near Juodkrantė (West Lithuania), demonstrated the colony's impact on the dominant rodent, yellow-necked mouse (*Apodemus flavicollis*). The age and sex structure of the sampled mice (n = 432), along with body weight, body condition index, and residuals from the linear regression, were used to analyse data from five zones of the colony and the surrounding forest. We found that in the most active zones of the cormorant colony, the age structure of the population was tilted towards a prevalence of juveniles, while sex structure was towards a prevalence of males (P < 0.0001). Despite males being significantly longer in body and heavier, body condition index was the same in both sexes. The effect of the zone of the colony was confirmed for body weight and its residuals; body length and body condition index (main effects ANOVA) were negative in the zones where cormorants were nesting actively.

Key words: *Phalacrocorax carbo sinensis*, breeding colony, *Apodemus flavicollis*, body condition

1. Introduction

Great cormorants (*Phalacrocorax carbo sinensis*) are able to form extremely large breeding colonies near water bodies; for example, there are 11,600 breeding pairs at Katy Rybackie in Poland, the largest tree-nesting colony in Europe (http://ec.europa.eu/environment/nature/cormorants/numbers-and-distribution.htm). In Lithuania, after 100 years of eradication, great cormorants started to breed again in 1989 (Stanevičius and Paltanavičius, 1997). The number of breeding pairs in the largest colony in the country, located near Juodkrantė, Kuršių Nerija (West Lithuania), was estimated at about 3000 in 2005–2010 (Pūtys, 2012), but was as high as 3800 breeding pairs in 2011 (Pūtys, 2012) and 3200 in the summer of 2012 (Dagys and Zarankaitė, 2013).

The influence of the colony on the environment is mainly due to an increase in N and P levels by 10^4 to 10^5 times, leading to death of the forest (Garcia et al., 2011). As the trees die, glades are formed and shrubs later replace the dead forest (Żółkóś and Markowski, 2006). Generally, in the active areas of the colony, plant biomass is decreased (Kolb et al., 2010).

The influence of the cormorant colony and an associated grey heron (*Ardea cinerea*) colony has already been shown on lichens (Żółkóś et al., 2013), fungi (Osono, 2012), plants (e.g., Anderson and Polis, 1999), insects, spiders, and lizards (Polis and Hurd, 1996). Due primarily to increased nitrogen levels, the abundance of herbivores and detritivores may increase.

In this colony of great cormorants in Lithuania, complex investigations into the influence of the colony on the ecosystem have been performed over the last few years as part of the National Research Programme "Ecosystems in Lithuania: Climate Change and Human Impact (2010–2014)". It has been shown that despite a general increase in the abundance of myxomycetes in the territory (Adamonytė et al., 2013), the most active part of the breeding colony alters fungal diversity in a negative way, with fungal abundance being at its lowest. The biggest decrease was observed in mycorrhizal species, but at the same time, coprophilous fungi appeared in the forest litter and specialised fungi species were recorded on plants (Kutorga et al., 2014). Due to altered pH, as well as the content of N, P, and Ca, lichen diversity was also affected, mostly in the active zone of the great cormorant colony (Motiejūnaitė et al., 2014).

So far, the only research into small mammals in colonies of great cormorants has been from Lithuania, showing a reduction in species diversity and a lower abundance in the most active parts of the breeding colony (Balčiauskienė et al., 2014).

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The aim of the current study was to determine if population structure and body condition of the dominant small mammal species, the yellow-necked mouse (*Apodemus flavicollis*), is affected by living in the zones of the great cormorant colony, with various intensities of influence by the breeding birds.

2. Materials and methods

We investigated the small mammal community living in the colony of great cormorants (*Phalacrocorax carbo sinensis*) and the surrounding territory, situated near Juodkrantė in Kuršių Nerija National Park (55°33′10″N, 21°07′30″E), West Lithuania. We defined five zones, each differing in the intensity and duration of the impact of the colony (Balčiauskienė et al., 2014).

