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Loss of Diversity in a Small Mammal Community in a Habitat Influenced by a Colony of Great Cormorants

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Abstract: The diversity and relative abundance of small mammals was studied in the territory occupied by the largest colony of breeding great cormorants (*Phalacrocorax carbo sinensis*) in Lithuania. The area of 13.6 ha with over 3800 cormorant nests, is situated in the Curonian Spit National Park in West Lithuania. The aim of the study was to test if the small mammal community is influenced by the presence of the colony. We found that in general the diversity of small mammals in the area was low. The community was dominated by yellow-necked mice (73.1% of all trapped individuals), with bank voles subdominant (22.2%). The proportion of five other species trapped in the territory of the colony and its edge was in the range of 0.6–1.6%. The zones of colony expansion (where influence of the colony is just started) and established active colony (long term influence) were found to have most negative impact on the small mammal community (only 3–4 species present, Shannon's H = 0.55–1.10). Only two species were registered in the edge of these zones. The relative abundance of small mammals was lower in the territory of active zones of influence. In zones of the former influence of the colony, however, the abundance was higher, than in the zones of recent influence.

Keywords: *Phalacrocorax carbo sinensis*; colony influence; voles and mice

Introduction

The continental subspecies of great cormorant (*Phalacrocorax carbo sinensis*) forms breeding colonies near inland water bodies and along the shores of lagoons, with the largest colonies in Europe containing up to 12-14 thousand breeding pairs (Kirikova *et al.* 2007, Nemtzov 2008, Herrmann *et al.* 2012). Cormorants were eradicated from the Baltic Sea region in 19th century, but returned and started breeding again in 1938 (Ivanauskas 1938; Samusenko 2008, Herrmann *et al.* 2012). By 2009, approximately 165,000 pairs of great cormorants bred in the basin of the Baltic Sea. In recent years, the population of the southern part of the Baltic has been stable, whilst in central and northern parts it has been increasing (Herrmann *et al.* 2012).

The cormorant colony on the Curonian Spit of Lithuania established itself in the 19th century, was eradicated around 1887 (Gražulevičius, Elertas 2005) and once again re-established in1989 (Stanevičius, Paltanavičius 1997). The number of breeding pairs reached 2700 by 2003, stabilized at about 3000 from 2005 to 2010, then peaked at 3808 in 2011 (Ložys, Dagys 2008, Putys 2012). In 2011, the cormorant colony covered an area of 12.0 ha.

This remains the largest cormorant colony in Lithuania, occupying coniferous forest habitat (Adamonytė *et al.* 2012). After trees dry from the excrements and finally die, new nests are built, thereby spatially expanding the colony (Žydelis *et al*. 2002). The Juodkrantė cormorant colony is occupied from March, when the first birds return, and maximum nest occupancy occurs in April. Young

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appear at the beginning of May and stay in the nests till July. From mid-July, the cormorants disperse and in October they migrate southward.

The colony has great influence on forest stands, mainly due to guano increasing the nitrogen and phosphorus levels by 10^4 to 10^5 times, leading to the death of trees and formation of glades (Kameda *et al.* 2000, Laiviņš, Čekstere 2008, Garcia *et al.* 2011). Though soil fertility is increased, plant biomass is lower in the active colony (Kolb *et al.* 2010) and, after the birds disappear, shrub communities replace the dead forest (Źółkóś, Markowski 2006). It was shown that myxomycete diversity in the Juodkrantė colony was lower in the active part of the colony with the most fresh and numerous nests (Adamonytė *et al.* 2012).

So far, there have been no investigations on how the cormorant colony influences mammals. This paper intends to present the first data on the loss of diversity of the small mammal community in the area affected by the colony of great cormorants in Juodkrantė.