The strongest and longest-lasting influence of the colony (Zone A, Figure 1) was recorded in the zone of long influence, which contained the greatest number of cormorant nests in 2011–2013. In Zone A, the shrub layer was scarce or significantly reduced, and trees were dying or dead (Figure 2A). Nitrophilic species of plants dominated in the herbage layer, the projection of which was less than 10% (Adamonytė et al., 2013).

Quite strong influence of the colony was observed in the expanding part of the colony, typified by fresh nests (Zone B, Figure 1). Shrub and herbage layers were scarce and trees were dying (Figure 2B). Bare patches without herbage or even moss were found on the ground.

The next zone was characterised by a strong former influence (Zone C, Figure 1) of the colony, but with most nests currently already abandoned by great cormorants. Dead and rotten trees were characteristic (Figure 2C). Tree saplings and shrubs were regrowing, the herbage layer was

reestablishing, and the moss layer was absent (Adamonytė et al., 2013).

Two other zones were characterised by even lower impact of the colony. We investigated Zone D (Figure 1, Figure 2D), which was the ecotone between the surrounding forest and Zones A, B, and C, and Zone E, which was a control zone, an area where the trapping of small mammals was performed at a distance from the colony. Two types of forest were characteristic of Zone E: dry pine forest and mixed forest.

The areas of the zones where small mammals were trapped were as follows: Zone A = 4.2 ha, Zone B = 3.2 ha, Zone C = 4.6 ha, Zone D = 1.6 ha, Zone E = 28 ha (Balčiauskienė et al., 2014).

Small mammals were trapped by snap traps, using lines of 25 traps each 5 m apart, baited with bread crust with sunflower oil, exposed for 3 days, and checked every day in the morning (Balčiauskas, 2004; Balčiauskienė et al., 2014). Trapping was done in September and October 2011; May, September, and November 2012; October and November 2013; and June 2014. Snap-trapping effort was equal to 4725 trap/days.

According to Lithuanian law, permission for small mammal snap-trapping is not required and thus was not issued by the Ministry of the Environment.

In addition, live trapping was performed in June, August, and September 2013; individuals found dead in live traps were added to the sample. Live-trapping effort was equal to 900 trap/days.

In total, 578 small mammal individuals (of 7 species) were trapped in the territory of the colony. The dominant species was yellow-necked mouse (*Apodemus flavicollis*): 432 individuals (74.7% of all catch) were trapped in the great cormorant colony and the control zone (Table 1).

Trapped small mammals were identified and weighed to an accuracy of 0.1 g. Standard measures were taken to an accuracy of 0.1 mm; the individuals were then dissected, with age and sex recorded. Three age categories were used, based on the presence and involution of the thymus gland and reproductive status of the animals (Prévot-Julliard et al., 1999). We examined the mammary glands, uteri, and ovaries in females; those with visible placental scars and corpora lutea, or who were pregnant or lactating, were defined as adults. Females with inactive reproductive organs, such as small nipples and closed vagina, were defined as subadults, while females with a thread-like vagina were classified as juveniles. Males with scrotal testes and full cauda epididymis were defined as adults, those with developed abdominal testes as subadults, and those with hardly visible testes as juveniles (Prévot-Julliard et al., 1999; Balčiauskas et al., 2012).