Material and Methods

Study area

The study area is located to the south of Juodkrantė settlement on the Curonian Spit, West Lithuania 55° 33' 10'' N, 21° 07' 30'' E) in the Curonian Spit National Park. Small mammal trapping was conducted in the various zones of the great cormorant colony (55° 31' N, 21° 06' E), as well as the margin between the inhabited zones and the surrounding forest and at a control site located in a nearby forest. According to duration and degree of the impact of great cormorants on the habitat, five zones were investigated (Fig. 1):

I – control zone. No influence of nesting cormorants on the habitat. Two habitat types dominating forests on the Curonian spit were investigated in the control zone – dry pine forest (Ia) and mixed forest (Ib). Trees in the control zone were somewhat younger than the dead trees within the colony. According Adamonytė et al. (2012), there are no remaining areas on the Curonian spit which fully correspond to the colony site in vegetation composition, age and position on the slope.

II – zone of initial influence of the colony. This part of the colony is currently expanding, thus is the most recent and the influence is just developing. Trees are still alive, but with reduced vitality, shrub layer reduced and herb layer is scarce. Moss layer is thin, with bare patches.

III – zone of long term influence of the colony. The highest concentration of nests is recorded in this zone. In the former oligotrophic pine forest, the trees are dead or dying and the shrub layer is reduced, formed by mesotrophic *Sorbus aucuparia* as well as by eutrophic *Sambucus nigra* and *S. racemosa* of low projection cover, and sparse, dying *Juniperus communis*. The projection cover of the herb layer is 10 % or less of predominantly nitrophilic species like ruderal *Chelidonium majus*; moss layer is absent (Adamonytė *et al.* 2012).

IV – zone of former active influence of the colony. Trees are dead, many of them rotten, fallen and decaying. The territory is re-growing with young trees and shrubs, the herbaceous layer is thick. Nitrophilic plant communities are establishing with sparse mesotrophic *Calamagrostis epigeios* that is supplemented by mesoeutrophic ruderal herbs and alien eutrophic *Sambucus nigra* and *S. racemosa*. Moss layer is absent (Adamonytė *et al.* 2012). Abandoned part of the colony with only few nests still in use.

V – zone of the ecotone between zones II and III and the surrounding forest that was not influenced by the colony.

Sampling

Small mammals were trapped with snap traps set in lines, each consisting of 25 traps spaced 5 m from each other. Traps were baited with bread and sunflower oil. They were left exposed for two or three days (one trapping session) and checked once a day (Balčiauskas 2004). In total, 51 snap trap lines were operated in September-October 2011 and May-November 2012, with total sampling effort of 3300 trap nights (Table 1). The relative abundance of small mammals was expressed as the number of individuals per 100 trap nights.

Small mammal communities in the different zones were characterized by their diversity (Shannon's H, on the base of log2 transformed data) and dominance (Simpson's c) (Krebs 1999, Balčiauskas 2004). Diversity indices were calculated from the pooled data.

Diversity assessment

Differences in small mammal diversity in different zones were tested using Rényi diversity numbers. Diversity profiles were calculated using scale parameter α between 0 and 4. Scale parameter α = 0 shows Rényi diversity equal to the logarithm of the number of species, α = 1 yields Rényi diversity equal to Shannon's H, α = 2 is related with Simpson's index of dominance, while α = 3 and 4 represent growing emphasis on the dominant species (Tóthmérész

Fig. 1. Trapping design in different zones of the great cormorant colony in Curonian Spit National Park in West Lithuania

1998). All diversity-related calculations (H±SD, c±SD and significance of difference) were performed in the freeware DOSBox ver. 0.74, running DivOrd program ver. 1.90 (Tóthmérész 1993). Differences in species composition of the communities were tested using chi-square test. All differences with $p > 0.05$ were considered non-significant. Differences in relative abundance were tested using non-parametric Kruskal Wallis H test for multiple groups and paired Kruskal Wallis ANOVA with Bonferroni correction. Calculations were done with Statistica for Windows, ver. 6.0 software (StatSoft 2004).

Results and Discussion

In 2011-2012, seven small mammal species were trapped in the different zones of the great cormorant colony and adjacent: common shrew (*Sorex araneus*), pygmy shrew (*S. minutus*), bank vole (*Clethrionomys glareolus*), meadow vole (*Microtus agrestis*), root vole (*M. oeconomus*), yellow-necked mouse (*Apodemus flavicollis*) and harvest mouse (*Micromys minutus*). The dominant species was *A. flavicollis*, accounting for 73.1% of all trapped individuals, with *C. glareolus* subdominant (22.2%). The proportion of other species was negligible (Table 2).

The diversity of small mammals was very low in all study plots (Table 2), as compared to other habitat types of the Curonian spit (Juškaitis, Ulevičius 2002). Five small mammal species were recorded both in the control zone and in the zone of former influence of the colony with abandoned nests. In the zones of initial and long term influence, the number of registered small mammal species was lower (3–4 species), whilst in the ecotone of these zones it is lowest (only two dominant species were found). The differences between the numbers of small mammal species between zones is also shown in Fig. 2A.

At $\alpha = 0$, Rényi diversity equal the logarithm of the number of species. At $\alpha = 1$ Rényi diversity numbers are equal to Shannon's H, while $\alpha > 1$ represents diversity of the higher order; $\alpha = 2$ represents dominance in the community (Tóthmérész 1998). From Fig 2A, it is clear that differences in diversity (Shannon's H) and dominance (Simpson's c) in small mammal assemblage are not well expressed between the five investigated zones of the great cormorant colony (values presented in Table 2). In the zone of initial influence of the colony, Shannon's H was significantly less than in the control zone ($t=1.96$, $p < 0.05$), in the zone of long term influence ($t=2.07$, $p < 0.05$) and in the zone of former influence of the colony ($t=2.53$, $p <$

0.01). Dominance was highest in the zone of initial influence of the colony. Compared with the zone of long term influence, zone of former influence and the ecotone zone, differences were significant at $p < 0.01$ (respectively, t=2.68. t=2.83 and t=2.78). Other differences were not statistically significant.

Comparing the least affected (I+IV) and the most affected (II+III+V) zones, we found that the diversity of the small mammal community was significantly higher in the less affected zone – Shannon's H respectively, was H = 1.17±0.005 and H = 0.98±0.005, while the difference in dominance was not significant – Simpson's c, respectively, was c = 0.58±0.004 and c = 0.60±0.004 (Fig. 2B).

The proportions of dominant *A. flavicollis* and subdominant *C. glareolus* in the small mammal community between the zones of the colony differed (see Table 2). A significantly higher proportion of *A. flavicollis* (90.3% of small mammals trapped, $\chi^2 = 5.19$, p = 0.02) and lower proportion of *C. glarelous* (6.5%, $\chi^2 = 4.92$, p = 0.03) was observed in zone II (the zone of initial influence of the expanding cormorant colony). In the zone V (the ecotone of zone II), the proportion of *A. flavicollis* was the lowest (67.4% of all trapped individuals, $\chi^2 = 0.99$, NS) and the proportion of *C. glareolus* the highest (32.7%, $\chi^2 = 3.63$, p = 0.06). No differences in the proportions of dominant and subdominant small mammal species in the community were observed when comparing the less affected (I+IV) and the most affected (II+III+V) zones

The average relative abundance of small mammals in the zones of the colony and surrounding areas was 12.00±1.50 ind. / 100 trap nights, with differences between the zones being statistically significant (Kruskal-Wallis test, $H_{4,51}$ =12.05 p =0.017). The highest relative abundance of small mammals was observed in zone V (ecotone). It was higher than in the zone of initial influence (Kruskal-Wallis ANOVA, $H_{1,13}$ =4.97 p =0.10) and in the control zone ($H_{1,21}$ =5.36 p =0.08). An abundance almost as high was also observed in the zone IV, former active influence of the colony. It was higher than in the zone of initial influence ($H_{1,20}$ =5.85 p =0.062) and in the control zone ($H_{1,28}$ =7.69 p =0.02).

In the control, no small mammals were trapped in a dry pine forest (Ia), while in a mixed forest (Ib) their relative abundance was 11.63±2.77 ind. / 100 trap nightss, i.e. higher than in the zones of initial (II) and long term (III) influence of the cormorant colony (Table 2, differences not significant).