The age and sex structures of *A. flavicollis* in all zones were compared using chi-square statistics.
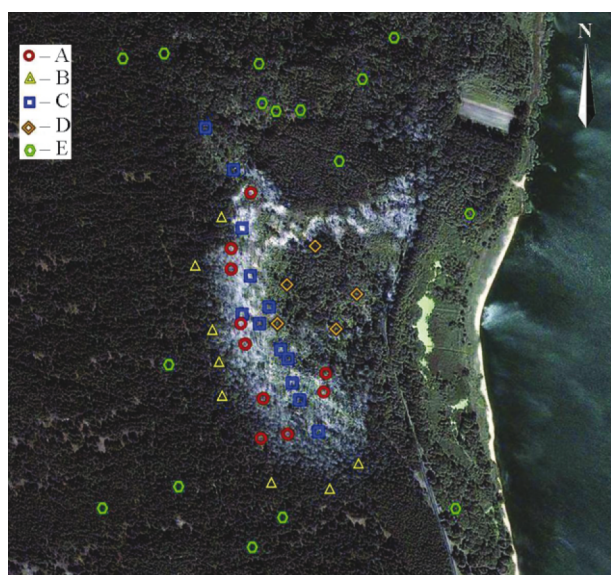

Figure 1. Location of Zones A–E in the colony of great cormorants near Juodkrantė, West Lithuania, 2011–2013.

Figure 2. Zones A–D, in which small mammals were trapped in 2011–2014: Zone A – strongest and longest-lasting influence of the colony; Zone B – expanding part of the colony, Zone C – strong former influence; Zone D – ecotone zone between colony and surrounding forest.

Table 1. Sample size of *A. flavicollis* trapped in the colony of great cormorants near Juodkrantė, West Lithuania, 2011–2014.

Year	Males			Females			Both sexes together			
	Adult	Sub.	Juv.	Adult	Sub.	Juv.	Adult	Sub.	Juv.	Total*
2011	7	4	16	12	4	7	19	8	23	50
2012	32	33	23	16	27	39	48	71	63	187
2013	34	18	16	20	19	34	54	37	50	141
2014	23	2	9	19		3	39	2	12	54
Total	96	68	64	64	50	83	160	118	148	432

*: A few individuals, mainly destroyed by carnivores or insects, were not aged or sexed, and thus the total is bigger than the simple sum.

To define the body condition of the trapped individuals, we selected an index based on the ratio of body weight and body length (Drouhot et al., 2014). Such indices are used as indicators of animal health (Peig and Green, 2009). We used the body condition index $C = (Q/L^3) \times 10^5$, where Q is body weight in g and L is the body length in mm (Moors, 1985).

We applied GLM main effects ANOVA for body condition index C, body weight, and body length with year and month of trapping, zone, sex, and age of an individual as categorical predictors for testing of possible influence according to Tête et al. (2013).

Based on the assumption that body length is the best descriptor of body structure (Peig and Green, 2009; Tête

et al., 2013), we regressed body weight against body length of every trapped individual, excluding pregnant females and individuals destroyed or eaten in traps by insects or carnivores from the sample. We used linear regressions and the least square method based on the high correlation between body weight and length. Due to the significant differences in body size, regressions for males and females were calculated separately. Structural body weight was obtained for every individual based on the regressions. Individuals with positive residuals were assumed to be in better condition as predicted by their size, and vice versa (Blackwell, 2002). We calculated the number of individuals in better and in worse condition for all five zones and tested their proportions using the chi-square test.

All calculations were done with Statistica 6.0 for Windows (www.statsoft.com).

3. Results

The sex and age structure of trapped *A. flavicollis* was different between zones of the great cormorant colony (Figure 3). The percentage of males significantly differed among the zones ($\chi^2 = 35.79$, df = 4, P < 0.0001), being highest in the zone of strongest and longest-lasting influence (over 70%). Females prevailed insignificantly only in the control zone.

The age structure of the trapped *A. flavicollis* was also different between zones of the colony: in the active zones, Zones A and B, the percentage of adult individuals was the lowest, while that of juvenile individuals the highest, at over 40%. In the control zone, Zone E, and in the ecotone between the colony and the surrounding forest, the percentage of adult mice was the highest at about 45%, while juveniles were less than 30% (Figure 3). Differences in the proportion of adult and subadult individuals ($\chi^2 = $

32.02) and the proportion of adult and juvenile individuals ($\chi^2 = 25.29$, both df = 4, P < 0.0001) between zones was significant, while the proportion of the subadult and juvenile mice was not ($\chi^2 = 3.38$, P < 0.5).