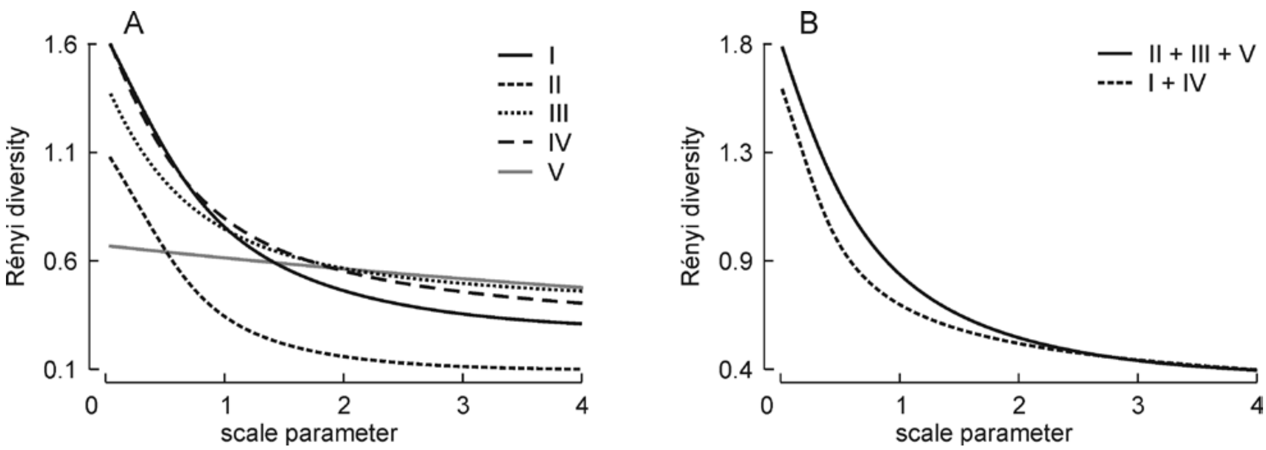

Fig. 2. Small mammal diversity in the zones of different influence of the great cormorant colony: A – differences between zones I-V, B – differences between the most affected (II+III+V) and the least affected (I+IV) zones, where I – control zone, II – zone of initial influence, III – zone of long term influence, IV – zone of former active influence and V – zone of the ecotone between zones II and III and the surrounding forest habitat. Scale parameter $\alpha = 0$ gives Rényi diversity equal to the logarithm of the number of species, $\alpha = 1$ yields Rényi diversity equal to Shannon's H, $\alpha = 2$ is related with Simpson's index of dominance, while $\alpha = 3$ and 4 represent growing emphasis on the dominant species (according Tóthmérész 1998)

Table 1. Trapping effort in different zones of the great cormorant colony, 2011–2012

	Zone				
	I	**II**	**III**	**IV**	**V**
Number of trap lines	16	8	10	12	5
Number of trap nights	1075	550	600	775	300
Area trapped, ha	28	3.2	4.2	4.6	1.6

Table 2. Number of trapped small mammals, their diversity (Shannon's H, Simpson's c) and relative abundance (RA, ind./100 trap nights) in the zones of different influence of the great cormorant colony (2011-2012), where I – control zone, II – zone of initial influence, III – zone of long term influence, IV – zone of former active influence and V – zone of the ecotone between zones II and III and the surrounding forest habitat. Subscripts show differences between groups, statistically significant at p<0.05 or higher level (t-test for Rényi diversity profiles, Kruskall Wallis ANOWA for relative abundance)