As for size, males of *A. flavicollis* were larger than females (body mass 38.02 ± 0.70 and 31.30 ± 0.60 g, respectively, Student's t = 7.09, df = 403, P < 0.0001). However, body condition was the same in both sexes, C = 3.31 ± 0.03 in males and C = 3.36 ± 0.05 in females, t = 0.94, P = 0.34. Following this, we regressed body weight against body length for males and females separately. In animals of both sexes, body weight was significantly correlated to body length (Figure 4).

Residuals of the standardised body weight of *A. flavicollis* showed that the influence of the great cormorant colony was negative (Table 2). Body condition in the control zone was balanced, i.e. there was a similar ratio of mice with greater and lower body weights than predicted by linear regression; for males it was 54% and 46% and for females it was 45% and 55%, i.e. 49% and 51% accordingly (differences not significant). In the zones influenced by the colony (A, B, and C), about 40% of mice had body weights greater than predicted, while 60% were smaller than predicted. This is significantly less than in Zone D, where the rate of *A. flavicollis* with body weights greater and smaller than predicted by linear regression was 65% and 35%, respectively (the difference significant for males, $\chi^2 = 10.95$, df = 1, P < 0.001; for females, $\chi^2 = 5.23$, P = 0.02; and for all individuals, $\chi^2 = 105.73$, P < 0.0001).

We found that the body weight of mice depended on trapping year and month, the zone, the sex of the animal, and age (main effects ANOVA, $F_{15,389} = 47.72$, P < 0.0001, $R^2 = 0.63$). All parameters analysed were highly significant for influence of the zone (Figure 5A). The body length of
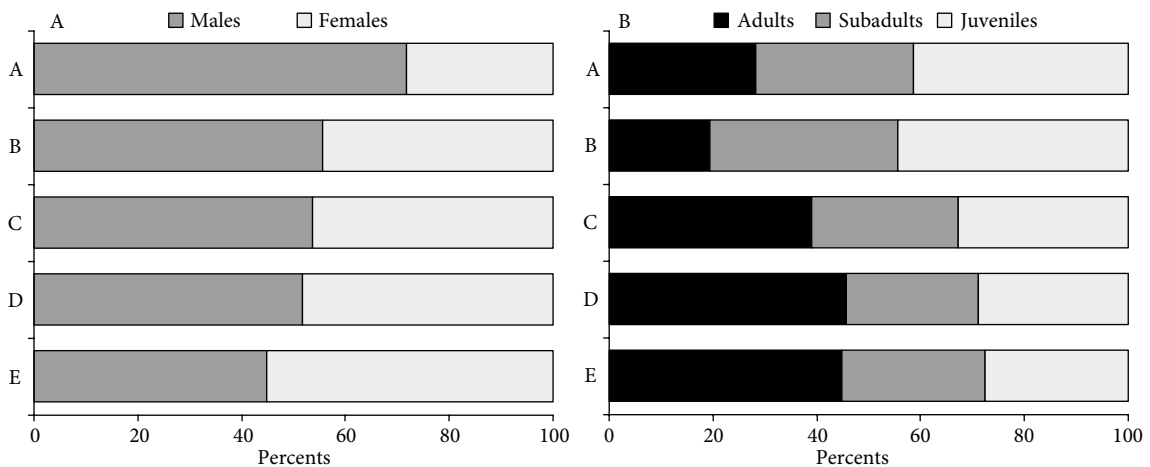