	Zones of the colony					Total (n, %)
	I	II	III	IV	V	
S. araneus	2	1	0	2	0	5 (1.6)
S. minutus	2	0	0	0	0	2 (0.6)
M. glareolus	10	2	15	29	16	72 (22.2)
M. agrestis	0	0	1	0	0	1 (0.3)
M. oeconomus	1	0	1	3	0	5 (1.6)
M. minutus	0	0	0	2	0	2 (0.6)
A. flavicollis	50	28	37	89	33	237 (73.1)
Total N	65	31	54	125	49	324 (100)
Number of species	5	3	4	5	2	7
Shannon's H±SD	1.11±0.02	$0.55±0.02^{I,III,IV}$	1.10±0.01	1.16±0.007	0.91±0.002	1.11±0.003
Simpson's c±SD	0.62±0.01	$0.82±0.01^{III,IV,V}$	0.55±0.01	0.56±0.006	0.56±0.009	0.59±0.002
RA±SE	8.00±2.34	7.50±2.06	10.40±4.01	$18.67±3.17^{I}$	19.20±3.88	12.00±1.50

An earlier investigation of the small mammals on the Curonian Spit of Lithuania (Juškaitis, Ulevičius 2002) indicated that small mammal assemblages in the three types of forests in the Spit were extremely poor in species composition. Only three species (*S. araneus*, *A. flavicollis* and *C. glareolus*) were registered in coastal pine forests, while only two species occurred in black alder and birch stands. Average relative abundances were 8.8 ind. / 100 trap nights in the pine stands, 12.0 in the black alder and only 4.0 ind. / 100 trap nights in the birch stands. *A. flavicollis* and *C. glareolus* were co-dominants in the forests (Jujъkaitis, Ulevičius 2002). In the continental dry pine forests in South Lithuania, the relative abundance of *A. flavicollis* was 4-8 ind. / 100 trap nights, with that of *C. glareolus* being 0-8 ind. / 100 trap nights. The total number of species did not exceed four (Ulevičius, Juškaitis 2003). Thus, our results are in line with data of other research from pine forests in Lithuania.

The results of this research are valuable in several aspects. First of all, there are no published data on small mammal communities in landscapes influenced by large colonies of great cormorants. We discovered that in the most heavily influenced zones, the diversity and the relative abundance of the small mammal community decreased. The nitrogen and phosphorus loads in the Juodkrantė colony are extreme: in the soil of zones II, III and V, the quantity of nitrogen was 1.57-1.66 g per kg of soil, with phosphorus occurring at 0.29-0.39 g/kg. In zone IV, the area of former influence, the respective amounts were 2.87 and 0.93 g/kg.

At such high loads of the nutrients, small mammals can be influenced in various ways: for example, the ground is covered by faeces and fish remains in the breeding period of cormorants, noisy birds cause disturbance, acidity is higher than usual over the whole territory, the plant composition is altered, shelter is lacking in the zones of active influence, etc.

Small mammals cannot play role in nutrient cycling, when the load by birds is so high. Even in grassland ecosystems, small mammals bring in 3.5-4.0 kg/ha/year of nitrogen (Clark *et al.* 2005). While such an amount in natural ecosystems may alter nitrogen cycling, in the colony of great cormorants it is insignificant.

Nitrogen enrichment of the ecosystem, so heavily expressed in the great cormorant colony, does not only change plant communities, a phenomenon well-known and not requiring further proof (Odum, Barret 2005), but also results in changes in reproductive output and survival of juveniles; in the field ecosystem this may lead to a decrease in small mammal diversity (Parsons *et al* 2005). None of these possible effects were studied in the colony of great cormorants. In the future we are going to analyze reproduction parameters of the small mammals in different zones of the colony as well as their diet.

Conclusions

Our results showed that small mammal assemblage was different in the various zones of the colony of great cormorants. Primarily, reduction of species diversity was found in the most heavily bird-influenced parts of the colony. A significant impact was found in the zone of initial influence (expansion of the colony, short term impact) and in the zone of long term influence of the colony (colony established for a longer time, still active). The diversity of the small mammal community in these zones and their ecotone was lower than in the control zone and zone of former impact (most of the nests not used anymore). Only two species, dominant yellow-necked mouse *Apodemus flavicollis* and subdominant bank vole *Clethrionomys glareolus*, were numerous in all zones. The proportion of other five small mammal species, trapped in the territory of cormorant colony and in the control area nearby, was negligible. The relative abundance of small mammals was also lower in the territory of active zones than in the zone of former influence of the colony.

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