Figure 3. Sex (A) and age (B) structure of *A. flavicollis* trapped in 2011–2014 in the zones of the great cormorant colony (Zone A – strongest and longest-lasting influence of the colony; Zone B – expanding part of the colony; Zone C – strong former influence; Zone D – ecotone zone between colony and surrounding forest; Zone E – control).
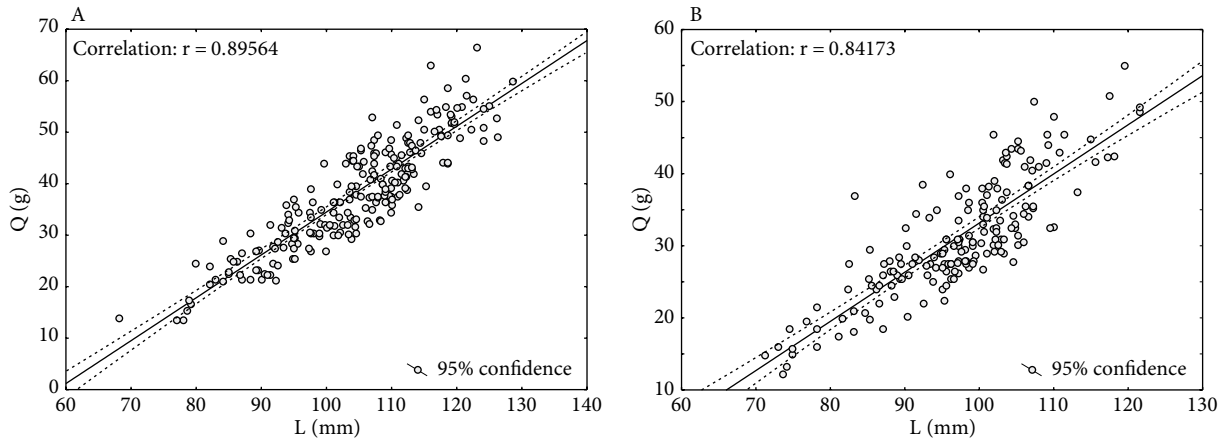
Figure 4. Correlation of the body weight and length of *A. flavicollis* trapped in 2011–2014 in the great cormorant colony: A – males, B – females.

Table 2. Distribution of residuals of standardised weight according to linear regression of *A. flavicollis* trapped in 2011–2014 in the zones of the great cormorant colony (Zone A – strongest and longest-lasting influence of the colony; Zone B – expanding part of the colony; Zone C – strong former influence; Zone D – ecotone zone between colony and surrounding forest; Zone E – control; positive residuals = body condition is better than predicted from body length, negative residuals = body condition is worse than predicted).

Zone	Males (n)		Females (n)		Total (n)	
	Positive	Negative	Positive	Negative	Positive	Negative
A	14	19	5	8	19	27
B	10	10	3	12	13	22
C	36	57	31	41	67	98
D	30	13	22	14	52	27
E	19	16	19	23	38	39

the mice was also influenced by all five parameters (main effects ANOVA, $F_{15,389} = 31.95$, $P < 0.0001$, $R^2 = 0.54$). The influence of the zone was also highly significant (Figure 5B). Variation of the body condition index was defined ($F_{15,387} = 6.53$, $P < 0.0001$, $R^2 = 0.17$) and was influenced mostly by the month of trapping ($F_{5,387} = 14.32$, $P < 0.0001$), and then by zone (Figure 5C) and year of trapping ($F_{3,387} = 2.71$, $P < 0.05$), but not by age or sex of the animal.

4. Discussion
In a colony of tree-nesting colonial birds, the main pressure on the environment is the input of nutrients, mainly nitrogen, phosphorus, and organic carbon (Breuning-Madsen et al., 2010). Depending on the N input from birds in nonproductive ecosystems, plants may be more productive (Anderson and Polis, 1999), resulting also in an increase in abundance of insects, spiders, and lizards (Polis and Hurd, 1996). Consumption of plants and detritus high in N may lead to an increase in the body size of herbivorous or detritivorous organisms (Anderson and Polis, 1999). However, negative impacts of the colonies are not uncommon in fungi (Osono, 2012; Adamonytė et al., 2013), lichens (Żółkóś et al., 2013; Motiejūnaitė et al., 2014), plants (Adamonytė et al., 2013), and insects (Kolb et al., 2012). Positive impacts may also be recorded in some species of lichens (Motiejūnaitė et al., 2014) and insects (Kolb et al., 2012).

Small mammal diversity in the active great cormorant colony is suppressed (Balčiauskienė et al., 2014). It is known that even small amendments of nitrogen negatively influence the survival of small mammals in a territory (Clark et al., 2005). However, not much is known about the underlying mechanism of the nitrogen impact; it has been shown that small granivores/omnivores might have higher N requirements than larger herbivores do (Parsons et al., 2005). It can only be said that landscape structure
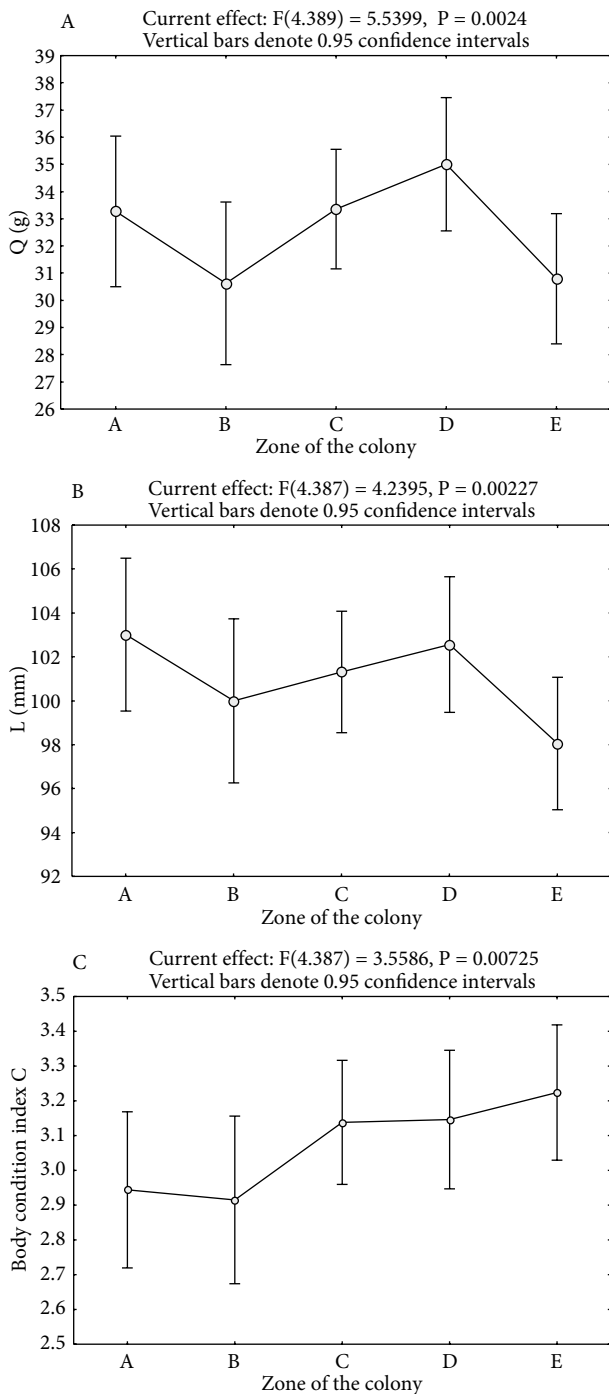
Figure 5. The influence of the zone on body weight (A), body length (B), and body condition index (C) of *A. flavicollis* trapped in 2011–2014 in the zones of the great cormorant colony (Zone A – strongest and longest-lasting influence of the colony; Zone B – expanding part of the colony; Zone C – strong former influence; Zone D – ecotone zone between colony and surrounding forest; Zone E – control).

influences long-term changes within small mammal communities (Schweiger et al., 2000), and thus, even after great cormorants stop breeding, the territory remains affected. In our study, this was the case in the zone of former strong influence (Zone C). Although the active influence of the colony in Zone C had already ceased, the amounts of N, P, and Ca in the soil of this zone in 2010–2011 were higher than in other zones of the colony, with a soil pH of 3.36 ± 0.28 (Adamonytė et al., 2013). In this zone, the diversity of myxomycetes had been somewhat restored (Adamonytė et al., 2013), and both nitrophilous lichens and those characteristic to mixed forests were recorded (Motiejūnaitė et al., 2014). As of yet, there have been no investigations on the time required for small mammals to reestablish diversity and abundance after cormorants no longer breed.

We found that the negative impact of the breeding colony of great cormorants in 2011–2014 was still present in the zone of former strong influence (Zone C). Body weight, body condition index, and population structure of the dominant small mammal, *A. flavicollis*, in this zone were similar to those of the zone of active colony influence, not to the control or ecotone zones. The same tendency was shown by the distribution of residuals of standardised weight against linear regression. In this respect, the influence of the colony is comparable to that of pollution shown in other species of the genus *Apodemus*, e.g., striped field mouse (*A. agrarius*) and wood mouse (*A. sylvaticus*) (Velickovic, 2007; Tête et al., 2013; Drouhot et al., 2014). However, due to short generation, intensive breeding, and migration, small mammals are able to rapidly recover as soon as the disturbance factor is removed (Bush et al., 2012).

The term "condition" or "body condition" may be used in quite different ways (Schulte-Hostedde et al., 2005). It is mainly used for the relation of the body weight to body size, where body length (Velickovic, 2007) or condylobasal skull length (Alcántara and Díaz, 1996) may be used as a size measure. A more sophisticated approach is to use residuals of standardised body weight or body condition index against linear regression, describing the relation of body size to mass (e.g., Schulte-Hostedde et al., 2005; Peig and Green, 2009, 2010). Linearity of relation between body size and weight is very important for the correct use of body condition indices (Schulte-Hostedde et al., 2005). For small mammals this relation is expected to be linear (Peig and Green, 2009, 2010), and so it was in our sample of *A. flavicollis*.

In small mammals, body weight and body condition may depend on many factors, among them animal sex, geographic location, habitat where the sample was collected, and pollution (Alcántara and Díaz, 1996; Díaz et al., 1999; Stevenson and Woods, 2006; Velickovic,

2007; Peig and Green, 2010; Tête et al., 2013; Drouhot et al., 2014). In turn, body weight and body condition may impact litter size (Evsikov et al., 2008). The complexity of factors determining body condition may explain why residuals from the linear regression explain only a small part of the variation in the body condition index in small mammals (Schulte-Hostedde et al., 2005).

Our results show that life in the territory under the nests of the breeding colony of great cormorants imposes consequences on the dominant small mammal, *A. flavicollis*. In the most intensively used territory, the population structure of *A. flavicollis* is biased towards a higher representation of males and young individuals. Generally, a biased sex ratio shows poor or disturbed habitat, or variation of the habitat quality over time (Julliard, 2000). In our case all three presumptions may work. In another study, males were prevalent in both mice and voles as an outcome of heavy grazing (Bush et al., 2012). It is quite possible that, in disturbed habitat, litters

are male-biased due to higher cortisol level in mothers, as has been shown for ground squirrels (Ryan et al., 2012).

We also found that in the most intensively used zone, mice were characterised by smaller body weight and body condition indexes. Variation of the body weight and length was dependent on animal sex and age, but not the body condition index. Thus, differences in the age and sex structure of the mice trapped in different zones had no influence on results: despite a greater number of juvenile *A. flavicollis* and an insignificantly higher body condition index in this age group, the average body index was lower in the zone actively used by nesting cormorants. In conclusion, we confirm that the negative impact of the breeding colony of great cormorants was strongest in the most active zones of the colony.

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